Impact of Litter Removal and Seasonality on Soil Greenhouse Gas Fluxes and Nutrient Cycling in an Austrian Beech Forest

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Master Thesis

Impact of Litter Removal and Seasonality on Soil Greenhouse Gas Fluxes and Nutrient Cycling in an Austrian Beech Forest

1. Abstract

Climate change is expected to cause the alteration of forest ecosystems, which may result in shifts in soil GHG fluxes, and soil nutrient cycling between the atmosphere, the forest floor community and the tree community. The presented study aims to demonstrate the influence of the litter layer on soil-greenhouse gas emissions and nutrient cycling. In this Master's Degree project, which was conducted in a pure beech transect in the BOKU Forest Demonstration Center Rosalia, Lower Austria, soil CO_2, CH_4 and N_2O emissions were determined through weekly manual gas sampling from static headspace chambers from July to November 2012. Twelve pairs of gas measurement chambers were installed. Each pair consisted of two treatments: a control treatment and a no-litter treatment where the litter layer had been removed and replaced by a black garden foil, thereby stopping nutrient input from the litter into the soil, without changing soil moisture and temperature. In addition, monthly soil samples were taken adjacent to the chambers and analyzed to determine pH, total C, total N, NO_3^-, NH_4^+, PO_4^{3-}, DOC/TN ,and microbial parameters such as microbial biomass C and N, glucose and respiration. Further, in the beginning and at the end of the measuring period, soil profile samples were collected to determine the distribution of C and N in the soil profile. The removal of the litter layer strongly reduced soil CO_2 emissions on the no-litter treatment (by a mean of 35%). Other climatic factors such as increased soil temperature had a positive effect on CO_2 emissions whereby the temperature sensitivity factor Q_{10} showed a higher sensitivity in the no-litter treatment, especially during summertime. The litter removal caused an increased CH_4 uptake on the no-litter treatment. Soil nutrient cycling was less strongly disturbed by the litter removal than assumed. No significant differences in nutrient concentrations were found between the two treatments.

2. Zusammenfassung

Die Veränderung des globalen Klimas kann bewirken, dass Waldökosysteme und deren Boden-Treibhausgasflüsse sowie Nährstoffkreisläufe zwischen der Atmosphäre, der Waldbodengemeinschaft und der Pflanzengesellschaft verändert werden. Das Ziel dieser Arbeit war es, den Einfluss der Laubschicht auf die Treibhausgase sowie Nährstoffkreisläufe aufzuzeigen. Die vorliegende Masterarbeit wurde im BOKU Lehrforst Rosalia in Niederösterreich auf einem reinen Buchenbestand durchgeführt. Von Juni bis November 2012 wurden wöchentlich Treibhausgasmessungen (CO_2, CH_4 und N_2O) mit statischen Gasmesskammern durchgeführt. Dafür wurden insgesamt 12 Kammerpaare installiert. Ein Paar setzt sich aus einer Kontrollfläche und einer Fläche ohne Laub zusammen. Bei der Fläche ohne Laub wurde eine schwarze Gartenfolie als Laubsubstitut aufgelegt. Die Nährstoffzufuhr vom Laub in den Mineralboden sollte somit verhindert werden. Auch sollte die Bodentemperatur sowie die -feuchte mit der Folie unverändert bleiben. Zusätzlich wurden monatlich Bodenproben entnommen, die auf ihren pH-Wert, gesamt Kohlenstoff (C) und Stickstoff (N), NO_3^-, NH_4^+, PO_4^{3-}, DOC/TN und mikrobielle Parameter wie Glukose, den mikrobiellen C und N und die mikrobielle Atmung untersucht wurden. Zu Beginn und zu Ende der Messperiode wurden zudem Bodenprofile genommen, um die vertikale Kohlenstoff- und Stickstoffverteilung zu bestimmen. Bei der Fläche ohne Laub kam es zu einer Reduktion der CO_2-Emissionen um rund 35%. Höhere Bodentemperaturen im Sommer hatten einen positiven Effekt auf die CO_2-Emissionen auf beiden Flächen. Der Q_{10}-Faktor wies jedoch im Sommer eine höhere Temperatursensibilität der CO_2-Emissionen auf der Fläche ohne Laub auf. Die Fläche ohne Laub nahm mehr CH_4 aus der Atmosphäre auf. Außerdem zeigten die Fläche ohne Laub beinahe keine signifikanten Einflüsse auf die Nährstoffkreisläufe durch die Laubschichtentfernung.

3. Introduction

It is common knowledge that the climate has not always remained constant over longer periods. Substantial changes in climatic processes, over periods of about 100,000 years, contributed to these long-term fluctuations (Rahmstorf and Schellnhuber 2007). Hence, in the last few years, it has become more and more evident that the global climate is undergoing an untypical process of change. The International Panel on Climate Change (IPCC) reports that global temperatures have increased by around 0.6°C during the last decades (IPCC 2001) and that this development will continue (other scientists claim that the predicted values are underestimated (Lovelock 2009)). These quantitative and temporal changes are unusual indeed but may seem not much. Nevertheless, these climatic changes cause alterations to various systems such as the terrestrial, aquatic, and atmospheric or biogeochemical ecosystem structures (e.g. rising sea levels, melting of the Arctic sea ice, impacts on ecosystems, changing ocean circulation or increase of weather extremes (Rahmstorf and Schellnhuber 2007), which, in turn, have an impact on the chemical and physical environment (Walker, Steffen et al. 1999). This feedback refers, for instance, to the reduced solar reflection from the earth's surface due to the reduced surface of the Arctic ice shields (Kromp-Kolb and Formayer 2005). These consequences are related to climate change and to the so-called "greenhouse effect".

Scientists distinguish between the natural greenhouse effect and the anthropogenic greenhouse effect. It is the natural greenhouse effect, which makes life on earth possible and keeps the average global temperature at 15°C. Without the natural greenhouse effect, the average global temperature would amount to -18°C (Kromp-Kolb and Formayer 2005). Carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), water vapor, chlorofluorocarbons and ozone in the atmosphere are the primary gases correlated with global warming or the greenhouse effect (Beever, Cleemput et al. 1992). These gases emitted by the Earth's surface and human activities act like a blanket over the surface and provide the life-sustaining environment (Houghton 2005).

Due to the accelerated industrialization and other human activities (burning of fossil fuels and large-scale deforestation), atmospheric concentrations of the greenhouse gases (GHGs)

CO_2, CH_4 and N_2O have increased significantly up to 391ppm, 1803ppb and 324ppb and exceeded the pre-industrial levels by 40%, 150% and 20%, respectively (IPCC 2013). The increasing atmospheric concentrations of these GHGs prevent the exit of infrared radiation from the Earth's surface to outer space (Chapin, P.A. Matson et al. 2002). Normally, solar radiation passes through the atmosphere, heats the Earth's surface and, when reflected back to space, is converted into infrared radiation. Due to the atmospheric absorption of the infrared radiation by the GHGs, the atmosphere is heated up. The rate of infrared radiation that has not been absorbed by the greenhouse gases is released back into space. The absorbed infrared radiation is re-emitted towards the Earth's surface and boosts global warming. That implies that since the Industrial Revolution the amount of greenhouse gases in the atmosphere has been steadily increasing and therefore, more infrared radiation has been re-emitted towards the Earth's surface (Kromp-Kolb and Formayer 2005). What does global warming have to do with the presented project? The answer is very simple: When global temperatures increase, soil temperatures will rise, too, and this, in turn, affect terrestrial ecosystems.

For example, under natural conditions, litter is colonized by different microorganisms and fungi (Colpaert and vanTichelen 1996) that degrade the litter and transform organic matter into inorganic material (CO_2 and nitrogen forms) and humic substances through decomposition (Facelli and Pickett 1991; Berg and McClaugherty 2003). In this process, fungi and microorganisms connect litter and soil and form a nutrient cycle where organic compounds translocate from the litter into the soil and reverse (Fahey, Yavitt et al. 2011). Alterations of climatic conditions (e.g. increased surface temperature) can change these transformation processes (Zhang, Parker et al. 2005). Therefore, it is necessary to understand how processes convert substances into other forms and identify factors that control the rate of these transformations (Scholes, Schulze et al. 1999). Achieving a better understanding of these interacting processes enables science to predict potential feedbacks of terrestrial ecosystems due to chemical and physical conditions.

The objective of the study was to determine the effects of litter removal (no-litter treatment) on soil GHG emissions and on soil nutrient cycling in comparison with natural circumstances (control treatment) and determine climatic and chemical interacting

variables. Hence, weekly manual gas samples were obtained from static headspace chambers from July to the end of November 2012. Soil samples were taken monthly from around the chambers; additionally, soil profile samples were taken once at the beginning and once at the end of the sampling period. The findings of data analysis should serve to either reject or accept the following hypotheses:

(i) Due to increased substrate availability for microorganisms, litter-covered soil produces more CO_2 than soil under no-litter treatment;

(ii) CH_4 consumption of the control treatment is lowered by the decreased gas diffusion capacity through the litter layer;

(iii) N_2O fluxes emitted from litter-covered soils are higher as litter is usually dominated by fungi which are mostly unable to reduce N_2O to N_2 during the denitrification process;

(iv) Litter removal contributes to the loss of soil nutrients in comparison no-litter treatment with the more stable conditions of the control treatment.

4. Material and Methods

4.1 Study Site

The presented master's thesis project was conducted at the BOKU Forest Demonstration Center Rosalia, Lower Austria (47° 42' 26" N /16° 17' 59" E) (Figure 1). The study site measured 40x30 meters and was located on a pure beech stand (stand age: 100 years) with pseudo-gleyic cambisols on metamorphic rock (n.g. 2006). The soils had an average pH of 3.8 in the upper 5cm. The mean annual precipitation was 796mm and the mean annual temperature was 6.5°C. The A horizon had a thickness of 2.5cm. The thickness of the A/B horizon varied between 2.5 and 12cm. The relative amount of sand and clay particles decreased from the A horizon to the C horizon. Plant species included *Dentaria bulbifera*, *Oxalis acetosella*, *Geranium robertianium* and *Viola reichenbachiana* (Amann and Summerer 2004). The site is exposed towards NW and its altitude is 600 m above sea level.

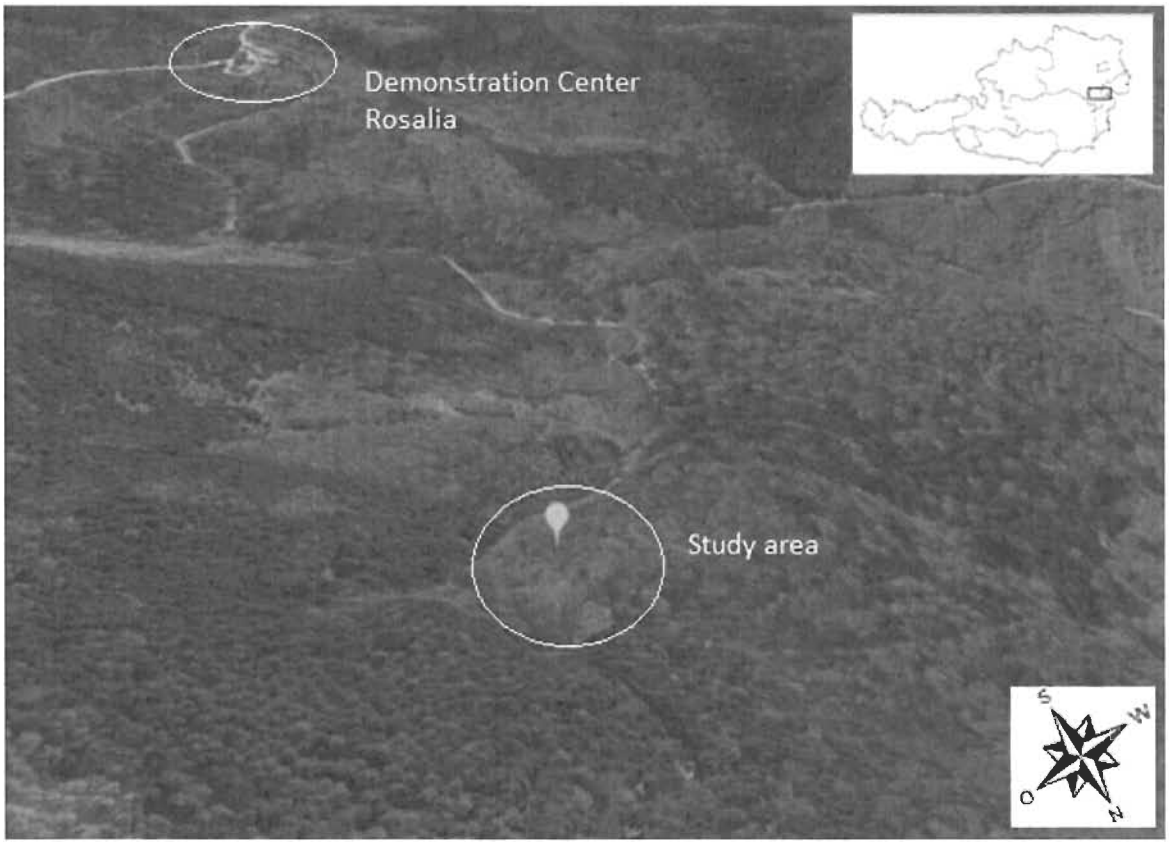


Figure 1: Study area at the BOKU training forest in Rosalia. Modified, based on (Google Earth 2013). Beech trees appear as light green and pine trees as dark green.

4.2 Sampling and Experimental Design

The gas and soil sampling was implemented according to a specific schedule. The timetable for the collection of gas and soil samples is explained in detail in the following chapters (see also Appendix 1).

To measure gas fluxes, twelve pairs of static manual headspace chambers were installed on a 12-m horizontal transect. Each pair consisted of two treatments: a control treatment without manipulation and a no-litter treatment where the litter layer had been removed on a site of 0.5x0.5m and had been replaced by a black garden foil (Appendix 2). Thereby, nutrient input from the litter into the soil was stopped without changing soil moisture and temperature. Furthermore, a fine wire-mesh fence was placed over the no-litter treatment in order to avoid any input from steadily falling tree material. Each static headspace chamber consisted of a polyvinyl chloride (PVC) cylinder with an inner diameter of 19cm, which was inserted a few centimeters into the ground to prevent any gas diffusion from ambient air into the chamber volume.

Soil samples were taken monthly within the half-a-square-meter area around each static chamber. Besides soil samples at the beginning and at the end of the measuring period, six soil profiles were dug around the sampling transect to determine the vertical distribution of carbon (C) and nitrogen (N) as well as the soil texture in the soil horizons.

4.2.1 Profile Sampling

For soil profile sampling, metal tubes with an inner diameter of 3.8cm were used. Before sampling, the soil surface was permanently cleared from leaf litter and plants; samples were taken from a depth of 0-5cm, 5-10cm, 10-20cm, 20-50cm, and 50cm down to 70cm. The soil samples were transported to the laboratory and oven-dried at 60°C. In a next step the total dry mass was determined. The samples were then crushed and sieved to a particle size less than 2mm. All stones were removed and the stone-free soil was weighed again. By using the stone-free dry weights and the sampling tube volume, corrected for the stone volume, bulk soil densities (soil particles <2mm) were measured. The density of stones was quantified by displacement in a water bath and averaged 2.49g cm^{-3}. Soil C and N stocks were then

calculated (see Chapter 4.4.3) according to the soil densities for each 5 or 10cm soil layer (Zimmermann, Meir et al. 2010).

4.2.2 Soil Sampling

The soil samples were collected with metal cylinders of 3.8cm inside diameter and 5cm height. Around each chamber, five soil cores were extracted from the top 5cm of soil and mixed to one pooled sample per chamber. The litter on the control treatment was carefully brushed aside and was put back to the same place after sampling. The soil samples were transported in a cooling box to the laboratory in Vienna. At the laboratory, samples were sieved to a size of <2mm and stored at 4°C before further analysis.

4.2.3 Gas Sampling

For gas sampling, the PVC cylinders were closed with a lid equipped with a rubber membrane through which gas samples were taken with a glass syringe (FORTUNA® OPTIMA®, Wertheim, Germany). After closing the chambers, gas samples were collected after zero, 10, 20, and 60 minutes, filled in pre-evacuated 30mL crimp top GC glass vials (Agilent Technologies, Vienna, Austria) and transported to the laboratory at BOKU Vienna for GC analysis on the same day. During gas sampling, penetration thermometers (Voltcraft DET3R, Conrad Electronic GmbH, Wels, Austria) were used to determine soil temperature in 5cm depth for each of the 24 chambers and air temperature above each chamber; soil moisture was measured with a SM300 sensor (SM300 Soil Moisture Kit, Delta-T, Cambridge, UK). Gas samples were taken weekly from the beginning of July to the end of November 2012. All in all, 18 sampling events were conducted and a total of 1728 gas samples was taken. One sampling event had to be discarded for technical reasons and could not be analyzed.

4.3 Gas Concentration Measurements

At the Vienna BOKU laboratory, the gas samples were analyzed for concentrations of CO_2, CH_4 and N_2O by a gas chromatograph (GC), consisting of an Agilent 7697A Headspace Sampler and an Agilent 7890A GC System. The GC system was equipped with a flame ionization detector (FID, front detector) and an electron capture detector (ECD, back detector). The FID was employed to measure the CO_2 flux, the FID methanizer to measure the CH_4 flux, while the ECD was used for determining the N_2O flux. GC equipment included two columns (Agilent J&W GC Columns, GS-Carbonplot, Length 30m × ID 320µm × Film 3µm), which had been purchased at Agilent Technologies, Vienna, Austria.

The sample vials were automatically transferred to the headspace sampler by a programmable gripper arm. Inside the headspace sampler, the oven temperature was kept at 70°C and samples were shaken and heated up for two minutes to create an equilibrium in the vials. Nitrogen overpressure ($N_{2)}$ of 80kPa was generated to transport 3mL from the sample vial into the loop. Loop temperature was set at 80°C. From the loop, the sample was injected through the transfer line (105°C) into the Agilent 7890A GC System because of the pressure differences between the headspace sampler and the GC. Before the sample was conducted to the two columns, the sample was split with a ratio of 3:1 by a split injector. Three parts were discarded from the system as waste and one part was carried into the two columns with a column head pressure of 36,5kPa. Column temperature was set to 35°C and the flow was set to 1mL min^{-1}.

The detection of CO_2 and CH_4 was performed with a front detector operated at 300°C; helium was used as a carrier gas with a flow of 30mL min^{-1}. Nitrous oxide was detected with a back detector equipped with a ^{63}Ni-CD source (nickel-cadmium, not radioactive). The heater was set to 375°C and H_2 was used as carrier gas. The concentration of CH_4, CO_2 and N_2O in ppm was visualized via peak detection using the software Agilent ChemStation32 (Agilent Technologies, Vienna, Austria). Further gas flux calculations were performed in R and are described in the following chapters.

Before starting a run, the GC-system was calibrated with three gas mixtures of CO_2, CH_4 and N_2O in N_2 (Linde Gas GmbH, Stadl-Paura, Austria). Table 1 displays the gas concentrations used for GC calibration:

Table 1: Standard gas concentrations for GC calibration

	CO_2	CH_4	N_2O
Std 1	250 ppm	100 ppb	50 ppb
Std 2	500 ppm	250 ppb	200 ppb
Std 3	1000 ppm	500 ppb	400 ppb

4.3.1 CO_2 Flux Calculation in R

Absolute gas concentrations in ppm obtained by the GC were imported into R. Before all calculations were completed, all gas data sets were checked for outliers and were removed if they occurred with an outlier function in R. Hence, a boxplot for all sampling events and each measuring time point was plotted. The relevant R script is enclosed in the appendix (see Appendix 3)and is described in the following section.

It was assumed that CO_2 fluxes would be highest in the first few minutes and effluxes would decrease with increasing incubation time. Gas concentrations versus chamber closing times were plotted for all 18 sampling days in order to evaluate the relation between measurement time and gas concentration changes for both treatments (Figure 2).

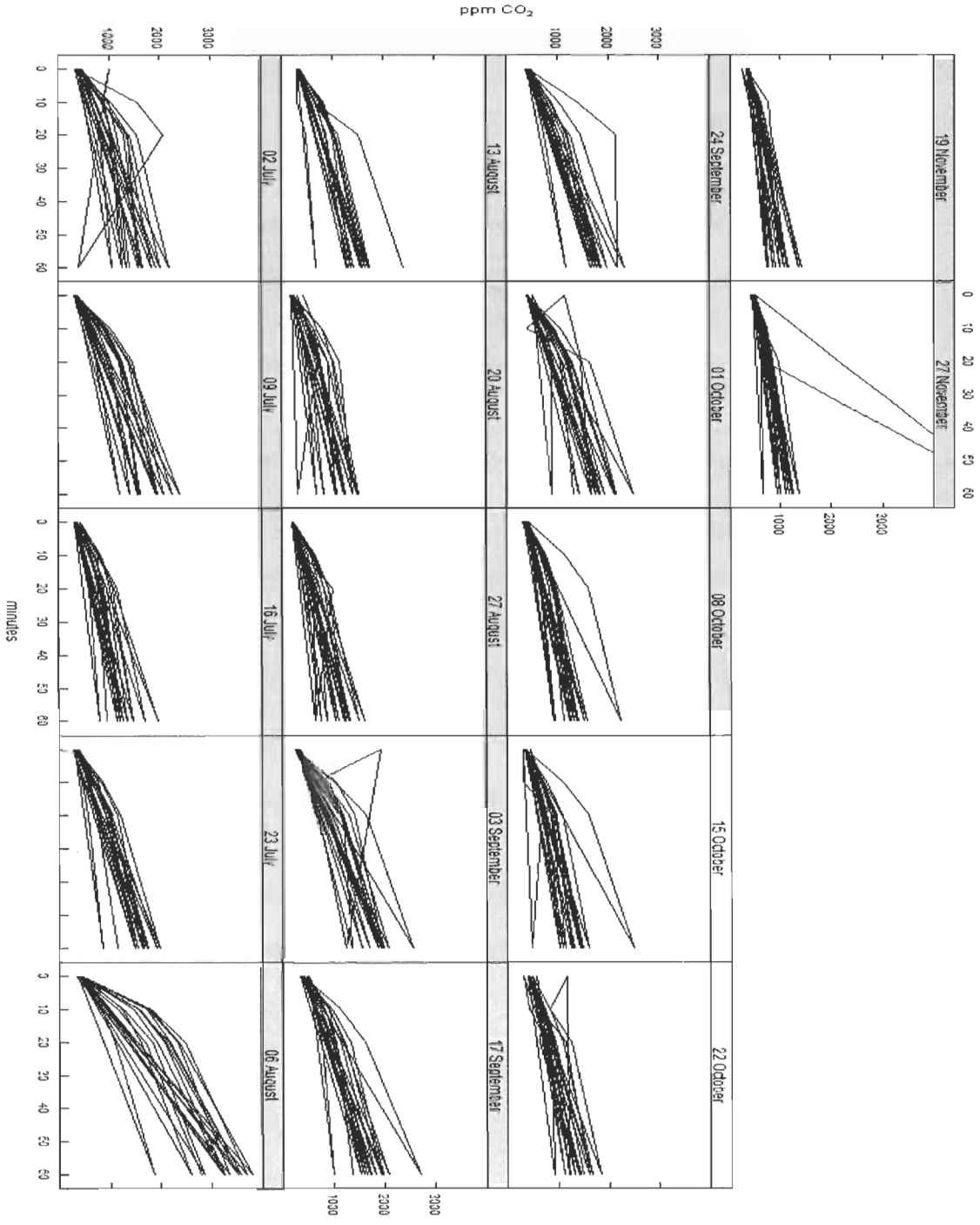


Figure 2: CO_2 concentration changes (ppm) in the headspace chambers of the no-litter treatment during a one-hour incubation for all 18 measuring dates (July to November 2012). Outliers are included. See control treatment in (Appendix 11).

This plot indicates that after chamber closing, the CO_2 effluxes were highest in the first ten minutes and concentrations were close to saturation after one hour. This close to saturation

state was due to a diffusion equilibration of CO_2 molecules between the atmosphere and the forest soil (Dobrinski, Krakau et al. 2010). Therefore, after the first ten minutes, diffusion flattened. After one hour, CO_2 molecule diffusion even reached equilibrium between the forest soil concentration and chamber atmosphere concentration. These observed CO_2 concentration trends in the headspace chambers are best described by equation 1, on which further calculations of the trends in CO_2 concentration were based.

Exponential rise to the maximum with three parameters:

$$y = y0 + a * (1 - exp(-bx)) \quad (1)$$

Equation 1 describes the increase in CO_2 concentration to a maximum over time whereby the additive constant a describes the curve shift towards the y-axis. If a is > 0 the curve shifts up. Three parameters in the equation provided the best curve fit for CO_2 efflux calculation (Papula 2000).

In a first step, the three parameters $y0, a$, and b were estimated for each treatment (control and no-litter) and each sampling day (18 sampling days in total), a treatment including 12 chambers per sampling day and each chamber consisting of 4 measurement points (0, 10, 20 and 60 minutes). This resulted in 48 measurement points that were included per sampling event and per treatment. A function according to equation 1 was fitted through these 48 measurement points and its regression p-value was calculated (Figure 3).

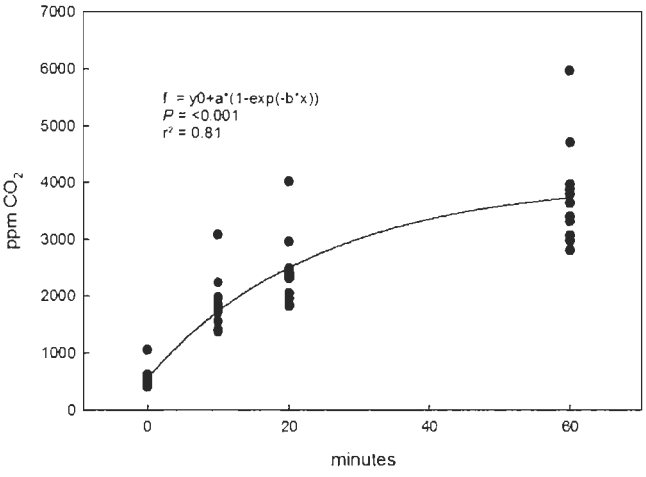


Figure 3: Combined 48 CO_2 ppm measurements of all 12 headspace chambers on 6 August 2012 during an incubation time of 60 minutes, fitted with an exponential equation (*f*=y0+a*(1-exp(-b*x))) which shows the rise to a maximum on the no-litter-treatment.

Variable x refers to the measured gas concentration and was used for specific calculations of CO_2 concentration at various time points. Based on the assumption that the natural CO_2 flux is best represented during the first minute of incubation (Morison 1987; Healy, Striegle et al. 1996), CO_2 concentrations were calculated at time points 0 minute and 1 minute. CO_2 concentrations for these two time points were calculated by applying 0 or 1 to the variable x. The difference between time point 0 and time point 1 was considered the natural CO_2 effluxes in ppm. These natural CO_2 effluxes were subsequently used to convert CO_2 effluxes in ppm into mg CO_2-C m^{-2} h^{-1} by using following equation.

Respiration soil (R_S) in mg CO_2-C m^{-2} h^{-1}:

$$R_S = \frac{\Delta C}{\Delta T} * \frac{P}{1000} * \frac{273}{t+273} * \frac{12.00}{22.41} * \frac{V_{ch}}{A} \quad (2)$$

By using equation 2, the gas concentration in ppm was corrected for air pressure, temperature, molecular weight, and chamber volume. Metcalfe et al. (2007, page 3) describe equation 2 as: "Respiration in mg CO_2-C m^{-2} h^{-1} where $\Delta C/\Delta T$ represents the change in CO_2 within the chamber (ppm) per unit time (seconds), P is atmospheric pressure (Pa), t is the temperature of the air within the chamber (°C), V_{ch} is the total internal volume of the chamber (m^3), and A is the ground area covered by the chamber (m^2)."

4.3.2 CH_4 Flux Calculation in R

CH_4 gas concentration analyses were based on methodical steps similar to those used for CO_2 concentration calculations. Like the case of CO_2, the methane dataset was checked for outliers and was removed if it occurred with an outlier function in R (Appendix 5 and Appendix 6).

A first overview of the dataset was obtained from an XY-plot illustrating the behavior of CH_4 concentrations for both treatments from time point 0 to 1 hour on all 18 sampling days (see Figure 3).

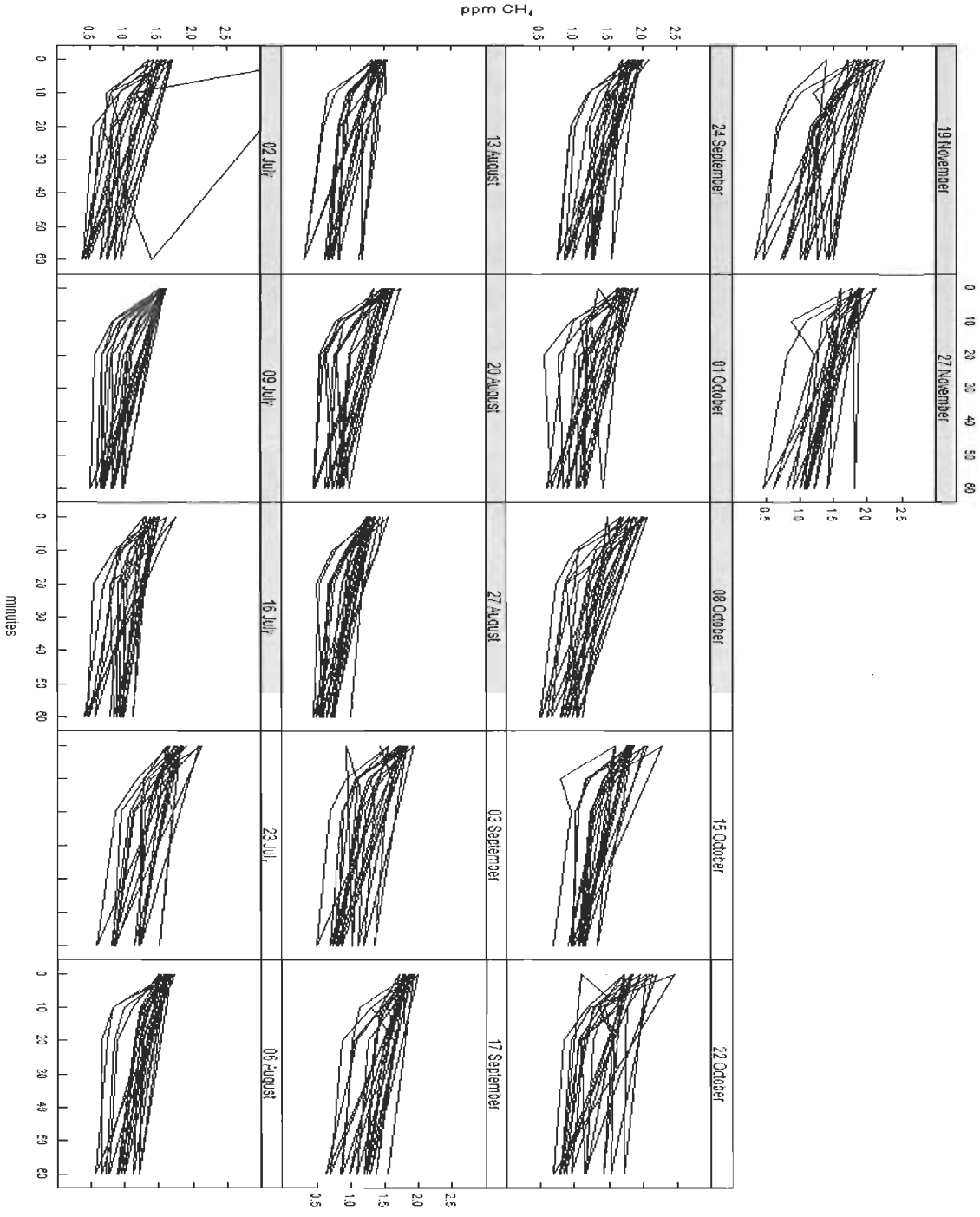


Figure 4: CH_4 concentration changes (ppm) in the headspace chambers of the no-litter treatment during an incubation time of 60 minutes for all 18 measuring dates from July to November 2012 on the no-litter treatment. Outliers are included. See control treatment in (Appendix 12).

This showed a methane uptake on all 18 sampling days. Based on the graphical illustration of the CH_4 concentration development, the following equation 3 was used to calculate CH_4 uptake.

Exponential decay with two parameters

$$y = a * exp(-bx) \quad (3)$$

Equation 2 described an exponential decrease in CH_4 concentration in the chamber (Papula 2000). Before CH_4 uptakes were calculated, all 18 measurement days were controlled to verify a significant decrease in CH_4. A curve with the function of equation 3 was fitted to the data (CH_4 concentration vs. time) in Sigmaplot® and p-values were checked for significant increases (Figure 4). All CH_4 uptakes in ppm showed a highly significant decrease over time (P<0.001 in all cases).

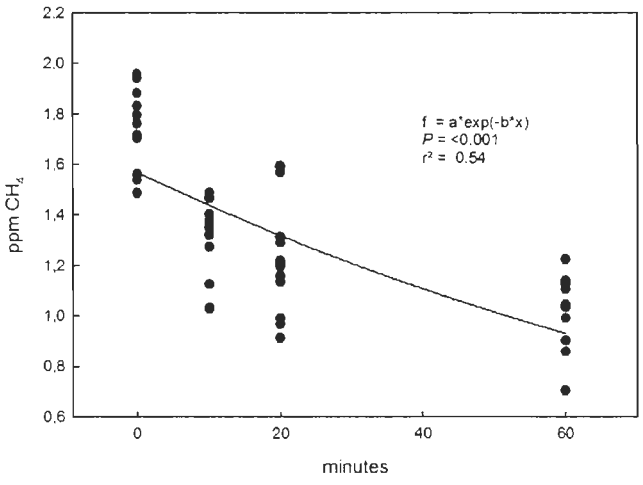


Figure 5: Combined 48 CH_4 ppm measurements of all 12 headspace chambers on 6 August 2012 during an incubation time of 60 minutes, fitted with an exponential decay equation (f=a*exp(-b*x)) on the no-litter treatment.

In a next step, the two parameters a and b were estimated for each sampling day similar to the calculation of CO_2 flux. For this, the function of equation 3 was fitted into the 48 measurement points and the parameters a and b were calculated and applied to equation 3. Furthermore, the same assumption was made for the natural CH_4 uptake as for the CO_2 efflux. CH_4 concentrations at time point 0 minute and 1 minute were calculated by applying 0 or 1 to the variable x. The difference between time point 1 and 0 was considered the natural CH_4 uptake in ppm. That natural CH_4 uptake was used to convert the CH_4 uptake in ppm into µg CH_4-C m^{-2} h^{-1} by using equation 2 as suggested by Metcalfe et al. (2007).

4.3.3 N_2O Calculation

Using the same method as for CO_2 and CH_4, the absolute N_2O concentrations in ppm of all 18-measurement days were plotted in an XY-plot to visualize the concentration changes over the four time points per treatment. In contrast to CO_2 and CH_4, which showed an exponential trend, N_2O concentrations displayed a linear trend (see Figure 5).

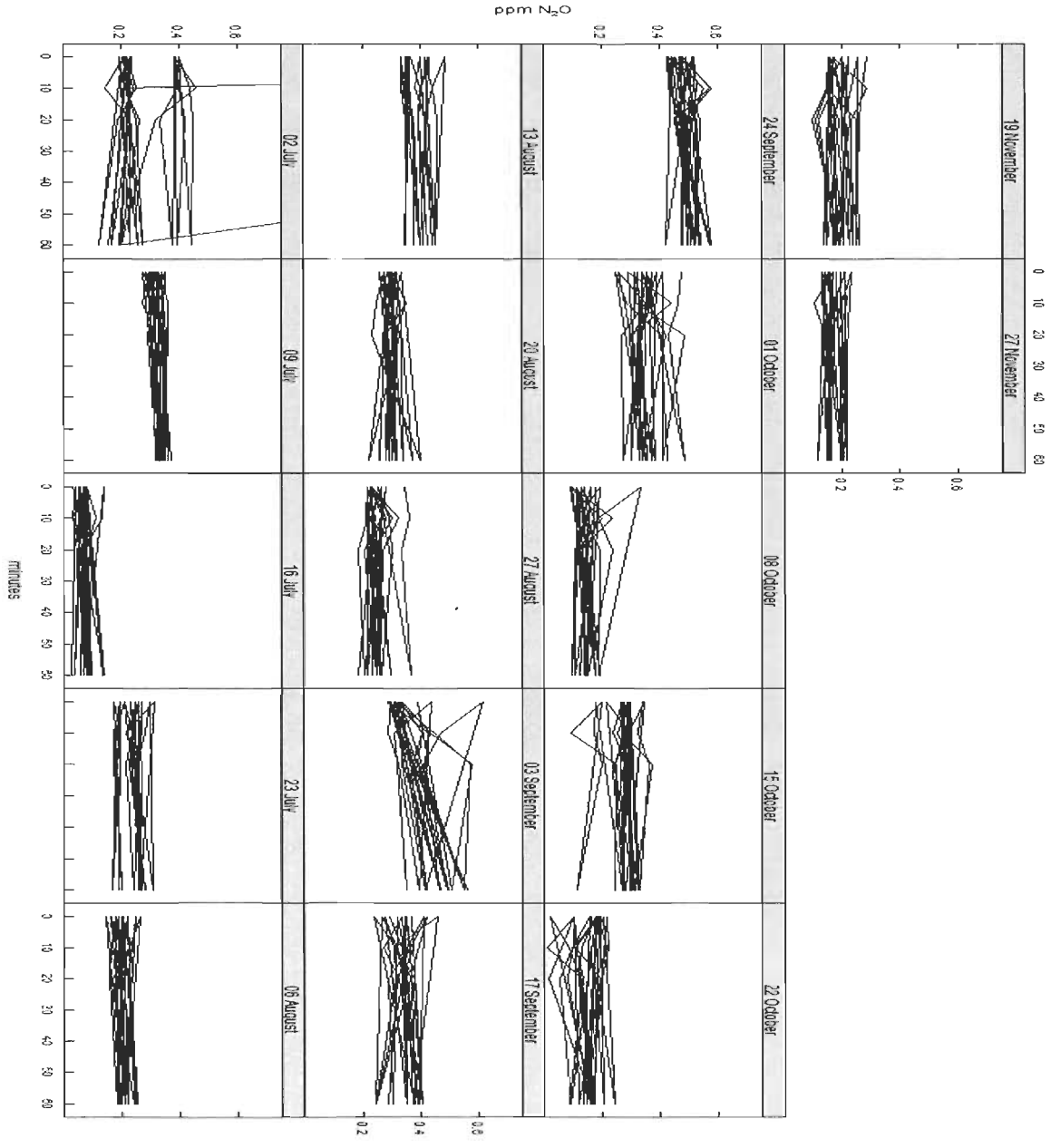


Figure 6: N_2O concentration changes (ppm) in the headspace chambers of the no-litter treatment during an incubation time of 60 minutes for all 18 measuring dates from July to November 2012 on the no-litter treatment. Outliers are included. See control treatment in (Appendix 13).

Based on the linear trend of N_2O concentrations over time, calculation of N_2O fluxes could be best estimated by means of equation 4.

Linear Regression

$$y = ax + b \tag{4}$$

Equation 4 is a linear regression where the gas in the chamber follows a steady increase over time (Papula 2000). Before parameters a and b were estimated all 18 measurement days were controlled to verify any significant changes of N_2O concentration over time. Using equation 4, a curve was fitted in Sigmaplot® for all days and the 48 measuring points and p-values were calculated for significant increases or decreases (Figure 6).

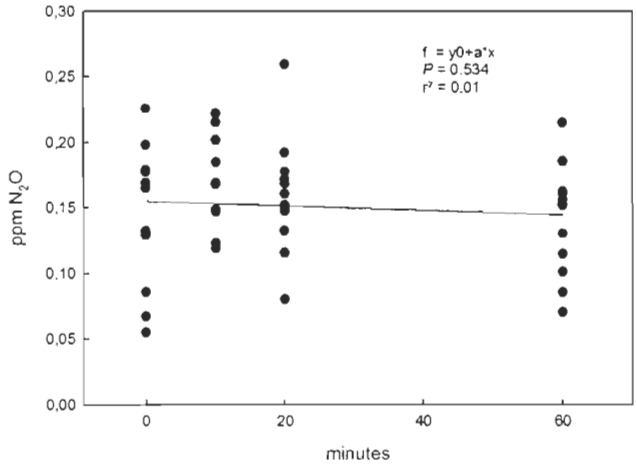


Figure 7: Combined 48 N_2O ppm measurements of all 12 headspace chambers on 01 October 2012 during an incubation time of 60 minutes, fitted with a linear equation (*f*=y0+a*x) on the no-litter treatment.

Most of the N_2O fluxes showed neither significant increases nor decreases over incubation time. All measuring days with a *P* lower than *0.05* were set to zero. On these days, no N_2O flux occurred and therefore no emissions happened (Table 2).

Table 2: *P*-values of linear regression between N_2O concentrations and incubation time (1 hour) of 12 closed chambers on the no-litter and control treatment.

Date	litter	no-litter	Date	litter	no-litter
Jul 02	0.566	0.228	Sep 03	0.701	0.776
Jul 09	***0.003***	***<0.001***	Sep 17	***0.028***	***0.036***
Jul 16	0.246	0.084	Sep 24	0.567	0.949
Jul 23	0.693	0.108	Okt 01	0.793	0.534
Jul 30	***0.044***	***0.024***	Okt 08	0.285	0.225
Aug 06	0.230	0.088	Okt 15	0.551	0.609
Aug 13	0.819	0.237	Okt 22	0.684	0.211
Aug 20	0.843	0.859	Nov 19	0.815	0.065
Aug 27	***<0.001***	***<0.001***	Nov 27	0.855	0.736

In a next step, the parameters a and b were estimated for all measuring days with significant fluxes. Applying the same procedure as for CO_2 and CH_4, a linear curve was fitted into the significant measurements and their 48 sampling points per day. Further, N_2O concentrations for time point 0 and 1 minute were calculated. The difference between time point 1 and 0 was considered the natural N_2O efflux in ppm per minute (see Appendix 7 and Appendix 8). Thereby the calculated N_2O effluxes in ppm were taken to transform ppm into µg N_2O-N m^{-2} h^{-1} effluxes by using equation 2 based on Metcalfe et al. (2007).

4.4 Soil Analysis

Standard soil laboratory analyses were performed to determine various soil parameters such as gravimetric soil water content, pH, NO_3^-, NH_4^+, PO_4^{3+}, microbial respiration, glucose, total organic carbon, and total nitrogen, providing the following findings.

4.4.1 Gravimetric Soil Water Content ($_{\%}$WC) and Volumetric Water Content (WC_{vol})

Sieved soil samples (particle size <2mm) from the top 5cm of 5g ± 0.05g were weighed into vessels and dried in an oven at 105°C for 24 hours. After drying, the samples were weighed again and the loss on drying corresponds to the water content (Scheffer 1967). In addition to $_{\%}$WC, volumetric soil moisture was collected by means of a TDR moisture meter (AT Delta-T, HH2 Moisture Meter; England) each time when gas samples were taken. The data were used for statistical analyses.

4.4.2 pH

Sieved soil samples (particle size <2mm) were weighed into vessels with an amount of 2g ± 0.05g each. 25mL of 0.01M calcium chloride solution was added to the soil samples in the vessels. The samples were incubated at room temperature for one hour. Further, the samples were measured with a calibrated pH-meter (Microprocessor pH-Meter, pH 537 WTW). The sum of protons, which is desorbed with the 0.01M calcium chloride solution, corresponds to the potential acidity of the soil.

4.4.3 Total Carbon (C_t)/Nitrogen (N_t)

The contents of total soil carbon (C_t) and nitrogen (N_t) were determined with elemental analysis (NA-1500 Carlo Erba, Italy). Soil samples were combusted in a pure oxygen atmosphere at 1250°C. Thus, carbon converted into CO_2 and nitrogen into N_2 and NO_x. An infrared detector recorded CO_2 absorbance; N_2 was detected by thermal conductivity. As a result of this analysis, the percent by weight of soil carbon and nitrogen was determined (ON 1998). As all soil samples were free from inorganic carbon, total carbon contents are equal to organic carbon contents.

4.4.4 Microbial Respiration (Mic_{Resp})

Soil samples (particle size <2mm) were weighed into polyester fabric bags with an amount of 20g ± 0.05g each and placed into SCHOTT bottles; 10mL 0.1M NaOH Titrisol (sodium hydroxide solution c(NaOH) = 0.1mol L^{-1}; Merck) was added. SCHOTT bottles were incubated for 24 hours at a temperature of 25°C to determine the heterotrophic soil respiration, which resulted in the degradation of soil organic matter through microorganisms, fungi, algae and protozoans. In this process, CO_2 produced from bacteria, fungi, algae and protozoa was absorbed by sodium hydroxide. After 24 hours, 2mL of barium chloride solution was added to precipitate the absorbed carbon. The amount of mg CO_2 g^{-1} dw $24h^{-1}$ was calculated by titration with Titrisol (Hydrochloride acid c(HCl) = 0.1mol L^{-1}; Merck) until decolorization of the indicator (Schinner F 1996).

4.4.5 NO_3^-, NH_4^+ and PO_4^{3-} Analyses

With an amount of 5g ± 0.05g, soil samples (particle size <2mm) were weighed into plastic vessels and 1M potassium chloride at a dilution ratio of 1:10 was added. The extracts were incubated and shaken for half an hour at room temperature and afterwards filtered through Wattmann filter paper (pore size <2µm). These extracts were diluted 1:10, 1:20 or 1:40, appropriately for each photometric analysis such as NO_3^-, NH_4^+, and chemical methods were used according to Hood-Nowotny and Hinko-Najera (2010). Phosphate was determined, with minor modifications, as described by Schinner (1996). Photometric analyses were conducted with a photometer from PerkinElmer® type 2300 EnSpire™ at the laboratory of BOKU University, Vienna. Concentrations of NO_3^-, NH_4^+ and PO_4^{3-} were measured according to the Beer-Lambert law (Lange, Vejdělek et al. 1987) and concentration conversions from µg/mL into µg (NO_3^-, NH_4^+ and PO_4^{3-}) g^{-1}dw were conducted. Additionally, the garden foil that simulated the litter layer on the no-litter treatment was tested for potential leaching of nutrients such as NO_3^-, NH_4^+ and PO_4^{3-}.

4.4.6 Hot Water-Soluble Reducing Sugars (Gluc)

Water-soluble reducing sugars describe the amount of readily available carbon in soil samples. 5g ± 0.05g of sieved soil samples (particle size <2mm) were weighed into Erlenmeyer flasks and 15mL 1M acetate puffer with a pH of 5.5 were added. The extraction was heated to 100°C for one hour. Afterwards the boiled extraction was filtered through Wattmann filter paper (pore size <2µm). The extracts were diluted 1:20 and prepared with Schinners (1996) method for photometric analysis with PerkinElmer® type 2300 EnSpire™ photometer.

4.4.7 Microbial Biomass Carbon and Nitrogen (C_{mic}/N_{mic}) – Fumigation Extraction Technique

In order to determine the biomass carbon (C_{mic}) and biomass nitrogen (N_{mic}), 5g ± 0.05g soil samples (particle size <2mm) were weighed into vessels and incubated in a chloroformed and evacuated desiccator at room temperature for 24 hours. After the fumigation, 25mL 1M potassium chloride was added, shaken for half an hour and filtered (Wattmann filter paper,

pore size <2µm). Further, these extracts were measured with a Shimadzu TOC/TN analyzer (Hood-Nowotny, Hinko-Najera Umana et al. 2010). The principle of detection is based on the peak detection with combusting and sparging the extracts at 680°C. Thus, carbon dioxide produced is detected with a non-dispersive infrared sensor (NDIR). Moreover, potassium chloride extracts form photometric analyses not fumigated were analyzed with a Shimadzu TOC/TN analyzer. After TOC/TN analysis, the difference between microbial carbon and nitrogen contents fumigated and not fumigated were calculated. Values calculated for C_{mic} and N_{mic} were corrected by a factor of 0.45, which takes into account a methodological underestimation of microbial biomass (Vance, Brookes et al. 1987; Sparling, Gupta et al. 1993).

4.5 Statistical Analysis

For statistical analysis, the open source program R was used. The dataset was divided into two sets. One set represented the control treatment and the other one represented the no-litter treatment. All outliers were removed from the two datasets by the box plot function and its outlier detection. For both data sets, a Shapiro-Wilk test was performed to test the null hypothesis whether the dataset comes from a normal distribution, against the alternative hypothesis that the dataset is not normally distributed. Normally and non-normally distributed data were assessed for homoscedasticity with a statistic Levene's test. Accordingly, data were checked for equality of variances. Further, in order to verify a difference between the two treatments, a t-test was performed on the normally distributed data and a Wilcoxon test on non-normally distributed data. Expected coherences between soil parameters and gas fluxes were determined with correlation tests. Spearman's correlation test was used for non-normally distributed data and Pearson's correlation test was applied to normally distributed data. In addition, a linear model (LM) regression was performed to evaluate significant correlations between parameters. The significance level of all tests was accepted at $P < 0.05$.

5. Results

5.1 Study Design

The no-litter treatment was performed with a black garden foil that imitated the litter layer. It was assumed that the foil kept soil moisture and soil temperature at the same level as on the control plots. For statistical control, a t-test was performed to compare the no-litter treatment with the control treatment on equality of volumetric soil moisture *(P = 0.248)*. Statistical analysis showed a *P>0.05* and confirmed equal conditions on both treatments even for T_{soil} *(0.509)* and the gravimetric water content *(0.776)* (Yan, Chen et al. 2013).

The garden foil was tested in the laboratory for any leaching of NH_4^+, NO_3^- and PO_4^{3-}. After two weeks of incubation in tab water, photometric analysis confirmed no leaching of soil nutrients from the garden foil. Thus, the study design served its purpose that samples were collected on both treatments under same condition and that the no-litter treatment was not contaminated by any nutrient leaching from the garden foil.

5.2 Soil Parameters

It was the aim of the litter removal to provoke changes in soil parameter development such as pH, µg NO^{3-} g^{-1}dw, µg NH^{4+} g^{-1}dw, µg PO_4^{3-} g^{-1}dw, microbial respiration (MicResp = mg CO_2 g^{-1}dw d^{-1}), glucose (µg Gluc g^{-1}dw) and total organic carbon (kg C m^{-2}) and total nitrogen (kg N m^{-2}) on the no-litter treatment as compared to the control treatment.

Possible changes were first tested with linear regressions to determine significant increases or decreases in soil parameters on both treatments over the measuring period from July to November 2012 (Table 3).

Table 3: Linear regression parameters of soil properties vs. time (measuring period from July to November 2012) on the no-litter and control treatments.

	No-litter treatment		**Control treatment**	
	R^2	*p-value*	R^2	*p-value*
pH	0.40	0.176	0.44	0.151
NO_3^-	0.08	0.579	0.09	0.570
NH_4^+	0.22	0.346	0.12	0.497
PO_4^{3-}	***0.92***	***0.002***	0.44	0.154
C_{mic}	0.38	0.195	***0.88***	***0.005***
N_{mic}	0.11	0.520	0.12	0.496
Mic_{Resp}	0.01	0.896	0.23	0.412
Gluc*	***0.80***	***0.016***	0.62	0.063
C_t	***0.83***	***0.011***	0.09	0.571
N_t	***0.67***	***0.047***	0.01	0.936

* = Values too few to make solid statistical statements while statistically significant

Bolded values show significant changes in soil parameters with a significance level of *P<0.05*. Significant increases or decreases occurred mostly on the no-litter treatment. Phosphorus, glucose, total soil carbon and total soil nitrogen were affected by decreases. On the control treatment, only the microbial biomass carbon showed significant changes towards an increase over time.

Further, the treatments were tested with a Wilcoxon test for non-normally distributed data and a t-test for normally distributed data if litter removal caused significant differences. Statistical tests did not find any significant variations between the treatments. All tested parameters showed a *P>0.05* and therefore, no variations in soil nutrients occurred over time.

5.2.1 Microbial Biomass – C_{mic} and N_{mic}

Microbial carbon (C_{mic}) concentration on the control treatment ranged between 27g m^{-2} up to 48g m^{-2} in the first 5cm of top soil, with similar concentrations on the no-litter treatment. C_{mic} showed a significant increase in concentration over time on the control treatment (Figure 8 and Table 3). On the no-litter treatment, no significant increase appeared during the measuring period. When both treatments were tested for significant differences with a

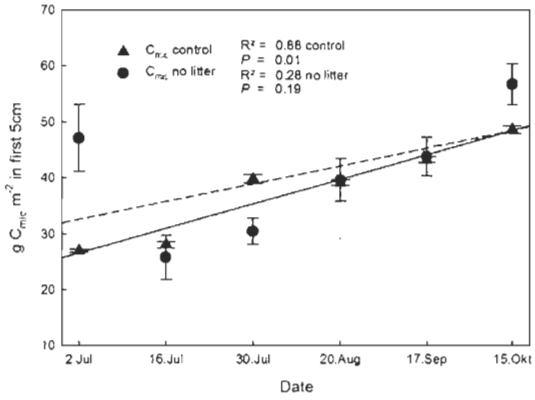


Figure 8: Comparison of C_{mic} concentrations in the first 5cm of soil on the control treatment (▲) and no-litter treatment (●) during the measuring period; significance level for linear regression = *P<0.05*; concentration values shown with standard errors.

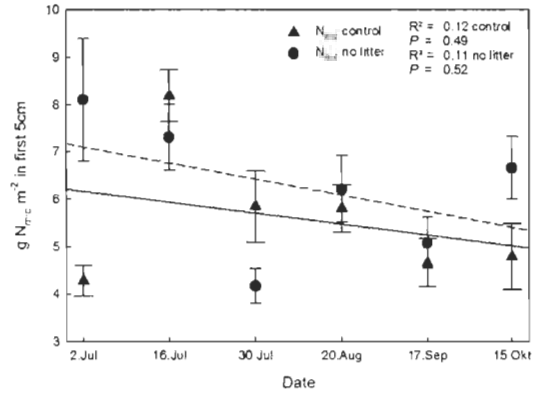


Figure 9: Comparison of N_{mic} concentrations in the first 5cm of soil on the control treatment (▲) and no-litter treatment (●) during the measuring period; significance level for linear regression = *P<0.05*; concentration values shown with standard errors.

Wilcoxon test, no significant difference was found *(P of C_{mic} = 0.719)*. Therefore, the null hypothesis was accepted and no difference between the treatments was observed.

Microbial nitrogen also displayed no significant difference between the two treatments when tested with a Wilcoxon test *(P of N_{mic} = 0.781)*. Linear regressions to detect significant decreases or increases in N_{mic} concentrations showed no significant changes over time on both treatments (Figure 9). Concentrations varied between 8 and 4g m^{-2} in the first 5cm of the top soil on both treatments.

5.2.2 NO_3^- and NH_4^+

Measured concentrations of soil nitrate ranged between 10 and 42µg NO_3^- g^{-1}dw on each treatment and did not show any significant increases or decreases over time on none the control treatment or the no-litter treatment (Figure 10). A Wilcoxon test revealed no significant difference between the two treatments *(P of NO_3^- = 0.219)*. Therefore, the null hypothesis was accepted and no changes in concentrations were observable on both treatments.

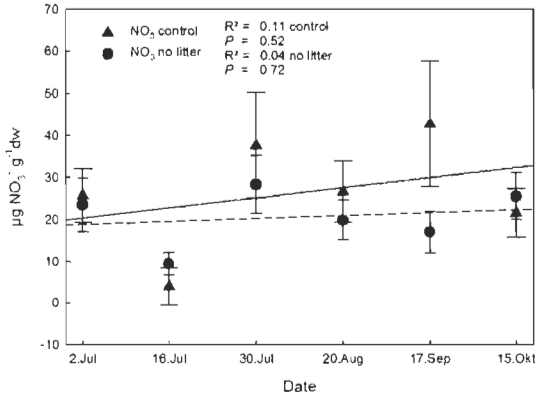


Figure 10: Comparison of µg NO_3^- g^{-1}dw concentrations on the control treatment (▲) and no-litter treatment (●) during the measuring period; significance level for linear regression = *P<0.05*; concentration values shown with standard errors.

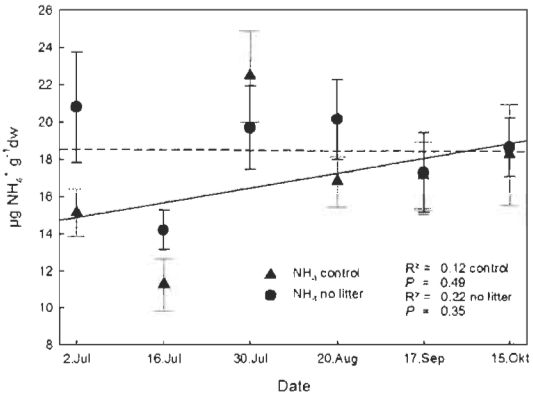


Figure 11: Comparison of µg NH_4^+ g^{-1}dw concentrations on the control treatment (▲) and no-litter treatment (●) during the measuring period; significance level for linear regression = *P<0.05*; concentration values shown with standard errors.

Similar results were observed when the ammonia household of the treatments was analyzed. Both treatments showed no significant increase or decrease in ammonia over the measuring period (Figure 11). When tested with a t-test, no significant differences between the treatments were detected either *(P of NH_4^+ = 0.283)*. Therefore, the null hypothesis was accepted and no significant changes had happened during the measuring period. Ammonia concentrations ranged between 11 and 23µg NH_4^+ g^{-1}dw on both treatments. Based on the statistical results, soil parameters ammonia and nitrate were not affected by the litter removal.

5.2.3 Soil C_t and N_t

With a *P* of *0.57,* total soil carbon (C_t) in kg m^{-2} in the top 5cm showed no significant decrease on the control treatment. By contrast, no-litter treatment significant decrease with a *P* of 0.01 was found on the no-litter treatment (Figure 12). On the no-litter treatment, total soil carbon content decreased on the no-litter treatment from 8.7kg soil C_t m^{-2} at the beginning of the measuring period down to 5.8kg soil C_t m^{-2} at the end of the measuring period. Subjected to a Wilcoxon test, no significant differences between the treatments were found *(P of C_t = 0.5)*. We can assume that the slight trend of decreasing soil carbon on the no-litter treatment was caused by the litter removal.

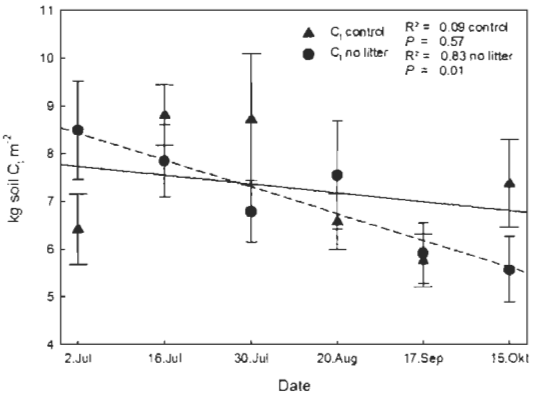


Figure 12: Comparison of kg soil C_t m^{-2} concentrations on the control treatment (▲) and no-litter treatment (●) during the measuring period; significance level for linear regression = *P<0.05*; concentration values shown with standard errors.

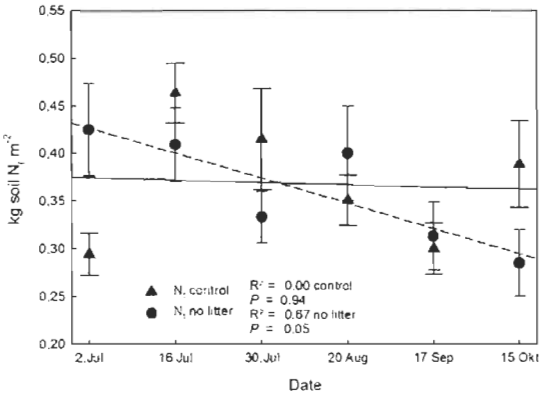


Figure 13: Comparison of kg soil N_t m^{-2} concentrations on the control treatment (▲) and no-litter treatment (●) during the measuring period; significance level for linear regression = *P<0.05*; concentration values shown with standard errors.

The changes in nitrogen (N_t) content on the treatments behaved similarly to C_t content as described above. Even on the no-litter treatment, a significant decrease in total soil nitrogen was observed (Figure 13). Soil N_t amounts decreased from 0.43kg soil N_t m^{-2} to 0.29kg soil N_t m^{-2}. The control treatment showed no significant decrease in the N_t contents (Table 3). Further, both treatments were tested for significant differences in their contents. The Wilcoxon test showed no significant differences *(P of N_t = 0.394)*. We can assume that the slight trend of decreasing soil nitrogen on the no-litter treatment, which resulted in a loss of nutrients, was caused by the litter removal.

5.2.4 PO_4^{3-} and Microbial Respiration

Another interesting observation concerning the soil parameters concerns the phosphate concentrations. As was the case with nitrate and ammonium, which were characterized by a significant decrease in concentration on the no-litter treatment (Table 3), we also found a significant decrease in soil phosphate concentrations on the no-litter treatment (Figure 14). Concentrations in µg PO_4^- g^{-1}dw decreased from nearly 3µg PO_4^{3-} g^{-1}dw at the beginning of July to about 1.5µg PO_4^{3-} g^{-1}dw in October.

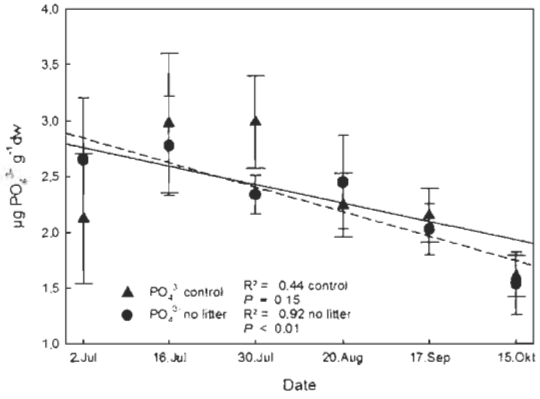


Figure 14: Comparison of µg PO_4^{3-} g^{-1}dw concentrations on the control treatment (▲) and no-litter treatment (●) during the measuring period; significance level for linear regression = *P<0.05*; concentration values shown with standard errors.

In contrast, the control treatment revealed no significant decrease. Further, a Wilcoxon test rendered no significant differences between the treatments *(P of PO_4^{3-} = 0.578)*.

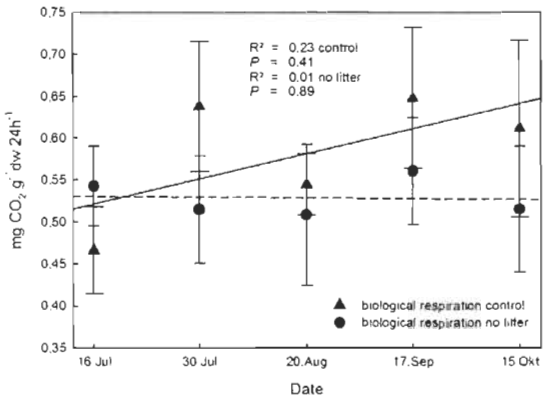


Figure 15: Comparison of mg CO_2 g^{-1}dw $24h^{-1}$ concentrations on the control treatment (▲) and no-litter treatment (●) during the measuring period; significance level for linear regression = *P<0.05*; concentration values shown with standard errors.

Statistical analyses of microbial respiration were limited due to the small dataset. Therefore, results have to be handled with care. In general, we found no significant difference between the two treatments when estimated with a Wilcoxon test *(P of Mic_{Resp} = 0.067)*. Further, both treatments indicated no significant increase or decrease in respired CO_2. Concentrations ranged between 0.46mg CO_2 g^{-1}dw $24h^{-1}$ and 0.63mg CO_2 g^{-1}dw $24h^{-1}$ (Figure 15).

5.2.5 Relationships between Soil Parameters

Using linear models and correlation tests, all soil parameters were tested for potential coherences among themselves and among gas fluxes (Appendix 9 and Appendix 10). In the following section, we only present significant coherences between the soil parameters. Coherences between gas fluxes and soil parameters have been discussed in section 5.3.

Correlations were found among PO_4^{3-}, C_t and N_t on the no-litter treatment (Figure 16). What all three soil parameters had in common was a significant decrease in their concentrations and content over time, which was detected by linear regression. Moreover, all parameters had a significant relationship to one another.

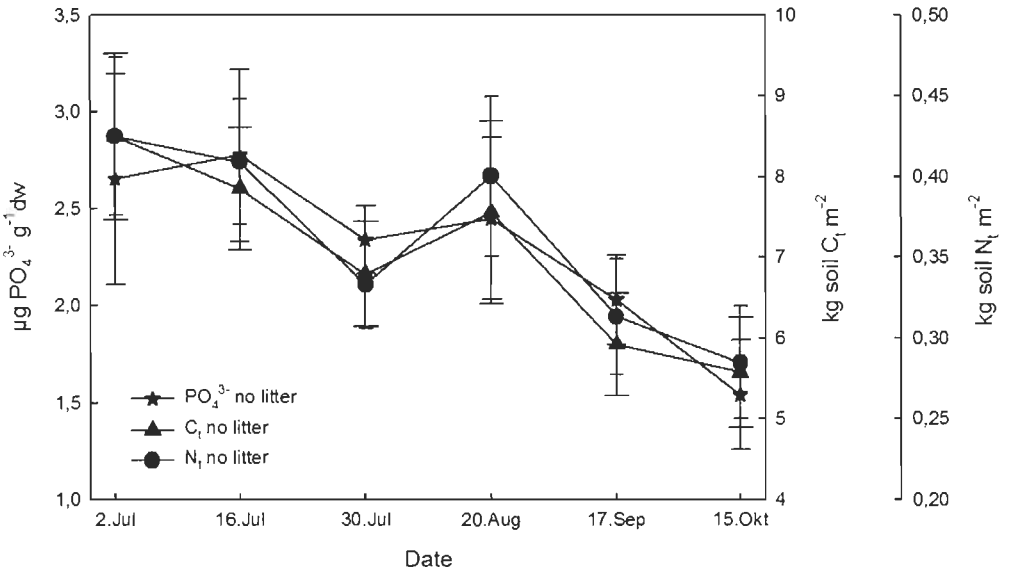


Figure 16: Phosphorus, total soil carbon and nitrogen contents during the measuring period, shown with standard errors.

Significant relationships calculated by linear model were additionally tested for their quality with a Pearson correlation test. The Pearson tests gave all relationships a very good quality by displaying a high correlation coefficient R^2 and a small P. Results from linear modeling revealed that all three parameters decreased in equal proportions (Appendix 9 and Appendix 10).

5.3 Greenhouse Gas Fluxes CO_2, CH_4 and N_2O

Gases of interest were carbon dioxide, methane, and nitrous oxide. Analyses focused on determining significant differences between gas fluxes on the no-litter treatment and on the control treatment. Another focus of interest was the influence of soil parameters on the gas exchange rates. For interpreting these points of interest, a Wilcoxon test, a t-test, a Spearman test, and a Pearson correlation test were performed.

The treatments differed on a high significance level in CO_2 effluxes *(P<0.001)* and CH_4 uptakes *(P<0.001)*. No significant difference was detected in N_2O effluxes *(P=0.292)*. In the following sections, more detailed results concerning the gas fluxes are presented.

5.3.1 CO_2 Fluxes

Statistical t-test showed a significant difference between CO_2 effluxes on the treatments. CO_2 effluxes on the control treatment were significantly higher. In summer, the control treatment reached fluxes higher than 350mg CO_2-C m^{-2} h^{-1} compared to almost 300mg CO_2-C m^{-2} h^{-1} on the no-litter treatment (Figure 17). According to the literature, two main factors may have a potential impact on CO_2 emissions: volumetric soil moisture and temperature. A first insight into the potential influence of these determinants on CO_2 concentrations in mg CO_2-C $m^{-2}h^{-1}$ over time is provided in Figure 16.

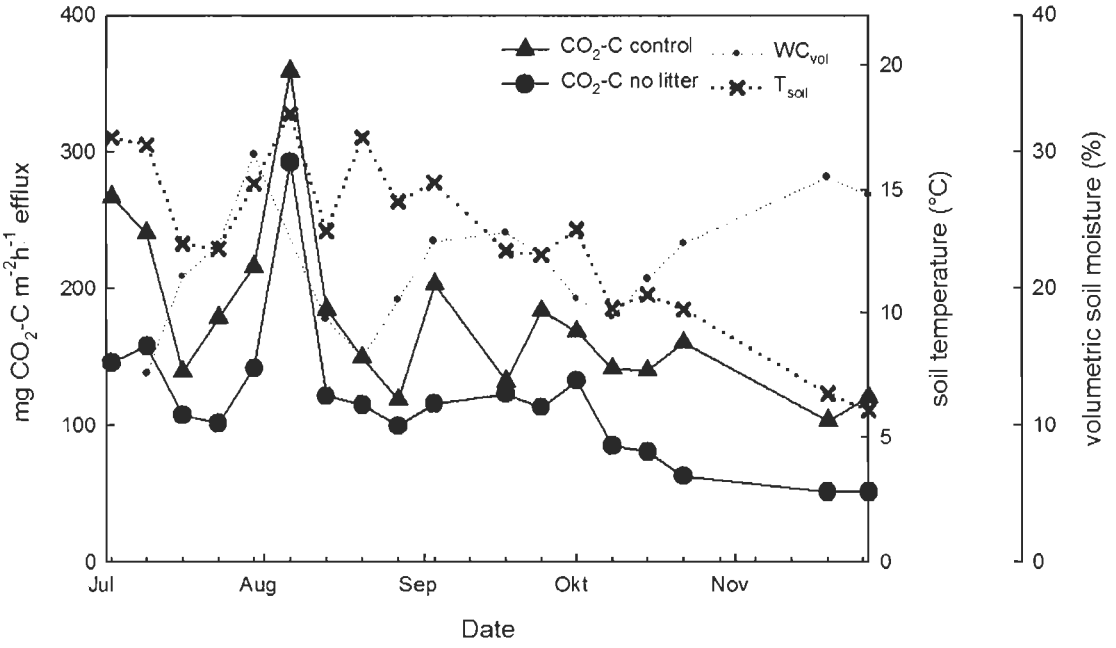


Figure 17: CO_2 fluxes (mg CO_2-C $m^{-2}h^{-1}$) on the control treatment (▲) and no-litter treatment (●) shown together with °C soil temperature (✖) and soil volumetric water content (•) during the measuring period. Each data point represents the daily mean calculated from 12 chambers and the surrounding soil.

Spearman correlation tests showed a highly significant influence of T_{soil} on CO_2 effluxes on both treatments (Table 4). When temperatures dropped, CO_2, emissions also decreased and vice versa in both treatments. The comparison of the p-values of the two correlations revealed that the CO_2 effluxes on the no-litter treatment correlated stronger with T_{soil} than on the control treatment. Total CO_2 emissions were higher on the control treatment. Most likely, the litter on the control treatment played a major role in the higher CO_2 emissions.

Table 4: Spearman correlation test between respired mg CO_2-C $m^{-2}h^{-1}$ volumetric water content and soil temperature on both treatments.

	p-value	***R^2***
CO_2-C vs. T_{soil} (control)	***<0.001***	***0.70***
CO_2-C vs. T_{soil} (no-litter)	***<0.001***	***0.83***
CO_2-C vs. WC_{vol}(control)	0.556	-0.16
CO_2-C vs. WC_{vol} (no-litter)	0.385	-0.23

Soil moisture, the second potential key determinant, was also tested for significant correlations with CO_2 emissions. Spearman correlation tests detected no significant correlation between CO_2 effluxes and volumetric soil moisture on both treatments (Table 4).

5.3.2 CO_2 Respiration from Litter

Respiration from the litter layer was calculated by subtracting CO_2 emissions of the no-litter treatment from the control treatment. The coarse gray bar in Figure 18 illustrates the calculated litter respiration in mg CO_2-C m^{-2} h^{-1}.

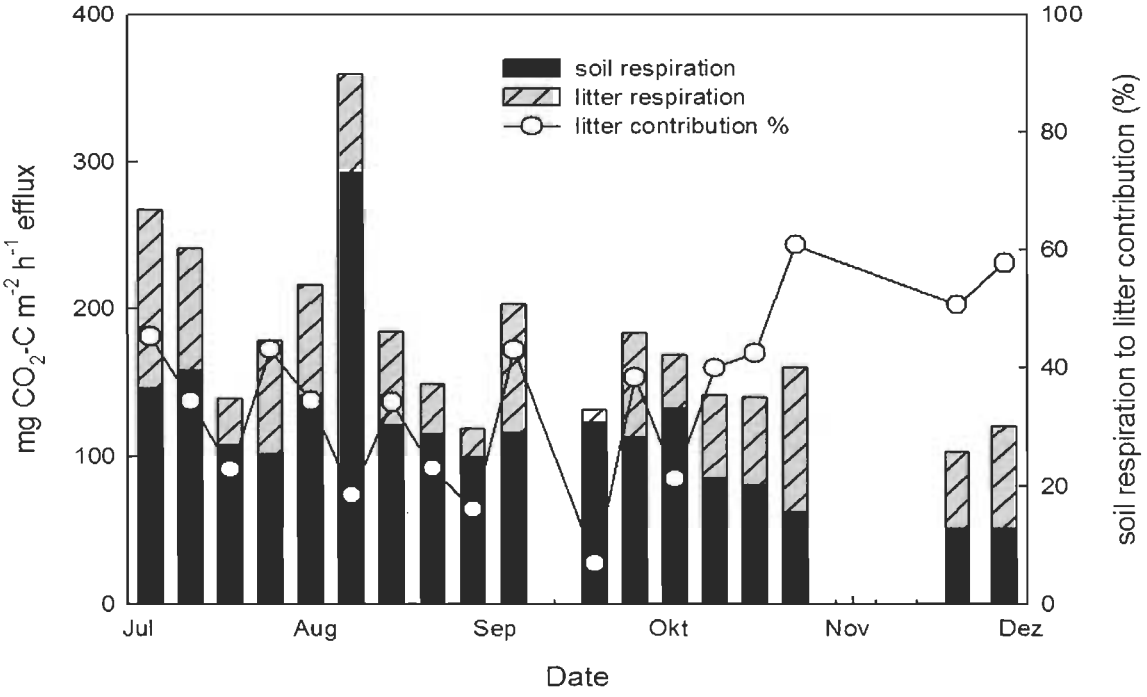


Figure 18: Soil respiration rates of the control treatment and the no-litter treatment. The black bars below the coarse gray bars represent the soil respiration rate from the no-litter treatment. The combined line and scatter plot represents the contribution of litter respiration in percent compared to the total soil respiration.

Significant trends between soil temperature, soil moisture and the calculated litter respiration rate were tested with a Spearman correlation. Results indicated no significant correlations between soil temperature and litter contribution to CO_2 emissions. Similar results were found for the correlation between soil moisture and litter contribution. (Table 5).

Table 5: Spearman correlation test between the contribution of the litter layer in mg CO_2-C $m^{-2}h^{-1}$, volumetric water content and soil temperature.

	p-value	R^2
CO_2-C (litter layer) vs. T_{soil}	0.593	0.13
CO_2-C (litter layer) vs. WC_{vol}	0.505	0.18

The only differences found in the contribution of litter respiration during the measuring period occurred from July to November. The litter contribution to CO_2 emissions ranged between <10% and >60% of the total CO_2 emissions without displaying any trends. The average contribution of the litter amounted to 35% of the total forest soil respiration.

5.3.3 Q_{10} Value – Temperature Sensitivity of Soil CO_2 Effluxes

Similar soil moisture conditions on both treatments allowed us to analyze the intensity of the influence of temperature on CO_2 emissions by means of the Q_{10} value. It describes how much the CO_2 emissions change over a 10°C interval.

Measured CO_2 concentrations were plotted against soil temperature with a correlation plot for both treatments. A Gaussian curve was fitted to these data points (Figure 19). The relationship between temperature and CO_2 effluxes follows best a Gaussian function, which is also recommended by Flanagan and Veum (1974). According to their findings, CO_2 does not increase exponentially with increasing temperature; CO_2 is more likely to flatten out as soon as a specific temperature is reached.

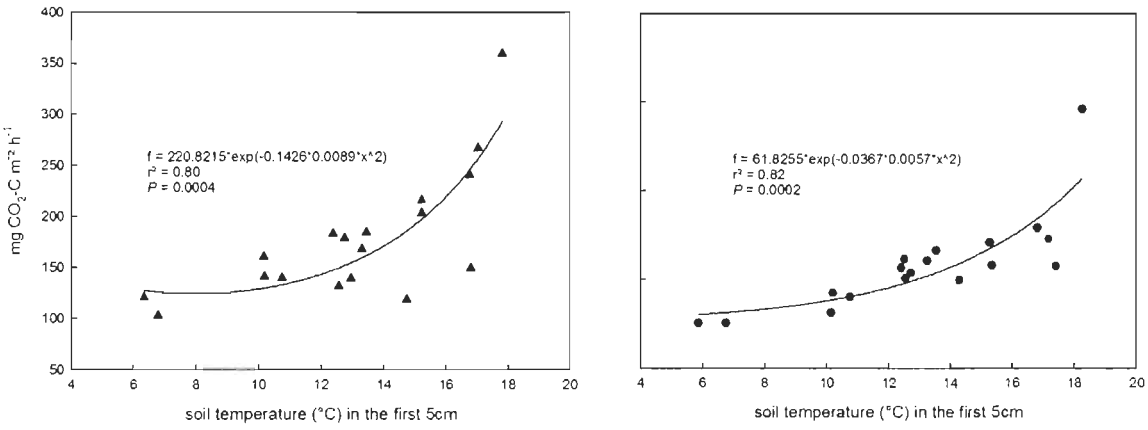


Figure 19: mg CO_2-C $m^{-2}h^{-1}$ concentrations measured at different soil temperatures with Gaussian function (f=a*exp(b*x+c*x^2)), fitted to estimate continuous respiration rates in a range of temperature between 5 and 20°C on the control treatment (▲) and no-litter treatment (●).

By employing the Gaussian regression function, continuous respiration rates over the temperature range between 5 and 20°C were calculated for both treatments (Tuomi, Vanhala et al. 2008).

In a next step, these estimated concentrations of CO_2 emissions formed the basis for the calculation of the Q_{10} value. Q_{10} was calculated with equation 5, as suggested by Fang and Moncrieff (2001):

$$Q_{10} = \frac{R_{T+10}}{R_T} \quad (5)$$

where R_T and $R_T + 10$ are respiration rates at temperatures of T and $T + 10$, respectively. Q_{10} calculation showed how intensely soil respiration reacted on temperature changes (Figure 20).

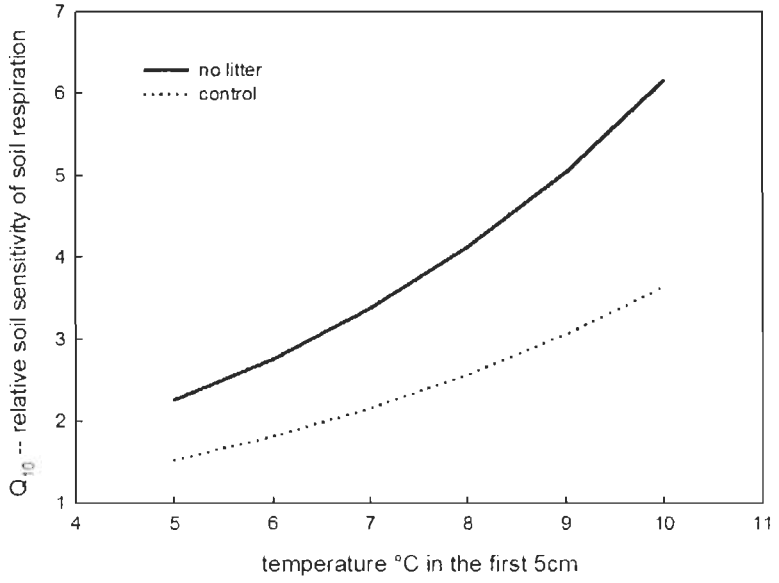


Figure 20: The relative sensitivity of soil respiration to changes in soil temperature (Q_{10} value).

Estimated Q_{10} values indicate that at a temperature of 5°C, the intensity of soil respiration almost doubled on the no-litter treatment as compared to the control treatment. When temperatures increased, the Q_{10} ratios of the two treatments actually drifted even further apart. That means that respiration on the no-litter treatment reacts stronger on temperature than on the control treatment.

5.3.4 CH_4 Fluxes

In general, both treatments were sinks of atmospheric CH_4 and their uptakes ranged from 21 up to 69µg CH_4-C m^{-2} h^{-1}. The mean CH_4 uptake on the no-litter treatment measured 47µg CH_4-C m^{-2} h^{-1} and 38µg CH_4-C m^{-2} h^{-1} on the control treatment (Figure 21). Statistical analysis

showed a significant difference in methane uptake on the treatments. The difference in CH_4 uptakes was attested by a t-test *(P<0.001)*. Significantly, higher CH_4 uptakes occurred on the no-litter treatment.

Theory often describes that methane fluxes are influenced by soil moisture. Consequently, we searched for significant coherence between volumetric soil moisture and methane uptakes. In addition, we considered soil temperatures as another expected determinant influencing the CH_4 uptakes. CH_4 fluxes over time combined with soil temperatures and volumetric soil moisture data are illustrated for both treatments in Figure 20.

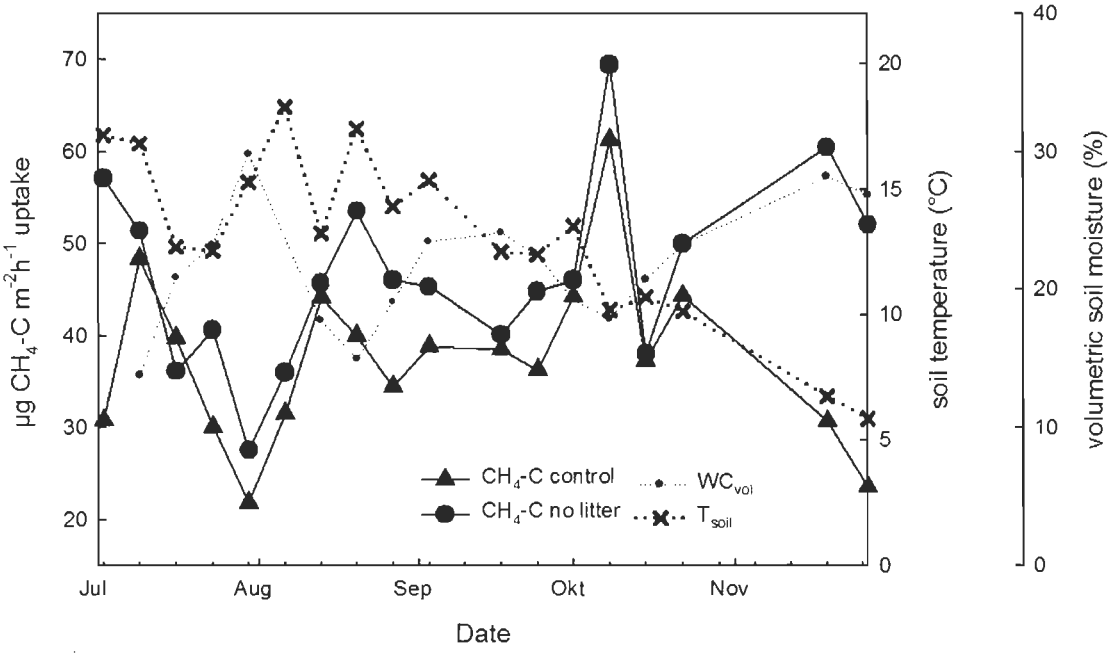


Figure 21: CH_4 uptakes (µg CH_4-C $m^{-2}h^{-1}$) on the control treatment (▲) and no-litter treatment (●), shown together with °C soil temperature (✖) and soil volumetric water content (•) during the measuring period. Each data point represents the daily mean calculated from 12 chambers and the surrounding soil.

Despite large differences in soil temperature during the measurement period, we found no significant correlations between soil temperature and methane uptakes over time on both treatments (Table 6). Instead, the Spearman correlation revealed a significantly negative correlation of CH_4 uptake with volumetric soil moisture on the control treatment (Figure 21).

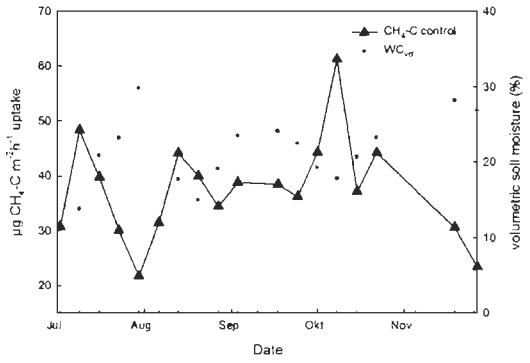


Figure 22: Weekly means of µg CH_4-C on the control treatment (▲) and volumetric water content (•). Each data point represents the daily mean calculated from 12 chambers and the surrounding soil.

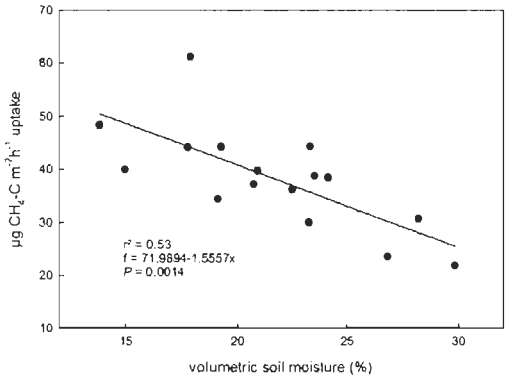


Figure 23: Correlation of the weekly means of methane uptake on the control treatment with the weekly mean volumetric soil moisture in percent during the measuring period.

The lowest CH_4 concentrations on the control treatment were detected when the forest soil was relatively wet (Figure 23). Consequently, the highest CH_4 concentrations occurred when the soil was relatively dry. In contrast, no correlations between volumetric soil moisture and methane uptake were found on the no-litter treatment.

Table 6: Spearman correlation test between µg CH_4-C $m^{-2}h^{-1}$, volumetric water content and soil temperatures of both treatments.

	p-value	***R^2***
CH_4-C vs. T_{soil} (control)	0.928	-0.02
CH_4-C vs. T_{soil} (no-litter)	0.422	0,20
CH_4-C vs. WC_{vol} (control)	***<0.001***	***0.67***
CH_4-C vs. WC_{vol} (no-litter)	0.288	0.28

5.3.5 Litter as Inhibitor or Producer of CH_4 Uptake

As mentioned in the previous section, we detected coherence between CH_4 uptakes and volumetric soil moisture on the control treatment. We expected similar coherence between the potential methane uptake of the litter layer, soil moisture and soil temperature.

For this purpose, we assumed that the differences in the CH_4 flux of the control treatment and the no-litter treatment represented the methane uptake of the litter layer. However, this assumption was wrong because the no-litter treatment had a

higher methane uptake than the control treatment. Therefore, the litter layer acted as an inhibitor of CH_4 or as a source of CH_4 rather than as a booster, such as the case of CO_2 emissions. For this reason, the calculated values did not represent any extra uptake, but resulted from the reduction of the total methane uptake, caused by the litter layer because, with the exception of one measuring day, CH_4 uptakes were higher on the control treatment (Figure 24). Therefore, we may conclude that the litter layer acts either as a CH_4 producer or as an inhibitor of methane uptakes.

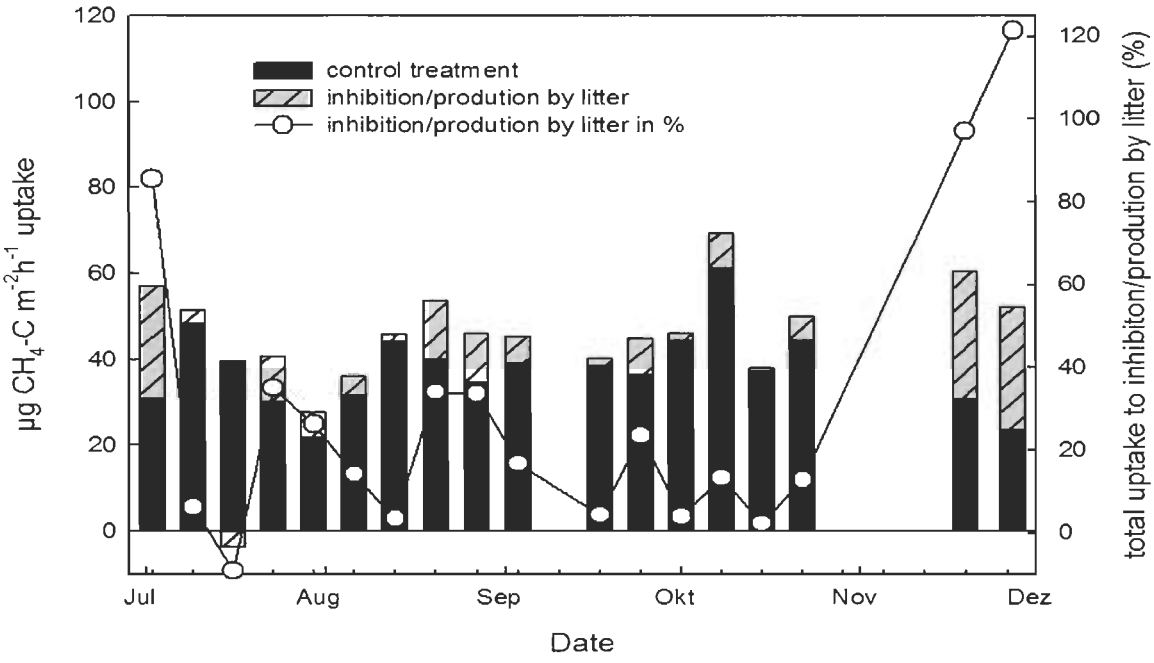


Figure 24: Uptakes on the no-litter treatment in µg CH_4-C m^{-2} h^{-1}. The combination of black bar and coarse gray bar represents the total CH_4 uptake. The black bars display the control treatment; the coarse gray bars illustrate the higher uptake of µg CH_4-C m^{-2} h^{-1} of the no-litter treatment. The combined line and scatter plot show the inhibition/production of the litter layer in relation to the total methane uptake in percent.

Correlations between the amount of inhibition or extra production of the litter layer and soil moisture, as tested with Spearman correlation tests, showed no significant trends. The same results were obtained with the correlation with soil moisture (Table 7).

Table 7: Spearman correlation test between contribution/production of the litter layer in µg CH_4-C $m^{-2}h^{-1}$, volumetric water content and soil temperature.

	p-value	R^2
amount of inhibited/produced CH_4-C vs. T_{soil}	0.726	0.09
amount of inhibited/produced CH_4-C vs. WC_{vol}	0.391	-0.23

With the exception of the first measurement, the mean CH_4 uptake on the no-litter treatment was 20% higher in summer as compared to the control treatment. In autumn, the methane uptake rates were about 110% higher on the no-litter treatment than on the control treatment. Viewed over the entire measurement period, the no-litter treatment absorbed 29% more of CH_4.

Further, a higher CH_4 uptake was observed on the no-litter treatment on all measurement days, except on July 16, when more methane was absorbed on the control treatment.

5.3.6 N_2O Fluxes

Nitrous oxide fluxes were rare and when effluxes did occur, they were very low. Linear curve fitting of the gas samples during the one-hour measuring periods in the field showed significant N_2O effluxes only on three sampling days. On all other sampling days, no significant trends between N_2O concentrations and chamber closing time were observed. For these days, N_2O-fluxes were set to zero. When N_2O effluxes were measured, they ranged between 2 and 14µg N_2O-N $m^{-2}h^{-1}$ on both treatments (Figure 25). A Wilcoxon test showed no significant differences between the two treatments. Data for N_2O effluxes, soil temperature, volumetric water content and the soil parameters (NO_3^-, NH_4^+ and N_t) are illustrated in Figure 25 and Figure 26.

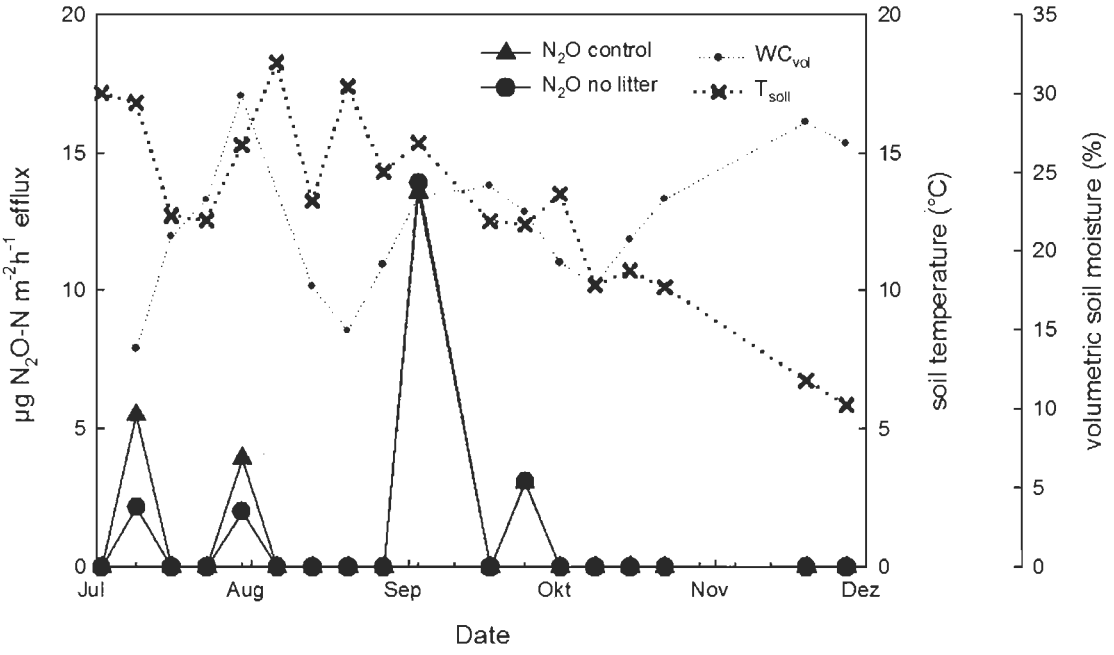


Figure 25: N_2O fluxes (µg N_2O-N $m^{-2}h^{-1}$) on the control treatment (▲) and no-litter treatment (●), shown together with °C soil temperature (✖) and soil volumetric water content (•) during the measuring period. Each data point represents the daily mean calculated from 12 chambers and the surrounding soil.

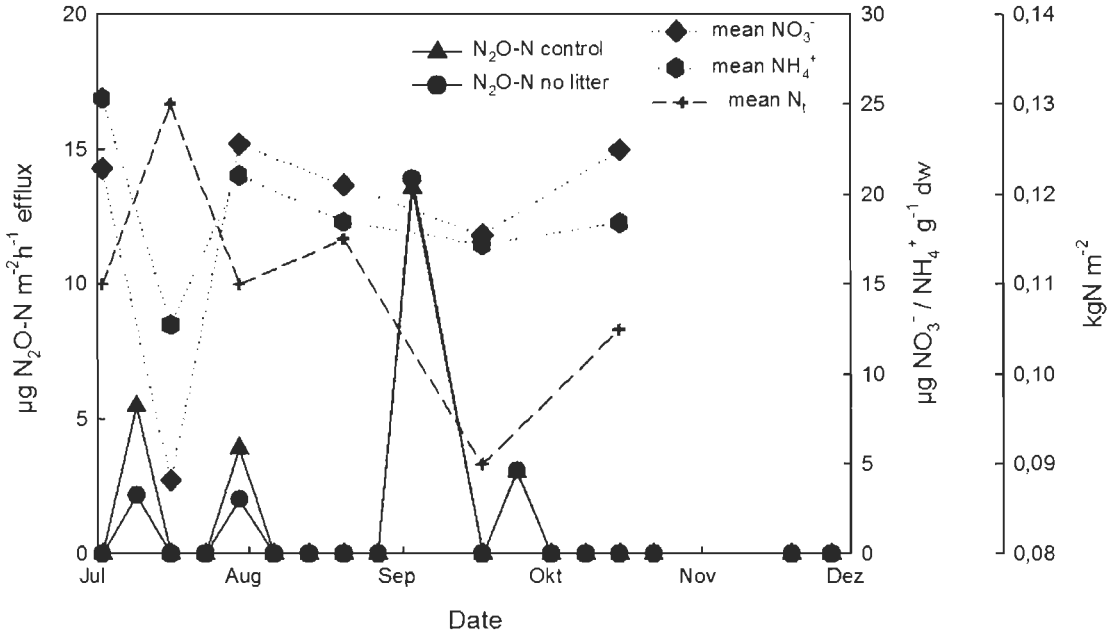


Figure 26: N_2O fluxes (µg N_2O-N $m^{-2}h^{-1}$) on the control treatment (▲) and no-litter treatment (●), shown together with mean nitrate concentration (⬢), mean ammonium concentration (◆) and mean nitrogen content (+) during the measuring period. Each data point represents the daily mean calculated from 12 chambers and surrounding soil.

On both treatments, results of a Person correlation test indicated no significant correlation between T_{soil} and N_2O effluxes. Additionally, on both treatments, no significant correlation was identified between N_2O effluxes and volumetric soil moisture. Furthermore, no significant correlations between N_2O effluxes and nitrate, ammonia and total soil nitrogen were found (Table 8).

Table 8: Spearman correlation test between µg N_2O-N $m^{-2}h^{-1}$, volumetric water content, soil temperature, nitrate, ammonium and total nitrogen on both treatments.

	p-value	R^2
N_2O-N vs. T_{soil} (control)	0.245	0.29
N_2O-N vs. T_{soil} (no-litter)	0.388	0.22
N_2O-N vs. WC_{vol} (control)	0.562	0.16
N_2O-N vs. WC_{vol} (no-litter)	0.743	0.09
N_2O-N vs. NO_3^- (control)	0.239	0.57
N_2O-N vs. NO_3^- (no-litter)	0.758	-0.16
N_2O-N vs. NH_4^+ (control)	0.158	0.65
N_2O-N vs. NH_4^+ (no-litter)	0.805	0.13
N_2O-N vs. N_t (control)	0.689	0.21
N_2O-N vs. N_t (no-litter)	0.842	-0.11

5.3.7 Litter as N_2O Emitter

Although few data on nitrous oxide emissions were obtained and no significant correlations were found, we explored the impact of litter on the total nitrous oxide emissions.

N_2O fluxes from the litter layer were calculated by subtracting emissions from the no-litter treatment from emissions of the control treatment (Figure 27).

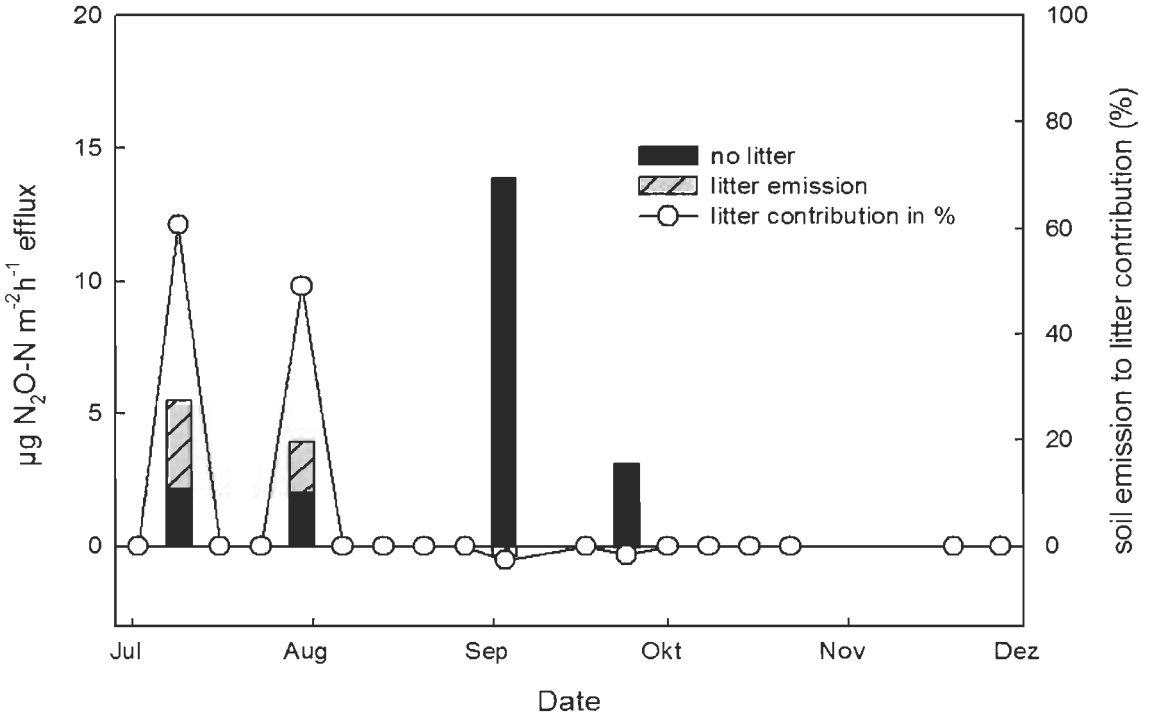


Figure 27: N_2O emissions (µg N_2O-N $m^{-2}h^{-1}$) of the no-litter treatment, the control treatment and the litter are expressed as difference. The black bars illustrate the no-litter treatment. The coarse gray bars stand for the calculated contribution of the litter layer to the total N_2O emissions. The combined line and scatter plot represent the contribution of litter N_2O emissions in percent of the total N_2O outgassing.

Despite scarce data resolution, the contribution of the litter layer to N_2O emissions was tested on relationships between soil temperatures, volumetric soil moisture and the soil parameters NO_3^-, NH_4^+ and N_t. A Pearson correlation test indicated no significant correlations between litter N_2O emissions and all soil parameters tested (Table 9).

Table 9: Spearman correlation test between the contribution of the litter layer in µg N_2O-N $m^{-2}h^{-1}$, volumetric water content, soil temperature, nitrate, ammonium and total nitrogen.

	p-value	***R^2***
N_2O-N (litter layer) vs. T_{soil}	0.214	0.31
N_2O-N (litter layer) vs. WC_{vol}	0.527	-0.17
N_2O-N (litter layer) vs. NO_3^-	0.540	0.31
N_2O-N (litter layer) vs. NH_4^+	0.623	0.26
N_2O-N (litter layer) vs. N_t	1.000	<0.001

The proportion between the litter contributions to total N_2O emissions seemed to change between summer and autumn. While in summer (July and August) the litter layer had a contributory role of around 60% of the total N_2O emissions, litter made no contribution to

the total N_2O emissions in autumn: From the beginning to the end of September, the no-litter treatment were higher on the no-litter treatment (see Figure 26). However, this observation is solely based on four measurement events.

6. Discussion

6.1 Soil Parameters

As described in various studies (Zeller, Colin-Belgrand et al. 2000; Dzwonko and Gawronski 2002a), it is obvious that litter removal significantly decreases soil nutrients. Soil parameters at our study site were affected by significant losses of phosphorus (P), total soil carbon (C_t) and total soil nitrogen (N_t). Other soil nutrients like NH_4^+ and NO_3^- remained unaffected by the litter removal. According to Sayer (2006), soil nutrient losses caused by litter removal follows three theoretical patterns over time and depend on the buffering capacity of the system. In the first pattern, no changes in the concentrations of the nutrients appear for a number of years when a sudden decrease occurs. This pattern indicates that the system is buffered against losses. The second pattern describes a linear decrease in the nutrients over time, caused by an intermediate buffering capacity for the nutrients. The third pattern is characterized by a strong decrease in the nutrient concentrations shortly after litter removal, which indicates that the system is unable to buffer well against losses of the nutrients (Figure 28).

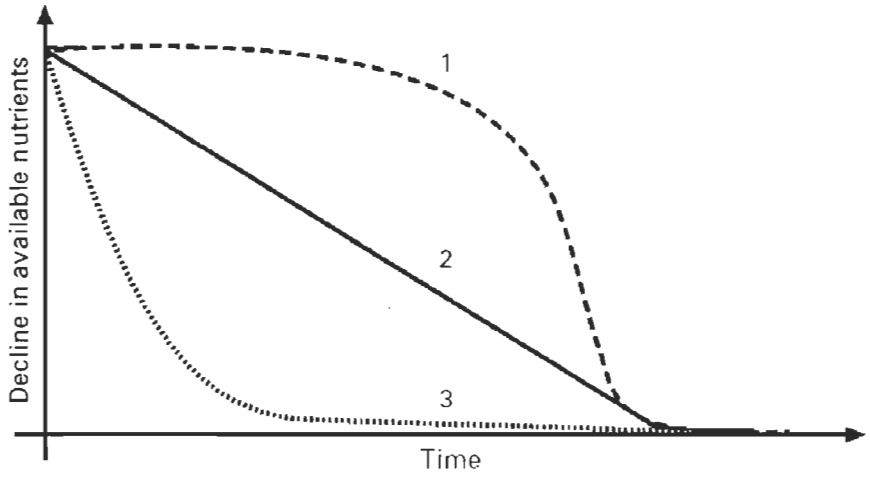


Figure 28: Three possible patterns of nutrient loss caused by litter removal over time (Sayer 2006).

6.1.1 Phosphorus

Considering the aforementioned three patterns of Sayer (2006), P content losses on the no-litter treatment followed the third pattern, which indicates a quick loss of the nutrient and a small buffering capacity of the system. Phosphorus contents decreased within three and a half month from nearly 3µg g^{-1}dw to 1.7µg g^{-1}dw, which means a loss of almost 50 percent after quite a short period. Phosphate depletion of soil was also observed in a litter removal experiment by Dzwonko and Gawronski (2002a). According to their long-term study, P did not follow the third pattern. They described the reduction of phosphate rather as a linear decrease over time, matching pattern two. Nevertheless, litter is known to represent a phosphate source for the soil, which is relatively quickly decomposed and mineralized (Berg and Mcclaugherty 1989; Vesterdal 1999; Moore, Trofymow et al. 2006). We assume that the nutrient balance of P is negatively affected by the removal of litter.

6.1.2 C_t, N_t, NH_4^+ and NO_3^-

According to Fahey et al. (2011), litter represents a principal source of C and N for forest soils. They describe significant N and C fluxes from litter into the forest soil within one year, which underlines our findings and those published by Kelley and Stevenson (1995) that total soil carbon and nitrogen significantly decreased on the no-litter treatment. In their two-year study, Park and Matzner (2003) also noted a substantial carbon loss. Rubino et al. (2010) observed losses of C from litter into the forest floor soil even during a one-year experiment.

Zeller et al. (2000) and Mo et al. (2003) detected a linear release of nitrogen from the litter layer into the mineral soil. This corresponds to our findings, which showed a significant decrease in N_t on the no-litter treatment. In contrast to the linear N losses, Mcclaugherty et al. (1985) and Rubino et al. (2010) found that N was first accumulated in the litter and by the end of a specific time, N started to be released from the litter. In a detailed study, Micks et al. (2004) describe nitrogen losses from decaying litter in the form of dissolved organic nitrogen (DON) rather than in the form of dissolved inorganic forms like NH_4^+ and NO_3^- (DIN). Results show that DIN is mainly produced in mineral soils; they probably just leached from the litter layer to the mineral soil in small amounts. Due to the fact that N is mainly released from the litter layer in the form of DON like proteins (e.g. simple amino acids)

(Hedin, Armesto et al. 1995; Micks, Downs et al. 2004), we suspect that the litter removal caused the bacteria to use more nitrogen resources stored in the soil because of a diminished N supply from the litter layer. This would explain the total nitrogen loss on the no-litter treatment despite stable ammonia and nitrate households on both treatments.

In addition, losses of N may be enhanced by the missing function of fungal hyphae, which were removed with the litter layer, yet take up external N during decomposition (Li, Moorhead et al. 2009) and transport N from the litter to the soil (Hart and Firestone 1991).

Based on the results of other studies and our own findings, we suggest that C and N concentrations decline in a linear pattern. Moreover, Aerts (1996) has pointed out that P concentrations in the soil and in the foliage decrease more rapidly than N and C. We assume that nutrients were not lost from soil during the measuring period but that they shifted into lower layers because of a disturbed nutrient cycle (Sayer 2006). It is possible that the removal of the litter layer would have led to higher leaching rates of nutrients in the soil matrix with a longer period of experiment.

6.1.3 Microbial Biomass

We found no significant differences between the two treatments. However, we detected a decreasing trend on the no-litter treatment and we suspect that significant differences might appear with a longer study period.

Due to a significant increase of C_{mic} on the control treatment, development of the microorganisms on the no-litter treatment seemed to be negatively affected by the withdrawal of the litter biomass. We assume that the natural conditions on the control treatment supported the development of the microorganism, as no significant decreases or increases evolved. Li et al. (2004) reported a 67% decline of total microbial biomass after seven years of litter removal. Applying the substrate-induced respiration method Fisk and Fahey (2001) measured a 17% decline of microbial biomass over a nine-year litter removal study. Anderson and Domsch (1989) point out that the volume of the microbial biomass in soils is related to the annual C input. Based on significant C_t losses on the no-litter treatment, we assume that the decreasing bacteria content was additionally negatively

influenced by a decreasing C_t content. These findings show that the litter manipulation had a negative effect on the bacterial community whereas the bacterial community was more stable on the control treatment.

6.1.4 pH, Microbial Respiration and Glucose

No significant differences in pH, microbial respiration rates or glucose contents were detected between the treatments. However, we think that the period of the study was too short to record any differences caused by litter removal. For instance, Ponge et al. (1993) detected a soil pH decrease when litter was removed in a four-year study. Dzwonko and Gawronski (2002b) report significant decreases in pH on a nutrient-poor deciduous forest stand in Poland over a 16-year study period.

As regards microbial respiration, we found no significant differences between the two treatments. However, based on the decreasing trend in the microbial biomass on the no-litter treatment it seems reasonable to assume that after a prolonged study period, significant differences may occur. The same might be true for glucose.

6.2 Gas Fluxes

6.2.1 Soil Respiration

When looking at the results, we accept the hypothesis that CO_2 effluxes on the control treatment are higher than the effluxes on the no-litter treatment. Just like Li et al. (2004), Nadelhoffer et al. (2004), Vasconcelos et al. (2004), Sotta et al. (2006) and Yan et al. (2013), we detected higher CO_2 emissions on the control treatment where litter still covered the forest floor. Our findings show a contribution of 35% of the litter to the total CO_2 respiration. When comparing these data with other studies, it is important to mention that the value does not represent the annual mean but the period between July and November. We assume that the mean litter contribution of CO_2 is overestimated due to missing CO_2 concentrations during the winter period and springtime or maybe is underestimated due to low root respiration in winter and ongoing litter decomposition. Nadelhoffer et al. (2004) note that in their study the contribution of litter to the total CO_2 emissions was 26% per year (oak-maple-birch forest); Vasconcelos et al. (2004) found a significant reduction in soil CO_2 effluxes on a litter removed treatment with an annual mean reduction of 28% of total CO_2 emissions (tropical forest). Yan et al. (2013) describe a reduction of CO_2 emissions averaging approximately 39% through litter exclusion in a pine forest. Due do missing CO_2 fluxes during spring and winter, it is difficult to compare our calculated values with annual results, but our values are still within the range of observations of other studies. We assume that the reduction of CO_2 emissions on the no-litter treatment is due to the reduced substrate availability required for the metabolic processes of fungi and bacteria (Yiqi and Xuhui 2006; Yan, Chen et al. 2013).

The amount of substrate available for heterotrophic decomposers is not the only factor affecting soil respiration. We found significant correlations between soil temperature and CO_2 emissions on both treatments, which has also been indicated by various other analyses of soil respiration rates (Raich and Schlesinger 1992; Lloyd and Taylor 1994; Fang and Moncrieff 2001; Sotta, Veldkamp et al. 2006). The results reveal that CO_2 effluxes increase with rising soil temperatures and vice versa (Flanagan and Veum 1974; Dong, Scharffe et al. 1998; Yan, Zhang et al. 2005; Kitzler, Zechmeister-Boltenstern et al. 2006a).

Various studies have provided evidence that soil moisture can positively influence soil respiration (Raich and Schlesinger 1992; Sotta, Veldkamp et al. 2006; Yan, Chen et al. 2013): After heavy rain events, high peaks of CO_2 emissions are released, caused by new substrates available for increased microbial activity. In our study we observed no significant correlation between soil respiration and soil water content, as found in other studies (Dong, Scharffe et al. 1998; Brechet, Ponton et al. 2009). Kitzler at al. (2006a) and Yiqi and Xuhui (2006) conclude that this is a result of decreased O_2 diffusion into the soil, which, in consequence, reduces CO_2 emission due to anaerobic soil conditions.

However, this approach was not appropriate for our study because of the lack of precipitation, anaerobic soil conditions could not develop. As no reduction or increase in CO_2 effluxes was observed when the soil was relatively wet, we assume that in our study, soil moisture never reached a completely dry or saturated condition. Therefore, respiration took place under intermediate soil moisture conditions and water had no significant effect on CO_2 emissions. It is also likely that soil temperature was the most influencing factor for altering CO_2 emissions at our study site and precipitation was too low to effect CO_2 emissions alone. According to Yan et al. (2005), Tang et al. (2006) and Zhao et al. (2013), it is the interaction of soil temperature and soil moisture which affects soil respiration.

6.2.2 Litter-Derived CO_2 Emissions

Although many studies describe significant interactions between litter CO_2 effluxes, temperature, and moisture (Berg and McClaugherty 2003; Dannenmann, Gasche et al. 2007), we found no significant correlations. Due to the non-significant correlations between the calculated CO_2 emissions of the litter layer, soil temperature and soil moisture, it is difficult to make any clear statements. Nevertheless, the available data allow us to make certain assumptions. For instance, we can assume that soil temperature and litter temperature are two single parameters that refer to soil respiration and to the litter respiration, respectively. Verburg et al. (1999) found no effects on litter decomposition when leaf litter was incubated at elevated temperatures and they concluded that the increased temperature was offset by decreased moisture. This finding is consistent with that

of Dannemann et al. (2007), who note that CO_2 emissions of the litter layer are mainly driven by moisture.

Due to the lack of data on litter moisture and litter temperatures, it was not possible to establish sufficient proof that litter moisture or litter temperature are the dominant factors controlling CO_2 fluxes from litter. Studies conducted by Verburg et al. (1999) and Dannemann et al. (2007) provide evidence that specific data such as litter moisture and litter temperatures are needed.

6.2.3 Temperature Sensitivity of Respiration Rates

Lloyd and Taylor (1994) and Chen et al. (2000) report that Q_{10} values of soil respiration vary widely from 1 (low sensitivity) to more than 10 (high sensitivity) and depend on the climatic location and ecosystem type. Further, Raich and Schlesinger (1992) have calculated a global mean value for Q_{10} of 2.4, with a range of 1.3 to 3.3. On the other hand, Cheng et al. (2013) calculated a Q_{10} factor of 2.64 on the no-litter treatment and a slightly higher factor of 2.69 on the control treatment in a pine forest. When comparing our Q_{10} values, amounting to 3.5 for the control treatment and 6.1 for the litter removal treatment, we have to consider that the Q_{10} values from a pine forest are difficult to compare because of different ecosystem compositions. Another study conducted under similar ecosystem conditions by Yan et al. (2005) in a broadleaf forest show a higher Q_{10} value on the no-litter treatment (2.4) than on the control treatment (2.1). Even our Q_{10} values indicate that an increase in temperature by 10° has a stronger impact on respiration rates on the no-litter treatment (factor 6.1) than on the control treatment (factor 3.5).

However, if we consider the respiration rates of the two treatments over the study period, it becomes evident that the quantity of CO_2 emissions varies not only between the two treatments but also between the seasons. It appears that the quantitative difference in amounts of released CO_2 was smaller in summertime than in wintertime. Even though the summer CO_2 fluxes displayed a higher increase at the litter removal plots than at the control plots, their values never exceeded those of the control treatments.

One possible explanation for this observation may lie in the presence of the litter layer and its moisture content during summer although we do not have any data on litter moisture. Borken et al. (2003), Borken et al. (2006), Davidson et al. (2006a) and Davidson et al. (2006b) refer to inhibited respiration from the litter layer during summertime due to a limited water supply in the litter layer. This finding indicates that CO_2 release of the litter layer decreases with decreasing water content caused by increased temperatures. Thus, despite lacking data on litter moisture, we may assume that the limited water supply in the litter horizon reflected the warmer climatic conditions in summer, which involved a reduction in the CO_2 release. On the other hand, the no-litter treatment remained unaffected due to similar soil moisture conditions on both treatments; therefore, no water stress occurred on the no-litter treatment. The interaction between the litter layer, moisture, and temperature may also explain the higher differences in autumn compared to smaller differences in summer. Increased moisture and lower temperatures stopped the limited supply of water in the litter layer.

6.2.4 Methane Fluxes

Forest soils are the largest biological sinks for atmospheric methane (Le Mer and Roger 2001; Kolb 2011a). Even our results reflect solid methane uptakes on both treatments, displaying higher uptakes on the no-litter treatment (summer/autumn mean of 47µg CH_4-C m^{-2} h^{-1}). When comparing our results with other litter removal experiments, nearly all findings coincide with ours, which indicate that methane uptake is higher on litter removal plots (Dong, Scharffe et al. 1998; Brumme and Borken 1999; Smith, Ball et al. 2003). In contrast, Yan et al. (2005), Liu et al (2007) and Cheng et al. (2013) and could not make out any significant quantitative differences in CH_4 uptakes between the two treatments. They estimated a 24% increase in CH_4 uptake following the removal of the litter layer. Yan et al. (2008) report a 29% increase in CH_4 uptake due to the removal of the litter. Both results are similar to our findings, which revealed a mean increase by 29% during the summer and autumn period following the removal of the litter layer.

Furthermore, Borken and Beese (2006)and Vasconcelos et al. (2004) found that CH_4 consumption correlated negatively with decreasing soil moisture. This contradicts findings of

our study and others Dong et al. (1998), Brumme and Borken (1999), Tang et al. (2006), Liu et al. (2007), Guckland et al. (2009), Schaufler et al. (2010) and Yan et al. (2013) indicating that CH_4 consumption rates rose with the reduction of soil moisture.

Based on the similar soil water contents and soil temperatures on both treatments *($P<0.05$)*, we assume that bacterial metabolism in mineral soils takes place under similar conditions. We conclude that lower CH_4 uptake rates on the control treatment occur because the litter layer acts as a diffusion barrier into and out of the soil (Dong, Scharffe et al. 1998; Brumme and Borken 1999; Smith, Ball et al. 2003; Guckland, Flessa et al. 2009). Therefore, the decreased CH_4 uptake on the control treatment may mainly be attributed to a lower diffusion rate which inhibited CH_4 oxidation through a diminished contact between CH_4, O_2, and the biologically active soil layer (Dong, Scharffe et al. 1998; Kolb 2011b), especially when soil conditions were humid (Yan, Zhang et al. 2005).

In addition, it is possible that CH_4 absorption on the control treatment was partly offset by CH_4 production. We speculate that on days with higher precipitation and, hence, with higher water content in the lower levels of the leaf litter and the upper mineral soil (Kolb 2011b), anaerobic microsites may be formed, which activate methanogenic bacterial metabolism (Borken, Gründel et al. 2000). Brumme and Borken (1999) found that the litter layer was inactive in methane oxidation, which suggests that the litter layer was not strongly colonized by bacteria. This fits well the theory that fungi are the major decomposers of forest litter and produce CO_2 during mineralization (Boberg 2009). This context given, fungi dominate the decomposition processes in the litter layer (Tang, Liu et al. 2006) and, therefore, the litter layer is a major contributor to CO_2 emissions rather than to CH_4 emissions. Further, a probably small amount of CH_4 may be simultaneously produced in anaerobic microsites in the lower litter layer when conditions are wet, whereby the amounts of CH_4 produced in the lower litter layer hardly reduce the total net CH_4 uptake.

In contrast to increased methane uptakes on the no-litter treatment and no significant alterations of CH_4 uptakes, other authors refer to lower methane uptake rates on the no-litter treatment (Vasconcelos, Zarin et al. 2004; Borken and Beese 2006). We assume that lower methane uptake rates can also occur due to different physical (soil texture, main

geology), biological (forest type) and chemical (soil fertility, pH value) conditions. The amount of methanotrophic bacteria in the pine litter layer (Borken and Beese 2006) probably constituted the larger part of total bacteria rather than the amount of total soil bacteria. Therefore, the essential part of methanotrophs was removed with the litter.

Another interesting observation was made when looking at the CH_4 fluxes at the end November (see Figure 24). The CH_4 uptakes on the no-litter treatment were almost twice the amount of the control treatment. Before that time, the quantitative differences between the treatments had never become so obvious. Apparently, the CH_4 uptake on the control treatment had been limited, which led to diminished CH_4 uptakes. One possible explanation could be that the combination of low temperatures and high soil moistures in autumn caused this pattern. The absence of the litter layer may also have had a crucial influence when temperatures dropped and soil moisture increased. A possible interpretation is that due to the wetter conditions in autumn, the litter layer was saturated with water and CH_4 production occurred because of anaerobic conditions. Schaufler (2010) found that methane uptakes turned into CH_4 emissions when the water-filled pore space reached a percentage of 80- 95%. On the other hand, at that time of the year, the litter layer was an enhanced diffusion barrier and depressed the CH_4 uptake. On the other hand, the CH_4 uptakes on no-litter treatment were not decreased because the diffusion barrier was missing.

On 16 July, a higher CH_4 uptake occurred on the no-litter treatment for which we found no convincing explanation. Maybe it was due to error of measurement.

6.2.5 Nitrous Oxide Fluxes

During the measuring period from July to November, only three out of the 18 samples revealed N_2O fluxes. For the remaining measuring days, no fluxes were measured. Apparently, measuring N_2O fluxes with the closed chamber method is too coarse for solid flux detection. It seems that nitrous oxide fluxes are much more sensitive than, for example, CO_2 fluxes and thus require a higher temporal resolution of measurements (several measurements per day). Alternative measurement methods using a higher time resolution such as automatic systems with static chambers would be better suited for nitrous oxide measurements. However, comparable

studies refer to most likely correlations between N_2O, soil moisture (Schindlbacher, Zechmeister-Boltenstern et al. 2004; Wu, Brüggemann et al. 2010), soil temperature (Pilegaard, Skiba et al. 2006), and soil parameters like NO_3^- and NH_4^+ (Kitzler, Zechmeister-Boltenstern et al. 2006a; Kitzler, Zechmeister-Boltenstern et al. 2006b; Kroeze, Bouwman et al. 2007) and N_t (Liu and Greaver 2009).

Although we measured some significant N_2O fluxes, data are not sufficient to either accept or reject the hypothesis that the control treatments emit higher amounts of N_2O than the no-litter treatment. When considering the flux rates estimated during the study period (Figure 5), the emissions on the control treatment were twice as high as on the no-litter treatment. This result would confirm our hypothesis. Higher fluxes on the control treatment would also correspond to Yan et al. (2005) and Liu et al. (2007). However, during late summer and at the beginning of autumn, the emitted amounts of N_2O were slightly higher on the no-litter treatment. Cheng et al. (2013) describes similar N_2O fluxes whereby fluxes on the no-litter treatments were higher during the dry season. All other measuring days during the measuring period showed no significant emissions on both treatments.

Our N_2O results may be explained by comparing them with other manipulation studies. Regarding the weather conditions from July to the end of August, the total precipitation amounted to 370 mm (measured by a permanent precipitation station at the Rosalia study area); mean soil temperature was 15°C. These values contrast with a total precipitation of 230 mm/m^{-2} and steadily decreasing temperatures down to 5°C during the autumn period (from September to the end of November). When comparing the N_2O fluxes during summer with those of autumn, it becomes evident that the litter layer is mainly responsible for the slightly shifting patterns of N_2O fluxes. We assume that the changing weather conditions, turning from warmer and wetter to colder and drier conditions, blocked the N_2O production in the litter layer.

This would suggest that the litter layer is an N_2O producer that is positively influenced by wetter and warmer conditions. Warmer and wetter conditions lead to increased N_2O production in the litter layer. This hypothesis would contradict Tang et al. (2006) who suggest that microbial N_2O production is mainly related to the mineral soil rather than to the

surface litter layer. On the other hand, Cheng et al. (2013) describe patterns similar to ours. They refer to a positive effect of the litter layer in the wet season, resulting in increased N_2O emissions on the control treatment. Unfortunately, they found no significant correlation between N_2O and soil temperatures. Still, their findings back our assumption that the litter layer produces N_2O especially in wetter months. Further, various studies (Pilegaard, Skiba et al. 2006; Liu, Zhao et al. 2007) support our findings that N_2O fluxes are positively correlated with increasing soil temperatures and increasing soil moisture. Pilegaard et al. (2006) point out that, according to their findings, increasing soil temperatures increased N_2O emissions because rates of enzymatic processes generally increase with temperatures as long as other factors such as soil moisture or available substrate do not have a limiting effect.

Thus, it seems that N_2O emissions are mainly activated by soil moisture and soil temperature. However, our data did not provide a clear proof that the N_2O emission originated either from the litter layer or from the mineral soil. We assume that meteorological conditions (temperature and humidity) have a huge impact on the amounts of N_2O released. Further, meteorological factors seem to stimulate the litter layer and the mineral soil in different ways. It is still not clear how N_2O emissions and meteorological factors interact with the different layers.

7. Conclusion

CO_2

The findings provided evidence that elevated temperatures during summertime increased CO_2 emissions on both treatments, the no-litter treatment showing a higher dependence on temperature with a higher Q_{10} factor (6.1). We assume that less precipitation and warmer climatic conditions lead to water stress in the litter layer. This water stress inhibited microbial respiration on the control treatment whereas the no-litter treatment stored enough in the mineral soil. This finding suggests that global warming will promote microbial respiration, especially when the litter layer is removed, and will lead to increased CO_2 releases into the atmosphere. However, soil-warming experiments have demonstrated that the soil microflora adapts to increasing temperatures and that even more quantities of C are stored in boreal forests (Liski, Ilvesniemi et al. 1999; Giardina and Ryan 2000).

We expect that a long-term study will provide evidence that litter exclusion leads to a cut of available substrate in the mineral soil and affects the soil microbial communities and, hence, microbial CO_2 respiration of the soil declines (Yan, Chen et al. 2013).

Soil Nutrients

By removing the litter layer, we found a minor trend of decreasing soil nutrients over time, strengthened our assumption that the soil microflora started to take up nutrients in the mineral soil that are more difficult to access and would normally be uninteresting to microbes under natural conditions.

In addition, with a size of a half-square meter each, the no-litter treatments were too small. We suspect that surrounding nutrients were leached into the study area and, thus, the artificial blocking of the supply with nutrients did not work as planned. We assume that in a long-term study using with a larger surfaces of removed litter, significant decreases would become evident.

CH_4

Litter removal promoted the CH_4 uptake, especially in dry periods. Apparently, drier and, hence, warmer climatic conditions have a negative effect on global warming through reduced CH_4 atmospheric concentrations in a beech forests.

N_2O

Concerning N_2O emission, we recommend further studies that use a method other than static manual headspace chambers for detecting N_2O emissions. Measurement methods with a higher time resolution such as an automatic system with static chambers would be better suited for nitrous oxide measurements.

8. Appendix

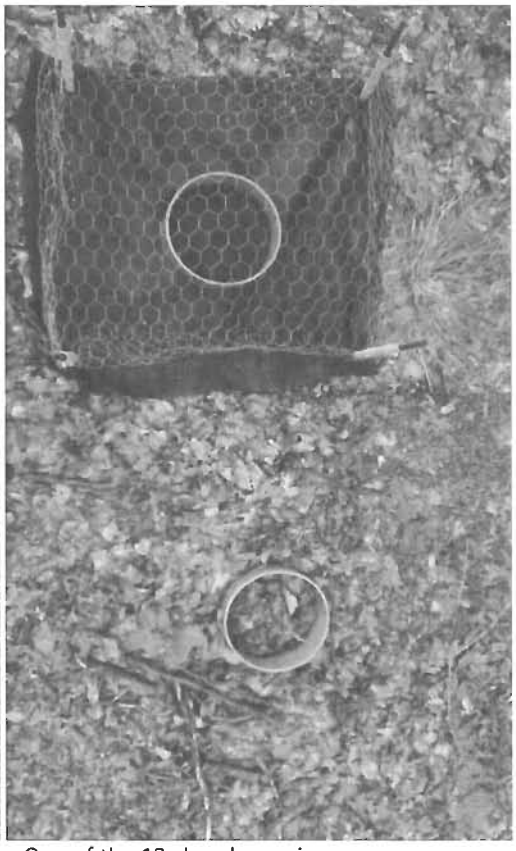
Appendix 1: Schedule of sampling soils, soil profiles, and soil gases in 2012

	Jul					Aug				Sep
	CW 26	CW 27	CW 28	CW 29	CW 30	CW 31	CW 32	CW 33	CW 34	CW 35
gas samples		x	x	x	x	x	x	x	x	x
soil samples		x		x		x			x	
soil profile samples			x							
preparation no-litter t.	x									

	Oct								Nov
	CW 36	CW 37	CW 38	CW 39	CW 40	CW 41	CW 42	CW 43	CW 44
gas samples	x	x	x	x	x	x	x	x	x
soil samples			x				x		
soil profile samples								x	

Appendix 2: Pairs of static manual headspace chambers, control treatment, and no-litter treatment covered with black garden foil and wire mesh fence

Half the transect in pure beech forest



One of the 12 chamber pairs

Appendix 3: Parameter estimation for CO_2 emissions with R

```
##loop for astemating the variables a b and y0 for all CO2 dates
paramsEstimator_CO2 <- function(Gase, date){
#params2 <- paramsEstimator(date = "AUG6", treatment = 1)
  D <- subset(Gase, Gase$Date == date)
  x <- D$min #bezug auf die x achse = die Zeit in sec
  y <- D$CO2 #Bezug auf die y achse mit dem Gas. Unter der Variable a
  library(lattice)
  xyplot(y~x, main = paste("CO2-Gehalt für Tag", date) )
  formula <- y ~y0+a*(1-exp(-b*x))

  ##find the best values for a, b and y0 for nls
  library(nls2)
  startdf <- data.frame(a = c(90, 5000), b = c(0,1), y0 = c(50,2000))
  start <- try(nls2(formula, algorithm = "grid-search", start = startdf,
                    control = list(maxiter= 800)))
  if(inherits(start, "try-error")) {
    print("error in first estimation")
    start.params <- c(1500, 0.02, 300)
  } else
  {
  start.params <- summary(start)$parameters[,1]
  }
  ##calculates the final parameters for a, b and y0 for each date
proceed <- try(nls(formula, control = list(maxiter=1000), algorithm =
  "port",  start = list(a = start.params[1], b = start.params[2], y0 =
  start.params[3])))
  if(inherits(proceed, "try-error")) {
    print("error in second estimation")
    final.params <- rep(NA,3)
  } else {
    final.params <- summary(proceed)$parameters[,1]
  }
  return(final.params)
  }
paramsAll_CO2 <- function(matrix){
params <- matrix(0, nrow = 18, ncol = 3)
date <- names(table(Gase$Date))
rownames(params) <- date

for(i in 1:18){
  params[i,] <- paramsEstimator_CO2(Gase = matrix, date = date[i])
  }
  return(params)
  }
flux_CO2 <- function(paramMatrix, time){
  intervals <- matrix(0, nrow = 18, ncol = 2)
  rownames(intervals) <- rownames(paramMatrix)
  for(i in 1:18){
  params <- paramMatrix[i,]
  intervals[i,]<- params[3]+params[1]*(1-exp(-params[2]*time));
}
  return(intervals)
}
```

Appendix 4: Outlier removal from estimated values and mg CO_2-C m^{-2} h^{-1} calculation

```
library(lattice)
source("paramsEstimator_CO2.R")

GaseOriginal <-
read.table("C:/Users/LCK/Dropbox/MASTERARBEIT/Statistik/R/Gasdaten_test.t
xt", header=TRUE, sep="",
  na.strings="NA", dec=",", strip.white=TRUE)

 l <- as.factor(GaseOriginal$Date)
 k <- GaseOriginal$soilC

 box <- boxplot(k~l, data=GaseOriginal[GaseOriginal$Sample==-1,])

summary(Gase) #check if there are some outleiers, look on Max. and Min.
vlaues

#plotten of gases for all measurment dates
GaseOriginal$ort=rep(1:12, rep(8, 12))
xyplot(CO2~min|Date, data=GaseN[GaseN$Sample==-1,]) ##GaseN ist der
Datensatz wo die Ausreißer bereits entfernt sind


xyplot(N2O~min|Date, data=GaseOriginal[GaseOriginal$Sample==-1,],
type="l", ylab = expression(paste("ppm ", "N"
        ["2"], "O")), xlab = "minutes", ylim = c(0,0.8), scales =
list(tck = c(-1,-1)))

xyplot(CO2~time|Date, data=GaseOrginal[gase$Sample==-1,], groups=ort,
type="l")
xyplot(CH4~time|Date, data=gase[gase$Sample==1,], groups=ort, type="l")
xyplot(CH4~time|Date, data=gase[gase$Sample==-1,], groups=ort, type="l")

##------------------------remove outleiers-------------------------------
------------

#Boxplot für die Messdaten aller Daten zum Zeitpunkt 0, 10,.. und 60
# w <- as.factor(Gase$min)  ##die Zeit wird als Faktor verwendet um alle
4 Boxplots darstellen zu können.
# z <- Gase$CO2
# box <- boxplot(z~w, main="CO2ppm timeline", xlab="time", ylab="ppm
CO2", data=Gase[Gase$Sample==-1,])
#
# Gase33 <- Gase[Gase$min == 1 & Gase$Sample == -1,] ##um zu schaun
wieviele Werte für 1 und -1 vorhanden sind

##-----------------------------------No-LITTER-------------------------
----------------------------------
# Gase <- subset(GaseOriginal, Sample == -1)
# Gase0 <- Gase[Gase$min == 0,] ##weist den Datensatz für den Zeipunkt
null aus
# box0 <- boxplot(CO2~Date, main="CO2ppm timeline", xlab="time_0",
ylab="ppm CO2", data=Gase0)
```

```
#
# Gase10 <- Gase[Gase$min == 10,]
# box10 <- boxplot(CO2~Date, main="CO2ppm timeline", xlab="time_10",
ylab="ppm CO2", data=Gase10)
# ind10 <- which(Gase10$CO2 %in% box10$out[c(2,5,6,8,10,11)])
# Gase10 <- Gase10[-ind10,]
#
# Gase20 <- Gase[Gase$min == 20,]
# box20 <- boxplot(CO2~Date, main="CO2ppm timeline", xlab="time_20",
ylab="ppm CO2", data=Gase20)
# ind20 <- which(Gase20$CO2 %in% box20$out[c(1,3,5,6,7,8,9,10)])
# Gase20 <- Gase20[-ind20,]
#
# Gase60 <- Gase[Gase$min == 60,]
# box60 <- boxplot(CO2~Date, main="CO2ppm timeline", xlab="time_60",
ylab="ppm CO2", data=Gase60)
# ind60 <- which(Gase60$CO2 %in%
box60$out[c(1,2,3,4,5,6,7,8,9,10,12,13)])
# Gase60 <- Gase60[-ind60,]
#
# GaseN <- rbind(Gase0, Gase10, Gase20, Gase60)

##-------------------------CONTROL---------------------------------------
-------------------------
Gase <- subset(GaseOriginal, Sample == 1)

Gase_0 <- Gase[Gase$min == 0,]
box_0 <- boxplot(CO2~Date, main="CO2ppm timeline", xlab="time_0",
ylab="ppm CO2", data=Gase_0)
ind_0 <- which(Gase_0$CO2 %in%
box_0$out[c(1,2,3,5,6,7,8,9,10,11,15,16,18)])
Gase_0 <- Gase_0[-ind_0,]


Gase_10 <- Gase[Gase$min == 10,]
box_10 <- boxplot(CO2~Date, main="CO2ppm timeline", xlab="time_10",
ylab="ppm CO2", data=Gase_10)
ind_10 <- which(Gase_10$CO2 %in% box_10$out[c(2,3,4,5,6,8,9,10)])
Gase_10 <- Gase_10[-ind_10,]

Gase_20 <- Gase[Gase$min == 20,]
box_20 <- boxplot(CO2~Date, main="CO2ppm timeline", xlab="time_20",
ylab="ppm CO2", data=Gase_20)
ind_20 <- which(Gase_20$CO2 %in% box_20$out[c(1,2,3,4,5,8,11,12,14,15)])
Gase_20 <- Gase_20[-ind_20,]

Gase_60 <- Gase[Gase$min == 60,]
box_60 <- boxplot(CO2~Date, main="CO2ppm timeline", xlab="time_60",
ylab="ppm CO2", data=Gase_60)
ind_60 <- which(Gase_60$CO2 %in% box_60$out[c(1,5,7,8,9)])
Gase_60 <- Gase_60[-ind_60,]
boxplot(CO2~Date, main="CO2ppm timeline", xlab="time_60", ylab="ppm CO2",
data=Gase_60)

 Gase_N<- rbind(Gase_0, Gase_10, Gase_20, Gase_60)
```

```
##-----------------------------------------------------------------

param_N <- paramsAll_CO2(matrix = Gase_N)
#paramN <- paramsAll_CO2(matrix = GaseN)

interval <-c(0,1)

#A <- flux_CO2(paramMatrix = paramN, time = interval)  #gestresst
B <- flux_CO2(paramMatrix = param_N, time = interval) #ungestresst

##--------noLITTER--------Berchnung der Mittelwerte für chm3,aream2 und
soilC----------------------

# date <- names(table(GaseOriginal$Date))
#
# meansN <- matrix(0, nrow = 18, ncol = 7)
# rownames(meansN) <- date
# colnames(meansN) <- c( "Vch", "A", "soilC", "H2O",  "mm3d", "mm2d", "Rs
mg C-CO2 m² h")
#
# for(j in 1:18){
#   cal_meanN <- data.frame(a = GaseOriginal$Date, b =
(GaseOriginal$Sample), c = GaseOriginal$chm3,
#                           d = GaseOriginal$aream2, e =
GaseOriginal$soilC, f = GaseOriginal$H2O,
#                           g = GaseOriginal$mm3d, h = GaseOriginal$mm2d)
#
#   meansN[j,1] <- mean(subset(cal_meanN, b == -1 & a == date[j])$c,
na.rm = TRUE)
#   meansN[j,2] <- mean(subset(cal_meanN, b == -1 & a == date[j])$d,
na.rm = TRUE)
#   meansN[j,3] <- mean(subset(cal_meanN, b == -1 & a == date[j])$e,
na.rm = TRUE)
#   meansN[j,4] <- mean(subset(cal_meanN, b == -1 & a == date[j])$f,
na.rm = TRUE)
#   meansN[j,5] <- mean(subset(cal_meanN, b == -1 & a == date[j])$g,
na.rm = TRUE)
#   meansN[j,6] <- mean(subset(cal_meanN, b == -1 & a == date[j])$h,
na.rm = TRUE)
#
#   meansN[j,7] <- (A[j,2]-A[j,1])/(1-
0)*(1009.20/1000)*(273/(meansN[j,3]+273))*(12.009/22.41)
#                   *(meansN[j,1]/meansN[j,2])*60
#   }

##---------------------------------CONTROL-------------------------------
-----------------

date <- names(table(GaseOriginal$Date))

means_N <- matrix(0, nrow = 18, ncol = 7)
rownames(means_N) <- date
colnames(means_N) <- c( "Vch", "A", "t", "H2O", "mm3d", "mm2d", "Rs mg C-
CO2 m² h")
```

```
for(j in 1:18){
  cal_mean_N <- data.frame(a = GaseOriginal$Date, b =
(GaseOriginal$Sample), c = GaseOriginal$chm3,
                           d = GaseOriginal$aream2, e =
GaseOriginal$soilC, f = GaseOriginal$H2O,
                           g = GaseOriginal$mm3d, h = GaseOriginal$mm2d)

  means_N[j,1] <- mean(subset(cal_mean_N, b == 1 & a == date[j])$c, na.rm
= TRUE)
  means_N[j,2] <- mean(subset(cal_mean_N, b == 1 & a == date[j])$d, na.rm
= TRUE)
  means_N[j,3] <- mean(subset(cal_mean_N, b == 1 & a == date[j])$e, na.rm
= TRUE)
  means_N[j,4] <- mean(subset(cal_mean_N, b == 1 & a == date[j])$f, na.rm
= TRUE)
  means_N[j,5] <- mean(subset(cal_mean_N, b == 1 & a == date[j])$g, na.rm
= TRUE)
  means_N[j,6] <- mean(subset(cal_mean_N, b == 1 & a == date[j])$h, na.rm
= TRUE)


  means_N[j,7] <- (B[j,2]-B[j,1])/(1-
0)*(1009.20/1000)*(273/(means_N[j,3]+273))^(12.009/22.41)
                  *(means_N[j,1]/means_N[j,2])*60
  }
```

Appendix 5: Parameter estimation of CH_4 emissions with R

CH_4 Parameter

```
paramsEstimator_CH4 <- function(Gase, date){
  D <- subset(Gase, Gase$Date == date)
  x <- D$min
  y <- D$CH4
  library(lattice)
  xyplot(y~x, main = paste("CH4-Gehalt für Tag", date) )
  formula <- y ~ a*exp(-b*x)

  library(nls2)
  startdf <- data.frame(a = c(0.5, 4), b = c(0,1))
  start <- try(nls2(formula, algorithm = "grid-search", start = startdf,
control = list(maxiter= 500)))
  if(inherits(start, "try-error")) {
    print("error in first estimation")
    start.params <- c(2.9, 0.008)
  } else {
    start.params <- summary(start)$parameters[,1]
  }

  proceed <- try(nls(formula, control = list(maxiter=500),algorithm =
"port", start = list(a = start.params[1], b = start.params[2])))
  if(inherits(proceed, "try-error")) {
    print("error in second estimation")
    final.params <- rep(NA,2)
  } else {
    final.params <- summary(proceed)$parameters[,1]
  }
  return(final.params)
  }

paramsAll <- function(matrix){
  params <- matrix(0, nrow = 18, ncol = 2)
  date <- names(table(Gase$Date))
  rownames(params) <- date
  for(i in 1:18){
    params[i,] <- paramsEstimator_CH4(Gase = matrix, date = date[i])
  }
  return(params)
  }

flux <- function(paramMatrix, time){
  intervals <- matrix(0, nrow = 18, ncol = 2)
  rownames(intervals) <- rownames(paramMatrix)
  for(i in 1:18){
    params <- paramMatrix[i,]
    intervals[i,]<- params[1]*exp(-params[2]*time)
  }

  return(intervals)
}
```

Appendix 6: Outlier removal from estimated values and mg CH_4-C m^{-2} h^{-1} calculation

```
library(lattice)
source("paramsEstimator_CH4.R")

GaseOriginal <- read.table("C:/Users/LCK/Dropbox/MASTERARBEIT/R/
                Gasdaten_test.txt", header=TRUE, sep="", na.strings="NA",
                dec=",", strip.white=TRUE)
#  l <- as.factor(GaseOriginal$Date)
#  k <- GaseOriginal$soilC
#  box <- boxplot(k~l, data=GaseOriginal[GaseOriginal$Sample==-1,])

GaseOriginal$ort=rep(1:12, rep(8, 12))
#xyplot(CH4~min|Date, data=GaseN[GaseN$Sample==-1,])

##------------remove outleiers---------------------------------

# w <- as.factor(Gase$min)
# z <- Gase$CH4
# box <- boxplot(z~w, main="CH4ppm timeline", xlab="time", ylab="ppm
                  CH4", data=Gase[Gase$Sample==-1,])
#
# Gase33 <- Gase[Gase$min == 0 & Gase$Sample == -1,] ##um zu schaun

##--------------------------NO Litter----------------------
# Gase <- subset(GaseOriginal, Sample == -1)
# Gase0 <- Gase[Gase$min == 0,]
# box0 <- boxplot(CH4~Date, main="CH4ppm timeline", xlab="time_0",
                ylab="ppm CH4", data=Gase0)
# ind0 <-which(Gase0$CH4 %in% box0$out[c(1,2,3,4,5,6,7,8,9,10,11,12,13)])
# Gase0 <- Gase0[-ind0,]
#
# Gase10 <- Gase[Gase$min == 10,]
# box10 <- boxplot(CH4~Date, main="CH4ppm timeline", xlab="time_10",
                  ylab="ppm CH4", data=Gase10)
# ind10 <- which(Gase10$CH4 %in% box10$out[c(1,2,3,4,5,6)])
# Gase10 <- Gase10[-ind10,]
#
# Gase20 <- Gase[Gase$min == 20,]
# box20 <- boxplot(CH4~Date, main="CH4ppm timeline", xlab="time_20",
                  ylab="ppm CH4", data=Gase20)
# ind20 <- which(Gase20$CH4 %in% box20$out[c(1,2,3,4,5,6,7,8,9)])
# Gase20 <- Gase20[-ind20,]
#
# Gase60 <- Gase[Gase$min == 60,]
# box60 <- boxplot(CH4~Date, main="CH4ppm timeline", xlab="time_60",
                  ylab="ppm CH4", data=Gase60)
# ind60 <- which(Gase60$CH4 %in% box60$out[c(1,2,3,4,5,6,7)])
# Gase60 <- Gase60[-ind60,]
#
# GaseN <- rbind(Gase0, Gase10, Gase20, Gase60)
#
```

```
##--------------------Control--------------------------------------

Gase <- subset(GaseOriginal, Sample == 1)

Gase_0 <- Gase[Gase$min == 0,]
box_0 <- boxplot(CH4~Date, main="CH4ppm timeline", xlab="time_0",
                 ylab="ppm CH4", data=Gase_0)
ind_0 <- which(Gase_0$CH4 %in% box_0$out[c(1,2,3,4,5,6,7,8,9,10,11,12)])
Gase_0 <- Gase_0[-ind_0,]

Gase_10 <- Gase[Gase$min == 10,]
box_10 <- boxplot(CH4~Date, main="CH4ppm timeline", xlab="time_10",
                 ylab="ppm CH4", data=Gase_10)
ind_10 <- which(Gase_10$CH4 %in% box_10$out[c(1,2,3,4,5)])
Gase_10 <- Gase_10[-ind_10,]

Gase_20 <- Gase[Gase$min == 20,]
box_20 <- boxplot(CH4~Date, main="CH4ppm timeline", xlab="time_20",
                 ylab="ppm CH4", data=Gase_20)
ind_20 <- which(Gase_20$CH4 %in% box_20$out[c(1,2,3,4,5,6)])
Gase_20 <- Gase_20[-ind_20,]

Gase_60 <- Gase[Gase$min == 60,]
box_60 <- boxplot(CH4~Date, main="CH4ppm timeline", xlab="time_60",
                 ylab="ppm CH4", data=Gase_60)
ind_60 <- which(Gase_60$CH4 %in% box_60$out[c(1,2,3,4,5,6,7)])
Gase_60 <- Gase_60[-ind_60,]
boxplot(CH4~Date, main="CH4ppm timeline", xlab="time_60", ylab="ppm CH4",
data=Gase_60)

 Gase_N<- rbind(Gase_0, Gase_10, Gase_20, Gase_60)

##-------------------------------------------------------------------

param_N <- paramsAll(matrix = Gase_N)
#paramN <- paramsAll(matrix = GaseN)

interval <-c(0,1)

#A <- flux(paramMatrix = paramN, time = interval)  #gestresst
B <- flux(paramMatrix = param_N, time = interval) #ungestresst

##----------------------NO.Liter-----------------------------------
#
# meansN <- matrix(0, nrow = 18, ncol = 7)
# rownames(meansN) <- date
# colnames(meansN) <- c( "Vch", "A", "t", "H2O", "mm3d", "mm2d", "Rs µg
                         C-CH4 /m²/h")
#
# date <- names(table(GaseOriginal$Date))
#
# for(i in 1:18){
#  cal_meanN <- data.frame(a = GaseOriginal$Date, b = (GaseOriginal$
                          Sample), c = GaseOriginal$Vch, d = Gase
                         Original$A, e = GaseOriginal$soilC, f =
```

```
                                GaseOriginal$H2O, g = GaseOriginal$mm3d, h =
                                GaseOriginal$mm2d)

#  meansN[j,1] <- mean(subset(cal_meanN, b == -1 & a == date[j])$c, na.rm
                       = TRUE)
#  meansN[j,2] <- mean(subset(cal_meanN, b == -1 & a == date[j])$d, na.rm
                       = TRUE)
#  meansN[j,3] <- mean(subset(cal_meanN, b == -1 & a == date[j])$e, na.rm
                       = TRUE)
#  meansN[j,4] <- mean(subset(cal_meanN, b == -1 & a == date[j])$f, na.rm
                       = TRUE)
#  meansN[j,5] <- mean(subset(cal_meanN, b == -1 & a == date[j])$g, na.rm
                       = TRUE)
#  meansN[j,6] <- mean(subset(cal_meanN, b == -1 & a == date[j])$h, na.rm
                       = TRUE)
#
#   meansN[j,7] <- (A[j,2]-A[j,1])/(1-0)*(1009.20/1000)*(273/(meansN
                    [j,3]+273))*(12.001/22.41)*(meansN[j,1]/meansN[j,2])
                     *60*1000
# }

##--------------------------------Control---------------
means_N <- matrix(0, nrow = 18, ncol = 7)
rownames(means_N) <- date
colnames(means_N) <- c( "Vch", "A", "t", "H2O", "mm3d", "mm2d", "Rs Rs µg
                        C-CH4 /m²/h")

date <- names(table(GaseOriginal$Date))

for(j in 1:18){
  cal_mean_N <- data.frame(a = GaseOriginal$Date, b = (GaseOriginal
                           $Sample), c = GaseOriginal$Vch, d = Gase
                           Original$A, e = GaseOriginal$soilC, f =
                           GaseOriginal$H2O, g = GaseOriginal$mm3d, h =
                           GaseOriginal$mm2d)

  means_N[j,1] <- mean(subset(cal_mean_N, b == 1 & a == date[j])$c, na.rm
                       = TRUE)
  means_N[j,2] <- mean(subset(cal_mean_N, b == 1 & a == date[j])$d, na.rm
                       = TRUE)
  means_N[j,3] <- mean(subset(cal_mean_N, b == 1 & a == date[j])$e, na.rm
                       = TRUE)
  means_N[j,4] <- mean(subset(cal_mean_N, b == 1 & a == date[j])$f, na.rm
                       = TRUE)
  means_N[j,5] <- mean(subset(cal_mean_N, b == 1 & a == date[j])$g, na.rm
                       = TRUE)
  means_N[j,6] <- mean(subset(cal_mean_N, b == 1 & a == date[j])$h, na.rm
                       = TRUE)

  means_N[j,7] <- (B[j,2]-B[j,1])/(1-0)*(1009.20/1000)*(273/(means
                  _N[j,3]+273))*(12.009/22.41)*(means_N[j,1]/means_N[j,2])
                   *60*1000
}
```

Appendix 7: Parameter estimation of N_2O emissions with R

```
paramsEstimator_N2O <- function(Gase, date){
  D <- subset(Gase, Gase$Date == date)
  x <- D$min
  y <- D$N2O

  library(lattice)
  xyplot(y~x, main = paste("N2O-Gehalt für Tag", date) )
  formula <- y ~ a + b*x

  library(nls2)
  startdf <- data.frame(a = c(0, 4), b = c(0,2))
  start <- try(nls2(formula, algorithm = "grid-search", start = startdf,
                control = list(maxiter= 500)))
  if(inherits(start, "try-error")) {
    print("error in first estimation")
    start.params <- c(0,001, 0.3)
  } else {
    start.params <- summary(start)$parameters[,1]
  }


  proceed <- try(nls(formula, control = list(maxiter=500),algorithm =
                "port", start = list(a = start.params[1], b = start
                 .params[2])))
  if(inherits(proceed, "try-error")) {
    print("error in second estimation")
    final.params <- rep(NA,2)
  } else {
    final.params <- summary(proceed)$parameters[,1]
  }
    return(final.params)
  }

paramsAll_N2O <- function(matrix){
  params <- matrix(0, nrow = 18, ncol = 2)
  date <- names(table(GaseOriginal$Date))
  rownames(params) <- date

  for(i in 1:18){
    params[i,] <- paramsEstimator_N2O(Gase = matrix, date = date[i])

  }
    return(params)
  }

flux <- function(paramMatrix, time){
  intervals <- matrix(0, nrow = 18, ncol = 2)
  rownames(intervals) <- rownames(paramMatrix)
  for(i in 1:18){
    params <- paramMatrix[i,]
    intervals[i,]<- params[1]+ params[2]*time
  }
  return(intervals)
  }
```

Appendix 8: Outlier removal from estimated values and mg N_2O-C m^{-2} h^{-1} calculation

```
library(lattice)
source("paramsEstimator_N2O.R")

GaseOriginal <- read.table("C:/Users/LCK/Dropbox/MASTERARBEIT/R/Gasdaten
                           _test.txt", header=TRUE, sep="", na.strings="NA
                            ", dec=",", strip.white=TRUE)
#
#  l <- as.factor(GaseOriginal$Date)
#  k <- GaseOriginal$soilC
#  box <- boxplot(k~l, data=GaseOriginal[GaseOriginal$Sample==-1,])

GaseOriginal$ort=rep(1:12, rep(8, 12))
# plot(GaseN$N2O~ GaseN$min)
# model <- lm(GaseN$N2O ~ GaseN$min)
# abline(a = 0.25653, b = 0.0002715)
# GaseN <- GaseOriginal
# model<-lm(GaseN$N2O ~ GaseN$min + GaseN$Date + as.factor(GaseN$Sample))
# summary(aov(model))
# summary(model)

#----------------remove outleiers---------------------------------
----------------NO-Litter-----------------------------------------
Gase <- subset(GaseOriginal, Sample == -1)
Gase0 <- Gase[Gase$min == 0,] box0 <- boxplot(N2O~Date, main="N2Oppm
timeline", xlab="time_0", ylab="ppm N2O", data=Gase0)
ind0 <- which(Gase0$N2O %in% box0$out[c(1,2,3,4,5,6)])
Gase0 <- Gase0[-ind0,]

Gase10 <- Gase[Gase$min == 10,]
box10 <- boxplot(N2O~Date, main="N2Oppm timeline", xlab="time_10",
ylab="ppm N2O", data=Gase10)
ind10 <- which(Gase10$N2O %in% box10$out[c(1,2,3)])
Gase10 <- Gase10[-ind10,]

Gase20 <- Gase[Gase$min == 20,]
box20 <- boxplot(N2O~Date, main="N2Oppm timeline", xlab="time_20",
ylab="ppm N2O", data=Gase20)
ind20 <- which(Gase20$N2O %in% box20$out[c(1,2,3,4,5,6)])
Gase20 <- Gase20[-ind20,]

Gase60 <- Gase[Gase$min == 60,]
box60 <- boxplot(N2O~Date, main="N2Oppm timeline", xlab="time_60",
ylab="ppm N2O", data=Gase60)
ind60 <- which(Gase60$N2O %in% box60$out[c(1,2,3,4)])
Gase60 <- Gase60[-ind60,]

GaseN <- rbind(Gase0, Gase10, Gase20, Gase60)

##-----------Control-------------------------------------------------
# Gase <- subset(GaseOriginal, Sample == 1)
# Gase_0 <- Gase[Gase$min == 0,]
# box_0 <- boxplot(N2O~Date, main="N2Oppm timeline", xlab="time_0",
                   ylab="ppm N2O", data=Gase_0)
# ind_0 <- which(Gase_0$N2O %in% box_0$out[c(1,2,3)])
# Gase_0 <- Gase_0[-ind_0,]
```

```
# Gase_10 <- Gase[Gase$min == 10,]
# box_10 <- boxplot(N2O~Date, main="N2Oppm timeline", xlab="time_10",
                    ylab="ppm N2O", data=Gase_10)
# ind_10 <- which(Gase_10$N2O %in% box_10$out[c(1,2,3,4,5,6)])
# Gase_10 <- Gase_10[-ind_10,]
#
# Gase_20 <- Gase[Gase$min == 20,]
# box_20 <- boxplot(N2O~Date, main="N2Oppm timeline", xlab="time_20",
                    ylab="ppm N2O", data=Gase_20)
# ind_20 <- which(Gase_20$N2O %in% box_20$out[c(1,2,3,4,5,6)])
# Gase_20 <- Gase_20[-ind_20,]
#
# Gase_60 <- Gase[Gase$min == 60,]
# box_60 <- boxplot(N2O~Date, main="N2Oppm timeline", xlab="time_60",
                    ylab="ppm N2O", data=Gase_60)
# ind_60 <- which(Gase_60$N2O %in% box_60$out[c(1,2,3,4)])
# Gase_60 <- Gase_60[-ind_60,]
# boxplot(N2O~Date, main="N2Oppm timeline", xlab="time_60", ylab="ppm
          N2O", data=Gase_60)
#
#  Gase_N<- rbind(Gase_0, Gase_10, Gase_20, Gase_60)
##-----------------------------------------------------------------

#param_N <- paramsAll_N2O(matrix = Gase_N)
paramN <- paramsAll_N2O(matrix = GaseN)

interval <-c(0,1)

A <- flux(paramMatrix = paramN, time = interval)  #gestresst
#B <- flux(paramMatrix = param_N, time = interval) #ungestresst

##--------NO Litter-------------------------------------

meansN <- matrix(0, nrow = 18, ncol = 7)
rownames(meansN) <- date
colnames(meansN) <- c( "Vch", "A", "t", "H2O", "mm3d", "mm2d", "Rs µg
                       N2O-N /m²/h")

date <- names(table(GaseOriginal$Date))

for(j in 1:18){
 cal_meanN <- data.frame(a = GaseOriginal$Date, b = (GaseOriginal
                         $Sample), c = GaseOriginal$Vch, d = Gase
                         Original$A, e = GaseOriginal$soilC, f = Gase
                         Original$H2O, g = GaseOriginal$mm3d, h =
                          GaseOriginal$mm2d)

  meansN[j,1] <- mean(subset(cal_meanN, b == -1 & a == date[j])$c, na.rm
                      = TRUE)
  meansN[j,2] <- mean(subset(cal_meanN, b == -1 & a == date[j])$d, na.rm
                      = TRUE)
  meansN[j,3] <- mean(subset(cal_meanN, b == -1 & a == date[j])$e, na.rm
                      = TRUE)
  meansN[j,4] <- mean(subset(cal_meanN, b == -1 & a == date[j])$f, na.rm
                      = TRUE)
```

```
  meansN[j,5] <- mean(subset(cal_meanN, b == -1 & a == date[j])$g, na.rm
                      = TRUE)
  meansN[j,6] <- mean(subset(cal_meanN, b == -1 & a == date[j])$h, na.rm
                      = TRUE)

  meansN[j,7] <- (A[j,2]-A[j,1])/(1-0)*(1009.20/1000)*(273/(meansN[j,3]
                 +273))*(28.014/22.41)*(meansN[j,1]/meansN[j,2])*60*1000
}

#------------------------------Control----------------
# means_N <- matrix(0, nrow = 18, ncol = 7)
# rownames(means_N) <- date
# colnames(means_N) <- c( "Vch", "A", "t", "H2O", "mm3d", "mm2d", "Rs µg
                          N2O-N /m²/h")
#
# date <- names(table(GaseOriginal$Date))
# for(j in 1:18){
#   cal_mean_N <- data.frame(a = GaseOriginal$Date, b = (GaseOriginal
                             $Sample), c = GaseOriginal$Vch, d = Gase
                             Original$A, e = GaseOriginal$soilC, f = Gase
                             Original$H2O, g = GaseOriginal$mm3d, h =
                              GaseOriginal$mm2d)
#
# means_N[j,1] <- mean(subset(cal_mean_N, b == 1 & a == date[j])$c, na.rm
                       = TRUE)
# means_N[j,2] <- mean(subset(cal_mean_N, b == 1 & a == date[j])$d, na.rm
                       = TRUE)
# means_N[j,3] <- mean(subset(cal_mean_N, b == 1 & a == date[j])$e, na.rm
                       = TRUE)
# means_N[j,4] <- mean(subset(cal_mean_N, b == 1 & a == date[j])$f, na.rm
                       = TRUE)
# means_N[j,5] <- mean(subset(cal_mean_N, b == 1 & a == date[j])$g, na.rm
                       = TRUE)
# means_N[j,6] <- mean(subset(cal_mean_N, b == 1 & a == date[j])$h, na.rm
                       = TRUE)

# means_N[j,7] <- (B[j,2]-B[j,1])/(1-0)*(1009.20/1000)*(273/(means_N[j,3]
                  +273))*(28.014/22.41)*(means_N[j,1]/means_N[j,2])*60*1000
#
# }
```

Appendix 9: Spearman and Pearson correlation matrix - no-litter treatment and control treatment

No litter treatment		Parameters																
Paramters	Indicator	pH	NO_3^-	NH_4^+	PO_4^{3-}	C_{mic}	N_{mic}	Mic_{Resp}	Gluc	H_2O_{grav}	$H_2O_{\%}$	C_t	N_t	µg CH_4-C m^{-2} h^{-1}	mg CO_2-C m^{-2} h^{-1}	µg N_2O-N m^{-2} h^{-1}	$°C_{soil}$
pH	*p-value*		0.1008	0.7139	0.2087	0.0105*	0.4772	0.9189	0.1355	0.8417	0.4181	0.3314	0.4621	0.2417	0.7139	0.3422	0.2974
	cor		0.73	0.20	-0.56	0.91*	0.36	0.06	-0.68	0.11	-0.48	-0.48	-0.38	-0.60	-0.20	-0.47	-0.51
NO_3^-	*p-value*	0.1008		0.0583	0.5092	0.0198*	0.6066	0.5050	0.4144	0.8642	0.5259	0.8028	0.9203	0.2417	0.6583	0.7579	0.7629
	cor	0.73		0.83	-0.34	0.88*	0.27	-0.39	-0.41	-0.09	-0.38	-0.13	-0.05	-0.60	0.26	-0.16	0.16
NH_4^+	*p-value*	0.7139	0.0583		0.4972	0.4972	0.8028	0.0538	0.9194	0.4194	0.6833	0.4972	0.2798	0.2417	0.2417	0.8047	0.1361
	roh	0.20	0.83		0.37	0.37	0.14	-0.87	0.08	-0.43	-0.30	0.37	0.53	-0.60	0.60	0.13	0.71
PO_4^{3-}	*p-value*	0.2087	0.5092	0.4972		0.2134	0.3250	0.9981	0.0702	0.3875	0.8482	***0.0018***	***0.0113***	0.4972	0.3556	0.9391	0.1394
	cor	-0.56	-0.34	0.37		-0.59	0.49	-0.01	0.78	-0.44	0.12	***0.96***	***0.91***	-0.37	0.49	-0.04	0.61
C_{mic}	*p-value*	0.0105*	0.0198*	0.4972	0.2134		0.6298	0.9944	0.0873	0.8503	0.4109	0.3946	0.5342	0.2972	1.0000	0.3832	0.6765
	cor	0.91*	0.88*	0.37	-0.59		0.25	-0.01	-0.75	-0.10	-0.48	-0.43	-0.32	-0.54	-0.03	-0.44	-0.22
N_{mic}	*p-value*	0.4772	0.6066	0.8028	0.3250	0.6298		0.8848	0.9393	0.2994	0.1354	0.2280	0.1461	0.3556	0.9194	0.1149	0.8426
	cor	0.36	0.27	0.14	0.49	0.25		0.09	0.04	-0.51	-0.76	0.58	0.67	-0.49	-0.09	-0.71	0.11
Mic_{Resp}	*p-value*	0.9189	0.5050	0.0538	0.9981	0.9944	0.8848		0.7572	0.8239	0.7650	0.7181	0.6559	0.8696	0.7406	0.4310	0.3500
	cor	0.06	-0.39	-0.87	-0.01	-0.01	0.09		-0.19	-0.14	0.19	-0.22	-0.27	-0.10	-0.21	-0.46	-0.54
Gluc	*p-value*	0.1355	0.4144	0.9194	0.0702	0.0873	0.9393	0.7572		0.7055	0.2600	0.1418	0.2658	0.4194	-0.3556	0.2577	0.4037
	cor	-0.68	-0.41	0.08	0.78	-0.75	0.04	-0.19		0.19	0.62	0.67	0.54	0.43	0.49	0.55	0.42
H_2O_{grav}	*p-value*	0.8417	0.8642	0.4194	0.3875	0.8503	0.2994	0.8239	0.7055		0.2324	0.2625	0.1716	0.0333*	0.7139	0.1321	0.2531
	cor	0.11	-0.09	-0.43	-0.44	-0.10	-0.51	-0.14	0.19		0.65	-0.55	-0.64	0.89*	-0.20	0.69	-0.55
$H_2O_{\%}$	*p-value*	0.4181	0.5259	0.6833	0.8482	0.4109	0.1354	0.7650	0.2600	0.2324		0.8736	0.5881	0.2884	0.3852	0.7425	0.0775
	cor	-0.48	-0.38	-0.30	0.12	-0.48	-0.76	0.19	0.62	0.65		-0.09	-0.33	0.28	-0.23	0.09	-0.45
C_t	*p-value*	0.3314	0.8028	0.4972	***0.0018***	0.3946	0.2280	0.7181	0.1418	0.2625	0.8736		***4.45E-04***	0.4972	0.3556	0.8424	0.0968
	cor	-0.48	-0.13	0.37	***0.96***	-0.43	0.58	-0.22	0.67	-0.55	-0.09		***0.98***	-0.37	0.49	-0.11	0.07
N_t	*p-value*	0.4621	0.9203	0.2798	***0.0113***	0.5342	0.1461	0.6559	0.2658	0.1716	0.5881	***4.45E-04***		0.3809	0.3809	0.6511	0.1055
	cor	-0.38	-0.05	0.53	***0.91***	-0.32	0.67	-0.27	0.54	-0.64	-0.33	***0.98***		-0.44	0.44	-0.24	0.72
µg CH_4-C m^{-2} h^{-1}	*p-value*	0.2417	0.2417	0.2417	0.4972	0.2972	0.3556	0.8696	0.4194	0.0333*	0.2884	0.4972	0.3809		0.1709	0.4069	0.4217
	roh	-0.60	-0.60	-0.60	-0.37	-0.54	-0.49	-0.10	0.43	0.89*	0.28	-0.37	-0.44		0.33	0.21	0.20
mg CO_2-C m^{-2} h^{-1}	*p-value*	0.7139	0.6583	0.2417	0.3556	1.0000	0.9194	0.7406	-0.3556	0.7139	0.3852	0.3556	0.3809	0.1709		0.1819	***1.28E-05***
	roh	-0.20	0.26	0.60	0.49	-0.03	-0.09	-0.21	0.49	-0.20	-0.23	0.49	0.44	0.33		0.33	***0.83***
µg N_2O-N m^{-2} h^{-1}	*p-value*	0.3422	0.7579	0.8047	0.9391	0.3832	0.1149	0.4310	0.2577	0.1321	0.7425	0.8424	0.6511	0.4069	0.1819		0.3876
	cor	-0.47	-0.16	0.13	-0.04	-0.44	-0.71	-0.46	0.55	0.69	0.09	-0.11	-0.24	0.21	0.33		0.22
$°C_{soil}$	*p-value*	0.2974	0.7629	0.1361	0.1394	0.6765	0.8426	0.3500	0.4037	0.2531	0.0775	0.0968	0.1055	0.4217	***1.28E-05***	0.3876	
	cor	-0.51	0.16	0.71	0.61	-0.22	0.11	-0.54	0.42	-0.55	-0.45	0.07	0.72	0.20	***0.83***	0.22	

* = These significant correlations were made by coincidence; bolded numbers in grey cells refer to significant correlations.

Control treatment		Parameters															
Paramters	**Indicator**	**pH**	**NO_3^-**	**NH_4^+**	**PO_4^{3-}**	**C_{mic}**	**N_{mic}**	**Mic_{Resp}**	**Gluc**	**H_2O_{grav}**	**$H_2O_{\%}$**	**C_t**	**N_t**	**µg CH_4-C m^{-2} h^{-1}**	**mg CO_2-C m^{-2} h^{-1}**	**µg N_2O-N m^{-2} h^{-1}**	**°C_{soil}**
pH	*p-value*		0.1704	0.01667*	0.9356	0.0281*	0.8275	0.0879	0.7169	0.0825	0.2138	0.6905	0.7202	0.4972	0.8028	0.2268	0.4371
	cor		0.64	0.94*	-0.04	0.86*	-0.11	0.82	-0.19	0.76	0.67	0.21	0.19	0.37	-0.14	0.58	-0.40
NO_3^-	*p-value*	0.1704		0.0583	0.6417	0.2414	0.1696	0.1878	0.5969	0.7996	0.5396	0.6365	0.3725	0.6583	0.5600	0.2390	0.5746
	cor	0.64		0.83	-0.24	0.57	-0.64	0.70	-0.28	0.13	0.37	-0.25	-0.45	0.26	0.31	0.57	0.29
NH_4^+	*p-value*	0.01667*	0.0583		0.6583	0.1028	1.0000	0.2333	0.4194	0.0835	0.0833	1.0000	1.0000	0.2972	0.9194	0.1583	0.4972
	roh	0.94*	0.83		-0.26	0.77	-0.03	0.70	-0.43	0.75	0.90	-0.03	0.00	0.54	0.09	0.65	-0.37
PO_4^{3-}	*p-value*	0.9356	0.6417	0.6583		0.4972	0.0583	0.4500	0.0583	0.7417	0.7833	0.2417	0.2798	0.6583	0.8028	0.4411	0.7139
	cor	-0.04	-0.24	-0.26		-0.37	0.83	-0.50	0.83	0.17	-0.20	0.60	0.53	-0.26	-0.14	0.39	0.20
C_{mic}	*p-value*	0.0281*	0.2414	0.1028	0.4972		1.0000	0.2333	0.1361	0.1248	0.3500	0.9194	0.8679	0.9194	0.3556	0.8047	0.0583
	cor	0.86*	0.57	0.77	-0.37		-0.03	0.70	-0.71	0.69	0.60	-0.09	0.09	0.09	-0.49	0.13	-0.83
N_{mic}	*p-value*	0.8275	0.1696	1.0000	0.0583	1.0000		0.2333	0.2417	0.3206	0.9500	0.0333*	0.0198*	0.6583	0.7139	0.4411	0.8028
	cor	-0.11	-0.64	-0.03	0.83	-0.03		-0.70	0.60	0.49	-0.10	0.89*	0.88*	-0.26	-0.20	0.39	-0.14
Mic_{Resp}	*p-value*	0.0879	0.1878	0.2333	0.4500	0.2333	0.2333		0.4500	0.4925	0.3500	0.3500	0.2189	0.3500	0.9500	0.5594	-0.6833
	cor	0.82	0.70	0.70	-0.50	0.70	-0.70		-0.50	0.41	0.60	-0.60	-0.67	0.60	-0.10	0.35	-0.30
Gluc	*p-value*	0.7169	0.5969	0.4194	0.0583	0.1361	0.2417	0.4500		0.9565	0.7833	0.2417	0.3809	0.9194	0.6583	0.4411	0.3556
	cor	-0.19	-0.28	-0.43	0.83	-0.71	0.60	-0.50		-0.03	-0.20	0.60	0.44	0.09	0.26	0.39	0.49
H_2O_{grav}	*p-value*	0.0825	0.7996	0.0835	0.7417	0.1248	0.3206	0.4925	0.9565		0.2480	0.2883	0.2254	0.4247	0.6584	0.1502	0.1731
	cor	0.76	0.13	0.75	0.17	0.69	0.49	0.41	-0.03		0.72	0.52	0.58	0.41	-0.23	0.66	-0.64
$H_2O_{\%}$	*p-value*	0.2138	0.5396	0.0833	0.7833	0.3500	0.9500	0.3500	0.7833	0.2480		0.7833	0.8048	***4.63E-03***	0.5563	0.5622	0.0625
	cor	0.67	0.37	0.90	-0.20	0.60	-0.10	0.60	-0.20	0.72		0.20	0.15	***0.67***	-0.16	0.16	-0.48
C_t	*p-value*	0.6905	0.6365	1.0000	0.2417	0.9194	0.0333*	0.3500	0.2417	0.2883	0.7833		0.0179*	1.0000	1.0000	0.2450	0.7627
	cor	0.21	-0.25	-0.03	0.60	-0.09	0.89*	-0.60	0.60	0.52	0.20		0.89*	0.03	0.03	0.56	-0.16
N_t	*p-value*	0.7202	0.3725	1.0000	0.2798	0.8679	0.0198*	0.2189	0.3809	0.2254	0.8048	0.0179*		0.8679	0.7379	0.6891	0.4956
	cor	0.19	-0.45	0.00	0.53	0.09	0.88*	-0.67	0.44	0.58	0.15	0.89*		-0.09	-0.18	0.21	-0.35
µg CH_4-C m^{-2} h^{-1}	*p-value*	0.4972	0.6583	0.2972	0.6583	0.9194	0.6583	0.3500	0.9194	0.4247	***4.63E-03***	1.0000	0.8679		0.8564	0.9688	0.9279
	roh	0.37	0.26	0.54	-0.26	0.09	-0.26	0.60	0.09	0.41	***0.67***	0.03	-0.09		-0.05	-0.01	-0.02
mg CO_2-C m^{-2} h^{-1}	*p-value*	0.8028	0.5600	0.9194	0.8028	0.3556	0.7139	0.9500	0.6583	0.6584	0.5563	1.0000	0.7379	0.8564		0.0369	***1.80E-03***
	roh	-0.14	0.31	0.09	-0.14	-0.49	-0.20	-0.10	0.26	-0.23	-0.16	0.03	-0.18	-0.05		0.49	***0.70***
µg N_2O-N m^{-2} h^{-1}	*p-value*	0.2268	0.2390	0.1583	0.4411	0.8047	0.4411	0.5594	0.4411	0.1502	0.5622	0.2450	0.6891	0.9688	0.0369		0.2449
	cor	0.58	0.57	0.65	0.39	0.13	0.39	0.35	0.39	0.66	0.16	0.56	0.21	-0.01	0.49		0.29
°C_{soil}	*p-value*	0.4371	0.5746	0.4972	0.7139	0.0583	0.8028	-0.6833	0.3556	0.1731	0.0625	0.7627	0.4956	0.9279	***1.80E-03***	0.2449	
	cor	-0.40	0.29	-0.37	0.20	-0.83	-0.14	-0.30	0.49	-0.64	-0.48	-0.16	-0.35	-0.02	***0.70***	0.29	

* = These significant correlations were made by coincidence; bolded numbers in grey cells refer to significant correlations.

Appendix 10: Matrix of regression values of Linear Model correlations – no-litter treatment and control treatment

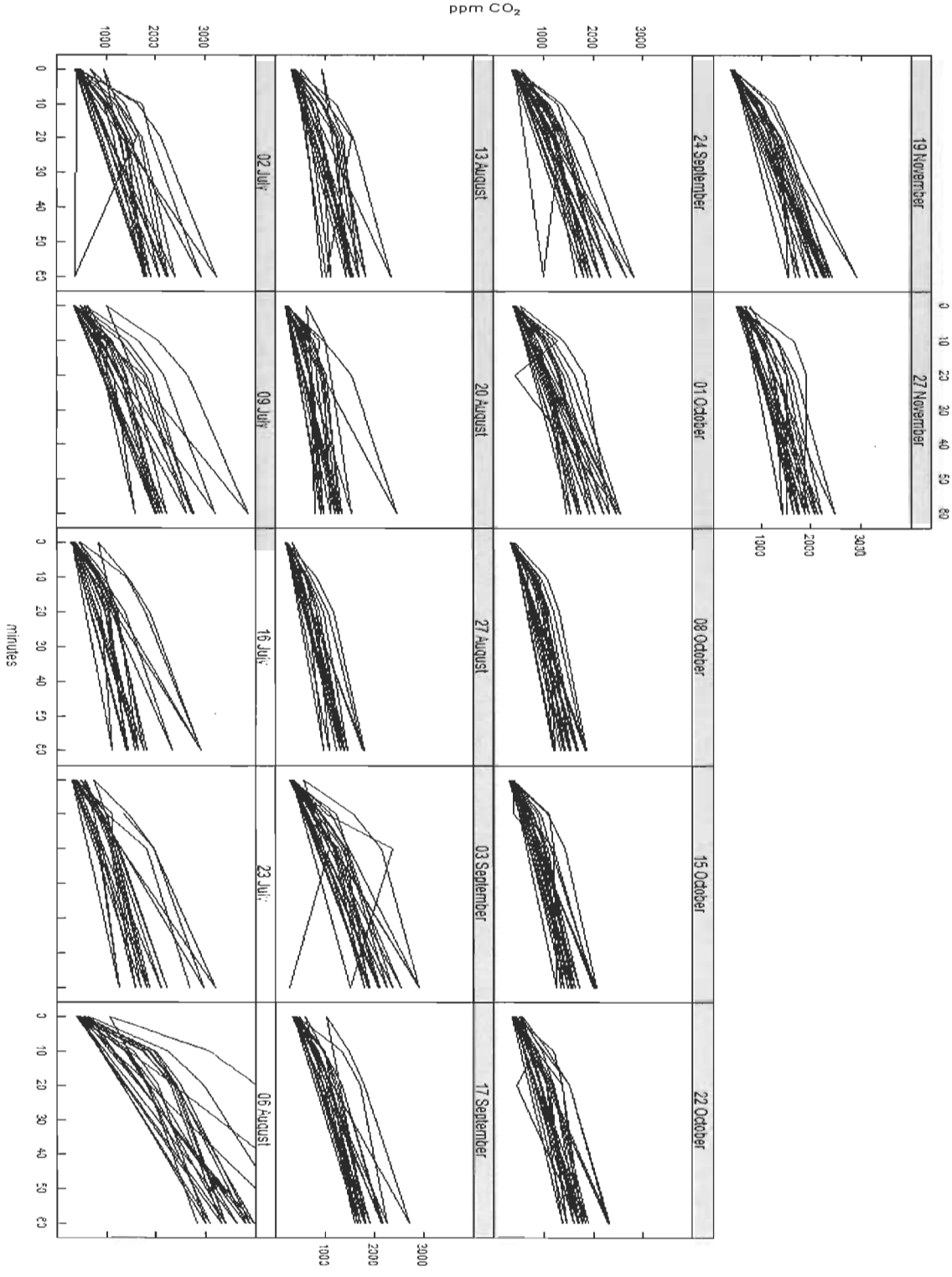
No litter treatment		Parameters																
Paramters	**Indicator**	**pH**	**NO_3^-**	**NH_4^+**	**PO_4^{3-}**	**C_{mic}**	**N_{mic}**	**Mic_{Resp}**	**Gluc**	**H_2O_{grav}**	**$H_2O_{\%}$**	**C_t**	**N_t**	**µg CH_4-C m^{-2} h^{-1}**	**mg CO_2-C m^{-2} h^{-1}**	**µg N_2O-N m^{-2} h^{-1}**	**$°C_{soil}$**
pH	*p-value*		0.1008	0.7285	0.2087	0.0106*	0.4772	0.9189	0.1355	0.8417	0.4181	0.3314	0.4621	0.7413	0.2108	0.3422	0.2974
	r^2		0.53	0.03	0.3591	0.84*	0.13	0.01	0.4654	0.01	0.23	0.23	0.14	0.03	0.36	0.22	0.26
NO_3^-	*p-value*	0.1008		0.1321	0.5092	0.0198*	0.6066	0.505	0.4144	0.8642	0.5259	0.8028	0.9203	0.325	0.9615	0.9615	0.7629
	r^2	0.53		0.47	0.12	0.78*	0.07	0.16	0.17	0.01	0.15	0.02	0.01	0.24	0.01	0.01	0.03
NH_4^+	*p-value*	0.7285	0.1321		0.4269	0.4587	0.3368	0.1982	0.6636	0.4948	0.9113	0.2667	0.2677	0.1349	0.2291	0.2291	0.1859
	r^2	0.03	0.47		0.16	0.14	0.23	0.47	0.05	0.12	0.01	0.29	0.29	0.47	0.33	0.33	0.39
PO_4^{3-}	*p-value*	0.2087	0.5092	0.4269		0.2134	0.325	0.2134	0.0702	0.3875	0.8482	***0.0018***	***0.0113***	0.4718	0.2327	0.9391	0.1934
	r^2	0.3591	0.12	0.16		0.35	0.24	0.35	0.6	0.19	0.01	***0.93***	***0.83***	0.14	0.33	0.01	0.38
C_{mic}	*p-value*	0.0106*	0.0198*	0.4587	0.2134		0.6298	0.9944	0.0873	0.8503	0.4109	0.3946	0.5342	0.4346	0.4819	0.3832	0.6765
	r^2	0.84*	0.78*	0.14	0.35		0.06	0.01	0.5593	0.01	0.23	0.185	0.11	0.16	0.13	0.19	0.05
N_{mic}	*p-value*	0.4772	0.6066	0.3368	0.325	0.6298		0.8848	0.9393	0.2994	0.1354	0.228	0.1461	0.1669	0.7409	0.1149	0.8426
	r^2	0.13	0.07	0.23	0.24	0.06		0.01	0.01	0.26	0.58	0.34	0.45	0.42	0.03	0.5	0.01
Mic_{Resp}	*p-value*	0.9189	0.505	0.1982	0.2134	0.9944	0.8848		0.7572	0.8239	0.765	0.7181	0.6559	0.925	0.9711	0.431	0.3511
	r^2	0.01	0.16	0.47	0.35	0.01	0.01		0.04	0.02	0.03	0.05	0.07	0.01	0.01	0.22	0.29
Gluc	*p-value*	0.1355	0.4144	0.6636	0.0702	0.0873	0.9393	0.7572		0.7055	0.26	0.1418	0.2658	0.6964	0.1557	0.2577	0.4037
	r^2	0.4654	0.17	0.05	0.6	0.5593	0.01	0.04		0.04	0.39	0.45	0.29	0.04	0.43	0.3	0.18
H_2O_{grav}	*p-value*	0.8417	0.8642	0.4948	0.3875	0.8503	0.2994	0.8239	0.7055		0.2324	0.2625	0.1716	0.0154*	0.8103	0.1321	0.2531
	r^2	0.01	0.01	0.12	0.19	0.01	0.26	0.02	0.04		0.43	0.29	0.41	0.8*	0.02	0.47	0.31
$H_2O_{\%}$	*p-value*	0.4181	0.5259	0.9113	0.8482	0.4109	0.1354	0.765	0.26	0.2324		0.8736	0.5881	0.2016	0.198	0.7425	0.0775
	r^2	0.23	0.15	0.01	0.01	0.23	0.58	0.03	0.39	0.43		0.01	0.11	0.11	0.12	0.01	0.21
C_t	*p-value*	0.3314	0.8028	0.2667	***0.0018***	0.3946	0.228	0.7181	0.1418	0.2625	0.8736		***4.44E-04***	0.2633	0.2708	0.8424	0.0968
	r^2	0.23	0.02	0.29	***0.93***	0.185	0.34	0.05	0.45	0.29	0.01		***0.97***	0.29	0.29	0.01	0.54
N_t	*p-value*	0.4621	0.9203	0.2677	***0.0113***	0.5342	0.1461	0.6559	0.2658	0.1716	0.5881	***4.44E-04***		0.2719	0.4197	0.6511	0.1055
	r^2	0.14	0.01	0.29	***0.83***	0.11	0.45	0.07	0.29	0.41	0.11	***0.97***		0.42	0.17	0.06	0.52
µg CH_4-C m^{-2} h^{-1}	*p-value*	0.7413	0.325	0.1349	0.4718	0.4346	0.1669	0.925	0.6964	0.0154*	0.2016	0.2633	0.2719		0.106	0.7091	0.2116
	r^2	0.03	0.24	0.47	0.14	0.16	0.42	0.01	0.04	0.8*	0.11	0.29	0.42		0.16	0.01	0.09
mg CO_2-C m^{-2} h^{-1}	*p-value*	0.2108	0.9615	0.2291	0.2327	0.4819	0.7409	0.9711	0.1557	0.8103	0.198	0.2708	0.4197	0.106		0.8774	***1.48E-04***
	r^2	0.36	0.01	0.33	0.33	0.13	0.03	0.01	0.43	0.02	0.12	0.29	0.17	0.16		0.01	***0.6***
µg N_2O-N m^{-2} h^{-1}	*p-value*	0.3422	0.9615	0.2291	0.9391	0.3832	0.1149	0.431	0.2577	0.1321	0.7425	0.8424	0.6511	0.7091	0.8774		0.3876
	r^2	0.22	0.01	0.33	0.01	0.19	0.5	0.22	0.3	0.47	0.01	0.01	0.06	0.01	0.01		0.05
$°C_{soil}$	*p-value*	0.2974	0.7629	0.1859	0.1934	0.6765	0.8426	0.3511	0.4037	0.2531	0.0775	0.0968	0.1055	0.2116	***1.48E-04***	0.3876	
	r^2	0.26	0.03	0.39	0.38	0.05	0.01	0.29	0.18	0.31	0.21	0.54	0.52	0.09	***0.6***	0.05	

* = These significant correlations were made by coincidence; bolded numbers in grey cells refer to significant correlations.

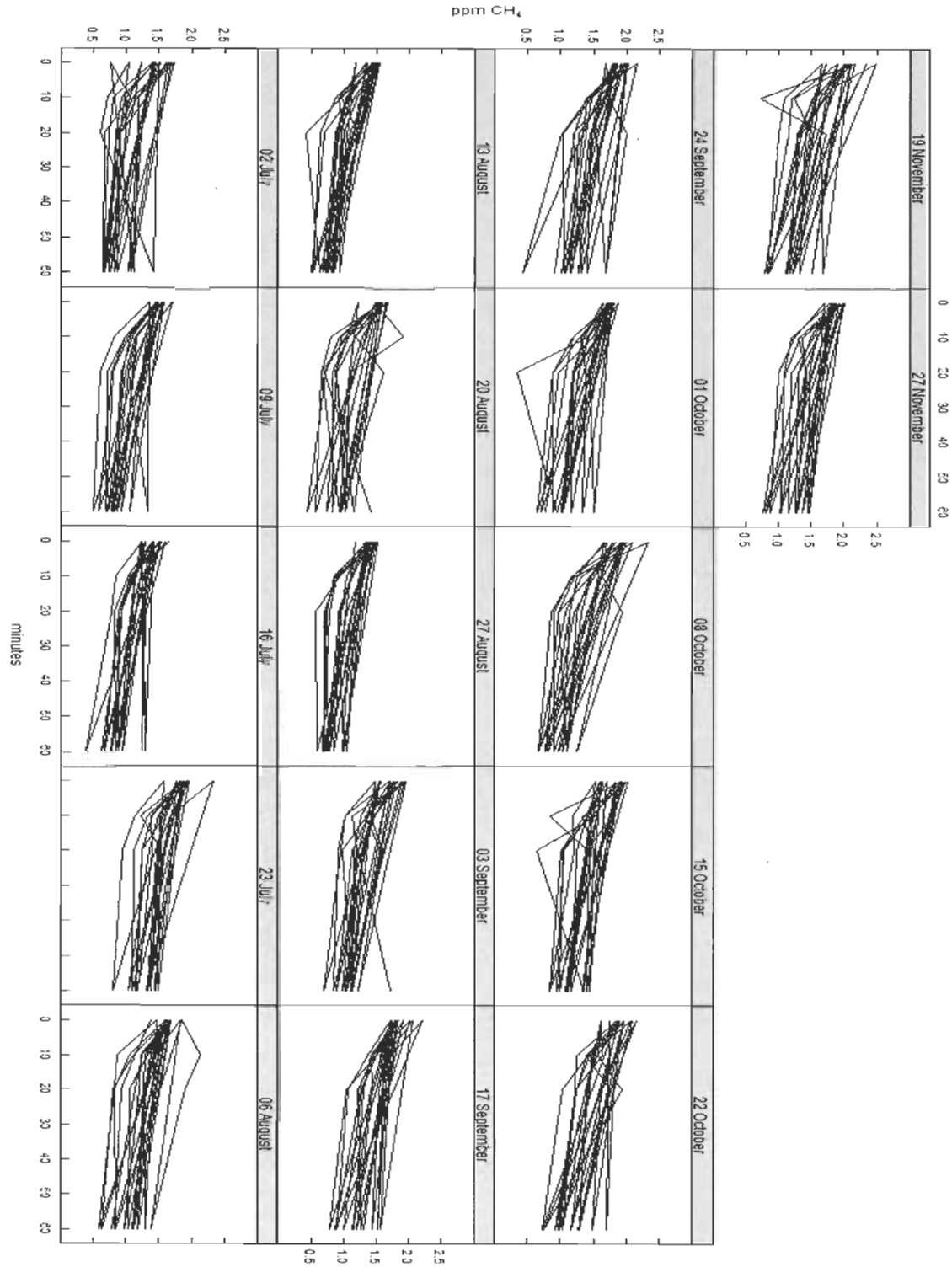
Control treatment		Parameters															
Paramters	**Indicator**	**pH**	**NO_3^-**	**NH_4^+**	**PO_4^{3-}**	**C_{mic}**	**N_{mic}**	**Mic_{Resp}**	**Gluc**	**H_2O_{grav}**	**$H_2O_{\%}$**	**C_t**	**N_t**	**µg CH_4-C m^{-2} h^{-1}**	**mg CO_2-C m^{-2} h^{-1}**	**µg N_2O-N m^{-2} h^{-1}**	**$°C_{soil}$**
pH	*p-value*		0.1704	0.5856	0.9356	0.0281*	0.8275	0.0879	0.7169	0.0825	0.2138	0.6905	0.7202	0.578	0.4829	0.2268	0.4371
	r^2		0.41	0.67	0.01	0.74*	0.02	0.68	0.04	0.57	0.45	0.04	0.04	0.08	0.13	0.34	0.16
NO_3^-	*p-value*	0.1704		0.0066*	0.6417	0.2414	0.1696	0.1878	0.5969	0.7996	0.5396	0.6365	0.3725	0.2271	0.5544	0.239	0.5746
	r^2	0.41		0.87*	0.06	0.32	0.41	0.49	0.08	0.02	0.14	0.06	0.2	0.34	0.09	0.32	0.09
NH_4^+	*p-value*	0.5856	0.0066*		0.874	0.1684	0.35	0.1212	0.8358	0.3488	0.2614	0.9406	0.7167	0.3306	0.6901	0.0866	0.9228
	r^2	0.67	0.87*		0.01	0.41	0.22	0.61	0.01	0.22	0.39	0.01	0.04	0.46	0.04	0.56	0.01
PO_4^{3-}	*p-value*	0.9356	0.6417	0.874		0.2946	0.0806	0.6344	0.0087*	0.4677	0.7376	0.3637	0.2957	0.4796	0.8094	0.2435	0.6187
	r^2	0.01	0.06	0.01		0.27	0.57	0.08	0.85*	0.14	0.04	0.49	0.27	0.13	0.02	0.32	0.07
C_{mic}	*p-value*	0.0281*	0.2414	0.1684	0.2946		0.4329	0.166	0.1586	0.3353	0.6521	0.706	0.8979	0.8939	0.2953	0.8137	0.2617
	r^2	0.74*	0.32	0.41	0.27		0.16	0.52	0.43	0.23	0.08	0.04	0.01	0.01	0.27	0.02	0.3
N_{mic}	*p-value*	0.8275	0.1696	0.35	0.0806	0.4329		0.1113	0.1493	0.5629	0.6974	0.0933	0.0318*	0.6915	0.4875	0.8688	0.8488
	r^2	0.02	0.41	0.22	0.57	0.16		0.63	0.44	0.09	0.06	0.55	0.72*	0.04	0.14	0.01	0.01
Mic_{Resp}	*p-value*	0.0879	0.1878	0.1212	0.6344	0.166	0.1113		0.6304	0.3075	0.1477	0.6067	0.2417	0.3442	0.5751	0.4465	0.6852
	r^2	0.68	0.49	0.61	0.08	0.52	0.63		0.09	0.33	0.56	0.1	0.41	0.3	0.12	0.2	0.06
Gluc	*p-value*	0.7169	0.5969	0.8358	0.0087*	0.1586	0.1493	0.6304		0.5939	0.6012	0.0654	0.2886	0.2919	0.4376	0.2359	0.5627
	r^2	0.04	0.08	0.01	0.85*	0.43	0.44	0.09		0.08	0.1	0.61	0.27	0.27	0.16	0.33	0.09
H_2O_{grav}	*p-value*	0.0825	0.7996	0.3488	0.4677	0.3353	0.5629	0.3075	0.5939		0.0059*	0.2089	0.3039	0.5229	0.4954	0.1866	0.1908
	r^2	0.57	0.02	0.22	0.14	0.23	0.09	0.33	0.08		0.94*	0.36	0.26	0.11	0.12	0.39	0.38
$H_2O_{\%}$	*p-value*	0.2138	0.5396	0.2614	0.7376	0.6521	0.6974	0.1477	0.6012	0.0059*		0.5299	0.9986	***0.0026***	0.4949	0.6889	0.0188
	r^2	0.45	0.14	0.39	0.04	0.08	0.06	0.56	0.1	0.94*		0.14	1.19E-06	***0.49***	0.03	0.01	0.34
C_t	*p-value*	0.6905	0.6365	0.9406	0.3637	0.706	0.0933	0.6067	0.0654	0.2089	0.5299		0.0178*	0.4691	0.9746	0.245	0.7627
	r^2	0.04	0.06	0.01	0.49	0.04	0.55	0.1	0.61	0.36	0.14		0.79*	0.14	0.01	0.32	0.03
N_t	*p-value*	0.7202	0.3725	0.7167	0.2957	0.8979	0.0318*	0.2417	0.2886	0.3039	0.9986	0.0178*		0.8878	0.4692	0.6891	0.4956
	r^2	0.04	0.2	0.04	0.27	0.01	0.72*	0.41	0.27	0.26	1.19E-06	0.79*		0.01	0.14	0.04	0.12
µg CH_4-C m^{-2} h^{-1}	*p-value*	0.578	0.2271	0.3306	0.4796	0.8939	0.6915	0.3442	0.2919	0.5229	***0.0026***	0.4691	0.8878		0.6074	0.3533	0.9123
	r^2	0.08	0.34	0.46	0.13	0.01	0.04	0.3	0.27	0.11	***0.49***	0.14	0.01		0.02	0.05	0.01
mg CO_2-C m^{-2} h^{-1}	*p-value*	0.4829	0.5544	0.6901	0.8094	0.2953	0.4875	0.5751	0.4376	0.4954	0.4949	0.9746	0.4692	0.6074		0.9345	***9.48E-04***
	r^2	0.13	0.09	0.04	0.02	0.27	0.14	0.12	0.16	0.12	0.03	0.01	0.14	0.02		0.01	***0.51***
µg N_2O-N m^{-2} h^{-1}	*p-value*	0.2268	0.239	0.0866	0.2435	0.8137	0.8688	0.4465	0.2359	0.1866	0.6889	0.245	0.6891	0.3533	0.9345		0.2449
	r^2	0.34	0.32	0.56	0.32	0.02	0.01	0.2	0.33	0.39	0.01	0.32	0.04	0.05	0.01		0.08
$°C_{soil}$	*p-value*	0.4371	0.5746	0.9228	0.6187	0.2617	0.8488	0.6852	0.5627	0.1908	0.0188	0.7627	0.4956	0.9123	***9.48E-04***	0.2449	
	r^2	0.16	0.09	0.01	0.07	0.3	0.01	0.06	0.09	0.38	0.34	0.03	0.12	0.01	***0.51***	0.08	

* = These significant correlations are made by coincidence; bolded numbers in grey cells are significant correlations.

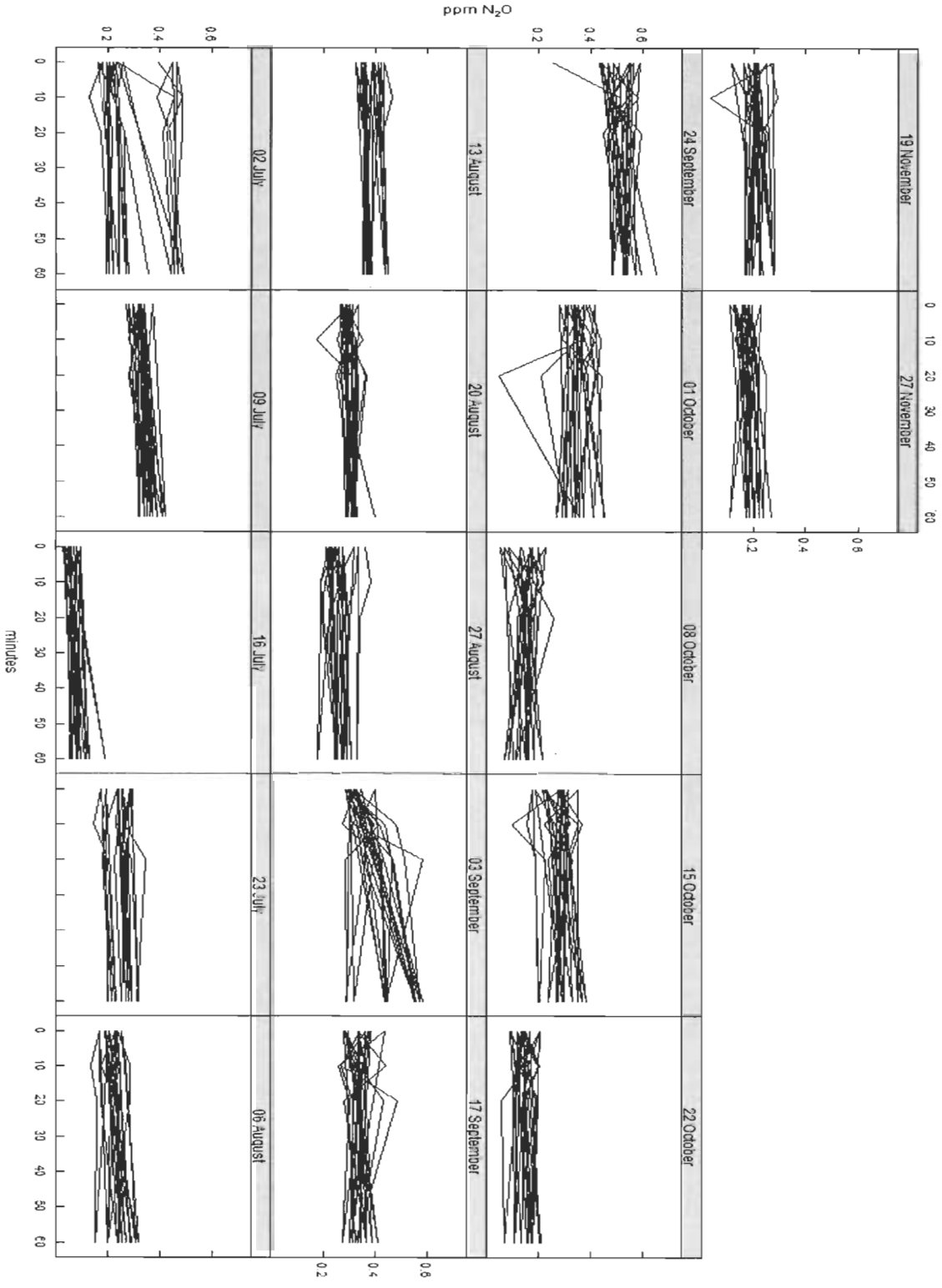
Appendix 11: CO_2 concentration changes (ppm) in the headspace chambers of the control treatment during a one-hour incubation for all 18 measuring dates from July to November 2012. Outliers are included.



Appendix 12: CH_4 concentration changes (ppm) in the headspace chambers of the control treatment during a one-hour incubation for all 18 measuring dates from July to November 2012. Outliers are included.



Appendix 13 N_2O concentration changes (ppm) in the headspace chambers of the control treatment during one-hour incubation for all 18 measuring dates from July to November 2012. Outliers are included.



Appendix 14: Poster Presentation at the Austrian Soil Science Society; Soil Science for the Future, Campus Tulln, Austria, 19 October 2012

Comparison of CO_2, CH_4 and N_2O soil effluxes with and without litter in a beech forest

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Introduction

The impact of greenhouse gases as CO_2, CH_4, and N_2O on the global climate is recognized more and more by a broad publicity. Not all greenhouse gases have the same warming potential as methane, for example, has a 25 fold higher potential to absorb thermal radiation than carbon dioxide.
The following master project determines soil greenhouse gas fluxes on a pure beech site with and without beach litter.

Hypotheses

H1: Litter covered soil produces more CO_2 than bare soil through increased substrate availability for microbial decomposition.

H2: lower methane consumption of litter covered soils by reduced gas diffusion ability through litter layer

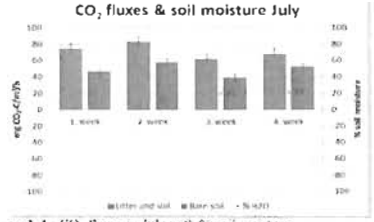
H3: Higher N_2O fluxes emitted from litter covered soils as litter is usually dominated by fungi and they lack in the reduction of N_2O in N_2 in the denitrification process.

Pic. 1 One of the 12 treatment pairs, gas chamber with and without litter.

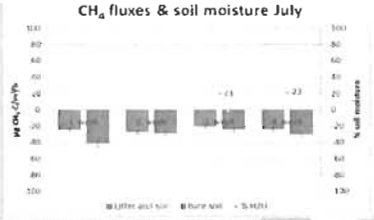
Pic. 2. Part of the gas chamber setup

Results so far

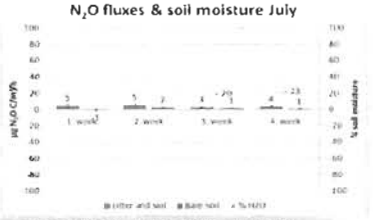
Gas fluxes: There is a significant difference in CO_2 production between the control treatment and its stressed opponent, as shown in graph 1 a higher production occurs on the treatment with litter on the soil. As well CH_4 consumption differs between the control treatment and the stressed treatment (graph 2). The soil without litter consumes more CH_4 than the bare soil. Further there is also a higher consumption in CH_4 comparing week three and week four. That can described with the higher soil moisture in week four. Graph 3 shows a higher N_2O production on the control treatment.



graph 1.: CO_2 fluxes in July with % soil moisture



graph 2 : CH_4 fluxes in July with % soil moisture



graph 3.: N_2O fluxes in July with % soil moisture

Material and Methods

Sampling site Rosalia:
The project is conducted in the BOKU Forest Demonstration Center Rosalia, in Lower Austria. Gas fluxes of CH_4, CO_2 and N_2O, and further beech forest nutrients are analyzed. The gas flux measurements are taken manually with static gas chambers (Pic.1,2) and preformed weekly form July until October 2012. The total setup exists of 12 pairs of chambers. Each pair consists of two treatments: a control treatment with no manipulation and a stress-treatment where the litter layer is removed and replaced by a black garden foil with small holes. Thereby nutrient input from the litter into the soil will be stopped without changing soil moisture and temperature (both parameters are measured each week). The chambers are made out of PVC and have an inner diameter of 19 cm. They can be closed with a lid, and gas samples from the closed chambers are taken at the start and after 10, 20 and 60 minutes with syringes and stored in vials for later GC-analysis in the lab.
Laboratory:
Once a month, soil samples are taken from every treatment, resulting in a total of 24 soil samples that get analyzed in the laboratory to measure pH, total C, total N, NO_3^-, NH_4^+, PO_4^{3-}, DOC/TN and microbial parameters like microbial biomass C and N, glucose and respiration. The same analytic procedure like for the soil samples is preformed two times to analyse the litter layer, in the beginning and in the end of the project.
Additionally, soil profiles beginning from zero down to 70cm has been taken in July and will be taken again in the end of October to determine the soils total vertical C and N stock distribution.

University of Natural Resources and Life Sciences, Vienna
Department of Forest- and Soil Sciences

9. Raw Data of Soil Nutrients

Date	Treat-ment	pH	NO^{3-}	NH^{4+}	PO_4^{3-}	N_{mic}	C_{mic}	Mic_{Resp}	Gluc	WC_{grav}	DW	C_t	N_t
02.Jul	1*	3.67	7.02	10.18	0.54	4.85	30.77	NA	1.43	0.22	0.78	1.52	0.076
02.Jul	1	3.78	30.21	16.43	0.52	4.04	23.78	NA	1.3	0.21	0.79	2.31	0.101
02.Jul	1	3.58	NA	12.98	NA	5.48	35.49	NA	1.66	0.23	0.77	2.33	0.111
02.Jul	1	3.26	NA	21.26	1.48	5.92	34.88	NA	3.24	0.29	0.71	3.84	0.107
02.Jul	1	3.57	0.55	16.74	0.94	5.77	35.59	NA	1.58	0.18	0.82	2.27	0.12
02.Jul	1	3.54	24.55	21.39	0.69	5.65	37.37	NA	1.78	0.2	0.8	2.36	0.12
02.Jul	1	3.64	13.09	14.19	0.35	2.79	19.79	NA	1.01	0.15	0.85	1.28	0.072
02.Jul	1	3.75	38.49	11.18	1.42	4.78	31.34	NA	0.92	0.17	0.83	1.3	0.056
02.Jul	1	3.69	45.14	14.64	2.16	2.34	15.3	NA	0.99	0.18	0.82	1.27	0.069
02.Jul	1	3.59	NA	21.16	2.65	3.18	21.16	NA	1.58	0.19	0.81	1.74	0.084
02.Jul	1	3.55	17.96	7.9	5.1	3.01	18.92	NA	1.13	0.19	0.81	1.26	0.068
02.Jul	1	3.64	55.08	13.62	6.25	3.6	19.76	NA	0.98	0.19	0.81	1.45	0.067
02.Jul	-1**	3.71	27.64	NA	2.93	14.9	79.78	NA	2.47	0.31	0.69	3.84	0.186
02.Jul	-1	4.32	9.89	29.5	1.61	8.92	46.67	NA	1.61	0.28	0.72	2.77	0.118
02.Jul	-1	4.31	5.56	NA	4.1	NA	NA	NA	2.54	0.51	0.49	3.84	0.188
02.Jul	-1	3.46	4.98	20.31	0.83	3.45	29.3	NA	2	0.2	0.8	2.23	0.123
02.Jul	-1	3.9	73.35	28.49	5.25	15.12	82.82	NA	NA	0.28	0.72	3.96	0.215
02.Jul	-1	3.72	40.96	23.04	1.38	5.34	38.06	NA	1.4	0.16	0.84	1.72	0.103
02.Jul	-1	3.68	34.73	12.27	NA	3.72	24.05	NA	0.82	0.17	0.83	1.4	0.081
02.Jul	-1	3.74	2.97	21.45	1.4	4.6	33.87	NA	1.47	0.18	0.82	2.78	0.132

02.Jul	-1	3.87	6.86	16.69	0.7	5.92	35.72	NA	1.13	0.23	0.77	2.82	0.135
02.Jul	-1	3.66	1.37	23.9	4.63	5.85	41.91	NA	2.36	0.32	0.68	2.91	0.124
02.Jul	-1	4.01	42.94	10.83	3.58	1.91	12.99	NA	0.56	0.16	0.84	0.83	0.045
02.Jul	-1	3.63	31.22	21.52	5.05	3.84	26.28	NA	2.25	0.11	0.89	1.25	0.069
16.Jul	1	3.42	NA	17.09	1.32	12.62	49.88	0.44	3.4	0.4	0.6	3.65	0.192
16.Jul	1	4.09	0.44	6.03	1.33	6.49	18.86	0.68	2	0.34	0.66	2.32	0.113
16.Jul	1	3.78	NA	5.07	1.69	11.07	41.03	0.6	2.48	0.36	0.64	2.63	0.138
16.Jul	1	3.61	NA	8.9	2.17	8.41	38.56	0.47	2.72	0.31	0.69	3.4	0.148
16.Jul	1	3.57	NA	17.86	1.68	10.09	43.13	0.62	NA	0.35	0.65	2.72	0.159
16.Jul	1	3.5	NA	6.87	1.94	7.62	37.82	0.69	1.16	0.28	0.72	2.37	0.141
16.Jul	1	3.68	NA	13.1	2.12	9.71	32.95	0.43	2.52	0.35	0.65	3.51	0.193
16.Jul	1	4.12	22.11	19.11	1.5	6.65	20.82	0.43	1.83	0.28	0.72	2.74	0.145
16.Jul	1	3.66	NA	6.47	6.08	4.94	9.72	0.46	2.25	0.27	0.73	1.76	0.107
16.Jul	1	3.71	NA	10.16	NA	4.7	9.97	0.52	1.58	0.27	0.73	1.8	0.097
16.Jul	1	3.65	NA	11.22	7.14	10.36	22.24	0.58	1.67	0.27	0.73	1.84	0.101
16.Jul	1	3.48	NA	13.65	7.42	5.24	16.53	0.24	2.05	0.27	0.73	2.7	0.12
16.Jul	-1	3.84	23.87	13.42	2.84	6.29	16.24	0.48	1.6	0.33	0.67	1.98	0.106
16.Jul	-1	4.12	4.45	19.17	NA	7.27	18.87	0.77	1.91	0.3	0.7	2.82	0.141
16.Jul	-1	3.84	NA	18.96	1.78	10.88	48.01	0.74	3	0.39	0.61	3	0.159
16.Jul	-1	3.47	17.19	13.02	NA	5.38	13.43	0.37	2.01	0.31	0.69	3.01	0.158
16.Jul	-1	3.8	NA	20.48	2.53	9.82	33.56	0.68	2.11	0.33	0.67	2.48	0.12
16.Jul	-1	3.7	5.79	14.7	1.79	11.51	54.23	0.69	1.81	0.22	0.78	2.32	0.118
16.Jul	-1	3.7	NA	11.72	1.91	3.46	6.08	0.36	1.29	0.22	0.78	1.4	0.087
16.Jul	-1	3.87	6.39	13.94	1.29	6.57	25	0.57	2.08	0.24	0.76	2.97	0.151
16.Jul	-1	3.61	5.29	11.53	2.6	6.96	25.59	0.6	1.79	0.28	0.72	3.24	0.179
16.Jul	-1	3.7	NA	14.93	3.52	6.99	29.1	0.59	2.38	0.26	0.74	2.54	0.125
16.Jul	-1	3.87	8.68	8.06	6.21	NA	NA	0.35	0.77	0.27	0.73	0.7	0.039

16.Jul	-1	3.64	3.93	10.65	4.02	3.25	2.05	0.31	1.2	0.25	0.75	1.59	0.078
30.Jul	1	4.53	68.67	21.6	2.59	5.97	40.5	0.79	2.52	0.41	0.59	3.08	0.149
30.Jul	1	4.15	28.16	23.95	1.8	4.42	27.11	0.46	1.55	0.32	0.68	1.56	0.075
30.Jul	1	3.6	16.82	25.68	2.53	10.43	66.71	0.86	2.23	0.46	0.54	3.97	0.194
30.Jul	1	3.67	NA	NA	7.29	14.04	86.13	1.22	2.93	0.55	0.45	NA	0.251
30.Jul	1	3.73	7.94	20.39	2.24	8.11	57.23	0.83	3.5	0.39	0.61	3.15	0.154
30.Jul	1	4.54	29.98	28.15	2.18	7.93	50.14	0.8	2.64	0.41	0.59	2.41	0.114
30.Jul	1	3.67	NA	22.99	2.92	4.02	30.73	0.61	2.09	0.34	0.66	1.72	0.094
30.Jul	1	4.49	20.64	17.06	1.72	2.36	19.33	0.5	1.21	0.29	0.71	1.36	0.075
30.Jul	1	3.8	24.96	22.59	1.74	4.95	33.87	0.54	1.91	0.34	0.66	2.18	0.117
30.Jul	1	3.91	7.89	17.63	2.8	1.99	17.48	0.39	1.42	0.31	0.69	1.61	0.071
30.Jul	1	3.54	NA	11.6	4.45	3.33	25.66	0.4	1.99	0.34	0.66	1.87	0.088
30.Jul	1	3.6	27.71	13.18	4.87	2.63	23.14	0.25	1.59	0.28	0.72	1.88	0.099
30.Jul	-1	3.56	NA	28.96	2.06	5.99	41.59	0.42	2.38	0.4	0.6	3.13	0.125
30.Jul	-1	3.67	NA	16.79	1.92	1.94	18.11	0.34	1.57	0.3	0.7	1.48	0.073
30.Jul	-1	3.94	NA	30.33	1.95	4.87	38.21	0.79	2.09	0.39	0.61	2.85	0.141
30.Jul	-1	3.7	38.68	17.39	2.55	2.86	24	0.29	2.09	0.34	0.66	2.04	0.104
30.Jul	-1	3.64	NA	30.45	3	6.35	46.2	0.77	3.56	0.34	0.66	2.61	0.111
30.Jul	-1	3.67	NA	8.68	2.19	3.48	26.09	0.41	1.81	0.3	0.7	1.74	0.097
30.Jul	-1	3.66	4.56	16.38	1.73	3.8	26.96	0.52	1.73	0.32	0.68	1.77	0.104
30.Jul	-1	3.97	27.14	17.83	1.94	6.67	42.71	0.84	2.13	0.38	0.62	2.69	0.137
30.Jul	-1	3.68	31.27	25.28	1.86	5.11	35.63	0.63	2.06	0.35	0.65	1.97	0.101
30.Jul	-1	3.78	NA	22.83	2.46	4.83	35.42	0.67	2.04	0.44	0.56	1.81	0.084
30.Jul	-1	3.8	32.36	10.34	2.91	2.01	14.72	0.18	1.16	0.31	0.69	1.14	0.057
30.Jul	-1	3.82	36.37	11.07	3.88	2.19	16.31	0.31	1.27	0.27	0.73	1.03	0.056
20.Aug	1	3.91	28.15	20.54	1.58	6.65	40.08	0.41	0.89	0.28	0.72	1.71	0.084
20.Aug	1	4.06	53.05	20.53	1.47	7.4	47.4	0.71	1.13	0.28	0.72	1.93	0.087

20.Aug	1	3.79	84.27	19.43	1.35	8.27	52.9	0.73	1.34	0.27	0.73	2.66	0.132
20.Aug	1	3.6	7.28	15.6	1.74	6.02	42.11	0.53	1.35	0.22	0.78	2.53	0.113
20.Aug	1	3.65	11.35	17.91	1.63	8.83	54.92	0.75	1.31	0.26	0.74	2.93	0.155
20.Aug	1	3.6	9.79	23.43	3.16	9.7	60.4	0.54	1.26	0.25	0.75	2.57	0.139
20.Aug	1	3.84	12.77	11.31	2.21	3.04	25.36	0.46	0.49	0.18	0.82	1.2	0.072
20.Aug	1	4.08	36.75	9.35	1.73	2.79	21.77	0.59	0.48	0.17	0.83	1.18	0.075
20.Aug	1	3.8	28.87	11.9	1.88	4.37	31.26	0.43	0.93	0.23	0.77	1.88	0.117
20.Aug	1	3.85	NA	14.81	2.91	2.11	21.4	0.43	0.75	0.19	0.81	1.29	0.079
20.Aug	1	3.75	17.52	21.91	3.43	5.65	36.86	0.43	0.94	0.25	0.75	1.74	0.104
20.Aug	1	3.64	3.56	15.12	4.74	4.9	35.86	0.51	1.03	0.23	0.77	1.89	0.096
20.Aug	-1	3.45	24.85	32.33	3.49	11.01	67.36	0.93	1.75	0.27	0.73	4.84	0.213
20.Aug	-1	4.33	10.03	20.65	1.89	6.09	35.24	0.52	0.78	0.22	0.78	2.34	0.12
20.Aug	-1	3.73	NA	11.51	1.03	2.49	21.18	0.15	0.95	0.16	0.84	1.78	0.089
20.Aug	-1	3.9	54.25	20.21	1.74	6.76	41.31	0.46	1.03	0.2	0.8	2.19	0.126
20.Aug	-1	3.63	NA	21.97	1.43	7.59	48.71	0.5	0.94	0.19	0.81	1.86	0.117
20.Aug	-1	3.68	2.13	12.17	2.54	5.33	35.13	0.35	0.71	0.19	0.81	1.49	0.09
20.Aug	-1	3.7	18.31	26.32	1.94	8.47	49.07	0.54	1.03	0.21	0.79	1.94	0.108
20.Aug	-1	3.67	23.12	23.32	1	4.25	29.86	0.35	1.14	0.17	0.83	2.18	0.119
20.Aug	-1	3.78	23.84	19.23	2.18	4.48	29.99	0.44	0.84	0.21	0.79	1.58	0.108
20.Aug	-1	3.85	9.44	29.49	4.61	13.16	77.66	1.21	1.42	0.31	0.69	4.31	0.218
20.Aug	-1	3.91	20.35	7.3	5.34	0.57	10.79	0.26	0.35	0.17	0.83	0.77	0.035
20.Aug	-1	3.61	12.69	17.15	3.85	4.41	29.42	0.39	0.88	0.2	0.8	1.71	0.085
17.Sep	1	4.39	NA	28.12	4.09	7.83	58.92	1.23	0.91	0.41	0.59	2.96	0.138
17.Sep	1	4.13	76.06	25.9	1.45	5.41	42.56	0.97	0.63	0.32	0.68	1.82	0.095
17.Sep	1	3.58	NA	16.74	1.1	4.99	48.49	0.64	NA	0.32	0.68	1.97	0.1
17.Sep	1	3.51	NA	9.13	2.08	3.69	37.7	0.45	NA	0.23	0.77	1.55	0.075
17.Sep	1	3.46	NA	17.5	2.42	9.83	78.73	0.94	1.21	0.34	0.66	2.47	0.135

17.Sep	1	3.77	NA	18.9	1.48	6.53	56.9	0.45	0.9	0.29	0.71	1.79	0.105
17.Sep	1	3.84	4.33	18.92	2.15	3.91	37.58	0.6	0.91	0.33	0.67	1.53	0.088
17.Sep	1	4.1	21.16	22.21	1.98	3.66	33.62	0.45	0.72	0.35	0.65	1.1	0.06
17.Sep	1	3.92	7.72	9.29	2.2	1	21.01	0.32	0.76	0.28	0.72	1.09	0.055
17.Sep	1	3.82	NA	15.84	2.31	2	28.71	0.44	0.53	0.25	0.75	1.19	0.057
17.Sep	1	3.73	NA	11.66	2.65	4.1	42.06	0.9	0.81	0.31	0.69	1.83	0.095
17.Sep	1	3.71	34.61	11.39	4.24	2.99	33.04	0.38	0.65	0.27	0.73	1.27	0.069
17.Sep	-1	3.78	3.76	24.2	1.52	8.4	61.79	0.74	0.94	0.4	0.6	2.48	0.116
17.Sep	-1	3.88	2.52	14.32	2.02	3.61	33.34	0.33	0.55	0.28	0.72	1.25	0.065
17.Sep	-1	3.83	NA	14.22	1.44	4.76	44.38	0.57	1.17	0.3	0.7	1.64	0.079
17.Sep	-1	3.61	32.98	9.05	1.78	3.04	30.36	0.34	0.62	0.05	0.95	1.22	0.062
17.Sep	-1	3.7	3.66	28.82	2.3	8.76	75.4	0.7	1.08	0.26	0.74	2.79	0.161
17.Sep	-1	3.84	7.6	23.11	1.27	7.33	54.2	0.67	0.63	0.32	0.68	2.12	0.117
17.Sep	-1	3.8	10.21	17.05	1.92	4.07	37.26	0.48	0.67	0.28	0.72	1.37	0.074
17.Sep	-1	3.84	51.08	27.44	1.51	4.99	43.9	0.56	0.92	0.24	0.76	1.87	0.101
17.Sep	-1	3.94	28.24	17.11	1.36	1.51	20.17	0.41	0.73	0.26	0.74	0.93	0.052
17.Sep	-1	3.86	NA	16.85	2.2	8.24	60.89	1.04	0.9	0.36	0.64	2.5	0.132
17.Sep	-1	3.94	15.08	9.96	4.31	1.29	19.93	0.24	0.48	0.26	0.74	0.82	0.039
17.Sep	-1	3.75	14.85	5.35	3	NA	NA	0.65	0.38	NA	NA	2.16	0.121
15.Okt	1	4.1	53.7	NA	2.27	9.18	77.72	1.17	0.75	0.4	0.6	3.45	0.166
15.Okt	1	4.07	59.53	26.85	0.65	9.67	79.4	NA	0.59	0.54	0.46	1.64	0.083
15.Okt	1	3.95	3.41	13.36	1.38	2.13	32.56	1.01	0.98	0.25	0.75	3.93	0.184
15.Okt	1	3.58	6.03	20.36	1.09	3.92	45.12	0.45	0.89	0.42	0.58	2.05	0.101
15.Okt	1	3.8	13.71	28.62	1.52	9.69	83.15	1.03	0.97	0.38	0.62	3.1	0.177
15.Okt	1	3.77	22.55	13.55	1.09	3.29	38.87	0.28	0.72	0.27	0.73	1.96	0.116
15.Okt	1	3.86	17.05	16.93	1.35	2.08	31.03	NA	0.39	0.24	0.76	1.11	0.058
15.Okt	1	4.1	45.9	16.45	0.86	3.2	39.44	0.59	0.54	0.27	0.73	1.74	0.103

15.Okt	1	3.88	14.2	8.63	1.36	8.92	66.33	0.31	0.36	0.24	0.76	1.1	0.059
15.Okt	1	3.84	1.09	9.45	1.34	1.73	30.9	0.46	0.65	0.29	0.71	1.82	0.095
15.Okt	1	4.01	5.78	16.1	2.59	1.62	27.7	0.49	0.57	0.29	0.71	3.04	0.171
15.Okt	1	3.75	15.71	9.54	2.74	2.1	31.07	0.32	0.49	0.21	0.79	1.41	0.073
15.Okt	-1	3.95	66.34	25.24	0.78	10.71	74.62	0.71	0.74	0.4	0.6	2.99	0.15
15.Okt	-1	4.18	25.77	20.31	3.44	8.68	68.91	0.85	0.63	0.54	0.46	2.09	0.114
15.Okt	-1	3.88	27.61	12.06	0.19	9.28	75.18	0.28	0.52	0.25	0.75	1.52	0.075
15.Okt	-1	3.69	31.44	11.1	1.09	6.93	68.07	0.26	0.54	0.42	0.58	1.29	0.062
15.Okt	-1	3.75	NA	19.81	1.13	12.06	87.25	0.86	0.88	0.38	0.62	2.19	0.118
15.Okt	-1	3.84	0.19	12.72	NA	6.54	56.45	0.34	0.34	0.27	0.73	0.84	0.046
15.Okt	-1	3.94	24.26	15.18	NA	4.05	39.9	NA	0.31	0.24	0.76	0.95	0.057
15.Okt	-1	4.02	32.63	26.12	NA	5.88	49.29	0.49	0.54	0.27	0.73	1.46	0.078
15.Okt	-1	4.12	3.63	23.96	NA	1.98	26.5	0.85	0.73	0.24	0.76	2.8	0.137
15.Okt	-1	4.02	35.82	24.36	1.57	4.9	48.25	0.38	0.6	0.29	0.71	1.39	0.071
15.Okt	-1	3.92	21.07	17.85	2.7	5.14	46.26	0.32	0.35	0.29	0.71	0.94	0.045
15.Okt	-1	3.82	11.78	14.91	3.36	3.85	40.09	0.33	0.54	0.21	0.79	1.45	0.065

* = control treatment; ** = no-litter treatment

10. Raw Data of GHGs

Date	Treat-ment	µg CH_4-C $m^{-2}h^{-1}$	mg CO_2-C $m^{-2}h^{-1}$	µg N_2O-N $m^{-2}h^{-1}$	T_{air}	T_{soil}	Wc_{vol} (mean)
02.Jul	1*	30.79	267.41	0	21.2	17.2	24.33
02.Jul	1	NA	NA	NA	21.1	17.2	NA
02.Jul	1	NA	NA	NA	20.5	16.9	NA
02.Jul	1	NA	NA	NA	21.7	16.4	NA
02.Jul	1	NA	NA	NA	20.8	16.8	NA
02.Jul	1	NA	NA	NA	20.9	17	NA
02.Jul	1	NA	NA	NA	21	16.9	NA
02.Jul	1	NA	NA	NA	21.1	17.1	NA
02.Jul	1	NA	NA	NA	21.9	17.5	NA
02.Jul	1	NA	NA	NA	19.7	17.3	NA
02.Jul	1	NA	NA	NA	20.6	17.2	NA
02.Jul	1	NA	NA	NA	21	17.3	NA
02.Jul	-1**	57.14	145.97	0	21.9	17.5	20.18
02.Jul	-1	NA	NA	NA	20.3	17.2	NA
02.Jul	-1	NA	NA	NA	19.8	17.3	NA
02.Jul	-1	NA	NA	NA	21.8	17.4	NA
02.Jul	-1	NA	NA	NA	21	16.6	NA
02.Jul	-1	NA	NA	NA	20.9	16.3	NA
02.Jul	-1	NA	NA	NA	21	16.9	NA
02.Jul	-1	NA	NA	NA	21.1	17.1	NA
02.Jul	-1	NA	NA	NA	21.9	17.5	NA
02.Jul	-1	NA	NA	NA	19.8	17.4	NA
02.Jul	-1	NA	NA	NA	19.6	17.5	NA
02.Jul	-1	NA	NA	NA	20.9	17.4	NA
09.Jul	1	48.37	241.03	5.49	19.2	16.9	NA
09.Jul	1	NA	NA	NA	18.9	16.7	NA
09.Jul	1	NA	NA	NA	18.8	16.6	NA
09.Jul	1	NA	NA	NA	19.4	16.7	NA
09.Jul	1	NA	NA	NA	18.3	16.7	NA
09.Jul	1	NA	NA	NA	17.7	16.6	NA
09.Jul	1	NA	NA	NA	19.2	16.7	NA
09.Jul	1	NA	NA	NA	18.7	16.7	NA
09.Jul	1	NA	NA	NA	18.4	17.1	NA
09.Jul	1	NA	NA	NA	19.5	17	NA
09.Jul	1	NA	NA	NA	17.6	16.8	NA
09.Jul	1	NA	NA	NA	17.5	16.8	NA
09.Jul	-1	51.42	158.15	2.16	19.4	16.8	NA

09.Jul	-1	NA	NA	NA	18.7	16.8	NA
09.Jul	-1	NA	NA	NA	18.6	16.8	NA
09.Jul	-1	NA	NA	NA	19.9	16.7	NA
09.Jul	-1	NA	NA	NA	18.5	16.8	NA
09.Jul	-1	NA	NA	NA	17.7	16.7	NA
09.Jul	-1	NA	NA	NA	19.2	16.7	NA
09.Jul	-1	NA	NA	NA	18.7	16.7	NA
09.Jul	-1	NA	NA	NA	18.4	17.1	NA
09.Jul	-1	NA	NA	NA	18.4	16.9	NA
09.Jul	-1	NA	NA	NA	17.9	17	NA
09.Jul	-1	NA	NA	NA	17.9	16.8	NA
16.Jul	1	39.78	139.24	0	13.8	12.9	19.47
16.Jul	1	NA	NA	NA	13.8	13.2	NA
16.Jul	1	NA	NA	NA	13.8	13.3	NA
16.Jul	1	NA	NA	NA	14.1	13.1	NA
16.Jul	1	NA	NA	NA	13.9	12.8	NA
16.Jul	1	NA	NA	NA	13.9	12.8	NA
16.Jul	1	NA	NA	NA	14.2	12.7	NA
16.Jul	1	NA	NA	NA	13.8	12.9	NA
16.Jul	1	NA	NA	NA	14.1	12.8	NA
16.Jul	1	NA	NA	NA	14.1	13.1	NA
16.Jul	1	NA	NA	NA	14.1	13	NA
16.Jul	1	NA	NA	NA	13.7	12.9	NA
16.Jul	-1	36.15	107.48	0	13.8	12.6	22.34
16.Jul	-1	NA	NA	NA	13.8	12.8	NA
16.Jul	-1	NA	NA	NA	13.8	12.9	NA
16.Jul	-1	NA	NA	NA	14.1	12.4	NA
16.Jul	-1	NA	NA	NA	13.9	12.8	NA
16.Jul	-1	NA	NA	NA	14	12.8	NA
16.Jul	-1	NA	NA	NA	14.2	12.7	NA
16.Jul	-1	NA	NA	NA	13.8	12.9	NA
16.Jul	-1	NA	NA	NA	14.1	12.8	NA
16.Jul	-1	NA	NA	NA	13.7	12.7	NA
16.Jul	-1	NA	NA	NA	14.2	12.5	NA
16.Jul	-1	NA	NA	NA	13.6	12.6	NA
23.Jul	1	30.08	178.62	0	14.4	12.5	22.92
23.Jul	1	NA	NA	NA	14.4	12.9	NA
23.Jul	1	NA	NA	NA	14.4	13.1	NA
23.Jul	1	NA	NA	NA	14.4	12.9	NA
23.Jul	1	NA	NA	NA	14.2	12.9	NA
23.Jul	1	NA	NA	NA	14.5	12.8	NA
23.Jul	1	NA	NA	NA	14.4	12.9	NA
23.Jul	1	NA	NA	NA	14.4	12.8	NA
23.Jul	1	NA	NA	NA	14.5	12.3	NA
23.Jul	1	NA	NA	NA	14.3	12.7	NA

23.Jul	1	NA	NA	NA	14.6	12.7	NA
23.Jul	1	NA	NA	NA	14.6	12.5	NA
23.Jul	-1	40.64	101.51	0	13.9	12.4	23.57
23.Jul	-1	NA	NA	NA	14.4	12.5	NA
23.Jul	-1	NA	NA	NA	14.4	12.7	NA
23.Jul	-1	NA	NA	NA	14.4	12.2	NA
23.Jul	-1	NA	NA	NA	14.4	12.9	NA
23.Jul	-1	NA	NA	NA	14.4	12.7	NA
23.Jul	-1	NA	NA	NA	14.4	12.9	NA
23.Jul	-1	NA	NA	NA	14.3	12.8	NA
23.Jul	-1	NA	NA	NA	14.5	12.5	NA
23.Jul	-1	NA	NA	NA	14.3	12.6	NA
23.Jul	-1	NA	NA	NA	14.6	12.2	NA
23.Jul	-1	NA	NA	NA	14.7	12.3	NA
30.Jul	1	21.84	216.38	3.93	15.7	15.2	29.3
30.Jul	1	NA	NA	NA	15.8	15.2	NA
30.Jul	1	NA	NA	NA	15.8	15.2	NA
30.Jul	1	NA	NA	NA	15.9	15.3	NA
30.Jul	1	NA	NA	NA	15.8	15.2	NA
30.Jul	1	NA	NA	NA	15.9	15.2	NA
30.Jul	1	NA	NA	NA	16.4	15.1	NA
30.Jul	1	NA	NA	NA	16.3	15.1	NA
30.Jul	1	NA	NA	NA	16.7	15.3	NA
30.Jul	1	NA	NA	NA	16.7	15.4	NA
30.Jul	1	NA	NA	NA	16.9	15.2	NA
30.Jul	1	NA	NA	NA	16.8	15.1	NA
30.Jul	-1	27.58	141.81	2	15.7	15.3	30.37
30.Jul	-1	NA	NA	NA	15.8	15.4	NA
30.Jul	-1	NA	NA	NA	15.8	15.4	NA
30.Jul	-1	NA	NA	NA	15.9	15.6	NA
30.Jul	-1	NA	NA	NA	15.8	15.3	NA
30.Jul	-1	NA	NA	NA	15.9	15.1	NA
30.Jul	-1	NA	NA	NA	16.4	15.1	NA
30.Jul	-1	NA	NA	NA	16.3	15.2	NA
30.Jul	-1	NA	NA	NA	16.7	15.2	NA
30.Jul	-1	NA	NA	NA	16.7	15.3	NA
30.Jul	-1	NA	NA	NA	16.9	15.3	NA
30.Jul	-1	NA	NA	NA	16.8	15.2	NA
06.Aug	1	31.52	359.21	0	25.3	17.7	NA
06.Aug	1	NA	NA	NA	25.3	17.6	NA
06.Aug	1	NA	NA	NA	25.4	17.8	NA
06.Aug	1	NA	NA	NA	25.4	17.9	NA
06.Aug	1	NA	NA	NA	22.8	17.6	NA
06.Aug	1	NA	NA	NA	25.3	17.3	NA
06.Aug	1	NA	NA	NA	27	17.6	NA

06.Aug	1	NA	NA	NA	27.4	17.8	NA
06.Aug	1	NA	NA	NA	27.8	18.3	NA
06.Aug	1	NA	NA	NA	27.9	18.3	NA
06.Aug	1	NA	NA	NA	27.8	18.1	NA
06.Aug	1	NA	NA	NA	26.7	18.2	NA
06.Aug	-1	36.01	292.55	0	25.3	17.9	NA
06.Aug	-1	NA	NA	NA	25.3	18.1	NA
06.Aug	-1	NA	NA	NA	25.4	18.1	NA
06.Aug	-1	NA	NA	NA	25.2	18.4	NA
06.Aug	-1	NA	NA	NA	25.3	17.9	NA
06.Aug	-1	NA	NA	NA	25.3	17.7	NA
06.Aug	-1	NA	NA	NA	27	18.6	NA
06.Aug	-1	NA	NA	NA	27.2	18.3	NA
06.Aug	-1	NA	NA	NA	27.8	18.7	NA
06.Aug	-1	NA	NA	NA	27.9	18.2	NA
06.Aug	-1	NA	NA	NA	27.8	18.8	NA
06.Aug	-1	NA	NA	NA	26.7	18.6	NA
13.Aug	1	44.19	184.79	0	14.1	13.4	16.79
13.Aug	1	NA	NA	NA	14.5	13.8	NA
13.Aug	1	NA	NA	NA	14.2	13.6	NA
13.Aug	1	NA	NA	NA	14.5	13.6	NA
13.Aug	1	NA	NA	NA	14.4	13.3	NA
13.Aug	1	NA	NA	NA	14.4	13.3	NA
13.Aug	1	NA	NA	NA	15.9	13.5	NA
13.Aug	1	NA	NA	NA	15.9	13.4	NA
13.Aug	1	NA	NA	NA	15.9	13.4	NA
13.Aug	1	NA	NA	NA	16.1	13.5	NA
13.Aug	1	NA	NA	NA	16.1	13.3	NA
13.Aug	1	NA	NA	NA	16.1	13.4	NA
13.Aug	-1	45.72	121.55	0	14.1	13.2	18.74
13.Aug	-1	NA	NA	NA	14.5	13.3	NA
13.Aug	-1	NA	NA	NA	14.2	13.4	NA
13.Aug	-1	NA	NA	NA	14.5	13	NA
13.Aug	-1	NA	NA	NA	14.4	13.2	NA
13.Aug	-1	NA	NA	NA	NA	NA	NA
13.Aug	-1	NA	NA	NA	15.9	13.2	NA
13.Aug	-1	NA	NA	NA	15.9	13.3	NA
13.Aug	-1	NA	NA	NA	15.9	13.5	NA
13.Aug	-1	NA	NA	NA	16.1	13.5	NA
13.Aug	-1	NA	NA	NA	16.1	13.3	NA
13.Aug	-1	NA	NA	NA	16.1	13.1	NA
20.Aug	1	39.98	149.4	0	NA	NA	13.45
20.Aug	1	NA	NA	NA	27,075	16.85	NA
20.Aug	1	NA	NA	NA	27.05	16.65	NA
20.Aug	1	NA	NA	NA	27.05	16,925	NA

20.Aug	1	NA	NA	NA	27.15	16.9	NA
20.Aug	1	NA	NA	NA	27.2	16,675	NA
20.Aug	1	NA	NA	NA	27,225	16,175	NA
20.Aug	1	NA	NA	NA	26,925	16.6	NA
20.Aug	1	NA	NA	NA	26,725	17.25	NA
20.Aug	1	NA	NA	NA	26.95	17,275	NA
20.Aug	1	NA	NA	NA	26,875	16,625	NA
20.Aug	1	NA	NA	NA	27,425	16,875	NA
20.Aug	-1	53.58	114.96	0	27	17.4	16.48
20.Aug	-1	NA	NA	NA	27.1	17.3	NA
20.Aug	-1	NA	NA	NA	27.1	17.5	NA
20.Aug	-1	NA	NA	NA	27.1	18	NA
20.Aug	-1	NA	NA	NA	27.2	17.3	NA
20.Aug	-1	NA	NA	NA	27.2	17.3	NA
20.Aug	-1	NA	NA	NA	27.1	16.8	NA
20.Aug	-1	NA	NA	NA	26.9	17.9	NA
20.Aug	-1	NA	NA	NA	26.8	17.7	NA
20.Aug	-1	NA	NA	NA	26.9	17.3	NA
20.Aug	-1	NA	NA	NA	27.1	17.4	NA
20.Aug	-1	NA	NA	NA	27.2	17.2	NA
27.Aug	1	34.45	118.92	0	14.4	14.9	18.74
27.Aug	1	NA	NA	NA	14.4	15.2	NA
27.Aug	1	NA	NA	NA	14.5	15.1	NA
27.Aug	1	NA	NA	NA	14.5	14.8	NA
27.Aug	1	NA	NA	NA	14.6	14.4	NA
27.Aug	1	NA	NA	NA	14.6	14.7	NA
27.Aug	1	NA	NA	NA	15	14.8	NA
27.Aug	1	NA	NA	NA	15	14.5	NA
27.Aug	1	NA	NA	NA	15.3	14.3	NA
27.Aug	1	NA	NA	NA	15.3	15	NA
27.Aug	1	NA	NA	NA	15.3	14.6	NA
27.Aug	1	NA	NA	NA	15.3	14.6	NA
27.Aug	-1	46.06	99.79	0	14.4	14.3	19.52
27.Aug	-1	NA	NA	NA	14.4	14.5	NA
27.Aug	-1	NA	NA	NA	14.5	14.5	NA
27.Aug	-1	NA	NA	NA	14.5	13.9	NA
27.Aug	-1	NA	NA	NA	14.6	14.4	NA
27.Aug	-1	NA	NA	NA	14.6	14	NA
27.Aug	-1	NA	NA	NA	15	14.2	NA
27.Aug	-1	NA	NA	NA	15	14.5	NA
27.Aug	-1	NA	NA	NA	15.3	14.5	NA
27.Aug	-1	NA	NA	NA	15.3	14.6	NA
27.Aug	-1	NA	NA	NA	15.3	14.2	NA
27.Aug	-1	NA	NA	NA	15.3	14.3	NA
03.Sep	1	38.84	203.45	13.56	17.5	15.3	23.73

03.Sep	1	NA	NA	NA	17.6	15.1	NA
03.Sep	1	NA	NA	NA	17.6	15.1	NA
03.Sep	1	NA	NA	NA	17.8	15.2	NA
03.Sep	1	NA	NA	NA	18	15.3	NA
03.Sep	1	NA	NA	NA	17.9	15.1	NA
03.Sep	1	NA	NA	NA	18.4	15.1	NA
03.Sep	1	NA	NA	NA	18.3	15.4	NA
03.Sep	1	NA	NA	NA	18.3	15.3	NA
03.Sep	1	NA	NA	NA	18.4	15.4	NA
03.Sep	1	NA	NA	NA	18.5	15.2	NA
03.Sep	1	NA	NA	NA	18.5	15.3	NA
03.Sep	-1	45.34	115.74	13.91	17.5	15.1	23.28
03.Sep	-1	NA	NA	NA	17.6	15.3	NA
03.Sep	-1	NA	NA	NA	17.6	15.5	NA
03.Sep	-1	NA	NA	NA	17.8	15.4	NA
03.Sep	-1	NA	NA	NA	17.9	15.2	NA
03.Sep	-1	NA	NA	NA	17.9	15.2	NA
03.Sep	-1	NA	NA	NA	18.4	15.5	NA
03.Sep	-1	NA	NA	NA	18.3	15.5	NA
03.Sep	-1	NA	NA	NA	18.3	15.3	NA
03.Sep	-1	NA	NA	NA	18.4	15.4	NA
03.Sep	-1	NA	NA	NA	18.5	15.6	NA
03.Sep	-1	NA	NA	NA	18.5	15.5	NA
17.Sep	1	38.47	131.99	0	16.6	12.7	22.92
17.Sep	1	NA	NA	NA	16.6	12.7	NA
17.Sep	1	NA	NA	NA	16.9	12.7	NA
17.Sep	1	NA	NA	NA	17.2	12.5	NA
17.Sep	1	NA	NA	NA	17	12.5	NA
17.Sep	1	NA	NA	NA	16.9	12.6	NA
17.Sep	1	NA	NA	NA	17.4	12.6	NA
17.Sep	1	NA	NA	NA	17.5	12.5	NA
17.Sep	1	NA	NA	NA	17.4	12.4	NA
17.Sep	1	NA	NA	NA	17.7	12.6	NA
17.Sep	1	NA	NA	NA	17.4	12.5	NA
17.Sep	1	NA	NA	NA	17.5	12.5	NA
17.Sep	-1	40.11	122.84	0	16.6	12.3	25.35
17.Sep	-1	NA	NA	NA	16.6	12.6	NA
17.Sep	-1	NA	NA	NA	16.9	12.7	NA
17.Sep	-1	NA	NA	NA	17.2	12.1	NA
17.Sep	-1	NA	NA	NA	17	12.5	NA
17.Sep	-1	NA	NA	NA	16.9	12.4	NA
17.Sep	-1	NA	NA	NA	17.4	12.5	NA
17.Sep	-1	NA	NA	NA	17.5	12.6	NA
17.Sep	-1	NA	NA	NA	17.4	12.5	NA
17.Sep	-1	NA	NA	NA	17.7	13.1	NA

17.Sep	-1	NA	NA	NA	17.4	12.4	NA
17.Sep	-1	NA	NA	NA	17.5	12.4	NA
24.Sep	1	36.28	183.63	3.05	14.3	12.5	22.35
24.Sep	1	NA	NA	NA	14.2	12.4	NA
24.Sep	1	NA	NA	NA	14.5	12.5	NA
24.Sep	1	NA	NA	NA	14.6	12.3	NA
24.Sep	1	NA	NA	NA	14.9	12.3	NA
24.Sep	1	NA	NA	NA	14.5	12.3	NA
24.Sep	1	NA	NA	NA	14.2	12.3	NA
24.Sep	1	NA	NA	NA	14.4	12.4	NA
24.Sep	1	NA	NA	NA	14.5	12.3	NA
24.Sep	1	NA	NA	NA	14.6	12.4	NA
24.Sep	1	NA	NA	NA	14.8	12.4	NA
24.Sep	1	NA	NA	NA	14.9	12.4	NA
24.Sep	-1	44.8	113.13	3.1	14.3	12.3	22.61
24.Sep	-1	NA	NA	NA	14.2	12.5	NA
24.Sep	-1	NA	NA	NA	14.5	12.4	NA
24.Sep	-1	NA	NA	NA	14.7	12.2	NA
24.Sep	-1	NA	NA	NA	14.9	12.3	NA
24.Sep	-1	NA	NA	NA	14.5	12.2	NA
24.Sep	-1	NA	NA	NA	14.2	12.4	NA
24.Sep	-1	NA	NA	NA	14.4	12.5	NA
24.Sep	-1	NA	NA	NA	14.5	12.5	NA
24.Sep	-1	NA	NA	NA	14.6	12.8	NA
24.Sep	-1	NA	NA	NA	14.8	12.4	NA
24.Sep	-1	NA	NA	NA	14.9	12.4	NA
01.Okt	1	44.28	168.58	0	18.7	13.4	19.1
01.Okt	1	NA	NA	NA	18.9	13.3	NA
01.Okt	1	NA	NA	NA	18.8	13.3	NA
01.Okt	1	NA	NA	NA	18.8	13.2	NA
01.Okt	1	NA	NA	NA	19.1	13.5	NA
01.Okt	1	NA	NA	NA	19.3	13.2	NA
01.Okt	1	NA	NA	NA	19.3	13.4	NA
01.Okt	1	NA	NA	NA	19.5	13.4	NA
01.Okt	1	NA	NA	NA	19.5	13.3	NA
01.Okt	1	NA	NA	NA	19.8	13.3	NA
01.Okt	1	NA	NA	NA	20.2	13.2	NA
01.Okt	1	NA	NA	NA	19.8	13.3	NA
01.Okt	-1	46.05	132.67	0	18.7	13.5	19.43
01.Okt	-1	NA	NA	NA	18.9	13.6	NA
01.Okt	-1	NA	NA	NA	18.8	13.9	NA
01.Okt	-1	NA	NA	NA	18.8	13.4	NA
01.Okt	-1	NA	NA	NA	19.1	13.3	NA
01.Okt	-1	NA	NA	NA	19.3	13.6	NA
01.Okt	-1	NA	NA	NA	19.3	13.4	NA

01.Okt	-1	NA	NA	NA	19.5	13.7	NA
01.Okt	-1	NA	NA	NA	19.5	13.6	NA
01.Okt	-1	NA	NA	NA	19.8	13.5	NA
01.Okt	-1	NA	NA	NA	20.2	13.3	NA
01.Okt	-1	NA	NA	NA	19.8	13.5	NA
08.Okt	1	61.25	141.4	0	6.9	10.5	18.25
08.Okt	1	NA	NA	NA	6.8	10.3	NA
08.Okt	1	NA	NA	NA	6.9	10.7	NA
08.Okt	1	NA	NA	NA	7	9.7	NA
08.Okt	1	NA	NA	NA	7.4	10.1	NA
08.Okt	1	NA	NA	NA	7.6	10.1	NA
08.Okt	1	NA	NA	NA	7.4	9.9	NA
08.Okt	1	NA	NA	NA	8	10.4	NA
08.Okt	1	NA	NA	NA	8.4	9.6	NA
08.Okt	1	NA	NA	NA	8.2	10.5	NA
08.Okt	1	NA	NA	NA	8.1	10.4	NA
08.Okt	1	NA	NA	NA	7.9	10.3	NA
08.Okt	-1	69.43	84.82	0	6.9	10,475	17.53
08.Okt	-1	NA	NA	NA	6,825	10,275	NA
08.Okt	-1	NA	NA	NA	6,925	10.65	NA
08.Okt	-1	NA	NA	NA	6,975	9,675	NA
08.Okt	-1	NA	NA	NA	7.4	10.05	NA
08.Okt	-1	NA	NA	NA	7,625	10.05	NA
08.Okt	-1	NA	NA	NA	7.4	9.9	NA
08.Okt	-1	NA	NA	NA	7,925	10,275	NA
08.Okt	-1	NA	NA	NA	8.25	10,175	NA
08.Okt	-1	NA	NA	NA	8,175	10,625	NA
08.Okt	-1	NA	NA	NA	8.1	10,025	NA
08.Okt	-1	NA	NA	NA	7.95	10.25	NA
15.Okt	1	37.21	139.93	0	13.3	10.9	23.15
15.Okt	1	NA	NA	NA	14.1	11.1	NA
15.Okt	1	NA	NA	NA	13.4	10.9	NA
15.Okt	1	NA	NA	NA	13.2	10.7	NA
15.Okt	1	NA	NA	NA	13.5	10.6	NA
15.Okt	1	NA	NA	NA	13.5	10.8	NA
15.Okt	1	NA	NA	NA	13.6	10.8	NA
15.Okt	1	NA	NA	NA	13.5	10.8	NA
15.Okt	1	NA	NA	NA	13.4	10.4	NA
15.Okt	1	NA	NA	NA	13.9	10.7	NA
15.Okt	1	NA	NA	NA	13.6	10.7	NA
15.Okt	1	NA	NA	NA	13.8	10.7	NA
15.Okt	-1	38.06	80.38	0	13.3	10.8	18.29
15.Okt	-1	NA	NA	NA	14.2	10.8	NA
15.Okt	-1	NA	NA	NA	13.4	10.9	NA
15.Okt	-1	NA	NA	NA	13.2	10.6	NA

15.Okt	-1	NA	NA	NA	13.5	10.7	NA
15.Okt	-1	NA	NA	NA	13.5	10.8	NA
15.Okt	-1	NA	NA	NA	13.6	10.8	NA
15.Okt	-1	NA	NA	NA	13.5	10.9	NA
15.Okt	-1	NA	NA	NA	13.4	10.8	NA
15.Okt	-1	NA	NA	NA	13.9	10.8	NA
15.Okt	-1	NA	NA	NA	13.6	10.3	NA
15.Okt	-1	NA	NA	NA	13.8	10.7	NA
22.Okt	1	44.31	160.22	0	9.9	10.4	23.15
22.Okt	1	NA	NA	NA	9.9	10.3	NA
22.Okt	1	NA	NA	NA	10.1	10.5	NA
22.Okt	1	NA	NA	NA	10.2	10.1	NA
22.Okt	1	NA	NA	NA	10.5	10.2	NA
22.Okt	1	NA	NA	NA	10.4	10.3	NA
22.Okt	1	NA	NA	NA	13.5	10.3	NA
22.Okt	1	NA	NA	NA	14.2	10.2	NA
22.Okt	1	NA	NA	NA	13.7	9.9	NA
22.Okt	1	NA	NA	NA	10.1	9.9	NA
22.Okt	1	NA	NA	NA	9.9	10	NA
22.Okt	1	NA	NA	NA	10.4	10	NA
22.Okt	-1	49.99	62.69	0	9.9	10.4	23.46
22.Okt	-1	NA	NA	NA	10.2	10.3	NA
22.Okt	-1	NA	NA	NA	10.1	10.5	NA
22.Okt	-1	NA	NA	NA	10.2	10.1	NA
22.Okt	-1	NA	NA	NA	10.5	10.2	NA
22.Okt	-1	NA	NA	NA	10.4	10.3	NA
22.Okt	-1	NA	NA	NA	13.5	10.3	NA
22.Okt	-1	NA	NA	NA	14.2	10.3	NA
22.Okt	-1	NA	NA	NA	13.7	10.2	NA
22.Okt	-1	NA	NA	NA	10.3	10	NA
22.Okt	-1	NA	NA	NA	10	9.5	NA
22.Okt	-1	NA	NA	NA	10.4	9.7	NA
19.Nov	1	30.68	103.22	0	8.3	6.9	28.19
19.Nov	1	NA	NA	NA	8.2	6.8	NA
19.Nov	1	NA	NA	NA	8.3	6.8	NA
19.Nov	1	NA	NA	NA	8.3	6.6	NA
19.Nov	1	NA	NA	NA	8.2	6.8	NA
19.Nov	1	NA	NA	NA	8.3	6.9	NA
19.Nov	1	NA	NA	NA	9.1	7	NA
19.Nov	1	NA	NA	NA	9.2	6.8	NA
19.Nov	1	NA	NA	NA	8.9	6.7	NA
19.Nov	1	NA	NA	NA	8.2	6.6	NA
19.Nov	1	NA	NA	NA	9	6.7	NA
19.Nov	1	NA	NA	NA	9.1	6.8	NA
19.Nov	-1	60.48	50.89	0	8.3	6.8	28.19

19.Nov	-1	NA	NA	NA	8.3	6.8	NA
19.Nov	-1	NA	NA	NA	8.4	6.8	NA
19.Nov	-1	NA	NA	NA	7.8	6.4	NA
19.Nov	-1	NA	NA	NA	8.2	6.8	NA
19.Nov	-1	NA	NA	NA	8.3	6.8	NA
19.Nov	-1	NA	NA	NA	9.1	6.9	NA
19.Nov	-1	NA	NA	NA	9.2	6.8	NA
19.Nov	-1	NA	NA	NA	8.9	6.9	NA
19.Nov	-1	NA	NA	NA	9	6.7	NA
19.Nov	-1	NA	NA	NA	9	6.7	NA
19.Nov	-1	NA	NA	NA	9.1	6.7	NA
27.Nov	1	23.54	120.66	0	4.8	6.6	27.34
27.Nov	1	NA	NA	NA	4.9	6.6	NA
27.Nov	1	NA	NA	NA	5.3	6.5	NA
27.Nov	1	NA	NA	NA	5	6.1	NA
27.Nov	1	NA	NA	NA	5.1	6.4	NA
27.Nov	1	NA	NA	NA	4.9	6.5	NA
27.Nov	1	NA	NA	NA	4.9	6.5	NA
27.Nov	1	NA	NA	NA	4.9	6.3	NA
27.Nov	1	NA	NA	NA	5.4	5.8	NA
27.Nov	1	NA	NA	NA	5.6	6	NA
27.Nov	1	NA	NA	NA	6.1	6.3	NA
27.Nov	1	NA	NA	NA	5.7	6.4	NA
27.Nov	-1	52.11	51.01	0	4.8	6	26.37
27.Nov	-1	NA	NA	NA	4.9	6.1	NA
27.Nov	-1	NA	NA	NA	5.3	6	NA
27.Nov	-1	NA	NA	NA	5	5.3	NA
27.Nov	-1	NA	NA	NA	5.1	5.9	NA
27.Nov	-1	NA	NA	NA	4.9	6	NA
27.Nov	-1	NA	NA	NA	4.9	6	NA
27.Nov	-1	NA	NA	NA	4.9	5.9	NA
27.Nov	-1	NA	NA	NA	5.4	5.9	NA
27.Nov	-1	NA	NA	NA	5.6	5.8	NA
27.Nov	-1	NA	NA	NA	5	5.8	NA
27.Nov	-1	NA	NA	NA	5.3	5.9	NA

* = control treatment; ** = no-litter treatment

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