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Impact of Land Use Land Cover on Phosphate Concentration in Upper Lake Bhopal Using Remote Sensing and GIS Techniques

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Abstract- Non point source pollution needs special attention to control the surface water quality. Knowledge of critical buffer zone is of great importance for watershed management. For this study annual average of phosphate concentration, landsat image and ASTER DEM was used. Image was classified in four land cover classes using ERDAS Imagine software. buffer zones at radial distances of 100m, 200m, 500m, 1000m and 2000m from the discharge point of stream into the lake, were generated by Arc GIS software. Area of different classes was measured using FRAGSTAT software. Six spatial interpolation techniques were compared and best fitted technique (SK) was used to predict the phosphate concentration at all discharge points. Statistical analysis software SPSS was used to correlate area of land use and phosphate concentration. Area of agriculture and barren land in 500m buffer zone was found most effectively correlated with phosphate concentration.

Index Terms- Spatial interpolation, buffer zone, phosphate, Simple Kriging.

I. Introduction

Surface water can be polluted by anthropogenic activities in two ways: 1. by point sources, such as storm water runoff, sewage treatment discharge and industrial waste discharge; and 2. by non-point sources such as runoff from agricultural and urban areas. Natural catchment characteristics such as surface geology and topography can affect surface water quality. Despite the importance of natural characteristics, their influences are not usually included in the study of watershed management because they complicate the analysis considerably.

Studies of watershed management and catchment at different buffer scale have become more important in determining the impact of anthropogenic activities on water quality within the watershed. Study on the basins of Fish river, Alabama, USA developed a model to relate land use, land cover and water pollution in the stream. It was concluded that the size of critical buffer zone depends on the level of non point source pollution, geometrical characteristics of an area and standard level of water quality parameters (*Basnyat P. et.al., 1999).* Land use land cover in catchment area of river in Yamguchi Prefecture, western Japan and water quality parameter were used to present a mathematical model. This model can be used to predict the effect of proposed land use planning on water quality of the river *(AMIRI Bahman Gaborone et al. 2008).* The area adjacent to stream shows great influence on the nitrate level *(Basnyat P. et.al. 2000).* Although these studies were more common in the past few decades, they still leave a number of questions unanswered. For example, there is still a dispute regarding the effective buffer zone, which is more important in influencing the quality of water *(Delong and Brusven, 1991)* These uncertainties are still unrevealed because thorough investigations of catchment are extremely resource and time consuming. Analytical tools, such as multivariate statistics, geographical information systems (GIS) and patch analysis, are effectively able to deal with the problem. *(Alberti Marina et al.,2007, Guo QingHai et al., 2010).* However the accuracy of results depends upon the quantity and quality of data collected which may be sparse. One method of study of correlation between land use land cover of a watershed and its water quality is to use secondary data generated by government agencies at regular interval.

This study used such secondary data to determine the impact of land use land cover on the phosphate concentration in water of upper lake Bhopal. Phosphate concentration of upper lake was provided by the Environmental Planning and Co-ordination Organization (EPCO), Bhopal, India. This database was generated by EPCO having a basic monitoring objective, without any extensive study purpose hence it is limited spatially. Therefore, spatial interpolation techniques are required for the prediction of spatially continuous data of water quality parameters for the unsampled locations using data from the sampling point. A number of spatial interpolation methods are available. But these are data specific and their results depend on many factors *(Li and Heap, 2011).* It is very difficult to select an appropriate method for a given data set and study area *(Li and Heap, 2011).* In various research papers, comparison between stochastic and deterministic approaches of spatial interpolation has been published to estimate missing data. Six methods of spatial interpolation were used by (*Eischeid J. et al.,2000)* to create a serially complete daily precipitation and temperature data set for the united states.

The objectives of this study were: (1) to determine the effect of land use, land cover on the phosphate concentration of upper lake Bhopal; and (2) to determine the critical buffer zone influencing the phosphate concentration most effectively.

Method

Study Area

The study area Upper Lake is located in the western part of Bhopal, the capital of Madhya Pradesh, India. Upper lake is the major source of potable water for the city located at 23°12' - 23°16' N, 77°18' - 77°23' E. It is surrounded by urban area in east, urban and agricultural land in the north, urban; rural; agriculture in the South and agriculture land in the west.

Image classification and Patch Analysis

Land cover data for 2011 were interpreted from Landsat Thematic Mapper ™ imagery for the Bhopal region. The Landsat TM image was reprojected to the UTM projection system. The classification procedure

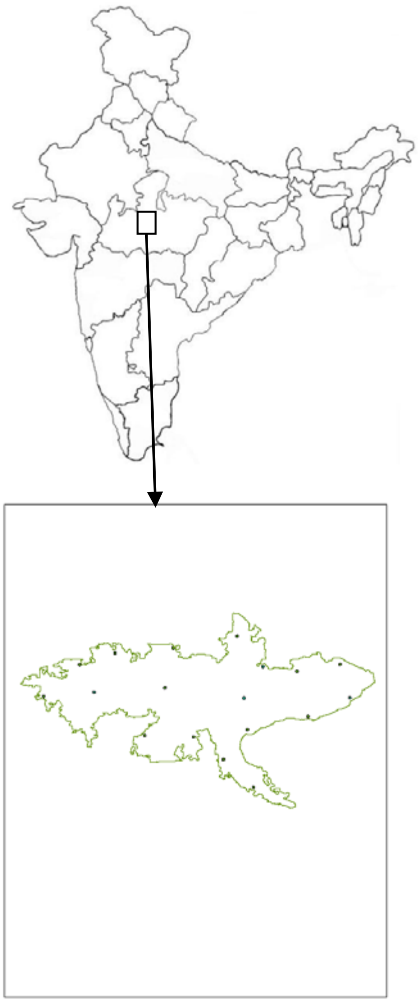

Fig. 1. Location of study area and sampling stations providing observed data.**creates four class land cover system: Agriculture, Vegetation, Built up land and Barren land.**

Lake boundary and sub watershed boundary was generated using ASTER DEM for the month of Oct. 2011. A contour was identified as the lake boundary in contour map generated by DEM. In this study it is assumed that a stream is formed when minimum 100 cells drains to a point. Using flow accumulation grid stream network raster for threshold value of 100 pixels was created. Stream raster then converted to stream vector and point of intersection of stream and lake boundary identified as point of discharge of water in lake through each stream. Using basin hydrology tool in the Arc GIS boundary of a sub watershed was created. Vector map of buffer zone for each sub watershed was created for radial distance of 100m, 200m, 500m, 1000m, and 2000m. Landsat image was subsetted and classified using ERDAS Imagine to obtain land cover map for different buffer zones of each sub watershed.

Land cover map of each buffer zone was analyzed through FRAGSTAT to extract index of patches of all four classes. For this study class area (CA) was used to understand the correlation between land cover and phosphate concentration in upper lake Bhopal. Class area is the summation of area of all patches of the same class. (McGarigal K. et al., 1995).

Water Quality

Water quality data for 18 sampling stations: Kolans, Bhori, Betha, Bairagarh, Bairagarh east, Khanugaon, Karbala, Medical college, Kamla park, yacht club, Van Vihar, Spill channel, Bhadbhada, Stud farm, Bisenkhedi and three deeper zones were obtained from the website of Environmental Planning & Coordination Organization (*EPCO*) Bhopal. Twelve month Phosphate concentration for the month of June 2010 to July 2011 was averaged to obtain annual average data of phosphate at all sampling points. As the positions of sampling stations are selected by government agencies, we were missing data for this study. To overcome this deficiency of data, we used spatial interpolation technique to predict phosphate concentration at unmeasured locations.

Accuracy and comparison of spatial interpolation techniques have been investigated in a number of studies. The more reliable interpolation technique gives a better assessment of the spatial distribution of the data *(Robinson, T.P.et al., 2006; Shi. W. et al., 2009).* We compared six methods: Inverse Distance Weighting, Radial Basis Function, Local Polynomial Interpolation, Ordinary Kriging, Disjunctive Kriging, and Simple Kriging, for this study. Most suitable method with minimum root mean square error was used to predict phosphate concentrations at required location. Inverse Distance Weighted technique assumes that the value at any point is a distance-weighted average of the values at sampling stations within a well defined neighborhood surrounding the estimated point. This is an exact local deterministic interpolation method. IDW considers that the predicted value of parameter will be more affected by the points closer to the prediction location than points located farther away. Inverse distance weighting method is one of the most commonly compared method *(Li and Heap, 2011).* Radial Basis Functions include different basis functions. RBFs permit the prediction of points above and below the maximum and minimum measured value. Polynomial Interpolation method fits a mathematical function of the measured point. These mathematical functions range from first to higher order polynomials. Polynomial interpolation is of two types – global and local. Global polynomial fits a model based on all measured points to the entire surface while Local polynomial interpolation fits a number of polynomials using subsets of the measured points(ESRI, 2008). Kriging method assumes that the spatial variation of data is neither stochastic nor deterministic. Kriging methods are of two types: linear and nonlinear *(Moyeed R.A., Papritz A., 2002).* Simple kriging assumes statistical variation, a known constant mean and no underlying trend. While ordinary kriging assumes an unknown constant mean. Mean must be estimated using data. Disjunctive kriging is a general nonlinear method.

The results obtained using different interpolation techniques were compared and analyzed. The root mean square errors of predicted values were used to evaluate the performance of different methods using following formula:

$$\text{RMSE} = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\left(Z(Xi) - \check{Z}(Xi)\right)^2}$$

Where $Z(Xi)$ and $\check{Z}(Xi)$ is the measured value and predicted value respectively and N is the number of samples. Smaller RMSE and ME values indicate less error (Xie et al, 2011).

Statistical Analysis

We used SPSS 17 to do correlation analysis. As the phosphate concentration data was normally distributed, Pearson correlation coefficient was used. Significance of the effects of the class area of Agriculture, Vegetation, Built up land and Barren land on phosphate concentration were tested using two-tailed hypothesis tests.

II. Results and Discussion

Spatial interpolation

The Local Polynomial Interpolation method is the least effective with the 0.231 mg/l error. The contrary, the method of the Simple Kriging is the most suitable method with Root Mean Square error 0.117 mg/l. Model parameters are the most important factor to obtain accurate simulation. In general IDW, LPI and RBF need a less parameter. In contrast OK, SK and DK have more complex calculation with more input parameters. More complex calculations and input parameters might be the reason of accurate prediction for SK. On the basis of best estimation method phosphate concentration was found at unmeasured location.

Correlation analysis

The relationship between percentage of land use and phosphate concentration at different scales are presented in table 1. Proportion of agriculture land had negative significant correlation with phosphate concentration within 100m ($p = 0.03$), 200m ($p = 0.039$) & 500m ($p = 0.039$) while the barren land had

positive relation within 100m ($p = 0.007$), 200m ($p = 0.002$) & 500m ($p = 0.003$). Proportion of vegetation was negatively correlated to the phosphate concentration within 1000m ($p = 0.050$) buffer only.Our results indicate that proportion of agriculture land had negative correlation with phosphate concentration while the barren land had positive impact on phosphate concentration within 100m, 200m and 500m buffer zones. This may be due to presence of phosphate in soil up to 500m distance. Plants of agriculture land utilize phosphate of soil, and hence reduce phosphate concentration in the water reaching lake. Barren land in the study area is the agriculture land without crop during study period. Agricultural waste and soil of barren land may be the source of phosphorus. Vegetation, the natural absorbent of phosphate contributes negatively to upper lake.

III. Conclusion

Through this study relationship between area of land use and phosphate concentration in buffers at different spatial scales was explored. We concluded that the effect of area of land use on phosphate concentration. The impact of land use on phosphate concentration is stronger in the effective buffer. Using buffer analysis effective buffer distance can be determined. This indicates that effective buffer zones could be helpful for management and planning of watershed.

Table1: Root Mean Square Error and Mean Error for six spatial interpolation methods

	DK	**SK**	**OK**	**LPI**	**RBF**	**IDW**
RMSE	0.210	0.117	0.179	0.231	0.172	0.198

Table 2: Pearson correlation coefficient and p value within 100m, 200m, 500m, 1000m and 2000m buffer zones.(Blank space indicates that relation was not significant)

		100m	**200m**	**500m**	**1000m**	**2000m**
PHOSPHATE	AGRICULTURE	-.390*	-.373*	-.393*		
		(0.03)	*(0.039)*	*(0.039)*		
	VEGETATION				-.414*	
					(0.050)	
	BUILTUP LAND					
	BARREN LAND	.475**	.537**	.537**		
		(0.007)	*(0.002)*	*(0.003)*		

* *Correlation is significant at the 0.05 level (2-tailed).*

** *Correlation is significant at the 0.01 level (2-tailed).*

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