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Secchi Disk Estimation for Trophic State Index in Barail range Doyang Reservoir Nagaland

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Abstract

The study aimed to conduct an ecological evaluation of Doyang Reservoir fed by perennial streams in Nagaland, India, by assessing its water transparency as an indicator for determining the trophic state index (TSI). The goal was to understand the seasonal variations in water quality by comparing pre-monsoon and post-monsoon data. The TSI, as proposed by Carlson (1977), was used to estimate the trophic condition of the reservoir. During the pre-monsoon period, the mean TSI was 61.52, indicating a high nutrient load, while the post-monsoon TSI was 45.44, reflecting the impact of reduced water inflow. In the post-monsoon season, the reservoir was classified as mesotrophic, whereas it was hypereutrophic during the pre-monsoon period due to the influx of agricultural runoff, waste, and soil erosion.
Keywords: Trophic State Index, Doyang, Secchi Disk.

Introduction

In recent decades, both natural and anthropogenic factors have significantly altered Earth's surface and environment. Climate change having a particularly profound effect on mountainous regions like the Himalayas. This has also impacted water bodies, which are influenced by both natural and human activities. The need to monitor and assess the quality of freshwater ecosystems is increasingly important, especially in developing countries where water pollution and resource depletion are rising concerns. Nutrient enrichment in water bodies, a key issue in managing and conserving aquatic systems, requires careful monitoring.

The evaluation of freshwater water quality therefore, becomes essential because of the extreme demand and vulnerability to pollution in developing countries and also for the concern of being diminished in the near future (Ongley 2000; Yan *et al*. 2015). Water transparency is one commonly used indicator of water quality. It is mentioned as a supporting factor for the biological elements in the Water Framework Directive

(Solimini *et al*. 2006). High transparency values indicate clear water, whereas, low transparency values indicate turbid or highly absorbing water, which usually means poor water quality. Water transparency defines how deep sun light will penetrate and hence, the depth at which plants can grow. A common measure of water transparency is Secchi depth. It is measured using a circular white and black plate, known as a Secchi disk, which is lowered into the water until it is no longer visible (Toivanen *et al*. (2013)).

The quality of water has been studied through different methods such as water quality index (WQI) and TSI. Water Quality Index is similar to the TSI in that both were developed for the statewide assessment of surface waters. While both are useful as thumbnail indicators of water quality, they are non-regulatory measurements which maybe used to identify water bodies. Transparency of the surface water layer in large lakes defines the depth of light penetration, which is essential for the growth of green plants as sunlight provides the energy for photosynthesis. Water transparency decreases as colour, suspended sediments and algae increase (Mikhail, 2008). Water transparency also serves as a simple and understandable indicator for assessing water quality in aquatic environments, even for non-specialists, as low transparency makes the water less attractive for swimming and boating and diminishes the aesthetic appeal of the reservoir (Angradi *et al*. 2018). The simplest method for assessing water transparency involves visually determining the depth at which the Secchi disk becomes invisible to the observer (Golubkov and Golubkov (2024)).

Secchi Disk (SD) is a simple yet effective equipment for measuring transparency of water. Secchi disk is of white and black colour combination with a diameter generally about 30 cm. It is the oldest "optical instrument" used for different applications based on its transparency from diver visibility to climate change studies measuring transparency of ocean and lake waters (Leea *et al*. 2015). Presence and absence of organism classifies lakes into different trophic categories (e.g., oligotrophic, mesotrophic, eutrophic). In lakes with higher nutrients, especially phosphorus and nitrogen, shallower Secchi depth is observed.

The environmental health of any lake system is essentially determined through its trophic state level basically, on a classification scale for how productive the lake is. Trophic status is therefore, calculated by exploiting a combination of quality parameters like water clarity and penetration of light, a measure of algal activity and phosphorus concentration, an essential nutrient needed by aquatic plants and algae to grow (Abdallah *et al*. 2018).

Water quality index is used for streams, black waters (natural tea- and coffee-coloured waters), and springs, while TSI is used for lakes and estuaries. TSI is crucial and meaningful to lake ecosystems as a representative indicator of eutrophication (Carlson (1977), Zhang *et al*. (2023)). Lake eutrophication can be strongly affected by constant sediment re-suspension and release of historically accumulated nutrients, which further exerts a profound impact on underwater light and primary production, and changes the structure and function of the lake ecosystem with the bottom-up effect (Wilkinson *et al.* (2022)).

Secchi depth is one of the major parameters used to calculate the TSI. Monitoring lake water quality through the TSI is a widely used method for assessing the nutrient levels and overall health of aquatic ecosystems. The TSI is a numerical scale that classifies the trophic status of a lake based on its nutrient content, specifically nitrogen and phosphorus, as well as its biological response, such as algal growth and water clarity.

The SD has also been employed to assess water quality in coastal and estuarine environments, where turbidity may be influenced not only by phytoplankton but also by suspended sediments, organic matter, and terrestrial runoff. In these environments, Secchi depth may not always directly correlate with chlorophyll-a concentration, making the interpretation of TSI more complex. TSI based on Secchi depth are influenced by a combination of biological, physical, and chemical factors, emphasizing the need for multi-parameter approaches in these environments

TSI helps determine the degree of eutrophication in a lake, which refers to the process where a body of water becomes overly enriched with nutrients, leading to excessive algae growth, oxygen depletion, and deterioration of water quality. The TSI categorizes lakes into different states:

1. **Oligotrophic**: Low nutrient levels, clear water, and healthy aquatic ecosystems. These lakes have low primary production.
2. **Mesotrophic**: Moderate nutrient levels, clear to slightly turbid water, and moderate primary production.
3. **Eutrophic**: High nutrient levels, often murky water due to algae, with high primary production that can lead to hypoxia (low oxygen) and fish kills.
4. **Hypereutrophic**: Very high nutrient levels, leading to severe algal blooms, poor water clarity, and oxygen depletion in deeper parts of the lake.

The values of trophic state index of a reservoir as per Pomari and Nogueira (2018) are

TSI Class	TSI Carlson	TSI reservoir
Ultraoligotrophic	<20	$TSI<47$
Oligotrophic	21-41	$47<TSI\leq52$
Mesotrophic	41-50	$52<TSI\leq59$
Eutrophic	51-60	$59<TSI\leq63$
Super eutrophic		$63<TSI\leq67$
Hypereutrophic	>61	$TSI>67$

Study Area

The study area comes under Wokha district in Nagaland, situated in the Northeastern part of India. It is situated on the Barail mountain range, a part of the Eastern Himalayas. The area comes under Lotha tribal community ancestral land. Doyang reservoir is the largest reservoir in Nagaland which is well-known for its Amur Falcon roosting sites particularly, Pangti Village. The area comes under subtropics and experiences torrential rainfall during the monsoon. Landslide and erosion along with domestic wastes creates an environment of sediment load in the lower catchment of Doyang. The present of agricultural activities along with wastes drained from the upper reaches of the drainage makes the reservoir vulnerable to eutrophication process.

The geographical coordinates are 94°25'9910' 'E -94°30'6639" E longitude and 26° 27'3203" N-26°21'2055" N Latitude. The area considered for the study is approximately 8 km2. The major tributary of Doyang is Dzudza. Doyang passes through a great part of Wokha district of Nagaland and is called 'POFU' by the local inhabitants (Lotha) which simply means 'encircle' because the river flows right through the middle of the district touching all the three ranges encircling the whole district (Akumtoshi *et al.* (2020)). There are reports of numerous fish species within the reservoir. It is estimated that 90 species of fishes belonging to 19 families are present in the reservoir. Out of these 90 species, 51% are ornamental fishes and 35% are of commercial importance (Odyuo and Nagesh (2012)). Hence, besides being an economic hub due to generation of hydel power. Doyang reservoir caters to different economic needs such as presence of a rich biodiversity making the region known as "Land of plenty".

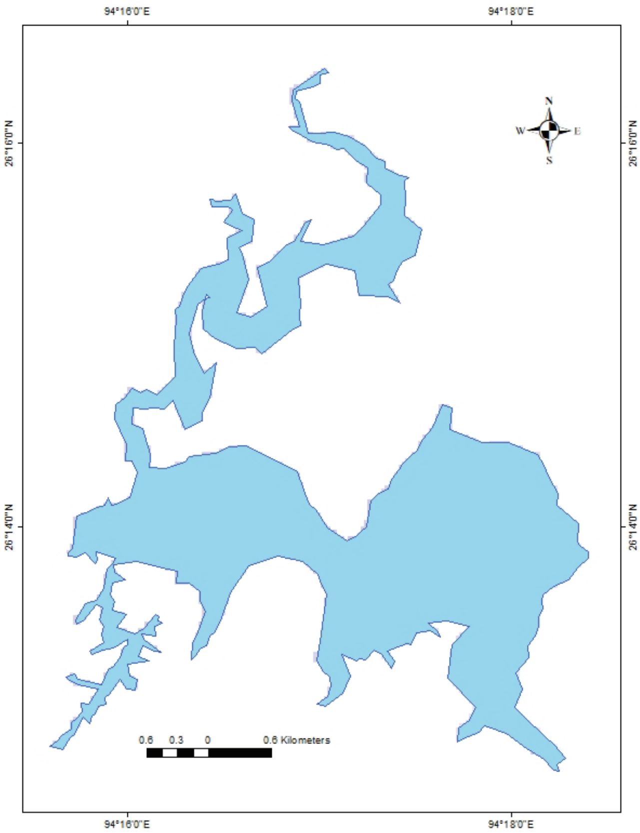

Figure 1:. Location map of the study area.

Material & Methods

For estimation of TSI, field survey readings based on pre-monsoon and post-monsoon was collected. Trophic state index based on Carlson work was used to estimate the eutrophication level in the reservoir. The equation is given below;

$$TSI = 10(6 - (\frac{lnSDT}{ln2}))$$

Where, SD is the sechi disk reading.

Assessment of Trophic state index of a lake /reservoir is measured using a 30 cm instrument known as SD. SD are crucial for a sustainable planning since it brings out the following management plan such as;

1. **Monitoring Trends**: By measuring TSI over time, changes in lake health can be tracked, such as increasing eutrophication, declining water quality, or improvements following nutrient reduction efforts.
2. **Management Decisions**: TSI can help inform lake management strategies such as controlling nutrient input (e.g., reducing agricultural runoff), improving waste treatment, or introducing aeration system in extreme water bodies with high eutrophication level.
3. **Assessment of Ecological Health**: It provides a clear, quantitative means to assess and compare the trophic level of different lakes or water bodies.

Result & Discussion

A significant variation in the form of suspended sediments and its concentration was observed in the centre, the inlet and the outlet of the reservoir. The inlet and other input sources bring in sediments, waste water, excessive nutrients originating from the sources like settlement, infrastructural inputs, agricultural sector, waste, etc. The nutrient enrichment in the reservoir is recorded and observed as shown in the given Fig 1. and 2. respectively. Different samples were collected in the reservoir along the reservoir course to bring out precise interpretation of the reservoir.

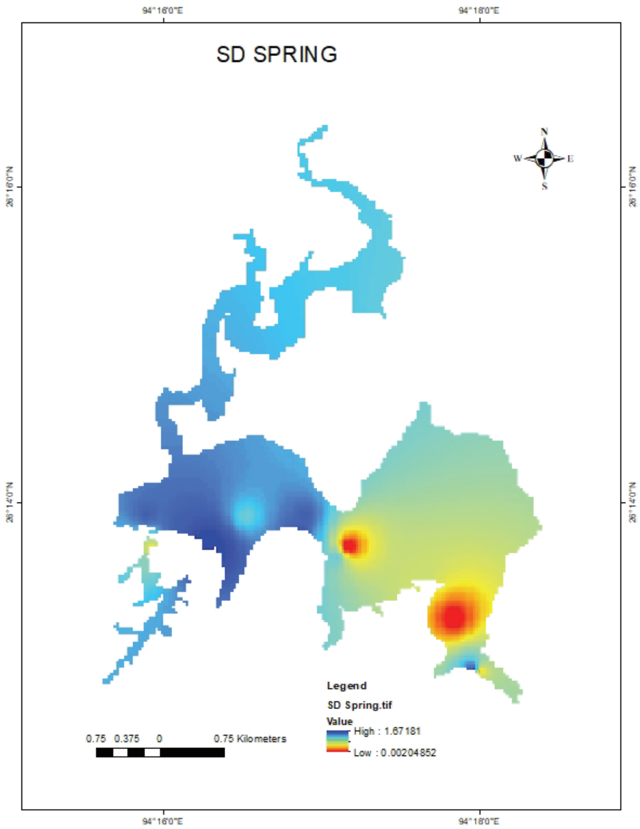

Figure 2: SD distribution during pre-monsoon (Spring) in the study area.

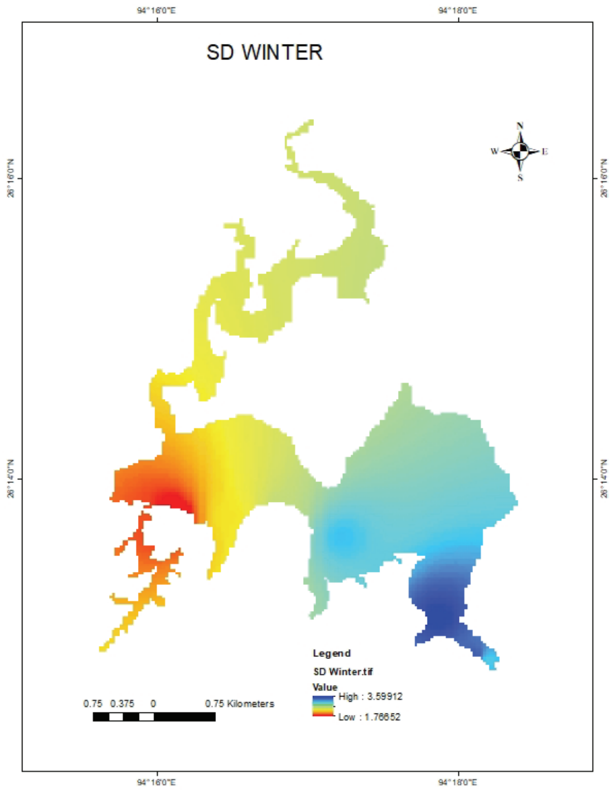

Figure 3: SD distribution during post-monsoon (Winter) in the study area.

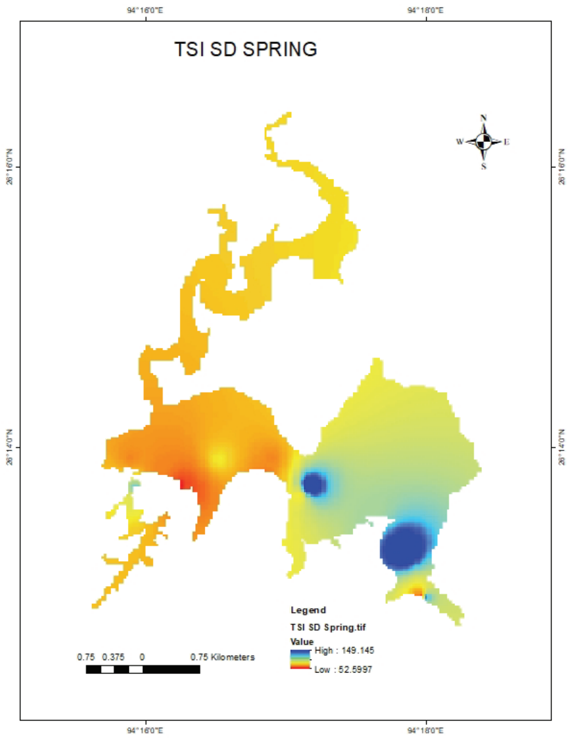

Figure 4: TSI of pre-monsoon (Spring).

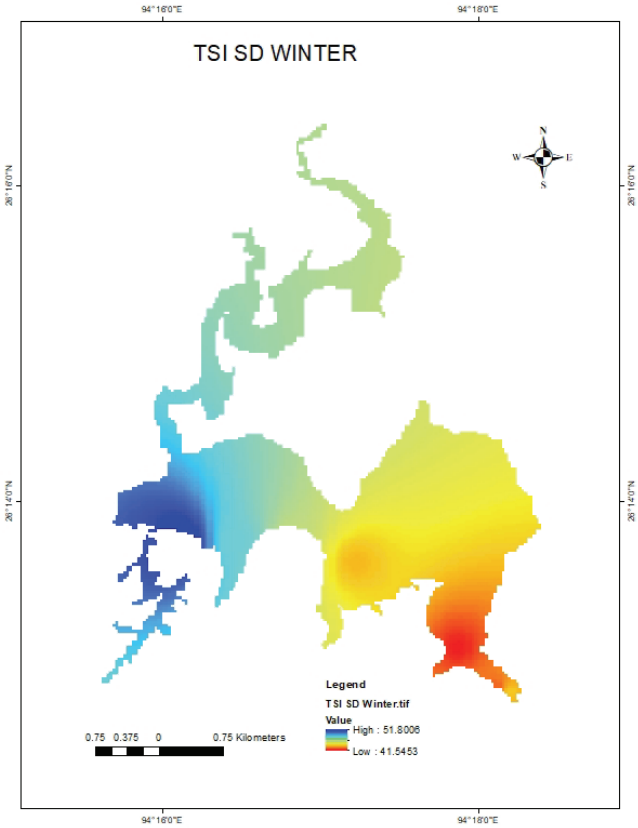

Figure 5: TSI of post-monsoon (Winter).

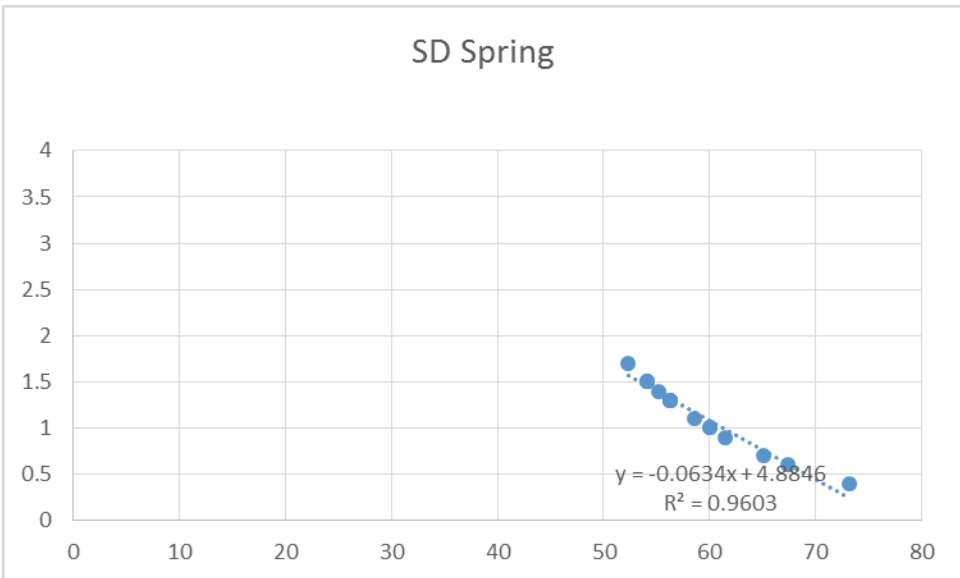

Figure 6: Graph of SD Pre-monsoon (Spring).

Fig 6. shows the scatter plot of SD and TSI relation. The value of R^2 is 0.9603 which shows high affinity between SD and TSI where the relationship is established. The scatterplot for pre monsoon for Doyang reservoir lay between 50 to 75 TSI value while for the SD reading it lies between 0.25 to 1.75. For the scatterplot relation between SD and TSI post monsoon. The TSI values between 50 and 55 while for SD values is observed between 1.5 to 3.75. The relationship has strong affinity with R^2 value showing 0.9851. Trophic state of Doyang determined by the SD showed mean value of 61.52 for pre monsoon. For the reading regarding post monsoon, mean TSI value showed 45.44. This value based on the result showed that the Trophic state level has decreased since the sediments or nutrient have reduced due to the season. Post monsoon, the drainage which engulfs the reservoir with nutrients have significantly reduce owing to reduced drainage flow. Thereby, reducing the accumulation of sediment particles which in turn improves the TSI value showing lesser pollution/nutrient content. The observation from Fig 4. and Fig 5. showed the reservoir flow dynamics which indicates the inlet and outlet movement of water. During pre-monsoon the high TSI value is observed in the reservoir inlet that is situated towards the east. In post-monsoon reading, the TSI values are reversed with pre-monsoon, where, the inlet observes lower TSI value while the outlet shows a higher TSI value.

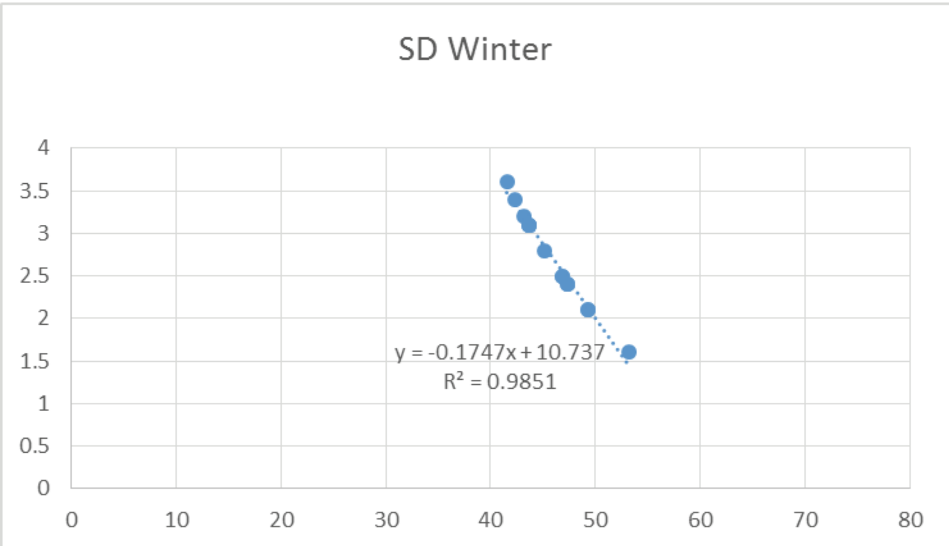

Figure 7: Graph of Post-monsoon (Winter).

Conclusion

The usage of SD continues to play a crucial role in assessing the trophic state of aquatic ecosystems through its integration into the TSI. Despite its simplicity and limitations, the SD provides an accessible and reliable method for monitoring water quality, particularly in lakes and reservoirs. SD remains an essential tool for both scientific research and practical management of water resources. Further research is required to improve the accuracy of TSI calculations in diverse environments and to refine the use of the Secchi disk in conjunction with other water quality metrics. The main purpose of the research was to estimate the trophic condition of Doyang

reservoir. The study shows that Doyang reservoir has turbid water quality which may not be alarming at the moment. Yet, for a sustainable and healthy reservoir, steps to manage and monitor direct and indirect pollutants should be implemented.
Although developing a standard equation for remotely sensed water clarity is still uncertain, its usefulness for routine applications for lake water clarity cannot be ignored. There is, however, still work to be done on what and how physio-chemical parameters changes with time. Similarly, temporal factors namely- Pre-monsoon and post-monsoon readings, as mentioned in this paper, can have a major impact on the results. Thus, the ground measurements would have to be closer in time and monitored for a longer period of time.

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