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Water Quality Mapping and Analysis in a Stretch of Ganga River

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ABSTRACT

A major barrier to water quality modeling is the lack of an efficient system for water quality monitoring. Traditional water quality sampling is time-consuming, expensive, and can only be taken for small size samples. Also, instant and accurate water quality data cannot always be provided to satisfy the demands of water quality modeling and parameter calibration. So, we need a modern approach which is based on Remote sensing and Geographical information System (GIS) for water quality trends. In this Study a decision making tool have been generated for water quality mapping of Ganga River in part of Kanpur district of Uttar Pradesh, India.

Water sample have been collected from nine stations and analyzed in the laboratory which provides results of various water quality parameters. Digital numbers (DN values) for four bands Blue, Green, Red and NIR of LANDSAT 8 images have been calculated. Observed DN values on those nine sampling stations of each band along with principal component analysis and band ratios are compared with measured water quality parameters. The water quality parameters includes pH, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Dissolve oxygen (DO), Total Solids (TS), Total Dissolve Solids (TDS), Total Solids (TS), Ammonical Nitrogen, Fluoride, Chloride, Magnesium, Turbidity, Conductivity and Phosphorus. Using DN values of LANSAT 8 images and in situ measured data of water quality parameters correlation and multiple linear regression models have been generated which is based on most appropriate band combinations having highest multiple correlation coefficient, R^2 value. Using these multiple regression models, water quality parameters can be predicted for entire study area. Then, applying simple linear discriminate function to each pixel in study area, grouping of these dependent water quality variables into discrete classes achieved the classification to produce water quality maps.

KEYWORDS: Water Quality parameters; Water Quality Mapping; DN Values; Principal component analysis, Band Rationing, Multiple linear regression model, multiple correlation coefficient.

1. Introduction

The present study has been attempted to analyze the variation in major water quality parameters such as pH, DO, COD, Electrical Conductivity (EC), Total Dissolved Solids (TDS), fluoride, Turbidity, Total Suspended Solids (TSS), Ammonical Nitrogen, Chloride, Magnesium, Phosphate and BOD using geo-spatial technology. GIS and Remote sensing can be used as a powerful tool to develop solutions for water related problems for assessing water quality andanalyzing water quality parameters on a local or regional scale.

Ganga River is the primary source of fresh water for the nearby cities. With the time and due to increased human intervention, the water of sacred Gangahas become impure. Now polluted water has replacedthe purewater of River Ganga. It receives vast quantities of untreated sewage, a lot of pesticides, fertilizers, street washouts bringing oil, sediments, asphalt and industrial wastes which can significantly alter the physio-chemical characteristics of the Ganga water.

Thus, water of River Ganga is clogged with pollutants. According to a study, people are afraid of being affected by skin disease after taking a dip in the Ganga. Thus, it is very important that the River Ganga be reconstructed to its past glory. To improve water quality of River Ganga, regular assessment and monitoring of water quality is needed. A witting effort to reverse the current trends of worsening of water quality of River Ganga is the need of the hour.

Remote sensing and GIS are two areas of computer-aided technologies that have potential to expand the usefulness of physical-based water quality models. The application of remote sensing in hydrology is reported in numerous publications and papers such as the Manual of Remote Sensing (Colwell, 1983) and REFLEX (Department of Energy, 1988; Hooghart, 1990). Published research demonstrates the interfacing of remotely sensed data with hydrologic model output (Beasley, 1980; Mace, 1983; Schaal, 1986; Rango and OWeill, 1982; Schultz, 1988;

A numberof studies have shown that satellite imagery, such as Landsat and SPOT, has acapability of meeting the demand for a large sample area to provide a spatial andtemporal view of water quality (Scarpace et al., 1979; Lillesand et al., 1983;Verdin, 1985; Lathrop and Lillesand, 1989; Ritchie et al., 1991; Harding et al.,1995; Ruiz-Azuara, 1995).Landsat imagery has been used to characterize certain water qualitycharacteristics of lakes for 40 years. Some of the earliest uses of Landsat imagery werefor simple qualitative observations. These included locating and mapping pollution andpollution plumes (e.g., Lind, 1973; Pluhowski, 1973). Shortly thereafter, Landsat imagerywas correlated to field based measurements (e.g., Yarger, 1973; McCauley, 1974; Brooks, 1975) and finally used for quantitative assessment of water quality (e.g.,turbidity, chlorophyll and water clarity, frequently expressed in terms of Secchi depth)(e.g., Brown et al., 1977a; Lillesand et al., 1983; Ritchie et al., 1990; Lathrop et al., 1991,1992; Dekker and Peters, 1993), but until recent times these reports usually describedinvestigative efforts involving only one or a few lakes and/or short observation periods.

One early exception was the work of Martin et al. (1983), who used semi-automatedprocedures to assess the trophic status of around 3,000 lakes in Wisconsin using LandsatMultispectral Scanner (MSS) imagery. Dekker et al. (2002) described procedures usinganalytical optical modeling that could be used for retrospective analysis of Landsat andSPOT imagery for regional water quality assessment where there is no concurrent fielddata. Kloiber et al. (2002a) and Olmanson et al. (2001) described an efficient andpractical procedure using empirical methods based on Landsat imagery for routine,regional-scale assessments of lakes for water clarity, and Kloiber et al. (2002b) used thisapproach to assess spatial patterns and temporal trends in approximately 500 lakes in theseven-county Twin Cities Metropolitan Area (TCMA) of Minneapolis-St. Paul,Minnesota. Olmanson et al. (2002) expanded this work to a statewide level, reporting thefirst census of water clarity for Minnesota lakes.

The present study shows the ability of Geo-spatial techniques to monitor water quality in Ganga River. Pollution because of increase in population, other anthropological activities and industrialization are effecting the water quality parameters of river water. In this study, water quality trends and quantification of various water quality parameters in Ganga River has been monitored using Geo-spatial techniques. This study proposed to find out the appropriate regression models to establish and analyzed the remote sensing methods to retrieve water quality parameters, and to show the possibility of performing routine water quality monitoring.

2. Study Area

The study area covers Ganga River in part of Kanpur district, Uttar Pradesh. River water channel length is about 14.66 km and it is located between 26º 30' 22.7436" N to 26º 25' 57.9329" N Latitude and 80º 19' 06.1170" E to 80º 24' 37.2733" E Longitude.

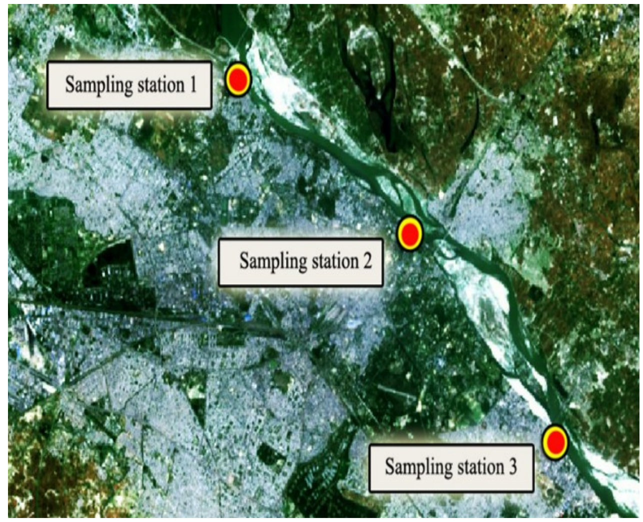

Figure 1: Sampling stations along with Kanpur city

2.1 Details about sampling stations

Details are shown in Table 2.1.

2.2 Details about Satellite Data

Landsat 8 OLI/TIRS multispectral images have been downloaded from the site http://earthexplorer.usgs.gov. Satellite image acquired on 18th March 2015 (Path- 144, Row- 42) and have OLI_TIRS sensor with 30 meter resolution.

3. Methodology

Water quality mapping has been done in two stages; one is assessment of water quality in the laboratory and second is preparation of water quality maps for selected sites with the help of Erdas Imagine software. There are following steps;

Table 2.1: Description of the Sampling Locations

City	Samlping Site	Sampling Site No.	Sampling Date	Location	
				Latitude	Longitude
Kanpur	Ganga Barrage	1	18-03-15	26º 30’ 22.7436’’ N	80º 19’ 06.1170’’ E
	ParmatGhat	2	18-03-15	26º 28’ 58.7002’’ N	80º 21’ 08.0023’’ E
	Jajmau Ganga Bridge	3	18-03-15	26º 25’ 57.9329’’ N	80º 24’ 37.2733’’ E

3.1 Selection of sampling stations

The three sampling stations have been selected in such a way that it provides approximate information about water quality parameters for whole study area. All the three sampling stations are located uniformly across the River channel in respective city. Two stations are located upstream and downstream of the river while third one is located approximately at mid-point.

3.2 Water sample collection with GPS coordinates

Water samples are collected from 3 sampling stations of Kanpur. Water samples are collected and handled carefully before reaching to the laboratory. The coordinates of these stationsare recordedusing a GPS device.

3.3 Analysis of water quality parameters in the laboratory

Analysis of water quality parameters have been done in the Environmental laboratory. There are parameters and various methods/Instruments used to obtain results.

3.4 Acquisition of multispectral Landsat 8 images

Landsat 8 OLI/TIRS multispectral images have been downloaded from the site http://earthexplorer.usgs.gov. This is taken into account that the acquisition date of Image data sets are same or very close to the date of samples collection.

3.5 Preprocessing of multispectral images

After image acquisition, the river channel of Ganga River having water spread area have been extracted from the multispectral images so that only water channel would be analyzed for further processes.

3.6 Principal Component Analysis and Band Rationing

Band rationing and principle component analysis have been done for image enhancement to obtain different values of digital number or DN values. Blue, red, green and NIR bands are very useful bands for water quality study. Band rationing are done using the modular of Erdas Imagine 13 software.

Band rationing is effective in enhancing latent information when there is a

direct or indirect relationship between two spectral responses to the same bio-physical or bio-chemical phenomenon. Principle component analysis is a statistical procedure concerned with linear transformation which have capability to rotate image axis in an image space along with maximum variance. After principle component analysis, new set of transformed images have been generated.The rotation is based on the orthogonal eigenvectors of the covariance matrix generated from a sample of image data from the input channels.The PCA1 axis is most widely stretched and its values are highest and retain nearly two thirds of the information contained in the sum of these four bands, axes 2, axes3 and axes4 of PCA 2, PCA3 and PCA4 are followed successively.

3.7 Development of Multiple Linear Regression model

Development of multiple linear regression equation is a statistical procedure which is done using XLSTAT 2015 software. Multiple linear regression is developed to find out correlation between Landsat 8 DN values (Independent variable) and River Ganga water quality parameters (Dependent variable). The multiple correlation coefficient (R^2) have been calculated for various combination of independent variables with dependent variables. The maximum value of multiple correlation coefficient (R^2) have been taken into account in the multiple linear regression equation. 95 percent confidence level have been considered with other statistical parameters i.e. Adjusted R^2, Multiple R, P, F and standard errors etc. The independent variables have been selected with respect to dependent variables to give maximum multiple correlation coefficient (R^2). Only those combination of independent variables with dependent variables have been taken into account which have highest value of R^2 for linear regression equation to estimate water quality parameters.

3.8 Mapping

Using the linear regression models, mapping has been done for all water quality parameters which is extended to the entire study area. The extension to these models the study area was achieved by using a simple linear discriminate function. Applying this function to each pixel in the study area and then grouping these continuous water quality variables into discrete classes achieved the classification. A unique function for each water quality parameters was applied to the Landsat 8 data, producing fourteen water quality parameter maps for each selected city.

4. Results

4.1 Analysis of the water samples in laboratory

After sampling, samples are taken to laboratory where assessment of water quality parameters have been done to find out actual value of pH, BOD, COD, TSS, TDS etc. Results of water quality parameters are shown in table 4.1.

Table 4.1 Results of water quality parameters of all sampling stations

Water Quality parameters	Sampling Stations		
	1	**2**	**3**
pH	7.75	7.46	7.28
DO (mg/L)	8.76	5.16	3.91
COD (mg/L)	11.68	7.57	23.58
BOD (mg/L)	3.73	1.85	5.93
TS (mg/L)	203.6	292.8	303.7
TDS (mg/L)	189.6	203.4	276.6
TSS (mg/L)	14	89.4	27.1
Turbidity (NTU)	210	230	520
Conductivity (µS/cm)	316	339	461
Fluoride (mg/L)	0.623	0.836	1.023
Chlorides (mg/L)	32.2	34.65	43.33
Magnesium (mg/L)	77.75	93.5	110.5
Ammonical Nitrogen (mg/L)	0.82	1.73	3.5
Phosphate (mg/L)	0.3	0.23	0.66

4.2 Principal Component Analysis and Band Rationing

Principal component analysis have been done Erdas Imagine software. The PCA results are based on orthogonal eigenvectors of the covariance matrix generated from a sample of image data from input channels. B3/B2, B3/B4, B4/B2 and B5/B2 are the band ratios which are used in present study. These band combination provides better images with enhanced details.

4.3Water Quality Regression Models

Water quality regression model have been developed using most appropriate band combinations/ratios and PCA values which provides highest multiple correlation coefficient (R^2). Multiple regression models have been generated using XLSTAT 2015 software. Tables 4.2, and 4.3 are showing details related to R^2, coefficients (a, b, c and d) and variables (X1, X2 and X3).

4.4 Water Quality Mapping Results

The results of quality parameters of each sample points are presented in table 4.1. DN values of each band at every respective sampling stations have been calculated. Band rationing and PCA analysis have been done. Multiple linear regression models are used to explore the relationship between water quality parameters (dependent variables) and DN values (independent variables). Only those combination have been selected which have higher value of correlation coefficient (R^2). The relationship established between the water quality parameters and DN values are extended to the entire study area (Ganga River), producing a series of class maps which were grouped and color-coded to represent the distribution of water quality parameters. Maps are shown in figure 2.

Sampling Stations	B2	B3	B4	B5	PC1	PC2	PC3	PC4	B3/B2	B3/B4	B4/B2	B5/B2
1	4	5	4	2	-1.320	-0.045	-0.520	0.491	1.25	1.25	1.00	0.50
2	4	7	6	3	0.649	1.459	-0.505	0.971	1.75	1.17	1.50	0.75
3	5	4	7	3	1.355	-0.838	-1.121	0.043	0.80	0.57	1.40	0.60

Table 4.2. Principal Component Analysis and Band Rationing results

Table 4.3. Regression Equation, R^2 and coefficient values of water quality Parameters for Kanpur

Water Quality Parameters	R^2 Value	Regression Equation: Y= a+ bX1 +cX2 +dX3						
		X1	X2	X3	Coefficient			
					a	b	c	d
pH	0.626	PC2	B2	B4/B2	18.77	-4.22	53.88	19.55
DO (mg/L)	0.489	PC3	B4/B2	B5/B2	5.28	5.11	9.26	3.99
COD (mg/L)	0.939	B2	PC1	B3/B4	3.37	7.67	4.17	2.4
BOD (mg/L)	0.788	PC4	B3/B2	B2	3.37	8.12	4.6	2.61
TS (mg/L)	0.340	PC3	B5/B2	B4/B2	2.7	4.66	-1.54	-0.12
TDS (mg/L)	0.978	B2	PC4	B4/B2	1.6	10.08	-0.48	0.95
TSS (mg/L)	0.773	PC1	B3/B4	B5/B2	4.55	3.88	5.07	2.27
Turbidity (NTU)	0.997	PC4	B2	B4/B2	3.27	7.35	3.43	2.08
Conductivity (µS/cm)	0.978	B2	PC1	B4/B2	1.6	10.08	-0.5	0.95
Fluoride (mg/L)	0.717	PC3	B4/B2	B3/B4	2.31	7.17	0.57	0.55
Chlorides (mg/L)	0.956	PC3	B2	B4/B2	0.78	11.2	-2.74	0.23
Magnesium (mg/L)	0.769	PC2	B4/B2	B2	1.43	8.38	-2.9	-0.16
Ammonical Nitrogen (mg/L)	0.889	B2	PC3	B5/B2	3.53	6.45	3.56	2.01
Phosphate (mg/L)	0.977	B2	PC3	B3/B2	3.35	7.55	3.96	2.31

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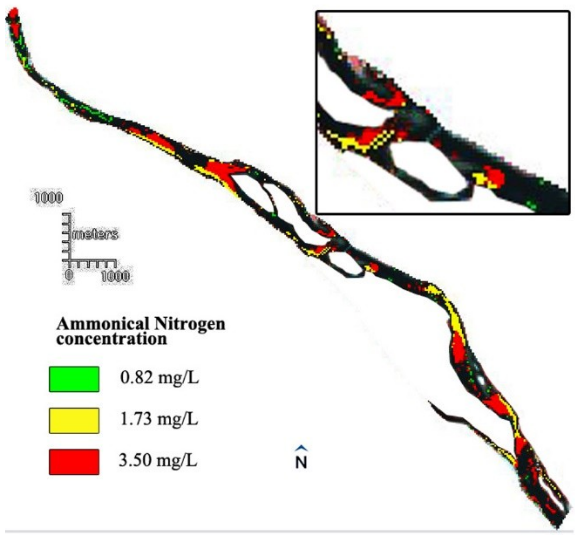

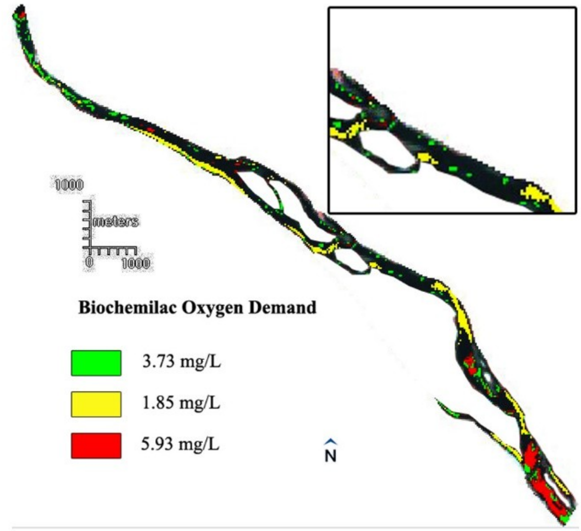

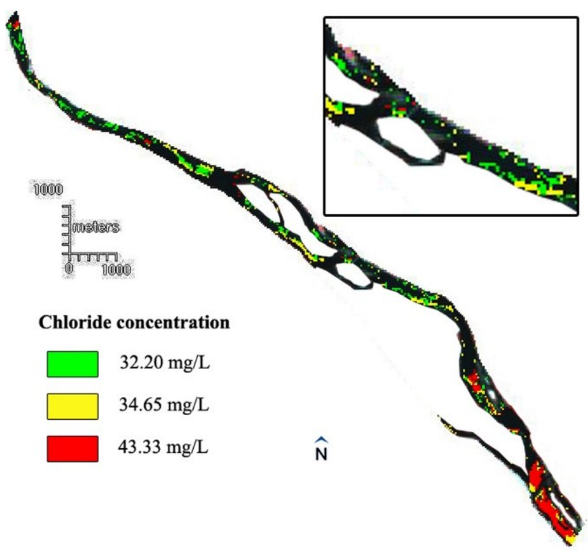

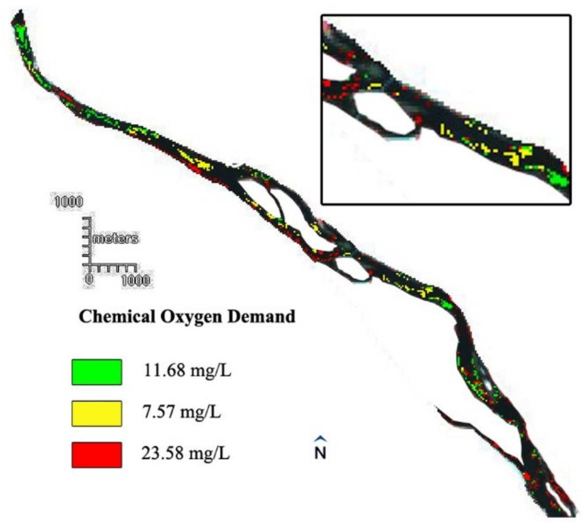

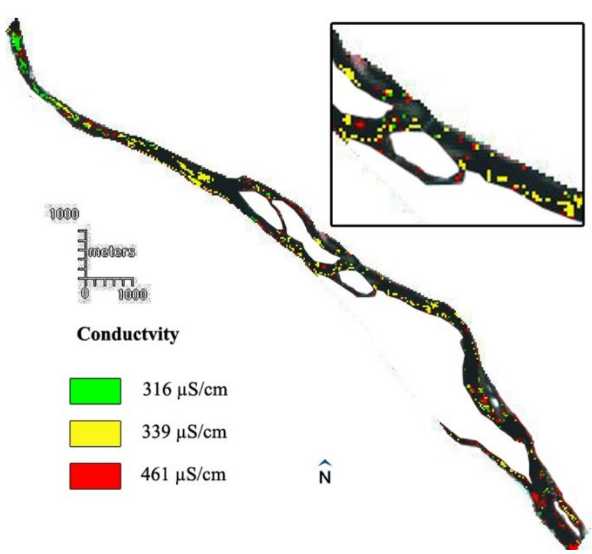

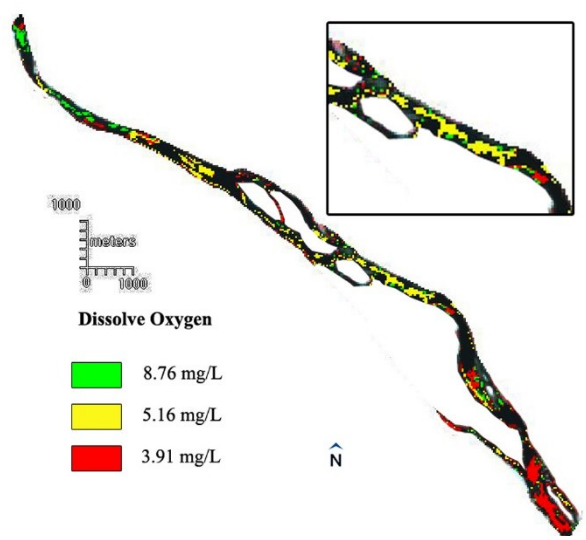

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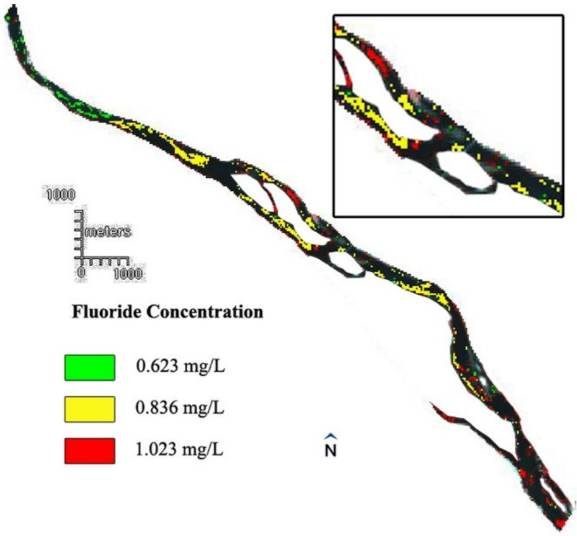

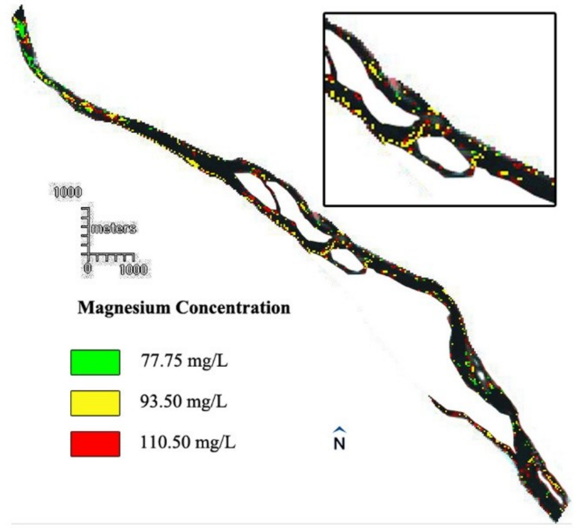

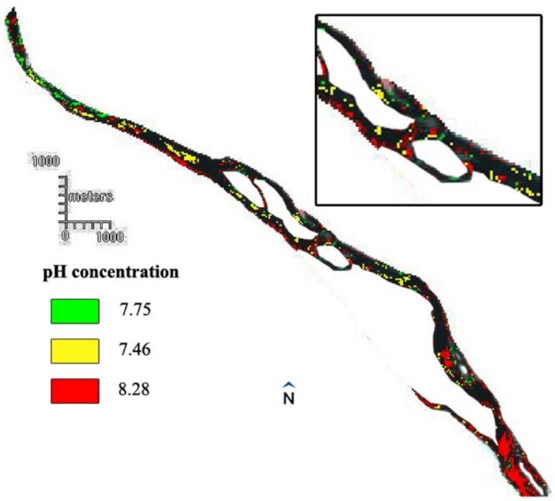

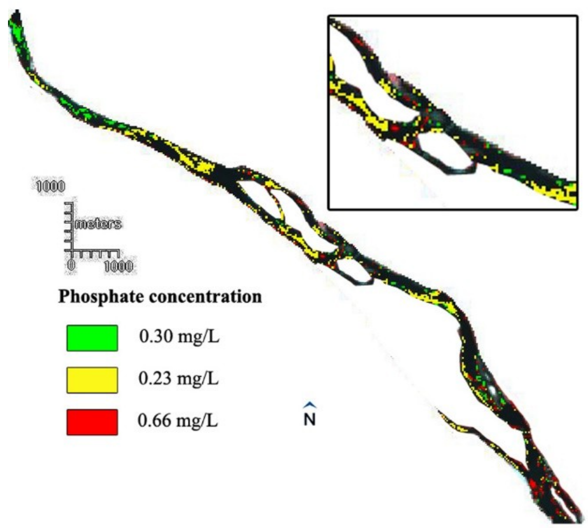

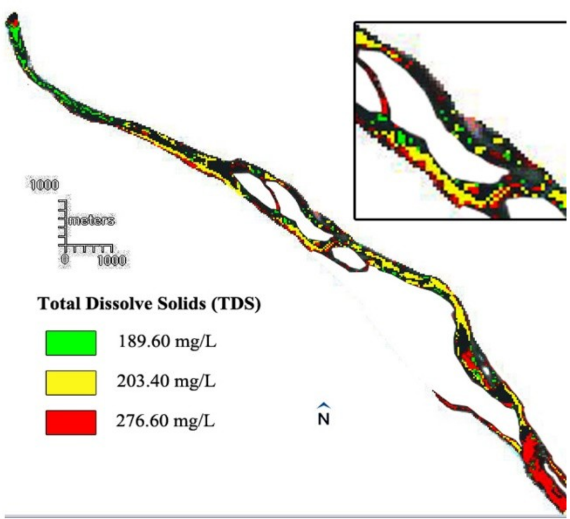

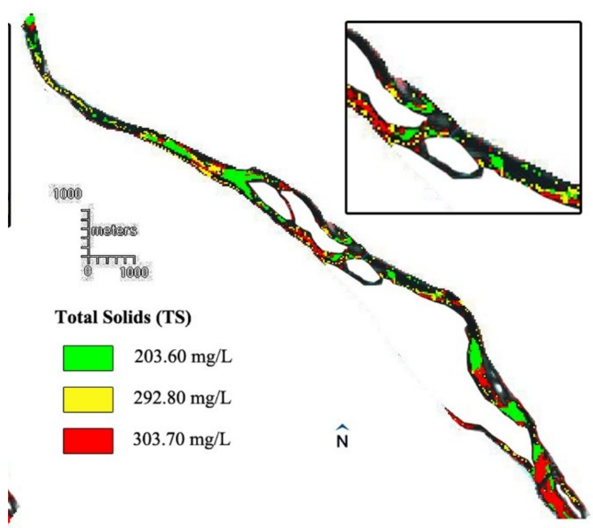

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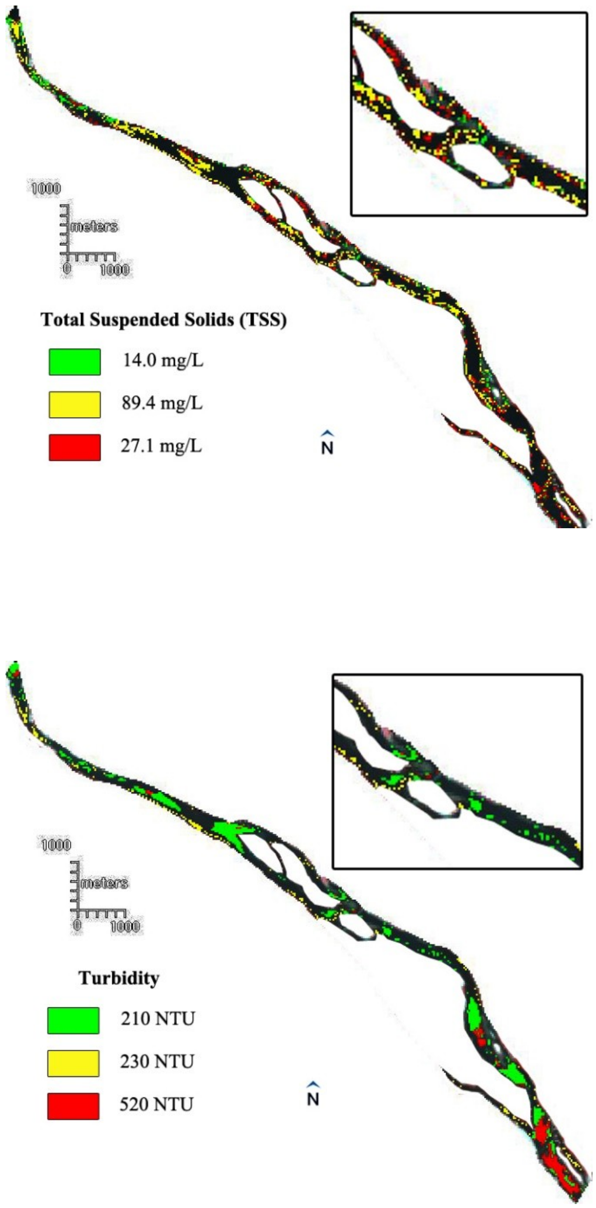

Figure 2: Water Quality maps of Different parameter in Kanpur Region

Conclusion

This study made use of the LANDAST 8 images to map water quality in the stretch of Ganga River along with Kanpur district of Uttar Pradesh, India. For this purpose, water samples are collected from nine sampling stations (Three in each selected cities) then water quality parameters like pH, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Dissolve oxygen (DO), Total Solids (TS), Total Dissolve Solids (TDS), Total Solids (TS), Ammonical Nitrogen, Fluoride, Chloride, Magnesium, Turbidity, Conductivity and Phosphorus have been analyzed in laboratory. Digital Number (DN) value of each band (blue, green, red and NIR) for those sampling stations have been calculated. Band rationing and Principal component analysis have done to get better result. Using DN value and measured data of water quality parameters correlation and multiple linear regression models are developed. To develop multiple linear regression model, appropriate band combinations have been selected which are having highest multiple correlation coefficient (R^2). Then all these measured water quality parameter are correlated with Landsat 8 DN values. Applying simple linear discriminate function to each pixel in study area, grouping of these dependent water quality variables into discrete classes achieved the classification.

After seeing results, we can say that water quality parameters can be predicted for other region within study area easily with the help of these maps. So, we can save time, money and human resource using this method. Also larger area can be analyzed easily using this approach. So overall we can say that this technique can be used as an alternative for analyzing water quality parameters which covers larger using less Money, Time and labors.

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