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Eutrophication Assessment for the Dantaramakki Lake of Chikmagalur City Using GIS Technique

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Abstract: Rapid industrialization and urbanization in urban areas has greatly decreased the available water resources in India. The study was carried out on the assessment of trophic state of Dantaramakki Lake by using GIS technique. A representation of the spatial distribution was developed using the inverse distance weighted interpolation method. The eutrophication level of the lake was determined with the help of a Carlson's scale. Based on Trophic State Index calculations and spatial distribution by Geographic Information System technique, the lake was found to be mesotrophic in February and March, eutrophic in April. In the study period, the lake was found to be almost in moderately eutrophic conditions.
Key words: Eutrophication, Geographical Information System (GIS), Trophic State Index (TSI).

Introduction

Pollution resulting from increased human activities is threatening the lakes and its effects being characterized by serious eutrophication. The total output of the eutrophication is loading of lake with phosphate and nitrates. These two elements basically increase the fertility of lake water and lead to growth of water hyacinth and floating micro algae. Eutrophication refers to continuous enrichment of water by addition of substances that provide for the increasing growth of aquatic life [1]. Eutrophication is the process of enhanced trophic status due to increased nutrient inputs [2]. If the waters are nutrient poor with low productivity are characterized as "oligotrophic" whereas, nutrient rich waters with high algal biomass are characterized as "eutrophic". The intermediate conditions characterize "mesotrophy" [3]. Phosphorus is the nutrient for the productivity in lakes. Lakes receive phosphorous from a variety of external sources either as dissolved or detrital input [4]. Phosphorous enters the lakes in a particulate form, which can be directly deposited as dissolved phosphate. If phosphorous loading is excessive, phytoplankton is favored and this has significant negative implications for the overall water quality and biodiversity of the lake [5]. The various forms of nitrogen are urea, ammonia, organic nitrogen, nitrites and nitrates through processes like nitrification, denitrification and ammonification. Nitrification consists of two reactions, the conversion of ammonia to nitrite by nitrosomonas and then from nitrite to nitrate by nitrobacter. The extent of nitrogen as nitrate is also used as an indicator of the trophic state of the water bodies. Higher concentrations of nitrate primarily contribute to the eutrophication of water bodies [6]. Geographic Information System is a computer based information system used to digitally represent and analyses the geographic features present on the earth's surface and the events that taking place on it. The meaning to represent digitally is to convert analog into digital form. The Geographic Information System is very powerful for analysis and creation of models that incorporates the relations between the different features on the surface and its effect on the environment [7]. Geographic Information System has been built around existing database management system. All geographical data can be reduced into three basic topographic concepts, which are points, lines, and polygons or areas. The main aim is to study and analyze the eutrophic status of the lake by calculating tropic state index by identifying the source and characteristics of (nutrient) discharge into the lake and estimating the rate of eutrophication and creation of spatial variations using Geographic Information System technique.

Materials and Methodology

Study Area

The Chikamagalur city is situated at an altitude of 1021 m above the mean sea level and is located on 13^0 36' north altitude and 75^0 45' eastern longitude. The Dantaramakki Lake is situated in the "Kaveri basin" in Chikamagalur city, Karnataka, India. The total water spread area is 47.75 hectares. The lake is located $19^0 19^{'} 45^{''}$ N latitude and $75^0 47^{'} 39^{''}$ E. The lake capacity is 49.93 million cubic feet and total irrigation area is 310 hectares, the bund length is 930 m. The preliminary survey is done by collecting water quality data from Karnataka State Pollution Control Board (KSPCB) Chikamagalur, capacity, surface area and bund length of the lake was collected from Irrigation department, Chikamagalur. Numbers of inlet and outlet points were inspected. Source of inlet wastewater to the lake was identified and sampling points were selected which covers the major portions of lake.

Sampling

To determine the variations in the lake, samples were collected bimonthly. Between February 2013 to April 2013, the predetermined sampling points to represent station 1 (inlet), corresponding point's station 2, station 3 and station 4 (outlet). The co-ordinates of the four stations were determined with Geographic point system (GPS). The study area and sampling points are shown in the figure 1 and 2 and their GPS point locations are shown in the table 1. Water samples were collected by using an alpha bottle sampler and were placed in dark polyethylene two-liter bottles [8]. They were stored in dark coloured bottles according to standard methods [8]. To determine the lake conditions temperature, electrical conductivity, pH, dissolved oxygen, Secchi depth (SD), total nitrogen (TN), total phosphorus (TP) and chlorophyll-a, samples were measured.

Table 1: GPS Point Locations

Sampling Stations	**Points**	**GPS Readings**	
		Latitude	**Longitude**
STATION 1	INLET	13°19'49.85''N	75°46'45.85''E
STATION 2	2	13°19'49.34''N	75°46'52.80''E
STATION 3	3	13°19'48.75''N	75°46'58.99''E
STATION 4	OUTLET	13°19'43.02''N	75°46'55.33''E

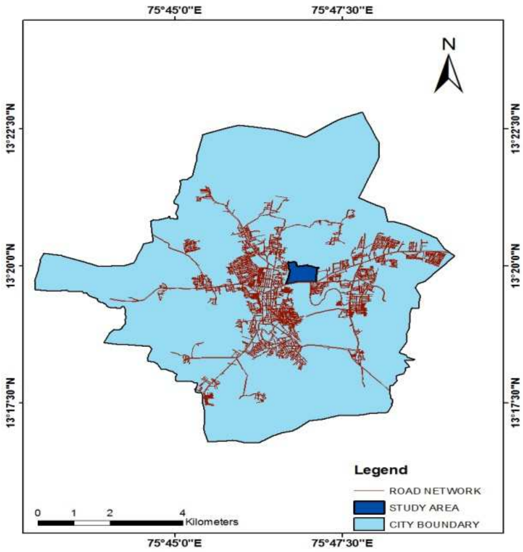

Figure 1: Study Area representation using GIS **Figure 2: Sampling Location**

Water quality determination

Using the HACH Sension 156, pH, temperature, electrical conductivity and dissolved oxygen were measured during the sampling. Transparency was measured using Secchi disk (SD). Total nitrogen (TN) was measured with kjheldal nitrogen distillation unit, total phosphorus (TP) was measured at the 880 nm wavelength by spectrophotometer using the ascorbic acid method in Standard Methods [8]. Chlorophyll-a (Chlor-a) values were measured by extraction in acetone and values were determined at the 665, 645 and 630 nm wavelengths by spectrophotometer in laboratory.

Assessment of Trophic State Index and by using GIS technique

The trophic status refers to the level of productivity in a lake which is measured with the reference by phosphorous, nitrogen, and transparency etc., TSI values can be used to rank the lakes within a region and between the regions. Numerous methods have been developed to measure the trophic state of lakes. Twenty-nine different methods commonly used were compared with respect to their ability to measure TSI of lakes [9]. Out of these methods Carlson's Trophic Status Index is the most important and popular TSI method selected for the present study. On the Carlson's scale if TSI is < 30 represents oligotrophy, from 30 to 50 represents mesotrophy, from 50 to 70 eutrophy and > 80 hyper eutrophy.

The following equations are used to compute the Carlson's TSI.

TSI - P = 14.42 * Ln [TP] + 4.15 (in mg/L) (i)

TSI - C = 30.6 + 9.81 Ln [Chlor-a] (in ug/L) (ii)

TSI - S = 60 - 14.41 * Ln [SD] (in meters) (iii)

Average TSI = [TSI (P) + TSI (Chlor-a) + TSI (SD)]/3 (iv)

Where, TP is Total Phosphorus, chlor-a is Chlorophyll-a, SD the Secchi Depth.

Inverse distance weighted (IDW)

The IDW Interpolation method is a local method that assumes that the unknown value of a point is influenced more by nearby points than those farther away. The degree of influence, or the weight, is expressed by the inverse of the distance between points raised to a power. A power of 1.0 means a constant rate of change in value between points, and the method is called linear interpolation. A power of 2.0 or higher suggests that the rate of change in values is higher near a known point and levels off away from it.

The general equation for the inverse distance weighted method is

$$Z_0 = \frac{\sum^{n}_{i=1} ZiI/di^{k}}{\sum^{n}_{i=1} I/di^{k}}$$

Where Z_0= Estimated value at point o, Zi = Z value at control point I, di = Distance between control point i and point o, s = Number of control points used in estimation, k = Specified power

Work flow of GIS

The approach essentially involves the database preparation. The city map is geo-referenced using ground control points collected from GPS and then Projected to WGS_1984_UTM_Zone_43N Coordinate System. Digitization of study area map is carried out in order to create the digital database, Plotting the sample locations, thematic map generation and spatial analysis of physical and chemical parameters. Methodology adopted in the present study is shown in the form of flow chart in figure 3. The data processing and analysis has been carried out in Arc Map 9.3 environment.

Results and Discussions

During the study period (February-April), the parameters were analyzed for Secchi disk transparency, total nitrogen, total phosphorous and chlorophyll-a and the analysis of lake water samples for the month of February, March and April is shown in the table 2, 3 and 4 respectively. The thematic maps generated by the IDW interpolation method and Carlson's Trophic Scale are presented spatially in the figures (figure 4 to 15).

Figure 4, 5 and 6 shows the spatial distribution of TSI (CHLA). Transparency is commonly measured using a secchi disk. Transparency determines the photic conditions of the lake. Summer season was observed to show the minimum value of transparency. The higher value of transparency very clearly speaks the high level of turbidity of lake water especially during study period. In station 1 the transparency of water is very negligible due to the entry of raw sewage at that inlet point. Reduced transparency during summer is due to increase of suspended particles on account of organic debris's decomposition with higher water temperature and reduced flow.

Nitrate is the important pollution indicator parameter and it is considered as an important plant nutrient. Blue green colouration of lake water, foul odour and massive production of mosquitoes are certain correlated phenomena which were frequently observed in study period and highlight the much more deteriorated water quality and high degree of eutrophication. Results showing nitrate values ranging from 0.3 to 3.9 mg/L. There were considerable differences between the inlet and the outlet nitrate concentrations which are shown in figure 7, 8 and 9. The overall nitrate levels were above 0.8 mg/L (mostly due to uptake by macrophytes or by algae/bacteria). However, higher values of NO_3-N were reported due to agriculture runoff. Lower concentration of nitrates during monsoon is due to dilution apart from algal and bacterial uptake.

In aquatic ecosystem inorganic phosphate as soluble orthophosphate play a dynamic role. In eutrophic lakes high phosphate content supports an increased level of primary production till nitrogen become limiting. The increasing trend of eutrophication as observed in present investigation may adversely affect the recreational value of the lake as well as the aquaculture practices which are operated regularly. Phosphorous along with nitrogen causes explosive growth of algal species that leads to eutrophication. The permissible limit of phosphate is 0.050 mg/L. The phosphate content of the water was in the range of 6.05 to 15.2 mg/L. The highest value of 15.2 mg/L was recorded in April at inlet, while the minimum value 0.4 was recorded at station 4 in March as shown in figure 10, 11 and 12.

Chlorophyll-a is a green pigment, which is used to estimate the amount of phytoplankton or algae in an aquatic system. Although there are no regulatory standards for chlorophyll-a, it is a useful parameter for determining the biological productivity of a water body. Several techniques are available to measure chlorophyll, including spectrophotometry, high performance liquid chromatography (HPLC), and fluorometry. As shown in the figure 13, 14 and 15, in Dantaramakki Lake the range of chlorophyll was between 2.12 to 11.01 mg/L. At the inlet point, the chlorophyll-a was found to be very high in all the study period.

Table 2: Analysis of Water Samples of lake in the month of February

Sampling points	February			
	Secchi Disc Transparency (m)	**Total Nitrogen (mg / L)**	**Total Phosphorus (mg / L)**	**Chlorophyll a (µg /L)**
Station 1(INLET)	0.21	2.4	7.0	6.68
Station 2	0.65	0.48	5.4	4.58
Station 3	0.59	0.67	3.2	2.12
Station 4(OUTLET)	0.75	0.3	1.3	2.58

Table 3: Analysis of Water Samples of lake in the month of March

Sampling points	March			
	Secchi Disc Transparency (m)	**Total Nitrogen (mg / L)**	**Total Phosphorus (mg / L)**	**Chlorophyll a (µg /L)**
Station 1(INLET)	0.27	3.9	11	9.50
Station 2	0.72	0.5	8.4	5.81
Station 3	0.69	0.8	1.0	3.34
Station 4(OUTLET)	0.80	0.4	0.4	3.66

Table 4: Analysis of Water Samples of lake in the month of April

Sampling points	April			
	Secchi Disc Transparency (m)	**Total Nitrogen (mg / L)**	**Total Phosphorus (mg / L)**	**Chlorophyll a (µg /L)**
Station 1(INLET)	0.2	under range	15.2	11.01
Station 2	0.71	3.30	11.3	7.11
Station 3	0.76	2.04	5.64	4.89
Station 4(OUTLET)	0.82	2.1	4.45	4.81

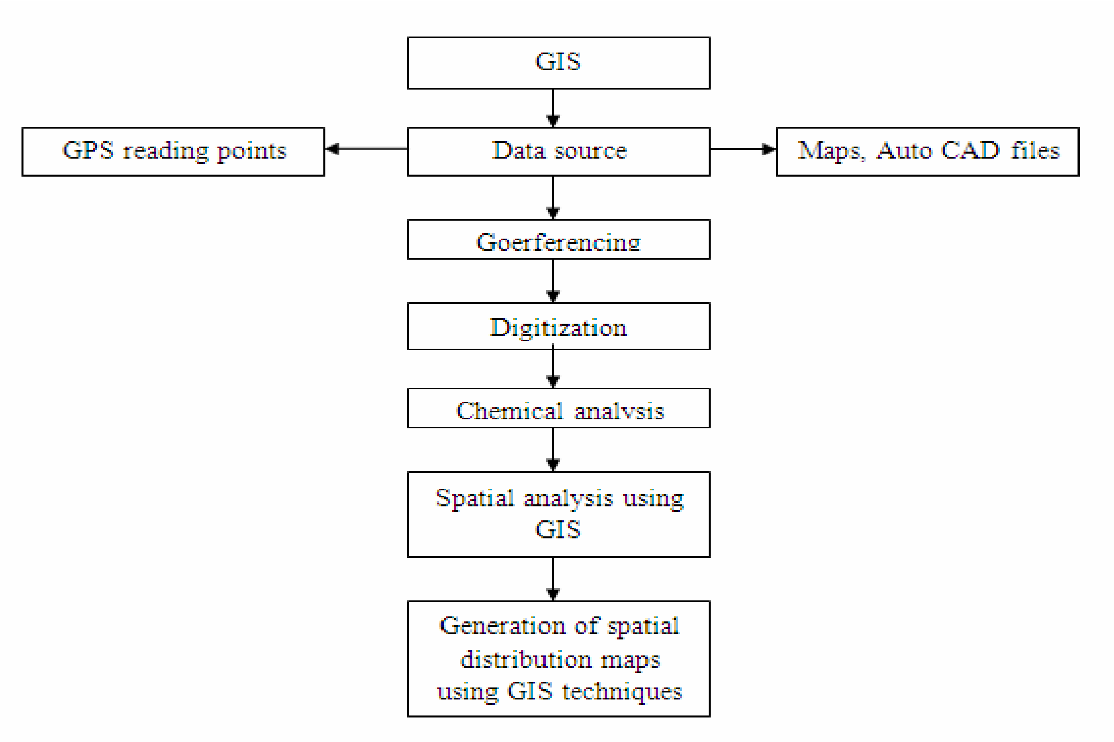

Figure 3: Flow chart representing the Methodology Adopted in GIS operations.

Conclusions

Based on the experimental results obtained, the following conclusions have been drawn.

1. From the results obtained, it can be concluded that the lake is polluted due to continuous discharge of municipal wastewater and from the agricultural runoff.
2. Based on the Carlson's TSI calculation the Dantaramakki Lake has been classified as moderately eutrophic**.**
3. Based on the analysis of DO level at different points within the lake (0 mg/L). Hence, it will be difficult for aquatic life to survive.
4. Due to the excess algal growth, aesthetic appearance of the Dantaramakki Lake is hampered.
5. Due to the growth of the weeds the water holding capacity of the lake is decreased.
6. The periodical survey of the lake is to be done to find out the water quality and abatement programs to check further deterioration of water quality.
7. The spatial distribution of dantaramakki lake eutrophication levels is closely correlated with the actual conditions of the lake.
8. Results revealed that the lake associated with different trophic levels could be clearly defined in a final eutrophication map.
9. The GIS manages the spatial and attribute data, in addition to manipulate and display the results of TSI calculations.

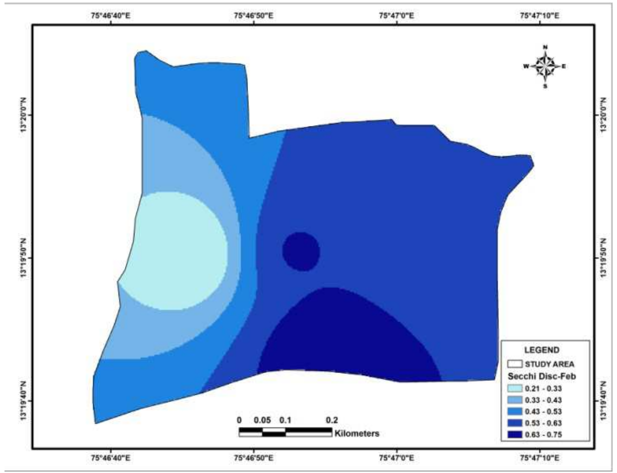

Fig 4: Spatial variation of Secchi Disk in February

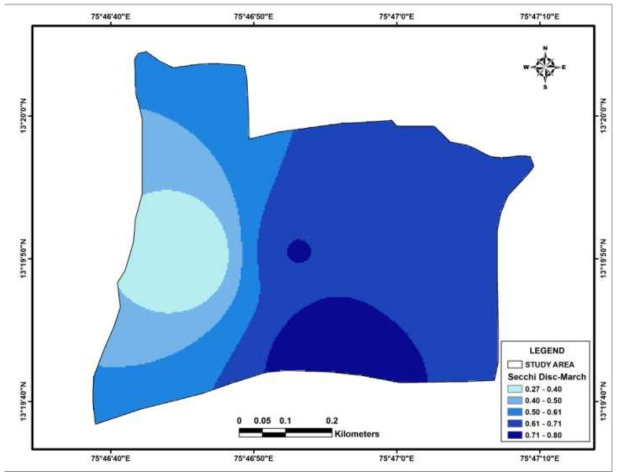

Figure 5: Spatial variation of Secchi Disk in March

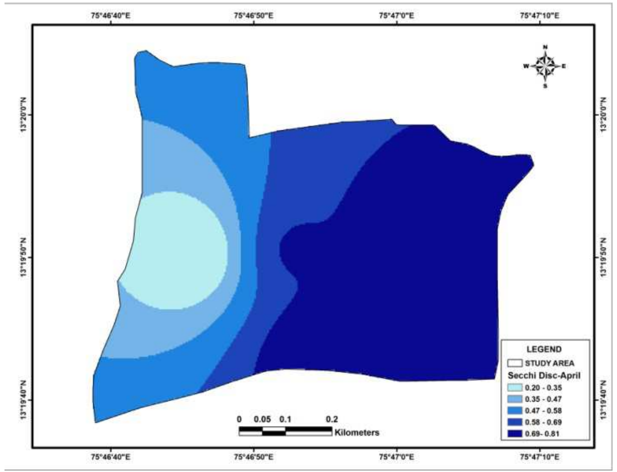

Figure 6: Spatial variation of Secchi Disk in April

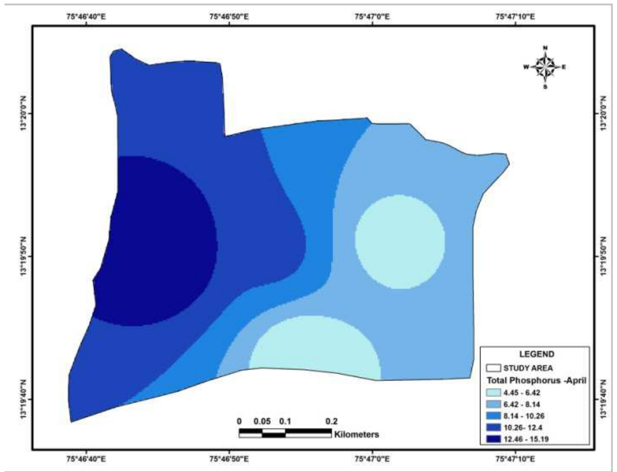

Figure 7: Spatial variation of Total Nitrogen in February

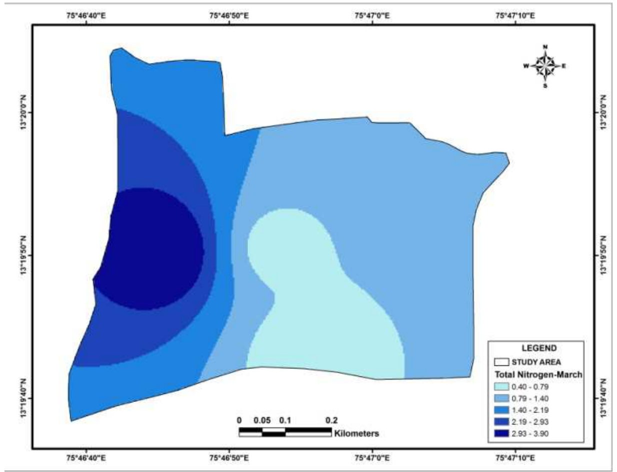

Figure 8: Spatial variation of Total Nitrogen in March

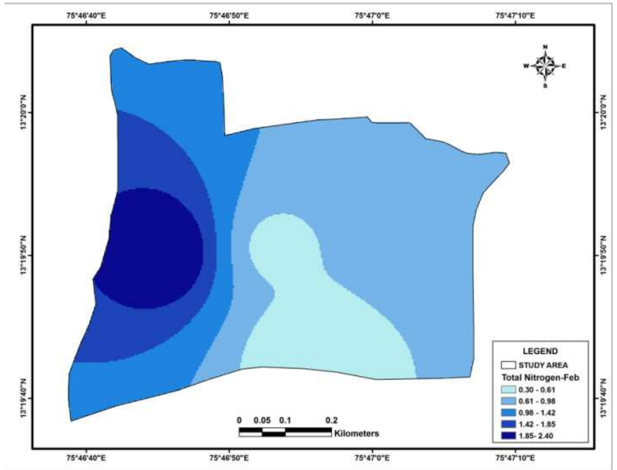

Figure 9: Spatial variation of Total Nitrogen in April

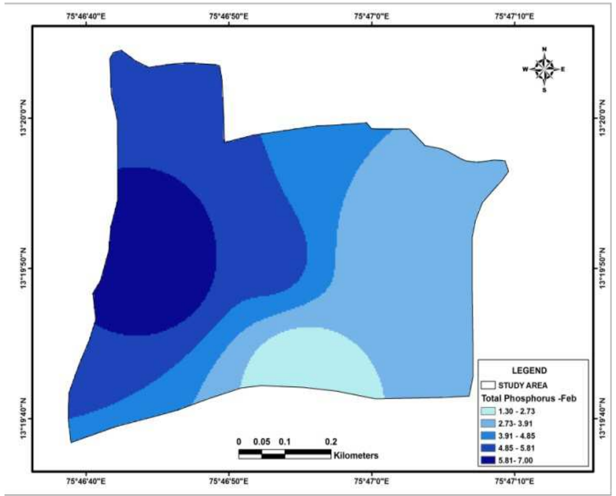

Fig 10: Spatial variation of Total Phosphorous in February

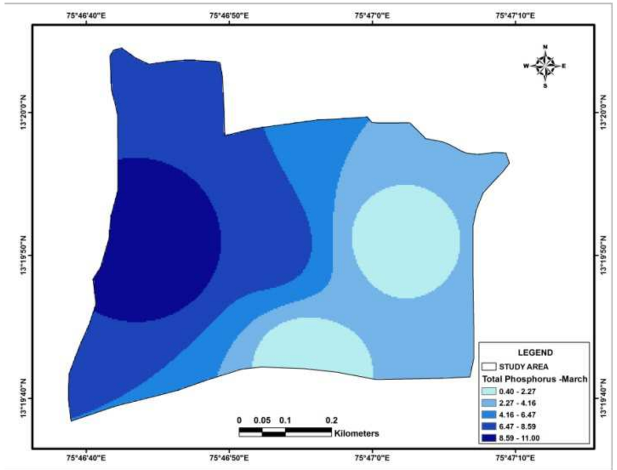

Figure 11: Spatial variation of Total Phosphorous in March

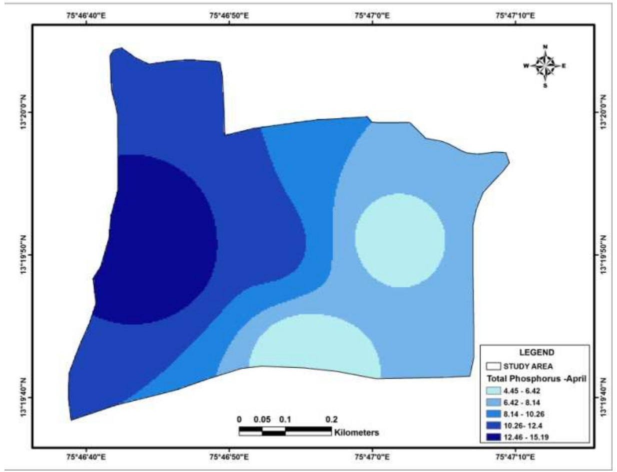

Figure 12: Spatial variation of Total Phosphorous in April

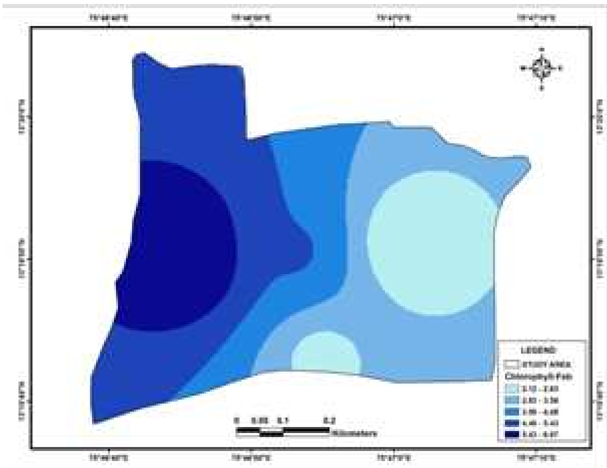

Figure 13: Spatial variation of Chlorophyll in February

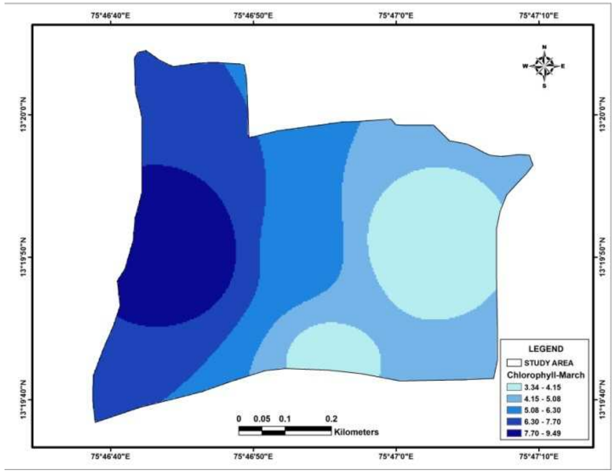

Figure 14: Spatial variation of Chlorophyll in March

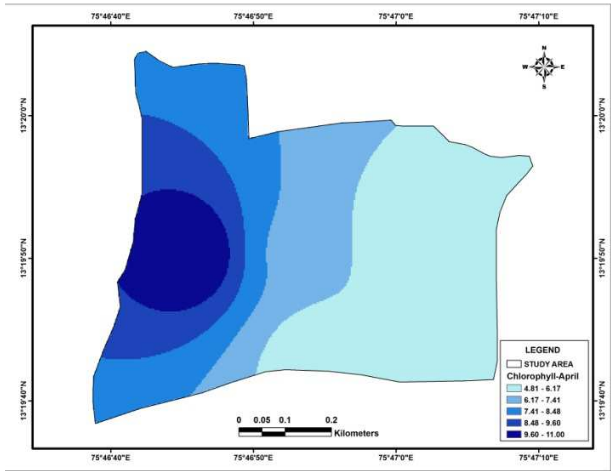

Figure 15: Spatial variation of Chlorophyll in April

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