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A comparative study of daytime-based methane emission from two wetlands of Nepal Himalaya

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HIGHLIGHTS

- Daytime methane emission variations were stronger in dry season than in monsoon.
- Methane emissions were higher during monsoon than those in dry season.
- Plant community height, standing water depth and soil temperature were key factors.

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ABSTRACT

Natural wetlands constitute one of the major sources of methane emission to the atmosphere. Data on methane emission from wetlands on southern slopes of the Himalaya (SSH) have not been reported so far. Such data are very valuable for filling the gap and generating the whole emission patterns at regional or even global scale. We selected two wetlands at different altitudinal locations in Nepal, i.e. Beeshazar Lake (286 m a.s.l.) and Dhaap Lake (2089 m a.s.l.), to monitor the daytime methane emissions in monsoon season and dry season separately. Daytime methane emission varied between monsoon and dry seasons and also across different plant communities. The daytime methane emission variations were stronger in dry season than in monsoon season. The source/sink strengths of the two selected plant communities in each wetland were significantly different, presenting the strong spatial variation of methane emission within wetland. The methane emissions recorded in monsoon season were significantly higher (7.74 ± 6.49 mg CH_4 m^{-2} h^{-1} and 1.00 ± 1.23 mg CH_4 m^{-2} h^{-1} in low and high altitude wetlands, respectively) than those in dry season (1.84 ± 4.57 mg CH_4 m^{-2} h^{-1} and 0.27 ± 0.71 mg CH_4 m^{-2} h^{-1} in low and high altitude wetlands, respectively). Methane emissions from the low altitude wetland were significantly higher than those from the high altitude wetland in both of the seasons. Plant community height, standing water depth and soil temperature correlated to the methane emission from wetlands in this region.

1. Introduction

Wetlands are among the most important sources of atmospheric methane (Ramaswamy, 2001). However, spatio-temporal patterns of their methane emissions are poorly known (Ciais et al., 2013), which limits the accuracy to estimate methane emissions from wetlands (Kirschke et al., 2013). The Himalaya, which runs northwest to southeast in a 2400 km long arc, embodies large land area of 6.06×10^5 km^2 in its southern slopes, and the overall wetland area of the southern slopes of the Himalaya (SSH) is estimated to be approximate 1.48×10^4 km^2, which accounts for 2.4% of the land area of SSH (Bhandari et al., 1994; Sharma et al., 2010; Panigrahy et al., 2012). Although wetlands are widely distributed in SSH (Gujja, 2007; Mitsch and Gosselink, 2007; IPCC, 2014), they have received very little attention in terms of scientific enquiry into carbon budget, hydrological regulation, and biodiversity at local

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and regional scales (WWF-India, 2006; Wu et al., 2013). However, till date there have not been any attempts at quantifying the dynamics of methane emission and no reports are available on this aspect from the wetlands located in SSH.

Spatially, the wetlands in SSH are distributed along a wide altitudinal range from less than 100 m a.s.l. (flood plains of *Terai* belt) to glaciated valleys in the Himalaya up to 5500 m a.s.l. (Bhuju et al., 2010; Lacoul and Freedman, 2006; Panigrahy et al., 2012). These wetlands are strongly influenced by the summer monsoon originating from the Indian Ocean. It has already been proved that the patterns of methane emissions from wetlands are largely controlled by climatic factors such as temperature and precipitation (Bergström et al., 2007; Marani and Alvalá, 2007). Therefore, the spatio-temporal pattern of methane emission from wetlands in SSH should be studied. Furthermore, at a smaller spatio-temporal scale, methane emission was reported to vary among plant communities within a single wetland in a wide geographical range (Chanton et al., 1993; Wickland et al., 1999; Juutinen et al., 2004; Wang et al., 2006) and the daytime pattern of methane emission also changes with high seasonal variability (Satpathy et al., 1997; Juutinen et al., 2004). Thus, an essential reference for scheduling the sampling strategy is required to make a reasonable estimation on emission (Ding et al., 2004a).

This paper deals with the preliminary findings on methane emission measured from two wetlands located at different altitudes in SSH during different seasons. The main objectives of the study were to: 1) understand the daytime variation of methane emissions; 2) compare the pattern of methane emission across varying plant communities, seasons and altitudes; and 3) figure out the key environmental factors influencing methane emissions.

2. Material and method

2.1. Site selection and description

Of the fourteen Ramsar Sites in SSH (nine in Nepal, three in Indian and two in Bhutan), eight are lake ecosystems and two are reservoirs (http://www.ramsar.org). This underlines the predominance of lakes in this region. Therefore, we selected two lakes in Nepal as representative wetlands for present study. The first site, Beeshazar Lake, located in the buffer zone of Chitwan National Park, represents low altitude wetlands in Terai belt or flood plains (286 m a.s.l.; 27°37′04″N, 84°26′11″E). The second site, Dhaap Lake (2089 m a.s.l.; 27°48′31″N, 85°27′32″E) is located in Shivapuri-Nagarjun National Park (Fig. 1).

Beeshazar Lake is a freshwater lake with open water area of 32 km^2, surrounded by tropical moist deciduous forest dominated by Sal (*Shorea robusta*). It is a typical freshwater wetland in the tropical belt of SSH, receiving water directly from rainfall during the monsoon season and through inflow of the Khageri irrigation canal in its vicinity. The lake water is supplied to the canal and streams during the dry season. Beeshazar and adjacent water bodies were listed as Wetlands of International Importance under Ramsar Convention in 2003. The climate in Chitwan National Park is typically tropical monsoon type with rainy season from June to September, and dry season from October to next May. Most of the annual rainfall (mean annual being 2500 mm) is received during monsoon season. The highest monthly mean temperature is 30.5 °C in June, while the lowest 15.7 °C in January (Fig. 2).

Dhaap Lake is also a freshwater lake with open water area of 0.01 km^2 distributed on the mountain ridge of Shivapuri-Nagarjun National Park which is situated in the Mid Hills or Mahabharat range and acts as the headwater of the Bagmati River, a major source of water for Kathmandu Valley. There is a dam that was built on its outlet several decades ago in order to elevate the water table and improve the water storage capacity of the lake by reducing the discharge during the monsoon season, so that the discharge during the dry season is maintained. Therefore, the design of this dam is quite simple as there was no active regulation schedule with it. During the study period the water table in this dam varied from very high (monsoon season) with water overflowing the dam to very low with flowing only through the tunnel at the bottom (dry season). The climate of Shivapuri-Nagarjun area is typically temperate, with annual mean rainfall of 1800 mm that is mostly received during May to September. The highest monthly mean temperature is 19.0 °C in June, while the lowest is 8.2 °C in January (Fig. 2).

2.2. Sampling plots and gas flux measurement

We chose the littoral zones of Beeshazar Lake to set up sampling plots. There are two topographic littoral zones in Beeshazar Lake, viz., steep littoral zone and smooth littoral zone. The steep littoral zone was characterized by presence of communities predominantly composed by kans grass (*Saccharum spontaneum*), *Cyperus pangorei* and *Persicaria hydropiper*, which is referred as KG in following text; while the vegetation in the smooth littoral zone was marked by the presence of water pepper (*Persicaria hydropiper*), *Mikania scandens* and *Eichhornia crassipes*, which was abbreviated as WP. Seven plots in KG and six plots in WP were randomly set up for further study. In the Mid Hills region of Nepal where Dhaap Lake is situated, the wetland is typically riverine in nature rather than lacustrine/littoral. Therefore, we chose the riverine zone along the outlet of Dhaap Lake to set sampling plots. Two plant communities dominated in the riverine zone were: 1) community with open moss bed comprising *Funaria hygrometrica, Thudium sp.* and other herbaceous species such as *Prunella vulgaris, Cyrtococcum accrescens* and *Rotala rotundifolia*, which is a typical wetland community dominated by water moss and abbreviated as WM accordingly; and 2) community dominated by sweet flag (*Acorus calamus*) with *Persicaria nepalensis, P. vulgaris* and *Axonopus* sp., and abbreviated as SF. Nine plots in WM and eight plots in SF were randomly set up for further study. Gas sampling in low altitude wetland (Beeshazar Lake) for monsoon season and dry season were done on June 10th and December 31st, 2013, respectively, and for high altitude wetland (Dhaap Lake) it was done on July 23rd, 2013 and January 21st, 2014, respectively.

Methane fluxes were measured with vented closed chambers (Mosier et al., 1991). The chambers (30 cm in diameter, 50 cm in height) were made up of cylindrical polyvinyl chloride (PVC) pipe. Through the top surface of the chamber, there was a pipe (0.5 mm in diameter) to connect with the ambient atmosphere, with a spiral part inside the chamber. The chamber anchors (20 cm in height) were driven 8–15 cm (depending on the stability of soils) into the soil 48 h prior to the flux measurement to maintain balance of the system. In order to minimize heating, aluminum foil was wrapped to cover the whole chamber. When the measurements began, we bound chamber tops and anchors with a tight rubber belt to make sure that the whole chamber was airtight.

Daytime gas sampling was carried out separately at 06:00, 09:00, 12:00, 15:00, and 18:00 h in Nepal standard time (GMT+5:45). For each plot, four gas samples from the chamber air headspace were taken into 5 ml airtight vacuumed vials at 0, 10, 20 and 30 min after deployment. All samples were transported to the laboratory in a cool box.

The methane concentration was determined by a gas chromatography (PE Clarus 500, PerkinElmer, Inc., USA), equipped with an FID (flame ionization detector) operating at 350 °C and a 2 m Porapak 80–100 Q Column. The column oven temperature was 35 °C and the carrier gas was N_2 with a flow rate of 20 cm^3 min^{-1}.