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Eutrophication assessment of Tiru reservoir using Carlson's trophic state index (TSI)

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Abstract

Water bodies all over the globe are contending with a severe issue of deterioration, which has the risk to have huge impacts on the ecosystem, society, and economy. Carlson's TSI (Trophic State Index) has been used in the Tiru reservoir to analyze its eutrophication level from August 2017 to January 2019. TSI (Secchi Disk Depth) was highest in June 2018, TSI (Chlorophyll-a) was highest in April and May (61), and TSI (Total Phosphrous) was highest in May 2018 (59). October 2017 had the lowest TSI (Secchi Disk Depth) = 64, TSI(Chlorophyll-a) = 42, and TSI (Total Phosphorus) = 35 values. Throughout the study, Tiru reservoir was eutrophic. The Tiru reservoir's water quality fluctuations were mostly caused by changing weather patterns during the research. Eutrophication in the Tiru reservoir was caused by less frequent monsoons, agricultural runoff, and monsoon sediment inflow.

Keywords: TSI, TP, Chl-a, SDD

Introduction

Water is essential for both human survival and ecological stability (Dogan *et al.*, 2016) [10]. Water is precious since it's vital for human survival as a natural resource (Sharma and Walia, 2016) [28]. Bodies of water provide water for human use and serve as a highly biodiverse environment that provides essential ecosystem services (Palmer *et al.*, 2014) [20]. Overpopulation, pollution, and industrial and economic expansion contribute to a steadily rising demand for freshwater, making water a limited resource (Priyantha Ranjan *et al.*, 2006; Schleich and Hillenbrand, 2009) [24, 27]. Worldwide, freshwater supplies are decreasing at an accelerating rate as rising demand burdens already-scarce resources (Ding *et al*. 2014) [8].

The introduction and spread of invasive species, nutrient enrichment and other kinds of physical and chemical and biological pollution, global warming, extreme weather (Okello *et al.*, 2015) [19], acidification, and the exploitation of upper stretch water sources some of the extreme environmental conditions are all factors that contribute to the degradation of water quality and threaten lakes and rivers (Carpenter *et al.*, 2011) [5]. The eutrophication these systems experience is a severe environmental threat. Inland waterways have gotten more attention in recent years due to their significance and understanding to account for fluctuations in weathr, climate, and other aspects of the environment. Our lakes and other water sources need to be protected now more than ever. Before recommending any conservation and management actions for the lake's restoration, it is necessary to have information on the system's current state (Sheela *et al.*, 2012) [30].

The idea of trophic status focuses primarily on algae, aquatic plants, and other organisms mainly concern with primary production (Dodds and Cole 2007; Silvino and Barbosa 2015) [9]. Naumann (1919) [18] pioneered the trophic state idea, which Thienemann (1926) was responsible for popularising. Hasler (1947) [14] expanded the meaning of the word eutrophication. in order to incorporate the concept of heavy algal blooming during the culture due to artificial incorporation of minerals that sped up a natural algal development in the reservoirs. (Kociolek and Stoermer 2009) [17]. The trophic level of a lake is an effective method for categorizing lakes and providing a description of lake dynamics in terms of the system's overall production. The idea is based on the observation that variations in nutrient status generate shifts in algae production (Chl-a), which changes the transperancy of lakes (SDD).

The TSI, first introduced by Carlson (1977) [4], is the method for categorizing lakes (TSI). Lakes, ponds, and reservoirs may be ranked on their biological production using the TSI, a ranking system developed for this purpose.

Researchers and governmental agencies have relied heavily on Carlson's TSI index to measure eutrophication (Cunha *et al*., 2013) [7]. Due to the complex character of the nutrient enrichment phenomena in reservoirs, consideration of more than one parameter is more realistic and accurate approach (Cruzado 1987; Xu 2008) [6, 34]. Carlson's (1977) [4] TSI provides a broad picture of a lake's eutrophication situation. Chlorophyll pigments, Secchi disc transperancy, and Phosphorus level are three linked variables that may each be used to make an independent estimate of algae production level based on the connection of them with each other (Carlson 1977) [4]. Carlson's TSI index is extensively used by various researchers and is very popular for estimating lake productivity (Walker, 1979; Porcella *et al*., 1980; Jin *et al*., 1990; Swanson, 1998; Xu, 2008) [33, 22, 16, 31, 34]. The typical TSI value is an excellent predictor of the overall trophic state of the water. The final TSI of the reservoir can be achieved by the totalling of the three TSI values based on total phosphorus, chlorophyll content and secchi disk transparency readings and averaging the total output. The result represents biological characteristics that are likely to be found in temperate water bodies (Pavluk and Bij De Vaate, 2017) [21]. In practice, the TSI indices does not have any upper or lower boundaries, and its range is roughly between 0 and 100, but in theory, the index does not have any restrictions.

The current research is concerned with estimating TSI level of the Tiru reservoir using Carlson's TSI Index. This research will aid in pinpointing the cause and magnitude of eutrophication in the target reservoir. Also, a thorough TSI evaluation will assist in establishing a foundation of knowledge from which to build regional strategies to address the eutrophication problems in this area.

Materials and Methods

Sampling location

The Tiru reservoir is situated at South-East Maharashtra region along the south-west of India (Fig. 1) and the geographic location is between 72º 02′ 38.35″ E and 18º 33′ 36.8″ N. It is an Earth-fill dam built on the Tiru river in the Udgir, district-Latur, Maharashtra, in 1976. Tiru river combines with Lendi river and further joins Manjara river (tributaries of Godavari river). Soybean cultivation fields encircle the Tiru reservoir. Reservoir water is primarily utilized for agricultural irrigation. Tiru reservoir is spread over a watershed of 270 square kilometre with a immersion area of 690 hactre. It occupies about 489 ha. of water spread area. Morphometric features are given in Table 01.

Table 1: Morphological characters of the Tiru Reservoir

No.	Item	Units	Value
1	Water immersion area	km^2	6.9
2	Average WSA	km^2	4.8
3	Watershed Area	km^2	270
4	Command area	ha	2654
5	Greatest Length	km	3.15
6	Greatest Width	m	930
7	Greatest Depth	m	7.31
8	Mean Depth	m	3.98
9	Volume	km^3	311
10	Watershed to lake surface area	km^2	39.13

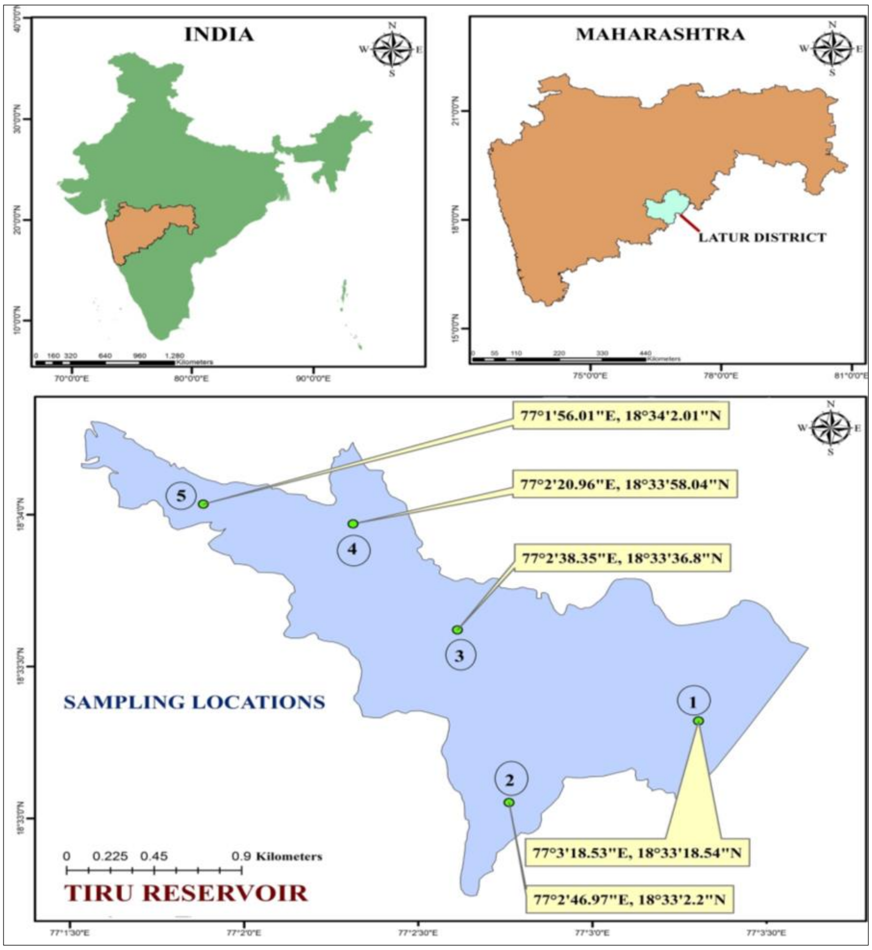

Fig 1: Sampling Locations in the Tiru reservoir

Rainfall pattern in the catchment area of Tiru reservoir

The weather of Maharashtra may be described as tropical monsoon, with scorching summers and mild winters due to the region's heavy rainfall during the monsoon season. The second week of June is often the beginning of the rainy season. Most of the rain in Maharashtra falls in July. However, there is also significant precipitation in August. With the arrival of September in the state, the monsoon begins its departure. Some areas of Marathwada, particularly the Latur and Beed districts, have been experiencing dry conditions for years. In 2016, the first 'Water Express' train rolled into Latur, India, to save residents from a severe drought. The Latur Water Special, a specially chartered train, made 108 round journeys, each delivering 25.95 lakh gallons of water to the dry area, home to three million people.

The rainfall pattern in the catchment of the Tiru reservoir is given in Table 02. In the event of a successful South-West Monsoon, the Tiru reservoir often reaches its overflow capacity in June and July. However, the reservoir was overflowing with water at any point throughout the research. Since Udgir, Ahmedpur, and Chakur Tahsil make up the reservoir's watershed region, their precipitation patterns significantly impact the reservoir's productivity and water level. In 2017, the Chakur Tahsil had the most significant monthly rainfall of 322.4 mm and the highest annual precipitation of 809.4 mm. In 2017, these three locations had an average rainfall of 669.41 mm; in 2018, the average rainfall was 551.94 mm.

Table 2: Precipitation frequency (mm)

Month Area	June	July	August	September	October	Total
2017						
Udgir	194.15	60.58	193.86	78.98	2.29	529.86
Ahmedpur	253.34	57	265.48	91.83	1.33	668.98
Chakur	290.2	81	322.4	113.8	2	809.4
2018						
Udgir	212.29	66.45	163.6	17.26	3.85	463.45
Ahmedpur	212.66	71.67	211.8	49.15	0.33	545.61
Chakur	351	69.6	194.02	17.2	15	646.82

Water sample collection

Monthly sampling was carried out, and water from 05 sampling stations were collected from Aug. 2017 to Jan. 2019 with great precision. Secchi disk transparency (SDD) was taken using a 12-inch Secchi disk while taking samples from sampling locations. These water samples were carried to the Laboratory in the ice box with the help of ice packs, and remaining parameters *viz.* Chl-*a*, and TP were analyzed. The water parameters were analyzed using conventional tools and procedures following APHA, 2005. All the chemicals were prepared using triple distilled water for greater accuracy.

Result and Discussion

Monthly and season-wise variation in the water parameters

Monthly and season-wise variation in the SDD, TP, and Chl-a is presented in Table 03.

Table 3: Monthly and season-wise variation in the water parameters

Season		**Secchi Disc Depth (m)**						**Chlorophyll-*a* (µg/l)**						**Total Phosphorus (µg/l)**					
	Location Month	**01**	**02**	**03**	**04**	**05**	**Mean**	**01**	**02**	**03**	**04**	**05**	**Mean**	**01**	**02**	**03**	**04**	**05**	**Mean**
Monsoon 2017	Aug.-17	0.55	0.49	0.52	0.47	0.44	0.50	3.21	3.29	3.24	3.35	3.48	3.31	21.80	23.9	24.65	21.20	21.65	22.64
	Sep.-17	0.69	0.62	0.56	0.57	0.53	0.59	2.41	2.51	2.67	2.62	2.73	2.59	12.50	15.8	14.60	12.30	13.80	13.80
Winter 2017	Average						0.55						2.95						18.22
	Oct.-17	0.74	0.76	0.79	0.76	0.69	0.75	1.32	1.25	1.24	1.28	1.34	1.29	8.60	9.35	8.15	7.85	7.25	8.24
	Nov.-17	0.66	0.69	0.74	0.64	0.58	0.66	2.55	2.41	2.34	2.67	2.72	2.54	15.61	14.05	13.66	12.88	13.27	13.89
	Dec.-17	0.65	0.64	0.69	0.56	0.63	0.64	2.76	2.78	2.69	2.87	2.82	2.78	19.54	22.34	20.10	21.36	19.12	20.49
	Jan.-18	0.76	0.68	0.66	0.53	0.51	0.63	4.21	4.46	4.58	4.53	4.71	4.53	25.52	30.64	25.36	28.72	24.72	26.99
Summer 2018	Average						0.67						2.79						17.40
	Feb.-18	0.68	0.63	0.66	0.59	0.61	0.64	3.32	3.48	3.34	3.67	3.52	3.47	26.36	25.64	27.26	24.74	27.26	26.25
	Mar.-18	0.64	0.60	0.63	0.56	0.53	0.59	7.31	7.65	7.45	7.94	8.11	7.69	34.52	34.94	33.68	34.94	32.84	34.18
	Apr.-18	0.62	0.58	0.62	0.54	0.51	0.58	8.35	8.39	8.18	8.63	8.83	8.48	41.70	43.24	39.06	40.82	42.36	41.44
	May.-18	0.61	0.53	0.62	0.46	0.48	0.54	8.81	8.83	8.74	9.24	8.93	8.91	44.05	43.13	47.04	43.82	43.59	44.33
	Average						0.59						7.14						36.55
Monsoon 2018	Jun.-18	0.52	0.46	0.49	0.47	0.47	0.48	5.01	5.21	5.18	5.32	5.78	5.30	35.6	36.72	36.08	37.04	36.72	36.43
	Jul.-18	0.53	0.50	0.54	0.51	0.47	0.51	3.83	4.06	3.98	4.04	4.43	4.07	26.12	27.10	25.98	27.52	27.38	26.82
	Aug.-18	0.57	0.53	0.59	0.56	0.52	0.55	2.27	3.35	2.28	3.31	3.36	2.91	16.76	18.20	16.28	17.12	16.28	16.93
	Sep.-18	0.66	0.63	0.59	0.57	0.56	0.60	1.78	1.82	1.88	1.92	1.98	1.88	17.36	19.88	19.16	19.40	18.92	18.94
	Average						0.54						3.54						24.78
Winter 2018	Oct.-18	0.72	0.74	0.76	0.75	0.64	0.72	1.67	1.51	1.23	1.44	1.72	1.51	9.65	8.60	10.25	10.85	7.70	9.41
	Nov.-18	0.65	0.67	0.65	0.67	0.58	0.65	2.52	2.38	2.41	2.22	2.58	2.42	10.16	11.48	10.52	12.20	9.44	10.76
	Dec.-18	0.63	0.71	0.62	0.64	0.58	0.64	2.68	2.57	2.71	2.64	2.74	2.67	19.12	20.38	19.68	20.24	19.54	19.79
	Jan.-19	0.59	0.65	0.63	0.61	0.59	0.62	3.46	3.13	3.21	3.42	3.51	3.35	21.64	21.92	21.08	22.9	20.94	21.70
	Average						0.66						2.49						15.42

Secchi disk depth (SDD)

A lake's trophic state index (TSI) may be calculated using the Secchi disc depth method, which is quick, simple, and inexpensive. The quantity of light penetrating a body of water is inversely proportional to its degree of transparency. Lakes with lower Secchi disc depth (SDD) measurements have greater algal concentrations. A Secchi disc with a 12-inch diameter was used to determine the depth of the water. Temporal and spatial variation in Secchi disc depth values is shown in Table 03. The study revealed that the smallest SDD values were obtained in August 2017 (0.5 m), with the most significant values reported in October 2017 (2.0 m) (0.75 m). Measurements of SDD were at their lowest level during the monsoons and highest throughout the winter. Sheela *et al.* (2011) [29] reported similar observations in the Akkulam-Veli lake, and Saluja and Garg (2017) [26] observed concurrent activities in Bhindawas Lake. During the monsoon season, water cloudiness not caused by algae and caused by rainwater that drains from the surface from agricultural areas contributes heavily to the low SDD readings.

Chlorophyll-a (Chl-*a*)

The concentration of chlorophyll-a (Chl-a) is directly taken from the algal cells, making it the primary variable to employ as a trophic status indicator (Boyer, 2009) [3]. Chl-a has numerous positive qualities as an indicator, including being responsive to ecological dynamics, being easily monitorable, and having a solid scientific basis (Boyer, 2009) [3]. In May 2018, the highest level of Chl-a was 8.91 µg/l, while in October 2017, it was only 1.29 µg/l. The most significant concentrations of chlorophyll-a were found in the summer season with 7.14 µg/l, followed by the monsoon season with concentration of 3.54 µg/l in 2018 and in the winter season with 2.79 µg/l concentration in 2017 and 2.49 µg/l level in 2018. Because summer has lower water levels and more nutrients available to the phytoplankton, its Chl-a concentration tends to be more significant. Winter may have the lowest Chl-a levels because primary production is insufficient due to several variables, including colder temperatures, fewer available nutrients, less photosynthetically active sunlight, and so on (Saluja and Garg, 2017) [26].

Total Phosphorus (TP)

It's no secret that plants and animals both need Phosphorus to flourish. Plants and animals require orthophosphate for growth, and it is formed by natural processes like decomposition and may be found in sewage. Total phosphorus content is one of the critical indicators of biological productivity. Summer had the most excellent total phosphorus content in the Tiru reservoir (36.55 µg/l), followed by winter (17.40 and 15.42 µg/l) and monsoon (18.22 and 24.78 µg/l). TP values ranged from 8.24 µg/l in Oct. 2017 to 44.33 µg/l in May 2018. Summer's greater TP levels are caused by two factors: lower water levels in the Tiru reservoir, and warmer temperatures, which stimulate microbial activity and cause Phosphorus to be discharged from soil layers (Saluja and Garg, 2017) [26]. More Phosphorus in the water causes more algae to grow in reservoirs, a process is known as eutrophication.

Estimation of Trophic State Index (TSI) by using Carlson's Index

Carlson's (1977) [4] Trophic State Index models, which are used to determine the trophic status of a reservoir, take into account the Secchi disc depth (also known as turbidity), the concentration of chlorophyll-a, and the total Phosphorus. The following are the equations that Carlson (1977) [4] presented by linking the Secchi disk transparency, Total Phosphorus, and Chl-a (Saluja and Garrg, 2017) [26]:

$$\mathrm{TSI}(\mathrm{SDD}) = 10 \times \left(6 - \frac{\ln(\mathrm{SDD})}{\ln(2)}\right) \quad (1)$$

$$\mathrm{TSI}(\mathrm{Chl}\text{-}a) = 10 \times \left(6 - \frac{2.04 - 0.68 \times \ln(\mathrm{Chl}\text{-}a)}{\ln(2)}\right) \quad (2)$$

$$\mathrm{TSI}(\mathrm{TP}) = 10 \times \left(6 - \frac{\ln(48/\mathrm{TP})}{\ln(2)}\right) \quad (3)$$

Where,
TSI (SDD) Trophic state index based on Secchi disk depth
TSI (Chl-a) Trophic state index based on Chl-a
TSI (TP) Trophic state index based on Total Phosphorus

Trophic State Index (TSI) of the Tiru reservoir using the Carlsons TSI model

Monthly and season-wise variation in the Trophic State Index values estimated as per Carlson's TSI model is as given in Table 04 and Fig. 02.

Table 4: Monthly and Season-wise TSI variation

TSI Month		**Carlson's TSI**			**TSI [TSI (SDD) + TSI (Chl-a) + TSI(TP)] / 3**
		SDD (m)	**Chl-*a* (µg/l)**	**TP (µg/l)**	
Monsoon 2017	Aug. 17	70	51	49	56.67
	Sep. 17	68	49	42	53.00
	Average	69.00	50.00	45.50	54.83
Winter 2017	Oct. 17	64	42	35	47.00
	Nov. 17	66	49	42	52.33
	Dec. 17	67	50	48	55.00
	Jan. 18	67	54	52	57.67
	Average	66.00	48.75	44.25	53.00
Summer 2018	Feb. 18	67	52	51	56.67
	Mar. 18	68	60	55	61.00
	Apr. 18	68	61	58	62.33
	May. 18	69	61	59	63.00
	Average	68.00	58.50	55.75	60.75
Monsoon 2018	June. 18	71	56	56	61.00
	July. 18	70	53	52	58.33
	Aug. 18	69	50	45	54.67
	Sep. 18	67	46	47	53.33
	Average	69.25	51.25	50.00	56.83
Winter 2018	Oct. 18	65	44	36	48.33
	Nov. 18	66	48	38	50.67
	Dec. 18	66	49	47	54.00
	Jan. 19	67	51	49	55.67
	Average	66.00	48.00	42.50	52.17

Lakes are categorized as either oligotrophic (low productive), mesotrophic (moderately productive), eutrophic (high productive), or hyper-eutrophic (highly productive) based on their CTSI values [Prasad and Siddharaju, 2012; Saghi *et al*., 2014] [23, 25]. The eutrophication levels of the Tiru reservoir were accessed by the Carlsons TSI estimation criteria given in Table 05.

Table 5: Eutrophication assessment of the reservoir based on Carlson's TSI values

Sr. No.	Trophic condition	SDD (m)	Chl-*a* (µg/l)	TP (µg/l)	TSI
01	Oligotrophic	>40	<2.6	<12	<40
02	Mesotrophic	20-40	2.6-7.2	12-24	40-50
03	Eutrophic	0.5-20	7.22-55.5	24-96	50-70
04	Hypereutrophic	<0.5	>55.5	>96	>70

Monthly variation in the TSI Values in the Tiru reservoir

Carlson's TSI model and classification criteria were used to determine the Tiru reservoir's Trophic State Index based on Chl-a, TP, and SDD. Among TSI (Chl-a), TSI (TP), and TSI (SDD) Trophic State Index based on Secchi disk depth [TSI (SDD)] higher readings. This might be because of the high amount of turbidity in the reservoir. Carlson (1977) [4] hypothesized that determining the trophic status using a TSI index generated with heavy turbidity might be deceptive.

Monthly variations in the Tiru reservoir are depicted in Table 04. And Fig. 02. Highest TSI (SDD) reading (71) was recorded in June 2018. Rainwater during the monsoon month carries heavy sediments into the reservoir, increasing turbidity and leading to improved TSI measurements. The lowest TSI (SDD) value (64) was recorded in October 2017. The highest TSI (Chl-a) readings were observed during April and May month (61), and the lowest TSI (Chl-a) reading (42) was recorded in October 2017. Water levels in the reservoir are at their lowest in the summer owing to rapid evaporation, and the nutrients in the reservoir are at their highest concentration then. In the summer, these nutrients boost the reservoir's eutrophication level by encouraging the proliferation of plankton. The highest TSI (TP) values were found during May 2018 (59), and the lowest during October 2017 (35). Phosphorus levels are at pick during the Summer months due to the concentration of the nutrients.

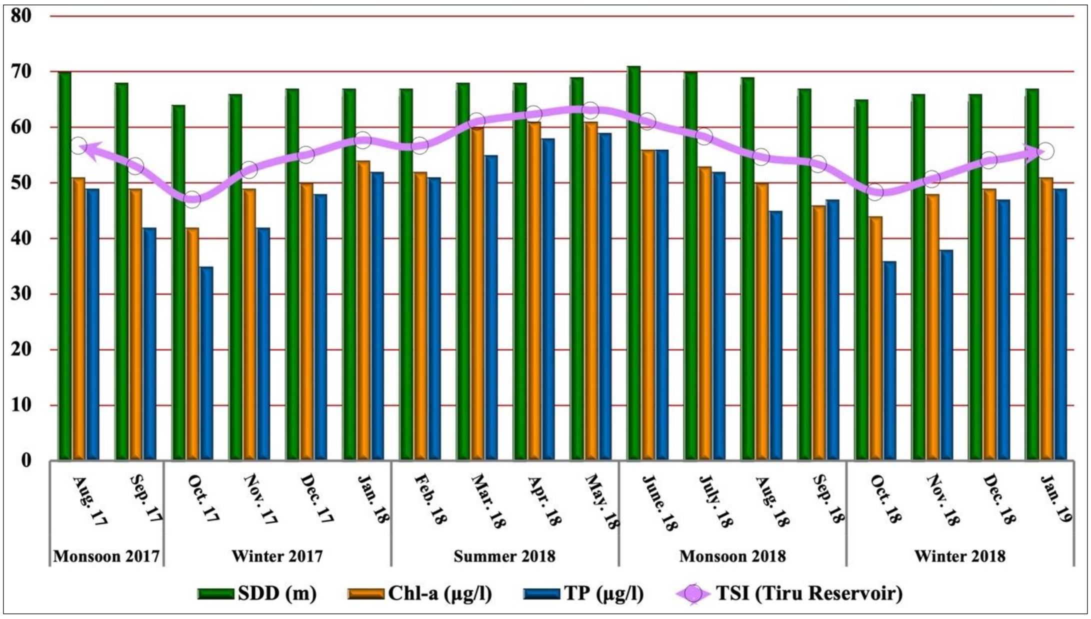

Fig 2: Monthly fluctuations in the TSI of tiru reservoir

Seasonal variation in the TSI Values in the Tiru reservoir

Seasonal fluctuations in the TSI range of the Tiru reservoir are presented in Table 06. And Fig 03. Seasonal average TSI readings were calculated using the following formula:

$$TSI\ (Total) = [TSI\ (Chl - a) + TSI\ (TP) + TSI(SDD)/3$$

According to Carlson's TSI estimation, the Tiru reservoir is in eutrophic condition throughout the study period. The enormous amounts of silt were carried via water discharge from surface in the rainy season significantly reduce sunlight penetration, which is why the monsoon has the highest TSI (SDD) measurements (69) during Monsoon 2017 and 69.25 during Monsoon 2018). Gradual drops in TSI (SDD) values were seen throughout the summer months (68), while the least values were recorded in the winter months (66). Carlson (1977) [4] hypothesized that calculating the trophic state index when there were a lot of turbidity's may provide inaccurate information about the trophic level. When the monsoons are in full swing, the Tiru reservoir is in a hyper-eutrophic condition; when summer rolls around, it transitions to a poly-eutrophic state; when winter rolls around, it's a eutrophic lake. In the summer season, TSI (Chl-a) was the highest (58.50), followed by the monsoon season (50, and then the winter season (48). During the monsoon, the dilution effect of rainwater was thought to be primarily responsible for the steady decline in chlorophyll concentration. At the same time, the least readings in winter might be attributable to low temperatures and less visibility and light penetration due to dim light condition, which would harm algal development. James *et al*. (2009) [15] and Gupta (2014) [13] found comparable outcomes.

In 2018, the summer season (55.75) recorded the highest average TSI (TP) readings. Due to low water levels, reservoir nutrients increased, raising TSI (TP) readings throughout summer. Due to rainwater dispersion of nutrients, monsoon concentrations have steadily declined. Meanwhile, agriculture runoff brings huge amount of nutrients to the reservoir, balancing the phosphorus content. Grazer phosphorus regeneration may also preserve TP balance. Carlson (1977) [4], James *et al*. (2009) [15], and Saluja and Garg (2017) [26] found comparable results.

Overall, Fig. 3 shows that TSI (TP) was highest (55.75) in summer and lowest (42.50) during winter. Monsoon TSI (SDD) was higher (69.25) than other indicators. Some researchers also found a similar pattern of higher TP levels during the summer season. (Elmaci *et al*., 2009; Sheela, 2011; Amardeep, 2018; Ghashghaie, 2018) [11, 29, 1, 12].

Table 6: Seasonal TSI status of the Tiru reservoir during 2017-18

Sr. No.	Seasons	SDD (m)	Chl-*a* (µg/l)	TP (µg/l)	Avg. TSI	TSI Status
01	Monsoon 2017	69.00	50.00	45.50	54.83	Eutrophic
02	Winter 2018	66.00	48.75	44.25	53.00	Eutrophic
03	Summer 2018	68.00	58.50	55.75	60.75	Eutrophic
04	Monsoon 2018	69.25	51.25	50.00	56.83	Eutrophic
05	Winter 2018	66.00	48.00	42.50	52.17	Eutrophic

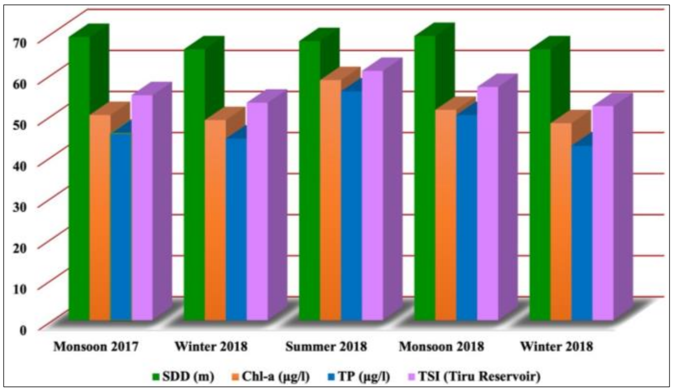

Fig 3: Seasonal fluctuations in TSI of Tiru reservoir

Conclusions

The current research revealed that the trophic condition of the Tiru reservoir is dynamic and fluctuates temporally. The TSI levels are predominantly controlled by agricultural runoff during the monsoon season. The Tiru reservoir was in a eutrophic condition throughout the whole-time frame of our investigation. The reservoir's primary productivity is controlled by the number of phosphorus loadings and other nutrients loaded into the reservoir from the surrounding agricultural areas. The current research concludes that non-algal turbidity and Phosphorus availability predominantly regulated the trophic condition throughout the monsoon and summer seasons.

In contrast, non-algal light attenuation significantly impacted the trophic state during the strong monsoon. It was determined that the TSI estimate strategy was efficient, easy, and precise for evaluating eutrophication in the water bodies. TSI (SDD) measurements cannot accurately predict the eutrophic condition of a reservoir in very turbid reservoirs. This research cautions that since TSI models rely on assumptions to make projections, they should be used with care.

References

1. Amardeep K, Abubakr A, Hassan SS. Trophic status assessment of Nigeen Lake, Kashmir (India). Journal of Entomology and Zoology Studies. 2018;6(4):1004-1009.
2. APHA. Standard methods for the examination of water and waste-water, 21st ed. American Public Health Association, Washington DC; c2005.
3. Boyer JN, Kelble CR, Ortner PB, Rudnick DT. Phytoplankton Bloom Status: Chlorophyll A Biomass as an Indicator of Water Quality Condition in the Southern Estuaries of Florida, USA, Ecological Indicators. 2009;9S(6):S56-S57.
4. Carlson RE. A trophic state index for lakes. Limnology and Oceanography. 1977;22:361-369.
5. Carpenter SR, Stanley EH, Zanden MJV. State of the World's Freshwater Ecosystems: Physical, Chemical, and Biological Changes. Annu. Rev. Environ. Resour. 2011;36:75-99.
6. Cruzado A. Eutrophication in the pelagic environment and its assessment. Eutrophication in the Mediterranean Sea: receiving capacity and monitoring of long-term effects. UNESCO Rep Mar Sci. 1987;49:57-66.
7. Cunha DGF, Calijuri MC, Lamparellib MC. A trophic state index for tropical/subtropical reservoirs (TSItsr). Ecological Engineering. 2013;60:126-134.
8. Ding Y, Tang D, Dai H, Wei Y. Human-water harmony Index: A new approach to assess the human water relationship. Water Resour. Manag. 2014;28:1061–1077.
9. Dodds WK, Cole JJ. Expanding the concept of trophic state in aquatic ecosystems: it's not just the autotrophs. Aquatic Sciences. 2007;69(4):427-439.
10. Dogan HM, Polat F, Kilic OM, Yilmaz DS, Buhan SD. Modeling and mapping Temperature, Secchi Depth, and Chlorophyll-a Distributions of Zinav Lake by using GIS and Landsat-7 ETM+ Imagery. Journal of Agricultural Faculty of Gaziosmanpasa University. 2016;33(3):55-60
11. Elmaci A, Ozengin N, Teksoy A, Topac FO, Baskaya HS. Evaluation of trophic state of Lake Uluabat, Turkey. J Environ Biol. 2009;30(5):757-760.
12. Ghashghaie M, Maralan MRS, Ostad-Ali-Askari K, Eslamian S, Singh VP. Determining the Eutrophication State of Ecbatan Reservoir using Carlson Index. American Journal of Engineering and Applied Sciences. 2018;11(2):491-500.
13. Gupta M. A New Trophic State Index for Lagoons. Journal of Ecosystems, 2014, 152473.
14. Hasler AD. Eutrophication of Lakes by Domestic Drainage. Ecology. 1947;28(4):383-395.
15. James RT, Havens K, Zhu G, Qin B. Comparative analysis of nutrients, Chlorophyll, and transparency in two large shallow lakes. Hydrobiologia. 2009;627:211-231.
16. Jin X, Liu H, Tu Q, Zhang Z, Zhu X. Eutrophication of lakes in China. China Environmental Sciences Press, Beijing; c1990. p. 614.
17. Kociolek JP, Stoermer EF. Oligotrophy: The forgotten end of an ecological spectrum Acta Botanica Croatica. 2009;68(2):465-472.
18. Naumann E. Nagra synpunkter angaende limnoplanktons okologi med sarskild hansyn till fytoplankton. Svensk Botanisk Tidskrift. 1919;13:129-163.
19. Okello C, Tomasello B, Greggio N, Wambiji N, Antonellini M. Impact of Population Growth and Climate Change on the Freshwater Resources of Lamu Island, Kenya. Water. 2015;7:1264-1290.
20. Palmer S, Kutser T, Hunter P. Remote sensing of inland waters: Challenges, progress and future directions. Remote Sensing of Environment. 2014;157:1-8.

21. Palvuk T, Bij De Vaate A. Trophic Index and Efficiency. Reference Module in Earth Systems and Environmental Sciences, Elsevier; c2017.
22. Porcella DB, Peterson SA, Larsen DP. Index to evaluate lake restoration. J Environ Eng. Div. ASCE. 1980;106(EE6):1151-1169.
23. Prasad AG, Siddaraju. Carlson's Trophic State Index for the assessment of trophic status of two lakes in Mandya district. Advances in Applied Science Research, 2012, 3.
24. Priyantha Ranjan S, Kazama S, Sawamoto M. Effects of climate and land use changes on groundwater resources in coastal aquifers. J Environ Manage. 2006;80:25-35.
25. Saghi H, Karimi L, Javid AH. Investigation on trophic state index by artificial neural networks (case study: Dez Dam of Iran). Applied Water Science. 2014, 5.
26. Saluja R, Garg JK. Trophic state assessment of Bhindawas Lake Haryana. Environ Monit. Assess. 2017;189:32.
27. Schleich J, Hillenbrand T. Determinants of residential water demand in Germany. Ecological Economics. 2009;68(6):1756-1769.
28. Sharma S, Walia YK. Water Quality Assessment of River Beas during Winter Season in Himachal Pradesh, India. Curr. World Environ. 2016;11(1):194-203.
29. Sheela AM, Letha J, Joseph S, Ramachandran KK, Sanalkumar SP. Trophic state index of a lake system using IRS (P6-LISS III) satellite imagery. Environ. Monit. Assess. 2011;177(1-4):575-592.
30. Sheela AM, Letha J, Joseph S, Ramachandran KK, Chacko M. Computation of physical characteristics of a lake system using IRS P6 (LISS-III) imagery. International Journal of Applied Earth Observation and Geoinformation. 2012;14:221–232.
31. Swanson ER. Trophic state index revisited. Lake Line. 1998;18(4):18-20.
32. Thienemann A. Der Nahrungskreislauf im Wasser. Verh. Dtsch. Zool. Ges. 1926;2:29-79.
33. Walker WW. Use of hypolimnetic oxygen depletion rate as a trophic state index for lakes. Water Res. 1979;15(6):1463-1470.
34. Xu FL. Trophic classification for lakes. In: Jørgensen SE, Fath BD (eds) Ecological indicators. Vol. 5 of encyclopedia of ecology, 5th ed^{n}.; c2008. p. 3594-3601.