

Assessment of water quality with comparative study of soil organic carbon stock in Nagdaha Lake and its adjacent agricultural land of Lalitpur, Nepal

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Abstract. Bhatta M, Joshi R. 2023. Assessment of water quality with comparative study of soil organic carbon stock in Nagdaha Lake and its adjacent agricultural land of Lalitpur, Nepal. *Intl J Bonorowo Wetlands* 13: 9-16. The lakes are an important component of the terrestrial Carbon (C) cycle. Estimates of global C burial by lakes suggest burial rates ranging from 0.03-0.07 Pg C yr⁻¹. In the present study, the water quality of Nagdaha Lake and comparative analysis of Soil Organic Carbon (SOC) in Nagdaha Lake and its adjoining agricultural area has been studied. Water quality was determined following APHA (1998); SOC was determined by the Walkey and Black (1934) Titration Method. The present study results show that the mean N-nitrate and P-phosphate concentration in the waters of Nagdaha Lake is 0.135 mg/L and 0.123 mg/L, respectively, and the mean SOC concentration of Nagdaha Lake (71.39±42.58g kg⁻¹) is higher than the adjacent agricultural land (14.36±8.38g kg⁻¹). The t-test result also shows that there is a significant difference in SOC concentration in lakes (t = 9.18) and agricultural (t = 7.66) for agricultural land (p < 0.0001). Nagdaha Lake's area decreased from 52 ropani to 42 ropani between 1964 and 2022. Despite the decrease in area, Nagdaha Lake has more carbon per unit area than agricultural land. Since the conversion of lake land to agricultural land can release a large amount of carbon into the atmosphere, it is imperative to preserve the lakes to mitigate increasing atmospheric CO₂ concentration.

Keywords: Agricultural land, Nagdaha Lake, organic carbon, water quality

INTRODUCTION

The Great Lakes play a greater role in global carbon (C) cycling than their area would otherwise predict (Toming et al. 2020). While the lakes make up less than 2% of the earth's surface area, they bury over three times more carbon in their sediments than the world's oceans combined (Dean and Gorham 1998; Bonnema et al. 2022). Small lakes with a lot of algae bury the most carbon, so small drainage, and farm ponds, as well as recreational lakes all over the world, are important sites for C cycling and a source of information about global climate change (Downing et al. 2008; Heino et al. 2021). The potential relevance of lakes to the global C budget has received attention recently, with the realization that lakes form an important component of the terrestrial carbon cycle (Algesten et al. 2004; Cole et al. 2007; Downing et al. 2008). It is estimated that the rate of global C burial by lakes ranges from 0.03 to 0.07 Pg C yr⁻¹ (Cole et al. 2007). Globally, the burial of organic carbon (OC) in the sediments of natural lakes has been estimated in the range of 30 to 70 Tg C a⁻¹ (Mulholland and Elwood 1982; Dean and Gorham 1998). Degradation of lakes due to eutrophication, excess evaporation due to rising temperatures, and irrigated water directly entering the wetland may be the primary causes of lake disappearance (Schindler 2001). Agriculture runoff is a serious pollutant of lakes (Higgins et al. 2020). Besides its role in enteric epidemics, it contains high amounts of nitrogen,

phosphorous, pesticides, etc. (Chowdhary et al. 2020). Agriculture runoff adds excess nitrogen and phosphorous from synthetic fertilizers, bringing about eutrophication (Domagalski et al. 2007). Carbon dioxide originates mainly from the bacterial degradation of organic matter, and oxygen is mainly produced by green plants (Nebbio and Piccolo 2013). Globally, this burial of OC in the sediments of natural lakes has been estimated to be 30 to 70 Tg Ca⁻¹ (Mulholland and Elwood 1982; Dean and Gorham 1998). Even though lakes bury huge amounts of carbon, they also tend to release more carbon dioxide into the atmosphere than they absorb, making them net sources of greenhouse gases (Mendonça et al. 2012). Generally, lakes drain large landscapes, and the carbon from forests, fields, and lawns becomes concentrated in lakes, where it can be buried or released into the atmosphere (Pilla et al. 2022).

Lakes and ponds have always been important water sources in Nepal because they are major water sources for different sectors like irrigation, drinking water, industrial uses, etc. (Gurung et al. 2019; Sunar et al. 2022), which cover 5% of the total land area in Nepal (Sharma 2008). They are distributed with geological and altitudinal variations in the form of springs, rivers and flood plains, ponds, and swamps (Maltby et al. 2011). The shrinking of lakes in many parts of the country has identified the importance of conserving and managing wetlands (Mitra et al. 2005). However, limited research and a lack of management have made the lakes vulnerable, especially

concerning carbon sequestration. Particularly, studies on carbon stock estimation in lakes are still hard to find in Nepal, especially in the upland. Because of the above matter, the present study has been conducted in Nagdaha Lake and its surrounding agricultural area. The study's main objectives are to assess the water quality and the differences in SOC concentration in Nagdaha Lake and its adjacent agricultural land.

MATERIALS AND METHODS

Study area

The research was carried out at Nagdaha Lake, located in Dhapakhel, Lalitpur; 5 kilometers away from Kathmandu, Nepal. The water flows out of the lake and forms two small wetlands covering an area of 3.07 ha with a zigzag shape. It is located at latitude 27°37'53" N latitude and 85°19'97" E longitude with 0.3 to 3.6 m depth (Thapa and Shrestha 2010; Parajuli 2017). The major water source is yellow water and has 2 eye-type outlets called "Ankhi Daha." Water is mainly used for irrigation, household purposes, washing clothes, bathing, subsistence, and commercial activity. About 300-400 ropani of agricultural land is irrigated by this lake water (DNPWC 2006) annually. Closed circles in Figure 1 denote sample locations for water quality determination, and "numbers" denote the samples of soil taken for carbon determination.

Sampling method

The required samples were determined using a formula developed by APHA (1998).

$$N = \left(\frac{t \cdot s}{D \cdot \bar{x}} \right)^2$$

Where: N= number of samples, t= t-test value, s= standard deviation, D= depth of soil sample in the core, and $\bar{x}$ = mean value. Soil samples were collected from the lake and agricultural land (present in the south and west), as shown in the schematic diagram (Figure 1), which were collected by systematic random sampling. For organic

carbon determination, 20 samples were taken from agricultural land. Soil cores were taken using a 5.5 cm diameter and an 18 cm high cylindrical column. Soil cores were limited up to the depth of the topmost soil horizon of the agricultural land. In the case of the lake, 30 core samples were taken from Nagdaha lake from surface sediment with the help of a Grab-Sampler (Wagtwch, Cambria, UK; Duncan and Associated Ltd.) without disturbing the upper natural layer. Samples were taken along an imaginary transverse line across the lake. Thus, obtained soil samples were placed in sealed plastic bags and used for soil analysis in the laboratory.

Soil analysis

The Walkey and Black Titration method determined Soil Organic Carbon determination. First, 0.5 g of soil was weighed and transferred to the well-labeled, dried 500 mL conical flask. Then, 10 mL of 1 N potassium dichromate solution and 20 mL of concentrated sulfuric acid were added and mixed by gentle swirling. The flask was kept for about 30 minutes to react with the mixture. After the reaction, the mixture was diluted with 200 mL of distilled water and 10 mL of phosphoric acid added, followed by 1 mL of diphenylamine indicator. Finally, the sample was titrated with 0.4 N ferrous ammonium sulfate, and the endpoint was changed to brilliant green. Then, the blank was run again, followed by the above procedure without the soil sample.

The percentage of Soil Organic Carbon (SOC) was calculated by using the following equation:

$$\% \text{ of SOC} = 3.951/g \times (1-T/S)$$

Where: g= weight of soil sample taken

S=ml (ferrous) solution with blank titration

T=ml (ferrous) solution with sample titration

The total Soil Organic Carbon (SOC) was calculated by using the method (Batjes 1996) as follows:

$\text{SOC (kg/m}^2\text{)} = \% \text{SOC} \times \text{bulk density (g/m}^3\text{)} \times \text{thickness of the soil horizon (m)}.$

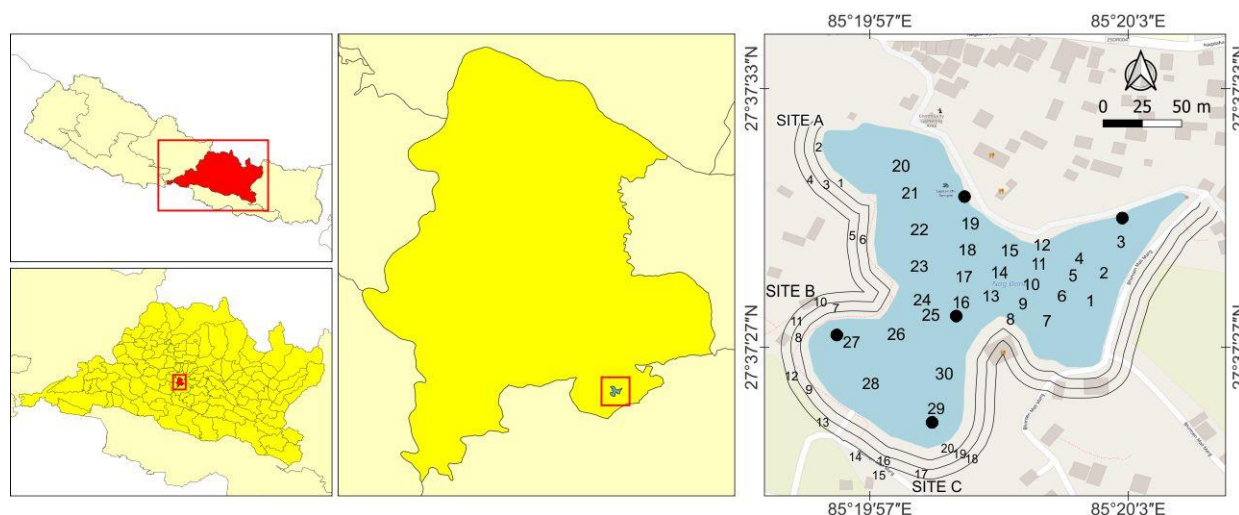


Figure 1. Schematic diagram of the study area

Bulk density

Soil bulk density was determined using a core sampling method of known volume. The soil samples were collected using core samplers without disturbing the natural structure. The collected soil samples were oven dried in a hot air oven at 105°C for 24 hours. Soil bulk density was calculated by using the following relationship:

$$\text{Bulk Density (D}_b\text{)} = W_{os} / V_{os}$$

W_{os} = weight of oven-dried soil)

V_{os} = volume of the core sampler

Organic matter

Organic Matter (OM) present in the soil was determined by:

$$\text{OM} = \%OC \times 1.724$$

Water quality determination

For the determination of different water quality parameters, 5 water samples were taken from Nagdaha lake. These five samples were taken from the lake's five sites (Figure 1). All the samples (water and soil) were tested in the Central Department of Environmental Science laboratory, Tribhuvan University, Kirtipur. In addition, water samples were immediately tested soon after they arrived from the field. As a result, the water quality of the lake was determined following APHA (1998) and Trivedi and Goel (1984) as follows:

Temperature

The water temperature was measured by using a mercury-filled Celsius thermometer. The surface water was collected in a beaker, and the reading was noted.

pH

Next, to measure the pH (Potentia Hydroegnii), a water sample was taken in a clean beaker, and the electrode (rinsed with water and blot dried) of the pH meter was dipped into the water sample until the constant displayed the score. Finally, equilibrium between the electrode and the water sample was established by stirring the water sample to ensure homogeneity.

Electrical conductivity

It was measured by a conductivity meter. The conductivity meter was dipped into a beaker containing the sample water, and the constant reading was noted.

Dissolved oxygen

It was determined by the Winkler or iodometric method. A BOD bottle of 300 ml was filled with sample water with the utmost care and immediate use of the stopper to avoid bubbling and trapping the air bubble in the bottle. Then, brown precipitation occurred after adding 2 ml of Manganese Sulphate (MnSO_4) and an alkaline Potassium Iodide (KI) solution. The solution was shaken well in an "8" shape repeatedly. Precipitation was allowed to settle the water completely, leaving a clear supernatant layer. Next, 2 mL of Hydrogen Sulphuric acid (H_2SO_4) concentration was added and shaken well to dissolve the precipitate. Then the 50 mL solution was taken in a conical

flask and added with 2-3 drops of starch solution as an indicator (turns blue). This solution was titrated against Sodium Thiosulfate until the solution changed color from blue to colorless. Dissolved oxygen was calculated as (if the fraction of the content is used for titration):

$$\text{Dissolved oxygen (mg/L)} = (\text{Volume} \times \text{Normality}) \text{ of titrant} \times 8 \times 1000$$

$$V_2 (V_1 - V) / V_1$$

Where,

V_1 = volume of the sample bottle

V_2 = volume of the part of content titrated

V = Volume of MnSO_4 and KI added

Calorimetric method

Phosphorus-Phosphate in the water was determined by the Calorimetric Method in the laboratory.

Phenol di-sulphuric acid method

Nitrogen-Nitrate was determined by the Phenol Di-sulphuric acid Method in the laboratory.

Data analysis

Data were analyzed with the SAS software, Ms-word, and Ms-Excel and statistically tested by student's t-test for comparisons of carbon content.

RESULTS AND DISCUSSION

Water quality determination

The water quality (temperature, pH, conductivity, DO, phosphate, and nitrate) and carbon content of the lake and its adjoining agricultural land were assessed. Water quality was determined from five sites in the lake based on allogenic sources in the lake. Because the lake is used for different purposes, water qualities were determined from different sites in the lake.

The water was slightly alkaline, and the pH was almost constant at around 8.070 ± 0.070 . Electrical conductivity was found to be $191.200 \pm 3.631 \mu\text{S/cm}$. Phosphorus-phosphate was $0.123 \pm 0.0004 \text{ mg L}^{-1}$, and nitrogen-nitrate was found at $0.135 \pm 0.067 \text{ mg L}^{-1}$. The Dissolvable Oxygen (DO) was found to be $3.636 \pm 0.416 \text{ mg L}^{-1}$. Thapa and Shrestha (2010) in his study found the lake hypereutrophic based on $\text{PO}_4\text{-P}$ while DO was slightly higher than in this study, i.e., 4.32 mg L^{-1} and $\text{NO}_3\text{-N}$ was 0.123 mg L^{-1} in three water samples. Similarly, Thapa and Shrestha (2010), in the wetland of Terai (Ghodaghodi Lake), have considered the lake with a mean DO of around 5 mg L^{-1} as eutrophic. The water samples from sites one to five were taken from the cloth washing outlet part, Nag temple, the middle part, the southern hotel side area, and the agricultural side, respectively (Table 1). Water quality also varied with the source of the sample taken.

Soil Organic Carbon stock in Nagdaha Lake

Carbon was estimated from 30 core samples taken from the lake (Figure 2). SOC in Nagdaha lake was found to be 2.032 kgm^{-2} . The mean OM (%) in the lake was $12.31 \pm$

7.31. Mean OC and SOC were $71.39 \pm 42.582 \text{ g kg}^{-1}$ and $20.530 \pm 8.948 \text{ g kg}^{-1}$ in Nagdaha Lake, respectively.

Carbon stock in agricultural land

The carbon stock was estimated from agricultural land (Figure 3). Altogether, 20 samples were taken from agricultural land, which covered more than half the boundary area around the lake. The mean carbon stock in agricultural land was 1.680 kg m^{-2} . The mean bulk density was 1.169 g mL^{-1} in agricultural land higher than the lake, i.e., $0.349 \pm 0.154 \text{ g mL}^{-1}$. The mean OC and SOC were $14.36 \pm 8.383 \text{ g kg}^{-1}$ and $16.8 \pm 10.082 \text{ g kg}^{-1}$, respectively.

Comparison of carbon in Nagdaha Lake and agricultural land

There is a significant difference in mean organic carbon between the two sources ($t = 9.18$ and $p < 0.0001$) (Nagdaha Lake and agricultural land). Similarly, mean organic carbon is lower in agricultural land. The conversion of the lake into agricultural land shows a difference of 57.024 g kg^{-1} organic carbon between Nagdaha lake and agricultural land. There is a significant

decrease in organic carbon in agricultural land ($t = 7.66$ and $p < 0.0001$) (Table 2).

Carbon accumulation in a lake is influenced by various factors, including initial primary productivity in the lake, external input, dilution by minerals, and post-depositional minerals in the lake (Last and Ginn 2005; Amezcua et al. 2021). On the other hand, the lake's age also affects the lake's carbon stock (Hinkel et al. 2003). Among the dissolved gases, carbon dioxide (CO_2) and oxygen (O_2) are biologically the most important ones (Bajracharya et al. 2016). CO_2 originates mainly from the bacterial degradation of OM, and O_2 is mainly produced by green plants (Miltner et al. 2005). Research shows that the CO_2 released from lakes comes from organism respiration and the breathing of bacteria, algae, zooplankton, fish, and other species (Hessen 1992; Cole et al. 2006; Brett et al. 2017). In the study area, nitrogen and phosphorus used on the agricultural land during the monsoon leach out and could enter the lake water, which might accelerate the vegetation growth in the lake that might be seasonal or all year around. Agricultural residues decompose into simpler forms of carbon sequestered in the agricultural soil.

Table 1. Water quality determination of Nagdaha Lake, Lalitpur, Nepal

Sample	pH	Temp.	Electrical conductivity ($\mu\text{S/cm}$)	P-phosphate (mg L^{-1})	N-nitrate (mg L^{-1})	DO (mg L^{-1})
1.	8.010	28.70	196.000	0.124	0.160	3.300
2.	8.010	24.10	194.000	0.123	0.106	4.109
3.	8.060	24.30	188.000	0.123	0.099	4.030
4.	8.080	24.90	190.000	0.123	0.111	3.536
5.	8.190	25.40	188.000	0.123	0.103	3.201
SD	0.070	1.870	3.631	0.0004	0.067	0.416
mean	8.070	25.480	191.200	0.123	0.135	3.635

Table 2. Statistical parameters

Sampled Area	Mean OC (g kg^{-1})	Standard deviation	Maximum value	Minimum value	t value	df	p
Lake	71.387	42.582	179.000	24.690	9.180	29	<0.0001
Agricultural land	14.363	8.383	32.930	3.290	7.660	19	<0.0001

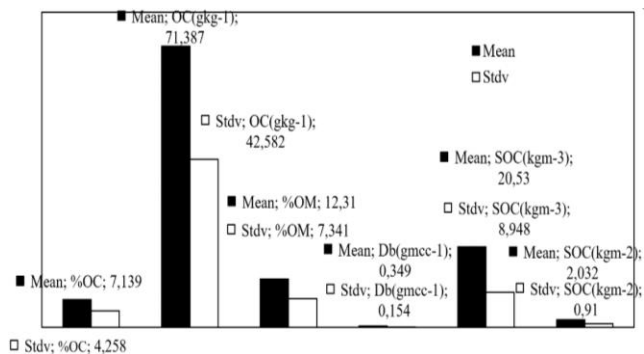


Figure 2. The carbon content of Nagdaha Lake, Lalitpur, Nepal

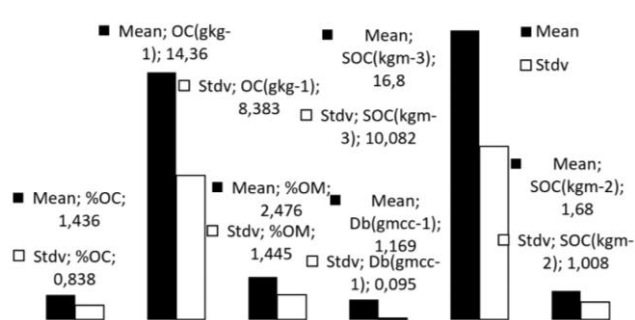


Figure 3. The carbon content of agricultural land adjacent to Nagdaha Lake, Lalitpur, Nepal

Similarly, human activities like bathing, washing, cleaning boats, etc., also contribute to the nutrient load of the lake and affect water quality. Cardille et al. (2007) estimated that the total regional carbon flux from the lake surface was 31% higher in the wet scenario and 46% lower in the dry scenario in highland lakes. The mean carbon stock in the lake was higher than on the agricultural land. SOC (kgm^{-3}) was found at 20.530 ± 8.948 in Nagdaha lake and 16.8 ± 10.082 in agricultural land. According to the Nagdaha Conservation and Improvement Committee (2011), the lake area was 2.65 hectares (52 ropani) in 1964, and in 2022, it was reduced to 2.14 hectares (42 ropani). That indicates that the lake area has decreased by 0.51 ha. Thapa and Shrestha (2010) found the lake area in 2008 decreased by 0.4. The lake is slowly changing into the land through the transformation from a lake to a swamp, grassland, and finally, agricultural land. Due to the high carbon load in lakes, the conversion of a lake into agricultural land could emit a large amount of carbon into the atmosphere. Lakes emit more carbon into the atmosphere than agricultural land because they bury more carbon. Agricultural land tends to have carbon-rich soil that, when tilled for cropping, is very susceptible to rapid erosion (Downing et al. 2008) and drains to lakes. Fertilizers used on agricultural land are major contributors to nutrients like phosphorus and nitrogen in the water. Shah et al. (2011) classified this Nagdaha lake in the fair water quality class using the macroinvertebrates-based Nepal Lake Biotic Index (NLBI) with a score of 4.55. According to Thapa and Shrestha (2010), OC was found at $111.49 \pm 75.16 \text{ g kg}^{-1}$ in Ghodaghodi lake and $89.86 \pm 28.25 \text{ g kg}^{-1}$ in Nakhrodi lake. Comparatively, OC was found lower in Nagdaha than in Ghodaghodi Lake and the associated Nakhrodi lake. These lakes are mainly covered by forest and grassland and are located in the lower Terai belt.

In conclusion, the water quality of the lake indicates that the lake is eutrophic. Agricultural land is a major contributor of nitrogen and phosphorus to the lake, increasing aquatic plants' growth rate. OC was found at $71.39 \pm 42.58 \text{ g kg}^{-1}$ in Nagdaha Lake, and $14.36 \pm 8.38 \text{ g kg}^{-1}$ in agricultural land and is significantly higher in the lake than in the agricultural land. Therefore, the conversion of lake land to agricultural land has the potential to release a large amount of carbon into the atmosphere.

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