DOI: 10.2478/jwld-2013-0008

JOURNAL OF WATER AND LAND DEVELOPMENT
J. Water Land Dev. 2013, No. 18 (I–VI): 65–72
PL ISSN 1429–7426

Available (PDF): www.itep.edu.pl/wydawnictwo; http://versita.com/jwld/

Received 19.11.2012
Reviewed 06.04.2013
Accepted 17.04.2013

A – study design
B – data collection
C – statistical analysis
D – data interpretation
E – manuscript preparation
F – literature search

The effect of an extensive use of meadow on moderately decomposed peat-muck soil on carbon balance

Janusz TURBIAK ABCDEF

Institute of Technology and Life Science, Kujawsko-Pomorski Research Centre, ul. Glinki 60, 85-174 Bydgoszcz, Poland; tel. +48 52 375-01-07, e-mail: J.Turbiak@itep.edu.pl

For citation: Turbiak J. 2013. The effect of an extensive use of meadow on moderately decomposed peat-muck soil on carbon balance. Journal of Water and Land Development. No. 18 p. 65–72.

Abstract

The study was aimed at estimating carbon balance in extensively used meadow ecosystem on moderately decomposed peat-muck soil. The balance was calculated from the measurements of CO_2 emission determined with the closed static chamber method using diffusion recorders. During the vegetation period, 88.5 Mg·ha^{-1} CO_2 were emitted from the meadow ecosystem while plants took up 65.9 Mg·ha^{-1} CO_2. Carbon losses associated with yield harvesting expressed in the CO_2 equivalent were 4.7 Mg·ha^{-1}. Total carbon losses during the vegetation period expressed as CO_2 amounted to 27.2 Mg·ha^{-1} on average for the whole study period. It means a loss of 7.4 Mg·ha^{-1} C or 13.2 Mg·ha^{-1} of organic matter of a carbon content of 56%. It was found that an extensive use of peat-muck soils increased carbon losses compared with moderately intensive use. Carbon losses in extensively used meadow ecosystems may be minimised by delaying the term of the first hay cut and by limiting the number of harvests.

Key words: *carbon balance, meadow ecosystem, net ecosystem exchange, total respiration*

INTRODUCTION

The decrease of cattle stock and demand for bulk fodder increased the area of extensively used meadows. According to WASILEWSKI [2009], the status of our meadows is now closer to natural lands and areas of ecological use than to productive agricultural lands that provide large amounts of valuable fodder. Extensive use of meadows resulted in a distinct decline of hay yields. In the years 1986–1990 mean hay yield was 6.02 Mg·ha^{-1} while in the years 2000–2008 – slightly more than 4 Mg·ha^{-1} on average. Only one cut is harvested on 24.2% of the total meadow area, mainly due to the need of mowing meadows to obtain areal subsidies and 17.4% of meadows are not used at all [WASILEWSKI 2009].

Extensive use of meadows is proposed in the Programme for the Development of Rural Areas. Agri-environmental programme aimed at protecting rare plant and animal species is realised within the project "The Improvement of Natural Habitat and Rural Areas" in a package "Extensive Grasslands". Recommendations contained in the package oblige beneficiaries to use permanent grasslands extensively, which means delayed hay harvest and limited application of mineral fertilisers.

It is important to estimate the effect of extensive use of post-bog soils on the rate of mineralization of organic matter accumulated there. Extensive use of soils decreases their biological activity and the rate of organic matter mineralization. Moreover, low level of fertilisation or its lack limits plant growth, which decreases organic matter input to soil and increases carbon deficit there.

In papers published so far, the effect of environmental factors such as ground water level, type of peat, land use (arable and meadow) [FRĄCKOWIAK 1980; GOTKIEWICZ, SZUNIEWICZ 1987; JURCZUK 2000; SZYMANOWSKI 1997] and climatic factors [CHOW *et al*. 2006; LOHILA *et al.* 2003; MALJANEN *et al*. 2004] on the rate of mineralization of organic matter was estimated. Poorly recognised is, however, carbon cycle in peat-muck soils of extensively used permanent meadows.

The aim of this study was to determine the effect of extensive use of meadow on moderately decomposed peat-muck soil on carbon balance.

STUDY OBJECTS AND METHODS

Studies were carried out in the object Minikowo situated in the Noteć River valley (53°08'59"N, 17°43'09"E), in kujawsko-pomorskie province. The object was covered by moderately decomposed peat-muck soil MtIIaa made of moss peat and classified to the wet (B) soil-moisture prognostic complex [OKRUSZKO 1979]. In the muck layer (0–20 cm) soil bulk density was 0.422 $Mg\cdot m^{-3}$, pH in KCl – 7.2, organic matter content 552 $g\cdot kg^{-1}$, and total nitrogen – 28 $g\cdot kg^{-1}$ dry mass. High pH was associated with the abundance of carbonates washed out of moraine hills situated at a distance 600 m. The meadow was extensively used without mineral fertilisation and with limited number of cuts. Only in the year 2010 the sward was mown twice – at the end of June and September. In other years only one harvest was collected – in 2008 and 2011 in the beginning of September and in 2009 – at the end of June.

Studies on the exchange of carbon between meadow ecosystem and atmosphere were carried out in the years 2008–2011. Measurements of CO_2 streams were usually made every ten days since mid-April till the end of October between 9:30 and 14:30 in two repetitions using two measurement sets. 15, 18 20 and 19 measurement cycles were made in the years 2008, 2009, 2010 and 2011, respectively. After CO_2 measurements, soil temperature at a depth of 10 cm, soil moisture (with the TDR probe) and ground water level (Tab. 1) were measured. Rainfalls and solar radiation (Tabs 1, 2) were recorded in the automatic meteorological station in Frydrychowo near Łabiszyn 23 km away from the study site.

Table 1. Mean values of selected habitat and meteorological parameters on the measurement dates in particular months and years

Period	Temperature of, °C		Soil moisture $m\cdot m^{-3}$	Ground water level cm	Hay yield $g\cdot m^{-2}$	Radiation $kW\cdot m^{-2}$
	soil	air				
Months						
IV	9.4	25.9	0.601	32.3	94	0.535
V	13.0	27.1	0.541	52.3	180	0.614
VI	17.9	34.9	0.460	71.8	218	0.672
VII	18.4	32.2	0.470	66.2	215	0.593
VIII	18.4	32.7	0.531	64.2	256	0.550
IX	14.9	25.2	0.547	68.5	213	0.493
X	9.3	14.8	0.595	54.5	165	0.285
Mean	**14.5**	**27.5**	**0.535**	**58.5**	**191**	**0.535**
Years						
2008	14.7	25.6	0.496	77.7	206	0.439
2009	14.0	27.5	0.525	75.2	203	0.592
2010	14.1	28.2	0.626	32.0	195	0.558
2011	15.1	28.9	0.492	49.2	161	0.549
Mean	**14.5**	**27.5**	**0.535**	**58.5**	**191**	**0.535**

Source: own studies.

Table 2. Monthly precipitation sums during the study period, mm

Year	Precipitation							Sum
	IV	V	VI	VII	VIII	IX	X	
2008	52.4	10.8	42.9	67.8	108.8	35.2	70.6	388.5
2009	28.8	23.8	66.4	45.4	7.8	0.4	42.4	215.0
2010	32.6	100.2	13.0	113.0	121.6	80.0	4.2	464.6
2011	8.2	38.1	100.6	99.8	19.1	19.5	10.4	295.7
1972–2003[1)]	25.0	44.0	58.0	76.0	49.0	44.0	36.0	332.0

Source: own studies and [1)] ŁABĘDZKI, KASPERSKA-WOŁOWICZ [2005].

Measurement of CO_2 exchange between meadow ecosystem and the atmosphere was carried out with the method of closed static chambers [LIVINGSTON, HUTCHINSON 1995]. The method consists in estimating the changes of gas concentration in a closed chamber installed on the soil surface.

Chamber of a size of 40×40×35 cm was made of transparent plexiglass and equipped with a fan (to maintain uniform gas concentration inside the chamber) and a valve that enabled levelling the pressure between the chamber and atmosphere. The chamber was placed in a square steel frame whose lower part was equipped with a 5 cm long blade pressed into the soil. The frame was pressed into the soil just before measurement. Tightness at the edge of the chamber and frame was obtained by filling the latter with water.

Diffusion meters Sense Air of a time constant of 2 min., reaction time of 15 s and gas flow of 0.2 $dm^{-3}\cdot min^{-1}$ were used for measuring CO_2 streams. The meters were equipped with recorders which recorded

CO_2 concentration and air temperature inside the chamber every minute. Two streams of CO_2 were measured – under solar radiation (to determine the net ecosystem exchange NEE) and after darkening the chamber with light impermeable cover (to determine the total ecosystem respiration TER) [ALM *et al.* 1997]. Two processes – photosynthesis and respiration – take place during the measurement of NEE. Depending on the predominance of one of these processes, the ecosystem may accumulate of emit CO_2. Therefore, NEE may be positive or negative.

Net ecosystem exchange allows for estimating whether sequestration or emission of CO_2 takes place in a given ecosystem. Based on NEE one cannot, however, conclude upon the actual amount of CO_2 photosynthesised by plants since the amount of CO_2 emitted from soil and above-ground plant parts is unknown during measurement. The parameter which estimates the total amount of CO_2 taken up by plants for photosynthesis in a time unit is gross photosynthesis (P_G) ($mg \cdot m^{-2} \cdot h^{-1}$). The gross photosynthesis was calculated from pairs of measurements of TER and NEE obtained in one measurement cycle according to equation:

$$P_G = \text{TER} - (\pm\text{NEE}) \tag{1}$$

Time of NEE measurement was 4–5 minutes, that of TER measurement – 5–6 minutes. Results of measurements in the first several minutes (when changes of CO_2 concentrations were linear) were used to estimate CO_2 flows. Under solar radiation, changes of CO_2 recorded from 1 to maximum 3 minutes were used, in the dark – those recorded from 2 to 4 minutes.

During measurements at solar radiation, air temperature in the chamber increased by ca. 3.0°C, accounting for time constant of the meter and time of CO_2 measurements (usually 1 minute). Changes in CO_2 concentration expressed in ppm were recalculated for $mg \cdot m^{-2} \cdot h^{-1}$ according to equation [MOSIER, MACK 1980]:

$$E = \rho \, V/A \, \Delta C/\Delta t \, 273/(T + 273) \tag{2}$$

where:

E – emission, $mg \cdot m^{-2} \cdot h^{-1}$;
ρ – gas density, $mg \cdot m^{-3}$;
V – chamber volume, m^3;
A – surface area of the chamber, m^2;
$\Delta C/\Delta t$ – mean rate of changes in the CO_2 concentration, $ppmv \cdot h^{-1}$;
T – temperature inside the chamber, °C.

Carbon balance in the vegetation season was estimated based on TER and P_G values. The amount of CO_2 taken up in the ecosystem ($Mg \cdot ha^{-1} \cdot month^{-1}$) was estimated by multiplying mean P_G ($mg \cdot m^{-2} \cdot h^{-1}$) in a given month by a factor 0.8 and by mean day length (h) and the number of days in this month. The amount of CO_2 emitted from the ecosystem ($Mg \cdot ha^{-1}$ $month^{-1}$) was a sum of CO_2 emission in days and nights. Emission in the night was calculated by multiplying mean TER ($mg \cdot m^{-2} \cdot h^{-1}$) in a given month by a factor of 0.7 and by mean night length (h) and the number of nights. Daily emission was calculated by multiplying TER by a factor of 0.8, by mean day length (h) and the number of days in a given month. Factors 0.8 and 0.7 were based on own studies which showed that mean P_G and TER in the day constituted 80% and mean TER in the night – 70% of emission measured between 9:30 and 14:30.

Carbon balance (B) in particular months ($Mg \cdot ha^{-1} \cdot month^{-1}$) was calculated as:

$$B = P_G + \text{TER} \tag{3}$$

Annual balance took into account the carbon losses associated with hay harvest. After ceasing measurements of NEE and TER the chamber was taken off and above-ground plant parts growing within the frame were cut. Harvested plants were dried at 40°C to determine hay yield. It was assumed that the content of absolutely dry mass in hay was 88% and carbon content in dry mass was 40%. Carbon content was recalculated to CO_2 according to equation:

$$M_{CO2} = 3.67 \, M_c \tag{4}$$

where:

M_{CO2} – CO_2 mass in $Mg \cdot ha^{-1}$;
M_C – C mass in $Mg \cdot ha^{-1}$.

RESULTS

Total respiration activity

Total respiration activity in the meadow ecosystem on moderately decomposed peat-muck soil ranged from 1940 $mg \cdot m^{-2} \cdot h^{-1}$ in 2008 to 2501 $mg \cdot m^{-2} \cdot h^{-1}$ in 2011 with the mean for the whole study period equal to 2217 $mg \cdot m^{-2} \cdot h^{-1}$ (Tab. 3). A higher respiration activity in 2011 compared with that in the years 2008–2010 was probably associated with more favourable rainfall distribution. In April and May 2011, despite relatively small precipitation, plants could use water retained in the soil profile. In June and July the sums of precipitation (ca. 100 mm, Tab. 2) created favourable conditions for plant growth.

The values of TER ranged from 399 $mg \cdot m^{-2} \cdot h^{-1}$ on 4th October 2008 to 4489 $mg \cdot m^{-2} \cdot h^{-1}$ on 30th July 2009 (Fig. 1). Distribution of the total respiration activity in the vegetation periods of the years 2008 and 2009 was close to normal. The lowest TER values were noted in the beginning and at the end of the vegetation season and the highest (about 4000 $mg \cdot m^{-2} \cdot h^{-1}$) in the middle of the season.

Table 3. Mean monthly values of the total ecosystem respiration (TER), mg·m^{-2}·h^{-1}

Month	TER				Mean
	2008	2009	2010	2011	
IV	1986±1184[1)]	2137±680	1367±1137	2455±1736	1986±205
V	1513±172	2024±1049	3172±464	3611±462	2580±204
VI	2309±195	2566±656	2834±1090	3545±499	2813±329
VII	3744±818	3630±1122	2582±386	2439±538	3099±137
VIII	2161±909	2649±135	2977±784	2577±398	2591±210
IX	1224±497	1883±366	1739±592	1920±941	1691±183
X	642±343	697±155	737±242	962±201	760±108
Mean	**1940±1059**	**2227±1031**	**2201±1055**	**2501±1121**	**2217±1065**

[1)] Mean value and standard deviation.
Source: own studies.

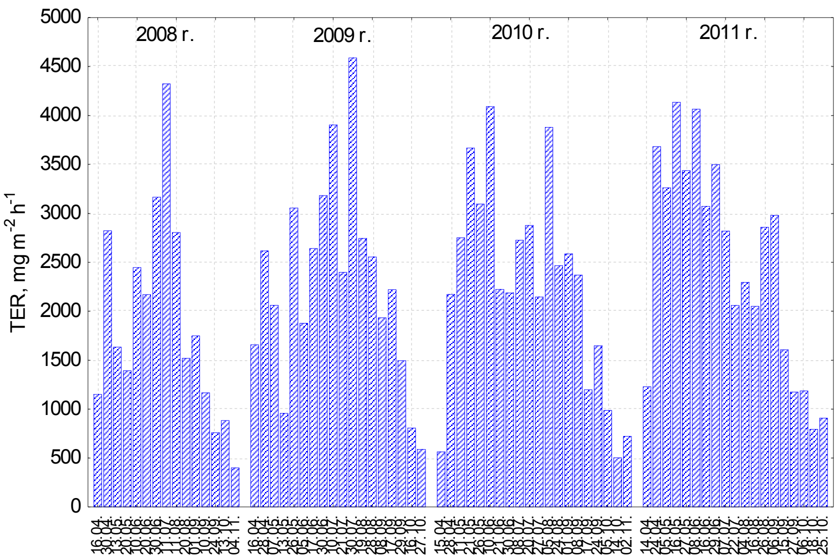

Fig. 1. Total ecosystem respiration (TER) on particular dates

Net ecosystem exchange

Mean ecosystem exchange for the whole study period was –289 mg·m^{-2}·h^{-1}. It means that the rate of CO_2 uptake by plants in the day was higher than the total ecosystem respiration. NEE was quite variable among years being equal to –11 mg·m^{-2}·h^{-1} in 2009 and –733 mg·m^{-2}·h^{-1} in 2011 (Tab. 4).

Substantial NEE variability was also noted among particular months of the vegetation season. Monthly mean NEE during the study period was –706 mg·m^{-2}·h^{-1} in April and 53 mg·m^{-2}·h^{-1} in June (Tab. 4). A high rate of decreasing CO_2 concentrations during measurements in April and also in May was associated with low respiration activity of the ecosystem in these months. CO_2 emission from soil was relatively low (especially in April), therefore plants took up CO_2 from air in the measurement chamber. Low values of NEE in June and July (–58 and 53 mg·m^{-2}·h^{-1},

Table 4. Monthly mean values of net ecosystem exchange (NEE), mg·m^{-2}·h^{-1}

Month	NEE in the year				Mean
	2008	2009	2010	2011	
IV	–706±44[1)]	–345±487	–384±525	–1390±93	–706±731
V	–476±503	–144±679	–530±27	–1260±322	–603±831
VI	477±169	–94±1030	710±843	–879±785	53±940
VII	–3±734	205±566	56±304	–489±466	–58±496
VIII	–347±686	214±84	–734±574	–115±1325	–246±435
IX	–29±725	57±145	–490±383	–531±735	–248±422
X	–210±588	33±244	–229±451	–471±123	–219±165
Mean	**–185±565**	**–11±519**	**–229±625**	**–733±664**	**–289±649**

[1)] Mean value and standard deviation.

Source: own studies.

respectively, Tab. 4) were mainly caused by increased respiration activity of the soil.

The values of NEE on particular dates ranged from –1627 to 1630 mg·m^{-2}·h^{-1} (Fig. 2). Minimum NEE was noted on 27.05.2011 at a large biomass of young plants and a high intensity of solar radiation while the maximum NEE was recorded on 21.06.2010 just after grass mowing, so at a lack of photosynthesis and high respiration activity of root systems and rhizosphere microorganisms.

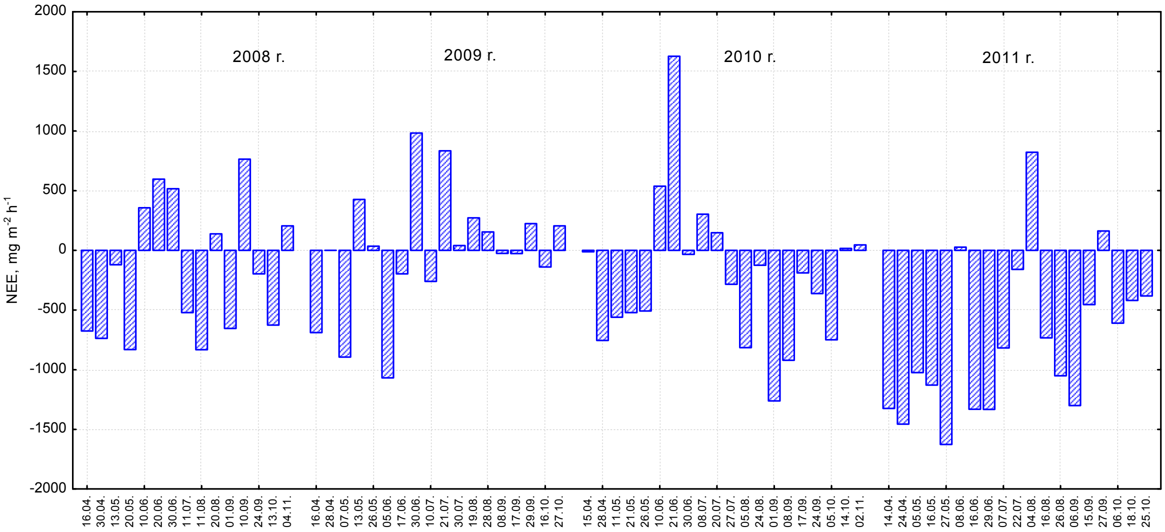

Fig. 2. Net ecosystem exchange values (NEE) on particular dates of the growing season

Gross photosynthesis

Mean P_G for the whole study period was 2489 mg·m^{-2}·h^{-1}. In the years 2008–2010 mean values of gross photosynthesis were similar (Tab. 5) while that for the year 2011 was much larger and amounted to 3235 mg·m^{-2}·h^{-1}. This was probably associated with moisture conditions optimum for this process.

Table 5. Mean monthly values of gross photosynthesis (P_G), mg·m^{-2}·h^{-1}

Month	Gross photosynthesis				Mean
	2008	2009	2010	2011	
IV	2692±982[1)]	2482±154	1751±1330	3845±1463	2692±1055
V	1988±265	2168±1136	3702±358	4871±414	3182±1138
VI	1831±291	2661±323	2123±1185	4424±318	2760±1023
VII	3747±1242	3425±1300	2526±140	2927±803	3156±927
VIII	2508±1276	2436±41	3220±847	2692±1379	2714±937
IX	1253±826	1825±402	2229±777	2451±1334	1940±855
X	852±745	664±319	966±538	1433±253	979±459
Mean	**2125±993**	**2237±883**	**2360±1008**	**3235±1217**	**2489±1070**

[1)] Mean value and standard deviation.
Source: own studies.

Monthly mean gross photosynthesis from April till August changed from 2692 to 3156 mg·m^{-2}·h^{-1} (Tab. 5). Despite the fact that the biomass of aboveground plant parts in April was over two times smaller than that between May and August, photosynthesis in April was only slightly smaller. It appears that the rate of CO_2 uptake by young plants in the beginning of the vegetation season was highest. Maximum gross photosynthesis was noted in May and smaller in June, which probably resulted from water deficits and hay harvest in June of the years 2009 and 2010. Mean soil moisture in June (0.46 m·m^{-3}) was the lowest in the whole vegetation period. The efficiency of photosynthesis markedly decreased in August, September and October (Tab. 5) mainly because of decreasing solar energy (Tab. 1).

Recorded mean gross photosynthesis was by 18.4% smaller than that on similar soil overgrown by meadow mown three times in the Frydrychowo object where plants took up 3051 mg $CO_2 \cdot m^{-2} \cdot h^{-1}$ on average in the years 2008–2011 [TURBIAK 2012].

Carbon balance

Carbon balance was calculated from gross photosynthesis dealt with as an input to the ecosystem and total ecosystem respiration dealt with as a loss from the ecosystem. Despite adopted simplifications, presented balance allows for estimating approximate carbon cycle in meadow ecosystem and conditions and terms at which inputs or losses are biggest.

During the vegetation period, meadow plants took up –65.9 Mg $CO_2 \cdot ha^{-1}$, on average, while CO_2 emission was 88.5 $Mg \cdot ha^{-1}$. It means that mean CO_2 losses in the vegetation season were 22.5 $Mg \cdot ha^{-1}$. Considering losses associated with hay harvest, total mean carbon losses expressed as CO_2 were 27.2 $Mg \cdot ha^{-1}$. This is equivalent to a loss of 7.4 $Mg \cdot ha^{-1}$ of carbon or 13.2 $Mg \cdot ha^{-1}$ of organic matter containing 56% of carbon during vegetation season.

Carbon losses from the meadow on peat-muck soil in the Noteć River valley were almost two times larger than those from meadow on peat soil in Finland (330 $g \cdot m^{-2} \cdot y^{-1}$ or 12.1 Mg $CO_2 \cdot ha^{-1} \cdot y^{-1}$) but similar to those from arable peatland in Finland [MALJANEN *et al.* 2004]. The latter amounted to 830 g C-$CO_2 \cdot m^{-2} \cdot y^{-1}$ (30.5 Mg $CO_2 \cdot ha^{-1}$) lost from barley crop.

The largest CO_2 losses were noted in 2009 and 2010 – 32.5 and 31.9 $Mg \cdot ha^{-1}$, respectively. In 2009 the sward was cut in June and in 2010 two cuts were harvested in June and in September. The years differed in the sum of rainfall in the vegetation period which equalled 215 mm in 2009 and 464 mm in 2010 (Tab. 2). These results might indicate that when nutrients were limited both water deficit and excess in the soil resulted in limited regrowth of sward after mowing and thus limited photosynthesis and worsened CO_2 balance.

The smallest CO_2 losses were noted in the years of average sums of precipitation (2008 and 2011) when only one hay harvest (18.2 and 26.0 $Mg \cdot ha^{-1}$, respectively) in September was made. The presence of meadow sward during the whole vegetation period supplemented carbon losses that occurred in the process of organic matter mineralization. One may conclude that in order to restrict carbon losses from extensively used meadow ecosystems one should limit the number of cuts to one performed at the end of the vegetation season.

CO_2 losses were noted in all months of the vegetation season, the largest in June, July and August – 4.4, 4.9 and 4.3 $Mg \cdot ha^{-1}$, respectively. The smallest CO_2 losses were recorded in the beginning and at the end of the vegetation period i.e. in April and October – 1.8 and 1.6 $Mg \cdot ha^{-1}$, respectively (Tab. 6). Large carbon losses in the summer months were associated with better soil aeration due to the decline of ground water level and higher soil temperature in the middle than in the beginning and at the end of the vegetation season.

Comparison of carbon balance parameters presented in this paper with results from a meadow cut three times [TURBIAK 2012] shows that the respiration in extensively used meadow was slightly smaller, by 2.3 Mg $CO_2 \cdot ha^{-1}$ (2.5%), than that in moist meadow of moderately intensive use. Gross photosynthesis was, however, much smaller, by 13.0 Mg $CO_2 \cdot ha^{-1}$ (16.5%), in the former than in the latter. It was found that in extensively used meadow, carbon losses, including the amount of carbon in hay, expressed in CO_2 were by 5.4 $Mg \cdot ha^{-1}$ (by 24.8%) larger than in meadow of moderately intensive use (Tab. 7). Therefore, one may conclude that the extensive use of peat-muck soils increased carbon losses. This was associated with nutrient deficits in soils which limited plant growth and, consequently, the gross photosynthesis.

Table 6. CO_2 balance in particular years, $Mg \cdot ha^{-1}$

Parameter	Month	Year				Mean
		2008	2009	2010	2011	
P_G	IV	–9.0	–8.3	–5.9	–12.9	–9.0
	V	–7.8	–8.5	–14.5	–19.1	–12.5
	VI	–7.4	–10.8	–8.6	–24.4	–12.8
	VII	–15.0	–13.9	–10.3	–11.9	–12.8
	VIII	–9.2	–8.9	–13.5	–9.8	–10.4
	IX	–3.8	–5.6	–6.8	–7.5	–5.9
	X	–2.2	–1.7	–2.5	–3.8	–2.6
	Sum	**–54.5**	**–57.7**	**–62.1**	**–89.4**	**–65.9**
TER	IV	10.8	11.7	7.5	13.4	10.8
	V	8.6	11.5	18.1	20.6	14.7
	VI	12.8	14.2	15.7	26.1	17.2
	VII	21.1	20.7	14.8	13.9	17.6
	VIII	12.2	15.0	16.9	14.6	14.7
	IX	6.6	10.2	9.4	10.4	9.2
	X	3.6	3.9	4.1	5.3	4.2
	Sum	**75.8**	**87.3**	**86.4**	**104.4**	**88.5**
Balance = P_G + TER	IV	1.8	3.3	1.6	0.5	1.8
	V	0.8	3.0	3.5	1.4	2.2
	VI	5.4	3.5	7.1	1.7	4.4
	VII	6.1	6.8	4.5	2.1	4.9
	VIII	3.1	6.1	3.3	4.8	4.3
	IX	2.8	4.6	2.6	2.9	3.3
	X	1.3	2.1	1.5	1.6	1.6
	Sum	**21.3**	**29.5**	**24.2**	**15.0**	**22.5**
CO_2 from yield		**4.7**	**3.0**	**7.7**	**3.2**	**4.7**
B = P_G + TER + CO_2 from yield		**26.0**	**32.5**	**31.9**	**18.2**	**27.2**

Source: own studies.

Table 7. Comparison of CO_2 balance ($Mg \cdot ha^{-1}$) in grassland ecosystems depending on the intensity of their use

Use system	P_G	TER	CO_2 from yield	Balance
Extensive	–65,9	88,5	4,7	27,2
Moderately intensive[1)]	–78,9	90,8	9,8	21,8

Source: own studies and [1)] TURBIAK [2012].

CONCLUSIONS

1. Mean respiration of extensively used meadow ecosystem on peat-muck soil classified to wet soil-moisture prognostic complex was 2217 $mg \cdot m^{-2} \cdot h^{-1}$ in the years 2008–2011. The values of TER ranged from 399 to 4489 $mg \cdot m^{-2} \cdot h^{-1}$. The ecosystem emitted 88.5 Mg $CO_2 \cdot ha^{-1}$ in the whole vegetation period.

2. Gross photosynthesis of extensively used meadow ecosystem depended on the status of meadow sward, intensity of solar radiation and soil moisture. Mean gross photosynthesis was 2489 $mg \cdot m^{-2} \cdot h^{-1}$. In the whole vegetation season plants took up 65.9 Mg $CO_2 \cdot ha^{-1}$.

3. Extensively used meadow ecosystem on peat-muck soil was a CO_2 emitter. Mean carbon losses in the vegetation season expressed in CO_2 amounted to 27.2 $Mg \cdot ha^{-1}$ in the study years. It means a loss of 7.4 $Mg \cdot ha^{-1}$of carbon or 13.2 $Mg \cdot ha^{-1}$ of organic matter containing 56% of carbon.

4. Carbon losses in extensively used meadow ecosystems may be decreased by delaying the first hay harvest and by limiting the number of cuts.

5. Extensive use of peat-muck soils increased carbon losses compared with moderately intensive use. This was associated with nutrient deficit which limited plant growth and, consequently, the amount of CO_2 taken up for photosynthesis.

REFERENCES

ALM J., TALANOV A., SAARNIO S., SILVOLA J., IKKONEN E., AALTONEN H., NYKÄNEN H., MARTIKAINEN P. 1997. Reconstruction of the carbon balance for microsites in a boreal oligotrophic pine fen, Finland. Oecologia. Vol. 110 p. 423–431.

CHOW A.T., KENNETH K.T., GAO S., DAHLGREN R.A. 2006. Temperature, water content and wet-dry cycle effects on DOC production and carbon mineralization in agricultural peat soil. Soil Biology and Biochemistry. Vol. 38 p. 477–488.

FRĄCKOWIAK H. 1980. Dynamika i wielkość mineralizacji związków azotowych w dawno odwodnionych glebach torfowo-murszowych na tle warunków siedliskowych i nawożenia [Dynamics and amount of nitrogen mineralization in long ago drained peat-muck soils in relation to habitat conditions and fertilisation]. Falenty. IMUZ rozpr. habil. pp. 136.

GOTKIEWICZ J., SZUNIEWICZ J. 1987. Przeobrażanie się siedlisk i gleb w rejonie doświadczenia agrotechnicznego. W: Wyniki 25-letniego stałego doświadczenia nad porównaniem wpływu sposobu użytkowania i nawożenia na glebę torfową w Zakładzie Doświadczalnym Biebrza [Transformation of habitats and soils in the area of agrotechnical experiment. In: Results of a 25-year permanent experiment on the effect of land use and fertilisation on peat soil in the Biebrza Experimental Farm]. Biblioteczka Wiadomości IMUZ. Nr p. 33–41.

JURCZUK S. 2000. Wpływ regulacji stosunków wodnych na osiadanie i mineralizację gleb organicznych [The effect of regulation of water relations on subsidence and mineralization of organic soils]. Biblioteczka Wiadomości IMUZ. Nr 96. ISSN 0519-7864 pp. 116.

LIVINGSTON G.P., HUTCHINSON G.L. 1995. Enclosure-based measurement of trace gas exchange: applications and sources of error. In: Biogenic trace gases: measuring emissions from soil and water. Eds. P. Matson, R. Harriss. Oxford. Blackwell Scientific p. 14–51.

LOHILA A., AURELA M., REGINA K., LAURILA T. 2003. Soil and total ecosystem respiration in agricultural fields: effect of soil and crop type. Plant and Soil. Vol. 251 p. 303–317.

ŁABĘDZKI L., KASPERSKA-WOŁOWICZ W. 2005. Zmienność warunków meteorologicznych i ewapotranspiracji użytków zielonych w dolinie Górnej Noteci w latach 1972–2003. W: Rola stacji terenowych w badaniach geograficznych [Variability of meteorological conditions and grassland evapotranspiration in the upper Noteć river valley in 1972–2003]. Eds. K. Krzemień, J Trepińska., A. Bokwa. Kraków. Wydaw. UJ. p. 238–246.

MALJANEN M., KOMULAINEN V. M., HYTONEN J., MARTIKAINEN P.J., LAINE J. 2004. Carbon dioxide, nitrous oxide and methane dynamics in boreal organic agricultural soils with different soil characteristics. Soil Biology and Biochemistry. Vol. 36. Iss. 11 p. 1801–1808.

MOSIER A.R., MACK L. 1980. Gas-chromatographic system for precise, rapid analysis of nitrous-oxide. Soil Science Society of America Journal. Vol. 44 p. 1121–1123.

OKRUSZKO H. 1979. Zasady prognozowania warunków wilgotnościowych w glebach hydrogenicznych według koncepcji kompleksów wilgotnościowo-glebowych. W: Kompleksy wilgotnościowo-glebowe w siedliskach hydrogenicznych i ich interpretacja przy projektowaniu melioracji i zagospodarowania [Principles of predicting moisture conditions in hydrogenic soils according to the concept of soil-moisture complexes. In: Soil-moisture complexes in hydrogenic habitats and their interpretation when designing reclamation and management]. Biblioteczka Wiadomości IMUZ. Nr 58 p. 4–20.

SZYMANOWSKI M. 1997. Wstępna ocena tempa mineralizacji różnie odwodnionych gleb torfowych metodą częściowo izolowanych próbek [Preliminary assessment of the rate of mineralization in variously drained peat soils with the method of partly isolated samples]. Wiadomości IMUZ. T. 19. Z. 2 p. 43–60.

TURBIAK J. 2012. Bilans węgla w ekosystemie łąkowym na średnio zmurszałej glebie torfowo-murszowej [Carbon balance in meadow ecosystem on moderately decomposed peat-muck soil]. Woda-Środowisko-Obszary Wiejskie. T. 12. Z. 4 (40) p. 281–294.

WASILEWSKI Z. 2009. Stan obecny i kierunki gospodarowania na użytkach zielonych zgodne z wymogami wspólnej polityki rolnej [Present status and management of grasslands according to the requirements of the common agricultural policy]. Woda-Środowisko-Obszary Wiejskie. T. 9. Z. 2 (26) p. 169–184.

Janusz TURBIAK

Wpływ ekstensywnego użytkowania łąki na średnio zmurszałej glebie torfowo-murszowej na bilans węgla

STRESZCZENIE

Słowa kluczowe: *bilans węgla, ekosystem łąkowy, ogólna aktywność respiracyjna, wymiana ekosystemu netto*

Celem badań było określenie bilansu węgla w ekstensywnie użytkowanym ekosystemie łąkowym na średnio zmurszałej glebie torfowo-murszowej. Bilans węgla obliczono na podstawie pomiarów strumieni emisji CO_2 oznaczanych metodą komór zamkniętych statycznych, z wykorzystaniem mierników dyfuzyjnych. W okresie wegetacyjnym z ekosystemu łąkowego emitowane było 88,5 Mg $CO_2 \cdot ha^{-1}$, natomiast rośliny pobierały 65,9 Mg $CO_2 \cdot ha^{-1}$. Straty węgla związane ze zbiorem plonu, wyrażone w ekwiwalencie CO_2, wynosiły 4,7 $Mg \cdot ha^{-1}$. Łączne straty węgla w sezonie wegetacyjnym, wyrażone w ekwiwalencie CO_2, wynosiły średnio w okresie badań 27,2 $Mg \cdot ha^{-1}$. Oznacza to ubytek 7,4 $Mg \cdot ha^{-1}$ węgla lub stratę 13,2 $Mg \cdot ha^{-1}$ masy organicznej o zawartości 56% węgla. Stwierdzono, że ekstensywne użytkowanie gleb torfowo-murszowych powodowało większe straty węgla w porównaniu z użytkowaniem średnio intensywnym. Straty węgla w ekstensywnie użytkowanych ekosystemach łąkowych można zmniejszyć przez opóźnienie terminu zbioru pierwszego pokosu siana oraz ograniczenie liczby pokosów.