Marshallplan scholarship final report

Contributions of fresh litter, old litter and soil to CO_2 efflux from oak girdled and non-girdled sites at Black Rock Forest

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Introduction

Soils play a central role in the global carbon cycle as they are a primary component of the terrestrial carbon sink (Intergovernmental Panel on Climate 2000) and release 60 – 70 % of the carbon dioxide (CO_2) from forest ecosystems (Steinmann et al. 2004). The soil carbon cycle is sensitive to both biotic and abiotic perturbations. Soil respiration denotes the efflux of CO_2 from the earth´s surface and is typically divided into two components – autotrophic and heterotrophic respiration.

Autotrophic respiration comes from living plant roots whose energy source is derived from photosynthates. Heterotrophic respiration is emitted from organisms that derive their energy by breaking down living or dead organic matter.

To make predictions about carbon sequestration in forests as well as to quantify feedback relationships with climate we need to have detailed understanding of the processes governing soil respiration.

Plant community composition is likely to play an important role in regulating forest soil respiration not only due to variations of CO_2 efflux rates within different types of plant communities, respiration rates are also varied by plant community composition and variation in plants at the species level.

These findings could result from indirect relationships between plant composition and soil respiration. Genotypic variation in one species can influence both microbial biomass and microbial community composition. Similarly, variations in for example condensed tannins among a species and its genotypes have been related to different rates of leaf litter decomposition (Levy-Varon et al. 2011).

Finally, the relationship between the production of photosynthates and their release back to the atmosphere via autotrophic respiration varies within plant communities (Craine et al. 1999; Högberg et al. 2001; Knohl et al. 2005; Kuzyakov and Gavrichkova 2010). This examples show the importance of plant composition on belowground carbon dynamics.

For the last couple of years concern has been raised on the decline of oaks (Quercus) located in the eastern USA. Pests, pathogens, and fungal diseases, bacterial leaf scorch, and oak wilt pose a direct threat to oak species and have already decimated a number of established oak populations. Additional fire suppression, and shade intolerance as well as high deer populations do their rest to fail a successful oak tree regeneration.

To quantify the role of Quercus in various components of ecosystem function a large-scale tree girdling experiment was implemented in Black Rock Forest during the summer of 2008. The experiment offers a unique opportunity to assess the role of Quercus in soil respiration amongst a lot of other things. Girdling blocks the phloem transfer of photosynthates to the roots with minimal disturbance to the root–mycorrhizal system.

An important component of the nutrient cycling process in forest ecosystems is litter decay. Decay rates of litter are related to climatic conditions (Prescott, 2009), but they can also vary significantly between litter materials at the same forest site (Moore et al., 1999).The rate of litter decompositions is influenced by moisture, temperature, nature of the microorganisms and soil fauna active in the decomposition process, and substrate quality which is defined as chemical composition of the decomposing material. The latter is considered a critical factor

in determining the rate of litter decay. Chemical composition include element concentrations especially nitrogen content is important in controlling rates of litter decomposition as well as lignin content (Meentemeyer 1978). Therefore, C/N ratios and lignin concentrations have often been found to be the best predictor of C losses from litter (e.g., Heim and Frey, 2004).
Litter fall accounts for more than half of the annual C input to soils (Perruchoud et al., 1999). C from aboveground litter is either mineralised to CO_2 or incorporated into mineral soils through soil fauna and dissolved organic C (DOC) (Rubino et al., 2010).

The processes determining the decay of litter fall can be physical (e.g. leaching) and biological (e.g. microbial activity). These processes provide organic and inorganic nutrients which are important for tree growth. Leaf litter in a mixed forest ecosystem can differ in timing of litter fall, quantity and quality of leaf litter production and consequently in decomposition rates due to several properties like species specific litter nutrient concentration, litter water holding capacity, species specific effects enhancing or inhibiting belowground mineralization processes, interaction dynamics of soil fauna and litter species diversity, and facilitative or inhibitory effects on decomposition of individual species litter types in mixed litter conditions. Litter chemistry is the endogenous control of litter decomposition and macroclimate the dominant external control.
Three phases of litter decomposition have been identified. The early phase is leaching which is principally caused by rainfall events, and decomposition of labile soluble compounds like unshielded cellulose and hemicellulose. Decomposition of lignified carbohydrates represents the intermediate phase before the final phase decomposition of recalcitrant (i.e. lignin) (Perez-Suarez et al. 2010).

The current tree species distribution at the research area at Black Rock Forest is a result of selective girdling of Quercus trees. Understanding the contribution of different forest species to decomposition may allow assessing impacts of land use change on nutrient cycling. Overall very little information exists for litter interactions in mixed forest ecosystems.
Five years after the girdling experiment has been implemented in 2008 respiration was measured again in fall 2013 to investigate the difference in CO_2 efflux between girdled and non-girdled plots, therefor between plots where all oaks have been killed to plots where Quercus are still alive. Also we wanted to know how different litter layers contribute to overall soil respiration which is defined as litter plus soil respiration.
In particular, we tested the following hypotheses:
– (1) Control plots (non-girdled) respire less CO_2 than oak girdled plots; due to the higher tendency of oak trees to store C.
– (2) The Upper leaf litter layer (fresh litter) will contribute higher CO_2 emissions to the overall soil respiration than the lower leaf litter layer (old litter fallen down in previous years) in both control and girdled plots; we base this hypothesis on the fact that decomposition of old litter has already started in previous year hence the first phase of litter decomposition has already or partly been processed and labile soluble compounds like unshielded cellulose and hemicellulose have already been decomposed.
– (3) Soil respiration accounts for approximately 70% of overall CO_2 emissions as compared to the leaf litter layer, which contributes about 30% of CO_2 emissions in both control and girdled plots (Berger et al. 2010).

Material and Methods

Site description

Black Rock Forest is a nearly 1600 ha natural living laboratory for field-based scientific research and education. The Black Rock Forest Consortium is the alliance of colleges and universities, public and independent schools, as well as leading scientific and cultural institutions formed in 1989 to promote scientific research, education, and conservation of the Forest.

Faculty, doctoral, and postdoctoral research work actively together on undergraduate education and research, elementary, middle, and high school programs, and staff and teacher training. The Consortium makes sure to combine scientific research and education, including collaborations among institutions, and also sets value on ecological resource management and environmental monitoring.

Black Rock Forest is located in the Hudson Highlands, 50 miles north of New York City. It features dramatic topography and numerous lakes and streams, and retains high habitat and species diversity. The Forest has a legacy of nearly 80 years of management. It was founded in 1928 by Ernest Stillman.

Black Rock Forest is located at the intersection of the New York-New Jersey Highlands and the Hudson River Basin. The Highlands consist of ancient Precambrian granites and gneisses more than one billion years old. These mountains have been resistant to human exploitation, and thus remain a greater portion of their natural biological diversity. Also the location of the forest contributes to the high biological diversity (picture 1); blue crabs, bald eagles, bobcats, and boreal conifers can be found all within a few miles of one another. The River is also enormously biologically diverse, with both freshwater and saltwater flora and fauna. Extremely polluted until the 1960s it ecologically recovered greatly since then, so that now more than 200 species can be found in the river. Inputs of fresh water, chemical nutrients, energy, organisms, and sediment from streams to the River link the Hudson to the surrounding watershed areas.

Containing some of the oldest rock in New York State additionally increases the specialty of the forest. The gneiss bedrock is a metamorphic rock from the Precambrian age which ranges from 1.1 to 1.3 billion years of age. The region was subject of weathering and erosion and a couple of mountain-building events. First one was a collision with an arc-shaped set of volcanic islands 460-440 million years ago; second was a collision with a continent located east of North America 375 to 335 million years ago; and last was a collision with West Africa where the super continent Pangaea was created before it split apart about 200 million years ago and started to form the continents we know today. The last glaciation (about 16000 years ago) is responsible for much of the local topography.

The name of the Black Rock Forest comes from the mineral magnetite that can be found throughout the Forest, which is as the name implies magnetic.

Picture 1: Black Rock Forest is known for its diversity.

Environmental Monitoring Network

The Black Rock Forest environmental monitoring network currently includes six stations. Data is compiled on computer dataloggers and automatically collected radiotelemetry. Figure 1 shows the lack Rock Forest area including environmental monitoring stations located in the area.

Open Lowland Station: air temperature, humidity, wind speed and direction, barometric pressure, precipitation, soil temperature, and solar radiation.

Ridgetop Station: air temperature, humidity, wind speed and direction, barometric pressure, precipitation, soil temperature, and solar radiation.

Cascade Brook Stream Station: stream depth and flow in real time and, during the growing season, water temperature, pH, conductivity, and dissolved oxygen

Fire Tower Station: air temperature, humidity, wind speed and direction, and precipitation; web camera with pan and zoom capabilities

Two Snow/Energy Balance Stations: net radiometer, snowpack sensors, snow pillow

Science Center Station: air temperature, humidity, water usage, energy usage, and other parameters particularly of interest in studying the performance of “green” architectural features versus those of traditional structures, solar panel network, inverters, and dataloggers; also the location of the Lamont-Doherty Cooperative Seismographic Network seismic station.

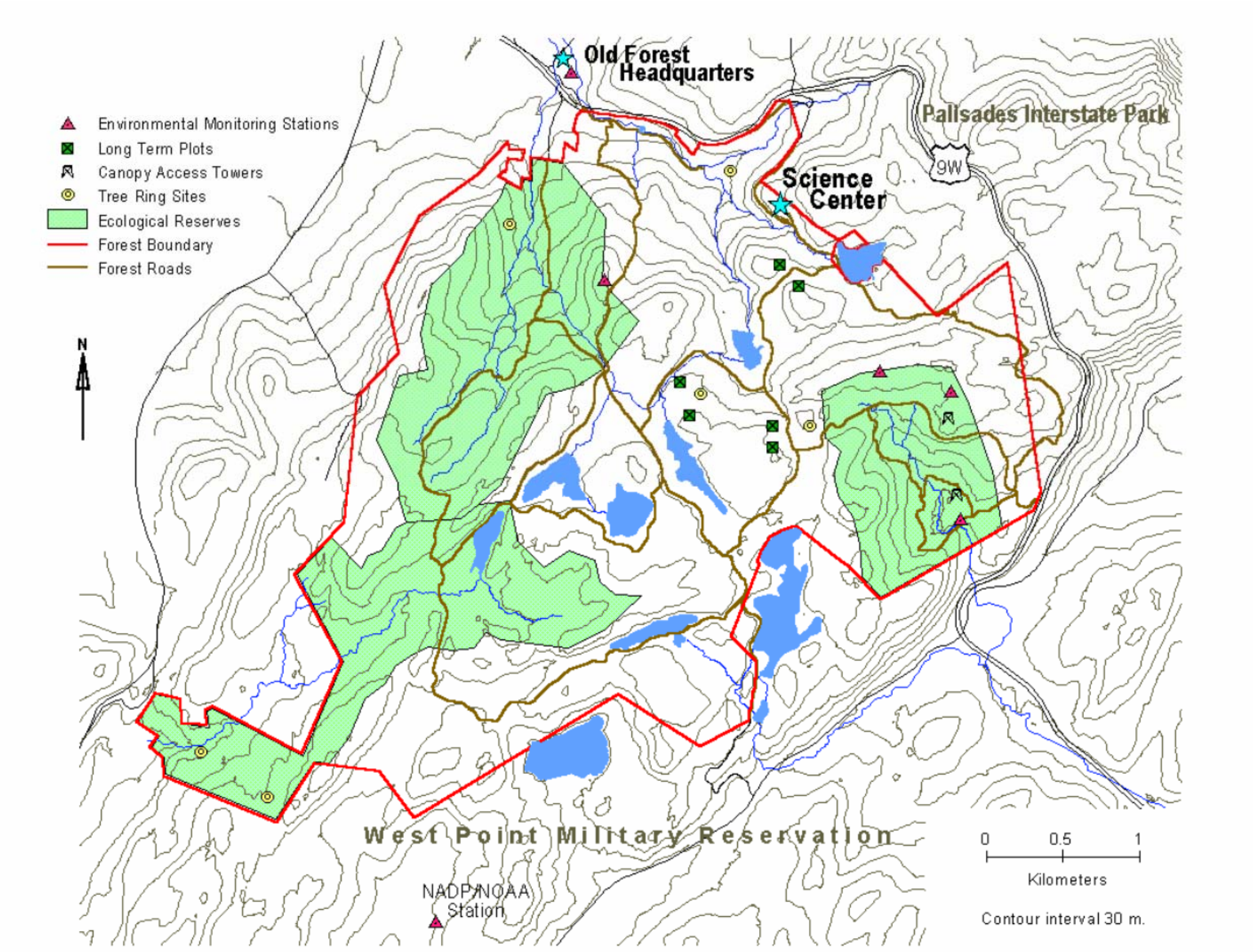

Figure 1: A map of the Black Rock Forest area which shows locations of environmental monitoring stations, long term plots, canopy access towers, tree ring sites, ecological reserves, forest boundary, and forest roads.

Research site:

Our research site is a 120 year-old Quercus-dominated forest on the north-facing slope of Black Rock Mountain (41.45° N, 74.01° W; 100 m a.s.l.). The canopy consists of 67% oak, predominately Quercus rubra L., Quercus prinus L., Quercus velutina Lam. and Quercus alba and 33% non-oaks, Acer rubrum L., A. saccharum March., Betula lenta L. and Nyssa sylvatica Marsh. The understory is sparse primarily comprised of Hamamelis virginiana, Vaccinium angustifolium, Berberis thunbergii, grasses, mosses and ferns.

Soils are acidic and nutrient poor clay loams and derived from glacial till overlying granitic bedrock. A more detailed description of the soil can be found on the National Resources Conservation Service (United States Department of Agriculture—Official Soil Series Descriptions; available at http://www.soils.usda.gov/technical/classification/osd/index.html website).

Air temperatures vary seasonally, f.e. the mean January air temperature in 2009 was -5.5°C, the mean July air temperature was 23.1°C, total annual precipitation was 1218 mm.

Sois are Swartswood and Mardin. This region experiences a seasonal climate.

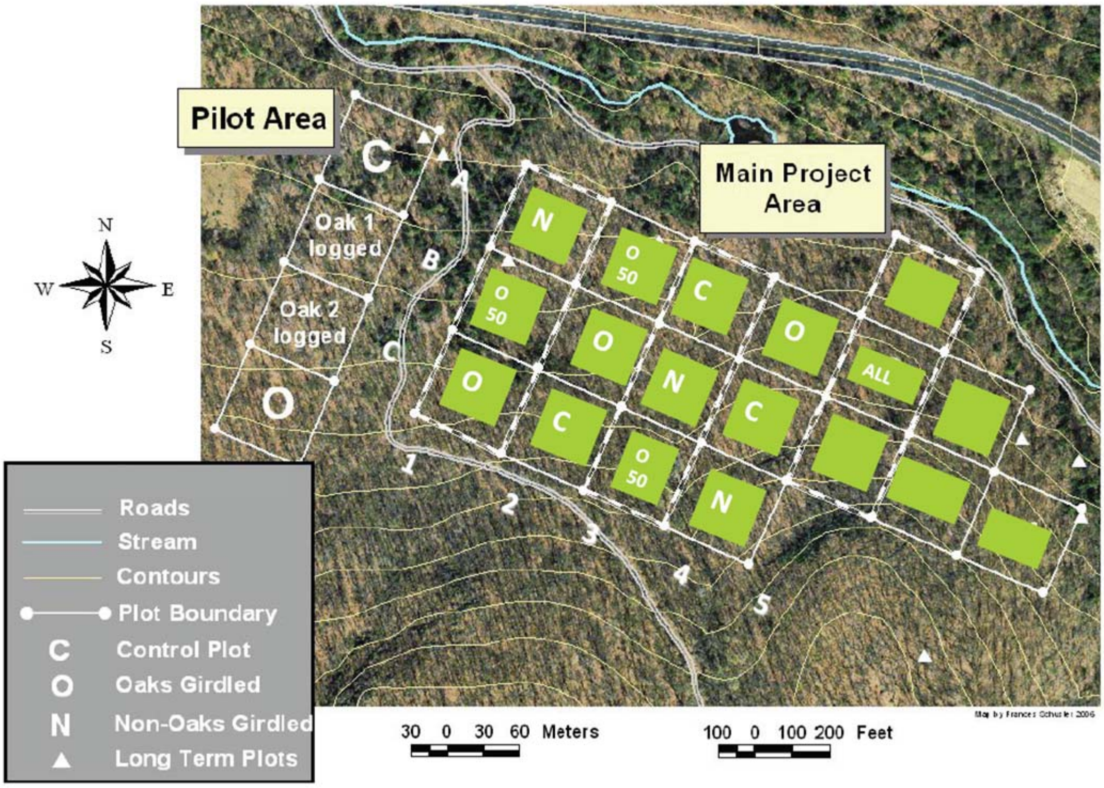

Figure 2: Map of the project area showing the location of plots and treatments on the north slope of Black Rock Mountain, Black Rock Forest, NY. ALL all trees girdled, O all oaks girdled, O50 50% oaks girdled, N all non-oaks girdled, C control

Experimental design

A large-scale girdling experiment was conducted between June 27 and July 9 2008 to asses the role of Quercus as a foundation taxon. A map of the project area can be seen in Figure 2. Twelve plots of 75 x 75 m in a randomized block design are grouped by the slope position lower, middle, and upper. The plots were girdled according to four treatments whereas blocks were named by the rows A, B, and C. Each row contains four plots with each representative of the following treatments.

O - girdling all the oaks on the plot
O50 - girdling half of the oaks on a plot
N - girdling all non-oaks on a plot
C - control

All of the 4 treatments were replicated three times. Tree density, basal area, aboveground biomass, and species composition did not differ between plots selected before girdling. An additional circular plot with a diameter of 50 m where all trees on the plot were girdled was created and named ALL.

Girdling

A 5 cm deep incision was cut with a chain saw at breast height around the circumference of the tree that penetrated bark, phloem, cambium, and outer xylem. Trees with a diameter smaller than 2.5 cm at breast height were selected not to be girdled which represented approximately 0 – 3 % of trees on any given plot.

Respiration measurements

Within the 12 main experimental plots, all measurements were made within a 25 x 25 m center subplot.
A LiCor 6400 portable photosynthesis system adapted with a soil respiration chamber (LI-900; Li-Cor, Lincoln, NE) was used to measure the soil surface CO_2 efflux in two of the center subplots; the all oaks girdled plot C1 and the control plot where no tree was girdled C2. Picture 2 shows the instrument which was built by Kevin Griffin at the research site in Black Rock Forest. Within one subplot measurements took place in close vicinity of three Hamamelis virginiana trees selected prior to measurements. In this study, consecutive respiration measurements were made first with all leaf litter covering the forest soil, then with removal of fresh litter followed by measurements with all litter removed to measure CO_2 efflux coming only from forest soil. Each of these three measurements was consecutively measured three times. Air and soil temperature (107 Temperature Sensor; Campbell Scientific) was measured additionally.

Picture 2: LiCor 6400 portable photosynthesis system (a) adapted with a soil respiration chamber (b) used for respiration measurements in October 2013 at the research site in Black Rock Forest.

Statistical analysis:

Statistical analyses were performed with the statistical open source programme R_language. An ANOVA and a Tuckey test were used to identify significant differences.

Results

Five years after a girdling experiment in 2008 CO_2 efflux was measured in fall 2013 to investigate the difference in CO_2 efflux between oak girdled and non-girdled plots as well as the contribution different litter layers account for to overall soil respiration which is defined as litter plus soil respiration.
Respiration measurements were conducted with all leaf litter, followed by removal of fresh litter and measurements with all litter removed. Shortcuts were used for all leaf litter plus soil respiration (AL), for old leaf litter plus soil respiration without fresh litter (OL), and only soil respiration without any leaf litter (S). For better understanding we will further refer to them as three different substances measured.
Respiration measurements took place on two plots; C1 the oak girdled plot and C2 the non-girdled plot. Within one plot three subplots in close vicinity of three Hamamelis virginiana trees were selected prior to measurements and are marked in this report with A, B, and C. All measurements at each subplot and substance (f.e. C1A/AL; C1A/OL; C1A/S, etc.) was consecutively conducted three times. CO_2 increase over time (one measurement every second) was measured to be able to calculate CO_2 efflux by using the slope of the trendline calculated over the CO_2 increase over time.

Figure 5 – Figure 22 show CO_2 measurements over time of all substances measured at plots (C1 and C2) and subplots (A, B, and C) investigated. By means of slopes, volume and surface area of the chamber CO_2 respiration rates were calculated which are summarized in Table 1.

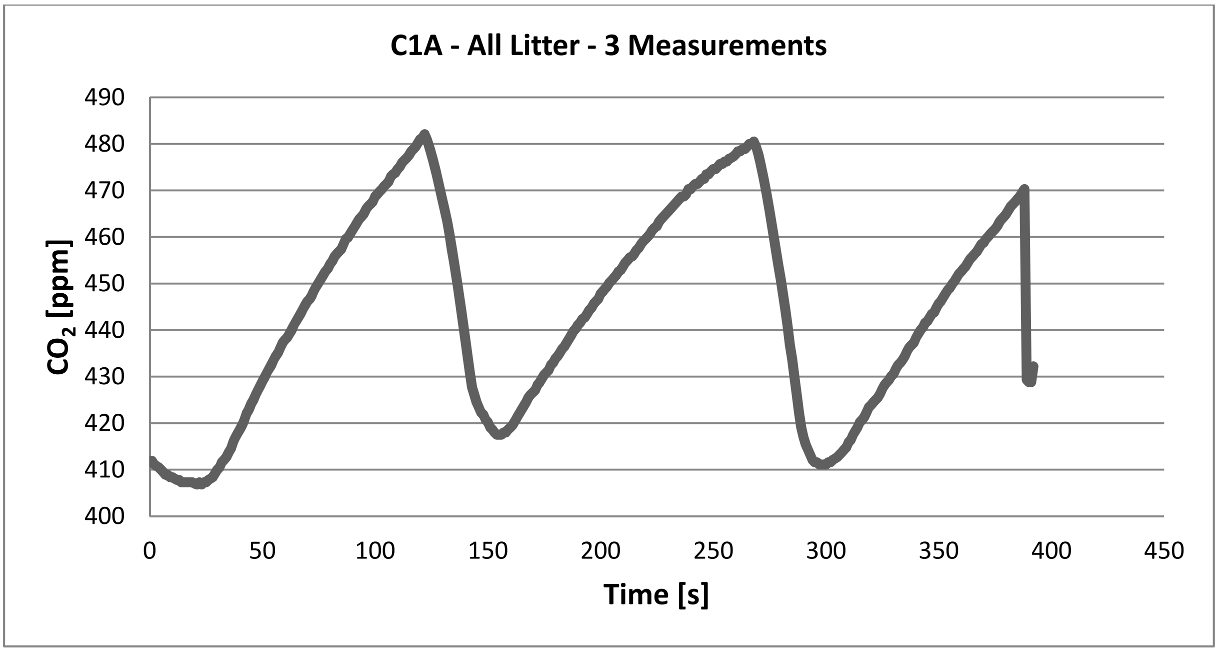

Figure 3: CO_2 respiration measurements over time (one measurement per second) conducted at plot C1 where all oaks have been girdled in 2008 in close vicinity to the Hamamelis virginiana tree marked A; CO_2 efflux coming from all litter additional to soil respiration.

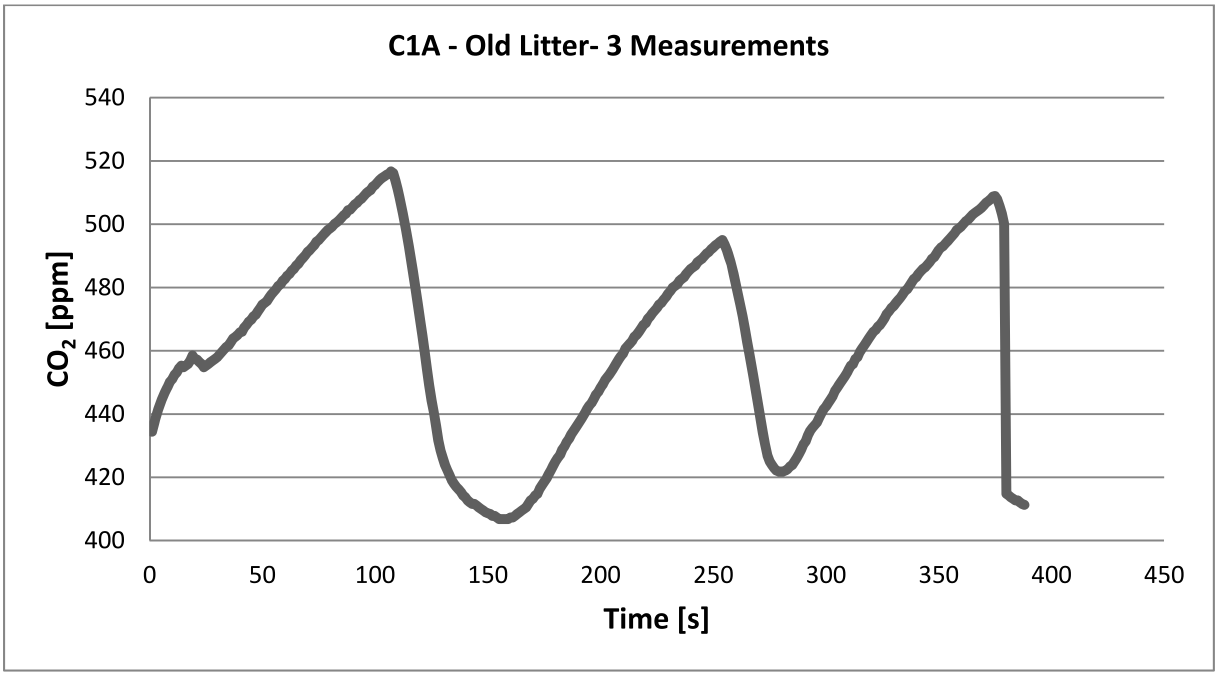

Figure 4: CO_2 respiration measurements over time (one measurement per second) conducted at plot C1 where all oaks have been girdled in 2008 in close vicinity to the Hamamelis virginiana tree marked A; CO_2 efflux coming from old litter additional to soil respiration.

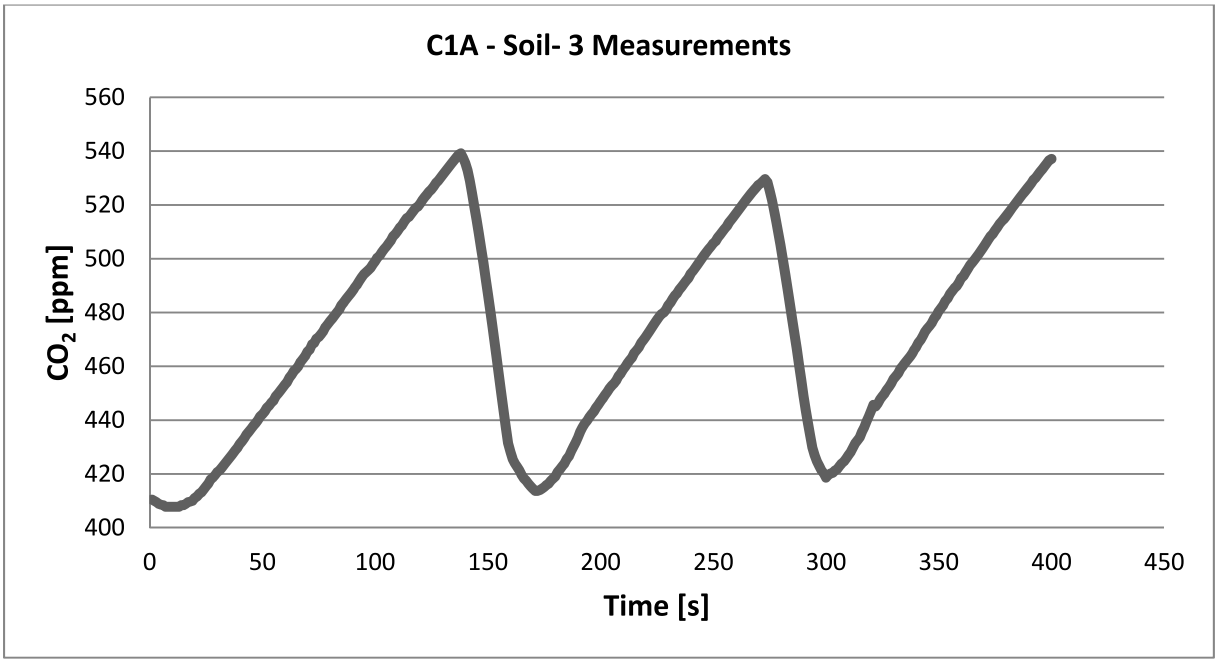

Figure 5: CO_2 respiration measurements over time (one measurement per second) conducted at plot C1 where all oaks have been girdled in 2008 in close vicinity to the Hamamelis virginiana tree marked A; CO_2 efflux coming from soil.

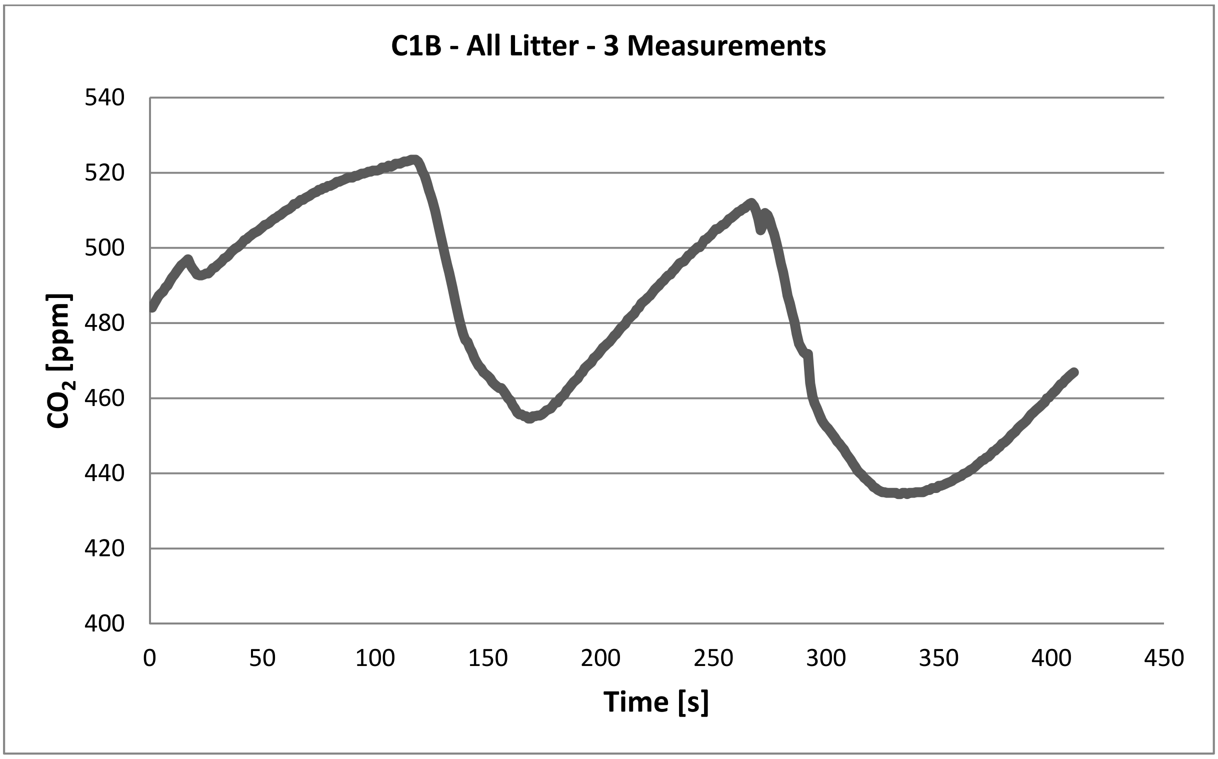

Figure 6: CO_2 respiration measurements over time (one measurement per second) conducted at plot C1 where all oaks have been girdled in 2008 in close vicinity to the Hamamelis virginiana tree marked B; CO_2 efflux coming from all litter additional to soil respiration.

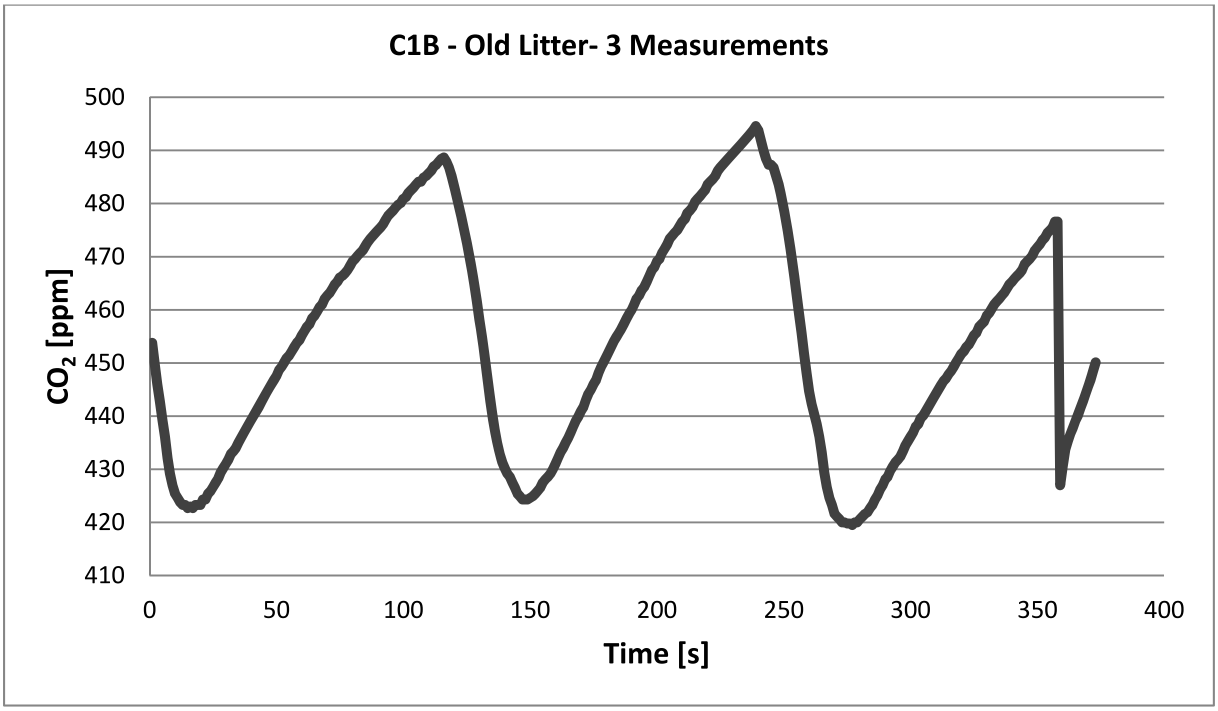

Figure 7: CO_2 respiration measurements over time (one measurement per second) conducted at plot C1 where all oaks have been girdled in 2008 in close vicinity to the Hamamelis virginiana tree marked B; CO_2 efflux coming from old litter additional to soil respiration.

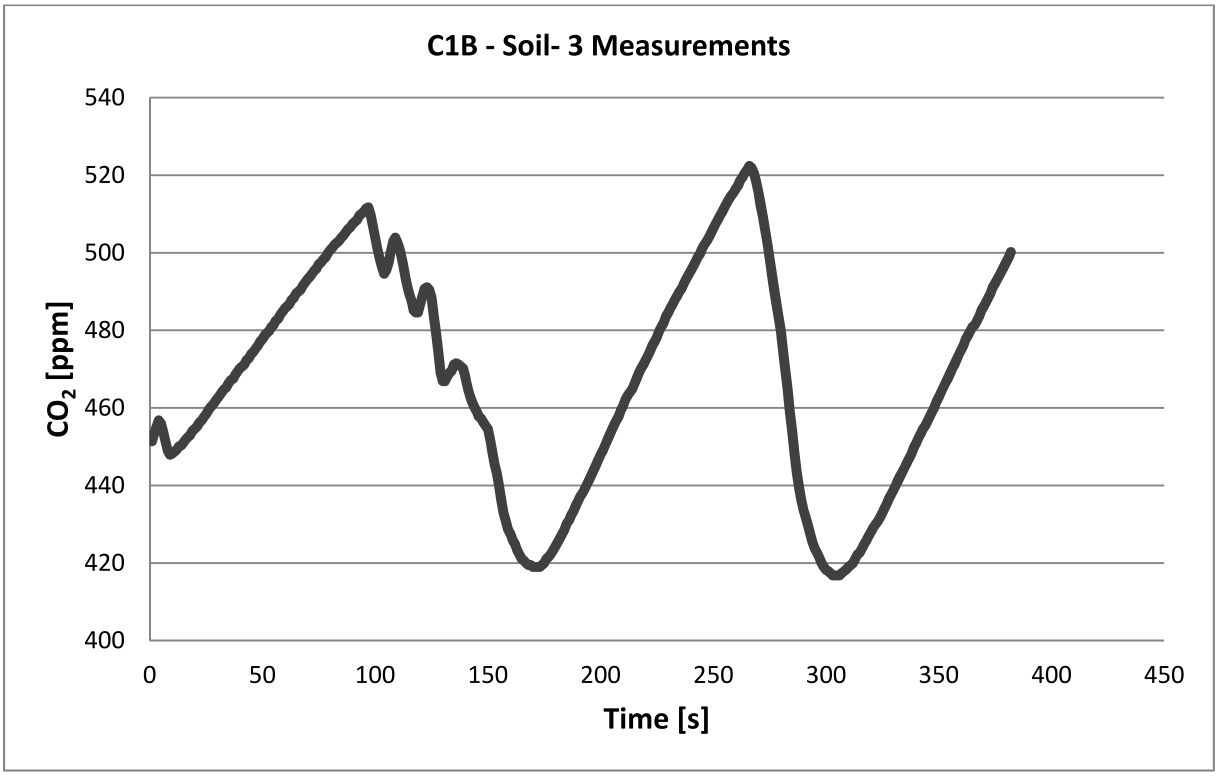

Figure 8: CO_2 respiration measurements over time (one measurement per second) conducted at plot C1 where all oaks have been girdled in 2008 in close vicinity to the Hamamelis virginiana tree marked B; CO_2 efflux coming from soil.

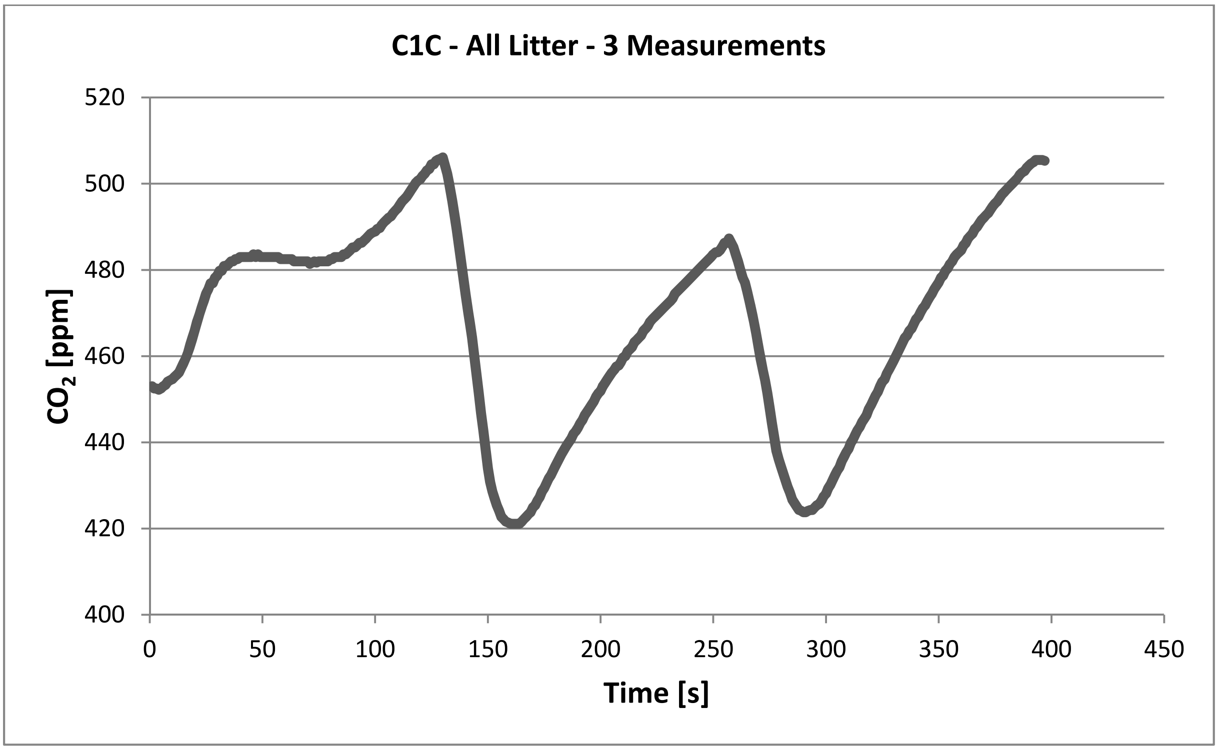

Figure 9: CO_2 respiration measurements over time (one measurement per second) conducted at plot C1 where all oaks have been girdled in 2008 in close vicinity to the Hamamelis virginiana tree marked C; CO_2 efflux coming from all litter additional to soil respiration.

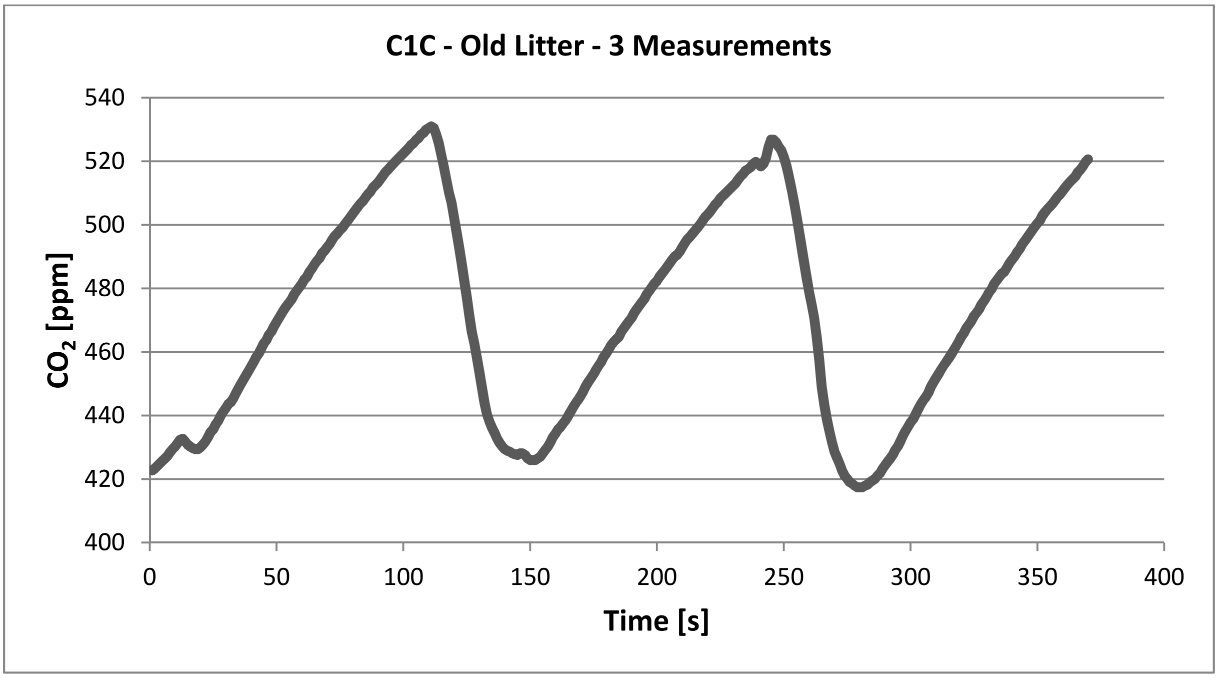

Figure 10: CO_2 respiration measurements over time (one measurement per second) conducted at plot C1 where all oaks have been girdled in 2008 in close vicinity to the Hamamelis virginiana tree marked C; CO_2 efflux coming from old litter additional to soil respiration.

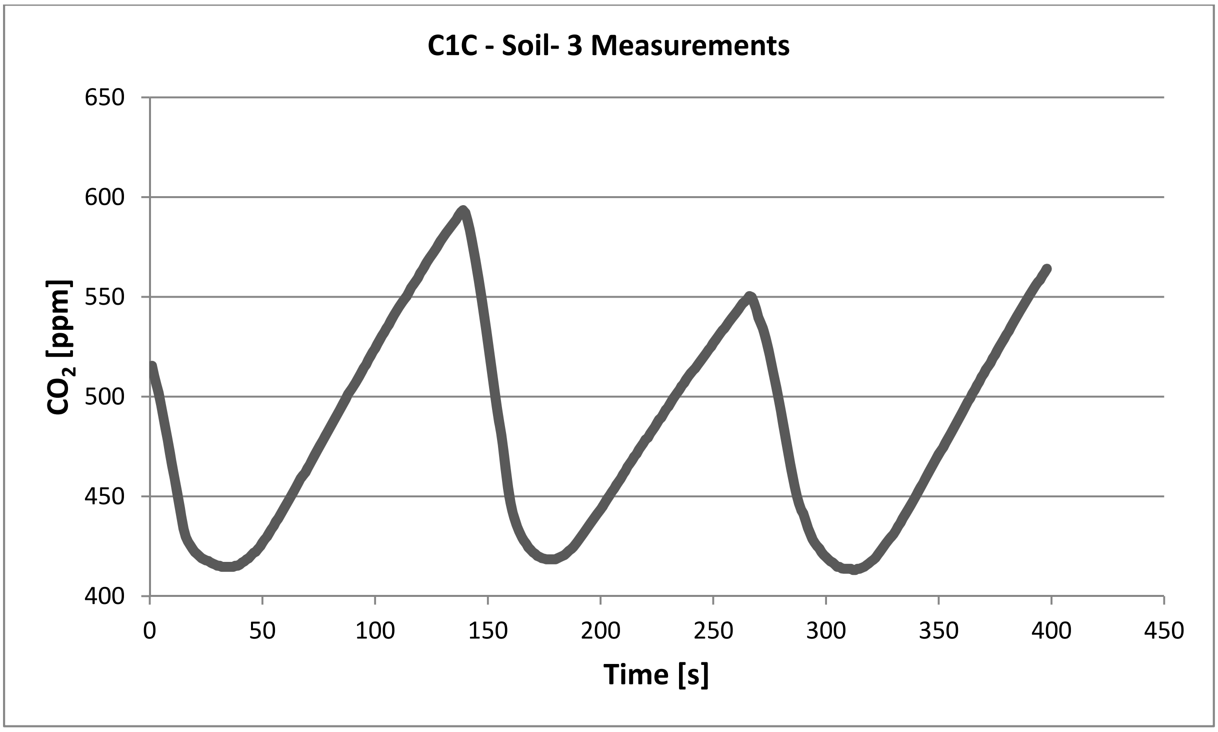

Figure 11: CO_2 respiration measurements over time (one measurement per second) conducted at plot C1 where all oaks have been girdled in 2008 in close vicinity to the Hamamelis virginiana tree marked C; CO_2 efflux coming from soil.

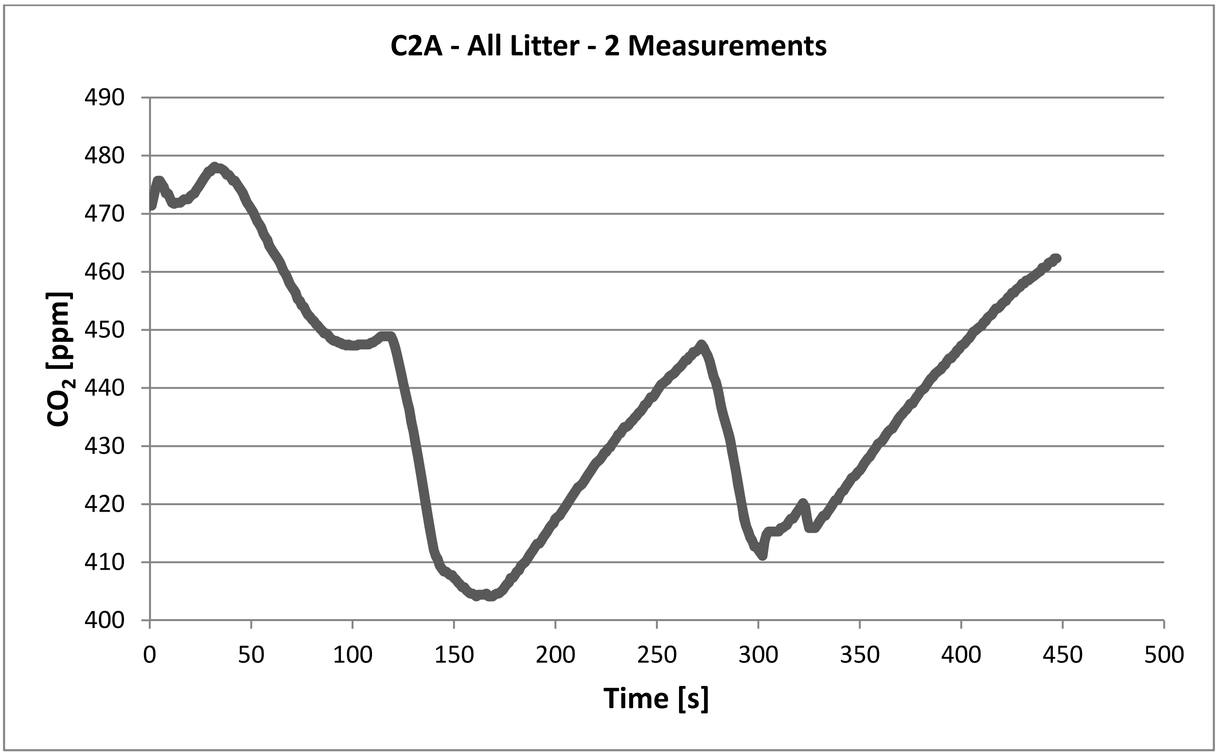

Figure 12: CO_2 respiration measurements over time (one measurement per second) conducted at plot C2 where all oaks have been girdled in 2008 in close vicinity to the Hamamelis virginiana tree marked A; CO_2 efflux coming from all litter additional to soil respiration.

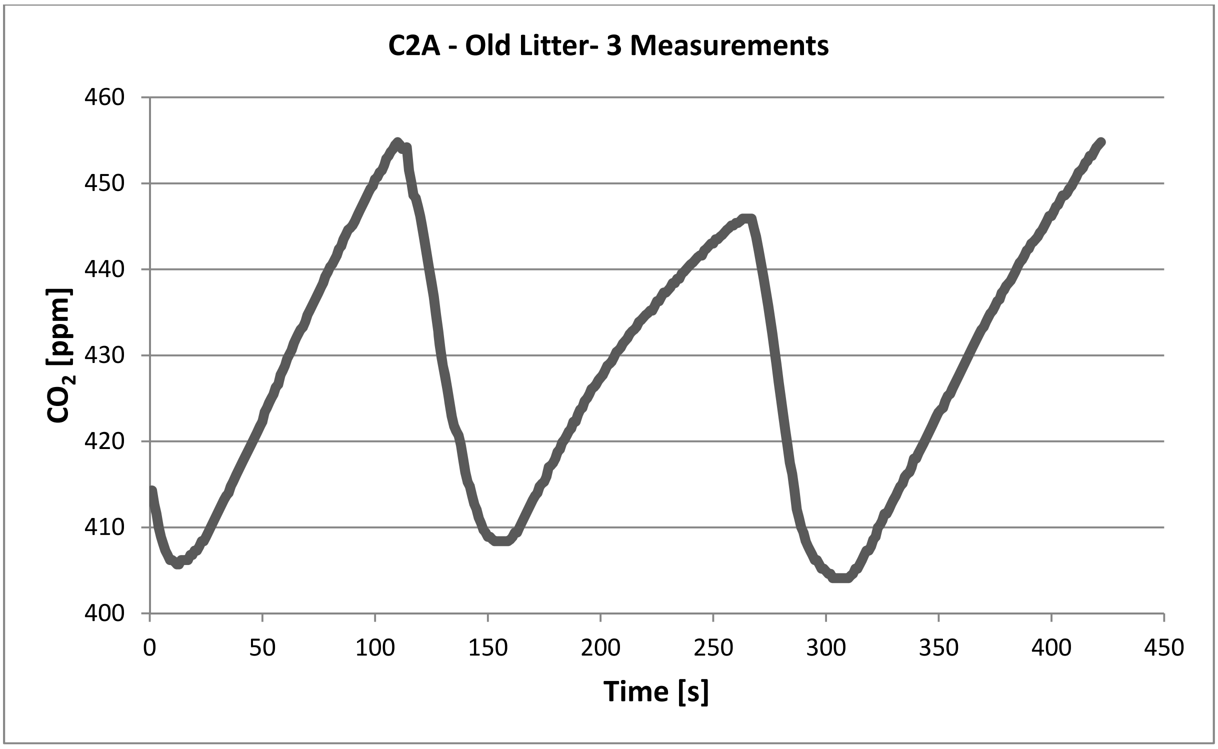

Figure 13: CO_2 respiration measurements over time (one measurement per second) conducted at plot C2 where all oaks have been girdled in 2008 in close vicinity to the Hamamelis virginiana tree marked A; CO_2 efflux coming from old litter additional to soil respiration.

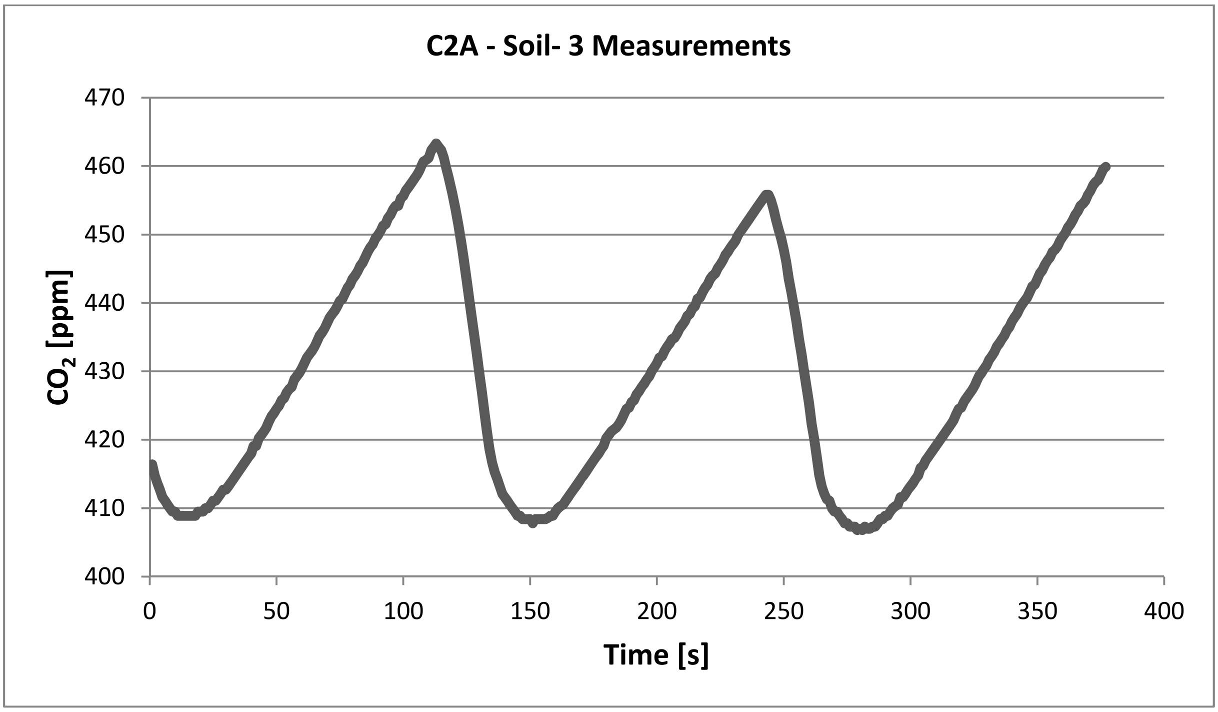

Figure 14: CO_2 respiration measurements over time (one measurement per second) conducted at plot C2 where all oaks have been girdled in 2008 in close vicinity to the Hamamelis virginiana tree marked A; CO_2 efflux coming from soil.

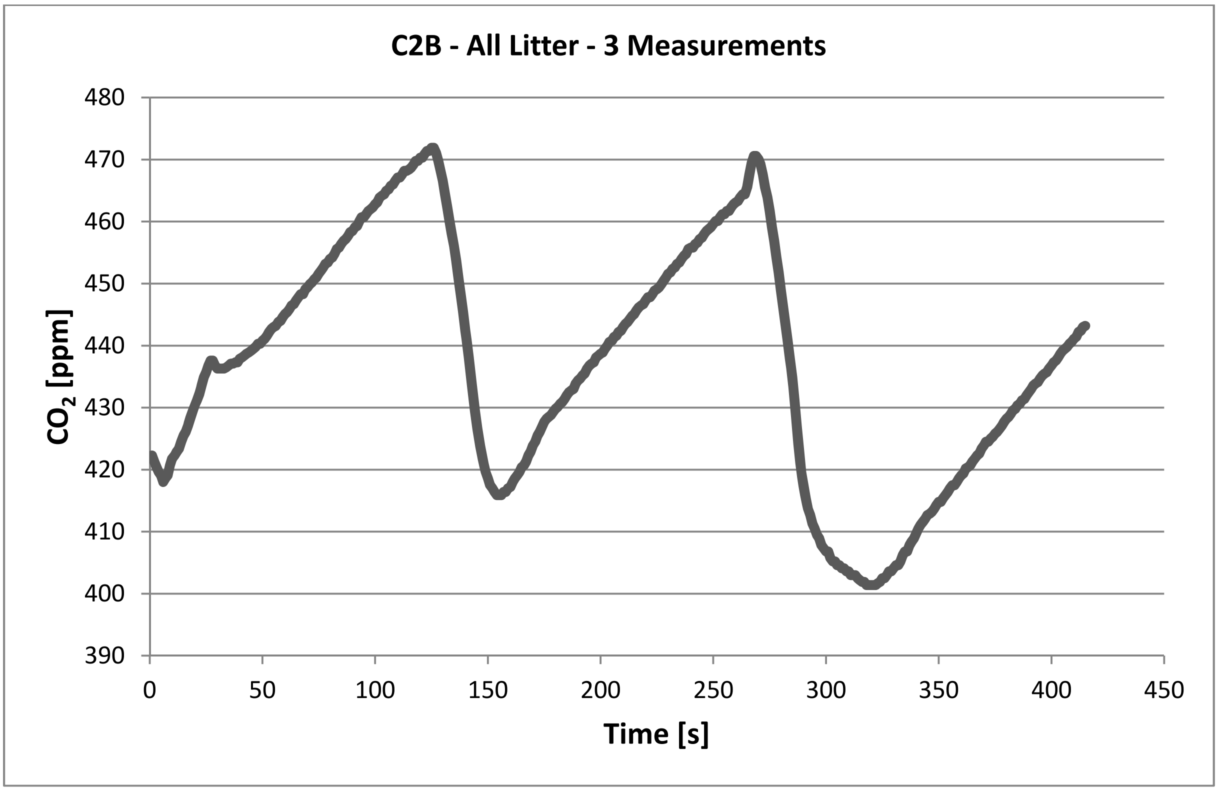

Figure 15: CO_2 respiration measurements over time (one measurement per second) conducted at plot C2 where all oaks have been girdled in 2008 in close vicinity to the Hamamelis virginiana tree marked B; CO_2 efflux coming from all litter additional to soil respiration.

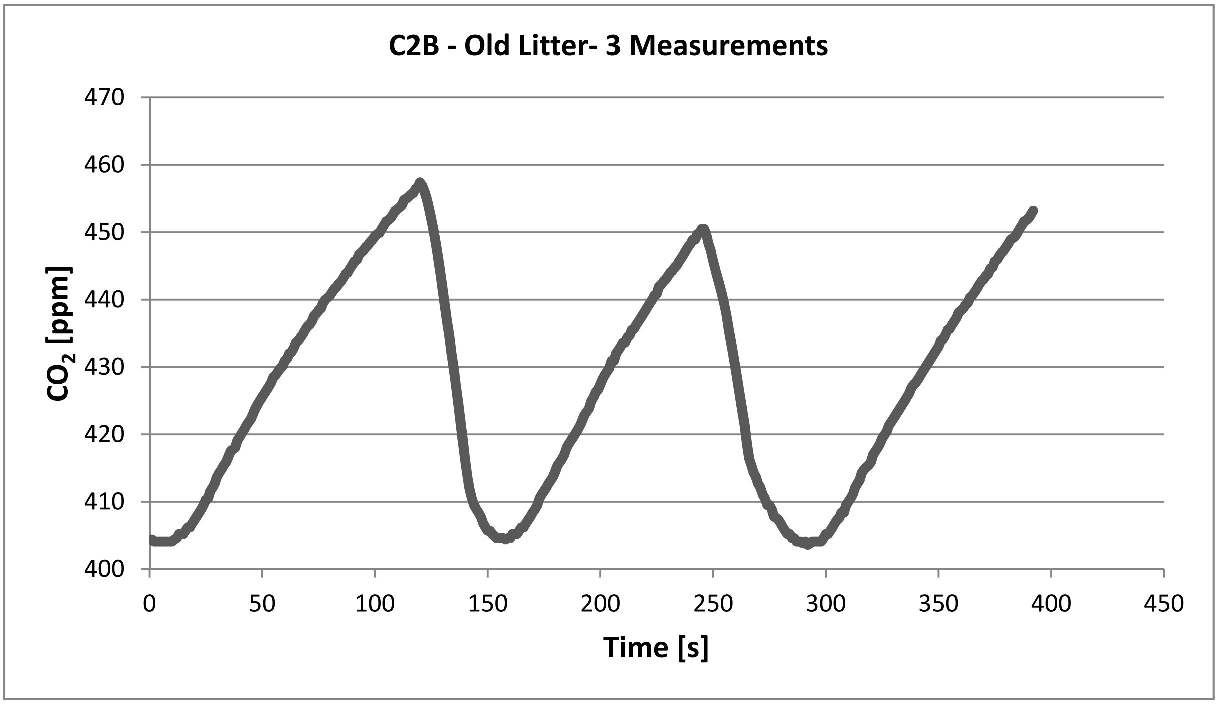

Figure 16: CO_2 respiration measurements over time (one measurement per second) conducted at plot C2 where all oaks have been girdled in 2008 in close vicinity to the Hamamelis virginiana tree marked B; CO_2 efflux coming from old litter additional to soil respiration.

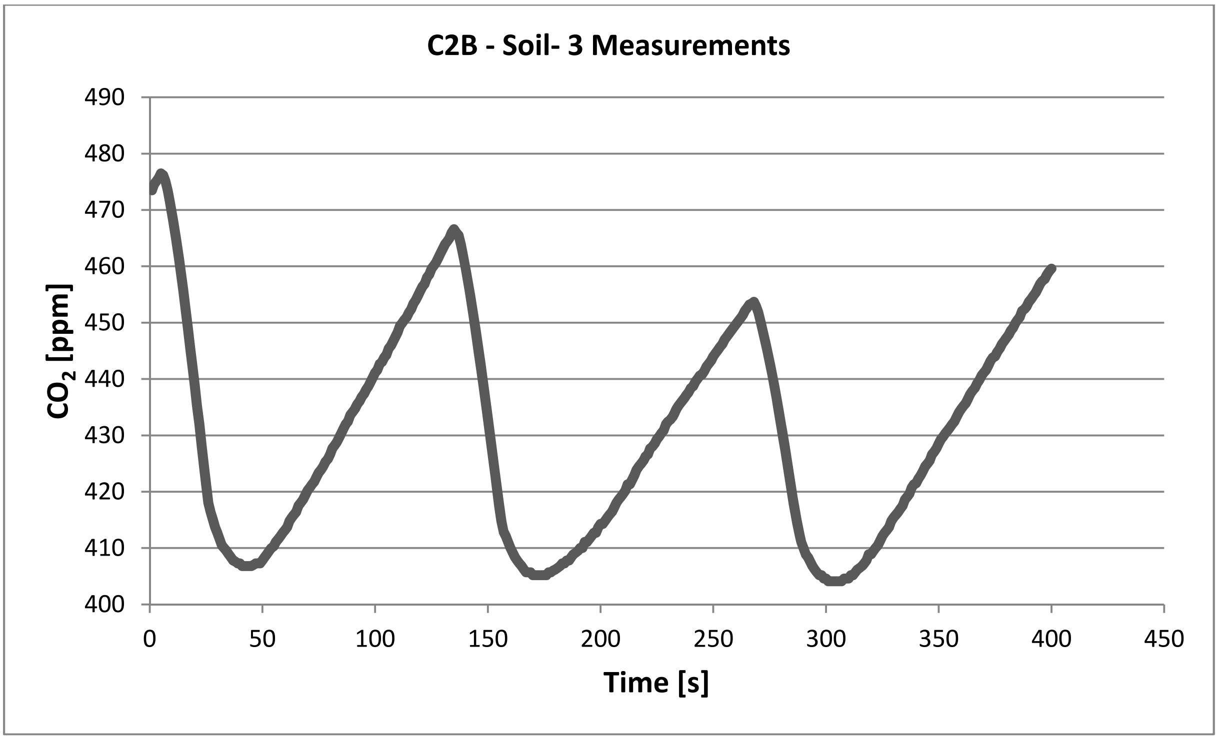

Figure 17: CO_2 respiration measurements over time (one measurement per second) conducted at plot C2 where all oaks have been girdled in 2008 in close vicinity to the Hamamelis virginiana tree marked B; CO_2 efflux coming from soil.

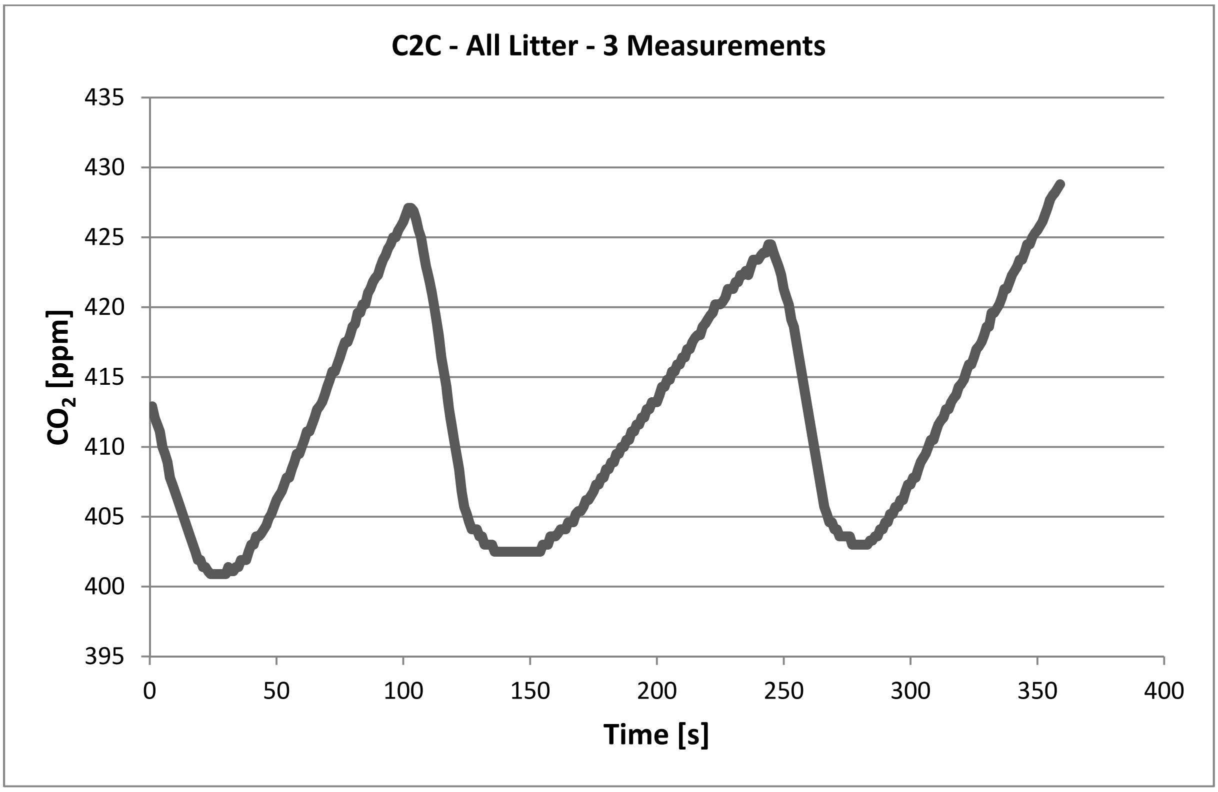

Figure 18: CO_2 respiration measurements over time (one measurement per second) conducted at plot C2 where all oaks have been girdled in 2008 in close vicinity to the Hamamelis virginiana tree marked C; CO_2 efflux coming from all litter additional to soil respiration.

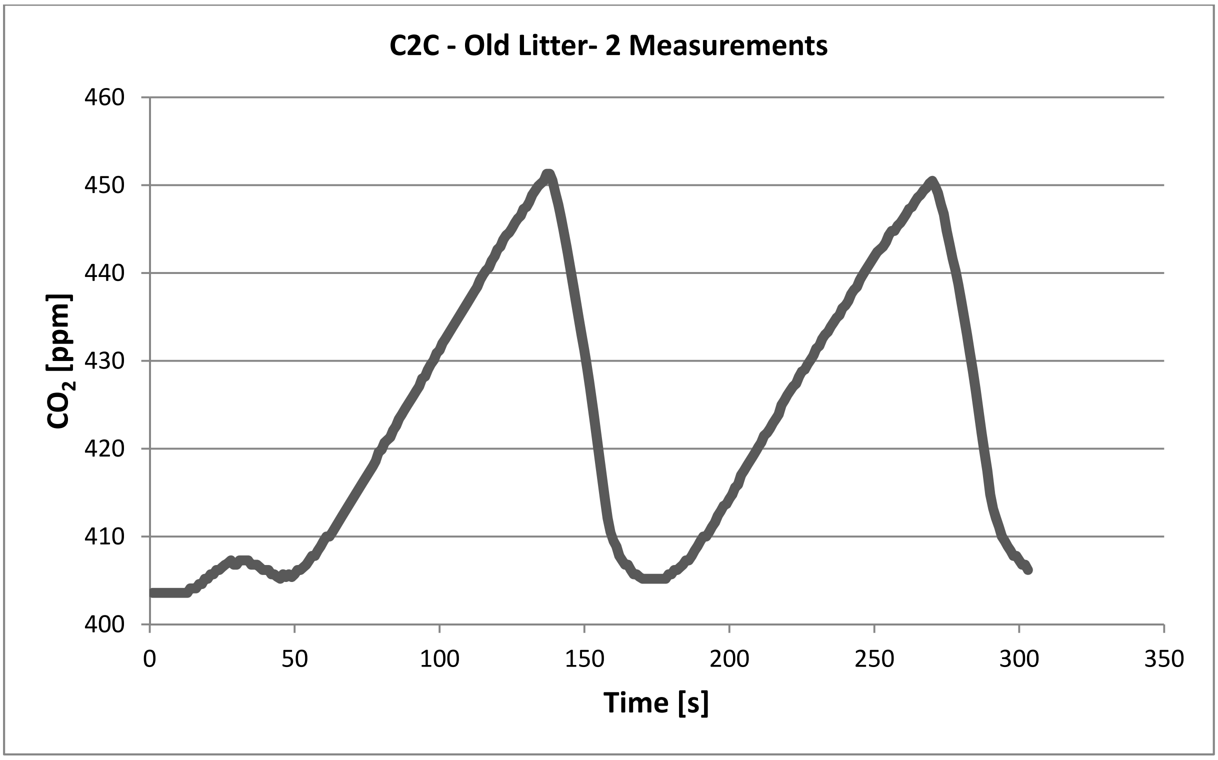

Figure 19: CO_2 respiration measurements over time (one measurement per second) conducted at plot C2 where all oaks have been girdled in 2008 in close vicinity to the Hamamelis virginiana tree marked C; CO_2 efflux coming from old litter additional to soil respiration.

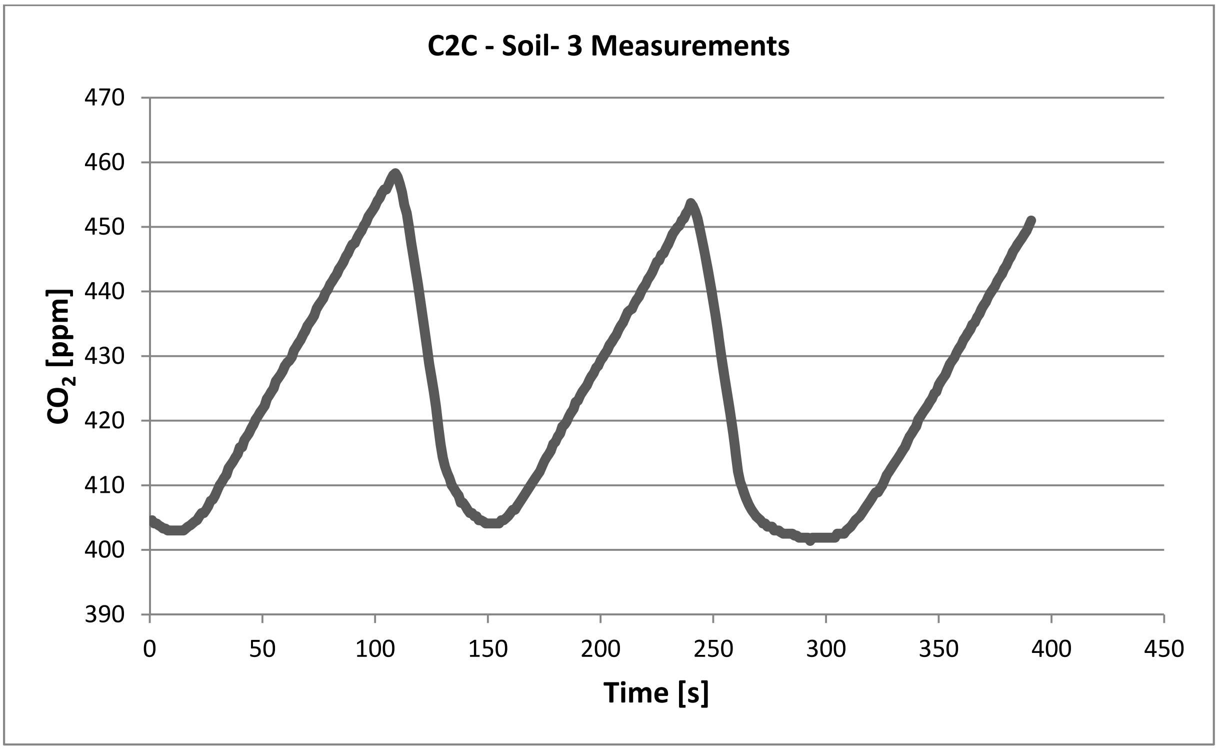

Figure 20: CO_2 respiration measurements over time (one measurement per second) conducted at plot C2 where all oaks have been girdled in 2008 in close vicinity to the Hamamelis virginiana tree marked C; CO_2 efflux coming from soil.

Plot	Tree	Substance	Slope	R²	CO_2 efflux
C1	A	AL	0,796	0,99375	0,017047005
C1	A	AL	0,5725	0,98809	0,012260565
C1	A	AL	0,7024	0,99856	0,015042482
C1	A	OL	0,7763	0,99757	0,016625113
C1	A	OL	0,9734	0,99167	0,020846174
C1	A	OL	0,9292	0,99253	0,019899594
C1	A	S	1,1198	0,99969	0,023981452
C1	A	S	1,1803	0,9988	0,02527711
C1	A	S	1,2243	0,99827	0,026219407
C1	B	AL	0,8142	0,99544	0,017436773
C1	B	AL	0,3189	0,96044	0,00682951
C1	B	AL	0,6267	0,99645	0,013421304
C1	B	AL	0,5169	0,98632	0,011069845
C1	B	OL	0,6922	0,99269	0,014824041
C1	B	OL	0,7584	0,99136	0,016241769
C1	B	OL	0,7239	0,99749	0,015502923
C1	B	S	0,7556	0,99964	0,016181805
C1	B	S	1,1474	0,99866	0,024572529
C1	B	S	1,1759	0,99974	0,02518288
C1	C	AL	0,714	0,98864	0,015290906

C1	C	AL	0,8456	0,98996	0,01810923
C1	C	OL	1,1253	0,99339	0,024099239
C1	C	OL	1,1017	0,9959	0,023593825
C1	C	OL	1,2228	0,99693	0,026187283
C1	C	S	1,9114	0,99924	0,040934227
C1	C	S	1,6343	0,99928	0,034999899
C1	C	S	1,9715	0,99958	0,042221318
C2	A	AL	0,4336	0,99685	0,009285906
C2	A	AL	0,3909	0,99499	0,00837145
C2	A	OL	0,5563	0,99861	0,011913629
C2	A	OL	0,3527	0,98235	0,007553365
C2	A	OL	0,4607	0,99689	0,009866275
C2	A	S	0,6178	0,99925	0,013230703
C2	A	S	0,5727	0,99977	0,012264849
C2	A	S	0,6118	0,99971	0,013102208
C2	B	AL	0,4172	0,99737	0,008934686
C2	B	AL	0,4286	0,9972	0,009178827
C2	B	AL	0,4473	0,99917	0,009579303
C2	B	OL	0,5048	0,99424	0,010810713
C2	B	OL	0,5689	0,99591	0,012183468
C2	B	OL	0,529	0,99707	0,011328977
C2	B	S	0,7049	0,99924	0,015096022
C2	B	S	0,5718	0,99676	0,012245574
C2	B	S	0,6381	0,99979	0,013665444
C2	C	AL	0,4075	0,99928	0,008726953
C2	C	AL	0,261	0,99779	0,005589533
C2	C	AL	0,3662	0,99931	0,007842479
C2	C	OL	0,5553	0,99962	0,011892213
C2	C	OL	0,5264	0,99857	0,011273295
C2	C	OL	0,5895	0,98611	0,012624635
C2	C	S	0,6215	0,99938	0,013309941
C2	C	S	0,6073	0,99964	0,013005837
C2	C	S	0,604	0,99888	0,012935164

Table 1: Slope of computed trendline of measured CO_2 over time, R^2 of calculated trendline, and CO_2 efflux calculated by the equation CO_2 efflux = Slope*Chamber Volume/Chamber Surface Area

Figure 23 visualizes mean values of all respiration measurements conducted. Without regard of any statistics hypothesis 1 can be accepted which stated forest areas containing oaks respire less CO_2 than forest areas containing no oaks. Control plot C2 respires less CO_2 than plot C1 where all oaks have been girdled. Figure 23 also shows that respiration increases with treatments AL, OL, and S which disproves hypothesis 3 which states that respiration measurements coming from substance S (only soil) should be lower than coming from substance AL (all litter plus soil) and makes hypothesis 2 invalid which states that CO_2 efflux coming from substance AL should be higher than coming from OL (old litter plus soil).

Knowledge of CO_2 emissions coming from litter is known in literature for a long time, therefor soil respiration should increase with additional litter layers measured.

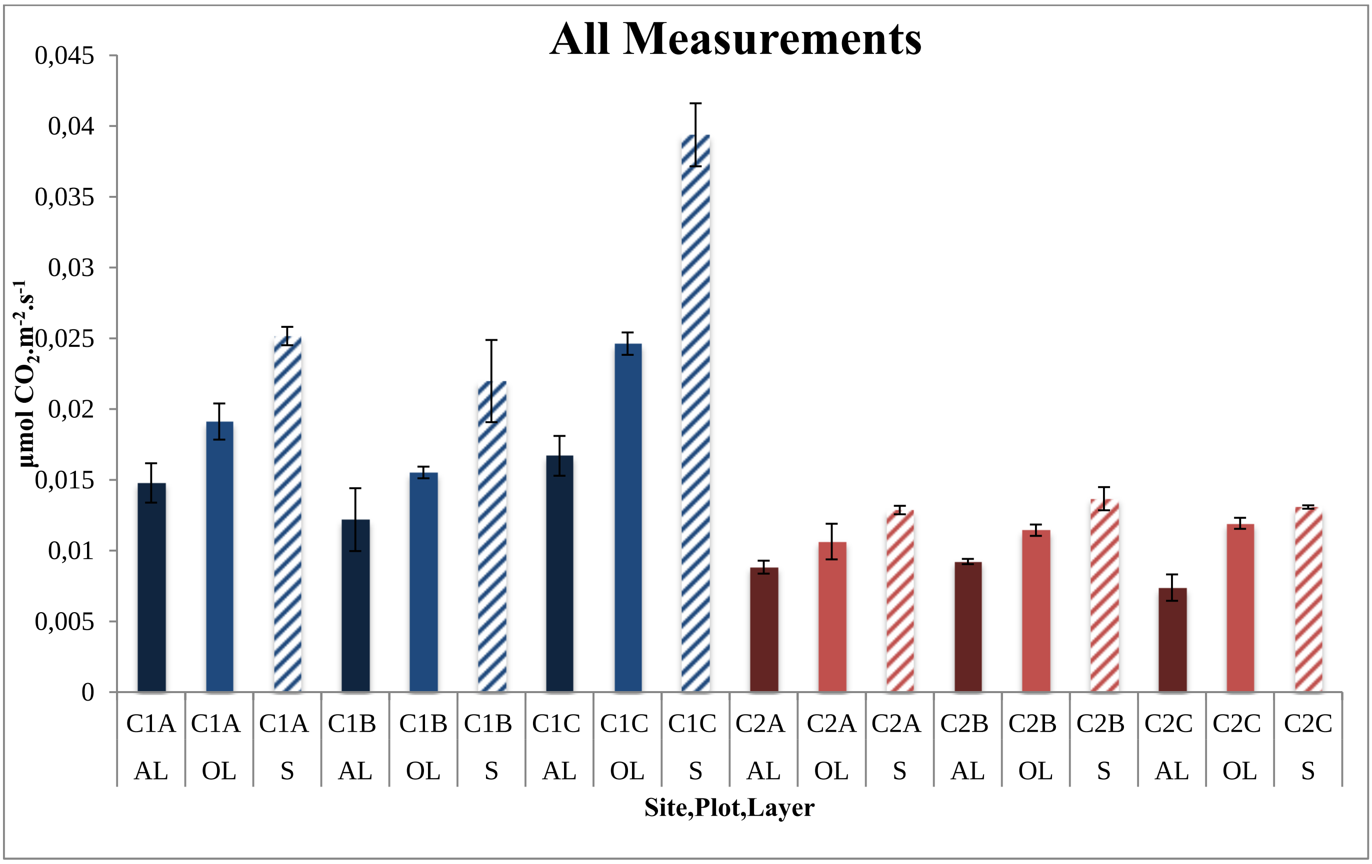

Figure 21: Mean values of CO_2 efflux coming from all substances all litter plus soil(AL); old litter plus soil(OL); only soil (S) at plot C1 where all oaks have been girdled and C2 where no oaks have been girdled and subplots A, B, and C, three individual Hamamelis virginiana trees.

Statistical analysis conducted with R_language indicates significant differences between sites, trees and treatments. Statistical analysis also shows significant differences in respiration between trees within one site and between treatments within one site.

R Results ANOVA

```
> ANOVA_Soilrespiration
Analysis of Variance Table

Response: Datenmatrix$Flux
                                    Df    Sum Sq       Mean Sq       F value    Pr(>F)
Datenmatrix$Site                     1 0.00129617    0,00129617    156,958    6,05E-16
Datenmatrix$Tree                     2 0.00029907    0,00014953     18,108    1,97E-06
Datenmatrix$Substance                2 0.00082463    0,00041231     49,928    6,16E-12
```

```
Datenmatrix$Site:Datenmatrix$Tree         2 0.00030948   0,00015474   18,738   1,41E-06
Datenmatrix$Site:Datenmatrix$Substance    2 0.00018804   0,00009402   11,385   0,000108
Residuals                                43 0.00035510   0,00000826

Signif. codes:  0 '***' 0.001 '**' 0.0    1 '*' 0.05 '.'   0.1 ' ' 1
```

The relevance of the statistical outcome is examined in detail. Figures 24 – 31 show site and tree differences compartmentalized into the three substances (AL, OL, and S), substance differences between sites calculated with the Tuckey test as well as overall substance differences also calculated with the Tuckey test.

Figures 24 – 26 in particular illustrate differences between sites of CO_2 efflux mean values coming from substances AL, OL, and S. CO_2 efflux measurements of all substances show significant differences between the two plots C1 and C2. Additionally, CO_2 emissions at plot C1 exceed emissions at plot C2 which means that oaks in a forest increase carbon sequestration.

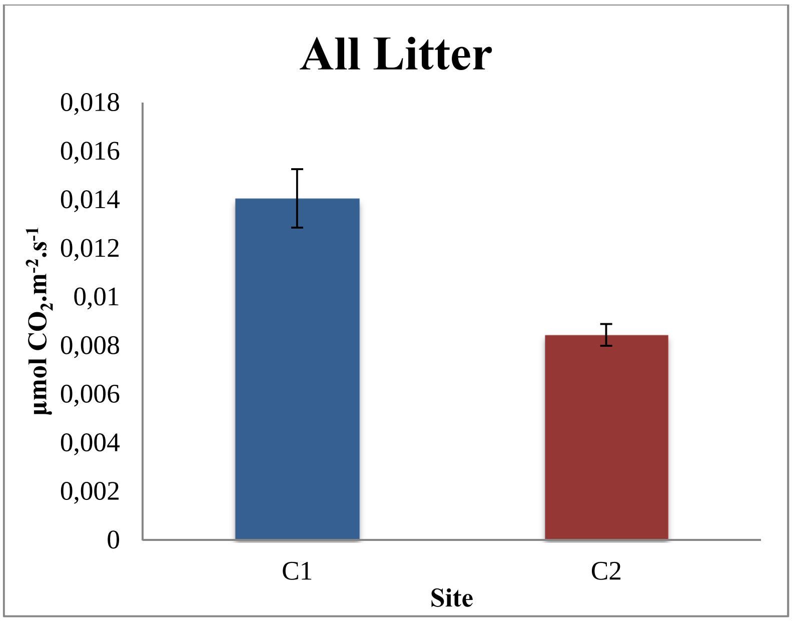

Figure 22: CO_2 efflux coming from substance AL (all litter plus soil) at plot C1 where all oaks have been girdled and C2 where no oaks have been girdled; mean values over subplots A, B, and C

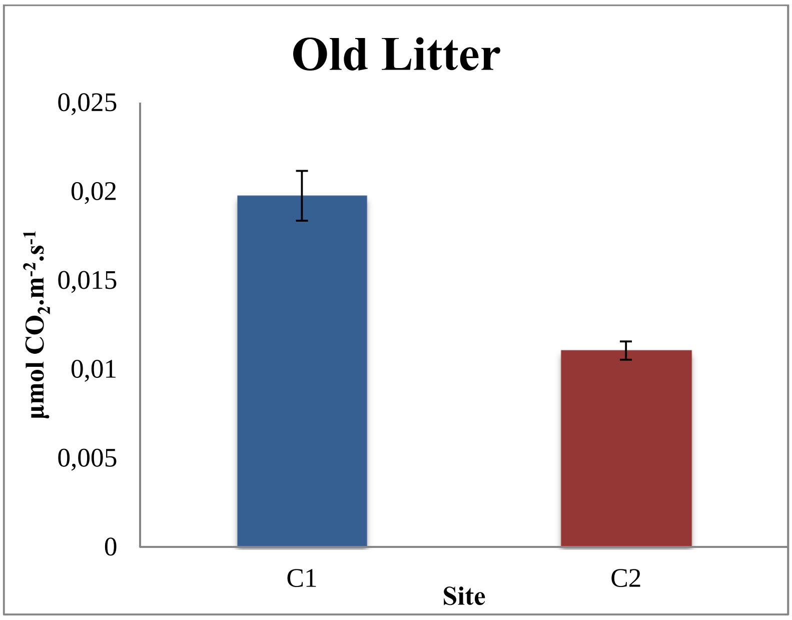

Figure 23: CO_2 efflux coming from substance OL (old litter plus soil) at plot C1 where all oaks have been girdled and C2 where no oaks have been girdled; mean values over subplots A, B, and C

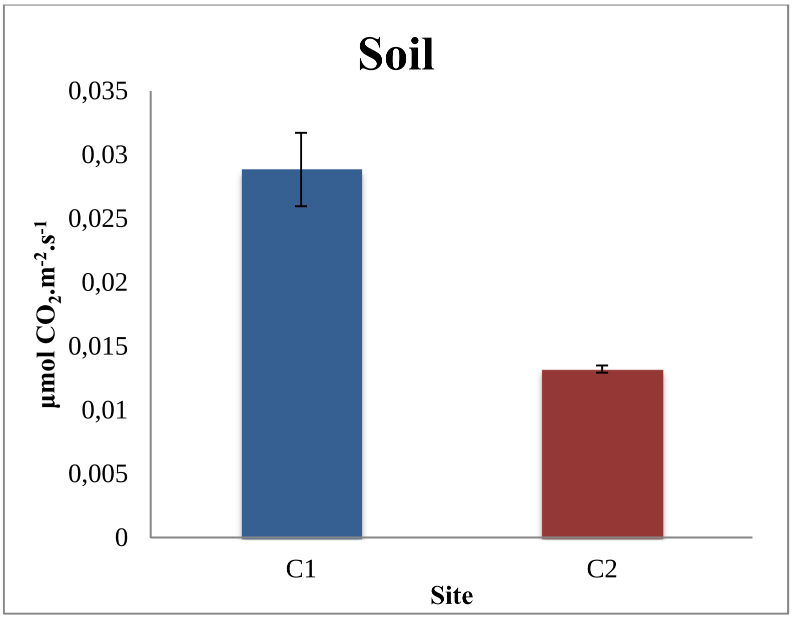

Figure 24: CO_2 efflux coming from substance S (only soil) at plot C1 where all oaks have been girdled and C2 where no oaks have been girdled; mean values over subplots A, B, and C

Statistical analysis showed significant differences between trees, even within one site. The reason for that might be fluctuations in water content of soils and leaf litter investigated. Forest floors often show high variability in moisture content. Figure 27 – 29 illustrate differences between trees of CO_2 efflux mean values coming from substances AL, OL, and S.

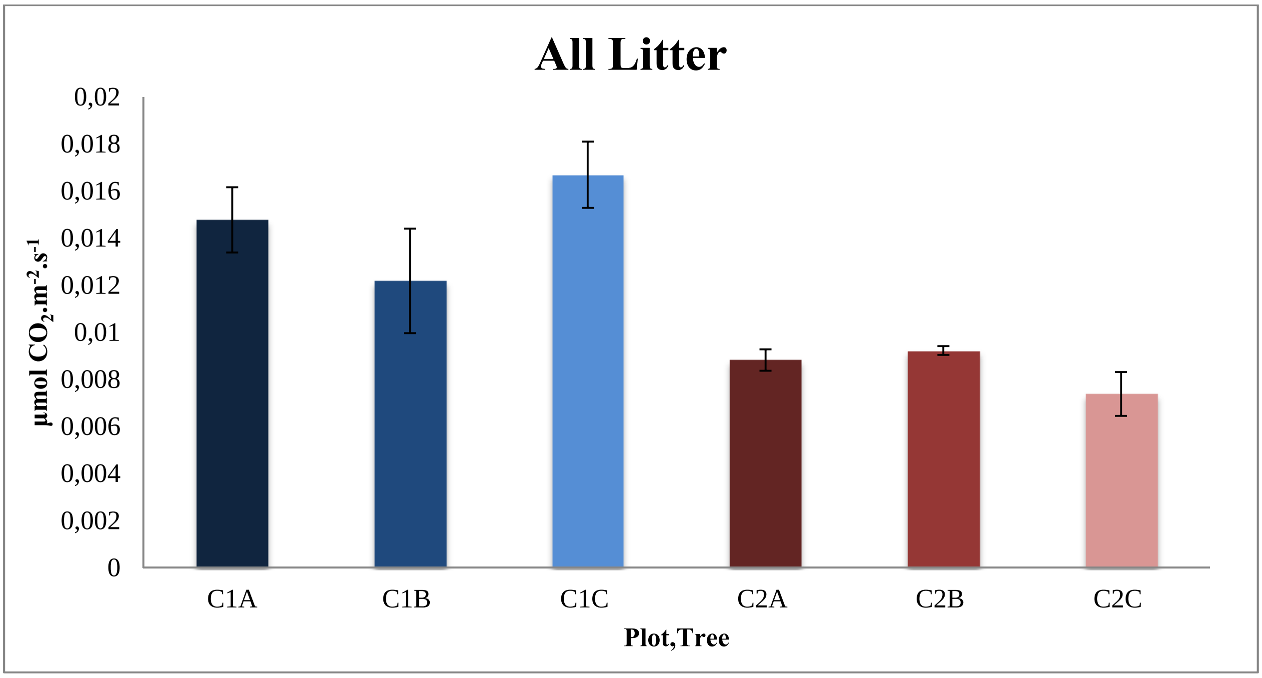

Figure 25: CO_2 efflux coming from substance AL (all litter plus soil) at subplots A, B, and C, and plots C1 where all oaks have been girdled and C2 where no oaks have been girdled.

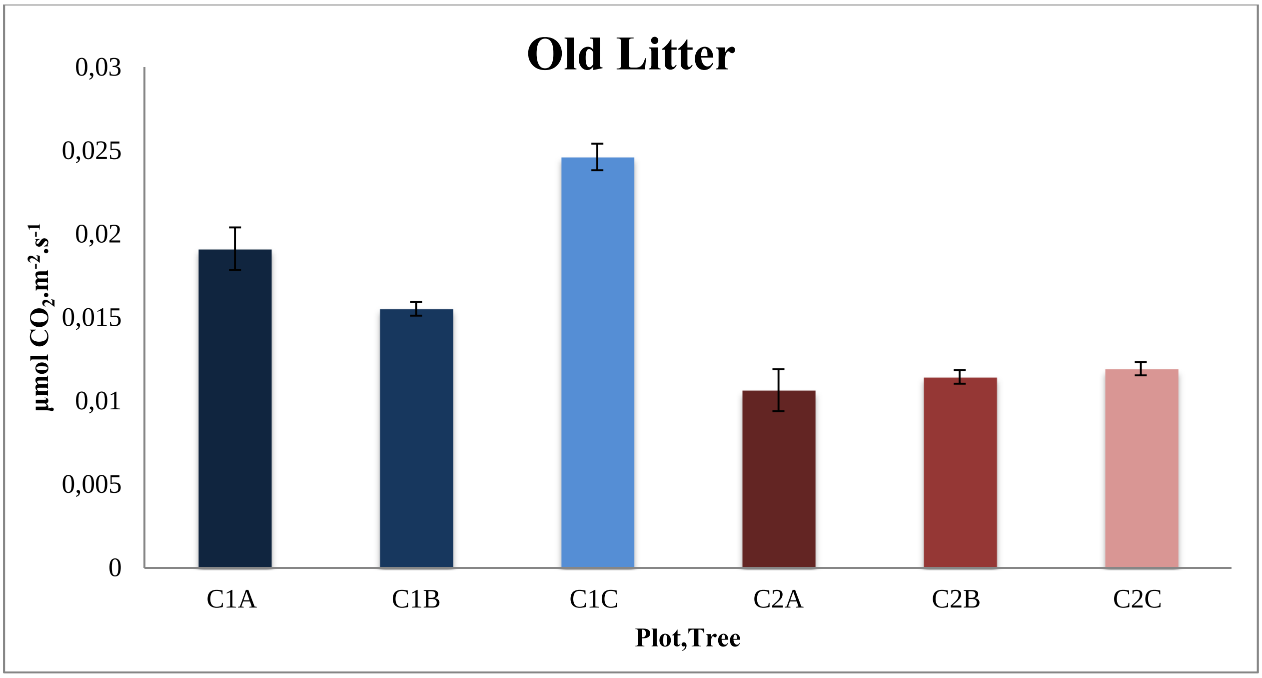

Figure 26: CO_2 efflux coming from substance OL (old litter plus soil) at subplots A, B, and C, and plots C1 where all oaks have been girdled and C2 where no oaks have been girdled.

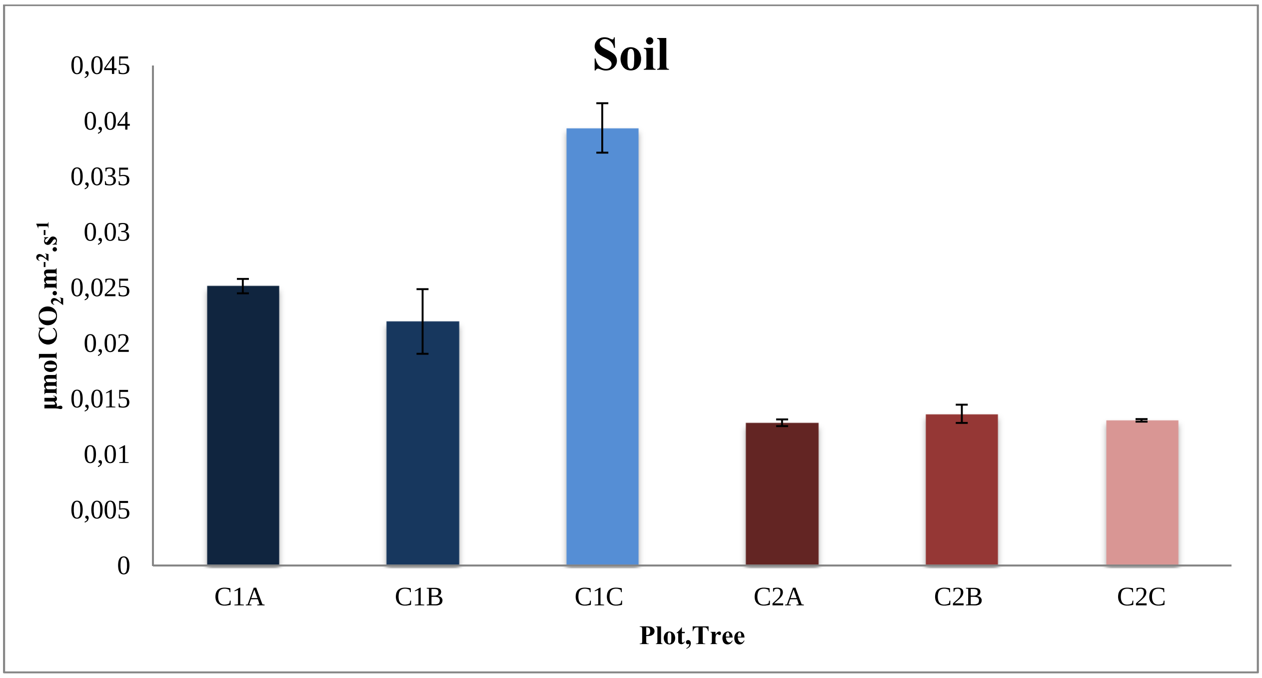

Figure 27: CO_2 efflux coming from substance S (only soil) at subplots A, B, and C, and plots C1 where all oaks have been girdled and C2 where no oaks have been girdled.

Figure 30 indicates substance differences between sites. The Tuckey test revealed significant differences between all substances at plot C1; C2 shows significant differences between CO_2 efflux coming from all litter (AL) and soil (S).

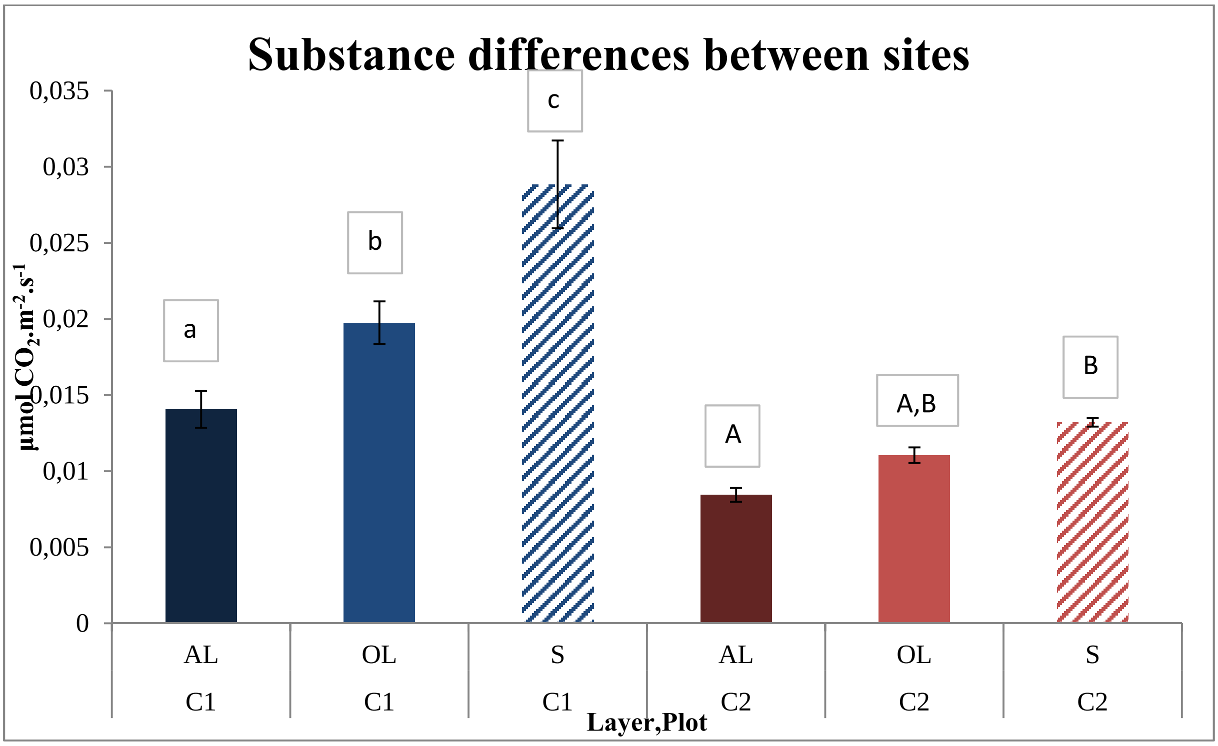

Figure 28: CO_2 efflux coming from substance AL (all litter plus soil), OL (old litter plus soil), and S (only soil) at plots C1 where all oaks have been girdled and C2 where no oaks have been girdled; mean values over subplots A, B, and C

Figure 31 shows overall differences between treatments of both, plot C1 and C2. The Tuckey test revealed significant differences between CO_2 efflux coming from all litter (AL) and soil (S).

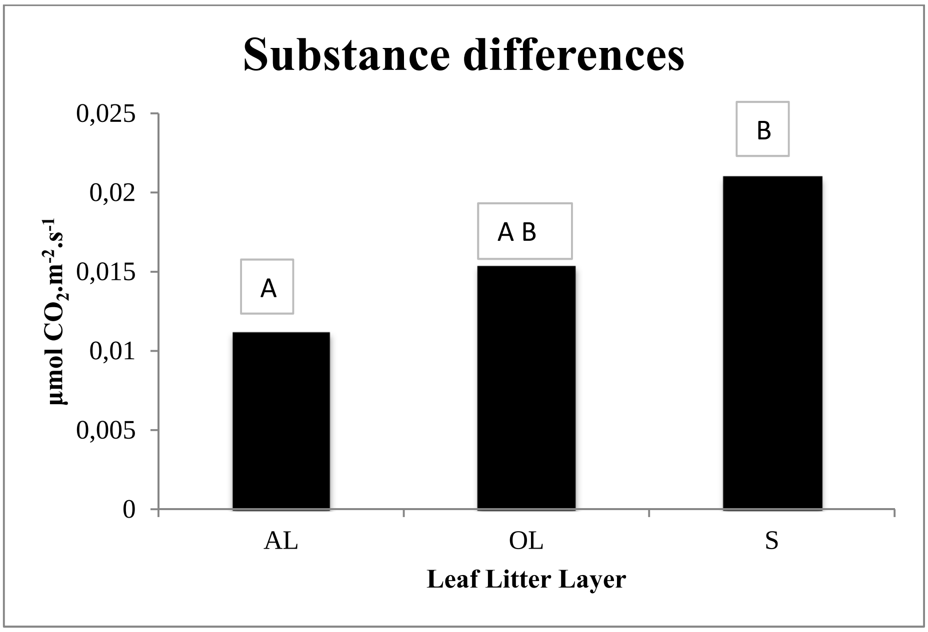

Figure 29: CO_2 efflux coming from substance AL (all litter plus soil), OL (old litter plus soil), and S (only soil); mean values over subplots A, B, and C and plots C1 where all oaks have been girdled and C2 where no oaks have been girdled

Air and soil temperature were measured additionally. Mean air temperatures were ranging between 11.5 and 12 °C. Mean soil temperatures could not be detected correctly due to a broken cable.

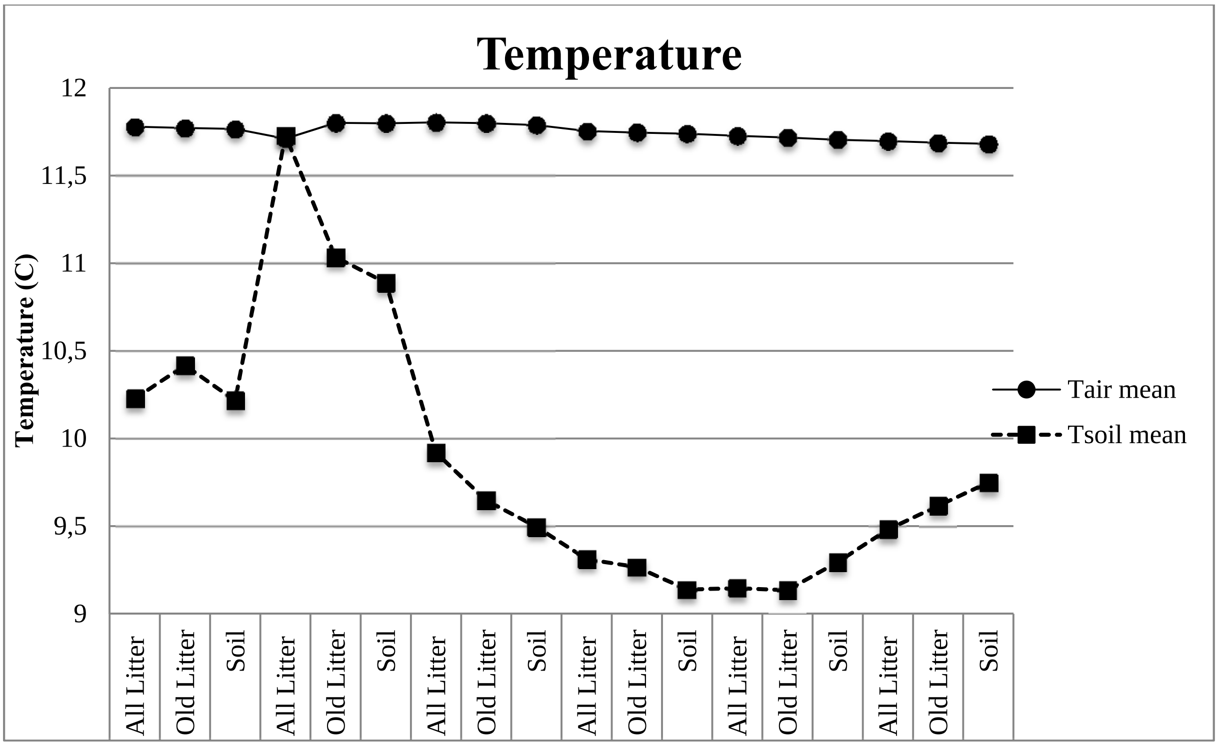

Figure 30: Mean values of air and soil temperature

Conclusions

A girdling experiment was implemented in summer 2008 at the investigated research site at Black Rock Forest, New York State, which involved selective girdling of oak (Quercus) trees. As a result all oaks girdled have died by now which created a unique research area at Black Rock Forest due to the current tree species distribution at the different plots. Understanding the contribution of different forest species to decomposition may allow assessing impacts of land use change on nutrient cycling. Overall very little information exists for the role oak trees play in mixed forest ecosystems.
While my research exchange visit at Columbia University I measured CO_2 efflux in fall 2013 to investigate the difference in respiration between oak girdled and non-girdled plots, therefor between plots where all oaks have been killed to plots where Quercus is still alive. Also I was interested in the contribution of different litter layers to overall soil respiration.

Respiration measurements were conducted with three substances; *all leaf litter plus soil*, followed by removal of fresh litter, *old litter plus soil* and measurements after all litter was removed, *only soil*. Two plots were selected for measurements, C1, a plot where all oaks have been girdled, and C2, a control plot where all oaks are still alive. At each plot three subplots have been positioned in close vicinity to the same tree species (Hamamelis virginiana).

In particular, following hypotheses were tested:
(1) Control plots (non-girdled) respire less CO_2 than oak girdled plots; due to the higher tendency of oak trees to store C.
All substances measured showed significant differences between plots C1 and C2. Hypothesis 1 can be accepted which states mixed forest areas containing oaks respire less CO_2 than mixed forest areas containing no oaks. These results allow further investigations of the impact of oak trees on carbon sequestration and designed land use change.

(2) and (3)
– The Upper leaf litter layer (fresh litter) will contribute higher CO_2 emissions to the overall soil respiration than the lower leaf litter layer (old litter fallen down in previous years) in both control and girdled plots; this hypothesis is based on the fact that decomposition of old litter has already started in previous year hence the first phase of litter decomposition has already or partly been processed and labile soluble compounds like unshielded cellulose and hemicellulose have already been decomposed.
– Soil respiration accounts for approximately 70% of overall CO_2 emissions as compared to the leaf litter layer, which contributes about 30% of CO_2 emissions in both control and girdled plots (Berger et al. 2010).
The Tuckey test revealed significant differences between all substances at plot C1; C2 shows significant differences between CO_2 efflux coming from all litter plus soil and only soil. Respiration increases from all litter plus soil CO_2 efflux to, old litter and soil CO_2 efflux, and only soil respiration which disproves hypothesis 3 that states that respiration measurements coming from only soil should be lower than coming from all litter plus soil.
Results also make hypothesis 2 invalid that states CO_2 efflux coming from all litter plus soil should exceed CO_2 efflux coming from old litter plus soil. The reason for our results might be that litter layers were covering up the soil and therefor prohibited gas exchange.

Statistical analysis conducted with R_language indicates significant differences between sites, trees and treatments as well as in respiration between trees within one site and between treatments within one site. The reason for significant differences between trees, even within one site, might be due to variations in water content of soils and leaf litter investigated. Forest floors often show high variability in moisture content. Temperature reasons can be ruled out as air temperature was ranging between a stable range (11.5 and 12 °C). Soil temperatures could not be detected correctly due to a broken cable.

Results confirm the important role Quercus plays in terms of C sequestration in mixed forest ecosystems. My recommendation for further measurements is to investigate all plots at the research site at Black Rock Forest, New York State, to see if findings similar to this report can be found. In terms of litter measurements better ventilation of the instrument system might lead to more accurate results.

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