EFFECTS OF LAND USE/LAND COVER CHANGES ON WATER QUALITY OF A SUB-TROPICAL RIVER BASIN

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ABSTRACT

Uncontrolled urbanization results into sudden and rapid changes into Land Use/Land cover (LU/LC) of a sub-tropical river basin. Water quality is an important indicator of river basin health. For better river basin planning and management, the information is required on the state of water quality and the changes occurring into it. Remote Sensing and GIS are efficient aids for such study. Water quality parameters such as pH, Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Nitrate, Nitrogen (total oxidized), Electrical conductivity (EC) and Fecal Coliform Bacteria, at different sampling stations across the Upper Bhima river basin were analyzed to monitor the water quality changes in the basin. It is attempted to find if any relationship exists between the LU/LC changes and water quality of the river basin. Results reveal that LU/LC is changing rapidly in the study area and is strongly related with changes in water quality parameters.

Index Terms— Ecosystem, land use/land cover, remote sensing, river basin, urbanization, water quality

1. INTRODUCTION

The ecosystems of the sub-tropical river basins are heterogeneous in nature and are very complex. All the components of a river basin ecosystem are interrelated with each other. Therefore, changes in the surface characteristics of a river basin leads to the changes in the hydrological components of the region such as stream flow, surface runoff, infiltration rate, ground water recharge and water quality. Urbanization is the major cause of LU/LC changes in the river basins. Throughout the world, the majority of the human population is settled either in the river basins or near the coastal areas. The reason is simply the presence of water which is an essential commodity for life. In developing countries like India which falls into a sub-tropical region, population is increasing exponentially. River basins are heterogeneous in their composition and therefore difficult to monitor [1]. It is important to monitor the LU/LC changes in the river basin and its impact on the ecosystem components such as vegetation cover, river morphometry, rainfall-runoff, stream flow, ground water, water quality, etc. Such studies are required for better LU/LC planning and management for sustainable development in the river basins.

Modern technologies viz. remote sensing and GIS help to collect information on the spatio-temporal changes occurring in the river basin. Hydrological model such as Soil Water and Assessment Tool (SWAT) is an efficient tool compared to the other conventional LU/LC change monitoring and modeling approaches. It can study the effects of LU/LC changes on various hydrological components such as stream flow, surface runoff, nutrient loadings and other water quality parameters, etc. [2]. Remote sensing and GIS serve as important aids to in-situ observed water quality parameters because they help in the rapid and efficient assessment of the water quality changes in the river basin due to urbanization [3].

2. BACKGROUND WORK AND OBJECTIVES

Due to uneven distribution of rainfall in the sub-tropical regions e.g. Upper Bhima river basin, it is already a water stressed region. Proper management of existing water resources is very essential and it is an important indicator of river basin health [4]. Due to rapid urbanization, the water quality of the river basins is deteriorating. The following questions need to be answered: what are the LU/LC changes and with what rate they are changing? What are the reasons and causative factors of such changes? What is their impact on the water quality? What is the threshold of LU/LC changes in a river basin which results in degradation of the water quality? [5] What is the correlationship between the LU/LC changes and water quality? This work is an attempt to answer some of these questions. Based on the research gaps identified, there are two main objectives of this study: (1) assessment of the LU/LC changes in two sub-watersheds of the Upper Bhima river basin, (2) a comparative

evaluation of the water quality changes across the unurbanized Bhima sub-watershed and urbanized Mula-Mutha sub-watershed.

3. STUDY AREA

Upper Bhima basin is a sub-tropical river basin which lies in Maharashtra state in India (Fig. 1). It is urbanizing rapidly due to increasing population in mega city Pune and industrial area Pimri-Chinchwad. Bhima river and Mula-Mutha rivers are important tributaries of the Krishna river. They originate from Western Ghats and flow from west to east. Upper Bhima river basin is water stressed due to rapid urbanization, and extensive agriculture. It has uneven distribution of rainfall and lies in Deccan Plateau, having basalts. Soil types are: black soils and red sandy soils. The study area has a total catchment of 6724.40 km^2. It has latitudinal extent of 18^0 17' to 19^0 05' and longitudinal extent of 73^0 20' to 74^0 34'. To understand the effects of urbanization on Upper Bhima river basin, the entire study area was divided into two distinct sub-watersheds viz. Bhima sub-waterhsed (unurbanized) and Mula-Mutha sub-watershed (urbanized). Therefore, a comparative study was done for both the sub-watersheds to understand the LU/LC changes and their effects on their water quality.

4. DATA USED AND METHODOLOGY

Time series satellite datasets viz. Landsat MSS (80 m) of October, 1980, Landast ETM+ (30 m) of October, 2002 and IRS LISS-III (23.5 m) of October, 2008 and November, 2009 were acquired and processed. Maximum Likelihood Classifier of Supervised classification was used to prepare temporal LU/LC maps of the study area on ERDAS Imagine image processing software ver. 2013 with 87% accuracy. Five LU/LC classes were : Built-up lands, forest lands, agricultural lands, wastelands and waterbodies. Base map for study area was prepared using Survey of India toposheets and was later updated with temporal satellite images to understand the changes. ASTER DEM data was used to delineate the Upper Bhima basin boundary and later on the basis of the topography and rivers, it was divided into two sub-watersheds viz. Bhima (unurbanized) sub-watershed and Mula-Mutha (urbanized) sub-watershed. Watershed delineation was done using Arc GIS 10.1 software. Population and industrial data of the study area were analyzed statistically to observe their changes in the basin. Hydro-meterological and water quality datasets were acquired from two Government of India departments viz. Hydrology Project office, Nasik and Maharashtra Pollution Control Board (MPCB), Mumbai.

SWAT model set-up was done and weather data was defined. Simulations were done on SWAT providing LU/LC maps (1980, 2002 and 2009), soil data, hydro-meteorological data, DEM and water quality data. The water quality data was analyzed for three locations in unurbanized Bhima sub-watershed : (1) Nighoje (on Indrayani river and 20 km north west (NW), before pune city), (2) Chaskman (on Bhima river and 42 km NW, before Pune city), and (3) Rakshewadi (on Bhima river and 51 km north east (NE), after Pune city). The water quality paramters (WQ) studied for this sub-waterhsed were pH, DO, BOD, COD, Nitrogen (total oxidized) and EC.

Water quality data was received for following monitoring stations in urbanized Mula-Mutha sub-watershed: Vithalwadi (on Mutha river and 7 km south east (SE), before Pune city), Bundgarden (on Mula-Mutha river and in center of the Pune city), Paragaon (on Bhima river and 54 km NE, after Pune city) and Daund (situated downstream of the Bhima river and 78 km, after Pune city) (Fig. 5). WQ parameters studied for this sub-watershed were pH, DO, BOD, COD, Nitrate and Fecal coliform bacteria. Water quality datasets of both the sub-watersheds were analysed seperately to detect the changes in the behaviour of the respective sub-watersheds w.r.t the changes in LU/LC. Finally changes were observed for LU/LC and water quality (Fig. 2, 3 and 4).

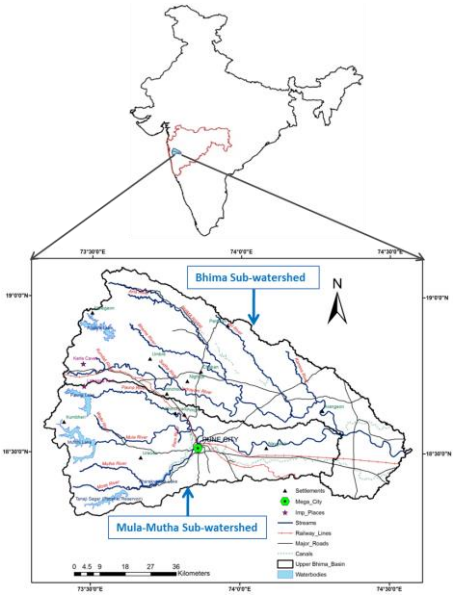

Fig. 1: Location Map of Upper Bhima Basin

5. RESULTS AND DISCUSSION

Bhima (unurbanized) sub-watershed covers an area of 3806.20 km^2 and Mula-Mutha (urbanized) sub-watershed covers an area of 2918.20 km^2. According to the Census data, population of mega city Pune has increased from 4.164 millions in 1981 to 9.426 millions in 2011. As per MPCB report 2009, just betwen the years 2005 to 2009, the number of industies have also incresed from 7017 to 9127. It is followed by the increase in the water demands.

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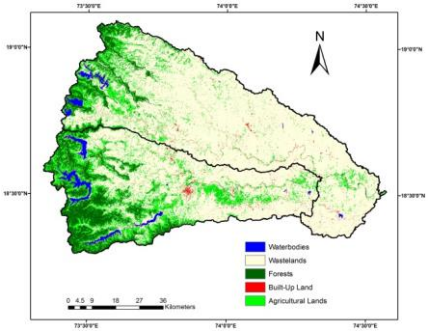

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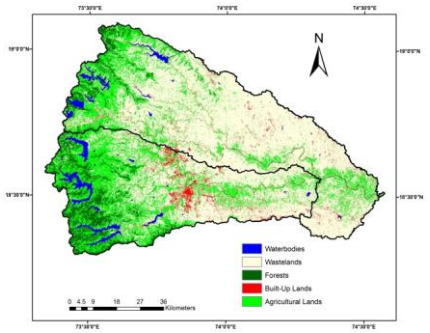

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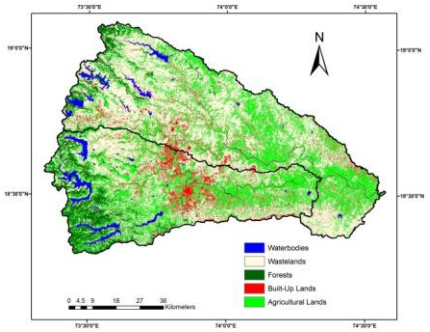

Fig. 2: Spatial maps of Bhima sub-watershed and Mula-Mutha sub-watershed of Upper Bhima river basin showing (a) Land Use/Land Cover map of 1980, (b) Land Use/Land Cover map of 2002, (c) Land Use/Land Cover map of 2009

5.1. LU/LC changes in Bhima (unurbanized) sub-watershed and Mula-Mutha (urbanized) sub-watershed

Out of the total area in Bhima (unurbanized) sub-watershed and Mula-Mutha (urbanized) sub-watershed, about 2.5% and 3.66% of the area is having built-up land respectively. Therefore, Mula-Mutha sub-watershed is comparatively urbanized and is drained by Mula-Mutha river. Unurbanized Bhima sub-watershed is drained by Bhima river and is basically an agricultural sub-watershed. In both the sub-watersheds as the population have increased, the built-up lands and waterbodies have also increased. This increase is on the expense of decreasing forest lands and wastelands. In Bhima sub-watershed the forest lands and wastelands are being used for agricultural purposes whereas in Mula-Mutha sub-watershed they are being used for urban dvelopment. Hence, forest lands and wastelands are decreasing in both the sub-watersheds but the changes are more drastic in Mula-Mutha (urbanized) sub-watershed. Table 1 and 2 are giving in detail the LU/LC changes in both the sub-watersheds.

Table 1: Land Use/Land Cover change detection in unrbanized Bhima sub-basin

Land Use Type	Area (%)			Changes	
	1980	2002	2009	1980-2002	1980-2009
Forest Land	2.02	1.34	1.27	-0.68	-0.75
Agricultural Land	3.69	7.23	10.29	3.54	6.59
Built Up Land	0.40	0.99	2.50	0.60	2.11
Waterbodies	0.34	0.55	0.78	0.21	0.44
Wasteland	26.88	23.23	18.50	-3.66	-8.38

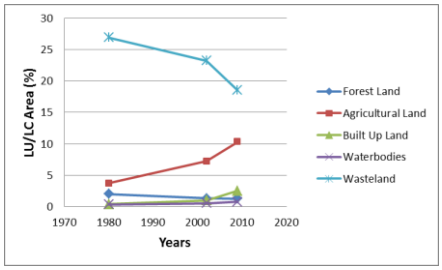

Fig. 3: Chart showing land use land cover changes 1980, 2002 and 2009 for unurbanized Bhima sub-basin

5.2. Water quality analysis

In unurbanized Bhima sub-watershed, the WQ parameters viz. pH, DO, BOD, COD, Nitrogen (total oxidized) and EC were analysed for the year 2000 to 2009. The pH value remained ± 8 for all the three stations. Not much variation observed. Average DO value for Nighoje station, Chaskman and Rakshewadi station were 6.6 mg/L, 6.9 mg/L, and 6.1 mg/L respectively. The average BOD value for all the three stations were 1.4 mg/L, 1.6 mg/L, and 2.4 mg/L respectively. Similarly average COD value Ranged from 10.6 mg/L, 9.9 mg/L, and 13.5 mg/L respectively. Average Nitrogen (total oxidized) value ranged from 0.5 mg N/L, 1.8 mg N/L, and 1.9 mg N/L respectively. The average EC value for all the three respective stations were 245, 300, and 644 µmho/cm.

There was no significant spatio-temporal variation found in the WQ parameters of unurbanized Bhima sub-watershed except for the Rakshewadi station. Among all three stations Rakshewadi has poor WQ. It is to be noticed that this sub-watershed has relatively very low BOD value and high COD value which is characteristic of agricultural basins. COD values are high for this basin because extensive agricultural practices are being done in this sub-watershed. The agricultural lands have increased by 3.69% to 10.29%

in between 1980-2009 (Table 1). The extensive agriculture is accompanied by extensive use of chemical fertilizers. Their residues are washed away into waterbodies and pollute them. The agricultural lands have increased west to east in the basin, therefore, Rakshewadi is the most affected station in terms of WQ. Hence, pollution level is not that severe in unurbanized Bhima sub-watershed.

Table 2: Land Use/Land Cover change detection in urbanized Mula-Mutha sub-basin

Land Use Type	Area (%)			Changes	
	1980	2002	2009	1980-2002	1980-2009
Forest Land	6.09	4.17	3.65	-1.92	-2.44
Agricultural Land	7.37	11.48	11.01	4.12	3.64
Built Up Land	0.58	1.71	3.66	1.13	3.08
Waterbodies	0.90	1.16	1.33	0.26	0.43
Wasteland	18.39	14.80	13.68	-3.59	-4.71

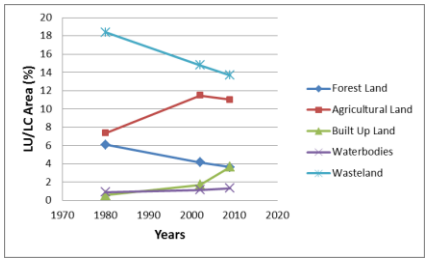

Fig. 4: Chart showing land use land cover changes 1980, 2002 and 2009 for urbanized Mula-Mutha sub-basin

In urbanized Mula-Mutha sub-watershed, the WQ parameters viz. pH, DO, COD, BOD, Nitrate and Fecal coliform bacteria were analysed for the year 2007 to 2013. The average pH value for Vittalwadi, Bundgarden, Paragaon and Daund station were 7.6, 7.6, 7.8, and 7.9 respectively. The DO values for these stations were 2.8 mg/L, 1.8 mg/L, 4.6 mg/L, and 4.9 mg/L respectively. The ranges of average values for COD were 21.4 mg/L, 30.7 mg/L, 17.7 mg/L, and 17.9 mg/L respectively. Similarly BOD varied from 13.3 mg/L, 18.2 mg/L, 8.7 mg/L, and 8.1 mg/L respectively. Nitrate value ranged from 0.8 mg/L, 1.1 mg/L, 0.7 mg/L, and 0.7 mg/L respectively. Fecal coliform bacteria count ranged from 245.3, 315.5, 182.6, and 181.3 MPN/100mL.

There are trends in the WQ changes in the urbanized Mula-Mutha river basin due to changes in LU/LC. Water pollution is most severe near Pune city. First station is Vittalwadi, just before the Pune city and its WQ is deteriorated due to Municipal and industrial discharges into the river. High BOD in this basin is an indicator of fecal contamination from Municipal discharges into the river. Next is the Bundgarden station which is in the heart of Pune city and is the most polluted station out of all the stations. First two stations are polluted because they pass through built-up land of Pune city. As the river passes the distance of 54 km away from Pune city, it enters a small town called Paragaon. The WQ gets better due to the natural self-cleaning capacity of the river. Further moving on to fourth station Daund, which is 78 km away from built-up land and is basically an agricultural area, the WQ improves further. At this station water is polluted due to agricultural fertilizers. Comparatively high nitrate in the water is the indicator of agricultural based water pollution. Hence, it is evident from the study that unurbanized Bhima sub-watershed is healthier. LU/LC changes have significant effect on WQ of a river basin.

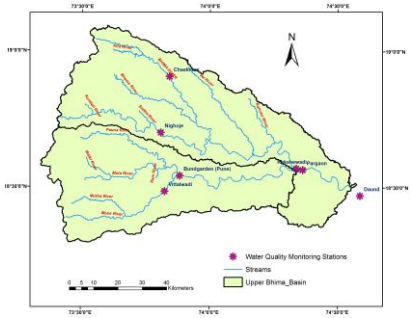

Fig. 5: Water quality monitoring stations in Bhima (unurbanized) and Mula-Mutha (urbanized) sub-watersheds

6. ACKNOWLEDGEMENT

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