Extended abstract No. 234 and 237

THE CARBON BALANCE UNDER DIFFERENT AGRICULTURAL REGIMES OF DRAINED PEATLAND IN UKRAINE

A. Mykytiuk, R. Truskavetsky, S. Truskavetsky

Alexander Mykytiuk, Dr.: Ukrainian Society for the Protection of Birds, Luteranska str. 21/12, 01024 Kyiv, Ukraine; Aleksander.Mykytyuk@birdlife.org.ua,; + 380677547853,
Roman Truskavetsky, Dr. Sc.Agr. Stanislav Truskavetsly, Can. Sc.

KEY WORDS: peat soil, drainage peatland, carbon balance, agricultural regimes, Ukraine

SUMMARY

Authors of this paper want to draw the attention of foreign researchers to Ukrainian scientific findings on the problems of contemporary evolution and depletion of drained peatlands. Measurements were made in pilot sites on drained slightly acid low-ash fen situated in the Northwest part of Ukraine. Regularities of anthropogenic change have been studied in areas of perennial grasses, meadow-field and tilled-crop rotations. Studies were conducted in both unfertilized and fertilized sites. Improving the methodology for carbon balance accounting should be considered as a crucial task of modern times. Regularity in the modern evolution of drained fen was found during observations on our pilot sites. It shows itself in the intensity of peat subsidence and depletion. However, such evolutionary alterations in the drained fen strongly depend on the conditions and land-use. The process of peat subsidence and depletion are the most intensive on unfertilized lands with tilled crops during the first years after drainage. Well-developed herbage cover creates optimal conditions for minimizing the intensity of these processes and particularly in losses of organic carbon. The results of our long-term studies show a significant depletion of carbon stocks in a pool of drained fen in unfertilized sites with tilled crops. Losses of dry peat mass have a similar pattern. Rates of peat subsidence and carbon losses are especially high in the first years of fen use but decrease over time.

INTRODUCTION

The large-scale drainage of peatlands in the second half of last century has altered the carbon balance in peatland ecosystems of Ukraine. Peatlands of Ukraine are mainly located in the southern edges of the band of peatlands extending across Eastern Europe. Formed in a warmer climate and being older than their northern counterparts, peatlands of Ukraine, unlike many northern ones, have reached their equilibrium state, including a steady state of carbon balance. Economic activities have abruptly upset this balance, causing it to become negative. Many researchers (Bradis *et al*. 1973, Tanovitsky 1980, Succow & Jeschke 1990, Bambalov&Rakovich 2005, Truskavetsky 2010) also point to the disappearance of some valuable species of plants and animals, to landscape wide biodiversity depletion, and to desertification. All of these negative phenomena are due, above all, to the large-scale drainage of wetlands and marshes which was carried out in Ukraine between 1965-1990. During this period, the total area of drained hydromorphic soils has been increased to 3,170,000 ha, out of which 825,000 ha is drained peatland which cover 1,077,000 ha agricultural land and constitute 77% of the total area of peatlands. For Ukraine, there was no need for such a continuous and extensive drainage of these ecologically fragile natural areas, as the country has a high potential of soil resources. As a result of drainage, the maximum losses of soil carbon occurred in 1990, when the area of drained land in Ukraine reached its peak. Intense mineralization and greenhouse gas emissions from drained peatlands have not been ceased since then. Moreover, they have increased over the last few years because of climate warming. Peat fires are also more frequent now causing large scale environmental damage. Literature analysis (Kleber 1994, Lal *et al*. 2005, Joosten & Augustin 2006, Zavarzin *et al.* 2007, Han&Li 2010) shows that the accounting and estimation of carbon balance in ecosystems can be performed by using two methodological approaches:

- continuous carbon mass measurements in all ecosystem's gas fluxes which constitute inputs and outputs to the soil carbon pool in an ecosystem;
- direct measurements of carbon stocks in dynamic pools of carbon stable compounds that are made at periodic intervals, with the main determinants of carbon balance of these pools taken into account.

Carbon balance accounting and assessment based on gas fluxes are too challenging because of the high temporal and spatial oscillations of gas composition of these fluxes. Therefore, improving the methodology for carbon balance accounting and assessment should be considered as a crucial task of modern times. Many researchers (Lal *et al*. 2005, Zavarzin *et al*. 2007, Han&Li 2010) do not support an idea of a unified methodology that should be compulsory for all countries. Each country has a right to examine existing foreign methodological approaches, to consider and adapt them to national conditions in accordance with the specific nature of local ecosystems, their state and purposes of use. International experience of accounting the losses of carbon soil emissions is very valuable. There is no such experience in Ukraine. Nevertheless, authors want to draw the attention of foreign researchers to Ukrainian scientific findings on the problems of contemporary evolution and depletion of drained peatlands.

OBJECTS AND METHODS

In order to solve the problem of carbon balance accounting and assessment, we have chosen the second methodological approach – the approach of direct measurements of peat subsidence and carbon stocks in peat soil which are made at certain intervals during peatland use. These measurements were made in pilot sites launched in 1964 on drained slightly acid low-ash fen of the Tcyr river floodplain which is situated near Vorokomle village in the Kamen-Kashirsky district of the Volyn region. The studied fen is one of the most representative and common peatlands in the Ukrainian Polesie. This area is predominantly represented by eutrophic fens with a low and moderate ash content (8-15% by mass) and mostly slightly or moderately acid reactions, and underlain by sand deposits. Regularities of anthropogenic change have been studied in areas of perennial grasses, meadow-field and tilled-crop rotations. Studies were conducted in both unfertilized and fertilized sites with annual application of P_{45-60} K_{120} and one application of 20 kg/ha $CuSO_4$ $5H_2O$ over four years. The high precision determination of two main parameters, a peat bulk density and a thickness of each stratiphigrafical layer of peatland, is necessary for getting an objective carbon balance. Such accuracy determines the reliability of all subsequent carbon balance calculations. Parameters of peat stratigraphy were obtained by periodical detailed probing in sampling points in the study area with the use of a peat corer constructed by the Moscow Peat Institute. The bulk density of peat layer was determined after harvesting crops in autumn when parameter stability had reached its maximum
The carbon balance was calculated using the "soil-pool model" and the following equation:

$$\Delta C = Ct_i - (Ct_0 + Ct) \quad , \qquad (1)$$

Where ΔC – losses (-) and increase (+) in carbon stocks in the soil pool during the calculation period; Ct_i – carbon stocks at the end of calculation period; Ct_0 – carbon stocks at the beginning of calculation period; Ct – carbon stocks in dry peat mass, involved into the process of soil formation during calculation period t.
Total carbon stocks in the peat soil in given period of observations (t_0 and t_i) were calculated as follows:

$$C_{total} = V \times p \times c\ , \qquad (2)$$

Where C_{total} – total carbon stocks in the peat soil, t/ha; V – volume of estimated peat layer, m^3/ha (in our calculations, this volume was 8000 m^3/ha); ρ – weighted average bulk density of the peat soil t/m^3; c – weighted average organic carbon content in the peat soil, % by mass.
If there is no empiric data on organic carbon content, a factor for conversion of organic matter to carbon can be applied (Table 1) using the equation:

$$\tilde{n}_{\text{з}} = H \times k\ , \qquad (3)$$

Where c_i – organic carbon content in estimated peat layer; H – organic matter content in estimated peat layer; k – factor for conversion of organic matter to carbon.

FINDINGS AND DISCUSSION

Organic matter conversion was strongly correlated with human induced land use change and statistically significant parameters in the carbon balance in drained fen were witnesses over comparatively short observation times. The evolution of drained peatlands depends on the duration and conditions of peatland use, changes in meteorology, and original nature of organic matter. The processes of organic matter destruction and synthesis occur mainly in the aerated top layer of peatland or, in other words, in the peat soil. The deeper the ground water and the thicker the aerated peat layer, the faster peat is mineralized, actively generating and releasing carbon dioxide into the atmosphere. Therefore, following the classification proposed by Skrynnikova I.N. (Skrynnikova 1961), a drained peatland should be divided into two parts: the top and well-aerated peat soil and the bottom peat-organogenic rock. The processes of intensive organic mass conversion, its mineralization and CO_2 emission occur in the peat soil; they constitute losses in the soil carbon pool. The main inputs in the soil carbon pool include an enhancement of a soil carbon pool due to sequestration of carbon from plant residues and an inclusion of carbon from peat-organogenic rock into the process of soil formation. This rock remains almost unchanged after the drainage period. But over the course of time, more parts of the underlying peat-organogenic rock become involved in soil formation as a result of organic matter decomposition, peat soil shrinkage and the deepening of the drainage system. These parts can be evaluated using the values of peat subsidence during the calculation period and the bulk density of the peat-organogenic rock top layer at the beginning of the calculation period.

Table 1. Factors for conversion of peat organic matter to carbon

Peat humification degree	Class on the Von Post scale	Conversion factor
Low	H_3 - H_4	0,525
Moderate	H_5 – H_6	0,540
High	H_7 – H_8	0,555
Very high	H_9 – H_{10}	0,570

Observing the dynamics of main peat parameters (bulk density, ash content, total carbon, and carbon of humic substances) in pilot sites, we found evidence that very few changes have occurred in the relative content of total organic carbon per unit of dry peat mass during the 28-year period of using the fen's peat soil (Table 2).

Table 2. Dynamic of the main parameters of peat soil under different agricultural regimes (average data for 0-30 cm layer)

Land use	Parameters	Baseline data (1964)	Duration of use, years		
			7	14	28
Perennial grasses	Bulk density, g/cm^3	0,176	0,229* 0,234	0,238 0,251	0,249 0,262
	Ash content, % by mass	8,5	9,4 9,8	10,1 10,5	11,6 12,4
	C total**, % by mass	49,5	48,8 not determined	48,0 50,2	48,2 49,5
	C h.s.***, % of C total.	19,4	not determined	22,8 23,5	28,6 31,4
Grassland-crops rotation	Bulk density, g/cm^3	0,186	0,230 0,240	0,258 0,272	0,264 0,283
	Ash content, % by mass	8,9	9,6 10,2	10,7 10,9	12,4 12,6
	C total, % by mass	49,8	48,4 not determined	47,9 48,8	48,0 49,2
	C h.s., % of Ctotal	20,2	not determined	23,6 24,2	32,2 31,9

* above the line –unfertilized sites; below the line – fertilized sites;
** C total. – total organic carbon
*** C h.s. – carbon of humic substances

Evolutionary alterations in the drained fen strongly depend on the conditions and land-use. The process of peat subsidence and depletion are the most intensive on unfertilized lands with tilled crops during the first years after drainage. On the contrary, well-developed herbage cover creates optimal conditions for minimizing the intensity of these processes and particularly in losses of organic carbon. The well-developed herbage cover optimizes the carbon balance to a considerable degree. With herbage cover, carbon losses did not exceed the projected level of carbon balance during the first seven years of using the fen. Meanwhile, carbon losses were higher on unfertilized sites with poor herbage cover. Thus, the results of our long-term studies show a significant depletion of carbon stocks in a pool of drained fen in unfertilized sites with tilled crops. Losses of dry peat mass have a similar pattern. Rates of peat subsidence and carbon losses are especially high in the first years of fen use but decrease over time. Our findings can simplify carbon balance accounting and assessment across the whole area of drained peatlands in Ukraine. Only information on the values of peat subsidence during the calculation period and the history of using these peatlands for the same period is required to do this. While evaluating the carbon balance, it is very important to consider all available data on the large-scale geological exploration on peatlands, as well as topographical and soil surveys. Various methods such as a remote sensing, GIS and satellite imagery can be used to obtain and manipulate actual data on areas of drained peatlands, the thickness of peat soils, water table levels, and the state of the drainage system.

CONCLUSIONS

The major area of peatlands of Ukraine (77%) has been drained and converted to farmland. Large-scale drainage and wasting regime of peatland use posed a high risk to their rapid and complete disappearance as unique natural objects that regulate an ecological balance in ecosystems. Peatlands have been transformed from carbon absorbers to a large source of greenhouse gases emissions. The processes of carbon stock depletion, occurring in drained peat soils, and greenhouse gas emissions also cause significant environmental damage.
In order to account for changes to the carbon balance in drained peatlands, we propose an objective and more user-friendly “soil - pool model”, built on the results of long-term studies carried out in pilot sites on the drained fen of the Tcyr river floodplain situated in the Kamen-Kashirsky district of the Volyn region in Ukraine. This model helps to simply carbon balance accounting and assessment. The methodology of the “soil – pool model” requires a wide use of modern remote sensing techniques and GIS. All available data from large-scale geological exploration, topographical and soil surveys, the history of land reclamation and use should be considered while making calculations. The “soil – pool model” aims to provide more accurate calculations for ensuring the best management decisions are taken to address the problems of effective peatland management, the reduction of CO_2 emissions into the atmosphere, the landscape and biodiversity renovation of degraded peat ecosystems.

REFERENCES

1. Bambalov, N.N., Rakovich, V.A. (2005) *Rol’ bolot v biosphere* **(***The role of marshes in the biosphere*. Minsk: Nauka (in Russian).
2. Bradis, E.M., Kuzmichov, A.I., Andrienko, T.L., Batiachov, E.B. (1973) Torphobolotny fond URSR, yogo rayonuvannia ta vykorystannia **(***The fund of peatlands and marshes in USSR, its zoning and use)*. Kyiv: Naukova dumka (in Ukrainan).
3. Joosten Hans, Augustin Jurgen (2006). Peatland restoration and climate: on possible fluxes of gases and money. In: *Materials of international conference “Peat and Solving the Problems of Energy Industry, Agriculture and Ecology”*, Minsk. – P. 412-417.
4. Kleber Markus, Stahr Karl, Henning-Müller I. (1994) Der Einfluß der Expositionszeit auf die Höhe der Bodenatmung bei Anwendung der Lundegardhmethode. *Z. Pflanzenernähr. Bodenk.* (The effect of exposure time on soil respiration rate while using the method of Lundergardh. *Plant Nutrition and Soil Science*), Vol. 157- P. 441- 445 (in German).
5. Lal, R., Kimble, J.M., Follett, R.F., Cole, K.V. (1998) The potential of U.S. cropland to sequester carbon and mitigate the greenhouse effect. Chelsea, USA, Ann. Arbor. Press.
6. Skrynnikova, I.N. (1961) *Pochvennye processy v okulturennyh torphianyh pochvah* (*Soil processes in cultivated peat soils).* Moskva: AN SSSR (in Russian).
7. Succow M., Jeschke L. (1990) *Moore in der Landschaft (The Peatland in Landscape).* Deutsch, Thun, Frankfurt-Main (in German).

8. Tanovitsky, I.G. (1980) *Racionalnoe ispolzovanie torphianyh mestorojdeniy I ohrana okrujayuschey sredy.* (*Rational use of peat deposits and environmental protection*). Minsk: Nauka i tehnica (in Russian).
9. Truskavetsky, R.S. (2010) *Torphianye pochvy i torphianiki Ukrainy (Peatlands of Ukraine).* Kharkiv: KP “Mis’ka drukarnia” (in Ukrainian).
10. Xiaozeng Han, Haibo Li. (2010) *SOM Pool of a black soil: impacts of land - use change and long-term fertilization*. - Beijing: Science Press.
11. Zavarzin, G.A. (ed.) (2007) *Puly y potoki ugleroda v nazemnyh ekosistemah Rossii* (*Carbon pools and fluxes in land ecosystems of Russia*) Moskva: Nauka (in Russian).