Protocol

Summer School – soil & water 2015

Pfrunger-Burgweiler Ried

Gas fluxes in wetlands

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Introduction:

Even small average global temperature change can affect for instance weather, biodiversity and agriculture in various ways. Because the climate is changing, effects of global warming and greenhouse gases are getting more and more important issues in our society. Natural events and human activities have been contributing to an increase in average global temperatures.
It is necessary to measure gas fluxes in wetlands because gases, produced thereby, like carbon dioxide, methane and laughing gas are known as greenhouse gases. Natural wetlands can either act as a carbon sink or as a carbon source depending to the height of the water table and the course of NEE during the day. Different kinds of land use can have a variable impact on the process of NEE. So it is important to detect what kind of land use and water table produces the lowest methane or laughing gas emissions and even acts as a carbon sink instead of a carbon source. The goal of the study is to investigate which degree of land use intensity is most affordable in regard of GHG emissions and the impact on global warming.
To measure gas fluxes in wetlands, chamber systems or the Eddy Covariance method, are used. The chamber system has more variety of usage in comparison to the Eddy Covariance, because a more homogenous environment has to be given. For the measurements of gas fluxes at the Pfrunger Ried from Ulm University also the chamber system is used.
Especially in Ulm it is also measured which kind of land use produces how much greenhouse gas emissions. This will first require an improved assessment of GHG emissions in Baden-Württemberg and the GHG balance under consideration of land use.

Material and Methods

The project was set up at five field sites, which form a land use intensity gradient. The measurement sites are defined as field, intensive meadow, extensive meadow, extensive pasture and a field which is not used.
Methane, nitrous oxide and carbon fluxes, ground water level, solar radiation, air and soil temperature were measured on each site. Afterwards, the data were evaluated. Already calculated data from the field with extensive pasture management was given. According to Alm et al. (2007) the manner of assessment of the gas exchange balances depend on the mere vertical distributions of live vegetation both above and below the peat surface level. Thus the instantaneous fluxes of CO_2, CH_4 and N_2O were measured by using closed dark chambers (see picture 1). The chambers were employed at the ecosystem-atmosphere boundary, so the headspace of the chamber is uncoupled from the atmosphere.

Pic. 1: closed dark chamber measurement

The CO_2 fluxes were measured with light chambers. The incubation time was between two and five minutes and the fluxes were measured eight times per day in one month. „*The flux is automatically calculated from the linear change of CO_2 concentration in chamber headspace in time as a function of chamber volume, air temperature, and air pressure according to the ideal gas law*“(Alm et al. 2007).

The exchanges of CH_4 and N_2O were measured with dark chambers every 15 minutes, for four times, so there was an incubation time of 45 minutes. The measurements were done one time per day, but two times per month. At every timepoint a gas sample was taken. There was always the double volume of the tube taken, to produce an overpressure. Afterwards the samples were sent to the University of Hohenheim to analyse them via a gas chromatography (GC). According to main gas chromatography principles, the GC detector is able to find presence of observed substances.
The water level was logged and PAR (photosynthetic active radiation 400 nm – 700 nm), air temperature (TL) and the soil temperature in a depth of 5 cm and 20 cm were also detected. R_{eco} (respiration of soil microorganisms, soil animals, plant roots, shoot), GPP (Gross Primary Production) and NEE (Nett Ecosystem Exchange) could be calculated. In doing so PAR and T_{air} are the factors influencing NEE. NEE is the overall flux of CO_2 and is the sum of R_{eco} and GPP. When NEE is positive the flux is going to the atmosphere, when it is negative the flux comes from the atmosphere.
To give a statement and to evaluate the fluxes of different gases, CO_2 equivalents had to be calculated. Therefore the daily fluxes and the respective GWP factor had to be multiplied. GWP stands for global warming potential and is important to show the different influences of several gases.

Results

In Table 1 the measured emissions of CH_4, CO_2 and N_2O of the several plots in the extensive pasture (field site IV) are shown. In every plot it was measured four times every 15 minutes. Methane, carbon dioxide and laughing gas emissions were measured.
The measurement results from the team of Ulm University were used for the calculations in the practical work. To make statements about the greenhouse gas emissions, the data had to be analyzed by making calculations and by generating diagrams with Excel.

Tab. 1: Data of the measurement plots in extensive pasture for CH_4, CO_2 and N_2O emissions

sample ID	site	plot	date	time	incubation duration HH:MM	incubation [min]	sample ID	CH4 [ppm]	CO2 [ppm]	N2O [ppb]
3100	4	1	20.08.14	13:28	0:00	0	3100	21,9081071	427,468384	386,553069
3101	4	1	20.08.14	13:43	0:15	15	3101	73,1694339	1008,96033	390,705876
3102	4	1	20.08.14	13:58	0:30	30	3102	80,2388214	1495,17292	396,581121
3103	4	1	20.08.14	14:13	0:45	45	3103	81,9564175	1936,2046	405,594097
3104	4	2	20.08.14	13:27	0:00	0	3104	2,47319487	398,357105	385,258526
3105	4	2	20.08.14	13:42	0:15	15	3105	9,61517018	904,798332	403,835506
3106	4	2	20.08.14	13:57	0:30	30	3106	16,1457298	1354,42848	426,919853
3107	4	2	20.08.14	14:12	0:45	45	3107	18,9218355	1752,47929	439,114479
3108	4	3	20.08.14	13:26	0:00	0	3108	3,4204974	392,66933	382,759568
3109	4	3	20.08.14	13:41	0:15	15	3109	38,709839	949,065359	398,896539
3110	4	3	20.08.14	13:56	0:30	30	3110	46,5871211	1434,56456	412,822018
3111	4	3	20.08.14	14:11	0:45	45	3111	53,305659	1920,11671	429,62983

As a first step to calculate the results, diagrams were generated for the emissions of each plot. The methane emissions for all of the three plots are shown in figure 1. It is seen that the concentration of methane (relative abundance of methane molecules) in the chamber is rising during the incubation time, but with different initial concentration and slope of the single plots. A regression line is used for determining the flux.

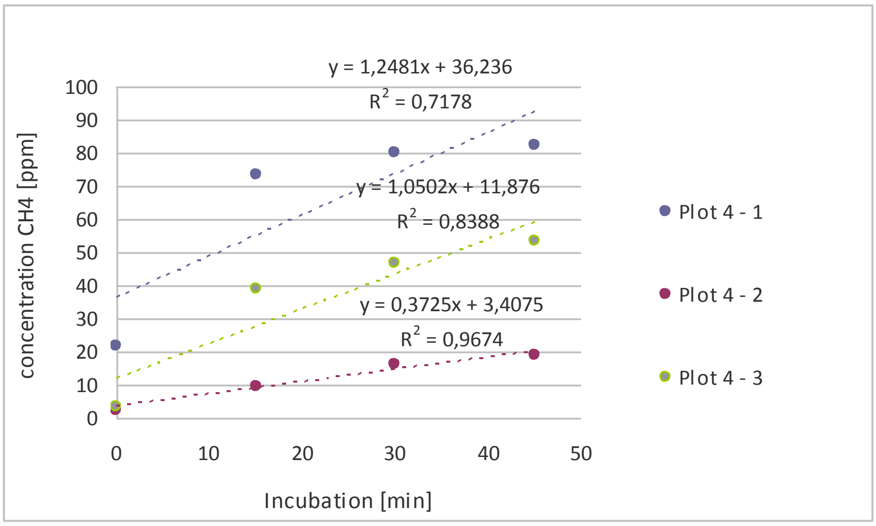

Fig. 1: CH_4 emissions from site IV.

Figure 2 shows the CO_2 emissions for all three plots. Here also the slope of the regression line was used for calculating the flux. The concentration of CO_2 molecules also rise over the time but are very similar in the three plots.

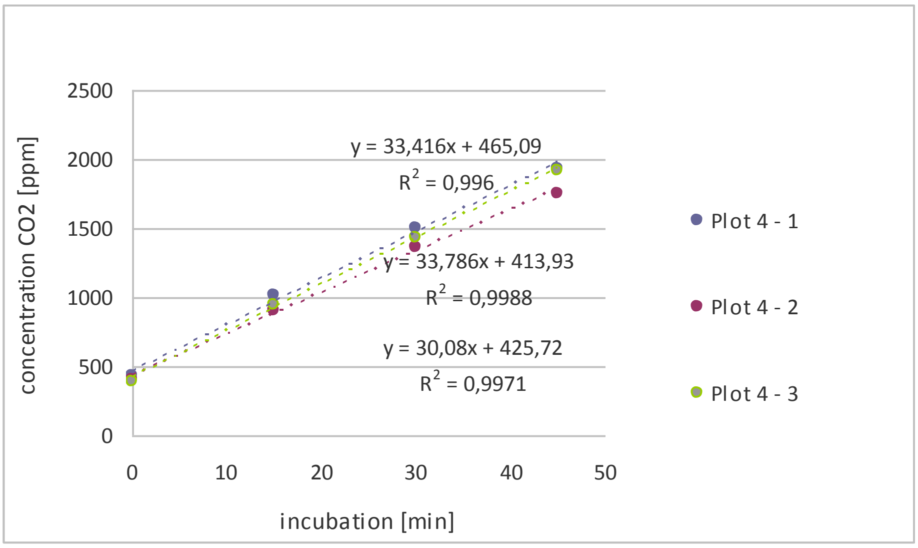

Fig. 2: CO_2 emissions site IV

The N_2O emissions for all the three plots are shown in figure 3. At the beginning the concentrations do not differ very much. Over the measurement time the three plot emissions also rise but in differing intensity. The slope of the regression line is again used to calculate the flux.

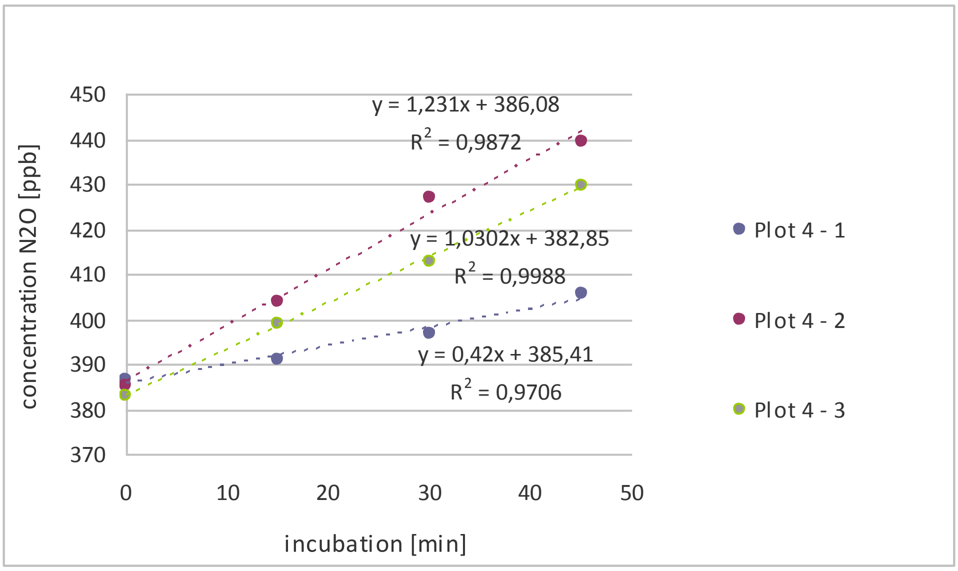

Fig. 3: N_2O [ppb] emissions site IV

In table 2 the fluxes of methane and laughing gas are shown. The fluxes of N_2O are less than the fluxes of CH_4 during the measurement of one hour.

Tab. 2 : Fluxes of CH_4 and N_2O for each plot of site IV

	Fluxes of CH_4 [mg m^{-2} h^{-1}]	**Fluxes of N_2O [mg m^{-2} h^{-1}]**
Plot 1	0,028709557	2,32193E-05
Plot 2	0,007488488	6,80548E-05
Plot 3	0,021112511	5,69537E-05

In table 3 (see in the attachment) the already calculated factors NEE, R_{eco} and GPP are given already calculated as a function of LAI, PAR, GWL and TL. This data was later used to generate diagrams to exemplify the data.

NEE (Nett Ecosystem Exchange) is the overall flux of CO_2. The positive fluxes are the ones which go to the atmosphere and the negative ones which come from the atmosphere. "NEE can be divided into the ecosystem respiration R_{eco} […] and the Gross Primary Production GPP." (Lengerer 2015)

Figure 4 shows R_{eco}, NEE, GPP and TL throughout the day. R_{eco} is increasing over the day following TL. NEE and GPP are decreasing over the day. GPP is always zero at night and gets negative during the day.

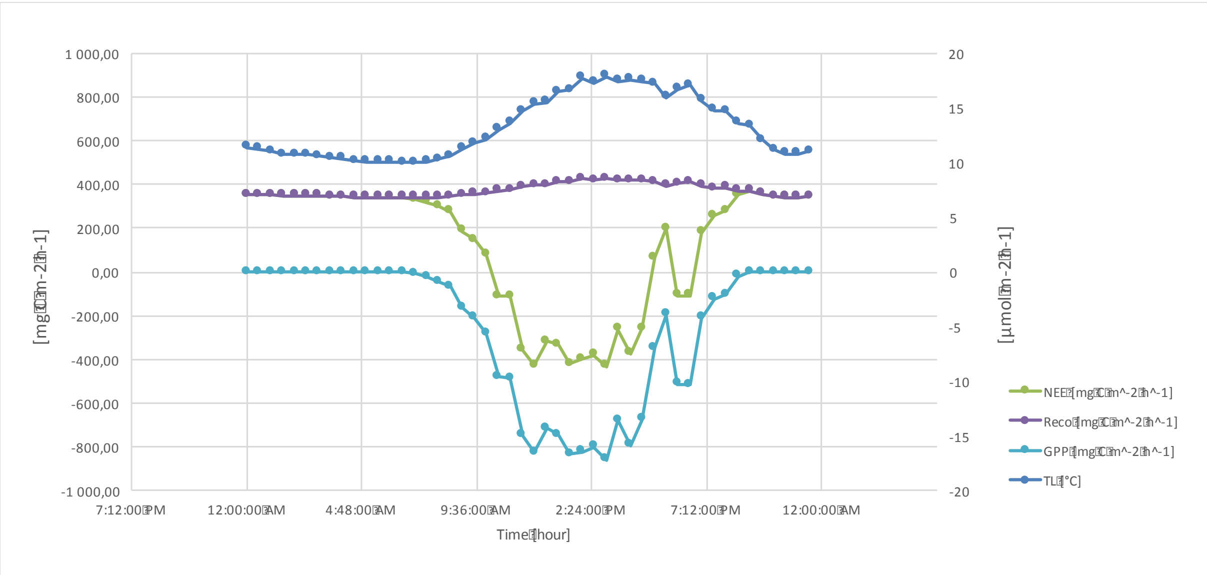

Fig 4: R_{eco}, NEE, GPP and TL over one day

Figure 5 shows R_{eco}, NEE, GPP and PAR over one day. R_{eco}, NEE and GPP are just the same as in figure 4 (because it depends on the same data). GPP is again always zero at night and gets negative during the day. PAR is increasing over the day.

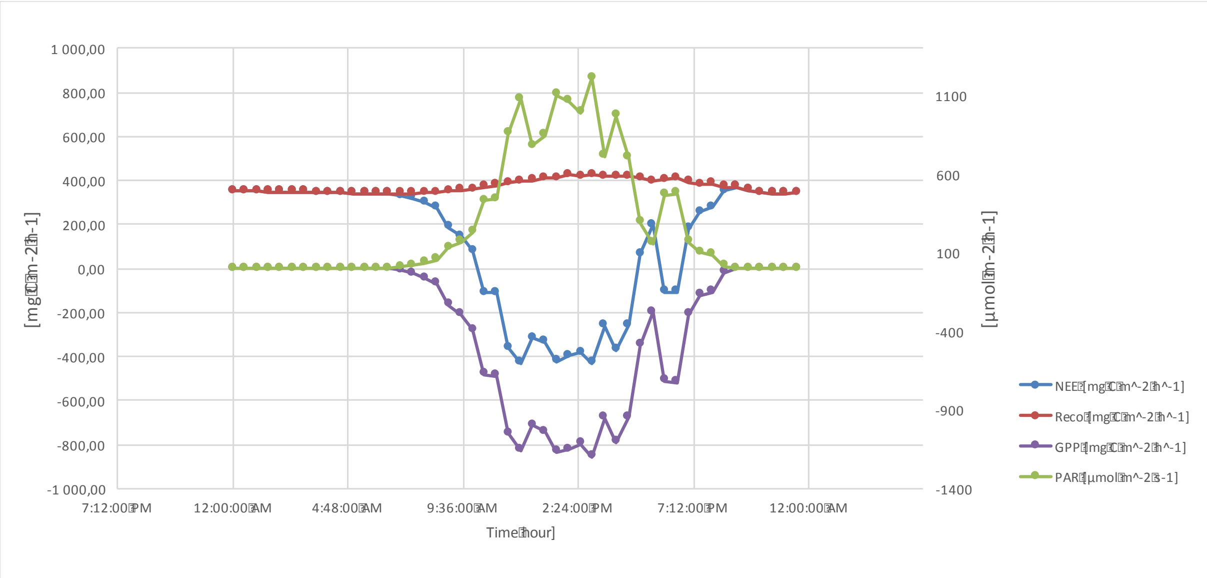

Fig. 5: R_{eco}, NEE, GPP and PAR over one day

For a final result the calculation of the daily fluxes and the translation of the fluxes to CO_2 equivalents are necessary. The daily fluxes are seen in table 4. CO_2 shows the highest flux amount, CH_4 a much lower amount and N_2O a very small amount. The daily fluxes have to be multiplied by the referring GWP 100 years, time horizon factor for getting the CO2 equivalents which are shown in table 6. The GWP factors are in table 5.

Tab 4: Daily fluxes of CO_2, CH_4 and N_2O

Daily flux CO_2 [g C m^{-2} d^{-1}]	**Daily flux CH_4 [g C m^{-2} d^{-1}]**	**Daily flux N_2O [g N m^{-2} d^{-1}]**
100,6994553	4,58484444	0,011858

Tab. 5: Conversion factors for the major greenhouse gases from IPCC AR 5 2013

Gas	**GWP 100 yrs. time horizon**
CO_2	1
CH_4	28
N_2O	265

Tab. 6: CO_2 equivalents for CO_2, CH_4 and N_2O

CO_2 [kg CO_2 eq ha^{-1} d^{-1}]	**CH_4 [kg CO_2 eq ha^{-1} d^{-1}]**	**N_2O [kg CO_2 eq ha^{-1} d^{-1}]**
100,699455	128,37564	3,142431

To compare the daily fluxes and the CO_2 equivalents the data is pictured in figure 6.

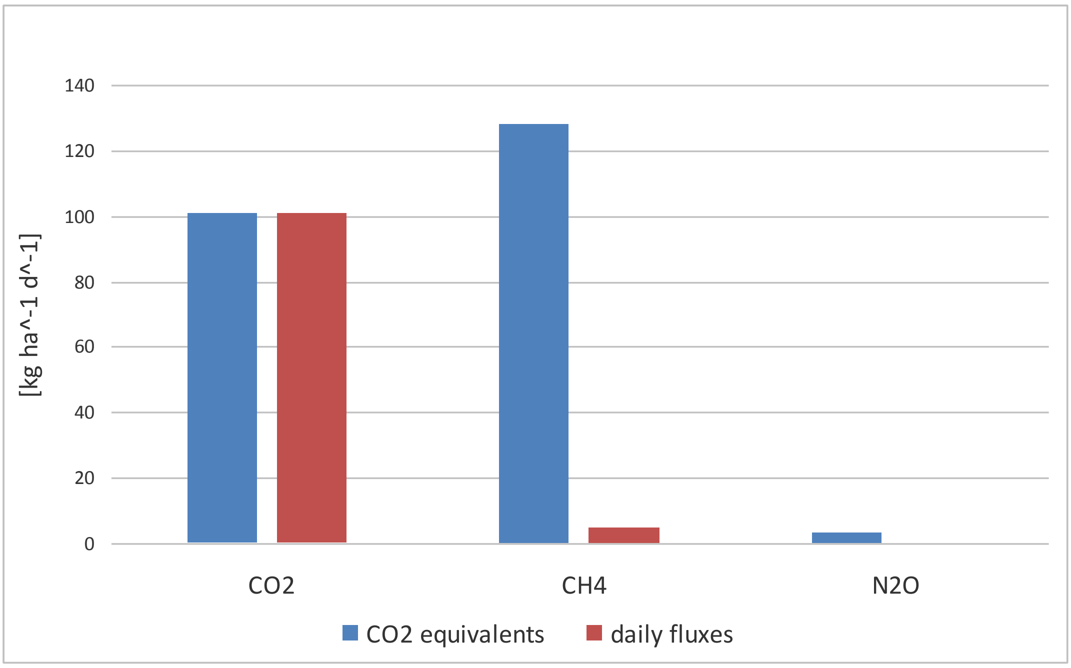

Fig. 6: GHG balance, showing daily gas fluxes and gas fluxes in CO_2 equivalents

So it is seen that the daily fluxes and the CO_2 equivalents from carbon dioxide are totally the same. It is evident to see, that little amount of CH_4 fluxes is linked to a great amount of CO_2 equivalents. For the N_2O the amount of the fluxes was just too small for the diagram to be pictured, but also the CO_2 equivalents are much higher so a bar can already be seen.

Discussion

The diagrams which show the outflow of all three plots for every greenhouse gas were necessary to calculate the flux. Therefore the slope of the regression line was required, but it is seen, that the slopes differ from each other over the three plots for one gas. The measurement field was heterogeneous, to avoid this bias, you have to measure the flux on several plots, so it would be the most representative. In fig 4 showing the relation of NEE and TL, it is shown that an increase of TL is inversely proportional to a decrease of NEE. The more NEE is negative the more the plot become a carbon sink. When NEE is getting positive the plot is a source of carbon. In this case NEE only depends on the course of Reco. In figure 5 where the association of NEE and PAR is pictured, it can be seen that an increase of PAR leads to a decrease of GPP and therefore to a decrease of NEE. Due to PAR photosynthesis takes place and so CO_2 of the atmosphere can be fixed which is seen in the increase of the GPP, it becomes more negative. Reco seems to be stable but follows the PAR variations; it is related to day and night cycle. When PAR has a strong value, we can see that NEE is inversely proportional to PAR. We can explain it by the fact that the more there is light the more there are exchanges. During the night there is no sun radiation, it explains the low exchanges. Reco is following the increase of PAR. The increased radiation leads the soil temperature to increase, also leads to a higher metabolism and thus to a higher respiration. That shows that the main factor is the cycle of day and night because there are no activities seen in the night, just when sun comes out at the day, there is activity seen. After calculating the daily fluxes and the referring CO_2 equivalents it is now possible to say something about the real effect of the greenhouse gases in the measurement site. It is seen that methane has a stronger impact than CO_2 because a little amount of methane shows a bigger impact to global warming than a huge amount of CO_2. The effect of N_2O is also much higher than its daily flux amount but still much smaller than CO_2 or CH_4, so in this specific measurement, N_2O has a minor impact on the global warming but over the year with different climate conditions it can have a severe impact. So the results in NEE and GWP are important to know to set up aims in the wetland management.

References

1. Alm J. et al., 2007. Methods for determining emission factors for the use of peat and peatlands – flux measurements and modeling. Boreal Environment Research, 12, pp.85-100
2. Andreas Langerer, 2015, course script: soil & water 2015 Uni Ulm practical course – topic 5 gas fluxes in wetland soils

Attachment

Tab. 3: The factors NEE, R_{eco} and GPP calculated as a function of LAI, PAR, GWL and TL

TL [°C]	LAI	GWL [m]	NEE [mg C m^-2 h^-1]	Reco [mg C m^-2 h^-1]	GPP [mg C m^-2 h^-1]
11,37	1,966667	-0,08833	351,928808	351,928808	0
11,25	1,966667	-0,08533	352,4599369	352,4599369	0
11,05	1,966667	-0,083	351,0240249	351,0240249	0
10,69	1,966667	-0,08233	347,568187	347,568187	0
10,73	1,966667	-0,08167	347,8714216	347,8714216	0
10,69	1,966667	-0,082	347,5388357	347,5388357	0
10,61	1,966667	-0,08333	346,7907213	346,7907213	0
10,41	1,966667	-0,084	344,8077234	344,8077234	0
10,37	1,966667	-0,084	344,432611	344,432611	0
10,17	1,966667	-0,08433	342,491682	342,491682	0
10,05	1,966667	-0,085	341,1825517	341,1825517	0
10,09	1,966667	-0,08533	341,4330881	341,4330881	0
10,05	1,966667	-0,086	340,7769995	340,7769995	0
9,97	1,966667	-0,08567	340,1861873	340,1861873	0
9,97	1,966667	-0,08633	330,6305654	339,872389	-9,241823568
10,05	1,966667	-0,08667	317,335163	340,4352322	-23,10006924
10,29	1,966667	-0,08667	298,80463	342,6682555	-43,86362557
10,61	1,966667	-0,08733	276,1091995	345,2811265	-69,17192703
11,21	1,966667	-0,08733	186,682305	351,0462689	-164,3639639
11,77	1,966667	-0,08733	146,0351343	356,616181	-210,5810467
12,13	1,966667	-0,088	79,43296642	359,8691321	-280,4361656
13,01	1,966667	-0,088	-112,2808129	369,3773647	-481,6581776
13,61	1,966667	-0,08833	-112,0187455	376,001894	-488,0206394
14,69	1,966667	-0,08867	-360,1149833	388,8452505	-748,9602338
15,37	1,966667	-0,08933	-429,5537285	397,0089624	-826,5626909
15,49	1,966667	-0,09067	-317,4765656	397,3747886	-714,8513543
16,45	1,966667	-0,09167	-334,1666402	409,2949674	-743,4616076
16,61	1,966667	-0,09267	-422,588806	410,4271424	-833,0159484
17,69	1,966667	-0,09367	-397,2459783	424,658739	-821,9047173
17,25	1,966667	-0,09433	-381,7502275	417,4951668	-799,2453943
17,85	1,966667	-0,094	-431,4415502	426,6054961	-858,0470462
17,41	1,966667	-0,09533	-261,3053825	418,5410682	-679,8464507
17,57	1,966667	-0,09667	-372,6919984	419,1095836	-791,801582
17,45	1,966667	-0,097	-257,8613181	416,9231845	-674,7845026
17,17	1,966667	-0,098	63,55313799	411,5355281	-347,9823901
15,93	1,966667	-0,09833	196,4024287	393,8998207	-197,497392
16,69	1,966667	-0,09833	-108,4837883	404,3047287	-512,788517
17,09	1,966667	-0,09867	-107,8441807	409,4664592	-517,3106399
15,69	1,966667	-0,098	180,5771993	391,158248	-210,5810487
14,77	1,966667	-0,09633	257,5842333	381,5118217	-123,9275884
14,73	1,966667	-0,09433	277,7980076	383,5626502	-105,7646425
13,57	1,966667	-0,09433	351,0149289	369,4965241	-18,48159524
13,41	1,966667	-0,093	369,2196662	369,2196662	0
12,05	1,966667	-0,09267	354,7130907	354,7130907	0
11,13	1,966667	-0,09267	345,4950536	345,4950536	0
10,81	1,966667	-0,093	342,0349186	342,0349186	0
10,81	1,966667	-0,093	342,0349186	342,0349186	0
11,01	1,966667	-0,09333	343,5719413	343,5719413	0

Tab7.: Daily factors for NEE, R_{eco} and GPP

Daily NEE [g m^{-2} d^{-1}]	**Daily R_{eco} [g m^{-2} d^{-1}]**	**Daily GPP [g m^{-2} d^{-1}]**
2,74634878	8,8949752	-6148626