Calculation of Methane Emissions from Wetlands in Slovakia via IPCC Methodology

Jozef Mindas, Jana Skvareninova

***Abstract*—**Wetlands are a main natural source of methane emissions, but they also represent the important biodiversity reservoirs in the landscape. There are about 26 thousands hectares of wetlands in Slovakia identified via the wetlands monitoring program. Created database of wetlands in Slovakia allows to analyze several ecological processes including also the methane emissions estimate. Based on the information from the database, the first estimate of the methane emissions from wetlands in Slovakia has been done. The IPCC methodology (Tier 1 approach) has been used with proposed emission factors for the ice-free period derived from the climatic data. The highest methane emissions of nearly 550 Gg are associated with the category of fens. Almost 11 Gg of methane is emitted from bogs, and emissions from flooded lands represent less than 8 Gg.

***Keywords*—**Methane emissions, wetlands, bogs, fens, Slovakia.

I. Introduction

METHANE (CH_4) has 25 times the global warming potential of carbon dioxide (CO_2) over a 100-year time frame, which means that even small changes in methane atmospheric concentration have large consequences for the strengthening of greenhouse effects in troposphere. Methane is responsible for about 18% of human induced radiative forcing, making it the second most important greenhouse gas after carbon dioxide [3]. This estimate of the global warming potential of methane (CH_4) could be reduced by 10-40% due to the indirect effects of CH_4 on aerosols and other chemical compounds (e.g. O_3). This fact has not yet been taken into account [2].

Anthropogenic methane emissions represent 54-72% of the total global flux, what includes livestock, biomass burning, landfills and other waste management, fossil fuel production, and rice agriculture as the largest anthropogenic sources. Wetlands are the largest natural source, but in some cases, they may be included as an anthropogenic source, rice fields are essentially agricultural wetlands with the similar fundamental processes leading to the CH_4 emissions. There is also major discussion about potential feedbacks between global change divergences and methane emissions from wetlands, such as climate, atmospheric CO_2 concentrations, and sulfur and nitrogen deposition are all known to positively or negatively influence CH_4 emissions [9].

The amount of CH_4 emitted from an ecosystem is the balance between CH_4 production (methanogenesis) and CH_4 oxidation (methanotrophy) (Fig. 1). While both of these processes are regulated by microbial activities, vegetation dynamics also serve as important controls over CH_4 flux by regulating CH_4 transport from the soil to the atmosphere and influencing both the production and consumption of CH_4 by microbes [12].

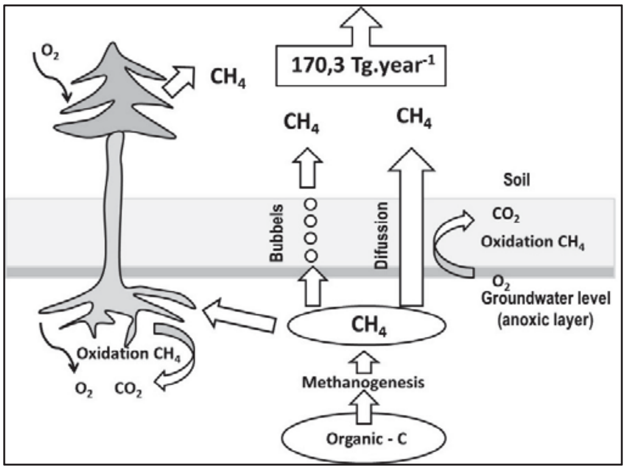

Fig. 1 Model of global methane cycle in wetlands: includes plant transport, ebullition process and diffusion [12] (modified by authors)

Methane emissions are associated with a number of processes in the biosphere, which may be of anthropogenic and natural origin. In some cases, it is difficult to separate processes as recalled by the IPCC methodology [4]. The methodology of the IPCC works with the category of “flooded lands”, which is associated with methane emissions from man-made water bodies or processes associated with anthropogenic processes.

Flooded Land may emit CH_4 in significant quantities, depending on a variety of factors such as age and depth of reservoirs, land-use prior to flooding, climate, and management practices. CH_4 emissions are highly variable spatially and temporally due to several ecological factors influencing the methanogenesis in water environment. Current measurements of CH_4 fluxes from Flooded Land are not sufficiently comprehensive to support the development of accurate default emission factors (especially for bubbles emissions and degassing emissions). In addition, data are not available for many countries and regions with substantial surface area cover by reservoirs. Measurement studies do not indicate that the time elapsed since flooding has a significant influence on CH_4 fluxes from boreal and temperate reservoirs [4].

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The aim of this work is to calculate the methane emissions from three wetland categories: flooded lands, bogs, and fens based on the data from national wetland database.

II. Methodology

A. Calculation Methods and Emission Factors

The IPCC Tier 1 method for estimating CH4 emissions from Flooded Land includes only diffusion emissions during ice-free period. Emissions during the ice-cover period are assumed to be zero. Equation (1) can be used with measured emissions provided in Table I and country-specific total area of flooded land [4]:

$$CH_4\ Emission\text{-}_{WWflood} = P * E(CH4)_{diff} * A_{flood\text{-}total\text{-}surface} \quad (1)$$

where: CH_4 emission-$_{WWflood}$ = total CH_4 emissions from Flooded Land, (kg CH_4 yr^{-1}); P = ice-free period, (days yr^{-1}); $E(CH_4)diff$ = averaged daily diffusive emissions, (kg CH_4 ha^{-1} day^{-1}); A_{flood}, total surface = total flooded surface area, including flooded land, lakes and rivers, (ha).

TABLE I
CH4 Measured Emissions for Flooded Land [4]

Climate	Diffusive Emissions (ice-free period) $Ef(CH_4)_{diff}$ (kg CH_4 ha^{-1} day^{-1})		
	MEDIAN	MIN	MAX
Polar/Boreal, wet	0.086	0.011	0.3
Cold temperate, moist	**0.061**	0.001	0.2
Warm temperate, moist	0.150	- 0.05	1.1
Warm temperate, dry	0.044	0.032	0.09
Tropical, wet	0.630	0.067	1.3
Tropical, dry	0.295	0.070	1.1

TABLE II
Emission Factors of Methane from Peatlands Addressing Climate, Peatland Type and Vegetation [5]

		kg CH_4 ha^{-1} a^{-1} mean (range)	
		Dry	
Boreal	Bogs	8.6 (-1.1 – 51)	
	Fens		
Temperate		0.2 (-4.0 – 9.0)	
		Wet	
		Without shunts	With shunts
Boreal	Bogs	24 (-1.7 – 164)	12 (3.1 – 59)
	Fens		123 (6.6 – 525)
Temperate		**50* (-0.2 – 250)**	**170* (0 – 763)**

*Emission factors have been recalculated as per day.
'Dry' means a mean annual water level below -20 cm, 'Wet' one above – 20 cm.

Our calculations were carried out with the median value for the cold temperate moist conditions (emission factor 0.061 kg CH_4 ha^{-1} day^{-1}).

Equation (2) can be used with measured emissions provided in Table II and country-specific total area of wetlands:

$$CH_4\ Emission\text{-}_{Wetlands} = P * E(CH4)_{diff} * A_{wetland\text{-}total\text{-}surface} \quad (2)$$

where: CH_4 emission-$_{Wetlands}$ = total CH_4 emissions from wetland category, (kg CH_4 yr^{-1}); P = ice-free period, (days yr^{-1}); $E(CH_4)diff$ = averaged daily diffusive emissions, (kg CH_4 ha^{-1} day^{-1}); $A_{wetland,\ total\ surface}$ = total wetland surface area, including bogs and fens, (ha).

Our calculations were carried out with the median value for the temperate wet conditions (emission factor 50 for bogs, and 170 for fens in kg CH_4 ha^{-1} $year^{-1}$).

B. Ice Free Period Calculations

Ice free period represents a period when wetlands are active and are not frozen. In the first approximation can be ice-free period derived as the number of days with an average temperature above 0 °C. Since wetlands database contains information about the altitude we were looking for a relationship between altitude and the number of frost-free days (Fig. 2).

Derived linear equation has been used to calculate the ice-free period for individual sites of wetlands.

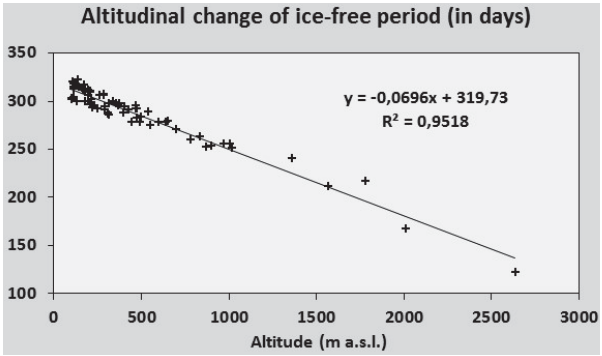

Fig. 2 Altitudinal change of ice-free period in Slovakia [9]

C. Wetland Categories

Since the 90s of the 20th century in Slovakia gradually built database of wetlands, the main reasons for the creation of such database were mainly requirements for implementation of the Ramsar Convention and the protection of rare species (especially flora) linked to wetlands environment. The database is made up of the State Nature Protection Agency and contains basic information about wetland sites (description of the site, spatial localization, cadastral area, etc.). The data are available to the public at the official web site (in Slovak): (http://www.sopsr.sk/cinnost/biotopy/mokrade/MokrSlov/). Fig. 3 provides information on the spatial distribution of bogs and fans in Slovakia.

It should be noted that the categorization of different types of wetlands does not fully meet the purposes of the calculation of methane emissions, since the classification according to the emission criteria requires more additional information such as the level of water etc. Despite this lack of having the mentioned database is usable for the determination of methane emissions, at least at the level of Tier 1 approach according to the IPCC methodology.

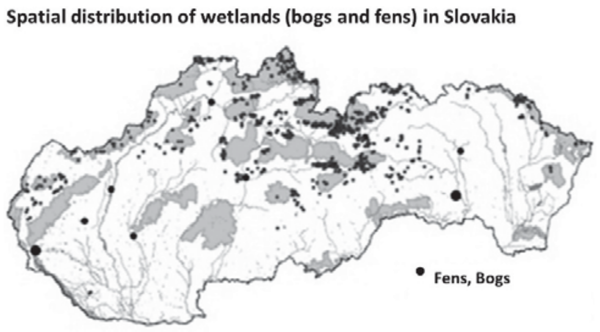

Fig. 3 Spatial distribution of wetlands (fens, bogs) in Slovakia [11]

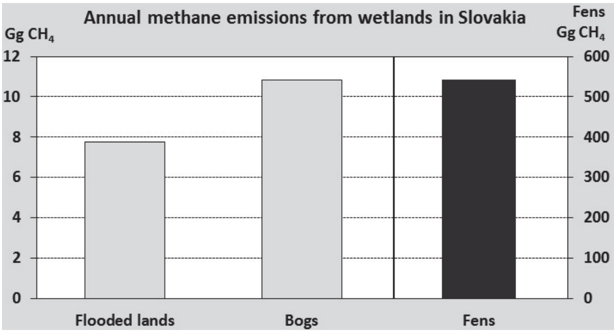

Fig. 4 Annual methane emissions (in Gigagrams - Gg) from individual wetland categories in Slovakia

III. Results

A. Wetlands in Slovakia – Basic Information

Data in Table III show that the largest group of wetlands are flooded lands, whether natural or anthropogenic origin. These are mainly large bodies of water (dams, lakes) but also alluvia of rivers and streams associated with high levels of ground water and the incidence of occasional flooding. This category represents an area of nearly 158,000 hectares, with the highest incidence in western and northern Slovakia.

The second largest category across the board are fens, whose area is more than 4,000 hectares, and is mostly represents by a lot of small scattered locations of size generally less than 1 ha.

TABLE III
Area of Individual Categories of Wetlands in Slovakia Used for Methane Emissions Calculation [12]

	Area in hectares
Flooded lands	157 874.60
Bogs	293.37
Fens	4 142.51

The least represented group of wetlands is bogs, whose area is less than 300 hectares. It should be noted that the border between fens and bogs is not clear from the description of a locality has not always been clear about which category it is. It is therefore necessary to fens and bogs regarded as two sub-categories, which are closely linked.

B. Methane Emissions from Wetlands in Slovakia

The results of the annual methane emissions by individual wetland categories are presented in Fig. 4. The highest methane emissions of nearly 550 Gg are associated with the category of fens. It is caused by an area of this category and the highest emission factor.

Almost 11 Gg of methane is emitted from bogs, which is mainly due to their small size and lower emission factor as in the fens. Together both categories represent the methane emissions of nearly 600 Gg. This involves methane emissions from natural sources.

Emissions from flooded lands represent less than 8 Gg of methane, mainly because of the low emission factor. This category is very important but because the balance sheet is included as a category under the IPCC [4]. For comparison, the value of methane emissions from livestock production in Slovakia in 2005 accounted for more than 37 Gg [6].

IV. Discussion

In Slovakia, the research focused wetlands generally to the field of evaluation flora, partially aqueous and the importance of wetlands in the country. Research on ecological and environmental factors affecting biogeochemical cycles wetlands virtually absent [10].

The first calculation of potential methane emissions has been published in [7], which reported emissions at 1.5 Gg for fens, 1 Gg for bogs and 3 Gg for flooded lands. Differences from the presented results are mainly in the areas, as well as emission factors based on the paper [1].

In general, there are still many gaps in data and methods to estimate methane emissions within the landscape. The issue of the impact of site factors on methane emissions from wetlands is still the subject of intense research since the range of dispersion of emission factors is very large and will not be easy to create usable models for more accurate national inventories [11].

Some simulated results from methane models failed to capture peak observed CH4 emission values during the growing season. The underestimation of CH4 emission pulse may be partly due to, on the one hand, external environmental triggers and CH4 contribution from microbial mat systems during summer not being included in many models. On the other hand, the ebullition events of short duration, which are often recorded as very high fluxes in the observation, are hard to reproduce since some dependent factors (e.g. the density of nucleation site) in CH4 ebullition process are difficult to simulate [8].

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