Research Progress on CH_4 Flux Emission from Alpine Wetland in Xinjiang Bayinbuluk

Hu Yao, Chunyu Yan, Jiaojiao Chen*

Yunnan Open University, Kunming, Yunnan, 650500, China.

Abstract: The alpine wetland in Xinjiang Bayinbuluk's anaerobic environment is conducive to the production of CH_4 released from soil through microbial action. It is very important to discuss the carbon cycle in Bayinbuluk Alpine Wetland to determine whether the wetland is a "source" or a "sink" of greenhouse gases and to assess the carbon emission inventory in this area.

Keywords: Bayinbuluk; Wetland; CH4 Flux; Spatial and Temporal Heterogeneity

1. Introduction

Climate change, mainly characterized by global warming and a universally acknowledged fact among the public and the scientific circle, remains the core issue in the field of global change science.

The surge in the concentration of greenhouse gases such as CO_2 and CH_4 leads to the reinforcement of greenhouse impact, and eventually results in the global warming [1]. Although the concentration of CH_4 in the atmosphere is lower than that of CO_2, the Global Warming Potential (GWP) of a single CH_4 molecule is 25 times as much as that of CO_2 [2], making CH_4 one of the most prominent greenhouse gases second only to CO_2. The increase in CH_4 concentration is predominantly caused by human activities, however, the emission from natural sources should not be overlooked, which accounts for 25.6% to 36.2% of total emission[3]. It is estimated that 15% to 30% of CH_4 in the atmosphere is emitted from soil annually [4]. Wetland ecosystem, as an essential part of carbon cycling, covers 6.4% of the total land area. It serves as a significant carbon sink second only to forest ecosystem and plays an important in global carbon balance and cycling. China, as a nation full of wetland resources, possesses unique arid alpine wetlands, with the most typical one being the Bayinbuluk wetland in Xinjiang, which covers an area of approximately 148,700 hectares. Due to differences in factors such as observation techniques, geographical location, and human intervention, there is considerable uncertainty regarding the "sources" and "sinks" of CH_4 in this wetland. Obviously, researches on the characteristics of CH_4 emission by wetland ecosystem in arid regions of China is relatively weak, which further hinder the assessment of carbon emission inventory in this region.

2. An overview of the Bayinbuluk Wetland

2.1 Geographic Location

The Bayinbuluk wetland is located in a mountainous basin in the central Tianshan Mountains, with an area of 148,700 hectares. The basin has a gentle topography, supplying favorable conditions for the nurture of basin marshes. Climate here is mainly affected by the westerly wind belt, with an average annual temperature of -4.8℃ and precipitation of 276.2 mm. Though the wetland is not so large, the Bayanbulak is extremely abundant in species. Due to the micro-topography and variation in water gradients, it provides advantageous conditions for the growth of different types of plants.

3. CH_4 Flux Measurement Methods

3.1 Chamber Method

The chamber method, the most commonly used and easiest one for operation, is widely applied currently. The working principle is to cover a certain area of soil and the vegetation above with a specially designed chamber in a certain size, meanwhile, isolate the free exchange of gases inside and outside of the chamber. Gas samples are periodically extracted from the chamber, and the concentration of greenhouse gases in the air is analyzed by using chemical reaction or gas chromatography methods to determine the change over time. And then the exchange flux is calculated accordingly. However, studies have shown that covering a chamber for an extremely long time may affect the micro-meteorological conditions on the measured surface. Additionally, this method is primarily used for measuring CO_2 gas and has lower precision.

3.2 Micrometeorological Method

The micrometeorological method is used to obtain gas flux value by measuring the near-surface flow conditions and the concentration of the gas measured. It mainly has three subtypes: aerodynamics method, heat balance method, and eddy covariance method. Peng Haijun et al. [5] adopts the eddy covariance method in micrometeorology to observe CH_4 emission in the Ruoergai peatland. This method directly measures energy and matter flux by identifying the fluctuations in wind velocity and physical quantity generated by atmospheric turbulence. In this sense, the eddy covariance method involves almost no hypotheses in the process of calculating flux. It's currently regarded as the best approach for observing microscale atmospheric exchange flux.

4. Factors Influencing CH_4 Emission

4.1 Soil Property

The activity of methanogenic bacteria in soil requires proper temperature. Low temperature can reduce their activities of methanogenic bacteria and other microbes, resulting in a decline in CH_4 flux. An increase in temperature can enhance their activity and accelerate oxygen consumption in the soil, leading to a decrease in redox potential. It's favorable for the production of methanogenic bacteria and an increase in CH_4 flux. CH_4 is produced by methanogenic bacteria from soil with organic matter under anaerobic reducing conditions, which is greatly dependent on soil moisture. Changes in moisture determine the degree of anoxia in wetland ecosystem. On one hand, under long-term flooded conditions, the Eh value of the soil decreases, providing favorable conditions for CH_4 production. On the other hand, excessive water level can obstruct the pathways for CH_4 transportation. CH_4 that has already been produced in soil can only be transferred to the atmosphere through diffusion in water or by bubbling. During this transport process, the amount of oxidation increases, resulting in a decrease in CH_4 emission.

4.2 Vegetation Factors

Vegetation plays a major role in the CH_4 flux emission process as a gas pathway for transporting CH_4. Moreover, it serves as a substrate for methanogenic bacteria. Finally, it helps transport CH_4 through plant roots, preventing CH_4 from being oxidized when passing through the oxidation layer and thereby increasing CH_4 flux. Hu Baoan points out that vegetation in wetland ecosystem offers a substrate for CH_4 production and holds that there is a significant positive correlation between the daily average CH_4 flux and aboveground biomass. However, it is also noted that certain plants serve as channels for oxygen transportation to the root zone. Plants supply oxygen to methane-oxidizing bacteria living in the root zone, leading to the oxidation of methane and a decrease in methane flux.

4.3 Human Factors

Yao Shouping et al. [8] discover that the addition of organic fertilizer provides abundant substrates for methanogenic bacteria, thus boosting methane production. The research reveals that the impact of organic fertilizer application on methane emission is smaller in soil with high organic matter content but greater in soil with low organic matter content. Additionally, He Guixiang et al. [7], in their study on the effects of long-term and short-term grazing prohibition on CH_4 emission, find that long-term prohibition accumulates more aboveground biomass than short-term prohibition, resulting in the formation of a water barrier layer on the ground. This has led to insufficient soil moisture and increased air influx, thereby inhibiting methanogenic bacteria activity and reducing methane production. Furthermore, tillage practices, fertilizer type, and application depth can also affect CH_4 production and emission. In summary, CH_4 emission are influenced by multiple factors. Currently, there is no definitive conclusion on the influencing factors and their degree of impact on CH_4 emission in the

Bayinbuluk wetland, which requires further research.

5. Spatiotemporal Heterogeneity of Methane Emission

Studies have found variations in CH_4 emission flux across different latitudes. For instance, the CH_4 flux in the Minjiang River Estuary is significantly higher than that in the Jiangsu Mudflat. In contrast, the Yangtze River Estuary and Yellow River Estuary act as sinks for CH_4 in the entire mudflat area, while the mangroves in southern China exhibit obvious spatial heterogeneity. Researches by Hu Baoan et al. [6] on summer CH_4 emission in the Bayinbuluk wetland reveal that, because of different moisture conditions, perennially inundated areas and seasonally inundated areas both act as sources of CH_4, but the daily average emission flux differs. Conversely, the perennially dry areas serve as CH_4 sinks. Researches on carbon exchange in the Bayinbuluk wetland in Xinjiang can effectively demonstrate that the carbon emission characteristics in the arid regions of northwest China. It provides data support for studying the carbon sequestration characteristics and assessing the functions of wetlands as carbon "sources" and "sinks" in the arid wetlands of Central Asian. Additionally, it also satisfies the strategic requirements for development of the Silk Road Economic Belt.

6. Conclusion

The main method for measuring methane emission in the Bayinbuluk wetland is the static chamber method, which is easy to operate and convenient to use. However, it has several limitations. Firstly, it can only cover very small areas and may introduce varying degrees of disturbance to the observed objects. Moreover, some experimental designs only sample over specific time periods during the day, and in terms of data processing, data obtained in daytime observations is often used for substituting diurnal variations, leading to biased results. Lastly, the sampling frequency in the chamber method is generally low (with intervals of 2 or 3 hours), which may result in missing data such as peak or valley values.

In recent years, the eddy covariance method has emerged as an alternative approach for observing methane emission in wetland. It offers advantages such as fast response, large coverage, and being able to overcome obstacles of discontinuity and point-source estimation in methane flux observation. By employing this method, a more accurate estimation of carbon flux in the entire wetland ecosystem can be reached, thereby determining its position and role in global climate change. In addition, interdisciplinary research is encouraged to investigate CH_4 flux emission to fill data gaps in carbon emission flux in the arid regions of northwest China, as well as providing data support for more precise estimation of carbon emission inventory.

References

[1] Yu, G.R., Sun, X.M. Principles of flux measurement in terrestrial ecosystems. (2006). Beijing: Higher Education Press, 4.

[2] Solomon, S., Qin, D., Manning, M. IPCC, Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. 2007.

[3] Houweling, S., Kaminski, T., Dentener, F. Inverse Modeling of Methane Sources and Sinks Using the Adjoint of a Global Transport Model. Journal of Geophysical Research Atmospheres. (1999). 104 (d21): 26137-26160.

[4] James, E., Hansen& Andrew, A., Lacis. Sun and dust versus greenhouse gases: An assessment of their relative roles in global climate change. (1990). Review Article, 346(6286): 713-719.

[5] Peng, H., Chi, J., Yao, H., Guo, Q., Hong, B., Ding, H.W., Zhu, Y.X., Wang, J., Hong, Y.T. Methane emissions offset net carbon dioxide uptake from an alpine peatland on the eastern Qinghai-Tibetan Plateau. (2021).Journal of Geophysical Research: Atmospheres 126, e2021JD034671.

[6] Hu, B.A., Jia, H.T., Zhu, X.P., Yang, L., Hu, Y., Wang, N.N., Li, D.P. Daily characteristics of summer CO2 and CH4 fluxes under different water conditions at Bayinbuluke alpine wetland. (2016). 30(6): 167-172.

[7] He, G.X., Li, K.H., Song, W., Gong, Y.M., Liu, X.J., Hu, Y.K., Tian, C.Y. The fluxes of carbon dioxide, methane and nitrous and nitrous oxide in alpine grassland of the Tianshan Mountains, XinJiang. (2014). Acta Ecological Sinica, 34(3):674-681.

[8] Yao, S.P., Luo, P., Wang, Y.F., Wu, N. Advances in the research on methane emissions from wetlands. (2007). 29(2): 58-63.

Fund Project： This study was funded by the Science Research Foundation of the Department of Education of the Yunnan Province. (Grant No. 2023J0800)