Supplementary Materials

Spatiotemporal Assessment of Water Pollution for Beira Lake, Sri Lanka

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Table S1 – Locations of sampling sites in Beira Lake in wet and dry seasons

Place	Location		Dry Season	Wet Season
	Longitude	Latitude		
Canal Number 01	6.9313	79.8475	✓	
	6.9308	79.8463	✓	
Galle Face Lake (GF.L)	6.9305	79.8459	✓	
	6.9304	79.8452	✓	✓
	6.9302	79.8447	✓	
	6.9301	79.8441	✓	✓
	6.9297	79.8435	✓	✓
	6.9300	79.8431	✓	✓
West Lake (W.L)	6.9299	79.8460	✓	✓
	6.9292	79.8464	✓	✓
	6.9275	79.8472	✓	✓
	6.9262	79.8473	✓	✓
	6.9251	79.8466	✓	✓
	6.9242	79.8472	✓	
	6.9239	79.8483	✓	✓
Canal Number 02	6.9227	79.8487	✓	
	6.921	79.8491	✓	
	6.9194	79.8494	✓	
Gangarama Lake (G.L)	6.9182	79.8499	✓	
	6.9179	79.8503	✓	✓
	6.9172	79.8510	✓	✓
	6.9177	79.8513	✓	✓
	6.9171	79.8523	✓	
	6.9168	79.8532	✓	✓
	6.9164	79.8542	✓	✓

	6.9161	79.8551	✓	✓
	6.9170	79.8541	✓	
	6.9188	79.8535	✓	
	6.9181	79.8527	✓	✓
	6.9181	79.8538	✓	
	6.9177	79.8523	✓	
	6.9182	79.8517	✓	
East Lake (E.L)	6.9314	79.8479	✓	✓
	6.9319	79.8483	✓	✓
	6.9308	79.8489	✓	
	6.9312	79.8496	✓	✓
	6.9311	79.8513	✓	
	6.9297	79.8520	✓	✓
	6.9310	79.8534	✓	✓
	6.9295	79.8528	✓	
	6.9295	79.8545	✓	✓
	6.9284	79.8555	✓	
	6.9274	79.8560	✓	✓
	6.9262	79.8564	✓	
	6.9256	79.8583	✓	✓
	6.9247	79.8572	✓	✓
	6.9241	79.8580	✓	
	6.9234	79.8592	✓	✓
	6.9227	79.8596	✓	✓
	6.9217	79.8602	✓	
	6.9209	79.8609	✓	✓

Table S2 Area, average depth, and the number of sampling points in each lake in the wet and dry season

Lake basin	Area (km^2)	Average depth (m)	Sample points	
			Wet season	Dry season
East Lake	0.433	2.2	12	20
Galle Face Lake	0.026	2.0	4	7
West Lake	0.081	1.5	6	10
Gangarama Lake	0.114	1.7	7	14

Table S3 Water quality indices value and their pollution status

WPI Value	**Pollution Status**
< 0.5	Excellent Water
0.5 – 0.75	Good Water
0.75 – 1	Moderately Polluted
>1	Highly Polluted
TSI Value	**Pollution Status**
<40	Oligotrophic
40-60	Mesotrophic
60-80	Eutrophic
>80	Hypertrophic
HPI Value	**Pollution Status**
<100	Low heavy metal pollution
100	Harmful health consequences are probable
>100	Water is unsuitable for consumption

Table S4 Spectral bands of the Sentinel-2 sensors used for water quality monitoring

Sentinel-2 Bands	Central wavelength(nm)	Bandwidth(nm)	Resolution(m)
Coastal aerosol	443	20	60
Blue	490	65	10
Green	560	35	10
Red	665	30	10

Spatiotemporal variation of Temperature (^{0}C), EC and TDS

Temperature (^{0}C)

According to the results of the statistical analysis, the temporal variability of temperature significantly varies within seasons. Still, it doesn't show significant spatial variation across the lakes in the wet and dry seasons. The reasons for not having a significant spatial variation of temperature may be due to the smaller masses of water involved, the shallowness of the lake, and the absence of strong winds over Beira Lake. Surface water temperature changes seasonally in urban shallow lakes, which may be due to ambient air temperature, evaporation, cooling, and mixing events of freshwater fluxes (Weerasinghe and Handapangoda, 2019). Beira Lake was below 32 ^{0}C during the wet season except for a few points near the McCullum Gates and Gangarama Lake area, where some industrial and Hotel effluent might be received (**Figure 2**). Higher ambient temperature was observed in the dry season (35.9 ^{0}C), and the lowest was observed during the wet season (28.8^{0}C) (**Figure** S1). Therefore, higher ambient air temperature has created higher temperatures on surface water(Weerasinghe and Handapangoda, 2019). Due to heavy rainfall, cooling and mixing events made lower temperatures in Beira Lake.

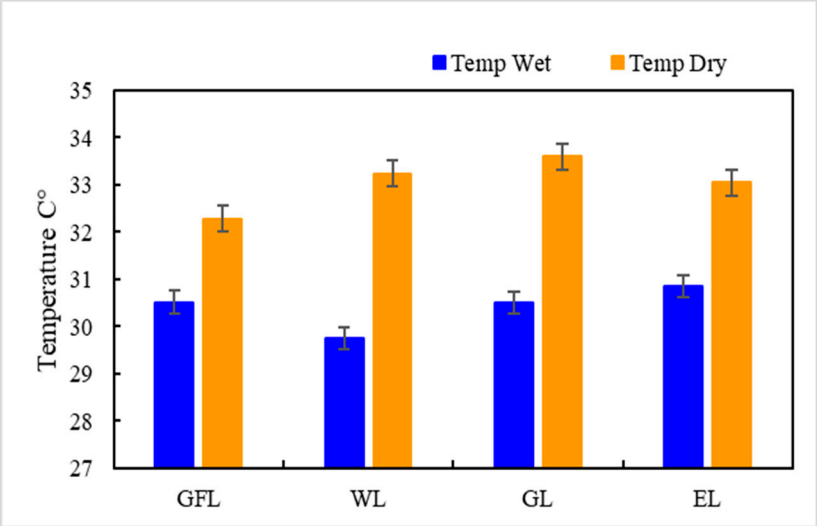

Figure S1- Spatial and temporal variation of temperature of the Beira Lake in wet and dry season

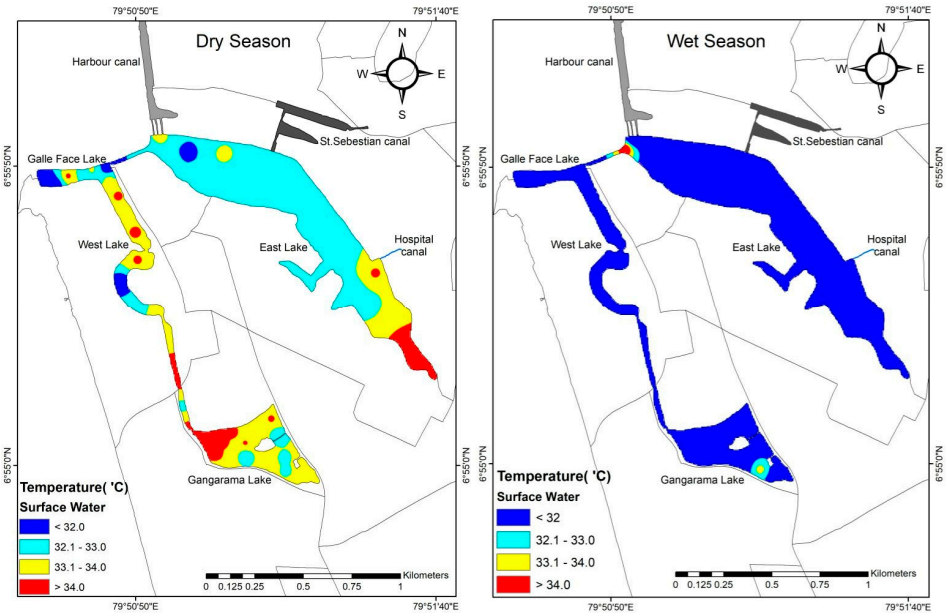

Figure S2- Spatial distribution map of temperature in wet and dry seasons

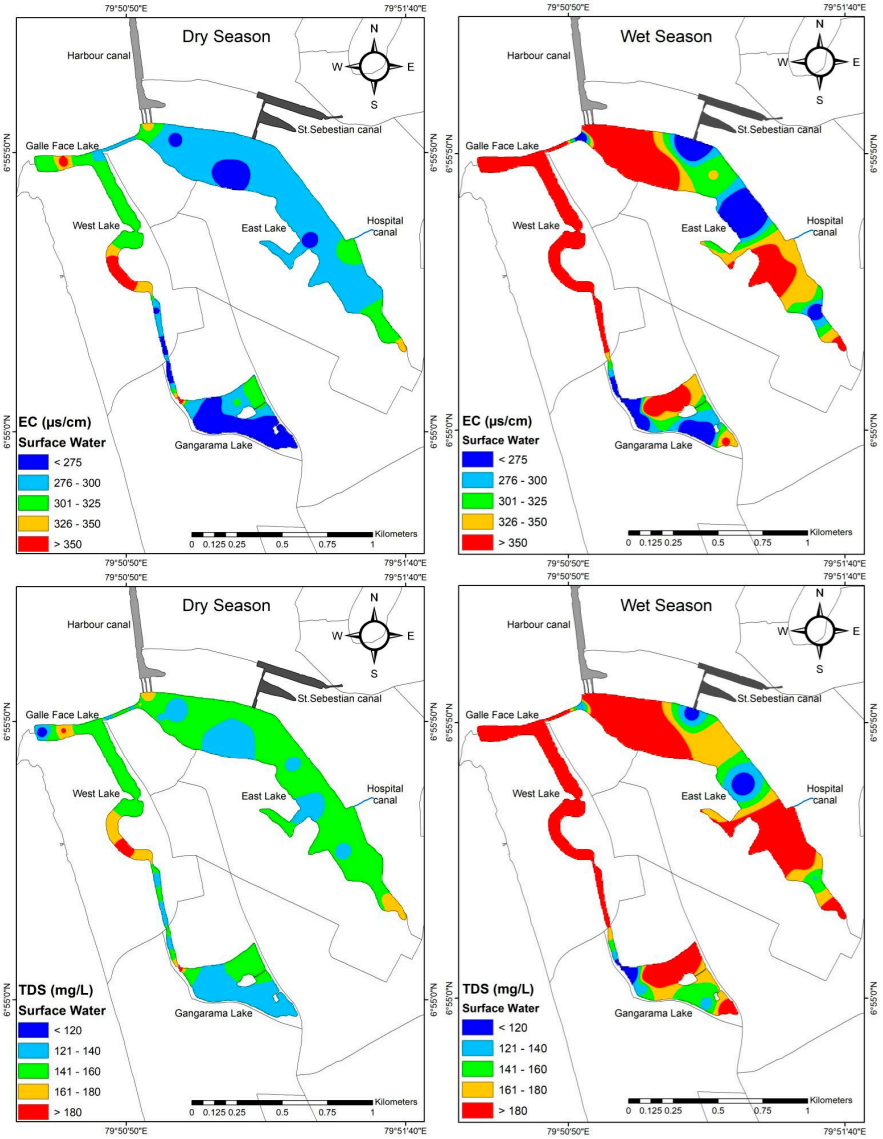

Figure S3 Spatial distribution map of EC and TDS of the Beira Lake in wet and dry seasons

Spatiotemporal Variation of Nutrient and Ions Analysis

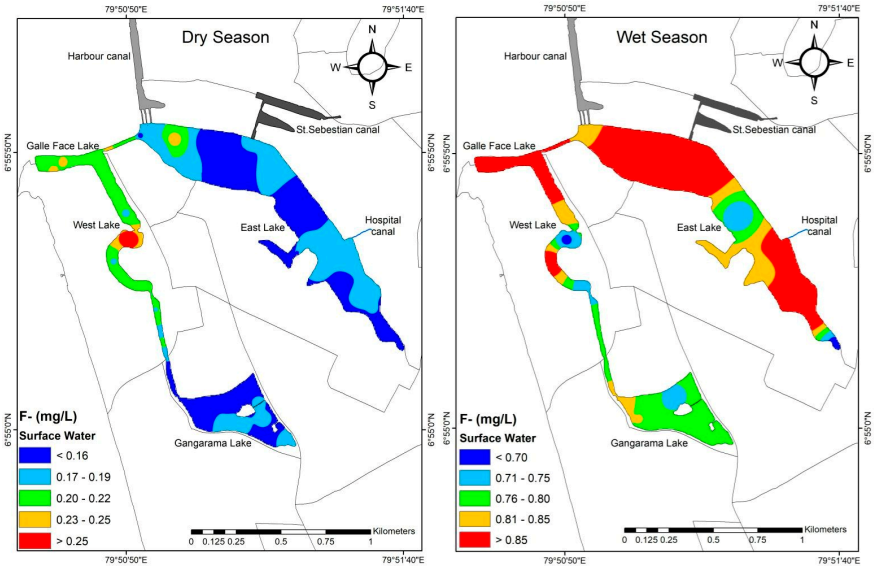

Figure S4 - Spatial distribution map of Fluoride (F^-) of the Beira Lake in wet and dry seasons

F^- concentration is high in the wet season especially EL and shows a low mean value in the dry season, which is a significant difference ($p<0.05$). F^- shows a significant difference between the two seasons ($p<0.05$) as receives a high amount of F^- during the wet season. High F^- ion distribution can be seen in the wet season in the Galle Face Lake, and the West Lake area(Figure-S6). Dynamic F^- ion distribution can be seen in dry season and wet season.

Spatiotemporal Variation of Heavy Metals Analysis

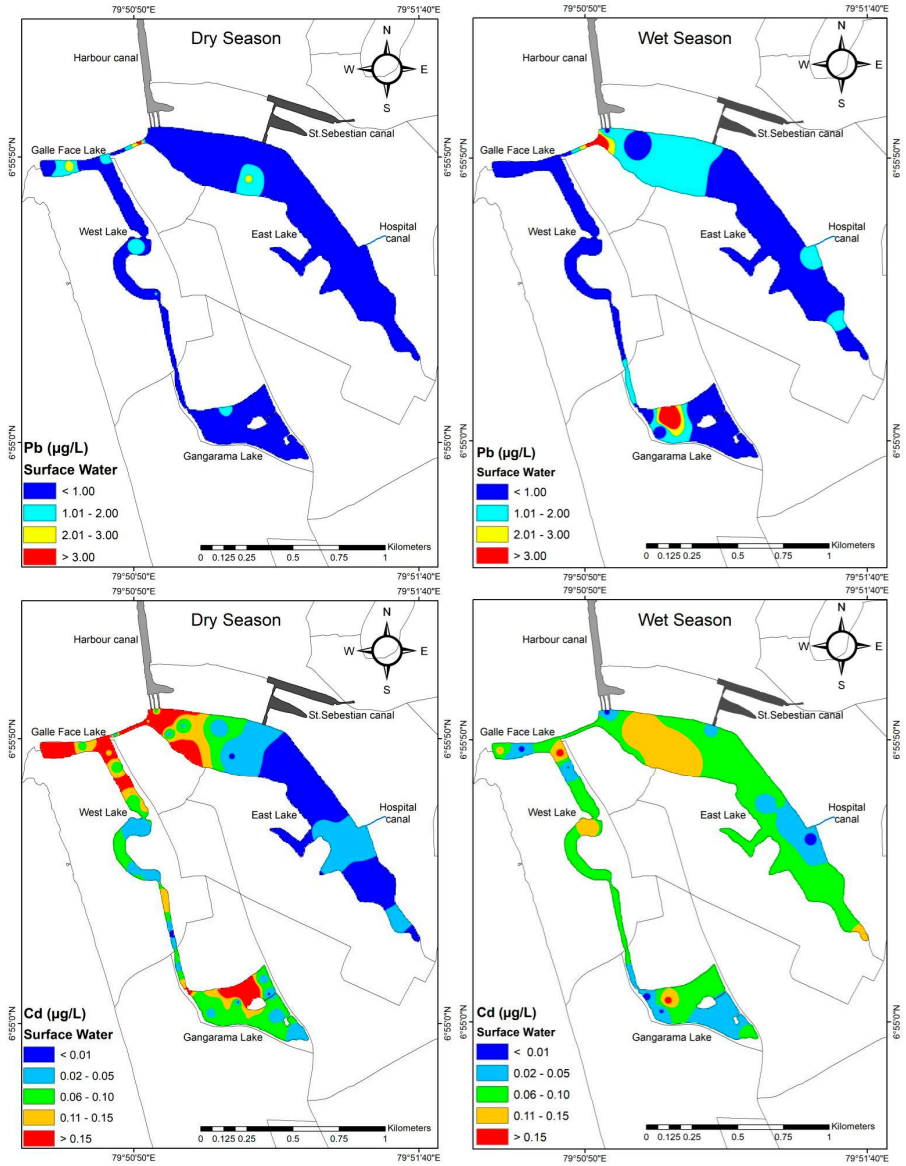

Figure S5-Spatial distribution maps of Pb and Cd of the Beira Lake in wet and dry seasons

Table S5 Concentration mean values of heavy metals of the surface water at Beira Lake seasonally

Season	Cd (µg/L)	Cr (µg/L)	Pb (µg/L)	Hg (µg/L)
Wet Season	0.07	3.06	0.74	0.02
Dry Season	0.13	1.30	0.64	1.71
Standard*	5	20	2	1

Water Quality Assessment Based on Index Analysis

Water Pollution Index (WPI)

Table S6- Considered physicochemical parameters and trace elements of the lake water samples in wet and dry seasons with standard guidelines

Parameter	Wet Season		Dry Season		Guideline Values		
	Range	Mean ± SD	Range	Mean ± SD	WHO (2022)	SLS 614	AWQS for category C* (2019)
pH	6.9-9.2	7.9±0.1	6.6-10.9	9.3±0.2	6.0 - 8.5	6.5-8.5	6.0 - 8.5
EC (µS/cm)	104-557	375±22	256-383	296±4	750	-	-
TDS (mg/L)	57-306	206.2±66.9	108-191	147.0±16.3	500	500	-
COD (mg/L)	52.0-802.0	201.1±25.7	34.0-738.9	221.3±31.7	-	10	15
NO_3^- (mg/L)	3.50-80.00	20.61±2.96	0.00-40.31	15.88±1.79	50	50	10
NH_3-N (mg/L)	0.27-2.06	0.44±0.06	0.00-29.05	4.41±1.21	-	0.06	0.22
SO_4^{2-} (mg/L)	1.00-14.00	4.59±0.60	5.22-64.57	13.63±1.45	250	250	-
Cl^- (mg/L)	2.22-20.67	11.18±0.98	14.01-44.68	36.92±6.28	-	250	-
F^- (mg/L)	0.68-0.96	0.84±0.02	0.10-1.62	1.98±0.31	-	1.0	-
Cd (µg/L)	0.01-0.17	0.06±0.01	0.00-0.80	0.07±0.02	3	3	5
Cr (µg/L)	0.00-9.10	3.06±0.61	0.35-5.48	1.16±0.16	50	50	20
Pb (µg/L)	0.05-7.01	0.74±0.30	0.15-2.60	0.61±0.08	10	10	2
Hg (µg/L)	0.01-0.08	0.02±0.00	0.69-3.69	1.66±0.10	2.0	1.0	1.0

* Category C shall be water suitable for aquatic life.

Table S7- WPI for surface water in wet season

Parameter	Wet Season		***Ci-7***	***Sib-7***	***Ci-7/Sib -7***	$WPI = \frac{1}{n}\sum_{i=1}^{n} PLi$
	Range	Mean ± SD				
pH	6.9-9.2	7.9± 0.1	0.94	1.50	0.63	2.38
EC (µS/cm)	104-557	375±22	367.90	743.00	0.50	
TDS	57-306	206.2± 66.9	199.20	493.00	0.40	
COD(mg/L)	52.0-802.0	201.1±25.7	194.07	8.00	24.26	
NH4+(mg/L)	0.27-2.06	0.44±0.06	-6.56	-6.78	0.97	
NO3− (mg/L)	3.50 - 80.00	20.61 ± 2.96	13.61	43.00	0.32	
SO4 2- (mg/L)	1.00 - 14.00	4.59 ± 0.60	-2.42	243.00	-0.01	
Cl-(mg/L)	2.22-20.67	11.18±0.98	4.18	243.00	0.02	
F-(mg/L)	0.68-0.96	0.84±0.02	-6.16	-5.50	1.12	
Cd (µg/L)	0.01-0.17	0.06±0.01	-6.94	-2.00	3.47	
Cr (µg/L)	0.00-9.10	3.06±0.61	-3.94	43.00	-0.09	
Pb (µg/L)	0.05-7.01	0.74±0.30	-6.26	3.00	-2.09	
Hg (µg/L)	0.01-0.08	0.02±0.00	-6.98	-5.00	1.40	

Table S8- WPI for surface water in the dry season

Parameter	Dry Season		***Ci-7***	***Sib-7***	***Ci-7/Sib -7***	$WPI = \frac{1}{n}\sum_{i=1}^{n} PLi$
	Range	Mean ± SD				
pH	6.6-10.9	9.3 ± 0.2	2.29	1.50	1.53	2.53
EC (µS/cm)	256-383	296 ± 4	288.73	743.00	0.39	
TDS	108-191	147.0± 16.3	140.00	493.00	0.28	
COD(mg/L)	34.00-738.88	221.33±31.71	214.33	8.00	26.79	
NH4+(mg/L)	0.00-29.05	4.41±1.21	-2.59	-6.78	0.38	
NO3− (mg/L)	0.00 - 40.31	15.88 ± 1.79	8.87	43.00	0.21	
SO4 2- (mg/L)	5.22 - 64.57	13.63 ± 1.45	6.63	243.00	0.03	
Cl-(mg/L)	14.01-44.68	36.92±6.28	29.92	243.00	0.12	
F-(mg/L)	0.10-1.62	1.98±0.31	-5.02	-5.50	0.91	
Cd (µg/L)	0.00-0.80	0.07±0.02	-6.93	-2.00	3.43	
Cr (µg/L)	0.35-5.48	1.16±0.16	-5.84	43.00	-0.13	

Pb (µg/L)	0.15-2.60	0.61±0.08	-6.39	3.00	-2.12	
Hg (µg/L)	0.69-3.69	1.66±0.10	-5.34	-5.00	1.06	

Trophic State Index (TSI)

Table S9- TSI values of the Lake in the wet and seasons

TSI Parameter	Dry Season	Wet Season
TSI(TN)	88.61	99.07
TSI(TP)	79.41	129.09
TSI(SD)	82.89	77.64

Heavy Metal Pollution Index (HPI)

Table S10- HPI for heavy metals over the lakes in the wet season

lake	***Heavy Metal***	***Mean (µg/L)***	***Highest permitted value for drinking water (Si)***	***Maximum desirable value (Ii)***	***Sub-index (Qi)***	***Unit weight Wi=(K/Si)***	***Qi*Wi***	***HPI(Wet)***
Galle Face Lake	Cd	0.05	5	3	-147.35	0.2	-29.47	136.40
	Cr	5.33	20	50	148.92	0.05	7.45	
	Pb	0.05	2	10	124.38	0.5	62.19	
	Hg	0.01	1	2	198.54	1	198.54	
						1.75	238.70	
West Lake	Cd	0.08	5	3	-146.13	0.2	-29.23	137.08
	Cr	1.38	20	50	162.06	0.05	8.10	
	Pb	0.16	2	10	123.02	0.5	61.51	
	Hg	0.01	1	2	199.50	1	199.50	
						1.75	239.89	
Gangarama Lake	Cd	0.05	5	3	-147.51	0.2	-29.50	132.54
	Cr	4.33	20	50	152.24	0.05	7.61	
	Pb	1.05	2	10	111.87	0.5	55.93	
	Hg	0.02	1	2	197.90	1	197.90	
						1.75	231.94	
East Lake	Cd	0.07	5	3	-146.48	0.2	-29.30	132.17
	Cr	2.40	20	50	158.67	0.05	7.93	
	Pb	1.07	2	10	111.65	0.5	55.82	
	Hg	0.03	1	2	196.84	1	196.84	
						1.75	231.30	

Table S11- HPI for heavy metals over the lakes in the dry season

lake	*Heavy Metal*	*Mean (µg/L)*	*Highest permitted value for drinking water (Si)*	*Maximum desirable value (Ii)*	*Sub-index (Qi)*	*Unit weight Wi=(K/Si)*	*Qi*Wi*	*HPI(Dry)*
Galle Face Lake	Cd	0.18	-28.23	3	-141.127	0.2	-28.23	20.00
	Cr	2.45	7.92	50	158.4928	0.05	7.93	
	Pb	1.13	55.42	10	110.8421	0.5	55.42	
	Hg	2.12	-0.12	2	-0.12477	1	-0.13	
							35.00	
West Lake	Cd	0.06	-29.39	3	-146.943	0.2	-29.39	12.68
	Cr	2.31	7.95	50	158.9699	0.05	7.95	
	Pb	0.64	58.50	10	116.9947	0.5	58.50	
	Hg	2.15	-14.87	2	-14.8675	1	-14.87	
							22.19	
Gangaram a Lake	Cd	0.11	-28.85	3	-144.256	0.2	-28.85	49.68
	Cr	0.77	8.21	50	164.1164	0.05	8.21	
	Pb	0.61	58.70	10	117.3945	0.5	58.70	
	Hg	1.51	48.88	2	48.88091	1	48.88	
							86.93	
East Lake	Cd	0.02	-29.83	3	-149.154	0.2	-29.83	53.32
	Cr	0.61	8.23	50	164.6247	0.05	8.23	
	Pb	0.42	59.85	10	119.6926	0.5	59.85	
	Hg	1.45	55.06	2	55.05523	1	55.06	
							93.30	

Water quality comparison in 2016 and 2023 based on Remote Sensing data

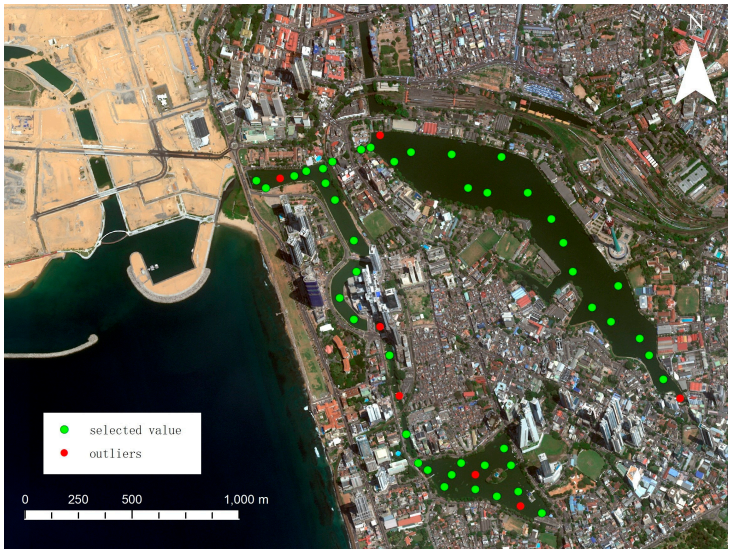

Figure S6 Distribution of measured points

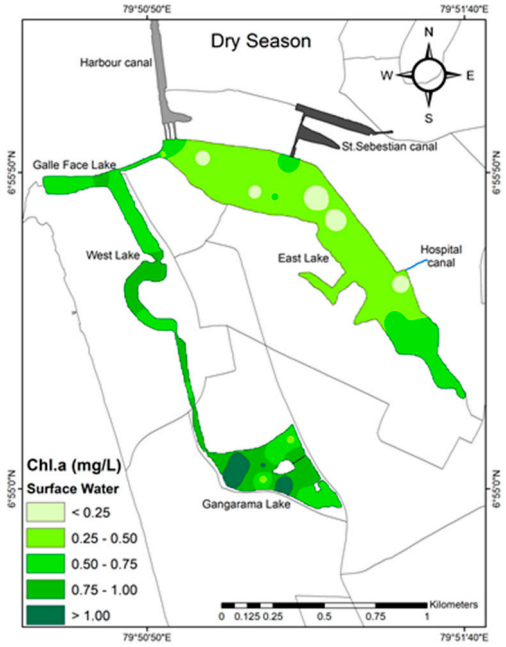

Figure S7 Chlorophyll.a map of 2023 in the dry season using chemical analysis

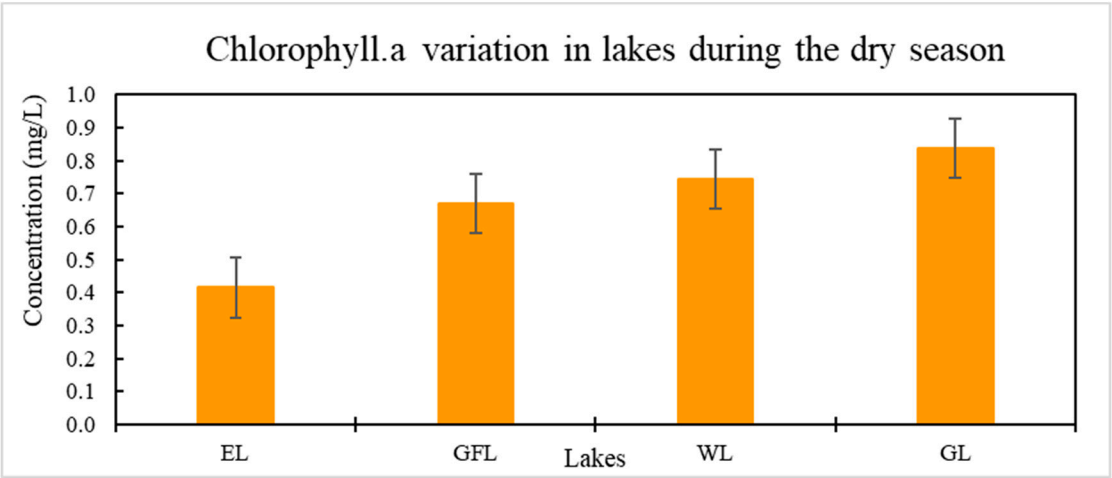

Figure S8 - Spatial variation of Chlorophyll.a of the Beira Lake in dry season

Table S12- Comparison of critical water quality parameters and heavy metal concentrations in the surface water of Beira Lake with other studies in Sri Lankan urban lakes.

Waterbody		COD (mg/L)	pH	DO (mg/L)	NH_3−N (mg/L)	TP (mg/L)	EC (µs/cm)	NO_3^- (mg/L)	PO_4^{3-} (mg/L)	Heavy Metals (µg/L)				Reference
										Cd	Cr	Pb	Hg	
Kurunegala Lake		13.3–28.3	7.04 ± 0.23	6.58 ± 0.02	–	0.88 ± 0.01	145.7 ± 1.52	1.20–1.80	< 0.01	–	–	–	–	[52], [53]
Diyawanna Lake		–	5.2–7.4	2.17–6.84	–	–	70–300	0.01–0.80	–	–	–	–	–	[54]
Bolgoda Lake		–	5.91 ± 0.13	5.5–8.5	–	0.04–1.02	176.1 ± 1.3	0.08 ± 0.00	0.28 ± 0.05	3	–	2	–	[55], [56]
Lake Gregory		–	–	7.0–9.0	–	–	–	–	–	<10	–	–	–	[55]
Kandy Lake		28.1–30.4	8.2	262%	–	–	264	1.6	0.03	1.0	12.0	ND	–	[51]
Lower catchment of Kelani River basin		20	6.9	6.8	–	–	55	0.2	0.01	0.2	4	2	–	[57]
St. Sebastian canal		370–730	6.7–7.11	0.17–5.23	–	–	0.101–0.577 (dS/m)	0.22–0.47	0.25–0.47	87	20	110	–	[50]
Beira lake	**Dry season**	**221.3 ± 31.7**	**9.3 ± 0.2**	**11.96 ± 0.70**	**4.41 ± 1.21**	**0.15 ± 0.09**	**296 ± 4**	**15.88 ± 1.79**	–	**0.13**	**1.30**	**0.64**	**1.71**	**This study**
	Wet season	**201.1 ± 25.7**	**7.9 ± 0.1**	**8.48 ± 0.32**	**0.44 ± 0.06**	**5.84 ± 2.31**	**375 ± 22**	**20.61 ± 2.96**	–	**0.065**	**3.06**	**0.74**	**0.02**	