Original Research Article

Analysis of Geospatial Causes for Lowering Discharge in Kanari River

Malay Singh[*], Y. K. Tiwari, M. K. Awasthi and Ayushi Trivedi

Department of Soil and Water Engineering, Jawaharlal Nehru Krishi VishwaVidyalaya, Jabalpur, M. P., India
*Corresponding author

A B S T R A C T

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Rivers are not only important for human beings but also serve a great purpose to the animals and trees as well. We will never know the worth of rivers until they dry up. A drop of water is worth more than a sack of gold to a thirsty man. We have to understand the need to save our rivers from pollution. Land use/land cover (LULC) changes are among the most important applications of Earth Observation (EO) satellite sensor data. It provides a comprehensive and good understanding of ecosystem monitoring and functioning, and responses to environmental factors. Remote sensing and Geographical Information Systems (GIS) are powerful tools to derive accurate and timely information on the spatial distribution of land use/land cover changes over large areas. In this study, watershed and sub watershed of Kanari river was delineated using Geographic Information System (GIS) and LULC changes were investigated using Remote Sensing and GIS in Kanari Watershed, Tehsil Sihora, District Jabalpur, State Madhya Pradesh from the year 1990 to 2019. The study area was classified into eight categories on the basis of field study, geographical conditions, and remote sensing data. The comparison of LU/LC from 1990 to 2019 derived from toposheet and satellite imagery interpretation indicates that there is a significant increase in built-up area, mines, agriculture, wasteland and decrease in water body, forest and vegetation. In the past few years even though we have had excess rainfall in study area, this excess rain just washes off, causing serious flood downstream because of increasing mines, habitat and water pollution and decreasing vegetation. Nothing gets stored in the soil, thereby causing rivers to dry up during summer months.

Introduction

A river is freshwater flowing across the surface of the land, usually to the sea. Rivers provide us with fresh drinking water. It is one of the biggest source of fresh water. Around 96% of the water body consists of saline water which cannot be consumed by humans. As a result, we need to rely heavily upon the rivers for drinking water. Hence, if we don't have a good amount of it, life on earth will

come to an end. They form a part of the ecosystem which is very important to maintain the balance in the food chain. Rivers are also a source of energy. It helps in creating electricity. Rivers also help in improving the economy of a country. This is because they help in transportation of goods from one place to another. Import and export of goods in turn improves the economy of a country. They also help in irrigation, urban development, navigation and energy. Rivers

are soul satisfying. Currently, there are lot of emphasis is given by government for watershed management and planning for efficient utilization of water resources in order to achieve sustainable growth for agriculture and farmers. A watershed is an area of land that drains water into a specific pond, stream or river for which it is named. Watersheds have boundaries, called divides, located at relatively high elevations or ridges. Whenever you leave one watershed, you immediately enter another. A healthy watershed performs many functions. It serves to capture, store and recharge groundwater, filter out water pollutants, and safely release precipitation or rainwater as to avoid flood events during severe rainfall. A comprehensive approach to watershed management and best land use management practices has been embraced as a leading strategy to address threats to the natural environment and to improve the conditions within a watershed.

Land use/land cover (LULC) changes are among the most important applications of Earth Observation (EO) satellite sensor data. It provides a comprehensive and good understanding of ecosystem monitoring and functioning, and responses to environmental factors. Remote sensing techniques have been recognized as a powerful means to obtain information on Earth's surface features at different spatial and temporal scales.

Land use/land cover (LULC) changes play a major role in the study of global change. Land use/land cover and human/natural modifications have largely resulted in deforestation, biodiversity loss, global warming and increase of natural disaster-flooding. These environmental problems are often related to LULC changes. Therefore, available data on LULC changes can provide critical input to decision-making of environmental management and planning the

future. The growing population and increasing socio-economic necessities creates a pressure on land use/land cover. This pressure results in unplanned and uncontrolled changes in LULC. The LULC alterations are generally caused by mismanagement of agricultural, urban, range and forest lands which lead to severe environmental problems such as landslides, floods etc.

Remote sensing is presently in transition from a descriptive phase to a quantitative technology. Measurements may be carried out from the ground (field measurements) but the advantages of remote sensing applications in hydrology as a source of spatial information (in opposition to point measurements) becomes more obvious if sensors on air or spaceborne platforms are used. Geographic Information Systems (GIS) in addition to remote sensing have contributed significantly to applied hydrology in state and government monitoring and forecasting projects. GIS technology can provide resource managers and decision makers with tools for effective and efficient storage and manipulation of remotely sensed information and other spatial and non-spatial information. A Questionnaire is any written set of questions, while a survey is both the set of questions and the process of collecting, aggregating and analyzing the responses from those questions.

Keeping this in view the study was planned for Kanari River with the following specific objectives:

Delineation of watershed and subwater shed of Kanari River using Geographic Information System (GIS).

Temporal change detection through land use land cover classification using satellite image and Erdas Imagine Software.

Materials and Methods

Kanari River is a river of Madhya Pradesh state in Central India. The river originates at Ghutehi hill, whose, latitude is 23.56441 and longitude is 80.11622, which is situated in Ghutehi village, Tehsil Sihora, District Jabalpur of State Madhya Pradesh. Geographically, the origin is located at a distance of about 62 km at northeast of Jabalpur and 32 km at South west of Jabalpur and the location of the area falls on Survey of India Toposheet no. F44C2, F44C3 and F44B15. The average MSL of the Kanari river is 399-401 m and climatically it comes under subtropical region. This river joins the Suhar river, whose, latitude is 23.489271 and longitude is 79.98575, which is situated in Budhi Village, Tehsil Majholi, District Jabalpur of State Madhya Pradesh.

Location map of study area is presented on Fig. 1. The climate here is mild, and generally warm and temperate. Precipitation here is about 1277 mm/50.3 inch per year. Precipitation is the lowest in April, with an average of 6 mm/0.2 inch. Most precipitation falls in July and August, with an average of 419 mm/16.5 inch. At an average temperature of 33.4 °C/92.1 °F, May is the hottest month of the year. In December and January, the average temperature is 16.5 °C/61.7 °F. It is the lowest average temperature of the whole year. According the data collected from 1982 – 2012, between the driest and wettest months, the difference in precipitation is 413 mm/inch.

The wettest Month is July (244.9 mm avg) and windiest Month is June (5 km/h avg). The study area consists of a long narrow plain running north-east and south-west, and shut in on all sides by highlands. Topographically, the area has gentle rolling topography with 1-2 metre elevation difference. This plain, which forms an offshoot from the great valley of the Narmada, is covered in its western and southern portions by a rich alluvial deposit of black cotton-soil. At study area, the soil is black cotton soil, and water plentiful near the surface.

Data Collection

For preparing LU/LC of year 1990, Landsat-5 data was used which have a resolution of 30 metre. For preparing LU/LC of year 2004 and 2009, Landsat-7 and Landsat-8 data was used, which have also a resolution of 30 metre. For preparing LU/LC of year 2019, Sentinel-2A data was used, which have a resolution of 10 metre. All four satellite image data are of same season or month. All data are downloaded in the form of Geo TIFF. Topographic map was used in this study are F44C2, F44C3 and F44B15 (purchased from Survey of India Office, Jabalpur). Table 1 represents the data collection used in this study.

Delineation of watershed and subwatershed of Kanari River

Watersheds, also known as basins or catchments, are physically delineated by the area upstream from a specified outlet point. Watersheds can be delineated manually using paper maps, or digitally in a GIS environment. The process outlined in this document includes steps for delineating watersheds in ESRI's ArcGIS Desktop 10.3 software. For delineating watershed, Digital Elevation Model (DEM) data required of my area of interest. This DEM data is downloaded from USGS Earth Explorer.

Work environment set up

First of all, open ArcMap and create a new, blank map document. Use the Add Data button to add the DEM of study area to the

ArcMap. The projected coordinate system was used in this study is Indian 1975 UTM Zone 44N and geographic coordinate system was used in this study is WGS 1984 44N.

Creation of depressionless DEM

The fill tool in the Hydrology toolbox is used to remove any imperfections (sinks) in the digital elevation model.

Creation of flow direction grid

A flow direction grid assigns a value to each cell to indicate the direction of flow – that is, the direction that water will flow from that particular cell based on the underlying topography of the landscape.

Creation of flow accumulation grid

The flow accumulation tool calculates the flow into each cell by identifying the upstream cells that flow into each downslope cell. In other words, each cell's flow accumulation value is determined by the number of upstream cells flowing into it based on landscape topography.

Then, set the first break value to a threshold number that will assist with delineating channels. This value will be based on your data, and is really up to the analyst. In this study, 5000 value was used as a threshold, which means that cells that have less than 5000 upstream cells flowing into them will be symbolized differently than cells with more than 5000 upstream cells. Leave the second value as the maximum value in the grid.

Creation of outlet (pour) points

Pour point placement is an important step in the process of watershed delineation. A pour point should exist within an area of high flow accumulation because it is used to calculate the total contributing water flow to that given point.

Snapping pour points

The snap pour Point tool accomplishes two things; it snaps the pour point/s created in above step to the closest cell of high flow accumulation to account for any error during placement, and it converts the pour points to raster format for input to the Watershed tool.

Watershed delineation

Watershed tool was used for delineating the watershed of Kanari River.

Convert watershed rasters to polygons

Most users will find vector watersheds more useful than raster files in order to run further geo-processing and analyses. Raster files can be converted to vector format using the Raster to Polygon tool.

Method of delineation of Subwatershed using ArcSWAT

SWAT is a popular model among many watershed hydrologists who are interested in studying the impact of agricultural activities and land use management on the overall watershed health including stream flow and water quality.

Project Setup

The first step in using ArcSWAT is to set up a project so that necessary folders and databases are created to store all the data. Click on SWAT Project Setup then, click New SWAT Project. Locate the project directory. The swat project geodatabase, raster storage geodatabase and the SWAT parameter geodatabase automatically get a name.

Adding data

Add the DEM and land use of study area to the map document. They should be in an appropriate projected coordinate system.

Sub-watershed delineation

Click on Watershed Delineator, then, click Automatic Watershed Delineation. Once the watershed delineation window is activated, click on the open file button in DEM setup portion, and then click on select from map, and then select project DEM. By leaving the default DEM based option unchanged in the stream definition portion, click on Flow direction and accumulation button. After flow direction and flow accumulation is complete, the area box will be populated with some number. This is the critical stream area threshold that uses to define the stream network. Next, in the watershed outlets selection and definition, click on the select Whole watershed outlet button, and then select desired outlet location using the cursor. After the outlet is selected, the Delineate watershed button will be activated in green. Click on the delineate watershed button to delineate the watershed. Click OK on the delineation done message. After the watershed is delineated, you will see that a polygon feature class with sub-basins is added to the map document.

Temporal change detection through land use land cover classification

These studies were employed by using the remote sensing data of Sentinel 2-A and Landsat images of 1990, 2004, 2009 and 2019. First of all, toposheet map of study area was georeferenced using ERDAS imagine software. Then, open up the satellite image of the study area in ERDAS Imagine software and named 'watershed.img'. This satellite image is downloaded from USGS Earth Explorer or Natioinal Remote Sensing Centre NRSC, Hyderabad. The resolution size of Sentinel-2A data is 10 metre and landsat data is 30 metre, so the resolution of Sentinel data was changed from 10 metre to 30 metre. All four data have a same resolution of 30 metre. This method is very important for comparing pixel by pixel change detection. Then, unsupervised classification was done. Unsupervised classification option is present in raster tab.

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Initially, 50 number of classes choosed and then classified this image into 8 classes using digitization i.e. water bodies, agriculture, forest/mountain, wasteland, open field, mines, habitat, vegetation. Click on color scheme options button and choose approximate true color.

In the Table of Contents right click on the classified image and then go to Attribute Table. Scroll to the right of the attribute table and type in the particular land cover class names and change their respective color by visual inspection of the map. Save and close attribute table. Do a map layout of this image which is classified using unsupervised

classification. Editing of attribute tables of these images to try and pull out as many classes as possible (many rows will have the same class and color assigned).

There are many places where land use/land cover is different from actual land use/land cover. So, in order to correct it and for improving the accuracy assessment, an AOI is drawn of each wrong land use/land cover. Then, recode the each AOI in a particular class, which match with the real world situation.

Finally, create and include a map layout of each land use/land cover map of different year.

Performing accuracy assessment in ERDAS Imagine Software

It is important to note that there are always errors in land cover maps derived from the remote sensing data. Accuracy assessment is the process of estimating how accurate the land cover data are in terms of thematic categories, in order to determine whether the product meets the requirements of the intended application. Accuracy assessment is the general term used for comparing the land cover classification results to geospatial data that are assumed to be true. The assumed-true data are derived from ground referencing data or other reliable data sources. Accuracy assessment can provide a comparison on a category- by-category basis of classification results vs. known reference data.

Reference data are the points on the classified image for which actual data categories are known. The reference locations are usually randomly selected. Accuracy Assessment tool is found in raster tab. Then select Create/Add Random Points. A new window was open to set the settings for the accuracy assessment. In this study, stratified random sampling was used, so that we can have at least 10 random points for each class. There are now 100 points listed in the Accuracy Assessment window and notice that the class field is empty, this is to prevent a bias when declaring the class that the point represents.

The reference column was filled with the number of the class that it represents. Comparison of each class to the reference data was done. To find each point more easily, select the row of the point and then click View. Show Current Selection and it will just show the point which have selected. This was performed for each point.

Accuracy Report was generated contains Overall Accuracy, Producers Accuracy, Consumer Accuracy, Error Matrix, and K-statistic.

Results and Discussion

Delineation of watershed and subwatershed of Kanari River

The utility of satellite remote sensing and GIS for watershed delineation is emphasized in the present study. Remote Sensing (RS) and Geographical Information System (GIS) are the most advanced tools for the watershed development. The latest advances in Remote Sensing (RS) techniques provide spatial information that is normally difficult to obtain. The figure of watershed delineation and flow patterns of Kanari River is presented on Fig. 2 and Fig. 3.

The drainage ordering map based on Strahler (1964) suggests that the Kanari River watershed is a 5th order stream. Some important points associated with Kanari river watershed (study area) are river flow between Sihora and Majhauli district, Kanari river is 63 km long (Bah nala also include), the catchment area of the river is 298 km square,

38 Gram Panchayats are present in study area and the delineated watershed was further divided into 14 sub-watersheds. The figure of sub-watershed delineation of Kanari River is presented on Fig. 4.

Trend analysis of LULC (Temporal change detection through land use land cover classification)

This study attempts to assess the Land use Land cover change and their effects on the hydrological regime of Kanari River watershed at Jabalpur district. Mapping of present and historical land use/ land cover conditions in the Kanari River watershed at Jabalpur district was carried out for assessing the changes that have taken place mainly due to human induced activities.

Satellite images were used as the prime source for mapping land cover dynamics. SENTINEL (10 m. resolution), and LANDSAT 7 and LANDSAT 5 (30 m. resolution) data were used to prepare land cover maps for three instances 1990, 2004, 2009 and 2019 respectively. Classification, categorization and quantification were performed on the basis of spectral characteristics using unsupervised classification technique (Isodata clustering) and visual interpretation. GCP's (ground control points) were utilized to improve and validate classification scheme. The overall accuracy and Kappa Coefficient were found to be 90% and 0.8690 in 1990, 83% and 0.8016 in 2004, 85.40% and 0.8328 in 2009, 84.44% and 0.8126 in 2019 respectively. The analysis of the changes that has taken place from 1990 to 2004, 2004 to 2009 and from 2009 to 2019 is presented in Fig. 5 to Fig. 9 and Table 2. The Land use Land cover analysis as shown in table and figure above, indicate that in the year 1990, a area under water body is 2366.45 hectare, a area under

agriculture is 2933.7 hectare, a area under forest/mountain is 11984.7 hectare, a area under wasteland is 119.827 hectare, a area under open field is 3771.41 hectare, a area under mines is 46.1703 hectare, a area under habitat is 147.763 hectare and area under vegetation is 8533.41 hectare.

In year 2004, a area under water body is 400.68 hectare, a area under agriculture is 12891.8 hectare, a area under forest/mountain is 7675.83 hectare, a area under wasteland is 347.58 hectare, a area under open field is 1212.84 hectare, a area under mines is 263.16 hectare, a area under habitat is 770.67 hectare and area under vegetation is 6377.58 hectare.

In year 2009, a area under water body is 268.38 hectare, a area under agriculture is 16981.5 hectare, a area under forest/mountain is 6535.08 hectare, a area under wasteland is 862.11 hectare, a area under open field is 1052.01 hectare, a area under mines is 316.44 hectare, a area under habitat is 803.79 hectare and area under vegetation is 3094.83 hectare.

In year 2019, a area under water body is 187.11 hectare, a area under agriculture is 18507.1 hectare, a area under forest/mountain is 4417.92 hectare, a area under wasteland is 1205.64 hectare, a area under open field is 591.75 hectare, a area under mines is 360.63 hectare, a area under habitat is 1617.8 hectare and area under vegetation is 3030.39 hectare.

The trend of land use land cover transformation was continued further, which is evident from the Table and Figure. After passage of about 29 years i.e. by the year 2019, the land use land cover over the study area has experienced more significant changes. The study shows a substantial loss of vegetation and plantation/forest area which has been ultimately converted to crop land and settlement (Built-up, Roads etc) area.

Table.1 Data collection

S.No.	Acquisition Date	Data Set	Producer	Type	Location
1	01-11-1990	Landsat-5	NRSC	Geo TIFF	Sihora, Jabalpur
2	01-11-2004	Landsat-7	USGS	Geo TIFF	Sihora, Jabalpur
3	01-11-2009	Landsat-8	USGS	Geo TIFF	Sihora, Jabalpur
4	01-11-2019	Sentinel-2A	USGS	Geo TIFF	Sihora, Jabalpur

Table.2 Area covered by various LULC categories in hectares

| CLASS NAME	YEAR			
	1990	**2004**	**2009**	**2019**
Waterbody	2366.45	400.68	268.38	187.11
Agriculture	2933.7	12891.8	16981.5	18507.1
Forest/Mountain	11984.7	7675.83	6535.08	4417.92
Wasteland	119.827	347.58	862.11	1205.64
Open field	3771.41	1212.84	1052.01	591.75
Mines	46.1703	263.16	316.44	360.63
Habitat	147.763	770.67	803.79	1617.8
Vegetation	8533.41	6377.58	3094.83	3030.39

Fig.1 Location map of the study area
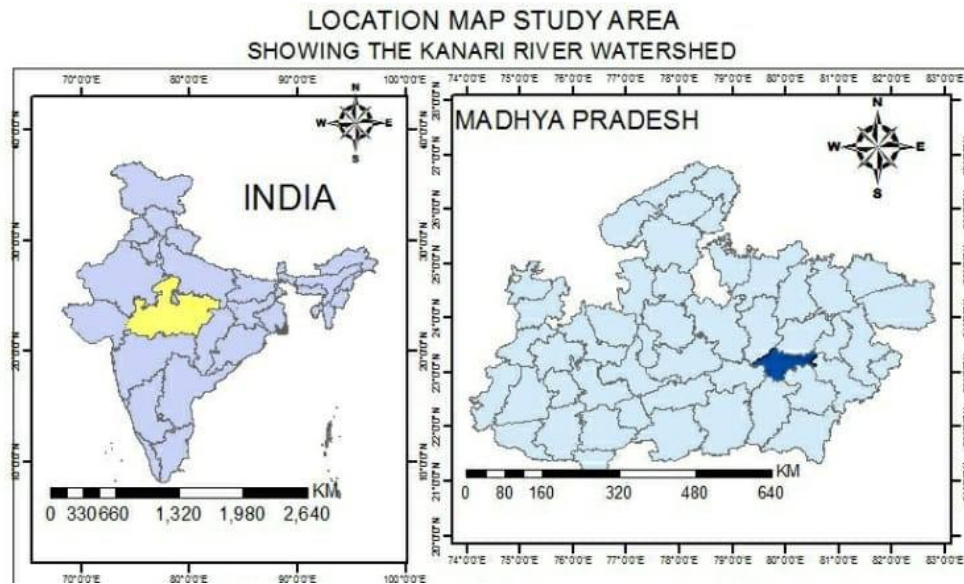
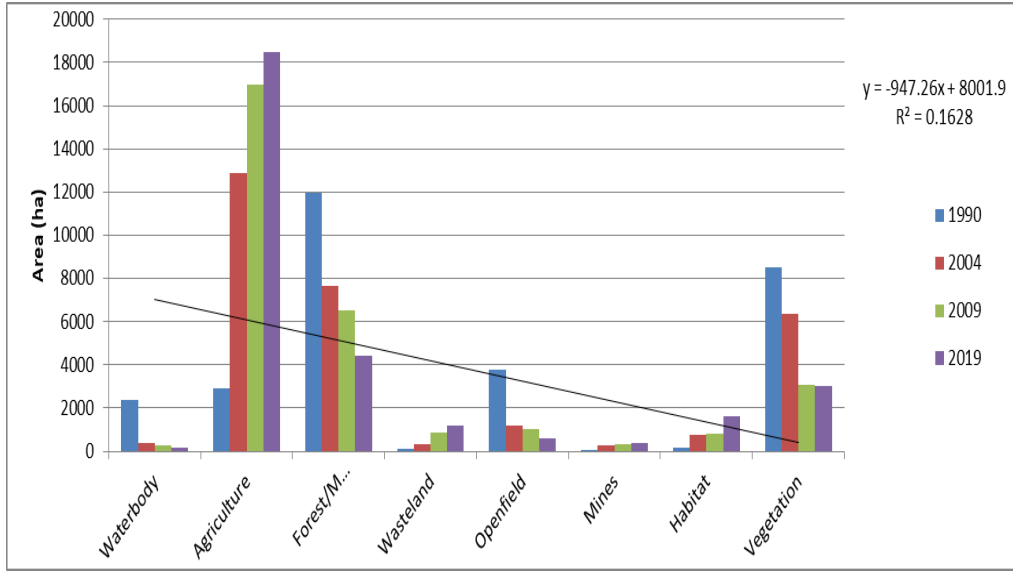**Fig.2** Image of watershed of Kanari River

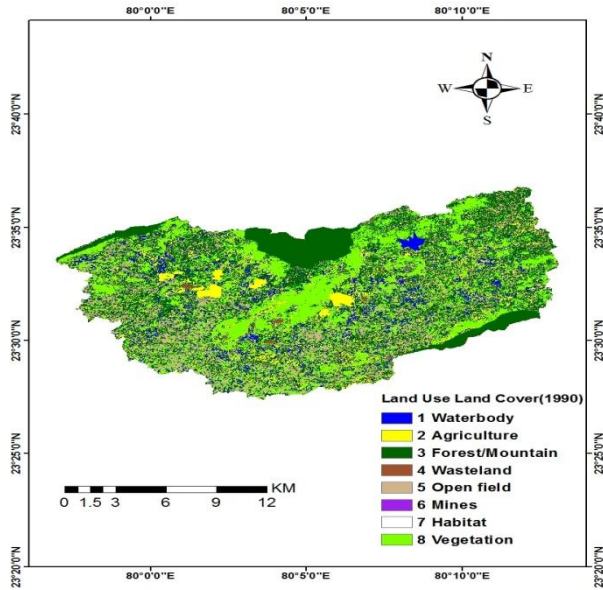**Fig.3** Stream order classification of Kanari River watershed
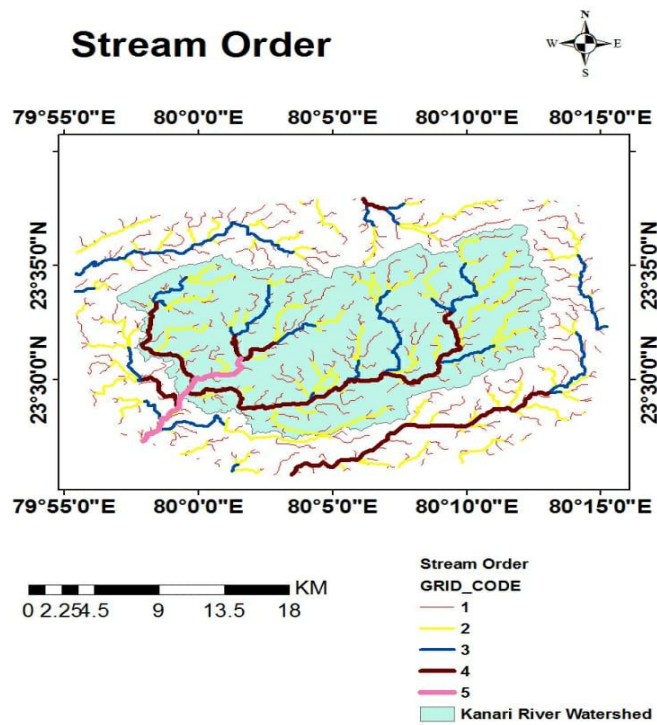
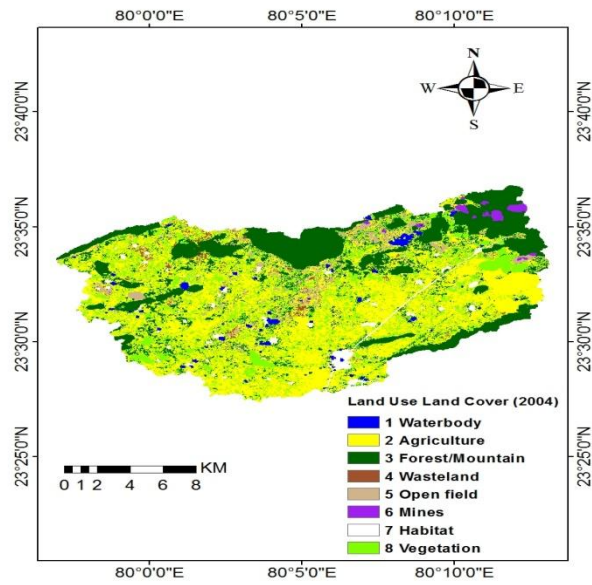**Fig.4** Image of subwatershed of Kanari River

Fig.5 LULC change status at four epochs: Year 1990, 2004, 2009, 2019
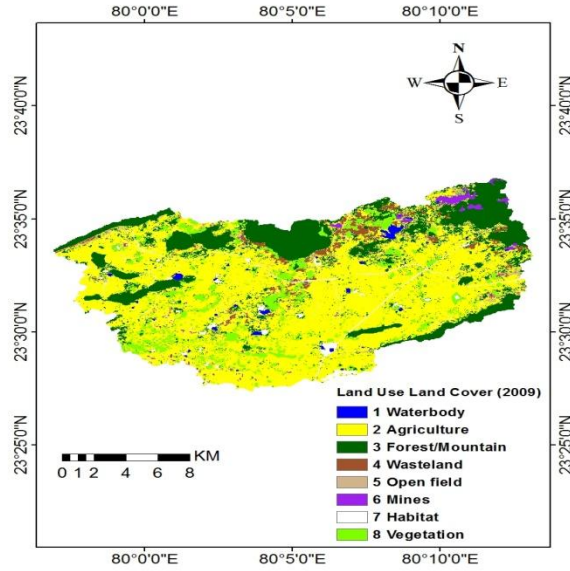

Fig.6 Land Use Land Cover map of the study area Kanari River Watershed, Jabalpur District, 1990
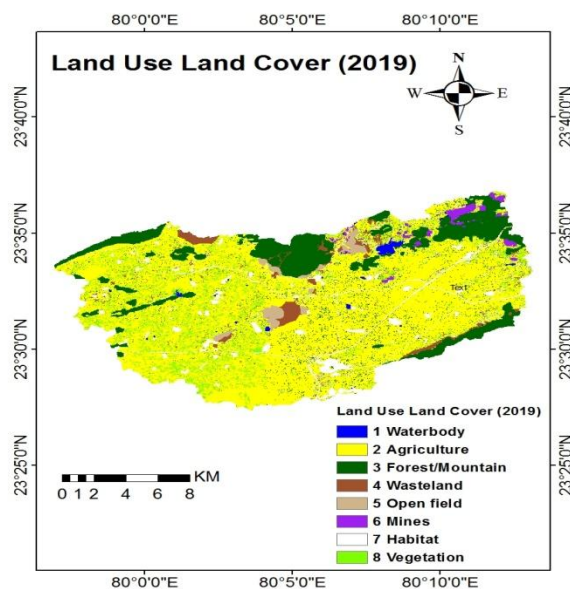
Fig.7 Land Use Land Cover map of the study area Kanari River Watershed, Jabalpur District, 2004

Fig.8 Land Use Land Cover map of the study area Kanari River Watershed, Jabalpur District, 2009

Fig.9 Land Use Land Cover map of the study area Kanari River Watershed, Jabalpur District, 2019

The major land area being shifted to settlement land is of great concern as it poses risk of soil loss through erosion caused by surface runoff. It also reduces infiltration and percolation characteristics thus again posing risk of reduced groundwater replenishment from rainfall. This type of land area loss is of great concern and major bottleneck for soil loss and crop production.

The utility of satellite remote sensing and GIS for watershed delineation is emphasized in the present study. Remote Sensing (RS) and Geographical Information System (GIS) are the most advanced tools for the watershed development. The drainage ordering map based on Strahler (1964) suggests that the Kanari river watershed is a 5th order stream. Kanari river is 63 km long (Bah nala also include). The catchment area of the river is 298 km square. 14 subwatershed delineated in Kanari River. The LULC map was developed for the Kanari river watershed with the help of satellite remote sensing for the time series of 1990, 2004, 2009, 2019 and the accuracy assessment was also performed.

The result shows that waterbody area, forest area, vegetation area goes on decreasing in the study area and mines area, habitat area, agriculture field area are goes on increasing in the study area. In the past few years even though we have had excess rainfall in study area, most of the rain is received in a few days. This excess rain just washes off, causing serious Floods downstream because of increasing mines, habitat and water pollution and decreasing vegetation. Nothing gets stored in the soil, thereby causing rivers to dry up during summer months. Rivers initially turn from perennial to seasonal and eventually dry up, when there's not enough rainfall in the hills.

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