Assessment of tank sediments in terms of plant nutrients equivalent: an approach towards agricultural sustainability

Bisweswar Gorain[1,*], V. R. Ramakrishna Parama[2] and Srijita Paul[3]

[1]Department of Soil Science, ICAR-Central Soil Salinity Research Institute, RRS, Bharuch 392 012, India
[2]Department of Soil Science, University of Agricultural Sciences, Bengaluru 560 064, India
[3]Agricultural Training Centre and State Agricultural Management and Extension Training Institute, Ramakrishna Mission, Narendrapur, Kolkata 700 103, India

The aim of this study was to assess the suitability of lake sediments of Bengaluru, Karnataka, India, as a nutrient source for agricultural crop production. The sediments were analysed for macro- and micronutrients and toxic heavy metals using standard procedures. The results showed high stocks of N, P and K and low heavy metal concentration in the upper 15 cm depth of the lake sediments, implying their suitability as a nutrient alternative. This will reduce the use of synthetic fertilizers, improve soil health and also increase water storage capacity in the lakes, and thus promote sustainable agricultural production.

Keywords: Food security, heavy metals, plant nutrients, surface-water run-off, sustainable agriculture, tank sediments.

THE judicious use and management of natural resources, viz. soil and water are vital for sustainable agriculture. In order to meet the growing demand for food, feed and fibre on a sustainable basis, proper soil management and rainwater conservation are essential. Due to the increasing demand for agricultural products, over-exploitation and inappropriate management of natural resources have become a common phenomenon. As a consequence, surface-water run-off, downstream flooding, soil erosion, loss of nutrient-rich topsoil and water scarcity are leading to soil degradation. The surface run-off erodes the topsoil, which finally gets deposited in the nearby water bodies[1]. Loss of nutrients and organic matter from farmlands reduces agricultural productivity and may threaten food security. Modern agricultural practices depend on synthetic fertilizers, pesticides and herbicides for crop production. Run-off from these farmlands not only erodes the topsoil and fine organic matter particulates, but also the heavy metals (component of pesticides and herbicides)[2].

Many household drains and industries in Bengaluru, Karnataka, India have their outlets in lakes[3]. Thus, essential nutrients and heavy metals from all these sources are finally accumulated in the tank sediments. These sediments can thus be used as a nutrient source in agriculture provided their heavy metal concentrations are within the threshold levels[4]. This not only saves the cost of synthetic fertilizers but can also moderate soil physical, chemical and biological properties, thereby improving soil health[5]. The desiltation of sediments also has the potential to increase the water storage capacity in the lakes and help in rainwater harvesting. With this background, sediments from nine different lakes in Bengaluru were collected and analysed for available plant macro- and micronutrients and heavy metal concentration, to assess their suitability as an alternate source of plant nutrients.

The city of Bengaluru stretches from 12°59″N to 77°57″E, located equidistant from the eastern and western coasts of the South Indian peninsula. It is situated at an altitude of 920 m amsl, with mean annual rainfall of about 880 mm. The summer and winter temperatures range from 18°C to 38°C and 12°C to 25°C respectively. The city delineates four watersheds, viz. Hebbal, Koramangala, Challaghatta and Vrishabhavathi[6]. Recent satellite imagery data suggest that the number of lakes has dropped from 262 (in 1961) to about 30, mostly due to encroachments, silt deposition and mismanagement. Table 1 shows the coordinates and extent of nine lakes of Bengaluru considered in the present study. Samples of tank silt were collected up to 15 cm depth at various locations in the tank-bed area. A composite sample was drawn using normal sampling procedure. The soil samples and tank sediments were dried in shade, ground with a wooden pestle and mortar and finally passed through a 2 mm sieve and stored in clean polythene bags for further analyses. Analysis of N, P, K, Ca, Mg and S was done using standard procedures (Table 2). Micronutrients and heavy metals were analysed by diethylene triamine pentaacetic acid (DTPA) extraction method using atomic absorption spectrophotometer (Perkin Elmer Analyst 700)[7]. The stocks of primary nutrients were calculated as follows

Stock of nutrient (kg) = Area of the lake (ha) × depth of lake sediment (m) × bulk density (Mg m^{-3}) × nutrient concentration (mg kg^{-1}) × 10^{-3}.

The equivalence of lake sediments (up to 15 cm depth) to bags of urea, SSP (single super phosphate) and MOP (muriate of potash) in terms of available plant nutrients was calculated using the following formulae:

Equivalent bags (50 kg each) of urea = (100 × stock of N in the lake sediment)/(46 × 50).

Equivalent bags (50 kg each) of SSP = (100 × stock of P_2O_5 in the lake sediment)/(16 × 50).

*For correspondence. (e-mail: Bisweswar.Gorain@icar.gov.in)

Table 1. Location of nine lakes in Bengaluru, Karnataka, India and their extent

Lake	Location	Area (ha)	Catchment area (ha)
Madiwala	12°54′N, 77°37′E	114.3	–
Lalbagh	12°56′N, 77°35′E	13	–
Bellandur	12°93′N, 77°66′E	360	14,800
Sankey Tank	13°01′N, 77°57′E	15	125.4
Ulsoor	12°58′N, 77°37′E	50	150
Yelahanka	13°06′N, 77°34′E	10	–
Yediyur	12°56′N, 77°34′E	6.45	–
Nagavara	13°02′N, 77°36′E	44	–
Hebbal	13°02′N, 77°35′E	75	–

Data not available.

Table 2. Methods used for the analysis of lake sediments

Estimation	Method
Particle size analysis	International pipette method[11]
Soil reaction (pH)	Potentiometry[12] (1 : 2.5 soil : water suspension)
Electrical conductivity (EC; d Sm^{-1})	Conductometry[12] (1 : 2.5 soil : water suspension)
Organic carbon (OC; %)	Chromic acid wet digestion method[13]
Available N (kg ha^{-1})	Alkaline permanganate method[14]
Available P_2O_5 (kg ha^{-1})	Olsen extraction method – spectrometry[15]
Available K_2O (kg ha^{-1})	Neutral normal NH_4OAC extraction-flame photometer[16]
Exchangeable calcium and magnesium (cmol (p+) kg^{-1})	Versenate titrimetry[12]
Available Zn, Fe, Cu and Mn	DTPA extraction and atomic absorption spectrometry[7]
Available Cr, Ni, Cd and Pb	DTPA method and atomic absorption spectrometry[7]

Table 3. Physico-chemical properties and primary nutrient concentration of tank sediments in Bengaluru

Lake	pH	EC (dS m^{-1})	OC (g kg^{-1} sediment)	N (ppm)	P (ppm)	K (ppm)
Madiwala	6.32	0.34	22.10	305.72	6.68	117.80
Lalbagh	8.15	0.53	19.30	293.08	6.65	117.68
Bellandur	6.15	0.34	25.60	253.18	6.84	123.47
Sankey Tank	7.50	0.76	22.10	284.61	7.20	122.76
Ulsoor	6.34	0.71	23.81	284.72	6.23	155.13
Yelahanka	7.15	0.65	18.50	238.54	8.60	154.82
Yediur	7.28	1.34	17.60	310.19	8.83	115.69
Nagavara	7.05	1.24	17.50	248.27	8.21	117.04
Hebbal	7.53	0.91	11.50	235.90	11.07	159.97
Mean	7.05	0.76	19.78	272.69	7.81	131.60

Equivalent bags (50 kg each) of MOP = (100 × stock of K_2O in the lake sediment)/(60 × 50).

Urea, SSP and MOP contain 46%, 16% and 60% of N, P_2O_5 and K_2O respectively.

Texture analysis provides an estimate of the relative distribution of sand, silt and clay in a given sample. The texture of tank sediments is a function of soil type, topography, rainfall intensity, crop cover and organic matter content of soils in the catchment area. The presence of finer fractions in tank sediments is indicative of the transportation of silt and clay particles with run-off water through erosion. In this study, fine sand in the samples ranged from 12% to 53%, whereas silt and clay content ranged from 30% to 71%. Texture analysis of lake sediments revealed similarities in soil type of the lake sediments and surrounding areas, indicating erosion of the topsoil layers. The pH of nine lakes of Bengaluru ranged from 6.15 to 8.15 (Table 3). The pH of Bellandur and Madiwala lakes was acidic and Lalbagh lake was in the alkaline range, whereas the others were neutral. Since crops differ in their sensitivity towards soil pH, use of sediments should be based on the type of crops to be grown. Sediments with high pH should preferably not be applied to high-pH soils and vice versa, as it may adversely affect soil health. Electrical conductivity (EC) is an indicator of the presence of dissolved salts in the sediments that might be added through surface run-off. EC in all the lake sediments under study was within safe limits (<2 dS m^{-1}). The available nitrogen content varied

Table 4. Secondary nutrient concentration of tank sediments in Bengaluru

Lake	Ca (meq l^{-1})	Mg (meq l^{-1})	S (ppm)
Madiwala	7.13	3.76	26.65
Lalbagh	6.13	3.92	16.55
Bellandur	5.13	2.92	27.34
Sankey Tank	7.18	3.73	36.65
Ulsoor	6.29	2.92	31.65
Yelahanka	6.85	3.54	76.55
Yediur	6.69	2.74	41.98
Nagavara	6.51	2.80	33.59
Hebbal	7.30	3.73	45.65
Mean	6.58	3.34	37.40

Table 5. Micronutrients concentration of tank sediments in Bengaluru

Lake	Cu (ppm)	Fe (ppm)	Zn (ppm)	Mn (ppm)
Madiwala	8.79	8.14	0.05	5.05
Lalbagh	3.13	8.12	0.05	7.23
Bellandur	4.64	20.28	6.40	5.81
Sankey Tank	1.79	7.82	5.88	3.15
Ulsoor	1.78	19.79	0.07	5.96
Yelahanka	3.54	18.12	0.06	5.75
Yediur	8.33	9.09	0.06	9.36
Nagavara	8.53	8.77	0.05	11.1
Hebbal	11.81	12.65	0.06	4.23
Mean	5.81	12.53	2.52	5.51

from 235.90 ppm in Hebbal lake to 310.19 ppm in Yediur lake (Table 3). The mean nitrogen concentration recorded in all the nine lakes was 272.69 ppm. The higher concentration of nitrogen in silt suggests significant run-off losses of applied nitrogen fertilizers from agricultural fields. Padmaja *et al.*[5] also recorded high N concentration in tank silt in the Medak district of Andhra Pradesh. Regular addition of high amounts of nitrogen is responsible for eutrophication in the surface water bodies and may cause nitrate pollution in groundwater. Among the nine lakes studied, the organic carbon (OC) concentration was highest in Bellandur lake (25.60 g kg^{-1} sediment) and least in Hebbal lake (11.50 g kg^{-1} sediment). OC content was higher in lake sediments compared to the nearby agricultural fields due to erosion of the topsoil layer and subsequent deposition in the lakes. In waterlogged condition, oxidation of OC is not possible, due to which loss of C decreases and thus C stock may build up with time[8]. Application of OC-rich sediments may improve soil health and stimulate microbial proliferation, as it is an important indicator of soil quality. The maximum available P content was recorded in Hebbal lake (11.07 ppm) followed by Yediur lake (8.83 ppm) (Table 3). Available potassium content ranged from 115.69 to 159.97 ppm, with mean concentration of 131.60 ppm. The concentration of calcium varied from 5.13 meq l^{-1} in Bellandur lake to 7.30 meq l^{-1} in Hebbal lake sediments (Table 4). Similarly, the magnesium content ranged from 2.74 to 3.92 meq l^{-1}. Higher concentration of alkali earth metals signifies their probable use as soil amendment in acidic soils. Higher sulphur content was recorded in Yelahanka lake (76.55 ppm) followed by Hebbal lake (45.65 ppm). The concentration of cationic micronutrients, e.g. Cu (1.78–11.81 ppm), Fe (7.82–20.28 ppm), Zn (0.05–6.40 ppm) and Mn (3.15–11.1 ppm) was variable (Table 5). The concentration of micronutrients in lake sediments was a function of the degree of soil erosion, and the amount of micronutrients added in the nearby agricultural fields and other point sources (domestic and industrial outlets). Traces of heavy metals, viz. Ni, Cr, Cd and Pb were found in the sediment samples. The concentration of Ni was maximum in Bellandur lake sediments (3.02 ppm), which is the sink of many industrial waste outlets, and minimum in Lalbagh lake (0.026 ppm) (Table 6). Sankey Tank was found to be highly contaminated with Cr and Cd. Pb content varied from 0.003 to 0.488 ppm in the nine lakes. Heavy metals in soil sediments can be translocated to the plant system and may contaminate the food chain[9]. Thus, build-up of heavy metals in sediments should be prevented in order to use them as a nutrient source and soil amendment.

The nitrogen stock depends on the concentration of nitrogen, bulk density of the sediments and area of the lake. Maximum nitrogen stock in the upper 15 cm of lake

Table 6. Heavy metal concentration in Bengaluru lakes

Lake	Ni (ppm)	Cr (ppm)	Cd (ppm)	Pb (ppm)
Madiwala	0.15	0.186	0.29	0.003
Lalbagh	0.026	0.025	0.001	0.035
Bellandur	3.02	6.55	0.002	0.009
Sankey Tank	0.218	8.92	5.83	0.431
Ulsoor	0.375	0.214	0.003	0.488
Yelahanka	0.027	0.025	0.262	0.041
Yediur	0.242	0.354	0.515	0.427
Nagavara	0.027	0.019	0.036	0.004
Hebbal	0.265	0.326	0.227	0.441
Mean	0.483	1.846	0.796	0.209

Table 7. Available N concentration and stock in Bengaluru lakes

Lake	N (ppm)	Bulk density (BD) (Mg m^{-3})	N content (kg/ha)	Area of the lakes (ha)	Total N content in the top 15 cm (kg)	No. of urea bags (50 kg)
Madiwala	305.72	1.02	467.7516	114.3	53,464.01	2,325
Lalbagh	293.08	1.01	444.0162	13	5,772.21	251
Bellandur	253.18	1.13	429.1401	360	154,490.40	6,717
Sankey Tank	284.61	1.08	461.0682	15	6,916.02	301
Ulsoor	284.72	1.16	495.4128	50	24,770.64	1,077
Yelahanka	238.54	1.1	393.591	10	3,935.91	171
Yediur	310.19	1.03	479.2436	6.45	3,091.12	134
Nagavara	248.27	1.05	391.0253	44	17,205.11	748
Hebbal	235.9	1.17	414.0045	75	31,050.34	1,350

Table 8. Available P_2O_5 concentrations and stocks in Bengaluru lakes

Lake	P (ppm)	BD (Mg m^{-3})	P_2O_5 content (kg/ha)	Area of the lakes (ha)	Total P_2O_5 stock in the top 15 cm (kg)	No. of single super phosphate bags (50 kg)
Madiwala	6.68	1.02	23.40	114.3	2675.15	334
Lalbagh	6.65	1.01	23.07	13	299.92	37
Bellandur	6.84	1.13	26.54	360	9557.92	1195
Sankey Tank	7.2	1.08	26.71	15	400.65	50
Ulsoor	6.23	1.16	24.82	50	1241.20	155
Yelahanka	8.6	1.1	32.49	10	324.95	41
Yediur	8.83	1.03	31.24	6.45	201.50	25
Nagavara	8.21	1.05	29.61	44	1302.90	163
Hebbal	11.07	1.17	44.48	75	3336.73	417

sediments was observed in Bellandur lake, which is equivalent to 6717 bags of urea (Table 7). The P_2O_5 stock was also maximum in Bellandur lake due to its larger area. The available phosphorus stock in Bellandur lake was 9557.92 kg, which is equivalent to 1195 bags of SSP (Table 8). Available phosphorus stock in Hebbal, Ulsoor and Madiwala lakes was equivalent to 417,155 and 334 bags of SSP respectively. K_2O concentration was maximum in Hebbal lake sediments (336.89 kg/ha), but total potassium stock in the upper 15 cm layer was maximum in Bellandur lake (90,409.67 kg), which is equivalent to 3014 bags of MOP (Table 9). This is similar to the results of a study by Padmaja *et al.*[10] in the lake sediments of Medak district, Andhra Pradesh. In the present study, all the nine lakes showed noticeable stocks of primary plant nutrients. The application of these sediments as nutrient substitute for crop production will not only reduce the cost of production, but also increase the water storage capacity of these lakes.

In this study, sediments collected from all the nine lakes were found to be rich in available N, P and K. The cationic micronutrients were found to be higher than the average soil concentration. The physico-chemical properties like pH and EC were recorded within the critical

Table 9. Available K_2O concentration and stocks in Bengaluru lakes

Lake	K (ppm)	BD ($Mg\ m^{-3}$)	K_2O content (kg/ha)	Area of the lakes (ha)	Total K_2O stock in the top 15 cm	No. of muriate of potash bags (50 kg)
Madiwala	117.8	1.02	216.28	114.3	24720.90	824
Lalbagh	117.68	1.01	213.94	13	2781.24	93
Bellandur	123.47	1.13	251.13	360	90409.67	3014
Sankey Tank	122.76	1.08	238.64	15	3579.68	119
Ulsoor	155.13	1.16	323.91	50	16195.57	540
Yelahanka	154.82	1.1	306.54	10	3065.43	102
Yediur	115.69	1.03	214.48	6.45	1383.45	46
Nagavara	117.04	1.05	221.20	44	9733.04	324
Hebbal	159.97	1.17	336.89	75	25267.26	842

limits. Higher concentration of OC was recorded in all the sediment samples. The tank silt obtainable from Bellandur lake up to a depth of 15 cm was equivalent to 6717 bags of urea, 1195 bags of SSP and 3014 bags of MOP. Since heavy metals concentration was found to be within safe limits, there is hardly any chance of heavy metals pollution in agricultural fields. Thus, sediments from all these lakes can be used as a nutrient substitute for crop production. This will increase water storage of the lakes, reduce the cost of cultivation and will increase farmers' income.

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