BJNRD (2022), 9(1): 54-65
Bhutan Journal of Natural Resources & Development

Article

www.bjnrd.org

Open Access

ISSN 2409–2797 (Print)
ISSN 2409–5273 (Online)

DOI: https://doi.org/10.17102/cnr.2022.72

Ecological Conditions of Luetshokha Lake and its Recharge Potential using Rooftop Rainwater Harvesting, Samtengang, Wangdue Bhutan

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Abstract

Luetshokha lake is noted to harbour invasive aquatic plants and experiences reduction in water level. This research assessed the water variables and floristic and macroinvertebrate compositions of Luetshokha lake in Samtengang, Wangdue and its potential to increase water level using rooftop rainwater harvesting (RWH). Presence of aquatic plants such as *Brasenia schreberi, Schnoeplectus pungens* and *Potamogeton distinctus* indicates organic pollution of water in the lake. Coenagrionidae and Baetidae families were the dominant macroinvertebrate taxa present in the lake. There was a positive relationship between aquatic plants and macroinvertebrate diversity indices (r_s = 0.20, p = 0.25), richness (r_s = 0.24, p = 0.16) and evenness (r_s = 0.29, p = 0.04). The relationships between aquatic plants and physico-chemical variables studied were negative; pH (r_s = -0.02, p = 0.90), conductivity (r_s = -0.45, p = 0.00), Total Dissolved Solids (TDS) (r_s = -0.43, p = 0.01) and salinity (r_s = -0.34, p = 0.56). However, temperature was positively correlated (r_s = 0.25, p = 0.14) with aquatic plants. Similarly, macroinvertebrate diversity was negatively correlated with pH (r_s = -0.31, p = 0.07), temperature (r_s = -0.11, p = 0.54), conductivity (r_s = -0.24, p = 0.17), TDS (r_s = -0.24, p = 0.16) and salinity (r_s = -0.27, p = 0.12). Family-level Biotic Index indicated good physical condition of lake water with low organic pollution. The lake water level was estimated to rise by 5 cm through a potential RWH of 1,784.37 m^3 from the roof catchment area of 2,221.01 m^2.

Keywords: aquatic plants, macroinvertebrate, physico-chemical, rainwater harvesting, water quality

Introduction

Luetshokha lake is a non-glacial lake located at an altitude of 1830 m in Samtengang, Wangdue district (Lhamo, 2020). The lake is currently invaded by invasive aquatic plant species such as *Brasenia schreberi* J.F Gmel., *Pontederia crassipes* Mart. (Phuntsho *et al.*, 2021) and emergent species such as *Schnoeplectus pungens* Vahl. Change in composition of aquatic plants adversely affects the biodiversity of lake mainly by replacing native aquatic plants species (Heino and Toivonen, 2008) and is likely to impact aquatic organisms dependent on them.

Luetshokha lake is also noted to be drying up slowly. Decreasing water level in the lake

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Received: March 22, 2022
Accepted: June 22, 2022
Published online: June 28, 2022
Editor: Tshering Dorji

could be attributed to decreasing rainfall received by the lake and diversion of water source for irrigation and drinking. Reduction could also be due to abundant presence of invasive aquatic plants species since they consume more water owing to their higher evapotranspiration rate compared to the native plant species (Chamier *et al*., 2012). The abundance of invasive aquatic plant species, if not controlled, can speed up drying of lake water (Phuntsho *et al*., 2021). Thus, deterioiation of lake will not only result in loss of ecosystem services, but also incur high economic cost in rehabilitation of the lake (Mccormick and Contreras, 2010).

Aquatic plants and animals serve as important bioindicators and can be used to monitor the pollution of an environment (Manickavasagam *et al*., 2019). In this study, we examined the ecological condtions of the lake by assessing aquatic plants and macroinvertebrate communities, physico-chemical variables of the lake and its potential recharge using rooftop rainwater harvesting (RWH).

Materials and Method

Study area

Luetshokha is a non-glacial, low altitude lake located at Samtengang under Nysiho Gewog, Wangdue District (Figure 1). The lake is located at 27°32'0" N and 90°0'0" E and receives the mean annual precipitation of 892.67 mm ± 172.60 *SD*. The lake covers an area of 34,356.27 m^2. Invasive aquatic plant species and emergent plants cover most of the area of the lake. The lake serves as a spot for recreation for the surrounding communities as well as for visitors. The lake also helps in recharging groundwater and in regulating climate.

Sampling of aquatic plants and macroinvertebrates

Sampling of aquatic plants and macroinverterbates were carried out in late winter. A total of 35 transect lines were systematically laid at the pheripery of the lake at an interval of 20 m. In each transect, a quadrat of 1 x 1 m was placed within 1 m of transect line towards the lake (Zbyszewski and Corcoran, 2011). Visual sampling and rake dragging were employed to estimate the percentage of the quadrat area covered by aquatic plants. The aquatic plant species were identified using Flora of Bhutan (Grierson and Long, 1983), Weeds of Bhutan (Parker, 1992) and available literature on the internet.

For macroinvertebrates, a 500 μm D-framed net was swept through the aquatic vegetation. Rocks, stones and cobbles were turned over to dislocate the organisms dwelling underneath and gently swept them into a 500 μm D-framed net. Unidentified organisms were preserved in 70% alcohol and labeled accordingly to be identified later. Macroinvertebrates were identified up to family level by referring “Field guide to freshwater invertebrates” (Thorp and Rogers, 2010) and available literatures from Bhutan (Wangchuk and Eby, 2013; Wangchuk and Kuenzang, 2018). The physico-chemical variables such as temperature, pH, conductivity, Total dissolved solids (TDS) and salinity were measured *insitu* using water samples collected from all the 35 sampling quadrants using PCSTestr 35.

Potential RWH volume was estimated using mean annual rainfall of Samtengang for 24 years obtained from National Center for Hydrology and Meteorology (NCHM), roof surface area of the catchment area (School infrastructure) and runoff coefficient of variation (CV) of the catchment area. The runoff CV of the roof depends on the type of roofing material used (Choiney *et al*., 2020). The runoff CV of the corrugated galvanized iron sheet (CGI), asbestos sheet, tiled and concrete roof is 0.90, 0.80, 0.75 and 0.70 respectively (Kumar, 2004). Purposive sampling was used to measure the catchment area of the rooftop rainwater harvesting potential.

Data analysis

Dominant aquatic plant species of Luetshokha lake was assessed using Importance Value Index (IVI) by following the formula based on Curtis and Mclntosh (1951).

IVI= Relative abundance (RA) + Relative Density + Relative frequency (RF)

In order to assess diversity, richness and the eveness for both aquatic plants and animals, Shannon-Wiener Index (*H'*) was computed based on Shannon and Weaver (1949) and eveness *(J)* based on formula developed by Pielou (1996).

$H' = \sum Pi*LnPi$

$J = H'/LogS$

H' stands for Shannon-Weiner index, *p* for the relative abundance of species *i* and is equal to n_i/N, where n_i is the number of individuals per species *i* and N is the total number of individuals found per plot. As for the eveness (*J*),S stands for taxa richness. IVI, Shannon-Weiner index, taxa richness, and eveness were calculated using Excel 2019.

Spearman's rho correlation was used for examining the relationship between aquatic plants, macroinvertebrates and physico-chemical variables. Water quality of the lake was assessed using the Family-level biotic index (FBI) based on Hilsenhoff (1988). Potential RWH was computed using the following formula based on Choiney et al. (2020).

RWH Potential = Roof Catchment Area (m^2) x Annual Rainfall (mm) x Coefficient of Variation (CV)

The potential rise in the water level of the lake water was determined by dividing the potential RWH by the lake's area (Wong, 2021).

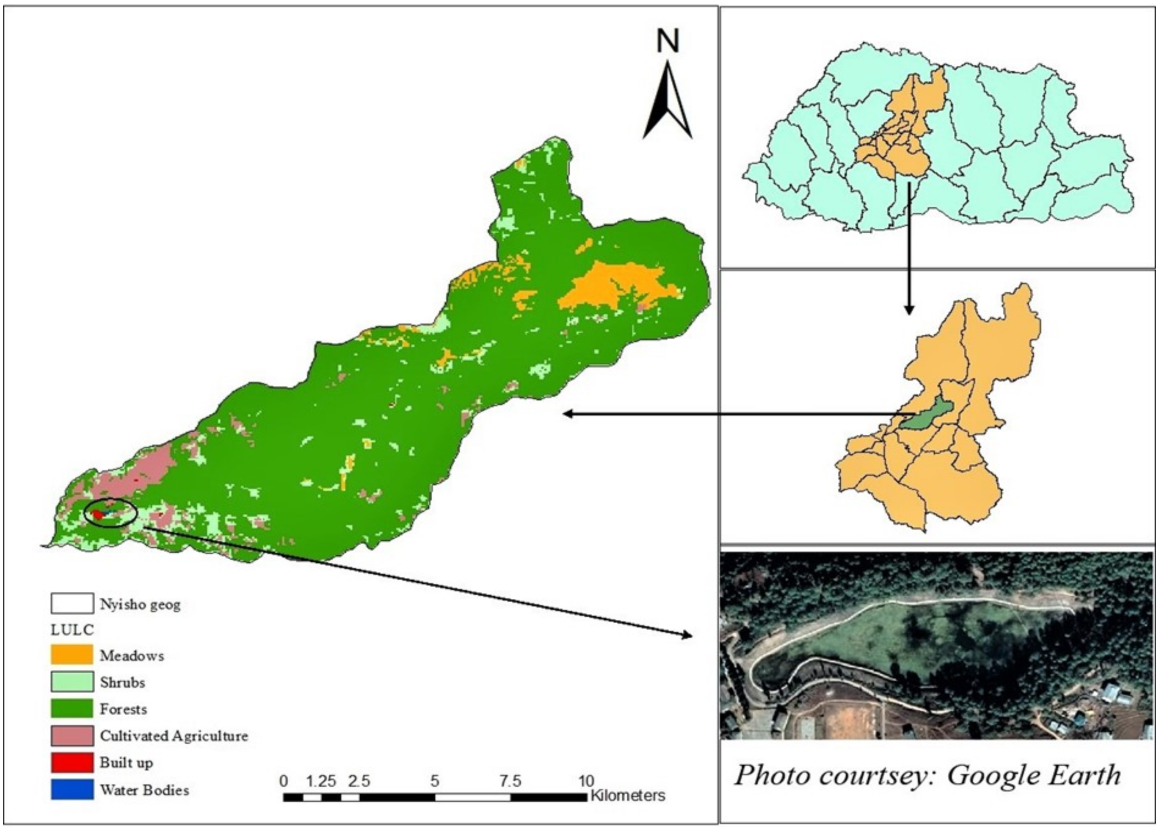

Figure 1: Map showing study area (Luetshokha lake)

Results and Discussion

Physico-chemical variables of Luetshokha lake water

The pH of Luetshokha lake water ranged between 6.02-7.62 with the mean pH of 6.64 ± 0.07 *SD* (Table 1). The mean pH of Luetshokha was within the optimum range (6.5-8) required by aquatic organisms (Alie, 2019). As Ramanathan and Eusden (2021) argue, the

Table 1: Physico-chemical variables of Luetshokha water

Physico-chemical variables	Minimum	Maximum	Mean (±SD)
pH	6.02	7.62	6.64 (±0.07)
Temperature (°C)	14.4	20.6	18.45 (±0.21)
Conductivity (uS/cm)	66.3	145.3	106.211 (±2.71)
TDS (mg/L)	46.4	104	75.91 (±2.07)
Salinity (mg/L)	25	49.4	37.4 (±0.91)

absorption of chemicals by aquatic plants may have contributed to the optimum pH of the lake water.

A mean water temperature of 18.45 ± 0.21 *SD* was recorded at the time of data collection (Table 1). Temperature between sampling plots varied from 14.40°C-20.60°C. The variation in the temperature at some sampling plots could be due to the presence of aquatic plants which help in regulating water temperature and low solar radiation received in late winter season. Willis *et al*. (2017) reported that the aquatic plants reduce the temperature by blocking the solar radiation by it's canopy.

Water conductivity ranged from 66.30-145.30 uS/cm with a mean of 106.21 ± 2.71 *SD* (Table 1). The conductivity was below the optimum range of 200-1,000 uS/cm (Fleming, 2019) that is suitable for most aquatic organisms. In case of Luetshokha lake, low conductivity indicated that the water is not contaminated by inorganic pollutants or run off from the sorrounding catchment area (Borowiak *et al*., 2020).

Luetshokha lake is a closed system without outlet and most of the nutrients entering the lake from the peripheral catchment area and streams settle in the lake. Therefore, the conductivity level may increase over the years (Mathur, 2015) and impose negative impact on aquatic organisms (Bhushal, 2017).

TDS of Luetshokha lake varied from 46.40-104 mg/L with the mean of 75.91 ± 2.07 mg/L (Table 1). The low concentration of TDS could be due to the stagnation and settlement of solids in the dry season (Yogita *et al*., 2017). The low concentration of TDS could also be due to low recharge of lake (Kumar *et al.*, 2018). According to Weber-Scannell and Duffy (2007), the concentration of chlorophyll decreases with increase in nutrient or dissolved solids. The high growth of aquatic plants in Luetshokha lake could be attributed to low concentration of TDS increasing the concentration of the chlorophyll.

Salinity of Luetshokha lake ranged from 25-49.40 mg/L with the mean of 37.4 mg/L ± 0.91 *SD* (Table 1). Kefford *et al.* (2003) reported that the salinity above 1 g/L affects aquatic organisms. The salinity concentration of the Luetshokha lake is within the optimum level required by aquatic organisms. Growth of aquatic plants decreases with an increase in salinity (Chowdhur and Ahmed, 2012). This means that the low salinity may have promoted the growth of aquatic plants. Overall, the conductivity, TDS and salinity indicated that the Luetshokha lake is not contaminated by inorganic pollutants.

Aquatic plants of Luetshokha

A total of 14 species of aquatic plants belonging to 12 families were recorded. Emergent plants were dominant (Importance Value Index [IVI] = 112.04), followed by submerged (IVI = 98.49) and floating plants (IVI = 89.46) (Table 2). Among emergent plants, Cyperaceae family was dominant (IVI = 71.05), Potamogetonaceae in the submerged (IVI = 39.83) and Cabombaceae (IVI = 61.19) in the floating aquatic plant species. *Brasenia schreberi* was a dominant (IVI = 61.19) species followed by *Schoenoplectus pungens* (IVI = 42.34) and *Potamogeton distinctus* (IVI = 39.83) (Table 2).

Sharma and Singh (2017) reported that the water level fluctuation favors the growth of emergent plants in lake. Therefore, the growth of dominant species such as *Schoenoplectus pungens* could be attributed to decreased water level and encroachment of riparian vegetation to littoral zone of the lake (Albert *et al.,* 2013). The decreasing rainfall received by the lake over the years (Figure 2) might have contributed to water level fluctuation in the lake thus favoring the dominance of emergent plants. Moreover, the lake is also shallow as the inlet runs dry for most part of the year. Presence of abundant aquatic plant could also be due to the increased sedimentation from the inlet stream.

Pereira *et al*. (2012) reported that the emergent plant indicates high organic enrichment whereas floating plants indicate intermediate nutrient enrichment. The presence of invasive floating species *Pontenderia crassipes* may be due to the presence of organic pollution resulting from the displacement of leaves and twigs to the lake since *Pontederia crassipes* grows in an organic-rich condition of the water (Ndimele *et al*., 2011) and can be used as the indication for organic pollution. Growth of such invasive aquatic plants can lead to the replacement of native species and alter the

Table 2: Importance value index (IVI) of aquatic plants of Luetshokha

Species	Family	RD	RF	RA	IVI
Emergent					
Schoenoplectus pungens	Cyperaceae	17.11	15.48	9.76	42.34
Pennisetum clandestinum	Poaceae	6.66	11.9	4.94	23.5
Ageratina adenophora	Asteraceae	0.64	4.17	1.35	6.15
Juncus effusus	Juncaceae	0.28	0.6	4.2	5.08
Trifolium repens	Fabaceae	0.6	1.19	4.46	6.26
Cyperus rotundus	Cyperaceae	0.96	1.79	4.73	7.47
Eleocharis palustris	Cyperaceae	6.31	7.74	7.19	21.24
					112.04
Submerged					
Persicaria sagittata	Polygonaceae	6.38	9.52	5.91	21.81
Potamogeton distinctus	Potamogetonaceae	15.73	9.52	14.58	39.83
Hydrocharis sp.	Hydrocharitaceae	0.92	2.98	2.73	6.63
Utricularia vulgaris	Lentibulariaceae	10.63	11.31	8.29	30.23
					98.49
Floating					
Pontederia crassipes	Pontederiaceae	4.14	2.38	15.36	21.89
Hydrocotyle himalaica	Apiaceae	0.85	2.38	3.15	6.38
Brasenia schreberi	Cabombaceae	28.8	19.05	13.34	61.19
					89.46

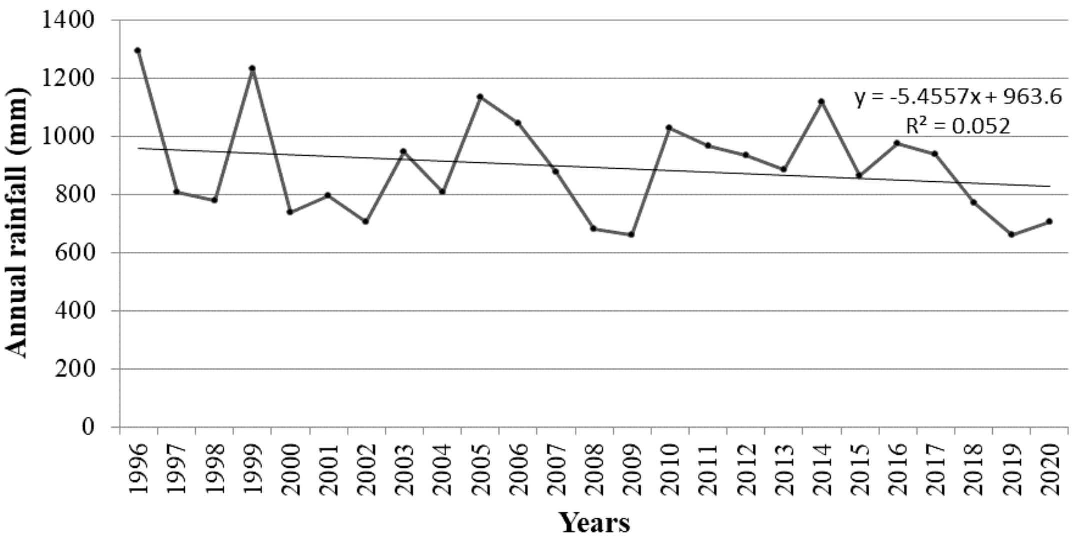

Figure 2: Annual rainfall for 24 years (1996-2020)

ecology of lake (Rejmankova, 2016).

Macroinvertebrates of Luetshokha

A total of 207 individuals belonging to 5 orders and 14 families were recorded (Table 3). Most macroinvertebrates belonged to the order Odonata (n = 68) and Coleoptera (n = 67). Coenagrionidae (n = 47) and Baetidae (n = 45) families from the order Odonata and Ephemeroptera were the dominant families among the macroinvertebrate recorded in terms of relative abundance (Table 3).

Presence of a relatively large percentage of Coenagrionidae and Baetidae indicates organic pollution of the lake water since they are tolerant to nutrient enrichment and can be found in diverse environemental conditions (Brady, 2021; Rico-Sanches *et al*., 2022).

Relationship between biological indices

Diversity of aquatic plant was positively correlated with macroinvertebrate diversity (r_s = 0.20, p = 0.25), richness (r_s = 0.24, p = 0.16) and evenness (r_s = 0.29, p = 0.04) (Table 4). There was a significant relationship between aquatic plant diversity and evenness of the macroinvertebrate ($p < 0.05$). Aquatic plant richness also showed weak positive correlation with diversity (r_s = 0.25, p = 0.16), richness (r_s = 0.29, p = 0.09) and significant difference in evenness (r_s = 0.43, p = 0.01) (Table 4). The positive correlation could be due to availability of abundant food, habitat and protection provided by different aquatic plants (Gallardo *et al.*, 2017). Similarly, there was a weak correlation between species evenness of aquatic plants with macroinvertebrate diversity (r_s = 0.02, p = 0.91), richness (r_s = 0.04, p = 0.81) and evenness (r_s = -0.07, p = 0.68).

Relationship between aquatic plant and physico-chemical variables

pH was negatively correlated with diversity (r_s = -0.02, p = 0.90) and richness (r_s = -0.14, p = 0.41), and positively correlated with evenness (r_s = 0.22, p = 0.21) of aquatic plants (Table 4). The negative and positive correlation with diversity and evenness respectively could be due to the elimination of less tolerant species, thus decreasing the diversity but increasing the eveness of aquatic plants.

Water temperature showed positive correlation with diversity (r_s = 0.25, p = 0.14), richness (r_s = 0.11, p = 0.55) and evenness (r_s = 0.44, p = 0.01) of aquatic plants (Table 4) indicating the growth of aquatic plants with increase in temperature (Zhang *et al*., 2019). According to Arnold *et al*. (2017), warmer temperature facilitates the growth of *Potamogeton* sp. but higher temperature is likely to eliminate the less heat tolerant aquatic plant species while promoting the growth of invasive aquatic species.

There was negative correlation of conductivity with diversity (r_s = -0.45, p = 0.00) and richness (r_s = -0.52, p = 0.00) and weak negative correlation with evenness (r_s = -0.05, p = 0.78) of aquatic plants (Table 4). The negative correlation may be due to increase in osmotic pressure of nutrients resulting from an elevated conductivity which reduces the nutrient intake by plants (Ding *et al*., 2018).

Spearman correlation indicated negative correlation between TDS and diversity (r_s = -0.43, p = 0.01), richness (r_s = -0.52, p = 0.00) and evenness (r_s = -0.02, p = 0.93) of aquatic plants (Table 4). There was a significant difference between TDS and aquatic plant diversity and richness ($p < 0.05$). Yogita *et al*. (2017) stated that high concentration of TDS, which is higher in summer when the rate of decaying aquatic plants is more, imbalances aquatic life.

Similarly, salinity is negatively correlated with diversity (r_s = -0.34, p = 0.56), richness (r_s = -0.50, p = 0.00) and positively correlated with evenness (r_s = 0.10, p = 0.05) of aquatic plants. The significant difference between salinity and richness of aquatic plants ($p < 0.05$) could be due to reduction of aquatic plants with elevated concentration of salinity (Nielsen *et al.,* 2003).

Table 3: Relative abundance of macroinvertebrates

Taxonomic Level	Family Count	RA (%)	Tolerance value
Ephemeroptera			
Leptophlebiidae	2	0.97	2
Baetidae	45	21.73	4
Coleoptera			
Dytiscidae	33	15.94	4
Gyrinidae	22	10.63	3
Noteridae	4	1.93	4
Haliplidae	2	0.97	5
Hydrophilidae	6	2.9	5
Odonata			
Gomphidae	5	2.41	1
Corduliidae	9	4.34	5
Aeshnidae	7	3.38	3
Coenagrionidae	47	22.7	9
Hemiptera			
Nepidae	1	0.48	5
Gerridae	3	1.45	8
Diptera			
Chironomidae (red)	19	9.18	8
Chironomidae (not red)	2	0.95	6

Relationship between macroinvertebrate and physico-chemical variables

Spearman correlation indicated weak negative association of pH and macroinvertebrate diversity (r_s = -0.31, p = 0.07), richness (r_s = -0.32, p = 0.06) and evenness (r_s = -0.28, p = 0.11) (Table 4). This is in accordance with the findings reported by Lhundup and Dorji (2018). Petrin *et al*. (2007) reported that only the tolerant macroinvertebrates can survive and adapt to low pH.

Temperature was negatively correlated with diversity (r_s= -0.11, p = 0.54), richness (r_s= -0.10, p = 0.59) and evenness (r_s= -0.27 p = 0.12) of macroinvertebrates. Similar findings were reported by Li *et al*. (2012). This could be due to low precipitation and increasing temperature received by the lake. It could also be due to stagnant water that is exposed to direct sunlight since the riparian zone is devoid of vegetation (O'Toole *et al*., 2014). They also reported that the shading from riparian vegetation lowers water temperature, thus influencing macroinvertebrate diversity.

Conductivity was negatively correlated with diversity (r_s= -0.24, p = 0.17), richness (r_s= -0.26, p = 0.14) and evenness (r_s= -0.30, p = 0.08) of macroinvertebrates (Table 4). Shackleton *et al*. (2019) reported that Ephemeroptera are more sensitive to elevated conductivity whereas Hemiptera, Coleoptera and Diptera are tolerant to elevated conductivity compared to EPT taxa.

TDS was negatively correlated with macroinvertebrate diversity (r_s= -0.24, p = 0.16), richness (r_s= -0.25, p = 0.14) and evenness (r_s = -0.25, p = 0.15) (Table 4). The negative correlation could be due to the negative impact of elevated concentration of TDS which eliminates less tolerant taxa. Similarly, salinity was negatively correlated with macroinvertebrate diversity (r_s= -0.27, p = 0.12), richness (r_s= -0.28, p = 0.10) and evenness (r_s= -0.33, p = 0.05).

Table 4: Spearman correlation between physico-chemical variables and biological indices

		Physico-chemical variables					**Aquatic Plant**			**Macroinvertebrate**		
		pH	***Temp***	***Cond.***	***TDS***	***Salt.***	***H***	***R***	***J'***	***H***	***R***	***J'***
Physico-chemical variables	pH	1	0.58**	0.32	0.33	0.39*	-0.02	-0.14	0.22	-0.31	-0.32	-0.28
			0	0.06	0.06	**0.02**	0.9	0.41	0.21	0.07	0.06	0.11
	Temp.		1	0.2	0.14	0.2	0.25	0.11	0.44**	-0.11	-0.1	-0.27
				0.24	0.41	0.24	0.14	0.55	**0.01**	0.54	0.59	0.12
	Cond.			1	0.96**	0.92**	-0.45**	-0.52**	-0.05	-0.24	-0.26	-0.3
					0	**0**	**0.01**	**0**	0.78	0.17	0.14	0.08
	TDS				1	0.95**	-0.43**	-0.52**	-0.02	-0.24	-0.25	-0.25
						0	**0.01**	**0**	0.93	0.16	0.14	0.15
	Sal.					1	-0.34*	-0.50**	0.1	-0.27	-0.28	-0.33
							0.04	**0**	0.56	0.12	0.1	0.05
Aquatic plants	H'						1	0.88**	0.50**	0.2	0.24	0.29
								0	**0**	0.25	0.16	0.09
	R							1	0.11	0.25	0.29	0.43**
									0.53	0.16	0.09	**0.01**
	J								1	0.02	0.04	-0.07
										0.91	0.81	0.68
Macroinvertebrates	H'									1	0.97**	0.74**
											0	**0**
	R										1	0.67**
												0
	J											1

Significant figures are shown in bold letters (p < 0.05)

** indicates significance at 0.01 level

* indicates significance at 0.05 level

Temp. = temperature, Cond. = conductivity, TDS = total suspended solids, Sal. = salinity, H = Shannon-Weiner diversity, R = richness, J = evenness

The negative correlation of biological indices with conductivity, TDS and salinity could be due to displacement of sands and vegetation litters from the riparian zone to the littoral zone of the lake during the lake cleaning process. Soil particles entering through a stream inlet from the catchment area of the lake may have contributed to increased siltation and sedimentation of the lake thereby increasing the conductivity, TDS and salinity.

Water quality of Luetshokha

Family Biotic Index (FBI) indicated that the lake water is good (FBI = 4.40) with a probability of some organic pollution. This could be due to unrestricted grazing of cattle displacing leaf litters, twigs and logs to littoral zone of the lake. The inlet stream had leaves, twigs and sawdust from surrounding areas. This phenomenon could have contributed to the possibility of organic pollution in the lake. As per Tang *et al*. (2013), high decomposition of aquatic plants can contribute to the increased organic material content of the lake.

Rainfall pattern

The mean annual rainfall of Samtengang for 24 years was 892.67 mm ± 172.601 *SD* (Figure 2). The minimum and maximum annual rainfall recorded was in 2009 and 1996 with an annual rainfall of 657.7 mm and 1292 mm respectively. The difference between the highest and lowest mean annual rainfall of Samtengang indicates that the area is receiving less rainfall over the years, thus depicting a decreasing trend.

Monthly and annual rainfall variability

The mean monthly rainfall for 24 years was 76.39 mm ± 71.36 *SD.* The Coefficient of Variation (CV) of annual rainfall between the years was 19.3% whereas the CV for mean monthly rainfall was 93.41%. The CV in rainfall amounts received on monthly basis for 24 years ranged from 38% to 203% (Figure 3) showing high variability in rainfall received on monthly basis (CV > 0.3). This high variability indicated erratic pattern of rainfall.

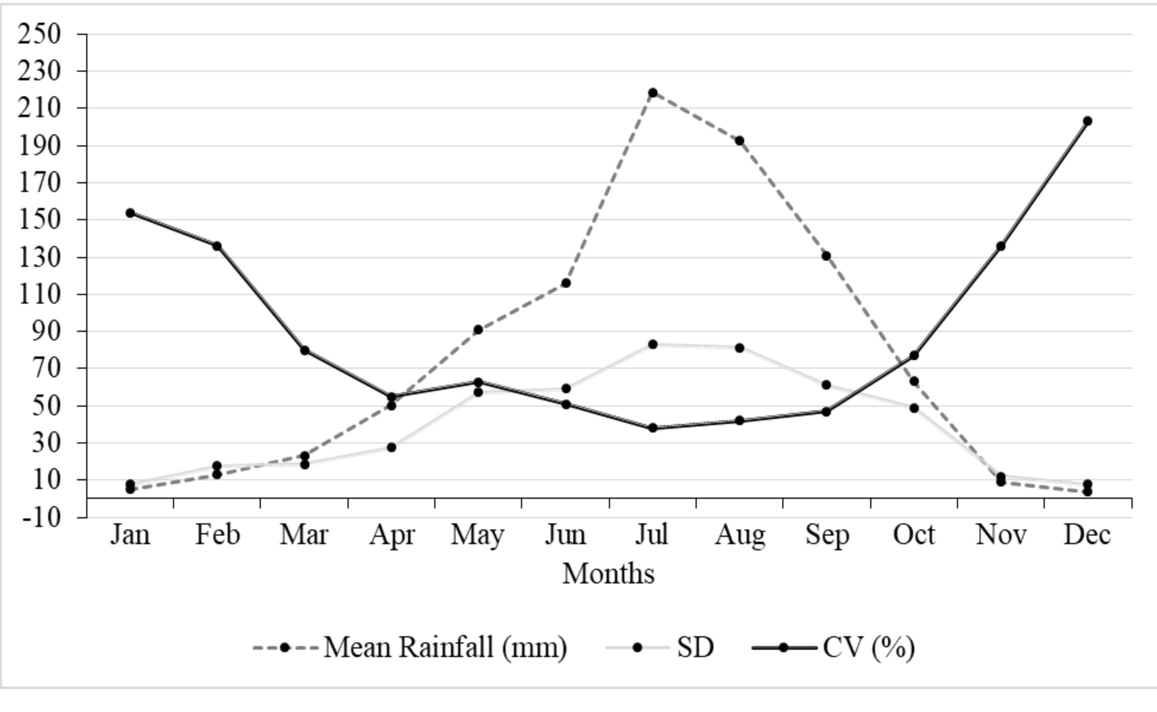

Figure 3: Monthly mean rainfall, SD and CV for 24 years (1996-2020)

Table 5: Potential RWH of the school infrastructure

School Infrastructure	Catchment Area (m^2)	Potential RWH (m^3)	Potential RWH (L)
Staff Room	429.39	344.97	344,973.21
Classroom Building 1	314.96	253.04	253,039.81
Classroom Building 2	222.3	178.6	178,596.49
Old Classroom Building	764.5	26.1	26,102.56
Canopy I	32.49	26.1	26,102.56
Canopy II	32.49	26.1	26,102.56
Canopy III	32.49	315.25	315,247.30
Boys Hostel	392.39	614.2	614,201.59
Total	**2,221.01**	**1,784.37**	**1,784,366.10**

Potential Rain Water Harvest (RWH)

Eight school's infrastructures located at higher ground than the lake were found feasible to direct rooftop rainwater to the lake. The total roof catchment area for all the infrastructures was 2, 221.01 m^2 and the mean annual rainfall was 892.67 mm (Table 5). A CV of 0.9 was used to estimate the potential RWH as the catchement area of all the infrasctucture were of CGI sheet. The total potential of RWH for the recharge of the lake was 1,784.37 m^3 or 1,784,366.10 L annually (Table 5). The total area of the lake calculated using ArCGIS is 34,356.27 m^2. Thus, the total potential for the rise in water level calculated was 0.05 m.

This means that if the rooftop rainwater from the school infrastructure are harvested and diverted to the lake, the lake has the potential to raise its water level by 5 cm annually. Wilcox (2008) reported the increase of invasive and emergent plant species with reduced lake water level. Thus, this volume of potential RWH may help in submerging the emergent and invasive aquatic plants that could be useful in improving the environment and water level of the lake.

Conclusion

A total of 15 aquatic plant species belonging to 13 families were observed from Luetshokha lake. Emergent aquatic plants were most dominant indicating sedimentation of the lake, water level fluctuation and organic pollution. A total of 207 individuals from 14 families and five orders of macroinvertebrates were identified. The dominance of Baetidae and Coenagrionidae indicated that the lake water has some level of organic pollution.

There was a negative correlation between diversity of aquatic plants and macroinvertebrate with physico-chemical variables. The physico-chemical variables indicated that the lake water is not polluted with inorganic pollutants whereas the presence of invasive aquatic plants such as *Brasenia schreberi* and *Pontederia crassipes* indicated the organic pollution. FBI also indicated that the quality of the lake water was good with some organic pollution.

One of the options to improve the lake is to increase water volume. Rainwater harvesting using rooftop catchment areas of eight school infrastructures could be useful to certain extend, but is not a total solution.

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