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Journal of Ecology and Natural Resources
ISSN: 2578-4994

Trophic Status of Lake Clusters of Pokhara Valley (LCPV): A Ramsar Site from Mid-hills, Nepal

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Research Article
Volume 6 Issue 1
Received Date: December 13, 2021
Published Date: January 12, 2022
DOI: 10.23880/jenr-16000268

Abstract

Eutrophication of wetlands is a global environmental problem. All lake bodies are subjected to natural eutrophication but anthropogenic activities like excessive utilization of inorganic fertilizers in the farmlands exacerbates it. The research was conducted to find trophic status of Lake Clusters of Pokhara Valley (LCPV), a Ramsar site from mid-hills. Taking into consideration parameters like Secchi depth (measured by Secchi disk), chlorophyll- a (estimated by Trichromatic method using spectrophotometric procedure) and Total Phosphorus (analysed by digesting with nitric acid and sulphuric acid followed by determining phosphorus content by Stannous chloride method), Carlson's Trophic State Index (CTSI) was followed to classify trophic status of LCPV. Study revealed that 33.33% of the lakes of Lake Clusters were mesotrophic during pre-monsoon and monsoon season while 66.67% of the lakes of Lake Clusters were eutrophic in both pre- monsoon and monsoon season. There is significant difference of Trophic State Index (TSI) during two seasons i.e. pre-monsoon and monsoon season (*p value = 0.001*). Strong positive correlation was found between Total Phosphorus, Chlorophyll-a and Secchi depth with TSI. Total phosphorus content of the lake seems to have cause high impact on TSI. The increased human activity in and around the lakes is responsible for causing lake eutrophication. Lakes important from the touristic point of view i.e. Fewa, Begnas and Rara were found to be maintained on a frequent basis and appropriate measures were taken to reduce nutrient content in the lake. Special attention is required to reduce organic load in other lakes to prevent them from being eutrophicated.

Keywords: Chlorophyll a; Eutrophication; Secchi Depth; Total Phosphorus; Trophic State

Introduction

Eutrophication of wetland bodies is naturally occurring process as lake ages Carpenter [1] but anthropogenic activities involving utilization of inorganic fertilizers containing phosphorus and nitrogen which ultimately reach to lake water bodies through runoff during precipitation is maximizing it [2]. Globally, eutrophication has become an environmental problem deteriorating water quality of natural water [3], where lakes constitute the major portion of them [4,5] and has been considered as principal source of contamination of fresh water ecosystem [6]. Except eutrophication, wetlands undergo various environmental problems like industrial discharge, solid waste, encroachment, shrinkage, sedimentation, over exploitation, land reclamation, alien species invasion [7]. Such activities lead to deterioration of water quality and impacts overall lake hydrology [8]. Wetlands being an integral part of Earth's landscape require to be monitored in terms of its eutrophication from being degraded further.

Eutrophication of natural water bodies like lake can be easily accessed by determining the concentration of nutrient substances and classifying the trophy based on their concentration [9]. Trophic State Index (TSI) is one of the most useful methods of classification of lakes based on their degree of trophy Carlson [10] and is an essential attribute of aquatic environment [11]. Determining trophic state of a lake body is crucial in scientific assessment which assist to understand (i) biotic and abiotic condition of water body; (ii) relation between bio-chemical parameters and (iii) condition of the lake in relation to human requirement and usefulness [12-14]. These indexes provide how factors like nutrient, light stimulate Chlorophyll-a and contribute in aquatic ecosystem enrichment [15].

CTSI the most common and classical method of determining TSI or overall health was developed by Carlson [10] which involves use of only three parameters viz., chlorophyll a, Total Phosphorus and secchi depth [10]. Before Carlson [10] formulated TSI, trophic state used to be examined from several criteria like faunal and floral quantity and quality, oxygen availability, nutrient concentration, productivity and lake morphometry which resulted difficulty in usage of trophic index because of multiple parameters use [16].

LCPV lacks water quality monitoring specially from perspective of eutrophication. The cluster is of high importance from the biodiversity and tourism viewpoint but is under various environmental stresses including eutrophication. In the absence of discrete wetland law in the country, the documentation regarding management and conservation is high but is fragile in terms of delivery process. Hence, this study assesses the trophic status of LCPV during pre-monsoon and monsoon seasons and seeks to find if there is any significant difference between TSI in these two seasons. The outcome is strong evidence in terms of eutrophication state of the lakes from which the lake management committee can formulate suitable plan, policy or program for its sustainable management and conservation. Conservation measures regarding eutrophication have also been suggested in the paper.

Materials and Methods

Study Area

LCPV comprising of nine lakes namely Fewa (or Phewa), Begnas, Rupa, Khaste, Dipang, Maidi, Gunde, Neurani and Kamalpokhari is the biggest and latest Ramsar Site covering a total basin area of 261.6 km2 and having water cover of 8.97 km^2 DNPWC & IUCN [17] (Figure 1). It spreads into Pokhara Lekhnath Metropolitan City, Annapurna Rural Municipality and Rupa Rural Municipality of Kaski district, Nepal. Fewa is the largest lake of the cluster. Begnas and Rupa Lake are comparatively large. But, other remaining lakes of the clusters are smaller and shallower [18]. The elevation of the lake area ranges between 622 meters above sea level (masl) at Rupa Lake and 2,403 masl at the Basin of Fewa Lake [18]. Among these lakes, only Fewa Lake had densely populated eastern shore while the surrounding areas of other play an important regional hydrological role contributing to groundwater recharge, flood control and sediment trapping [17].

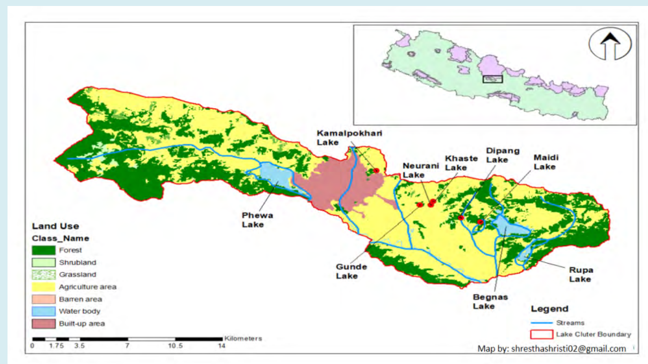

Figure1: Map showing the study area.

Sampling and Laboratory Analysis

In 2019, monsoon entered from Eastern Nepal on 20th June (delayed by 10 days against the normal onset date i.e., 10th June) and withdrew on 12th October (delayed by 19 days against the normal withdrawal i.e., 23rd September). Water samples were collected during two seasons i.e. pre-monsoon (April) and monsoon (September) following the seasonal details from Department of Hydrology and Meteorology, Nepal. A total 72 samples were collected from the cluster (8 from each) in a clean polyethylene bottle from different points making in total 72 samples for each season. The sampling sites were selected to include inlet, outlet, deepest part of the lake and other sites representing whole lake. The water samples were collected for the analysis of Total Phosphorus and Chlorophyll a while Secchi depth was measured directly at the sampling points using Secchi disc. The water samples were collected in the ice box at sampling site, refrigerated at 4°C during field and within two days transported to laboratory for further analysis.

Water transparency was measured by using Secchi disk and total phosphorus was determined by digestion with nitric acid and sulphuric acid followed by stannous chloride method [19]. Likewise, chlorophyll a was determined by trichromatic method using spectrophotometric procedure [20].

Trophic status of lake was determined by using Carlson Trophic State Index (CTSI). CTSI is one of the popular and mostly used methods that take into account measurement of variables namely Total Phosphorus, chlorophyll a and Secchi depth. The following standard equations were used to determine CTSI:

TSI (P) = 14.42 * ln TP (µg/l) + 4.15 ………………….. (i)

TSI (Chl) = 9.81 * ln Chl-a (µg/l) + 30.6 ………………….. (ii)

TSI (SD) = 60 – 14.41 * ln SD (meters) ………………….. (iii)

Carlson Trophic State Index (CTSI) = [TSI (P) + TSI (Chl) + TSI (SD)] /3 ………………….(iv)

Where, TP = Total Phosphorus (µg/l), Chl-a = Chlorophyll a (µg/l), SD = Secchi Depth (m) and ln = natural log

The value of indicator varies from 0 to 100 and each class of the trophic status is assigned with the following value ranges: 0-40 for oligotrophic (low productive), 40-50 for mesotrophic (moderately productive), and 50-70 for eutrophic (highly productive) and 70-100 for hypertrophic [21].

Statistical Analysis

Student's t-test was employed to find out whether there was any difference in TSI in pre-monsoon and monsoon season. Likewise, regression test was employed to observe whether there were any correlations of parameters with TSI value.

Results and Discussion

CTSI in Pre-monsoon and monsoon season

Analysis of Trophic State Index of LCPV using CTSI showed Lake Kamalpokhari (60.73 in pre-monsoon and 57.57 in monsoon) and Begnas (42.26 in pre-monsoon and 41.49 in monsoons) had highest and lowest values for TSI in both seasons respectively (Tables 1 & 2). The study also revealed that three lakes namely Fewa, Begnas and Rupa were mesotrophic in both pre-monsoon as well as monsoon seasons. The water of the lakes classified as mesotrophic (with TSI value 40 -50) had water moderately clear but there can be increasing probability of anoxia during the summer. Water from these lakes has been largely used for drinking purpose especially from Begnas [18]. This can be a strong evidence to prove the research results as CTSI of Begnas Lake is lowest among all. Also reports on pollution from agricultural chemicals, sewages and other waste (both solid and liquid) reveals that it is lowest in Begnas and Rupa [18]. In the past Fewa was very eutrophic as eutrophication of Fewa resulted in algal bloom and mass fish kills along with health impact in local communities but during the research period very few algal blooms were present. This may be due to various conservation efforts of local initiatives for the Fewa conservation.

S.N.	Lake cluster name		SD (m)	TP (µg/l)	Chl-a (µg/l)	TSI (SD)	TSI (TP)	TSI (Chl-a)	Pre monsoon TSI	Trophic Status	Specific attributes of the trophic status of the lakes as per CTSI
1	Fewa	Mean± S.E	1.65 ±0.0	2.94 ±0.2	4.41 ±0.4	53.15	19.32	55.96	42.81	Mesotrophic	Water moderately clear, but increasing probability of anoxia during the summer
2	Begnas	Mean± S.E	1.57 ±0.0	2.77 ±0.1	4.15 ±0.2	53.43	18.63	54.73	42.26	Mesotrophic	
3	Rupa	Mean± S.E	0.96 ±0.0	4.49 ±0.4	6.74 ±0.7	60.55	25.21	44.78	43.51	Mesotrophic	
4	Gunde	Mean± S.E	0.40 ±0.0	4.43 ±0.2	6.65 ±0.3	73.15	25.51	63.85	54.17	Eutrophic	Lower boundary of classical eutrophy: Decreased transparency
5	Maidi	Mean± S.E	0.47 ±0.0	5.52 ±0.0	8.28 ±0.1	70.89	28.77	64.72	54.79	Eutrophic	
6	Khaste	Mean± S.E	0.42 ±0.0	4.36 ±0.0	6.54 ±0.1	72.61	25.36	65.1	54.35	Eutrophic	
7	Neurani	Mean± S.E	0.62 ±0.0	3.99 ±0.1	5.98 ±0.2	66.96	24	68.48	53.15	Eutrophic	
8	Kamal pokhari	Mean± S.E	0.50 ±0.0	9.59 ±0.1	14.39 ±0.2	70.03	36.75	75.42	**60.73**	Eutrophic	Dominance of blue-green algae, algal scum probable, extensive macrophyte problems
9	Dipang	Mean± S.E	0.85 ±0.0	4.65 ±0.2	6.98 ±0.3	62.31	26.19	69.5	52.67	Eutrophic	Lower boundary of classical eutrophy: Decreased transparency

Table 1: CTSI of Lake Clusters of Pokhara valley during pre-monsoon season.

S.N.	Lake cluster name		SD (m)	TP (µg/l)	Chl-a (µg/l)	TSI (SD)	TSI (TP)	TSI (Chl-a)	Monsoon TSI	Trophic Status	Specific attributes of tropic status of the lake as per the CTSI
1	Fewa	Mean± S.E	1.37 ±0.0	2.43 ±0.1	3.65 ±0.2	55.45	16.76	54.69	42.3	Mesotrophic	Water moderately clear, but increasing probability of anoxia during the summer
2	Begnas	Mean± S.E	1.70 ±0.0	2.56 ±0.2	3.85 ±0.3	52.3	17.41	54.76	41.49	Mesotrophic	
3	Rupa	Mean± S.E	0.93 ±0.0	2.50 ±0.2	3.75 ±0.3	60.99	16.82	50.92	42.98	Mesotrophic	
4	Gunde	Mean± S.E	0.71 ±0.0	5.14 ±0.3	7.71 ±0.5	64.84	23.37	64.82	51.01	Eutrophic	Lower boundary of classical eutrophy: Decreased transparency
5	Maidi	Mean± S.E	0.41 ±0.0	4.55 ±0.1	6.82 ±0.1	72.79	25.97	61.6	53.45	Eutrophic	
6	Khaste	Mean± S.E	0.82 ±0.0	3.77 ±0.1	5.66 ±0.1	62.97	23.25	67.19	51.14	Eutrophic	
7	Neurani	Mean± S.E	0.70 ±0.0	3.95 ±0.1	5.92 ±0.2	65.13	23.88	67.39	52.13	Eutrophic	
8	Kamal pokhari	Mean± S.E	0.66 ±0.0	9.08 ±0.3	13.62 ±0.4	67.3	35.9	69.52	57.57	Eutrophic	
9	Dipang	Mean± S.E	0.97 ±0.0	4.40 ±0.2	6.60 ±0.3	60.42	25.4	68.11	51.31	Eutrophic	

Table 2: CTSI of Lake Clusters of Pokhara valley during monsoon season.

Lakes namely Gunde, Maidi, Khaste, Neurani, Kamalpokhari and Dipang were eutrophic in both pre-monsoon and monsoon season. The water of the lakes classified as eutrophic (with TSI value 50- 60) and has water with lower boundary of classical eutrophication with decreased transparency. The water of the lakes classified as eutrophic (with TSI value 60 -70) has water with dominance of blue green algae, algal scum and excessive macrophyte problem. Kamalpokhari is the only one lake that has TSI value greater than 60 in pre-monsoon season. The nutrients from agricultural runoff, sewage, wastewater, washing clothes and cattle ranching might have entered into the lake making it eutrophic. This can finally lead to nutrient enrichment in the water bodies thereby causing algal blooms. Furthermore decayed and dead algal blooms result in dissolved oxygen depletion causing anoxic environment.

Our results reported that Fewa, Begnas and Rupa Lake showed mesotrophic characteristics while other lakes showed eutrophic characteristics in both pre-monsoon and monsoon seasons. However, our results didn't coincide with findings of other studies [22-25]. Nakanishi [22] reported that the Fewa Lake is oligomesotrophic and Begnas and Rupa Lake are eutrophic based on the total phosphorus concentration. Rai [23] classified these three lakes as oligoeutrophic based on the chlorophyll a content. The general trend shows that these lakes showed oligotrophic characteristics mostly during monsoon season (June to August), mesotrophic characteristics during post-monsoon season (September to March) and eutrophic during pre-monsoon season (April to June). However, the trophic status of these lakes depends mostly on precipitation and the use of water by the farmers for irrigation [23]. Husen and Dhakal [24] found Fewa Lake fluctuating between mesotrophic and eutrophic, Begnas Lake fluctuating between oligotrophic and mesotrophic depending on seasons and Rupa Lake as eutrophic. The degree of nutrient inflow and the productivity in the lake are responsible for the change in the trophic stage from one stage to another [26].

Correlation between Total Phosphorus, Chlorophyll-a and Secchi depth with TSI

The correlation analysis between various parameters (phosphorus, chlorophyll- a and Secchi depth) with TSI is shown in Table 3. For pre-monsoon the correlation coefficient (r) between Secchi depth and TSI, Total Phosphorus and TSI and Chlorophyll and TSI are 0.84, 0.80 and 0.87 respectively. Likewise, in monsoon season correlation coefficient (r) between Secchi depth and TSI, Total Phosphorus and TSI and Chlorophyll and TSI are 0.79, 0.86 and 0.85 respectively. It is revealed that in both the seasons there is a strong positive correlation between parameters and TSI. Ariyani [15] has also reported positive correlations between parameters and TSI in their research.

Pre-monsoon analysis				
	Secchi depth	Total Phosphorus	Chlorophyll-a	TSI
Secchi disk	1			
Total Phosphorus	0.591528	1		
Chlorophyll-a	0.553613	0.566586	1	
TSI	0.845997	0.806889	0.872057	1
Monsoon analysis				
	Secchi depth	Total Phosphorus	Chlorophyll-a	TSI
Secchi disk	1			
Total Phosphorus	0.60474	1		
Chlorophyll-a	0.470017	0.622295	1	
TSI	0.795757	0.869664	0.858884	1

Table 3: Correlation analysis of the parameters with TSI.

In pre-monsoon season regression coefficient for Secchi depth, Total Phosphorus and Chlorophyll-a was found to be 0.695, 0.912 and 0.604 respectively (Figures 2-4). Similarly, in monsoon season, regression coefficient for Secchi depth, Total Phosphorus and Chlorophyll-a was found to be 0.743, 0.793 and 0.617 respectively (Figures 5-7). Looking upon the regression coefficient both in pre-monsoon and monsoon season Total Phosphorus seem to have done more impact in TSI. The phosphorus presence in lake clusters seem to have increased due to the human activities taking place around the lake. Moreover, Husen and Dhakal [24] has also found the high concentration of Total Phosphorus in Fewa Lake. Similarly, Pant [27] has found high concentration of phosphate in Rupa and Begnas. Lake clusters of the wetland lacks proper research regarding water quality. Our analysis has also shown the high concentration of total phosphorus in lake clusters upto 9.59 µg/l. Researches across the world also reveals similar kind of impact on TSI by phosphorus [15].

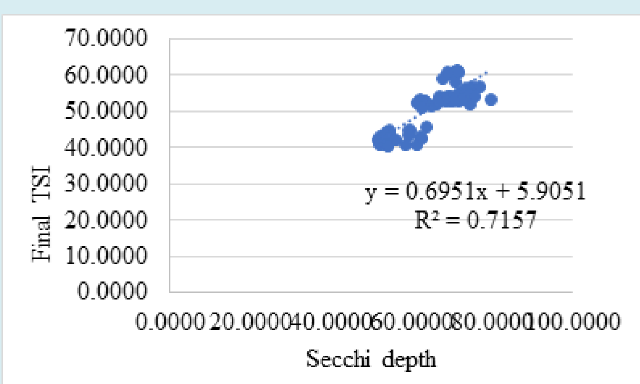

Figure 2: Regression analysis between Secchi depth and TSI in pre-monsoon season.

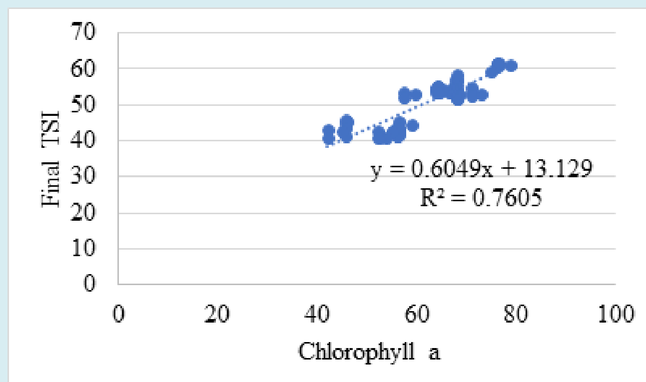

Figure 3: Regression analysis between Total phosphorus and TSI in pre-monsoon season.

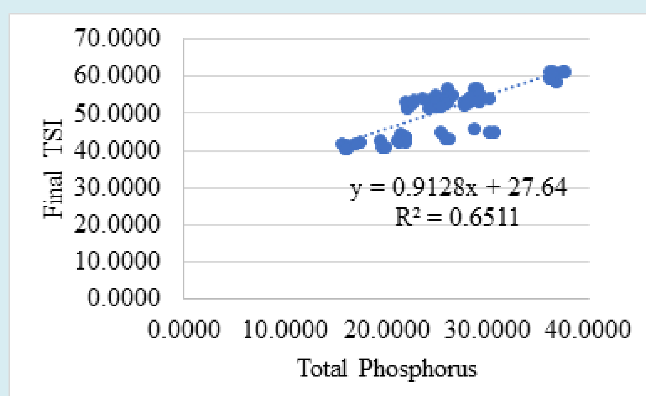

Figure 4: Regression analysis between Chlorophyll-a and TSI in pre-monsoon season.

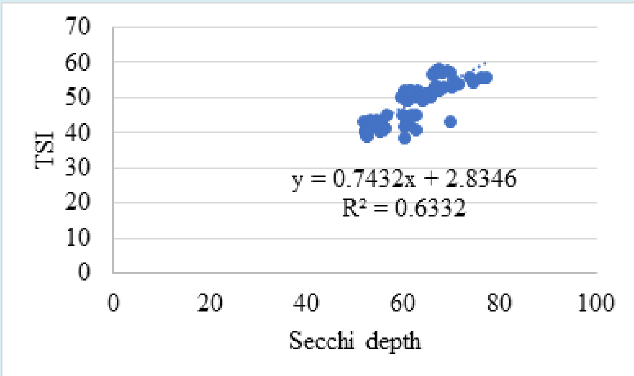

Figure 5: Regression analysis between Secchi depth and TSI in monsoon season.

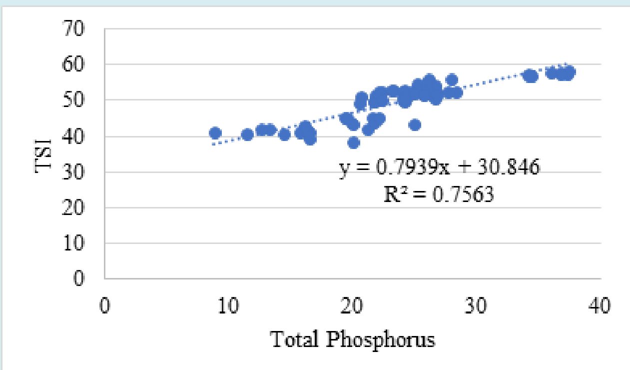

Figure 6: Regression analysis between Total phosphorus and TSI in monsoon season.

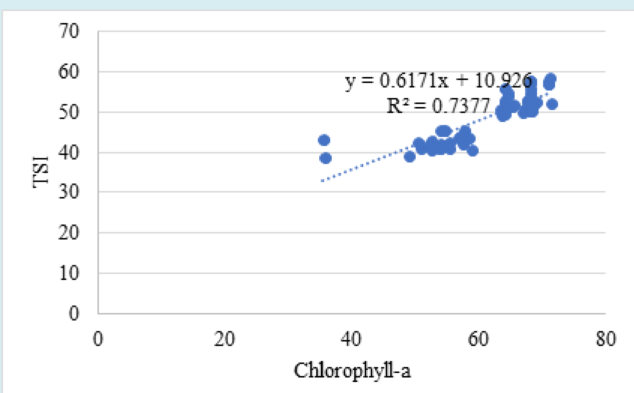

Figure 7: Regression analysis between Chlorophyll-a and TSI in monsoon season.

Comparative Assessment of TSI in Pre-Monsoon and Monsoon Season

The overall TSI is presented in Figure 8 in radar diagram. The comparative assessment of TSI in pre-monsoon and monsoon season carried out using student's t-test showed that there is significant difference in TSI during two seasons i.e. pre-monsoon and monsoon season (*p value = 0.001*) in LCPV. The average pre-monsoon TSI (50.94) is higher than monsoon TSI (49.26) by 1.673. The less value of TSI during monsoon might be due to more amount of rainfall in monsoon than pre-monsoon season which might have diluted the chemical concentration. Also, Pokhara Valley receives highest amount of rainfall in the country with reference record of 5244 mm average annual precipitation in Lumle [28].

Eutrophication of lakes is natural process but over the time it is mainly accelerated by human activities Steffanson [29] through increased plant nutrient mainly phosphorus [30]. During field visit it was observed that washing of the clothes and bathing activities have been taking place in the lakes namely Khaste, Neureni, Kamalpokhari and Dipang. These lakes are also very close to the agricultural lands. The phosphorus and nitrogen from detergents, soaps, and chemical fertilizers might have runoff in the lakes. Lakes were also colonized by blue-green algae. Chemical fertilizers, pesticides, disposal of sewage and liquid waste in the lake area and basin are polluting LCPV. Nutrient enrichment and waste disposal are widespread [18]. Eutrophication leads to impairment of activities, discomfort and visual unpleasantness that hamper the recreational use of water severely.

Besides eutrophication, LCPV is degrading at an alarming rate. Various driving forces like weak wetland governance, policy overlapping, and institutional clarity on encroachment, sedimentation, alien species invasion, land use change, illegal poaching and overharvesting of fishes prevail; this situation has also been reported by earlier studies [17,18,24,27]. Also, climate change has several impacts on water quality of some lakes of cluster like Fewa which could further trigger eutrophication [31].

Conclusion and Recommendations

Determination of TSI is an important water quality indicator. CTSI value based on Secchi depth determination, chlorophyll – a content and Total Phosphorus content revealed that water of LCPV is mainly eutrophic (66%) in both pre-monsoon and monsoon season. The increased human activity in and around the vicinity of the lake is highly responsible for causing eutrophication of the lake. There is significant difference of TSI during two seasons i.e. pre-monsoon and monsoon season (p value = 0.001). The development of lake from Oligotropic to Eutrophic condition is a natural process but is often accelerated due to human induced factors. Begnas, Rupa and Fewa Lakes being tourist attraction areas of the Pokhara are frequently cleaned on the regular basis and appropriate measures have been adapted to some extent to reduce nutrient content in the lake. While other lakes don't seem to have been properly maintained. The eutrophic condition of lakes should be regarded as a clarion call for initiating wetland restoration programs for conserving ecological health of such wetlands. The long-term synergistic effects of unsustainable human interventions can subsequently lead the eutrophic lakes to be hyper eutrophic further compromising the lake health and surrounding biodiversity.

This study provided useful information for decision makers aimed to the conservation and sustainable management of the lakes. This assessment depicts the urgent need for pollution mitigation and control measures as a matter of urgency.

Taking into account the above mentioned conclusions, following recommendations have been made which could be helpful for prevention of eutrophication in LCPV:

- Formulation of legal framework or implementation of management plan, specific laws regarding non-point pollution sources
- Integrated Lake Basin Management approach to attain sustainable management and good governance through spatially and thematically holistic and integrated approach
- Institutionalize Payment for Ecosystem Services to mobilize local community by fair and equitable benefit sharing
- Lake basin governance through taking integrated approach that engages all the relevant stakeholders
- Knowledge management to communicate, measure and monitor process
- Strengthen multi-sectoral and multi-stakeholder capacity and coordination with proper co-ordination among Lake Conservation Committee
- Awareness, educational and outreach program including with frequent research, monitoring and evaluation
- Ensure participation of women, vulnerable and marginalized groups (who are directly dependent upon wetland resources for livelihood) for lake management
- Networking at local and global level for improving technical and financial ability, socio-ecological prosperity etc.

Acknowledgement

The authors would like to thank Center of Research for Environment, Energy and Water (CREEW) for providing with this excellent opportunity to conduct the research on LCPoV by awarding first author with CREEW Young Researcher Fellowships Program, 2019. The authors would also like to thank Ms. Sabitri Rai and Mr. Roshan Chaudhary for their kind help in the field, Ms. Arati Shrestha for her help in laboratory analysis, Mr. Binod Shrestha for his help in map preparation and Mr. Suwash Silwal for helping in statistical analysis.

References

1. Carpenter SR (1981) Submersed vegetation: an internal factor in Lake Ecosystem succession. The American Naturalist 118(3): 372-383.
2. Ghosh TG, Mondal D (2012) Eutrophication: Causative Factors and Remedial Measures. J Today Biol Sci Res Rev (JTBSRR) 1(1): 153.
3. Wilkinson GM (2017) Eutrophication of Freshwater and Coastal Ecosystems. Reference Modile in Earth Systems and Environmental Sciences. Elsevier pp: 102-321.
4. Manojlovic D, Todorovic M, Jovicic J, Krsmanovica VD, Pfendta PA, et al. (2007) Preservation of Water Quality in Accumulation Lake Rovni: The Estimate of the Emission of Phosphorus from Inundation Area. Desalination 213: 104-109.
5. Istvanovics V (2009) Eutrophication of Lakes and Reservoirs. Encyclopaedia of Lakes and Reservoirs: 57-165.
6. Selman M, Greenhalgh S (2010) Eutrophication: Sources and drivers of nutrient pollution. Renewable Resources Journal 26(4): 19-26.
7. Xu T, Weng B, Yan D, Wang K, Li X, et al. (2019) Wetlands of International Importance: Status, threats, and future protection. Int J Environ Res Public Health 16(10): 1818.
8. Sharma MP, Kumar A, Rajvanshi S (2010) Assessment of Trophic State of Lakes: A case of Mansi Ganga Lake in India. Hydro Nepal 6: 65-72.
9. Bekteshi A, Cupi A (2014) Use of trophic state index (Carlson, 1977) for assessment of trophic status of the Shkodra Lake. Journal of Environmental Protection and Ecology 15(1): 359-365.
10. Carlson RE (1977) A Trophic State Index for Lakes. Limnology and Oceanography 22(2): 361-369.
11. Cunha DGF, Calijuri MC, Lamparelli MC (2013) A trophic state index for trophical/ subtropical reservoirs (TSI tsr). Ecological Engineering 60: 126-134.
12. Carlson RE, Simpson J (1996) A Coordinator's Guide to Volunteer Lake Monitoring Methods. North American Lake Management Society, pp: 96.
13. Matthews R, Hilles M, Pelletier G (2002) Determining trophic state in Lake Whatcom, Washington (USA), a

soft water lake exhibiting seasonal nitrogen limitation. Hydrobiologia 468: 107-121.

14. Wetzel RG (2001) Limnology: Lake and River Ecosystems, Academic Press, San Diego, California, pp: 1006.
15. Ariyani M, Agustian M, Maharani GS, Sunardi (2019) Assessment of seasonal trophic state of tropical man-made lake, The Cirata Reservoir. IOP Conf. Series: Earth and Environmental Science 277.
16. Jarosiewicz A, Ficek D, Zapadka T (2011) Eutrophication parameters and Carlson-type tropic state indices in selected Pomeranian lakes. Limnological Review 11(1): 15-23.
17. DNPWC & IUCN (2016) Lake Clusters of Pokhara valley. Department of National Parks and Wildlife Conservation. International Union for Conservation of Nature. Kathmandu, Nepal.
18. MoFE (2018) Integrated Lake Basin Management Plan of Lake Cluster of Pokhara Valley, Nepal (2018-2023). Ministry of Forests and Environment, Kathmandu, Nepal.
19. APHA (1995) Standard Methods for the Examination of Water and Wastewater. 19th (Edn.), American Public Health Association Inc., New York.
20. APHA (1989) Standard Methods for the Examination of Water and Wastewater, Part 3, Determination of Metals. 17th (Edn.), American Public Health Association, Washington DC, pp: 164.
21. Zbierska J, Lawniczak AE, Zbierska A (2015) Changes in the trophic status of Lake Niepruszewskie (Poland). Journal of Ecological Engineering 16(4): 65-73.
22. Nakanishi M, Terashima A, Watanabe M, Mishra PN (1982) Preliminary report on limnological survey in lakes of the Pokhara Valley (Nepal) in November-December, 1982. In: Kadota H (Eds.), Expedition report in Nepal, pp: 31-41.
23. Rai AK (2000) Limnological characteristics of subtropical lakes Phewa, Begnas and Rupa in Pokhara Valley, Nepal. Limnology 1: 33-46.
24. Husen MA, Dhakal RP (2009) Seasonal variations of Zooplankton, chlorophyll-a and nutrients in Phewa Lake, Pokhara Valley, Nepal. ECOPRINT 16: 51-57.
25. Husen MA, Bista JD, Dhakal RP, Prasad S, Nepal A (2012) Trophic status of Phewa, Begnas and Rupa lakes of Pokhara Valley, Nepal, 261-266 pp. In: Pradhan SM, et al. (Eds). Proceedings of the 6th NASA Convection 2011 Commercialization of livestock production for food security and prosperity. Nepal Animal Science Association NASC, Jawalakhel, Lalitpur, pp: 25-26.
26. Chaurasia S, Karan R (2014) Assessment of Water Quality Index and Trophic State Index of River Mandakini, India. The International Journal of Plant, Animal and Environmental Sciences 4(1): 343-347.
27. Pant RP, Pal KB, Adkhiakri NL, Adhikari S, Mishra AD (2019) Water Quality Assessment of Begnas and Rupa lakes, Lesser Himalayan Pokhara, Nepal. Journal of the Institute of Engineering. 15(2): 113-122.
28. Luitel DR, Jha PK, Siwakoti M, Shrestha ML, Munniappan R (2020) Climatic Trends in Different Bioclimatic Zones in the Chitwan Annapurna Landscape, Nepal. Climate 8(11): 136.
29. Steffanson C, Rose I, Nvoelz (2001) Trophic State Index measurements for six stems county lakes during June-September, 2001. Reports to stems county. Environmental Pub, pp: 14.
30. Harper D (1992) Eutrophication of fresh water, Chapman and Hill. London.
31. Raya (2016) Climate Change Impact on Water Quality of Phewa Lake. IDS Nepal.