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Land Use/Land Cover Change Dynamics and River Water Quality Assessment Using Geospatial Technique: a case study of Harmu River, Ranchi (India)

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Abstract— The aim of the present study is to analyse the Land use/land cover change dynamic and water quality assessment using geospatial technique for Harmu river variability with reference to various land use/ land cover map (1992-2009) using the multi-temporal satellite datasets in GIS environment, identification and onsite sampling of pollution level along the river channel in order to comprehend the pollution level of Harmu river over the years using the different water quality parameter which includes pH, Temperature, Electrical conductivity, Total dissolve solid (TDS), Total suspended solid (TSS), Ca^{++}, Mg^{++}, Total Hardness, Total solid (TS), Alkalinity Chloride and Dissolve oxygen. The comparison of Landuse/land cover classes from 1992-2009 indicates major increase in agricultural land (+115.14% in 2002 and +109.61% in 2009) and built up (+105.49%, in 2002 and 105.73% in 2009) classes with respect to area coverage in Harmu watershed whereas, the area of scrub land (-5.88 in 2002 and -42.95), open forest (-16.39% in 2002 and -80.4% in 2009) and wasteland (-22.56% in 2002 and -27.24% in 2009) classes has decreased. The substantial decrease in wasteland during the period could be attributed to the implementation of government wasteland reclamation measures. The pollution level of Harmu river is high at all sites due to the regular discharge of domestic sewage, disposal of automobile/ workshop waste, increasing settlement nearby the river and garbage which led to water not suitable for drinking as well as for domestic purpose. It was observed that the river/drainage channels were primarily encroached by built up land and few of the drainage channels were extinct due to urban activities.

Keywords—Harmu river; Remote Sensing; GIS; River pollution; Land use/land cover

I. Introduction

River is an important resource of surface water for domestic and irrigation purposes. Currently, the quality of river water is a matter of serious concern due to rapid increase in the population, urbanization, industrialization and deforestation. The available river water resources are getting depleted and being adversely affected both qualitatively and quantitatively [1,2,3]. India is a large country with number of big and small rivers. These rivers played very important role in the evolution of religion, culture, settlements of villages, towns and cities in India. They provide water for irrigation, bathing, washing, fishing and recreational purpose [4]. The water quality of these rivers started deteriorating in the last few decades. The important studies are of river Yamuna [5], river Ganga [6,7], Chambal [8], river Narmada [9] and river song [10].

Estimates indicate that the proportion of the global burden of disease associated with environmental pollution hazards ranges from 23 percent [11] to 30 percent [12]. These estimates include infectious diseases related to drinking water, sanitation and food hygiene. For many developing nations, sewage pollution is a growing problem [13]. The United Nations reported that more than 80 percent of sewage in developing countries is discharged untreated, polluting rivers, lakes and coastal areas [14]. Changes in land use and land management practices are primarily responsible for the alteration of receiving water quality [15]. As water drains from the land surface, it carries the residues from the land. As a result, the quantity of water available for runoff, stream flow and ground water flow, as well as the physical, chemical, and biological processes in the receiving water bodies can be affected [16]. It is, therefore, conceivable that there is a strong relationship between land-use types and the quantity and quality of water [17].

Remote sensing has become an important tool applicable to developing and understanding the global, physical processes affecting the earth [18]. Remote sensing and GIS have covered wide range of applications in the fields of agriculture [19], environments [20] and integrated eco-environment assessment [21]. Several researchers have focused on land use/land cover studies because of their adverse effects on ecology of the area and vegetation [22].

Satellite Remote Sensing and GIS are the most common methods for quantification, mapping and detection of patterns of LULCC because of their accurate geo-referencing procedures, digital format suitable for computer processing and repetitive data acquisition [23,24,25]. The availability of remotely sensed data with improved spatial and spectral resolutions along with temporal and multi scale explanations have generated momentum to establish a proper relationship amongst various associated land use/land cover [26]. Remote sensing is a valuable data source from which land-use/land-cover change information can be extracted efficiently [27,28,29,30,31,32]. Therefore the present study is an attempt to make an assessment of the change in the land use/ land cover and physico-chemical properties of Harmu River watershed using multi-temporal satellite images from 1992-2009 to have proper planning and utilization of natural resources and their management.

II. STUDY AREA

The study area is located between 85º 07' to 85º 34' E longitude and 23º 11' to 23º 32'N at an average elevation 640 m above mean sea level. Study area witnessed rapid development during past decades in terms of urbanization, industrialization, and also population increase substantially. The river Harmu flows from west to north- east and it is the minor tributaries of Subarnarekha River (Fig.1). The Subarnarekha River and its tributaries constitute the local river system. During the survey it was found that forest cover in the bank of Harmu River has almost non-existent. In addition to there was a large and small slum encroachments along the bank of the river. This encroachment of bank of the river has a resulted into a drastic situation where the Harmu river has slowly dried up. Summer temperatures range from 20°C-42°C degrees whereas winter temperatures from 0°C-25°C degrees. The normal annual rainfall indicate that average rainfall is 1260 mm with maximum rainfall (90%) concentrated during monsoon months (June-September).

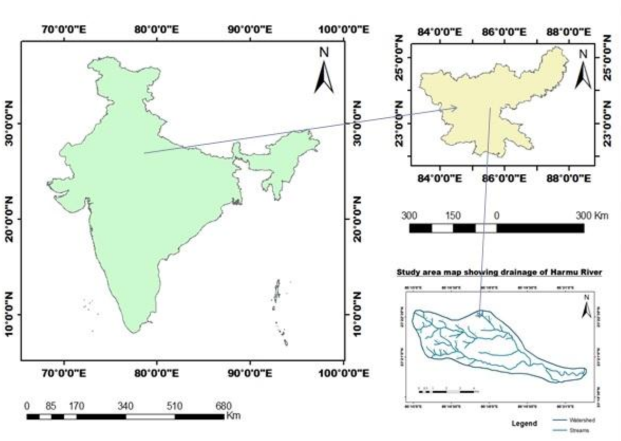

Figure. 1 Location map of the study area

III. DATA USED AND METHODOLOGY

As we know that the satellite data generally contain errors and the correction of deficiencies in the data are called pre-processing. Data pre-processing is an extremely important stage of satellite imagery processing and analysis, which has an impact on all further actions and final product quality. The goal of image pre-processing is to restore appropriate image data from distorted raw data. In case of LANDSAT imagery (TM and ETM^+), data are already processed with radiometric and geometric correction and geo-referenced to UTM map projection LANDSAT imagery comes in Geo- TIFF image format with each spectral band in a separate file. Before further processing, bands were stacked in one image file and area of interest was extracted. When utilizing spatial data from diverse sources, it is required that all datasets should accurately spatially overlap each other. This requires georeferencing of all the maps to a common projection system. Georeferencing is a process of transforming an uncorrected raw image from an arbitrary coordinate system into a map projection coordinate system. Image pixels are positioned and rectified to align and fit into real world map coordinates. The Landsat Multispectral Scanner (ETM^+) imagery was digitally registered to Survey of India (SOI) topographical maps of 1:50 000 scale. IRS LISS IV and Cartosat-1 were georeferenced using an image-to-map registration, keeping the Landsat image as the base layer. Ground control points were uniformly selected all over the image, where the locations can be easily and clearly identified and precisely located. Image-to-map transformation is performed using first-order polynomial transformation. The various land use / land cover features such as agricultural land, water bodies, settlement, open space, waste land were mapped along Harmu River three different years 1992, 2002 and 2009. The mapped land use/land cover features was then verified through field visits. After the verification of mapped earth features, the overall changes such as change in their land covered area and rate of change were estimated. The water samples of Harmu River were collected from surface near the margins of the Harmu river between 9a.m. to 11.30a.m. in one litre glass bottles at each selected site. After addition of appropriate preservatives like magnesium sulphate, alkyl iodide and sulphuric acid at the sampling sites, the collected water samples were tested in the laboratory immediately for analysis of various physicochemical parameters (Fig.2).

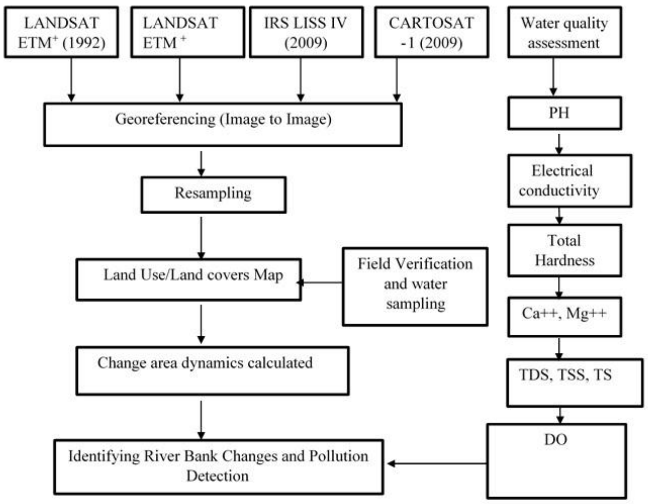

Figure. 2 Flowchart of the methodology

In this study, LULC change dynamic and water quality assessment techniques were estimated to examine the impact of urbanisation on the river and its water quality especially as along the river the urban encroachment has developed haphazardly and in unplanned way in recent years. The brief details of sampling site are presented in the Table 1.

S.No	Site Code	Sites	Description
1.	Site 1	Tangratoli	Before Muktidham
2.	Site 2	Near to Muktidham	Where the Harmu river enters the city.
3.	Site 3	Near to Kadru Colony	Located in the middle of the course of the Harmu river through the city.
4.	Site 4	Near to Niwaranpur	Where the Harmu river just leaves the city.
5.	Site 5	Chutia	Area near to railway station

Table 1 Details of sampling sites

IV. RESULT AND DISCUSSIONS

A. Land use/land cover dynamics

Land Cover is defined as observed physical features on the Earth's Surface. When an economic function is added to it, it becomes Land Use [33,34,35,36,37,38]. In the present study visual interpretation of satellite images was done to delineate landuse/land cover area using a prior knowledge of the study area using multi-temporal satellite images. To delineate LULC area we used bands 321 as RGB in case of IRS LISS IV camera operates in two modes; mono and multi-spectral mode. In multi-spectral mode, the data is collected in three spectral bands viz., green, red and NIR with 24 km swath, while in the mono mode the data is nominally collected in the red band with wider swath of 70 Km. The LISS IV data has an additional MIR band which was not used in the study. Combination of bands 432 as RGB was utilized for TM and ETM+ sensor data which has 7 bands that record radiation from the earth's surface in the blue (band 1), green (band 2), red (band 3), near-infrared (band 4), mid-infrared (bands 5 and 7), and the far-infrared (band 6) portions of the electromagnetic spectrum. Landuse/land cover dynamics indicated by percentage change in LULC area between successive years was computed using equation 1.

$$LULC_2 - LULC_1 \times 100 \ldots\ldots\ldots\ldots\ldots\ldots \text{Equation (1)}$$

Where, $LULC_2$ is the recorded landuse/land cover area for a given year and $LULC_1$ is the landuse/land cover area in the preceding year of $LULC_2$. The positive values indicate increase in landuse/land cover area with reference to previous year whereas negative values indicate decrease in landuse/land cover with reference to previous year. Zero values indicate no change in area.

The comparison of Landuse/land cover classes of 1992 and 2009 showed that there has been a marked change during the study period of 17 years (Table 2; Fig 3a; 3b; 3c). The results show that major increase with respect to area coverage in Harmu watershed was observed in Agricultural land and Built up classes whereas, the area of Scrub cover, Open forest and Wasteland classes has decreased. It was calculated that an area of 15.45 sq km (31.39%), 17.79 sq km (35.87%) and 19.50 sq km (38.81%) was covered by agricultural land during the year 1992, 2002 and 2009 respectively.

This increasing trend of land cover/land use change in the watershed's area (+115.14%, +109.61% in year 2002 and 2009 respectively) reinforces that economic forces are commonly a major stimulus on anthropogenic change of land and it is the main reason why the area near and around the main water-bodies and streams in the watershed has shifted from other land covers to Agriculture cover [39]. It has also been observed in watershed that the Built up areas are mostly surrounded by Agricultural area, especially in the catchment area and by the main streams. It means the area near the population has been cleared for the production of crops in order to fulfill the basic necessities of life.

The second class which faced an increment in the total area was built up land from 18.19 sq km (36.97 %) 19.19 sq km (38.68%) 20.29 sq km (40.39%) during the year 1992, 2002 and 2009, respectively. The reasons in increase in area were a number of new housing schemes, commercial, services, institutional and recreational pursuits that have been developed in and around area in the past 20 years. Along with these developments (+105.49%, +105.73% in year 2002 and 2009 respectively), there is an incline toward the construction of new pavements, highways, roads and other structures to access these areas. The area covered by waterbodies (0.41 sq km) class was static from 1992 to 2009.

The decrease in the open forest from 0.61 sq km (1.25%), 0.51 sq km (1.04 %), 0.10 sq km (0.20%) in 1992, 2002 and 2009 respectively. The much decrease (-16.39%, -80.4% in year 2002 and 2009 respectively) was due to rapid deforestation in the area which removed the vegetation cover from the land as forest wood was used for fulfilling household requirements like cooking and heating, cultivation and construction of built-up land [40]. During the 1992-2009 period the percentage area covered by wasteland class in watershed decreased by (-22.56%, -27.24% in the year 2002 and 2009 respectively. The substantial decrease in wasteland during the period could be attributed to the implementation of government wasteland reclamation measures [41,42,43,44].

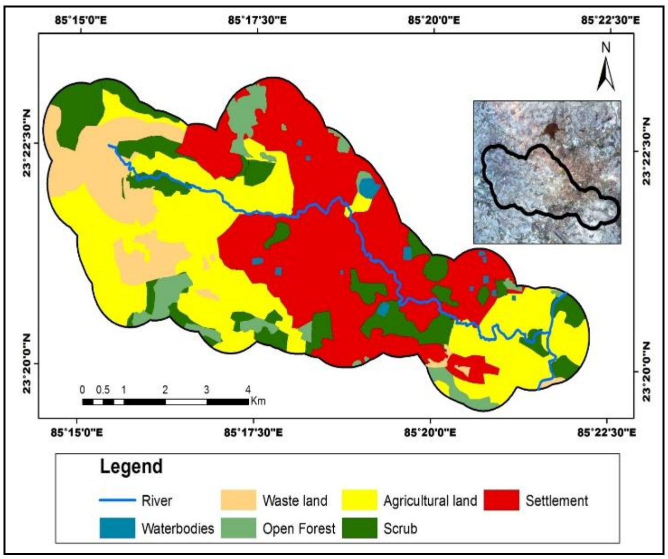

Figure. 3a Landuse/landcover map for 1992

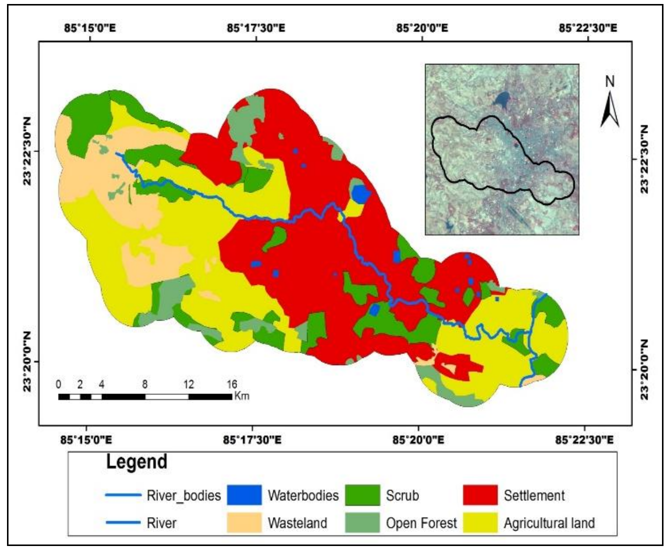

Figure. 3b Landuse/landcover map for 2002

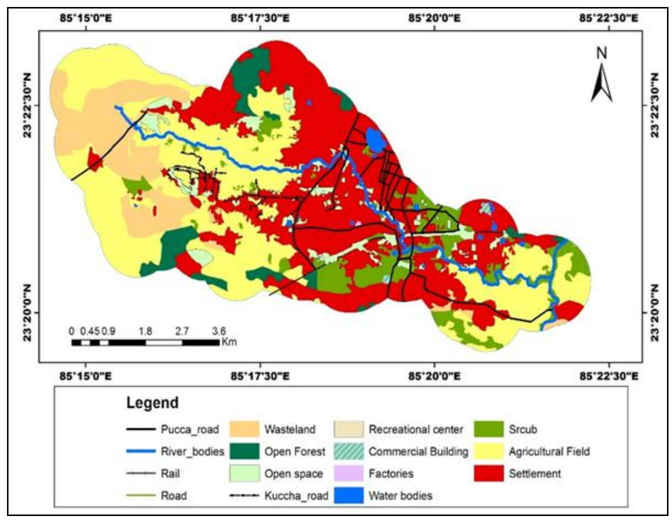

Figure. 3c Landuse/landcover map for 2009

Table 2 Changes in Landuse/land cover dynamics from 1992-2009

S.No	LULC Classes	Area Km^2 1992	Area (%)	Area Km^2 2002	Area (%)	Percentage change	Area Km^2 2009	Area (%)	Percentage change
1.	Agricultural land	15.45	31.39	17.79	35.87	+115.14	19.50	38.81	+109.61
2.	Built up land	18.19	36.97	19.19	38.68	+105.49	20.29	40.39	+105.73
3.	Scrub land	8.51	17.30	8.01	16.15	-5.88	4.57	9.09	-42.95
4.	Open forest	0.61	1.25	0.51	1.04	-16.39	0.10	0.20	-80.4
5.	Water bodies	0.41	0.82	0.41	0.82	0	0.41	0.82	0
6.	Wasteland	6.03	12.24	4.67	7.41	-22.56	3.37	10.69	-27.24

B. Physico-chemical analysis

All of the drinking water samples were taken from the selected sites from Harmu River and the samples were numbered from 1 to 5 against their locations and sources (Fig 4a; Fig b; Fig c; Fig d). The samples were collected in 1-liter polyethylene (PE) bottles, which were washed with deionized water before use. These sample bottles were sealed and placed in a dark environment at a constant temperature range of 4-10°C to avoid any contamination and the effects of light and temperature. For chemical analysis of collected water samples including pH, Temperature, Electrical conductivity, Total dissolve solid (TDS), Total suspended solid (TSS), Ca^{++}, Mg^{++}, Total Hardness, Total solid (TS), Alkalinity Chloride and Dissolve oxygen a representative water sampling was carried out from each location. Each of the samples were analysed for a number of parameters in the laboratory to determine the overall water quality (Table 3). It is very essential and important to test the water before it is used for drinking, domestic, agricultural or industrial purpose. The pH value of Harmu river ranges from 5.9-6.9, 7.78-7.9, 7.25-7.3, 7.1-7.23 and 6.9-7 at the site I, II, III, IV and Site V respectively. The values indicate that the water of the Harmu river at the site I and V are slightly acidic in nature due to the regular discharge of domestic sewage and the disposal of automobile/ workshop waste. The value of Electrical conductivity ranges from 1.42-1.5, 1.6-1.67, 1.5-1.63, 1.3-1.32 and 1.06-1.09 at site I, II, III, IV and Site V respectively. The obtained results indicate that the water of Harmu river at all the sites show maximum levels of electrical conductance in the water. The Maximum value of EC are found at site II and the minimum recorded at site V. The present study show that the water are bodies are loaded with waste water and domestic sewage from several house directly enter into the river.

Fig. 4a Site I (Tangratoli pond)

Fig. 4b Site II (Near Muktidham)

Fig.4c Site III (Near Chutia)

Fig.4d Site IV (Near Niwaranpur)

The presence of total dissolved solids (TDS) in the Harmu river is the turbidity due to the presence of silt content and organic matter. During the sampling it was evaluated that near the river large and small slum encroachments and settlements were present and their waste was directly drowns into the river. The value of TDS are recorded during the experiment are as 568 -585, 679-687, 567-592, 563-97 and 653-663 at the site I, II, III, IV and Site V respectively. The obtained results indicate that the water of Harmu river at all the sites are not suitable for drinking as well as for domestic purpose. During the experiment the minimum value of TDS are recorded at site IV that is (563-597 mg/l) and the maximum were at the site II. The maximum values at the site II may be due to the presence of several types of suspended particles, man-made religious activities that is burning of dead bodies at Muktidham Temple, run off from many bathing Ghats from the nearby people and dumping of solid waste. The higher concentration value of total suspended solid in river is an index that it is very much polluted and very harmful to use. As the water moves through soil and rock, it dissolves very small amounts of minerals and holds them in solution. The presence of Calcium and magnesium dissolved in water make water "hard" and it can be removed by water softeners. In the present study, it has been found that total hardness ranges from 104 -107 mg/l at site I, 460-467 mg/l at site II, 380-393 mg/l at site III, 216-223 mg/l at site IV and 184-197 mg/l at site V respectively. The level of total hardness is mainly due to the discharge of domestic sewage, washing clothes and animals in the river.

The value of Calcium hardness recorded during the experiment was 35.27- 35.87 mg/l, 81.76 - 82.03 mg/l, 76.95-77.63 mg/l, 72.14-72.94 mg/l, and 68.89 - 70.32 mg/l at the site I, II, III, IV and Site V respectively. The maximum value is recorded at site II and the minimum value is at I. High levels support only sparse plant and animal life and are not considered good for health. The value ranges from 3.89 - 3.97 mg/l, 62.21- 62.93mg/l, 45.69 - 47.23mg/l, 8.74 - 9.37 mg/l and 2.95 - 3.32mg/l at the site I, II, III, IV and Site V respectively. The maximum value is recorded at site II and site III and the minimum value is at V. All the value show highly magnesium hardness which can be caused due to the regular discharge of domestic sewage and the disposal of automobile/workshop waste. Alkalinity causes bitterness and sour taste in to the water bodies. In the present study, alkalinity ranges from 167-179 mg/l, 413-437 mg/l, 247-267 mg/l, 317-333 mg/l and 323-343 mg/l at the site I, II, III, IV and Site V respectively. The maximum value is recorded at site II, IV, site V and the minimum value is at site I because it is the a man-made water storage pond in which no house hold sewage is being dump and mainly used for the purpose of washing cloth, bathing . All the value show highly alkalinity except at the site I due to the dry season with concentration of salts, high carbonate content and discharge of domestic sewage in the river. The high alkalinity in the study area is also due to the presence of high carbonate content in the water samples. Chloride ranges from 414-413 mg/l, 550-553 mg/l, 459-462 mg/l, 382-383 mg/l and 388-343 mg/l at the site I, II, III, IV and Site V respectively. The maximum value is recorded at site II, III, I, V, and the minimum were recorded at the site IV. The source of highly contamination of water bodies is due to local sewage, local drains and domestic effluents.

The presence of DO level in surface water bodies indicates that the water bodies have the ability to support aquatic life. It is also being used to determine the actual concentration of dissolved oxygen in the water sample. DO varies from 5.1-5.3 mg/l, 2.3-2.5 mg/l, 2.7-2.8 mg/l, 2.1-2.3 mg/l and 3.6-3.7 mg/l at the site I, II, III, IV and Site V respectively. The maximum value is recorded at site I, and the minimum were recorded at the site IV. The amount of DO in water has been reported not constant but fluctuates, depending on the local temperature and depth of the water bodies. The decrease in DO at site IV may be attributed to absence of little turbulence in the river water and dumping of effluents along with urban garbage.

Table 3 Physico-chemical parameters of drinking water samples in Harmu river.

S. no.	*Temp*	*pH*	*CL*	*Ca++*	*Mg ++*	*DO*	*EC*	*TS*	*TSS*	*TDS*	*TH*	*Alk*
(BIS)	*30^0c*	*6.5 - 8.5*	*250mg/l*	*75mg/l*	*30mg/l*	*5.0mg/l*	*1.8microS/cm*	*500 mg/l*	*-*	*500 mg/l*	*200 mg/l*	*200 mg/l*
Site 1	*20^0c*	*7.65 - 7.7*	*414-413*	*35.27-5.87*	*3.89-3.97*	*6.0-6.5*	*1.42 - 1.5*	*705 - 727*	*137-142*	*568 - 585*	*104 -107*	*167-179*
Site 2	*22^0c*	*7.78 - 7.9*	*414 - 413*	*81.76-82.03*	*62.21- 62.93*	*2.3-2.5*	*1.6 - 1.67*	*848 - 870*	*169 - 183*	*679 - 687*	*460-467*	*413-437*
Site 3	*19^0c*	*7.25 - 7.3*	*459-462*	*76.95-77.63*	*45.69-47.23*	*2.7-2.8*	*1.5 - 1.63*	*711 - 757*	*144 - 165*	*567 - 592*	*380-393*	*247-267*
Site 4	*23^0c*	*7.1 - 7.23*	*382-383*	*72.14-72.94*	*8.74-9.37*	*3.3-3.5*	*1.3 - 1.32*	*724 - 774*	*161 - 177*	*563 - 597*	*216-223*	*317-333*
Site 5	*21^0c*	*6.9 - 7*	*388-343*	*68.89-70.32*	*2.95-3.32*	*3.6-3.7*	*1.06 - 1.09*	*793 - 820*	*143 - 157*	*650 - 663*	*184-197*	*323-343*

S. no.	*Temp*	*pH*	*CL*	*Ca++*	*Mg ++*	*DO*	*EC*	*TS*	*TSS*	*TDS*	*TH*	*Alk*
(BIS)	*30^0c*	*6.5 - 8.5*	*250mg/l*	*75mg/l*	*30mg/l*	*5.0mg/l*	*1.8microS/cm*	*500 mg/l*	*-*	*500 mg/l*	*200 mg/l*	*200 mg/l*
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Site 2	*22^0c*	*7.78 - 7.9*	*414 - 413*	*81.76-82.03*	*62.21- 62.93*	*2.3-2.5*	*1.6 - 1.67*	*848 - 870*	*169 - 183*	*679 - 687*	*460-467*	*413-437*
Site 3	*19^0c*	*7.25 - 7.3*	*459-462*	*76.95-77.63*	*45.69-47.23*	*2.7-2.8*	*1.5 - 1.63*	*711 - 757*	*144 - 165*	*567 - 592*	*380-393*	*247-267*
Site 4	*23^0c*	*7.1 - 7.23*	*382-383*	*72.14-72.94*	*8.74-9.37*	*3.3-3.5*	*1.3 - 1.32*	*724 - 774*	*161 - 177*	*563 - 597*	*216-223*	*317-333*
Site 5	*21^0c*	*6.9 - 7*	*388-343*	*68.89-70.32*	*2.95-3.32*	*3.6-3.7*	*1.06 - 1.09*	*793 - 820*	*143 - 157*	*650 - 663*	*184-197*	*323-343*

The presence of DO level in surface water bodies indicates that the water bodies have the ability to support aquatic life. It is also being used to determine the actual concentration of dissolved oxygen in the water sample. DO varies from 5.1-5.3 mg/l, 2.3-2.5 mg/l, 2.7-2.8 mg/l, 2.1-2.3 mg/l and 3.6-3.7 mg/l at the site I, II, III, IV and Site V respectively. The maximum value is recorded at site I, and the minimum were recorded at the site IV. The amount of DO in water has been reported not constant but fluctuates, depending on the local temperature and depth of the water bodies. The decrease in DO at site IV may be attributed to absence of little turbulence in the river water and dumping of effluents along with urban garbage.

V. Conclusions

The haphazard expansion of Settlement and Agriculture area in the watershed was mainly due to lack of proper management and land use planning since no EIA report is generated prior to land development in the study area. Built up area with the largest land cover of 18.19 sq km (in 1992) and was observed to have increased to 20.29 sq km in the year 2009. Also agricultural area which covers 15.45 sq km in 1992, increased to 19.50 sq km in the year 2009. Open forest area (with 0.61 sq km), Scrubland (with 8.51 sq km) and wasteland (with 6.03 sq km) in 1992 reduced to 0.10 sq km, 4.57 sq km, and 3.37 sq km respectively in 2009. The percentage range of land cover, 1992-2009, it was observed that there was a large increase in area of both agricultural (+115.14% in 2002 and +109.61% in 2009) and built up (+105.49%, in 2002 and 105.73% in 2009). While open forest (-16.39% in 2002 and -80.4% in 2009), scrubland (-5.88 in 2002 and -42.95) in 2009 and wasteland (-22.56% in 2002 and -27.24% in 2009) area tremendously decrease as so many buildings were constructed in the reserve and at the same period of time, farming activities was on the increase. The substantial decrease in wasteland during the period could be attributed to the implementation of government wasteland reclamation measures.

The pH value of Harmu river show slightly acidic in nature which can be caused due to the regular discharge of domestic sewage and the disposal of automobile/ workshop waste and is not good for health. Electrical conductivity is also high because of the increasing settlement nearby the river. TDS value indicate that the water of Harmu river at all the sites are not suitable for drinking as well as for domestic purpose. The total hardness of the river water is much high which is mainly due to the discharge of domestic sewage, washing clothes, animals in the river. The calcium concentration in water is beyond the permissible limit and can cause malformations of central nervous system, kidney stones, digestive health and constipation. The value of magnesium is high due to the regular discharge of domestic sewage and the disposal of automobile/workshop waste and leads to irregular heartbeat, low blood pressure, confusion, slowed breathing, coma, and death if the person use it. Chloride values are higher than its permissible limit and can cause breathing problem, coughing, chest pain and skin irritation. It is being seen that as the built up areas are increasing nearby the Harmu river which results in water being polluted. At the source of the Harmu river before Muktidham the river is dried up and doesn't have an existence whereas in Tangratoli a man-made pond is being used to store the rain water, whose chemical values are within the permissible limit which is quite good than the other sites. It was observed that the river/drainage channels were primarily encroached by build-up land and few of the drainage channels were extinct due to urban activities over the last few decades. This study has demonstrated that the geospatial technique provide powerful tool for mapping and detecting changes in land use/land cover.

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