Sri Lanka J. Aquat. Sci. 30(2) (2025): 101-111 http://doi.org/10.4038/sljas.v30i2.7625

Trophic state of dry zone reservoirs utilized for culture-based fisheries development in Sri Lanka

Thilina Yomal[1], Asanka Jayasinghe[1*], Ashoka Deepananda[2], Upali Amarasinghe[3] and Clive Jones[4]

[1]*Department of Limnology and Water Technology, Faculty of Fisheries and Marine Sciences & Technology, University of Ruhuna, Matara 81000, Sri Lanka*
[2]*Department of Fisheries and Aquaculture, Faculty of Fisheries and Marine Sciences & Technology, University of Ruhuna, Matara 81000, Sri Lanka*
[3]*Department of Zoology and Environmental Management, Faculty of Science, University of Kelaniya, Kelaniya 11600, Sri Lanka*
[4]*Centre for Sustainable Tropical Fisheries and Aquaculture, College of Science and Engineering, James Cook University, PO Box 6811, Cairns QLD 4870, Australia*

Corresponding author: asanka@fish.ruh.ac.lk

ORCID: https://orcid.org/0000-0002-7528-7718

Received: 28.06.2024 Revised: 17.01.2025 Accepted: 12.03.2025 Online: 15.09.2025

Abstract The Trophic State Index (TSI) can be used to classify lakes, rivers, and reservoirs into different trophic categories as well as to estimate the degree of eutrophication and the corresponding potential fish yield of a water body. Relations between Carlson's TSI models and culture-based fisheries (CBF) in non-perennial reservoirs are well documented, but their applicability in larger, perennial reservoirs remains less comprehensive. In the present study, 48 reservoirs of varying sizes were examined to investigate the relationships between TSI values derived from Secchi disk depth (SDD) and chlorophyll-a content (Chl-a). Perennial reservoirs varying in size were selected from northern districts: Anuradhapura, Kurunegala, Puttalam and southern districts: Hambanthota and Monaragala. From March 2018 to August 2019, conductivity, pH, water temperature, dissolved oxygen, Secchi disk depth (SDD), chlorophyll-a (Chl-a), and sediment organic matter content (SOM) were measured monthly at five randomly selected sites within each reservoir. Principal Component Analysis (PCA) based on ln(x+1) transformed limnological data, ordinated northern and southern reservoirs separately into two distinct clusters. The first three Principal Components explained 98.9% of the cumulative variance. Conductivity, pH and Chl-a were found to be more important in explaining the variance. When calculated, TSI(SDD) values in each reservoir were well above the TSI(Chl-a) due to the turbidity caused by non-algal particles or colour. When compared with the reservoir size, there were no correlations ($p>0.05$) between the two TSI types. Log natural converted SDD and Chl-a values showed no significant correlation ($p > 0.05$) with ln-transformed SOM values across the reservoirs. In conclusion, Chl-a values are more suitable for assessing the trophic state of reservoirs in general since non-algal particulates or colour dominate light attenuation. Further research is needed to find simplified tools such as SDD to relate to the trophic status, thereby improving fisheries management in reservoirs of Sri Lanka.

Keywords: trophic status, Carlson's TSI, agrarian reservoirs, chlorophyll-a content, culture-based fisheries

INTRODUCTION

Trophic state of a particular water body can be defined as "the total weight of the biomass in a water body at a specific location and time". The most widely used and conventional method for classifying the trophic status of lakes and reservoirs is to categorise them as oligotrophic, mesotrophic, or eutrophic water bodies (Naumann, 1929; Carlson & Simpson, 1996; Wetzel, 2001). Water bodies rich in nutrients, phosphorus, for example, are eutrophic, while water bodies that could be extremely poor in nutrients are oligotrophic. Mesotrophic condition is somewhere in between these two conditions.

Attempts to define and further clarify these broad ranges of trophic categories are found in the literature (Dillon and Rigler, 1974; Rast and Lee, 1978; Carlson and Simpson, 1996; Diaz *et al.*, 2000).

Carlson's Trophic State Index (TSI) is a numerical indicator of the productivity that characterizes the water body based on its trophic state and overall health. The index is calculated as a function of Secchi Disk Depth (SDD), concentration of Total Phosphorus (TP) and Chlorophyll-a content (Chl-a), which are directly related to the algal biomass of water bodies. TSI can be used to classify lakes, rivers, and reservoirs into different trophic categories and to predict the eutrophication level of the water body (Carlson, 1977). The capture fishery yield of lakes and reservoirs is influenced by the available nutrient content of the water body; therefore, trophic state classification has been used to develop empirical models to predict fish yield (Gomes *et al.*, 2002; Samuel *et al.*, 2015). Culture-based fisheries (CBF) is a hybrid of capture fishing and aquaculture, and is well recognized as a means of an environmentally friendly fisheries enhancement strategy (De Silva, 2003). In Sri Lanka, CBF development in inland reservoirs makes a significant contribution to the country's rural economy as well as to the food and nutritional security of its people (Amarasinghe and Nguyen, 2010). Jayasinghe *et al.* (2005a), Jayasinghe *et al.* (2005b), Jayasinghe *et al.* (2006) investigated the possibility of using limnological characteristics for planning CBF in small non-perennial reservoirs in Sri Lanka. Trophic status of the studied reservoirs was analysed following the TSI described by Carlson (1977) and Carlson and Simpson (1996). In oligotrophic water bodies, TSI calculated using SDD, TP, and Chl-a should be more or less similar. When TSI(Chl-a) is well below the other two indices, there is no comparable algae production in the water, although there is higher turbidity and higher TP contents. This suggests that turbidity is caused not by algae, but by suspended mud particles or colouration derived from plants or minerals. Jayasinghe *et al.* (2005b) reported that the non-perennial reservoirs of Sri Lanka were turbid due to non-algal particulates and/or colour.

Since 2003, fisheries and aquaculture authorities in the country have been making efforts to develop CBF in perennial reservoirs as well (Pushpalatha and Chandrasoma, 2010). Furthermore, recent attempts have been made to develop CBF on bottom-dwelling giant freshwater prawn (GFP, *Macrobrachium rosenbergii*) in Sri Lankan reservoirs, which has contributed significantly to enhancing rural income (Jones *et al.*, 2021). However, the applicability of TSI models related to CBF in perennial reservoirs in general is still not comprehensive. In the present study, an attempt was made to investigate TSI in reservoirs of varying sizes and perennial characteristics, with the aim of determining its suitability as a planning tool for CBF management.

MATERIALS AND METHODS

Forty-eight reservoirs of varying sizes in the Anuradhapura, Kurunegala, Puttalam, Hambanthota and Monaragala districts were selected for the present study, where CBF of finfish species and GFP is practised (Figure 1). Table 1 shows the size and GPS position of each reservoir. The selection of reservoirs was aligned with the annual stocking programme of the National Aquaculture Development Authority (NAQDA) of Sri Lanka. Anuradhapura, Kurunegala, and Puttalam districts are in the northern part of the country, while Hambantota and Monaragala are situated in the south. This study was carried out from March 2018 to August 2019, involving monthly visits to each reservoir to collect limnological data, as part of an inland fisheries development project funded by the Australian Centre for International Agricultural Research (ACIAR). Due to logistical constraints, some of the reservoirs in the northern region were visited by another project collaborator, who shared the data. Conductivity, pH, water temperature, dissolved oxygen (DO), Secchi disk depth (SDD), chlorophyll-a content (Chl-a) and sediment organic matter content (SOM) were measured from five randomly selected sites in each reservoir. Water temperature, pH, DO, and conductivity were measured in situ using a multipara water quality meter (HANNA, USA: model HI 98194). SDD was measured using a standard 20 cm ∅ Secchi disk. For Chl-a analysis, a known volume of water was filtered through GF/C filters (47 mm ∅), and the filters were brought to the laboratory in acid-free, lightproof vials in ice. In the laboratory, Chl-a was determined spectrophotometrically following Carlson and Simpson (1996). For the analysis of

SOM, sediment samples were collected by operating an Ekman grab at each site, and the samples were transported to the laboratory in polythene bags in ice. SOM was determined following the method described by Boyd (1995).

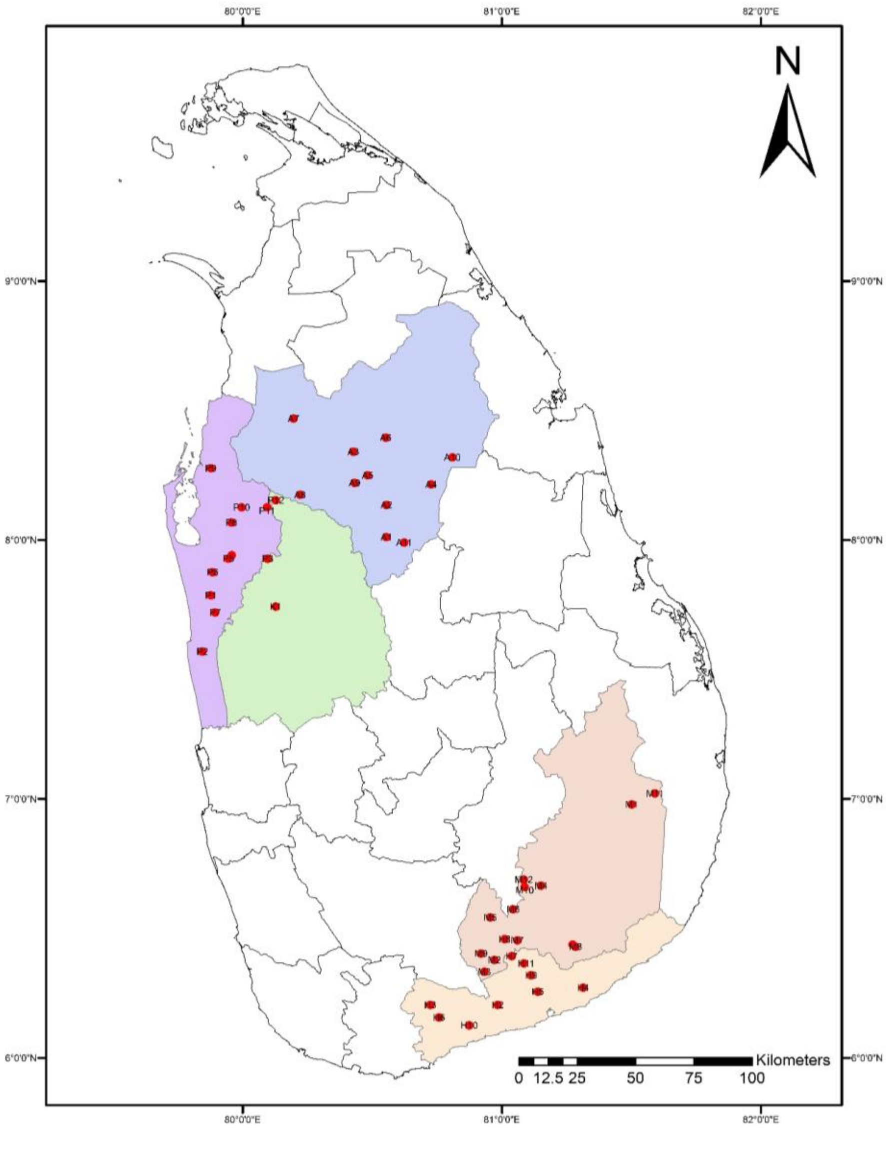

Fig. 1 Map of Sri Lanka showing the location of 48 study reservoirs.

Table 1. GPS Coordinates of the reservoirs selected for this study and their area at full supply level. Codes are given for the districts: A – Anuradhapura; H – Hambantota; K – Kurunegala; M – Monaragala; P – Puttalama.

Reservoir	Code	Area (ha)	GPS Coordinates	
			N	E
Kalawewa	A1	1440	8° 0'38.77"	80°33'16.69"
Rajaganaya	A2	1619	8° 8'6.19"	80°14'24.09"
Nuwarawewa	A3	1197	8°20'26.58"	80°25'37.52"
Huruluwewa	A4	1619	8°12'52.04"	80°43'39.67"
Nachchaduwa	A5	1781	8°14'57.61"	80°28'55.37"
Mahakanadarawa	A6	1457	8°23'42.65"	80°33'7.84”
Mahawilachchiya	A7	971	8°28'5.04"	80°11'46.78"
Angamuwa	A8	445	8°10'27.49"	80°13'17.35"
Thuruwila	A9	280	8°13'11.35"	80°25'54.78"
Kiwulekada	A10	192	8°12'11.28"	80°10'17.38"
Mahaelagamuwa	A11	80	7°99'33.06"	80°62'09.73"
Rideeyagama	H1	871	6º 12'15.17”	80 59'3.64”
Weerawila Wewa	H2	567	6º 17'13.30”	81 13'57.39”
Muruthawela	H3	516	6º 12'54.85 “	80 43'27.13”
Yoda Wewa	H4	486	6º 16'14.46”	81 18'51.85”
Bandagiriya	H5	381	6º 15'19.40”	81 8'20.14”
Udukiriwala	H6	263	6º 9'20.52”	80 45'28.05”
Mahagal Wewa	H7	140	6°23'54.00”	81° 2'2.64"
Maha Wewa	H8	80	6°27'29.93"	81° 0'40.03"
Pahala Andara Wewa	H9	80	6º 19'7.43”	81 6'46.82”
Kattakaduwa	H10	80	6º 7'30.35”	80 52'27.10”
Maha Aluthgama Ara	H11	70	6 21'51.57”	81 5'8.49”
Magallewewa	K1	263	7°44'31.69"	80° 7'38.82"
Muthukandiya	M1	560	6º 58'46.58”	81 30'07.66”
Kiriibban Wewa	M2	375	6º 22'33.46”	80 58'13.66”
Urusita Wewa	M3	262	6°19'55.17"	80°55'59.56"
Handapangala	M4	226	6º 39'56.88"	81 9'07.00”
Hambegamuwa	M5	210	6º 32'33.69”	80 57'19.19”
Balaharuwa Wewa	M6	150	6º 34'25.40”	81 23'7.56”
Demodara Wewa	M7	100	7 13'41.99”	81 10'6.77”

Milegama	M8	80	6°25'44.79”	81°17'4.44"
Habaralu Wewa	M9	80	6 24'10.23”	80 55'9.67”
Alugalge Wewa	M10	70	6°39'34.01”	81° 5'18.95"
Sugaladevi Wewa	M11	50	7 1'15.77”	81 35'28.14"
Buduruwagala Wewa	M12	145	6°41'15.59"	81° 5'6.03"
Gestupana Wewa	M13	80	6°26'13.67”	81°16'24.54"
Devalahandiya	P1	257	7°47'10.04”	79°52'36.61”
Karavitagaraya	P2	256	7°34'6.25”	79°50'39.75”
Mahauswewa	P3	212	7°55'37.36”	80° 5'47.61"
Kachichimaduwa	P4	65	7°56'25.37"	79°57'29.27"
Kotukachchiya	P5	70	7°55'39.29"	79°56'40.39"
Viluka	P6	65	7°52'30.80"	79°53'4.16"
Vijayakatupotha	P7	243	7°43'11.52"	79°53'36.83"
Thabbowa	P8	607	8° 4'0.34”	79°57'23.48"
Eluwankulama	P9	65	8°16'37.08"	79°52'37.63"
Pahariya	P10	72	8° 7'31.67"	79°59'46.04"
Saliyawewa	P11	85	8°10'6.55"	80° 5'38.89"
Thangusewa	P12	50	8° 9'11.93"	80° 7'40.10"

Following the Carlson’s Trophic State Index, TSI can be calculated as a function of SDD, TP and Chl-a (Carlson, 1977; Carlson and Simpson, 1996). These indices have been developed for temperate oligotrophic lakes on the basis that doubling of algal biomass causes halving of SDD. Three indices are interrelated as TSI (SDD) = TSI (Chl-a) = TSI (TP). In situations where non-algal particulate matter or colour dominates underwater light attenuation, TSI (TP) = TSI (SDD) > TSI (Chl-a), and Jayasinghe *et al.* (2005b) reported a similar pattern in tropical non-perennial reservoirs of Sri Lanka. Therefore, in this study, TP measurements were omitted to save time and resources, but SDD measurements were retained as a tool convenient for fisheries managers and non-technical persons to assess the relationship with Chl-a, which provides a more direct indication of the trophic state of the water body. The following equations were used to calculate

TSI:

TSI as a function of Secchi Disk Depth; $TSI\ (SDD) = 60 - 14.41 \ln SDD\ (m)$ ---- (1)

TSI as a function of chlorophyll- a content; $TSI\ (Chl\text{-}a) = 9.81 \ln Chl\text{-}a\ (mg/m^3) + 30.6$ ---- (2)

Commented [L1]: The word “TSI” Should be at the end of the 2nd column

All calculations and statistical analyses were performed using Microsoft Excel 2016, Primer 7, and RStudio-1.2.5033. Principal Component Analysis (PCA) was used to ordinate the sampled reservoirs based on the limnological data. Each parameter from the northern and southern reservoirs was compared with the Student’s t-test. Correlations between TSI (SDD), TSI (Chl-a) and other limnological parameters were tested. Since bottom-dwelling GFP was a popular candidate in stocking programmes for these reservoirs, the trophic state analysed using water quality parameters was also correlated with SOM.

RESULTS

Variations of different water quality parameters and the SOM content of 48 reservoirs are shown in **Error! Reference source not found.**2. Principal C omponent Analysis (PCA) based on ln(x+1) transformed limnological data ordinated reservoirs into two clusters (Figure 2). When northern and southern reservoirs are labelled as 'N' and 'S', respectively, the analysis clearly shows two clusters corresponding to the two regions. First Principal Component explained 59.7% of variance, while the cumulative variance explained by the first three components was 98.9%. Conductivity, pH, and Chl-a were found to be the most important factors explaining the variance among the reservoirs. Reservoirs in the Southern region had significantly lower conductivities compared with those in the Northern region (t-test: $p < 0.001$). In contrast, Southern reservoirs showed substantially higher pH values when compared with Northern reservoirs (t-test: $p < 0.001$). Similarly, SDD in reservoirs of the Northern region was significantly higher (t-test, $p < 0.01$), while SOM was lower (t-test, $p < 0.001$) compared with the Southern region. When TSI was calculated as a function of SDD, 77% of the reservoirs were in hyper-eutrophic status, while the remaining 23% were eutrophic with algal scums (Table 3). In contrast, when TSI was calculated using Chl-a, the majority of reservoirs (58%) were mesotrophic, whereas only 40% were eutrophic. Figure 3 shows that TSI(SDD) values in each reservoir are well above the TSI(Chl-a) due to the turbidity caused by non-algal particles or colour. When compared with the reservoir size, there were no correlations ($p>0.05$) between the two TSI types. Log natural converted SDD and Chl-a values did not show any correlation with lnSOM values ($p>0.05$) obtained for the reservoirs.

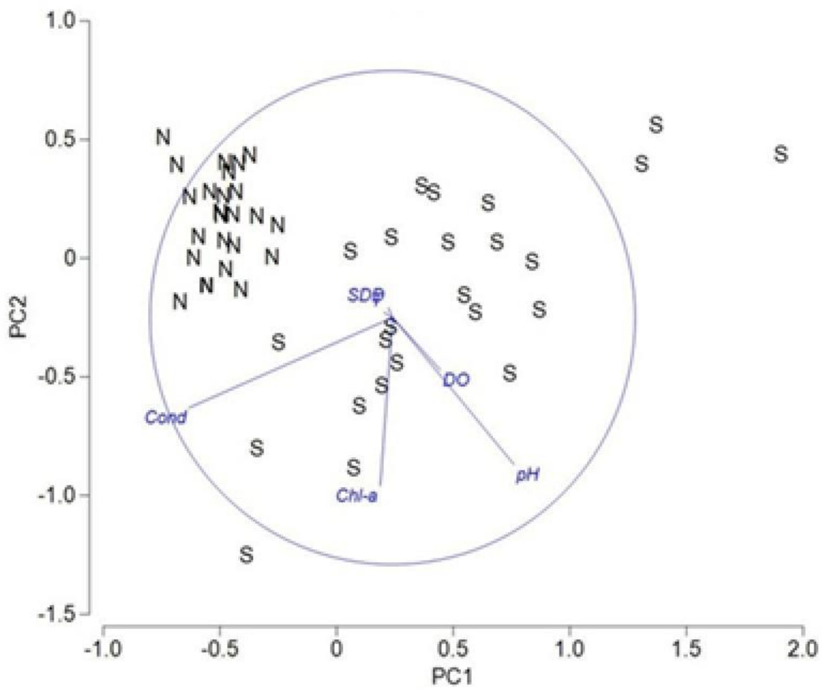

Fig. 2 Two-dimensional PCA plot ordinating 48 reservoirs based on the measured limnological parameters. Northern side reservoirs are labelled as 'N' and southern side reservoirs as 'S'. Length and the direction of the arrows show the influence of each limnological parameter on the ordination of reservoirs along a particular component.

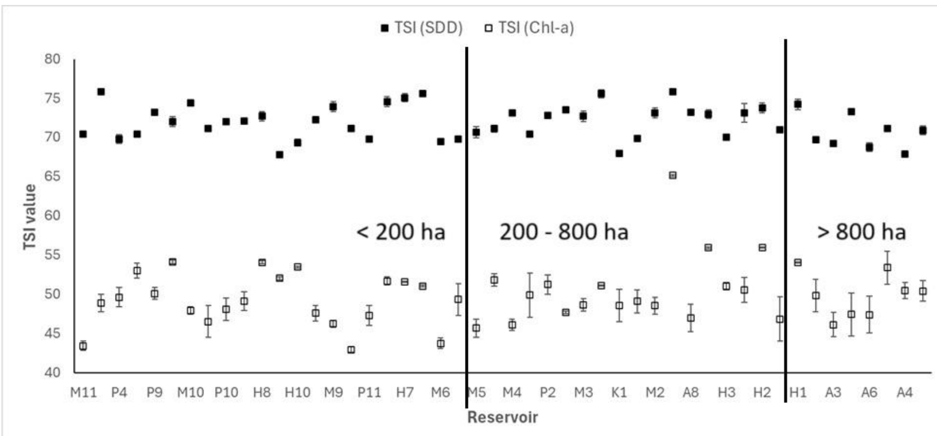

Fig. 3 Mean Trophic State Index (TSI) values based on Secchi disk depth (SDD) and chlorophyll-a content (Chl-a) in 48 reservoirs arranged in increasing order of reservoir area. Vertical lines separate the three size classes of reservoirs, followed by NAQDA during stocking programs.

Table 2. Mean value (±SE) of the measured limnological parameters for each study reservoir, T- water temperature (°C); DO- dissolved oxygen (mg/L); Cond- Conductivity (μS/cm); SDD- Secchi disc depth (m); Chl-a- chlorophyll-a (μg/L), Organic Matter Content (mg/m^3)

Reservoir	T	DO	Cond.	pH	SDD	Chl-a	SOM
A1	30.9±0.8	7.0±0.1	481±41	7.1±0.0	0.40±0.00	5.6±1.5	30.5±0.6
A2	30.1±0.6	7.3±0.1	659±81	7.3±0.1	0.46±0.02	10.3±2.2	29.7±0.8
A3	30.7±0.6	7.0±0.1	438±30	7.2±0.0	0.53±0.02	4.9±0.8	27.3±0.5
A4	30.6±0.9	7.2±0.1	472±24	7.1±0.0	0.58±0.03	7.6±0.8	30.2±0.5
A5	29.5±0.8	7.0±0.1	498±15	6.9±0.1	0.47±0.04	7.6±1.0	31.6±0.6
A6	30.1±0.7	7.1±0.1	535±17	6.8±0.1	0.54±0.04	5.6±1.3	28.2±0.3
A7	28.5±0.4	7.3±0.1	510±18	7.3±0.0	0.51±0.01	7.1±1.5	18.6±0.5
A8	28.2±0.3	7.2±0.1	567±37	7.4±0.0	0.40±0.01	5.3±0.9	13.5±0.4
A9	28.0±0.2	7.2±0.1	607±51	7.3±0.0	0.50±0.01	6.6±1.0	11.8±0.7
A10	29.7±0.5	7.0±0.1	451±39	7.3±0.0	0.50±0.01	6.8±0.8	11.0±0.5
A11	29.0±0.4	7.2±0.1	468±17	7.2±0.0	0.43±0.02	6.6±0.6	12.8±0.4
H1	28.6±0.2	10.7±0.3	488±39	7.5±0.1	0.37±0.02	11.0±0.1	16.1±0.6
H2	29.1±0.3	9.7±0.2	472±10	8.1±0.1	0.38±0.02	13.3±0.1	26.6±0.5
H3	28.3±0.2	10.6±0.5	194±15	8.2±0.1	0.50±0.01	8.1±0.1	44.4±0.6
H4	28.6±0.2	10.2±0.2	641±9	7.9±0.1	0.40±0.02	13.3±0.1	53.9±0.3
H5	28.6±0.1	10.3±0.2	572±22	7.7±0.1	0.33±0.01	29.6±0.4	38.0±0.4
H6	28.4±0.1	10.5±0.4	253±11	8.4±0.1	0.34±0.01	8.1±0.0	12.4±0.5
H7	28.6±0.2	10.5±0.3	364±15	8.0±0.1	0.35±0.01	8.6±0.2	28.8±0.3

H8	28.5±0.1	10.8±0.4	365±11	8.0±0.1	0.41±0.02	11.0±0.3	25.9±0.6
H9	28.6±0.1	11.3±0.5	474±21	8.2±0.1	0.58±0.01	8.9±0.2	33.8±0.4
H10	28.4±0.1	8.4±0.3	320±11	7.9±0.1	0.52±0.02	10.3±0.1	23.2±0.4
H11	28.1±0.1	11.0±0.2	56±9	7.7±0.1	0.43±0.02	11.1±0.3	24.9±0.7
K1	30.1±0.4	7.2±0.1	506±31	7.3±0.2	0.57±0.01	6.3±1.3	19.8±0.4
M1	28.2±0.1	10.4±0.2	197±16	7.8±0.0	0.40±0.03	7.7±0.8	30.3±0.7
M2	28.1±0.1	9.2±0.1	90±10	7.7±0.0	0.40±0.02	6.3±0.6	26.4±0.2
M3	28.4±0.1	9.8±0.1	189±12	7.7±0.1	0.41±0.02	6.3±0.5	33.0±0.6
M4	28.6±0.1	9.7±0.2	329±11	7.8±0.1	0.40±0.01	4.9±0.4	23.0±0.5
M5	28.6±0.1	9.2±0.1	423±23	7.9±0.0	0.48±0.02	4.7±0.6	26.2±0.7
M6	28.6±0.1	9.6±0.3	299±30	7.8±0.0	0.52±0.01	3.8±0.2	20.8±0.6
M7	28.5±0.1	9.8±0.1	239±20	7.9±0.0	0.36±0.02	8.6±0.4	32.8±0.6
M8	27.5±0.1	9.5±0.2	288±11	8.3±0.1	0.43±0.01	5.7±0.6	25.9±0.2
M9	28.5±0.1	9.9±0.2	105±8	8.0±0.1	0.38±0.02	5.0±0.2	15.9±0.6
M10	28.4±0.1	9.9±0.1	250±12	7.8±0.0	0.37±0.01	5.9±0.3	29.3±0.4
M11	28.1±0.1	9.8±0.1	280±14	7.9±0.0	0.48±0.01	3.7±0.2	26.1±0.7
M12	28.2±0.1	9.8±0.2	347±22	7.9±0.1	0.34±0.01	8.1±0.1	25.8±0.8
M13	26.8±0.1	10.1±0.1	250±18	8.5±0.1	0.46±0.01	3.5±0.1	26.8±0.6
P1	31.2±0.7	6.9±0.1	597±65	7.5±0.1	0.39±0.02	5.7±0.8	13.3±0.5
P2	30.4±0.8	6.8±0.1	598±61	7.2±0.0	0.41±0.02	8.3±1.1	12.7±0.6
P3	31.0±1.0	7.3±0.2	536±56	7.4±0.1	0.46±0.03	8.8±0.7	10.1±0.3
P4	29.9±0.6	6.6±0.2	516±49	6.8±0.1	0.51±0.04	7.0±0.9	8.3±0.7
P5	29.6±0.4	7.0±0.2	508±41	7.3±0.1	0.46±0.02	5.2±1.1	9.0±0.3
P6	29.1±0.8	7.1±0.1	492±38	7.2±0.1	0.48±0.02	9.9±0.9	8.5±0.4
P7	29.8±0.6	7.3±0.1	467±34	7.1±0.1	0.48±0.02	7.2±2.0	18.7±0.4
P8	29.7±0.9	7.3±0.1	468±16	7.6±0.1	0.47±0.02	5.3±1.5	27.0±0.8
P9	29.2±0.4	7.1±0.1	457±30	7.5±0.1	0.40±0.01	7.3±0.6	8.3±0.5
P10	29.0±0.6	7.2±0.2	428±26	7.1±0.0	0.43±0.02	6.0±0.9	9.3±0.8
P11	29.7±0.7	7.2±0.1	463±25	7.1±0.0	0.50±0.01	5.5±0.7	10.1±0.6
P12	30.0±0.7	6.8±0.2	494±27	7.1±0.0	0.33±0.02	6.5±0.7	11.5±0.7

Table 3. Average Trophic State Index (TSI) of 48 reservoirs (±standard error) calculated based on Secchi Disk Depth (SDD) and Chlorophyll-a content (Chl-a), and the identified corresponding trophic state.

Code	TSI (SDD)	Trophic State	TSI (Chl-a)	Trophic State
A1	73.38±0.13	Hypereutrophy	47.47±2.74	Mesotrophy
A2	71.18±0.29	Hypereutrophy	53.46±2.10	Eutrophy
A3	69.28±0.21	Eutrophy with algal scums	46.19±1.53	Mesotrophy
A4	67.92±0.39	Eutrophy with algal scums	50.51±1.02	Eutrophy
A5	70.93±0.55	Hypereutrophy	50.48±1.32	Eutrophy
A6	68.82±0.54	Eutrophy with algal scums	47.45±2.35	Mesotrophy
A7	69.78±0.13	Eutrophy with algal scums	49.88±2.05	Mesotrophy
A8	73.27±0.14	Hypereutrophy	47.01±1.75	Mesotrophy
A9	69.90±0.15	Eutrophy with algal scums	49.15±1.48	Mesotrophy
A10	69.87±0.12	Eutrophy with algal scums	49.38±2.04	Mesotrophy
A11	72.15±0.24	Hypereutrophy	49.17±1.21	Mesotrophy
H1	74.28±0.67	Hypereutrophy	54.08±0.09	Eutrophy
H2	73.81±0.62	Hypereutrophy	56.00±0.09	Eutrophy

Code	TSI (SDD)	Trophic State	TSI (Chl-a)	Trophic State
H3	70.10±0.28	Hypereutrophy	51.07±0.5	Eutrophy
H4	73.05±0.57	Hypereutrophy	55.99±0.10	Eutrophy
H5	75.86±0.35	Hypereutrophy	65.21±0.10	Eutrophy with algal scums
H6	75.64±0.52	Hypereutrophy	51.17±0.05	Eutrophy
H7	75.12±0.51	Hypereutrophy	51.65±0.07	Eutrophy
H8	72.75±0.56	Hypereutrophy	54.14±0.22	Eutrophy
H9	67.86±0.33	Eutrophy with algal scums	52.08±0.21	Eutrophy
H10	69.39±0.45	Eutrophy with algal scums	53.51±0.08	Eutrophy
H11	72.04±0.64	Hypereutrophy	54.20±0.25	Eutrophy
K1	67.99±0.21	Eutrophy with algal scums	48.62±2.04	Mesotrophy
M1	73.19±1.16	Hypereutrophy	50.58±1.58	Eutrophy
M2	73.19±0.66	Hypereutrophy	48.60±1.09	Mesotrophy
M3	72.75±0.71	Hypereutrophy	48.72±0.79	Mesotrophy
M4	73.19±0.32	Hypereutrophy	46.14±0.72	Mesotrophy
M5	70.72±0.69	Hypereutrophy	45.74±1.15	Mesotrophy
M6	69.51±0.37	Eutrophy with algal scums	43.81±0.64	Mesotrophy
M7	74.61±0.65	Hypereutrophy	51.74±0.52	Eutrophy
M8	72.32±0.39	Hypereutrophy	47.64±0.98	Mesotrophy
M9	73.96±0.62	Hypereutrophy	46.29±0.46	Mesotrophy
M10	74.45±0.38	Hypereutrophy	47.97±0.49	Mesotrophy
M11	70.47±0.35	Hypereutrophy	43.46±0.59	Mesotrophy
M12	75.64±0.38	Hypereutrophy	51.11±0.14	Eutrophy
M13	71.23±0.39	Hypereutrophy	42.98±0.36	Mesotrophy
P1	73.56±0.25	Hypereutrophy	47.74±0.14	Mesotrophy
P2	72.84±0.32	Hypereutrophy	51.31±1.24	Eutrophy
P3	71.18±0.43	Hypereutrophy	51.88±0.78	Eutrophy
P4	69.84±0.57	Hypereutrophy	49.66±1.23	Mesotrophy
P5	71.18±0.27	Hypereutrophy	46.57±2.04	Mesotrophy
P6	70.48±0.32	Hypereutrophy	53.06±0.93	Eutrophy
P7	70.51±0.28	Hypereutrophy	49.95±2.81	Mesotrophy
P8	71.03±0.33	Hypereutrophy	46.90±2.82	Mesotrophy
P9	73.23±0.17	Hypereutrophy	50.14±0.75	Eutrophy
P10	72.05±0.32	Hypereutrophy	48.12±1.44	Mesotrophy
P11	69.87±0.11	Eutrophy with algal scums	47.38±1.28	Mesotrophy
P12	75.92±0.22	Hypereutrophy	48.95±1.11	Mesotrophy

DISCUSSION

In this study, conductivity, pH and Chl-a were found to be more important in explaining the variance of the reservoirs. It was similar to what has been found so far regarding CBF in non-perennial reservoirs in Sri Lanka (Jayasinghe *et al.*, 2005a, Jayasinghe *et al.*, 2005b). Although reservoirs from the Northern and Southern regions showed conspicuous limnological differences, these might have resulted from instrumental variations or other human errors inherent in data sharing situations.

Lake or reservoir management, it is often impractical to use chemical procedures frequently to determine the trophic state of the waterbodies. As such, efforts have been made to relate trophic conditions to simple measurements such as SDD (Carlson, 1977; Hakanson and Boulion, 2003). In reservoir fisheries management, fast-growing herbivores and herbivore-directed omnivores that directly consume primary production receive high priority due to their vital role in bio-manipulation of the reservoir ecosystem. Therefore, there is a trend to determine relationships between trophic level, algal biomass or primary production and fish yield (Mcconnell *et al.*, 1977; Oglesby *et al.*, 1987; Carlson and Simpson, 1996; Gomes *et al.*, 2002).

Trophic status is one of the pivotal reflectors of ecological functions in aquatic ecosystems. TSI provides insight into the nutrient levels and light penetration in reservoirs and lakes, facilitating decision-making in water resource management (Cunha *et al.*, 2013). Carlson's model for estimating trophic state is preferred over other models for several reasons: (1) relatively easy to use, (2) requires less data to calculate, (3) easy to understand, and (4) easy to predict (Carlson and Simpson, 1996). Given that, it is worth mentioning that there are several drawbacks to using TSI. Since the trophic state is a measurement of biomass of total biological materials in a water body, TSI uses the total algal biomass—measured as chlorophyll-a— assuming a perfect relationship between algal biomass and chlorophyll-a content, Secchi disk depth and total phosphorus. But in practice, these relationships might not be perfect owing to the effects of different intrinsic and extrinsic factors, thus making the calculations of TSI in terms of chlorophyll-a, Secchi disk depth and total phosphorus doubtful (Carlson and Simpson, 1996). During the present study, data for total phosphorus were not collected to save time, money and energy. Jayasinghe *et al.* (2005b) proved that TSI(TP) is approximately similar to TSI(SDD) in tropical non-perennial reservoirs of Sri Lanka, and in conformity with the relationship described by Carlson and Simpson (1996) for the waterbodies dominated by non-algal turbidity. This research aimed to determine whether the same relationship is observed in perennial reservoirs. According to the results obtained for TSI(SDD), the majority of the reservoirs are in eutrophic and hyper-eutrophic status, whereas TSI(Chl-a) indicated a lower degree of eutrophication. Since eutrophication is a phenomenon associated with the algal production, it is generally more reliable to use Chl-a for estimating the trophic state in our tropical environment. The disadvantage is that the chemical analysis of Chl-a is technically complex and less understandable to fisheries managers or other non-technical personnel, compared with the simpler measurement of SDD.

During the field visits, it was observed that most of the reservoirs were influenced by the agricultural run-offs. The high run-off likely caused increased turbidity from suspended solids, resulting in elevated TSI(SDD) values, i.e., low SDD measurements. However, the contribution of organic inputs was negligible compared with inorganic particulates, as indicated by correlation tests with SOM. In conclusion, it is risky to use SDD values to predict the trophic state of reservoirs in Sri Lanka, where light attenuation is dominated by non-algal particulates or colour. Further research is needed to identify simplified tools, such as SDD, that can be related to trophic status, thereby improving fisheries management in reservoirs of Sri Lanka.

ACKNOWLEDGEMENT

This study was funded by the Australian Centre for International Agricultural Research (ACIAR) grant SRA/FIS/2017/002.

REFERENCES

Amarasinghe, U. S. & T. T. T. Nguyen 2010. Enhancing rural farmer income through fish production: secondary use of water resources in Sri Lanka and elsewhere. *Success Stories in Asian Aquaculture.* Berlin: Springer Science.

Boyd, C. E. 1995. *Bottom soils, sediment and pond aquaculture,* New York, Chapman & Hall.

Carlson, R. E. 1977. Trophic state index for lakes. *Limnology and Oceanography,* 22**,** 361-369.

Carlson, R. E. & J. Simpson 1996. *A coordinator's guide to volunteer lake monitoring methods,* Medison, Wisconsin, North American Lake Management Society.

Cunha, D. G. F., M. D. C. Calijuri & M. C. Lamparelli 2013. A trophic state index for tropical/subtropical reservoirs (TSItsr). *Ecological Engineering,* 60**,** 126-134.

De Silva, S. S. 2003. Culture-based fisheries: an underutilised opportunity in aquaculture development. *Aquaculture,* 221**,** 221-243.

Diaz, M., F. Pedrozo & N. Baccala 2000. Summer classification of Southern Hemisphere temperate lakes (Patagonia, Argentina). *Lakes and Reservoirs Research and Management,* 5**,** 213-229.

Dillon, P. J. & F. H. Rigler 1974. Phosphorus-chlorophyll relationship in lakes. *Limnology and Oceanography,* 19**,** 767-773.

Gomes, L. C., L. E. Miranda & A. A. Agostinho 2002. Fishery yield relative to chlorophyll a in reservoirs of the Upper Paraná River, Brazil. *Fisheries Research,* 55**,** 335-340.

Hakanson, L. & V. V. Boulion 2003. A model to predict how individual factors influence Secchi depth variations among and within lakes. *International Review of Hydrobiology,* 88**,** 212-232.

Jayasinghe, U. A. D., U. S. Amarasinghe & S. S. De Silva 2005a. Limnology and culture-based fisheries in non-perennial reservoirs in Sri Lanka. *Lakes & Reservoirs Research and Management,* 10**,** 157-166.

Jayasinghe, U. A. D., U. S. Amarasinghe & S. S. De Silva 2005b. Trophic Classification of Non-Perennial Reservoirs Utilized for the Development of Culture-Based Fisheries, Sri Lanka. *Internat. Rev. Hydrobiol.,* 90**,** 209-222.

Jayasinghe, U. A. D., U. S. Amarasinghe & S. S. De Silva 2006. Culture-based fisheries in non-perennial reservoirs of Sri Lanka: influence of reservoir morphometry and stocking density on yield. *Fisheries Management and Ecology,* 13**,** 157-164.

Jones, C., U. Amarasinghe, S. D. Silva, D. D. Croos, S. Digamadulla, A. Jayasinghe, G. A. T. K. Yomal & K. H. M. A. Deepananda 2021. Assessing production of giant freshwater prawns in reservoirs in Sri Lanka. Canberra, Australia.

Mcconnell, W. J., S. Lewis & J. E. Olson 1977. Gross photosynthesis as an estimator of potential fish production. *Transactions of the American Fisheries Society,* 106**,** 417-423.

Naumann, E. 1929. The scope and chief problems of regional limnology. *Internationale Revue der Gesamten Hydrobiologie* 21**,** 423.

Oglesby, R. T., J. H. Leach & J. Forney 1987. Potential stizostedion yield as a function of chlorophyll concentration with special reference to Lake Erie. *Canadian Journal of Fisheries and Aquatic Sciences,* 44**,** 166-170.

Pushpalatha, K. B. C. & J. Chandrasoma 2010. Culture-based fisheries in minor perennial reservoirs in Sri Lanka: variability in production, stocked species and yield implications. *Journal of Applied Ichthyology,* 26**,** 98-103.

Rast, W. & G. F. Lee 1978. Summary analysis of the North American (US portion) OECD Eutrophication Project: Nutrient loading, lake response relationships & trophic state indices. *Ecological Research Series.* Oregon: US Environmental Protection Agency.

Samuel, S., N. Suryati & V. Adiansyah 2015. Limnological condition and estimation of potential fish production of Kerinci Lake Jambi, Sumatra. *Indonesian Fisheries Research Journal,* 21**,** 9.

Wetzel, R. G. 2001. *Limnology. Lake and River Ecosystems* San Diego, Academic Press.