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ASSESSMENT OF CARBON SEQUESTRATION POTENTIAL OF LOKTAK LAKE IN MANIPUR - A BIODIVERSITY HOTSPOT

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Abstract

Wetlands are important natural resources and vital for human survival on the earth. They are one of the most productive environments and cradles for biological diversity. They are considered as wealth of carbon storage and provide a potential sink for global atmospheric carbon, but the role of the wetlands in carbon sequestration storage has been under estimated. The recent increase in the atmospheric carbon dioxide has led to growing concern among the public and scientific community to identify the potential of various ecosystem to sequester more carbon. There is growing interest among researchers to adhere to the Kyoto Protocol to stabilize the increase in atmospheric carbon dioxide and global warming through managing wetland restoration and conservation projects to exploit the carbon sequestration potential. The objective of the present study is to assess the soil organic carbon (SOC) in different sites of Loktak Lake to estimate the carbon stock and provide their potential of carbon sequestration capacity. The result from the analysis of SOC density ranges from 0.70kg/m^2 to 6.57kg/m^2 at a depth of 0…10 cm and density varies during the season with maximum SOC of 5.18kg/m^2 during post monsoon and 3.19kg/m^2 during winter. The total carbon sequestration potential of the Loktak Lake is 204181 tones year^{-1}. The outcome from the study will help in formulation of efficient strategies to mitigate the increase in carbon dioxide and reduction of the GHG emissions from wetlands in the Indo-Burma (Myanmar) Biodiversity Hotspot.

Keywords: *Carbon sequestration; Bulk density; Soil organic carbon; Loktak Lake; Wetland Protection, Sustainable management*

Introduction

Wetlands play an important role in the global carbon dynamics due to its large soil carbon pools, high methane emissions and potential for carbon sequestration. They occupy only 5% of earth's terrestrial surface but play a significant role in terrestrial carbon pool. Their soils have the largest carbon pool of 1400 ***picograms*** of carbon [1], which account for one third of the total global carbon cycle. Wetlands have the single largest estimation of carbon with 18–30% of the total soil carbon, and represent the largest carbon pool with a capacity of 770 gigatons of carbon more than the total carbon storage of farms, temperate and rain forest [2]. It was also found that some of the wetlands have been sequestrating as carbon sinks continuously for the last 4000–5000 years [3]. Wetlands are one of the most undervalued ecosystems that provide a wide range of ecosystem services including regulation of flood protection, nutrient retention, climate regulation, provisioning food and support biodiversity, nutrient cycling and cultural services [4, 5]. Among them, the regulation of climate has been considered the most important ecosystem service [6]. Compared with other ecosystems, the high carbon storage

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provides wetlands a high contributing value for mitigation and climate regulation service [7] in the global carbon cycle [8].

Developmental activities around the globe are releasing a huge amount of greenhouse gases, which is a major concern for the atmospheric CO_2 that increases the rate of global warming [9]. The increase in anthropogenic activities has resulted in the increase in concentration of carbon dioxide from the pre-industrial level of 280 ppm to the current level of 398.55 ppm, which exceed the permissible limit of 350 ppm [10]. This is the highest value seen in the last 650,000 years [11]. This increase in the atmospheric carbon dioxide has resulted in the rise of sea level as well as changes in carbon cycling [12]. Despite the huge potential for carbon sequestration, wetlands around the worlds are rapidly decreasing in size [13-15]. Significant tracts of wetland have been reportedly lost from various countries, including USA, China, Netherland and along the deltas of Nile River [16]. In India, the loss of wetland is mainly due to urbanization, land use changes, runoff from agriculture, infrastructure development and pollution from industrial effluent and climate change variability [17]. This loss in wetland has resulted in adverse impact on key functions performed by wetlands [18]. This decrease in wetlands has a negative impact on the climate mitigation as significant amounts of greenhouse gases are released [19]. The most convenient approaches for mitigation of this impact are through the capture and storage of atmospheric CO_2 in long-lived carbon pools [20]. In India, wetlands in the coastal area play a major role in carbon sequestration, and mangrove wetlands located in eastern India sequent more carbon than in the west due to larger area, higher diversity and network of canals [21].

In spite of its importance in the global carbon sequestration, there is limited research on wetlands due to lack of fundamental knowledge and limited information of carbon turnover and temporal dynamics in the global carbon cycle. Recently, there is an increased interest among researchers in linking carbon storage potential of wetland ecosystem [22] with the ongoing management efforts through the scale of carbon credits on carbon markets [23, 24]. But so far there is no report of previous study on carbon sequestration by wetlands located in North-East India, a mega biodiversity hotspot. In this paper we assess the distribution of soil organic carbon (SOC) in different areas of the Loktak Lake, their spatial distribution, and finally the role of Loktak Lake in soil carbon sequestration and contribution to societal benefits.

Methodology

Study site

The Loktak Lake located in the valley region of the north eastern state of Manipur (Fig.1). It is one of the important wetland under the Ramsar site and also one of the 48 wetlands around the world which is under the Montreux record of Ramsar. The lake is the largest fresh water lake in North East India covering an area of 246.72km² [25], located between 93°46' – 93°55'E and 24°25' – 24°42'N. The lake occupies about 1.10% of the total state area. The lake is of oval shape, with a maximum length of 32km and width of 13km. The depth varies from 0.5 to 4.6m, with an average depth of 2.7m. The lake is divided into three zones, the northern zones which extend from Nambol River near Ngaikhong Khunou to Phabakchao. The central zone is the main open water area which was relatively free from floating island, but due to the local people using floating island locally known as Phumdi (heterogeneous masses of vegetation, soil and organic matters in various stages of decomposition and has been thickened into a solid form) for fish cultivation, Phumdis number has increased considerably which result in a decrease in the open water area. The Keibul Lamjao National Park (KLNP) covering an area of 40km² located in the southern part of the wetland is the world's only floating national park and last natural habitat of Manipur brow antlered deer *Rucervus eldii eldii*, locally known as the Sangai, has its habitat in floating wetlands.

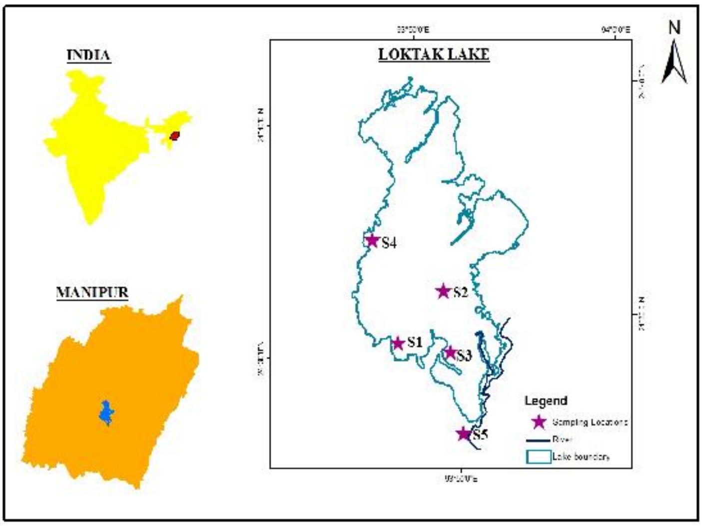

Fig. 1. Map of Loktak lake Location and sampling sites.

Soil sampling

Soil samples for the analysis were collected from various part of the Loktak lake including Sendra, Thanga Karang, Ningthoukhong, Keibul Lamjao National Park and Ithai. These sites were seasonally sampled during June 2013–May 2014. Three replicate cores were collected from each site. Samples were collected by following the IPCC 1997 [26] guidelines meaning that only the upper 30cm layer of the soil, which contains the actively changing carbon soil, was used for the present study. The soil samples were collected by inserting a 15cm long and 5cm diameter steel tube equipped with a sharpened bottom edge approximately 10cm into the soil, with minimal compaction. After extraction, each ring was sealed using tight-fitting end caps and frozen for later laboratory analysis. For the laboratory analysis, the soil cores were removed and allowed to defrost. Water was drained away and vegetation present was removed.

Sample analysis

Analysis of soil bulk density

The soil bulk density is an important parameter for the assessment of soil organic content [27]. The soil samples were determined by oven drying a known weight of the samples at 105ºC for 72 hours. Dry bulk density (g/cm^3) was estimated as the ration between dry mass (g) and wet sample volume (cm^3) by following Wilke method (2005) [28].

$$\mathbf{Psj} = \frac{\mathbf{mj}}{\mathbf{vj}} \qquad (1)$$

where ρ_{sj} is soil bulk density (g cm^{-3}) of the jth horizon, m_j is mass of soil sample in (g) of the jth horizon dried at 105ºC and v_j is volume of soil sample (cm^3) of the jth horizon. The dry samples were ground and sieve to get a 2mm particle size.

Soil organic carbon

The collected soil samples were analyzed for soil organic carbon content with slight modification using *Walkey and Black's* method [29]. In a conical flask of 250mL, 1g of the soil samples was taken, and 2mL of $K_2Cr_2O_7$ was added. This was followed by adding 4mL of conc. H_2SO_4 and the content was mixed by gentle mixing. The flask was kept in room temperature for 30 minutes for the reaction to complete. Then the content was diluted with 40mL of distilled water and 2mL of phosphoric acid was added to remove the inorganic carbon and 1ml of diphenylamine indicator was added. This content was titrated against 0.2N ferrous ammonium sulfate until the color changed to brilliant green. Blank titration of the acidic dichromate with ferrous ammonium sulfate solution was performed at the beginning of the batch analysis using the same procedure with no soil samples.

$$(1 - S / B) \times 10 \times 0.68 = \text{organic matter (\%) of sample} \qquad (2)$$

where, S = volume of Ferrous Sulfate solution required to titrate the sample, in mL, B = average volume of ferrous sulfate solution required to titrate the blanks, in mL, 10 = conversion factor for units and 0.68 = a factor derived from the conversion of % organic carbon to % organic matter

Soil organic carbon sequestration rate was estimated using the bulk density, soil organic carbon (SOC) content of soil and height of the soil layer following the method of Yu *et al.*, 2012 [30].

$$\text{SOCD} = \text{SOC x BD x H x } 0.01 \qquad (3)$$

where SOCD is soil organic carbon density ($kg \cdot m^{-2}$), SOC is soil organic carbon content ($g \cdot kg^{-1}$), BD is soil bulk density ($g \cdot cm^{-3}$), H is soil layer height (cm).

Based on the SOC per unit surface area, SOC stock at a depth of 10cm was calculated using Eq. (3) by SOC mass per unit surface area ($kg \cdot m^{-2}$). The total SODS stock in Loktak Lake was calculated by multiplying the total area (hectare using the formula (4).

$$\text{SODS} = \text{A x SOCD} \qquad (4)$$

where SODS is soil carbon storage (tones), A is the total area of the Loktak wetland (hectare)

Results and discussion

The bulk density in 0…10cm of soil layer was calculated for the five sites of the Loktak Lake. The distribution of bulk density varies in different landscape and season, as shown in Table 1 and Figure 2.

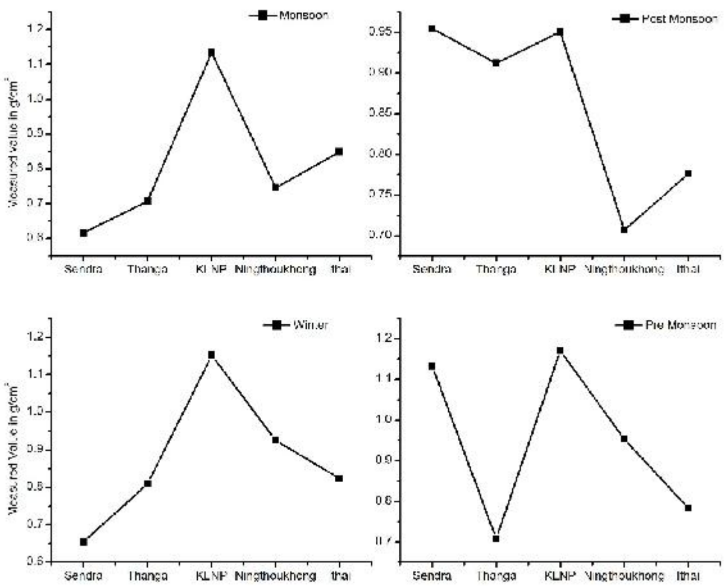

Fig. 2. Seasonal variation in the average bulk density.

During monsoon, KLNP (1.13g/cm^3) recorded the highest, follow by Ithai (0.85g/cm^3) and minimum is recorded in Sendra (0.62g/cm^3). In post monsoon, highest bulk density was recorded in Sendra (0.95g/cm^3) and KLNP (0.95g/cm^3) and minimum in Ningthoukhong (0.71g/cm^3). Similarly, in winter, KLNP recorded the highest (1.15g/cm^3) and minimum at Sendra (0.65g/cm^3). Lastly in pre monsoon KLNP recorded highest (1.17g/cm^3) and minimum at Thanga (0.71g/cm^3). The high bulk density in Keibul Lamjao National park is due to the low temperature thereby maintaining high moisture content and the low BD in Sendra and Ningthoukhong is due to frequent disturbance of the soil. The low bulk density in Ningthoukhong during monsoon is due to the drainage of water from Loktak for a hydro-power project and for fish farming, activities that disturb the soil regularly.

Table 1. Average seasonal variation of bulk density and Soil organic composition

Pre Monsoon

Location	Height of the soil (cm)	TOC %	Bulk Density (g/cm^3)	SOC (kg/m^2)
Sendra	10	5.8	1.13	6.57
Thanga	10	5.39	0.71	3.81
Keibul Lamjao National Park	10	5.48	1.17	6.41
Ningthoukhong	10	4.8	0.95	4.57
Ithai	10	5.16	0.78	4.04

Monsoon

Location	Height of the soil (cm)	TOC %	Bulk Density (g/cm^3)	SOC (kg/m^2)
Sendra	10	4.71	0.62	2.90
Thanga	10	5.7	0.71	4.03
Keibul Lamjao National Park	10	3.77	1.13	4.27
Ningthoukhong	10	0.94	0.75	0.70
Ithai	10	4.81	0.85	4.08

Post monsoon

Location	Height of the soil (cm)	TOC %	Bulk Density (g/cm^3)	SOC (kg/m^2)
Sendra	10	0.95	6.07	5.79
Thanga	10	0.91	6.31	5.75
Keibul Lamjao National Park	10	0.95	5.64	5.36
Ningthoukhong	10	0.71	5.7	4.03
Ithai	10	0.78	6.36	4.93

Winter

Location	Height of the soil (cm)	TOC %	Bulk Density (g/cm^3)	SOC (kg/m^2)
Sendra	10	0.65	5.6	3.66
Thanga	10	0.81	6.24	5.05
Keibul Lamjao National Park	10	1.15	4.64	5.34
Ningthoukhong	10	0.93	4.6	4.25
Ithai	10	0.82	5.65	4.64

The soil organic carbon density in 0…10cm soil layer was calculated using the values of SOC and soil bulk density. The distribution of the SOC in different land use classes are shown in Table 1 and Fig. 3. The SOC varies seasonally. During monsoon, KLNP recorded the highest (4.28kg/m^2) and minimum at Ningthoukhong (0.70kg/m^2). In pre-monsoon the highest was recorded in Sendra (5.80kg/m^2) and minimum at Ningthoukhong. Similarly during winter, KLNP recorded the highest (5.35kg/m^2) and minimum at Sendra (3.66kg/m^2). Lastly in Pre monsoon, SOC was recorded highest in Sendra (6.57kg/m^2) and minimum at Thanga (3.81kg/m^2). The low SOC in Sendra and Ningthoukhong is due to the disturbance of the soil by boat and runoff for generation of hydro power. It is well know that soil bulk density plays an important role in the assessment of SOC contents [31] and that it can vary according to the different land use and soil types. The bulk density of the present study shows a seasonal variation among the selected sites with highest was recorded in Keibul Lamjao National Park and minimum in Thanga and Ningthoukhong. Keibul Lamjao National park has high SOC content compared with other non-vegetated sites which is due to high organic matter from the macrophytes.

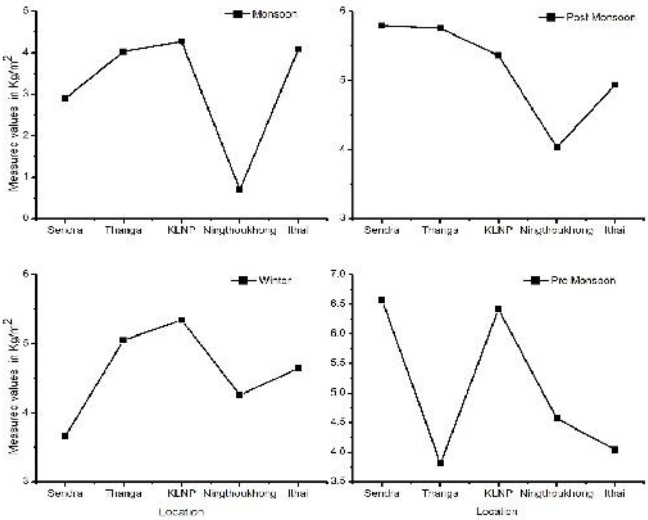

Fig.3. Seasonal variation in average soil organic content.

There is a strong correlation between the climate and soil organic contents, whereby organic carbon content decreases with increasing temperatures as decomposition rate doubles with every rise of 10° C in temperature [32]. It follows that wetlands in cooler region have higher net sink of carbon cycle than the wetlands present in temperate regions. The SOC of Loktak Lake could provide the baseline information for multi scale estimation of other important lakes located in North East India. The carbon sequestration potential of the Loktak Lake is also influenced by various factors including natural and human activities [33]. The soil erosion caused due to *Jhum* cultivation in the upper hilly region and the sediments bought down by important rivers discharging into the Loktak has caused an increase in sedimentation, thereby decreasing the depth of the lake. Also, eutrophication from Nambul and Nambol rivers and agricultural activities in the vicinity increase the level of organic carbon in the lake through sediment inflow. The human settlement on the Loktak Lake also increases carbon sequestration through the increase in nutrients from pollution [34]. The next approach for development of process base models is to understand the relationships between carbon dynamics and environmental factors including temperature, precipitation and hydrology [35].

Conclusions

The Loktak Lake is one of the important wetlands in the Indo-Burma hotspot. Rapid urbanization has resulted in a change of land-use pattern, which has degraded the wetland ecosystem. The estimation of SOC density of Loktak Lake could provide the baseline data for large scale estimation of other important wetland in North east India, a major biodiversity hotspot. From our study, the SOC density ranges between 6.57kg/m^2 and 0.70kg/m^2. The present study has provided the basic data for SOC estimation of one of the important wetland located in the Indo-Burma Biodiversity Hotspot, which will provide the scientific guidelines for policy makers and government agencies to check the CO_2 emission in the region. The Loktak lake needs to be conserved, as further destruction of the wetland will lead to large scale emission of carbon dioxide and loss of important natural resources including the world's only floating national park, The Keibul Lamjao National Park.

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