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Impact of Urbanization on Lakes—a Study of Gundolav Lake through Trophic State Index

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ABSTRACT: Gundolav Lake is a part of historical, cultural, economic, and recreational life of Kishangarh, Ajmer. It is facing multifold pressure due to urbanization, domestic and industrial waste discharge, bathing and washing, agricultural practices and wetland encroachment. The present work is aimed to investigate water quality index of Gundolav Lake using Carlson Trophic State Index (CTSI), which uses data like Secchi Disk Depth (SDD), Chlorophyll-a (Chl-a) and Total Phosphorous (TP) and provides information of these data in a single number. The CTSI value ranges from 0 to 100, the higher the score the higher will be the productivity. Different study stations at Gundolav Lake exhibited seasonal and inter-site variations in physico-chemical parameters. Present study revealed the fact that the CTSI values were lesser during post monsoon (46.03 to 52.95) and higher during pre-monsoon (46.20 to 54.07) due to nutrient enrichment by waste water rich organic waste both from point sources and non-point sources. The cumulative effects of anthropogenic pressure and exerted pollution load from point and non-point sources are affecting water quality of this urban water body. It may be concluded that the implementation of CTSI is necessary for public and decision makers to evaluate the water quality of the lake for sustainable management.

KEYWORDS: Water Quality, Gundolav Lake, Trophic State Index (CTSI), Urbanization.

I. INTRODUCTION

Water, as the prime necessity of life, has always been the soul and hope of the nature and sets the upper limit of the population and carrying capacity of the region (Sharma *et al.*, 1999). To anyone, who has seen satellite pictures of the planet earth, surely the most impressive feature is the apparent abundance of water. Water resources are important renewable natural resources and life support system on the earth, cover about 70% of the earth's surface to a mean depth of 3.8 KM, measures in volume about 1.4×10^9 KM³ (Solanki *et al.*, 2012; Gleick, 1996). Inland aquatic ecosystem exhibits a special prominence among our global freshwater resources. Inland water resources particularly lakes are the bodies of water that occupy as depressions on land surface with limited dimensions and is associated with a different set of problems, constituting a part of natural habitat, has its own physical, chemical and biological characteristics. Moreover, as a result of population growth, increasing industrialization and urbanization, increasing living standards and food supply, iniquitous division of water, development drive with climate change have led to pollution of our water resources and deteriorated the quality of water and also requirement for this natural resource far outweighs its supply and the crisis of access to adequate and safe water for drinking, agriculture, industry and livelihood activity is increasing in recent years. (Swaminathan and Manonmani, 1997, Ramakrishnaiah *et al.*, 2009; Allan, *et al.*, 2013). Therefore, characterization of physical, chemical and biological parameters serves as a good index in providing a comprehensive picture of the conditions prevailing in a water body. As there is lack of consensus among different experts and end users regarding perceptions and interpretation of various parameters of water quality. Therefore, it is necessary to translate water quality data in widely acceptable and unambiguous term. Water quality criteria that usually does not appear with definite conclusion is trophic status of the water body (Nauuman, 1929). Assessment of the trophic condition is an important step in the scientific assessment and management of lakes and used to classify the biological productivity of an aquatic system (Dodds and Cole, 2007; Devi Prasad, 2012; Sharma *et al.*, 2010). Shannon and Brezonik (1972) studied the multidimensional nature of the eutrophication and reported that no single variable can represent status of eutrophication of given water body.

In the traditional and multidimensional system to assess trophic status, various single parametric and multiparametric approaches were used and lakes has been divided into 3 major classes of trophic states, namely Oligotrophic, Mesotrophic and Eutrophic (Beeton and Edmondson 1972). Hence, to understand the level of pollution and nutrient status of a water body, it is becoming necessary to not only analyze the physical, chemical and biological parameter but also to report these parameters in term of various indices. To avoid this nomenclatural imprecision a different approach

to trophic classification of lakes was proposed by Carlson to quantify trophic state or overall health of water resources. **Carlson (1977)** proposed Carlson trophic state index (CTSI), which is biomass related numerical trophic state index requires a minimum data and is generally easy to understand and provide complete and more dynamic picture of nutrient status of water body to non – technical and semi technical public. Carlson’s trophic state index mainly uses algal biomass involving three variables namely chlorophyll-a (CA), Secchi disc depth (SD) and total phosphorus (TP). The Carlson’s trophic state index for lakes incorporates lakes in a scale of 0 to 100. The average values of TSI of these three parameters will be considered in determining the Carlson’s trophic state index. This index is widely used as an important tool in conservation of lakes and to assess trophic status monitoring. Therefore, present study is carried out to achieve trophic status of Gundolav Lake by using Carlson’s trophic state index.

II. STUDY AREA

Totally rain-fed Gundolav Lake is a manmade lake amidst low hills erected on almost plain surface of eastern semiarid agro-climatic zone, located in the North of Kishangarh (Rajasthan) at 26°28' N and 74°52' E, at 500 m above MSL. The data sets were compiled for the period of six months (January 2019 to June 2019). Gundolav Lake is one of the many perennial shallow water bodies around Kishangarh, of which Hamir Pond, Santolav Pond, Ransamand Pond are important. About 1,254 bigha land in the basin of the Gundolav Lake is used for farming, when lake dried up. Due to multifold pressure of urbanization and industrialization, urban wastewater discharge, cloth washing activities, agricultural practices and construction of hotels and housing colonies, the major part of the lake is greatly affected. Therefore, for water quality assessment a total of 5 sites has been taken to ensure accuracy in measurement and completeness of the whole geographical area. The total catchment area of the lake is 13.44 sq. km. and the terrain is semi hilly and rocky. On the northern end of Gundolav, is situated the beautiful and auspicious ‘Ram Tekri’. Yagya-sthali and Manak Tekri, Phool Mahal are other places near the lake. ‘Awanna’ beautifies the eastern side of the lake from where water used to come out. In the middle of the lake is situated ‘Mokham Vilas’ which gives a marvellous view [Source: Kishangarh Tavarikh]. Till the independence Gundolav Lake hold an important place as a source of drinking water supply to the city and was a destination for various recreational activities.

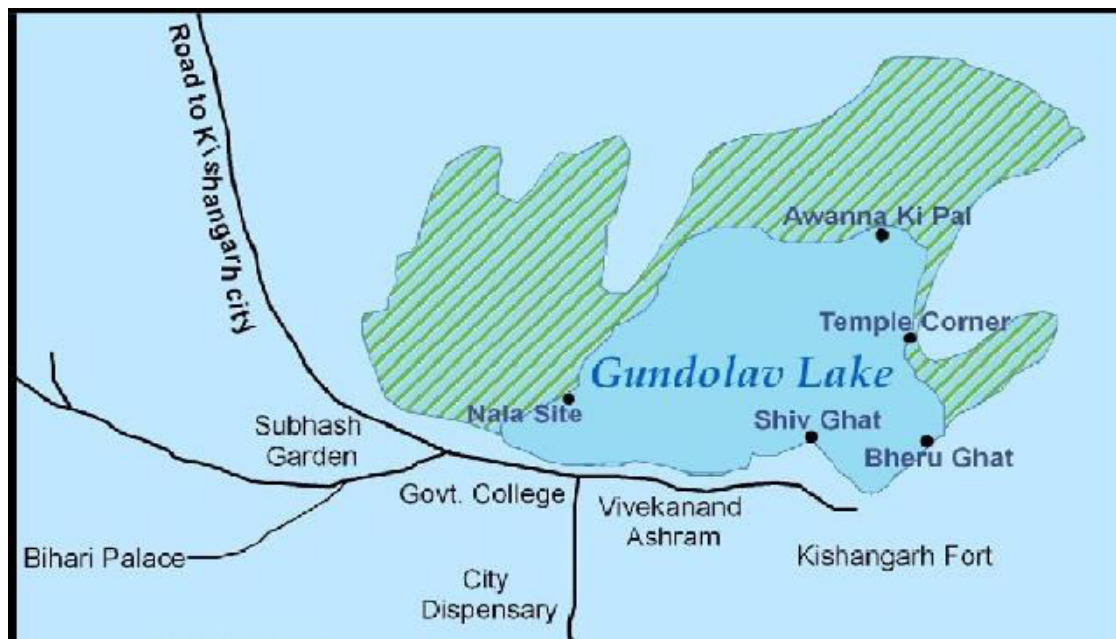


Plate 1: Map of Gundolav Lake showing different study stations and surroundings



Plate: 2 Map of Gundolav Lake showing Source of pollution entry at Nala site Station-IV

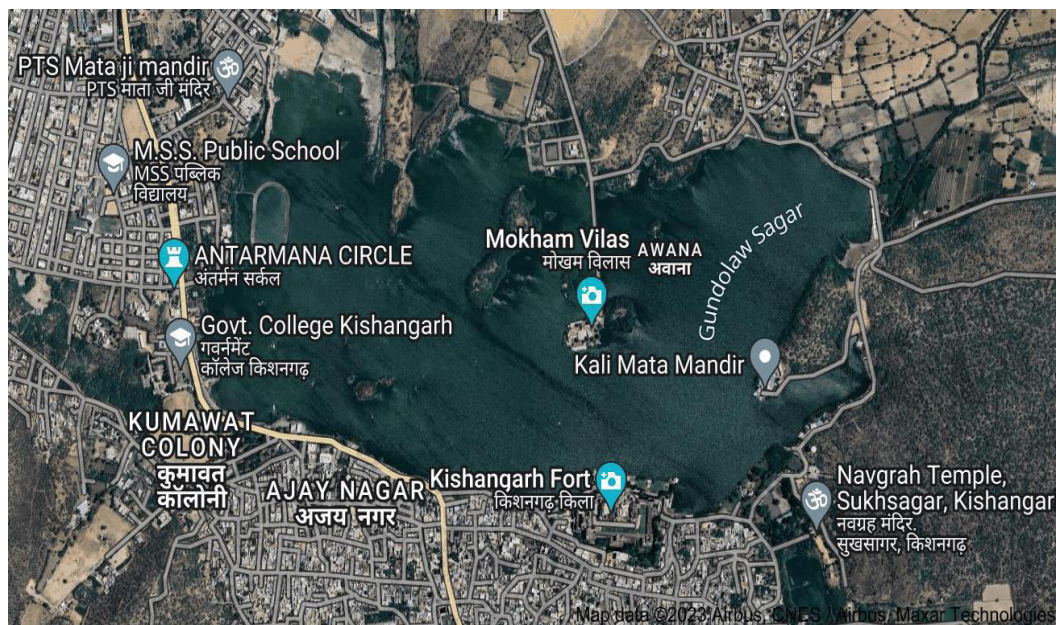


Plate 3: Satellite image of Gundolav Lake

III. OBJECTIVE OF STUDY

The study aimed to investigate the trophic Status of Gundolav Lake, Kishangarh (Ajmer). It is expected that the proposed study will contribute to a more informed evaluation and response to water quality deterioration and negligence of surface water systems and is relevant to present day interest in pollution control and environmental concerns; comprising a logical, scientific approach.

IV. REVIEW OF LITERATURE

Various methods have been employed for the classification of lakes and to indicate their trophic status. The most commonly and widely used method is based on productivity, and the frequently used biomass related trophic state index is that of Carlson (1977). The TSI for total nitrogen (TN) was developed by Kratzer and Brezonik (1981) for

Florida lakes. **Deshmukh and Tarar (2015)** studied trophic status of the freshwater resources of the Bhandara District of the central India and found that majority of lakes face severe nutrient pollution and are at risk of becoming eutrophic in near future. **Mishra et al., (2016)** evaluated the ecological health of Surha Lake, in Ballia (U.P.) using NSFQI and CTSI and found that the lake was in eutrophic state with average CTSI of 76.30 and average NSFQI was reported in medium water quality range. **Taşeli (2017)** assessed the water quality of Koycegiz-Dalyan Lagoon in the Turkey using TSI (trophic state index) and found values of both SD (secchi depth) and TP (total phosphate) within eutrophic category in the lake. Furthermore, the calculated TN/TP ratios suggested that lake can be considered to be P limited. **Khasani et al., (2018)** assessed the trophic status of East Banjir Kanal river in Semarang using Carlson's Trophic State Index and classified river in slight eutrophic status through calculated average Trophic State Index values between 53-57. **Tibebe et al., (2019)** made a study to assess spatio-temporal variations in water quality parameters and trophic status of shallow Tana Lake in Ethiopia by using Carlson Trophic State Index (CTSI) and found trophic state index average values of 69.77 which clearly indicated lake in eutrophic condition. **Lin et al., (2020)** have assessed trophic status of Lake Erhai, Yunnan Province in China using Carlson's TSI and revealed lake in the Mesotrophic status on the basis of calculated TSI. From the above literature, it is seen that Carlson's Index has largely been used to assess the trophic status of lakes in almost all the countries including India. As such no reports are available on the development of TSI system for Indian lakes but Carlson's TSI is presently used to assess the status of lakes in India.

V. METHODOLOGY

Numerous methods have been developed to measure the trophic state (TS) of lakes. Most of the methods have been found more effective in ranking the lakes using the total phosphorus standard compared to chlorophyll 'a' standard (**Lambou et al 1983**). A number of authors have used different methods in the literature to determine the TSI of lakes (**Naumann 1931; Palmer 1969; Shannon and Brezonik 1972 and Vollenweider 1975**). Out of these methods, the Carlson's Trophic Status Index method is selected for the present study. The field study of this research work was conducted during the period 2025. To investigate the water quality, 4 sampling sites were chosen in pond for the analysis of three parameters Secchi depth (SD), total phosphate (TP), and chlorophyll-a (Chl-a) to explore trophic status of ecological subsystem by using Carlson's Trophic State Index (CTSI (**Carlson, 1977**)). The sampling stations were chosen strategically to provide water samples from the core as well as peripheral region of the lakes. Water samples were collected at monthly intervals covering two distinct seasons, i.e. pre-monsoon and the post-monsoon season. or collection of lake water samples pre-acid-washed 1 L polyvinylchloride sample bottles were used, first rinsed well with deionized water, followed by sample water before filling up to the capacity. Lake water samples were collected at 0.3 m below the surface level and filled to the brim to prevent any air entrapment. Secchi depth was determined using a 20 cm black and white metal disk and the values are expressed in meters. The maximum depth at which the Secchi disc can be seen when lowered into the water is marked and measured. Total phosphorus was analyzed by colorimetric method and chlorophyll-a were estimated by acetone method and measured using a spectrometer. The total amount of TSI is the mean of these three parameters, and the value of TSI varies between 1 and 100. Then Carlson's trophic state indices (TSITP, TSIChl-a and TSISD) was calculated from the mean values of TP, Chl-a, and SD using the following equations.

$$\text{TSI (SD)} = 60 - 14.41 \ln (\text{SD}) \text{ (in meters)}$$

$$\text{TSI (CHL)} = 9.81 \ln (\text{CHL}) + 30.6 \text{ (in } \mu\text{g/L)}$$

$$\text{TSI (TP)} = 14.42 \ln (\text{TP}) + 4.15 \text{ (in } \mu\text{g/L)}$$

Based on Carlson's Trophic State Index, the state of the water body is characterized to oligotrophic, meso-trophic, eutrophic and hyper-eutrophic. Classification of water body as per scale if the lake has CTSI values are within 30 then it is oligotrophic lake, if it is within the range of 30-40 then it is Mesotrophic Lake, if the values range between 40-80 or above 80 then it is eutrophic lake. The higher the values of Carlson index, the worse the state of water quality. Finally, Carlson's trophic state indices used to classify the water reservoir as oligotrophic, mesotrophic and eutrophic. Once the overall CTSI score is known, it can be compared against the following scale to determine trophic status of water body.

Table-1: Interpretation of trophic status on the basis of TSI values

Classification	Sub-Classification	Trophic State Index
Oligotrophic	Strongly-oligotrophic Oligotrophic Slightly-oligotrophic	0-25 26-32 33-37
Mesotrophic	Slightly-mesotrophic mesotrophic Strongly-mesotrophic	38-42 43-48 49-53
Eutrophic	Slightly-eutrophic eutrophic Strongly-eutrophic	54-57 58-61 62-64
Hyper-Eutrophic	Hyper-Eutrophic 65+	65+

VI. HYPOTHESIS

Ho: The pollution load in Gundolav Lake remains within its natural resilience limit and does not affect the nutrient level to a considerable level spatially as well as temporally within the lake system. Ha: The pollution load in Gundolav Lake is variable beyond its natural resilience limit and affect the nutrient level to a considerable level spatially as well as temporally within the lake system.

VII. RESULTS AND DISCUSSION

Carlson's Trophic State Index (CTSI) of different months for each of the parameters for Gundolav Lake for a period of one year covering two distinct seasons, i.e. pre-monsoon and the post-monsoon season are presented in the tables 2 and 3 respectively.

CHLOROPHYLL-a: Chlorophyll-a is the major photosynthetic pigment of phytoplankton and index for trophic state classification to measure the functioning of a water body (Hosmani, 2010). The more chlorophyll corresponds to more phytoplankton and more eutrophic state of the water body and greater will be the value of TSI. In Gundolav Lake waters TSI values for Chlorophyll-a were found between 44.49 to 50.52 during pre-monsoon period and between 44.42 to 50.44 during post-monsoon period. The Chlorophyll-a was found higher than the permissible limit which is reflected from very high TSI values at the study area. Verma and Pandey (2017) in two freshwater lakes of Udaipur, Rajasthan reported the influence of catchment characteristics on nitrogen (N) and phosphorus (P) loading and phytoplankton production and found as higher the concentration of phosphorous in water, more is the primary productivity resulting in higher chlorophyll-a concentration, which is consonance to present investigation.

TOTAL PHOSPHATE: Phosphates are the chemical compounds consist of phosphorus and oxygen and they are necessary for growth of plants and animals. Phosphates are present in water in many forms, so total phosphates provide an estimation of the total amount of phosphates available in a water supply. More content of total phosphorus and greater will be the value of TSI. The phosphate is emerged as a serious problem regarding water quality as it was found many times higher than the permissible limit which is reflected from very high TSI values at the study area. In Gundolav Lake waters TSI values for total phosphorus was found between 24.98 to 32.70 during pre-monsoon period and it was between 25.84 to 33.05 during post-monsoon period. These higher values of TSI indicates heavy contamination in water. Willem *et al.*, (1972) suggested that phosphorus is always higher at polluted points in comparison to non-polluted points, which is in consonance with the present study as regards to the phosphate values.

TRANSPARENCY (SECHI-DEPTH): Transparency of water is inversely proportional to the turbidity, which in turn is directly proportional to the amount of suspended organic and inorganic matter. Transparency in fact, depends mainly on the optical properties of water and partly on the light flux. In Gundolav Lake waters TSI values for transparency

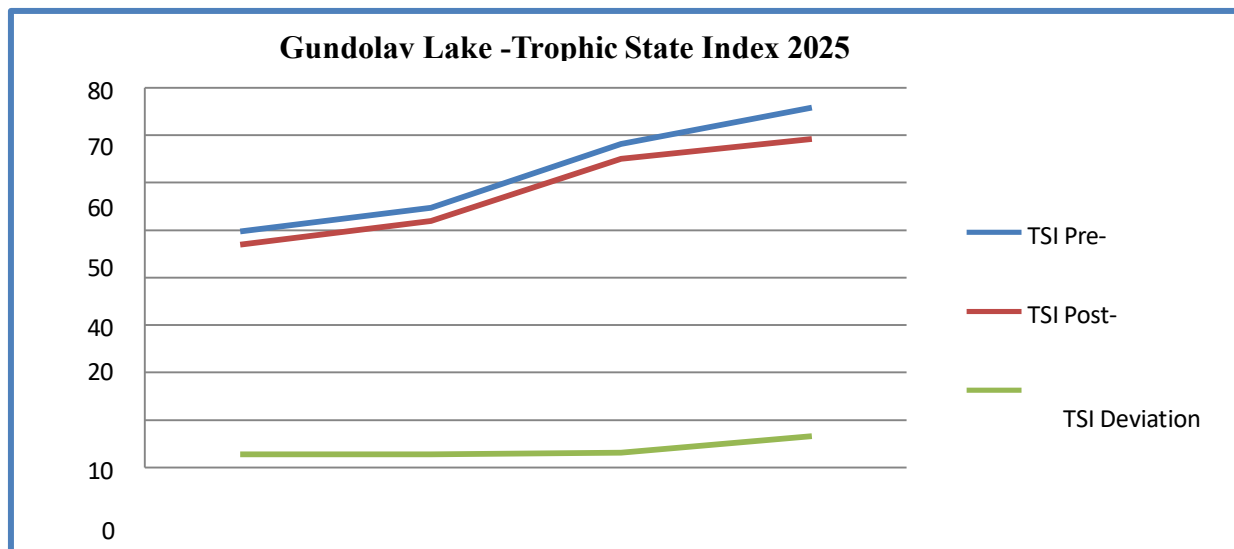
were found higher, between 71.18 to 80.55 during pre-monsoon period and between 67.84 to 76.87 during post-monsoon period, which clearly an indicative of degraded water quality in terms of transparency. In respect of seasonal behaviour, the winter season exhibited maximum transparency values decreasingly followed by summer and rainy season. This finding is in accordance with the views of Pradhan *et al.*, 2003.

Table 2: Consolidated CTSI values at different stations in the area under investigation of the water sample

Pre-monsoon 2025							
Station No.	Total Phosphorus (Mg/L)	Total Chlorophyll (Mg/L)	Secchi Depth (Mtr.)	TSI-TP	TSI Chl	TSI SD	TSI
1	5.86	5.36	0.46	29.65	47.07	71.18	49.3
2	6.51	7.62	0.24	31.16	50.52	80.55	54.07
3	4.24	4.12	0.53	24.98	44.49	69.14	46.20
4	7.24	6.59	0.39	32.70	49.10	73.56	51.78

Table 3: Consolidated CTSI values at different stations in the area under investigation of the water sample

Post-monsoon 2025							
Station No.	Total Phosphorus (Mg/L)	Total Chlorophyll (Mg/L)	Secchi Depth (Mtr.)	TSI-TP	TSI Chl	TSI SD	TSI
1	6.22	5.32	0.50	30.51	47	69.98	49.16
2	6.68	7.56	0.31	31.54	50.44	76.87	52.95
3	4.50	4.09	0.56	25.84	44.42	67.84	46.03
4	7.42	6.54	0.40	33.05	49.03	73.19	51.75



The CTSI values ranged from 46.20 to 54.07 (higher) during pre-monsoon while during post-monsoon, it varied between 46.03 to 52.95 (lessor) at various sampling stations. Sampling station near inlet of sampling station 4 have high CTSI due to nutrient enrichment by waste water rich organic waste. From the obtained results it is clear that the present status of Gundolav Lake is Eutrophic at all sampling stations due to indiscriminate disposal of domestic waste water from surrounding residential and commercial area except Station 4, which is highly eutrophic due to continuous inflow of nutrients from surroundings industrial area. This finding is also in line with Prasad and Siddaraju (2012) who studied Arakerelake and Thaggahalli Lake and found higher CTSI values in summer season.

The findings of the present study are also consistent with the results of a study conducted on Gilarlo Reservoir Dam (northeast of Iran), in which the researchers concluded that it was mesotrophic in August and eutrophic in October (Shamlou A, Naseri S, Nadafi K. 2004). Moreover, the TSI change as the difference of pre-monsoon and post-monsoon period is showing increasing trend suggesting high magnitude changes in pollution level at the sampling sites under study in which station 4 is depicting high TSI and high TSI change. Therefore, the null hypothesis that the pollution load in Gundolav Lake remains within its natural resilience limit and does not affect the nutrient level to a considerable level spatially as well as temporally within the lake system, is rejected. Overall, it was found that TSI (TP) is a key parameter in deciding the trophic status of the lake and any change in phosphorus concentration of fresh water ecosystem can also alter its trophic status.

VIII. CONCLUSION

In essence the trophic status of the pond reveals that it is tending, fast towards “eutrophism” particularly at station IV. It may be concluded that CTSI can be very well used to assess the TSI of a given water body. The quality of water is deteriorating day by day due to inflow of domestic sewage, municipal waste and effluents of organic waste of animal and human origin into the lake. Deterioration of water quality and eutrophication are assuming alarming state in lake due to casual attitude of people concerned with development of urban population. If waste input is not checked then it will severely impair water dynamics and will cause eutrophication of the entire system.

IX. RECOMMENDATIONS

In order to assist recuperation of the pond and to explore it in sustainable manner; immediate priority should be given to identification and abatement of lacuna in existing information and tools failing to conserve the pond and catchment area. It is also necessary to prepare action plan on pond restoration providing sufficient space to beautification in order to develop economic subsystem. Besides source control, some palliative actions should be commenced with prime importance in order to cope up the problem of eutrophication in the pond system. Community based indigenous knowledge system for water harvesting should be materialized to aware and insures involvement of community in efforts for conservation of this natural wealth. Therefore, coordinated efforts of various stakeholders and proper community involvement are the primary needs to restore the ecological subsystem of the pond and to make it useful for further social and economic exploration.

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