Chapter 9
Impact of Land Use/Land Cover Changes on Climate Change Parameters

Ratnakar Swain

Abstract Urbanization and industrialization are responsible for a variety of environmental issues like air pollution, increased runoff and subsequent flooding, increase in temperature, and deterioration of water quality. It is evident that for environment management and decision-making process especially in climate impact analysis, the study of land use/land cover (LULC) plays a vital role. The aim of this study is analyzing the climate change response due to land use/land cover (LULC) changes in the eastern India's Brahmani River Basin that experienced a fast increase in industrialization and deforestation in the recent decades. Herein, the Landsat satellite images were collected from the United States Geological Survey (USGS) from year 1975 to 2018 and processed in ERDAS Imagine software. The whole LULC mapping involves (1) geo-referencing, (2) mosaicking, (3) sub-setting on the basis of Area of Interest (AOI), (4) development of signature files, and (5) classification. The supervised classification method is followed herein to classify the study area with delineated classes such as water bodies, sand, barren/crop land, forest area, and built-up area. The study reveals that the major land cover in the study area is dense forest which decreases from 71.70% to 14.85% from year 1975 to 2018. The second major category of land is barren/crop land, which was increased by 30% due to development in agricultural technology, irrigation facilities. The third category of land cover is built-up area which increases by 32.73% from year 1975 to 2018 due to man-made activities. The sand comes under the fourth category which has slightly increased 6.57% to 7.05%. The least area covered by water bodies which is the fifth category of land cover was 0.33% in the year 1975 which increased to 1.65% in the year 1999 due to the construction of Rengali Dam and Samal Barrage but subsequently decreased to 0.87% in 2018. Hence, it is verified that the industrialization and development activities cause heavy deforestation in the catchment. It is also proved that the remote sensing satellite data can be efficiently used for the spatio-temporal changes in LULC in real time.

R. Swain (✉)
Department of Civil Engineering, National Institute of Technology, Rourkela, Odisha, India
e-mail: swainrk@nitrkl.ac.in

P. K. Shit et al. (eds.), *Geospatial Technology for Environmental Hazards*, Advances in Geographic Information Science, https://doi.org/10.1007/978-3-030-75197-5_9

Keywords LULC · ERDAS · Remote sensing · Brahmani River Basin · Landsat satellite

9.1 Introduction

Land use and land cover (LULC) analysis plays a crucial role in studying climate change parameters. As per the US National Research Council (NRC, 2005), LULC should be studied for the climate change analysis. Due to changes in vegetation, urbanization, and agriculture land, the greenhouse gases, CO_2 emission, CO_2 absorption, and other atmospheric changes occur (NRC, 2005). There is a huge impact of LULC changes on climatic conditions like temperature, precipitation, humidity, etc. in global and regional scale. NRC report also suggests that changes in landscape and human settlement have greater influence on ecological cycle and energy cycle which has link with climatic response. Different organization like International Geosphere-Biosphere Programme (IGBP) and the Global Energy and Water Cycle Experiment (GEWEX) also gives importance to LULC on climate change studies. In literature, it is proved that the deforestation and urbanization are mainly responsible for changes in daily peak rainfall and trends of rainfall (Kishtawal et al., 2010; Petchprayoon et al., 2010; Swain & Sahoo, 2015; Swain et al., 2018).

Petchprayoon et al. (2010) described changes in stream flow in the Yom River Basin due to change LULC particularly urbanization. Similarly, Sertel et al. (2010) verify the impact of land cover changes on climate parameters like temperature. Moreover, the changes in the island of Indonesia were studied by Tokairin et al. (2010) using meso-scale model and found that the human settlement and deforestation are prime reasons of the climate change. Also, Costa and Pires (2010) studied the tropical forest region of South America and concluded that the deforestation over the period of time changes the rainfall pattern and quantity. Lawrence and Chase (2010) studied the simulation of global climate with existing and maximum possible vegetation without any that anthropogenic LULC changes. In the southern region of the USA, agricultural especially the winter crop like wheat is the main responsible for the change in regional surface temperature as stated by Ge (2010). The effect of Three Gorges Dam is also being analyzed to study the changes in hydro-meteorological characteristics of the basin (Xiao et al., 2010).

From India's perspective, various studies have been conducted in different catchments of India to analyze the impact of LULC changes on climate change parameters. Hengade and Eldho (2016) studied both climate and LULC changes using VIC model in Ashti River Basin of India. Similarly, Khan et al. (2019) conducted a study on peninsular river basin in India to estimate future scenario of flow and sediment load under changes in climate and LULC. Moreover, the impact of LULC change on streamflow is assessed by Sinha et al. (2020a, 2020b). Sinha et al. (2020a, 2020b) used hydro-meteorological data of river basin of Western Ghat, India, and found there is a significant impact of both climate and LULC on streamflow in river. Impact of LULC and climate changes on river streamflow were also analyzed by Chanapathi and Thatikonda (2020) in Krishna River Basin, India. Chanapathi and Thatikonda (2020) and Garg et al. (2017) prove that the present and future scenario of LULC changes plays a major role in changing the river streamflow. With the streamflow characteristics, the sediment yield is directly affected by the change in climate and LULC in Netravati River Basin, Western Ghats, India, as shown by Sinha et al. (2020a, 2020b) and Sinha and Eldho (2018). Dynamics of hydrometeorological parameters such as evapotranspiration, surface runoff base flow and infiltration also is altered by the change in LULC in eastern India' river basin (Das et al., 2018). Furthermore, impact of LULC changes on streamflow response was studied in Tons River Basin, India, by Kumar et al. (2018), and in Nethravathi River Basin, India, by Babar and Ramesh (2015). A similar study is conducted in Tapi River Basin to analyze the streamflow as well as sediment yield. Nilawar and Waikar (2019) found serious impacts of climate change and LULC on streamflow and sediment concentration Purna River Basin, India.

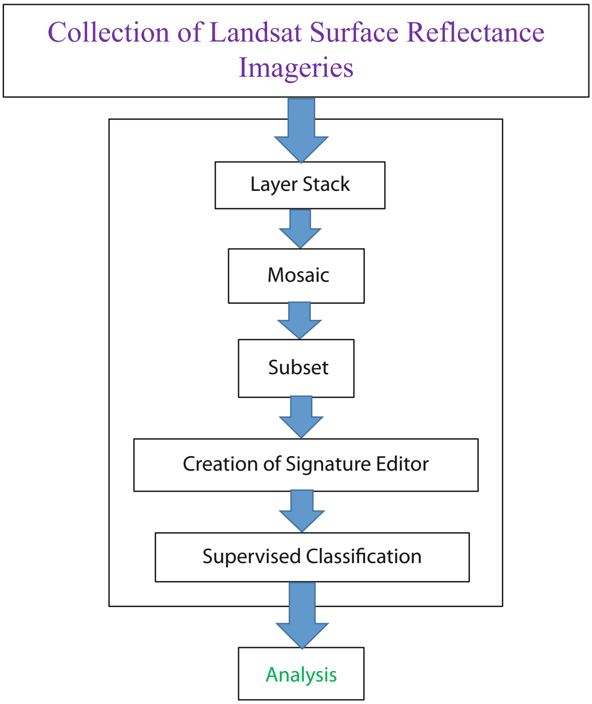
Many studies have been conducted by several authors across the globe and concluded that the disturbance in the LULC highly impacts the regional climate condition (Takahashi et al., 2010; Xiao et al., 2010; Strengers et al., 2010; Lawrence & Chase, 2010; Swain & Sahoo, 2015). Herein, the Brahmani River Basin of Odisha state of Eastern India is chosen due to various anthropogenic activities over the last 4–5 decades. Especially after the construction of Rengali Dam in the Brahmani River, there are huge agricultural activities which disturb the LULC of the basin. Moreover, the vast industrial setup in the basin is also the prime reason of human settlement which is responsible for deforestation and vegetation change (Swain & Sahoo, 2017a, b). In this study, the LULC changes have been studied over the last four decades. Impact of the LULC changes is verified with the change in climate change parameters like extreme temperature, extreme daily rainfall pattern, and extreme relative humidity. In the last, the peak streamflow at Jenapur a downstream gauging station in the Brahmani River is analyzed.

9.2 Methodology

Multispectral LULC classification is widely used in planning and management of the forest area and urban and rural area over the long period especially after development of various satellites (Hord, 1982). Nowadays due to development of different remote sensing satellites of various spatio-temporal resolutions, LULC mapping becomes more informative and also cost effective. Remote sensing techniques play a vital role in predicting LULC changes accurately (Comber et al., 2005; Townshend, 1992).

Recently, satellite images are widely used for the large-scale studies like LULC, landscape mapping, hydrological studies, etc. Herein, the freely available Landsat satellite images are used for the LULC mapping due to its 30 m × 16-day spatio-temporal resolution. All the Landsat-6, Landsat-7 TM, and Landsat-8 ETM as per the availability over the time period and study area are used for making the LULC

Fig. 9.1 Procedure of supervised LULC classification



mapping. ERDAS IMAGINE software is used for geo-referencing, mosaicking, and sub-setting of the images on the basis of area of interest (AOI). The LULC classification is carried out using supervised image classification algorithm. In this algorithm, firstly, pixel signature is assigned and then five types of landscape are provided based upon the digital number (DN) (Fig. 9.1). The delineated classes were crop land, sand, water bodies, built-up areas, and deciduous broad leaf forest which are identified in the study area. Maximum likelihood method of supervised classification is flowed here in which the classification is done based upon the training sets provided and field knowledge. The procedure to carryout supervised classification using ERDAS IMAGINE is described in Fig. 9.1. Herein, five types of signature are provided such as (1) barren/crop land, (2) sand, (3) water bodies, (4) built-up areas, and (5) dense forest.

After LULC mapping, the important climate change parameters such as extreme precipitation, maximum temperature, peak relative humidity, and maximum streamflow are taken into consideration for the analysis. Over the period of LULC study, all these hydro-meteorological data are plotted in time-series, and peak values are used in the analysis. The nonlinear regression-based trend analysis of the climate parameter is carried out to study the impact of LULC. The extreme values of climate parameters such as annual maximum temperature, maximum daily rainfall, and annual maximum relative humidity are taken into trend analysis. The daily average temperature and relative humidity over the study period are also considered to find any regional change in pattern. Since relative humidity and temperature have a vital role in changing precipitation, the daily peak over the years is added in the analysis. LULC also plays major role in change in infiltration and surface runoff. Therefore, the change in peak streamflow over the study period at the basin outlet is also considered in the analysis. It is evident that the industrial, domestic, and agricultural demand also affect streamflow characteristics along with LULC change. Therefore, it is difficult to relate streamflow with LULC change.

9.3 Study Area and Data Collection

Herein, the Brahmani River Basin, the second largest river of Odisha, is considered for the study due to vast industrialization and deforestation of its catchment. The Brahmani River is formed by the confluence of the Sankh and South Koel rivers, near the major industrial town of Rourkela at 22 15′N and 84 47′. After flowing through the districts such as Cuttack, Angul, Jajpur, Kendrapara, and Sundargarh, the Brahamani River forms a delta with the Baitarani River near Bay of Bengal. The total length of the rivers including its constituent streams is about 799 km of which 541 kilometers are in Orissa. Catchment area of the basin is about 39,033 km^2 (15,071 mi^2) in Odisha alone. The Brahmani River Basin is located in northern latitude of 20°28′ to 23°35′ and east longitude of 83°52′ to 87°03′. In the Brahmani River, there are many hydraulic structures constructed in the last 4–5 decades. Among the major structures are Rengali Dam and Samal Barrage located near Angul and Talcher town of the basin, respectively. The mean annual rainfall of the basin is around 1460 mm. 70–80% of rainfall occur only during southwest monsoon in the period of June–October. In the Bay of Bengal, low pressure and cyclonic precipitation is common throughout the year. The summer climate is hot, and gradually the peak temperature increases every year. The winter climate is medium cold, and temperature ranges from 10 to 15 °C. The peak temperature during summer varies from 38 to 50 °C (Figs. 9.2 and 9.3).

The Landsat satellite images of the study area were collected from USGS Earth Explore website (https://earthexplorer.usgs.gov/). The 33 years (1979–2012) daily stage and discharge data available at Jenapur gauging stations were collected from the Water Resources Information System (WRIS), India. The 0.50 lat-long gridded daily meteorological data for the study area for the same period were also collected from the Climate Forecast System Reanalysis (CSFR), India. The daily scale meteorological variables of maximum temperature, minimum temperature, rainfall, and relative humidity were downloaded for the study period from 1979 to 2014 (https://climatedataguide.ucar.edu/climate-data/climate-forecast-system-reanalysis-cfsr). To get the average LULC of the study area representing the study period, the available cloud-free Landsat images of November 19, 1975, and January 9, 2018, were downloaded from http://www.earthexplorer.usgs.gov. The various images collected are mentioned in Table 9.1.

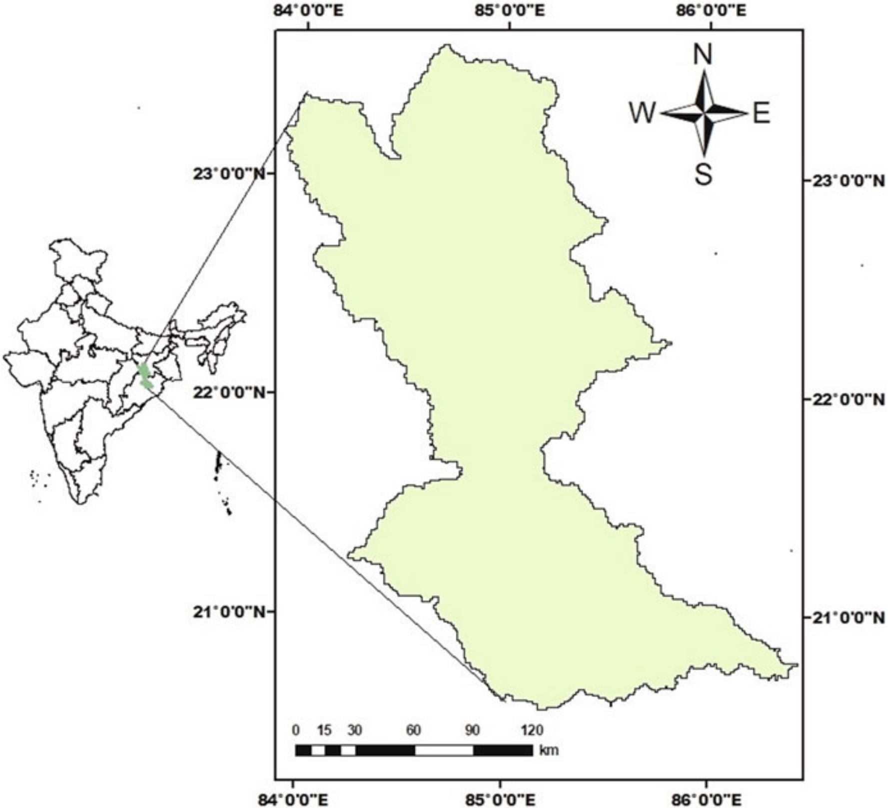
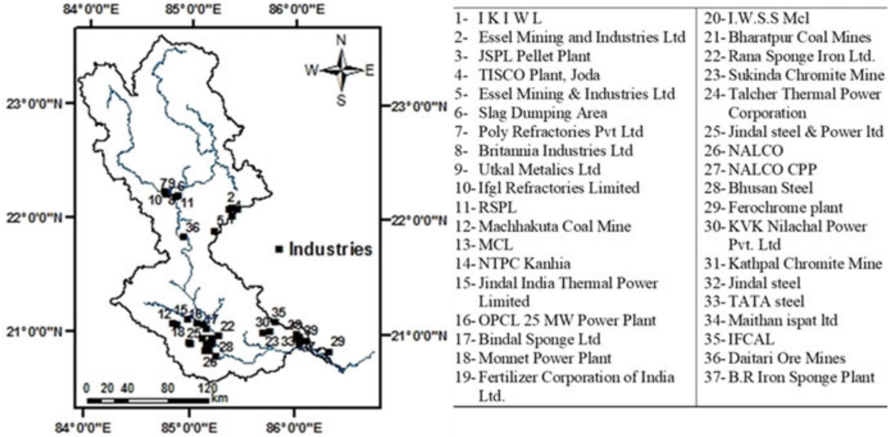


Fig. 9.2 Index map of Brahmani River Basin



1- I K I W L
2- Essel Mining and Industries Ltd
3- JSPL Pellet Plant
4- TISCO Plant, Joda
5- Essel Mining & Industries Ltd
6- Slag Dumping Area
7- Poly Refractories Pvt Ltd
8- Britannia Industries Ltd
9- Utkal Metalics Ltd
10- Ifgl Refractories Limited
11- RSPL
12- Machhakuta Coal Mine
13- MCL
14- NTPC Kanhia
15- Jindal India Thermal Power Limited
16- OPCL 25 MW Power Plant
17- Bindal Sponge Ltd
18- Monnet Power Plant
19- Fertilizer Corporation of India Ltd.
20- I.W.S.S Mcl
21- Bharatpur Coal Mines
22- Rana Sponge Iron Ltd.
23- Sukinda Chromite Mine
24- Talcher Thermal Power Corporation
25- Jindal steel & Power ltd
26- NALCO
27- NALCO CPP
28- Bhusan Steel
29- Ferochrome plant
30- KVK Nilachal Power Pvt. Ltd
31- Kathpal Chromite Mine
32- Jindal steel
33- TATA steel
34- Maithan ispat ltd
35- IFCAL
36- Daitari Ore Mines
37- B.R Iron Sponge Plant

Fig. 9.3 Location of major industries over Brahmani River Basin (Swain & Sahoo, 2017b)

Table 9.1 Specification of Landsat surface reflectance imageries used

Data	Period	Date
Landsat-MSS	1970–1980	November 19, 1975
Landsat-TM	1980–1990	February 8, 1988
Landsat-ETM	1990–2000	November 29, 1999
Landsat-2005	2000–2005	November 5, 2005
Landsat 8	2015–2020	January 9, 2018

9.4 Result and Discussion

LULC Classification

The supervised classification of LULC of the Brahmani River Basin over the years 1975–2018 are shown in Fig. 9.4a–c. The maroon color represents the built-up area, dark green color represents the forest area, blue color shows the water bodies, yellow color shows the crop land, and white shows the sand. The areas under each classification were calculated in km^2 and expressed in percentage (%). The areas under water bodies, sand, barren/crop land, forest area, and built-up area were subsequently entered in the table along with their respective dates. Classified images depict spatial distributional pattern of land use/cover of the Bramhani Basin for the year 1975–2018.

These data reveal that in 1975, about 71.70% (29,517 km^2) of area were under forest, 27.41% (11,284 km^2) under crop/barren land, 00.00% (0 km^2) under built-up land and 0.33% (134.34 km^2) under water body, and 0.56% (230.30 km^2) under sand. During 1988, the area under these land categories was found about 14.85% (22,369 km^2) forest, 34.7% (14,273 km^2) crop/barren land, 7.13% (2933 km^2) sand, 2.69% (1105.29 km^2) built-up land, and 1.11% (457.63 km^2) water body, whereas in 1999, it was found that about 39.39% (16,205 km^2) belongs to forest, 54.79% (22,538 km^2) crop/barren land, 2.87% (1182 km^2) sand, 1.3% (532.96 km^2) built-up land, and 1.65% (679 km^2) water body. During 2005 the area of deep forest was 29.18% (10,836 km^2), the area of crop/barren land 62.06% (23,044 km^2), the area of sand 0.12% (45.89 km^2), area of built-up land 7.49% (8454 km^2), and 1.13% (562.49 km^2) under water body. During 2018, the area under these land categories was found about 54.38% (5514 km^2) under forest, 51.46% (19,107 km^2) under crop/barren land, 0.08% (31.40 km^2) sand, 32.73% (12,153 km^2) under built-up land, and 0.87% (322.46 km^2) under water body.

Analysis of Change in LULC

The LULC change from year 1975 to 2018 is shown in Figs. 9.5 and 9.6. Figure 9.1 shows that the area of dense forest was high in 1975, i.e., 71.70%; eventually it was decreasing linearly to only 14.85% at the current time period. So, there is a huge loss of vegetation, and ultimately it has a great impact on the climate and rainfall. Also, it

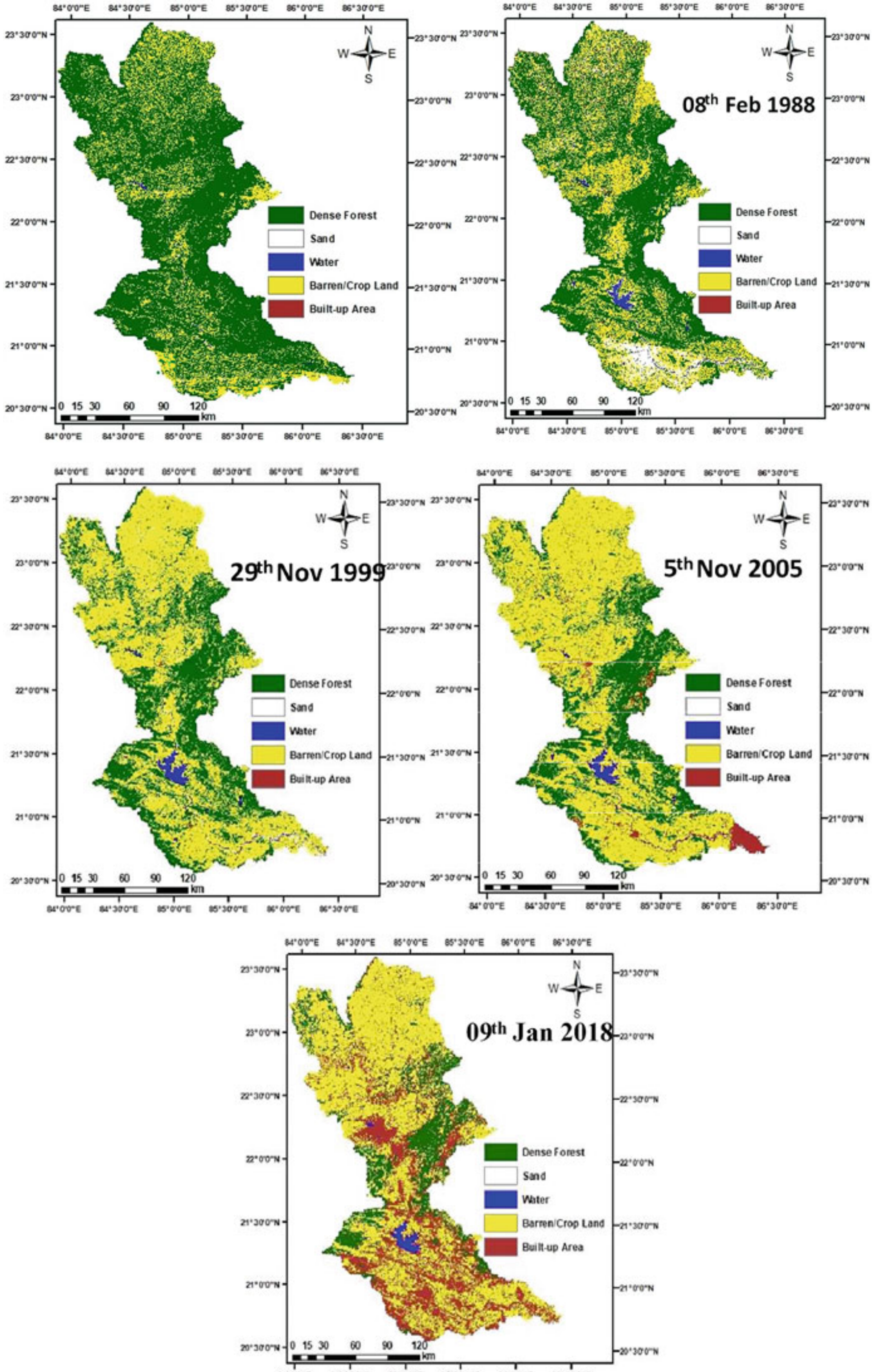


Fig. 9.4 (**a**) LULC classification of the Brahmani River Basin of dated November 19, 1975, and February 8, 1988. (**b**) LULC classification of the Brahmani River Basin of dated November 29, 1999, and November 05, 2005. (**c**) LULC classification of the Brahmani River Basin of dated January 9, 2018

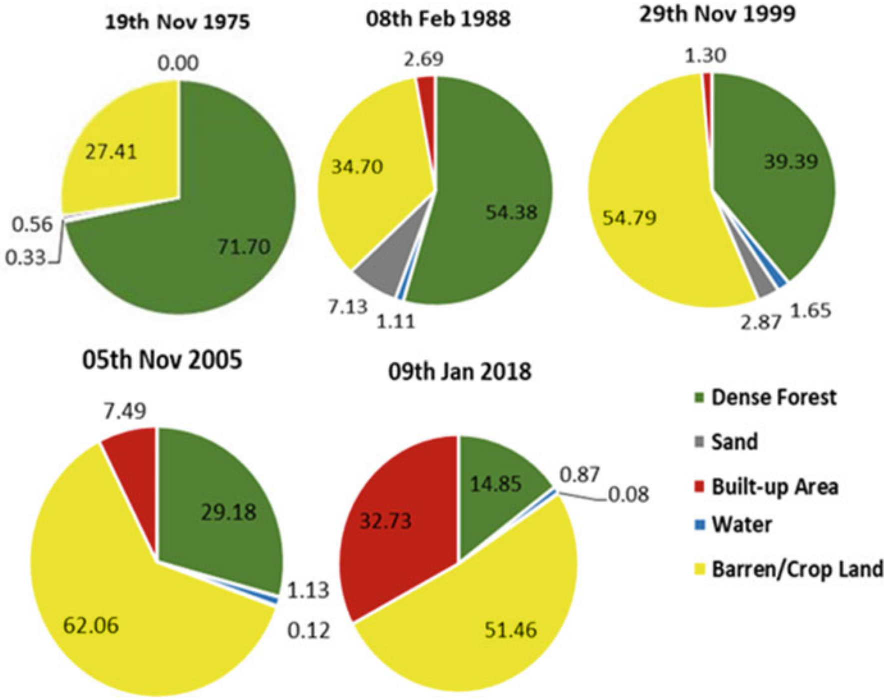


Fig. 9.5 Representation of LULC changes of Brahmani River Basin (%)

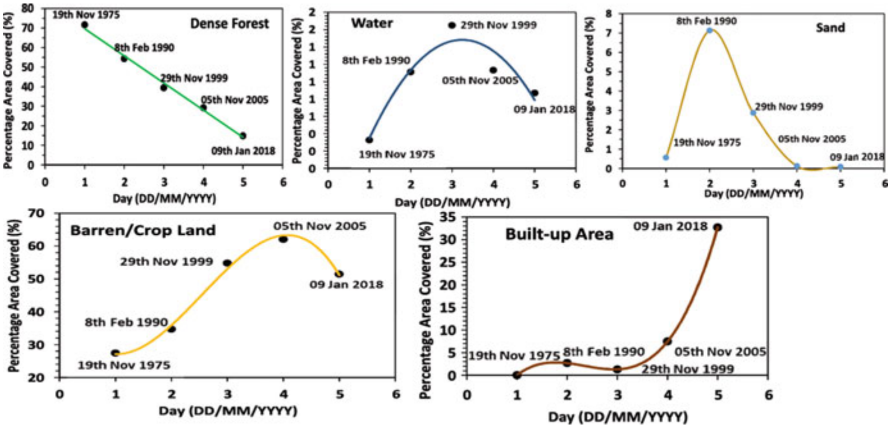


Fig. 9.6 Graphical representation of change in different land cover from 1975 to 2018

is clear from the table that in 1975, the water bodies are only 0.33% of the total area, but it is somehow increased to 1.65% in 1999 due to the construction of Rengali Dam and Samal Barrage. Then it is again decreased to 0.87% in current time period.

The area of sand was only 0.56% in 1975, and it reached to a pick of 7.13% in 1988, and it is again decreased to 1.13% and 0.08% in 2005 and 2018, respectively.

There was only 27.41% of crop land in 1975 due to the lack of irrigation facilities, but subsequently it increased to 62.06% in 2005. It is also clear from the table that there is a negligible portion of residential or built-up areas in 1975, but it increased in a steadily to 2.69% in 1988. And there is again a fall in built-up area in 1999, i.e., from 2.69 to 1.30%. Thereafter it increased to 7.49% in 2005, and at the current stage, it is 32.73%. The various graphs were also plotted for the change in the parameters of land cover with respect to the time period.

Analysis of Change in Climate Change Parameters

It is clear from the above analysis and from Figs 9.5 and 9.6 that the area of dense forest was very high in 1975, i.e., 71.70%; eventually it is decreasing in a linear manner to only 14.85% at the current time period. So, this indicates a very negative impact on our environment. So, there is a huge loss of vegetation, and ultimately it has a great impact on discharge, temperature, rainfall, and relative humidity (Figs. 9.7, 9.8, 9.9, and 9.10). The precipitation data from period 1979–2014 over the study area shows that the maximum of daily peak rainfall is increasing gradually (Fig. 9.7). The average first 5-year data and last 5-year data from the period 1979–2014 shows that there is 45% increase in peak rainfall. However, the average annual rainfall over the Brahmani River Basin is 1460 mm (Swain & Sahoo, 2015) which remains constant approximately. However, the maximum of daily peak rainfall increases in the pattern of exponential growth as shown in Fig. 9.7. Although the value of exponential power component value is only 0.0286 and coefficient of correlation (R^2), small increase in peak rainfall is the main responsible for frequent

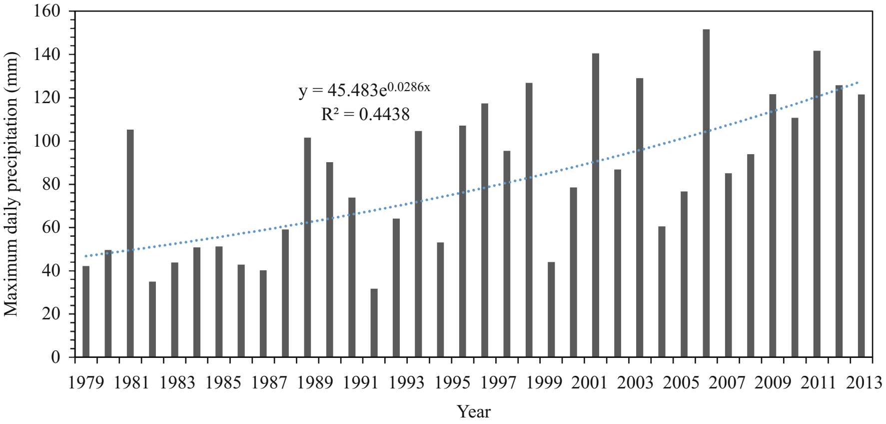


Fig. 9.7 Change in maximum daily maximum rainfall (mm) over the years 1979–2014

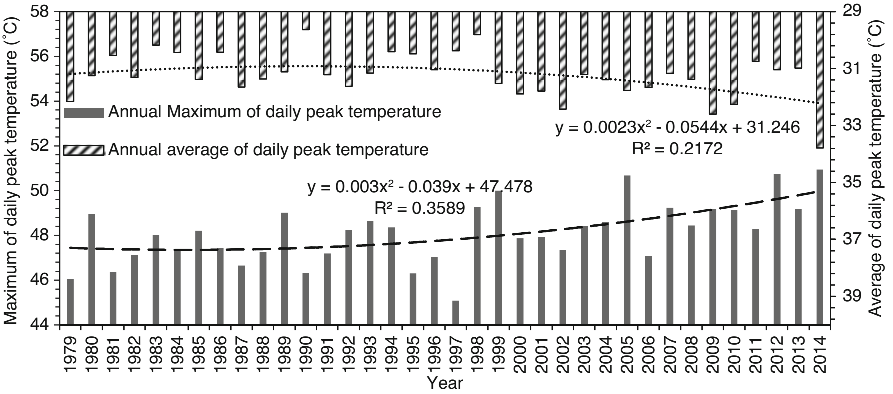


Fig. 9.8 Change in maximum and average of daily peak temperature (°C) over the years 1979–2014

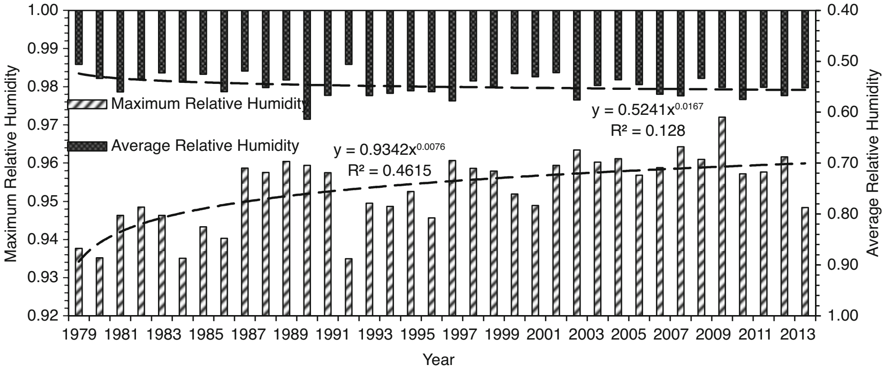


Fig. 9.9 Change in maximum and average of daily peak relative humidity (%) over the years 1979–2014

flood in the whole region. Rainfall water couldn't get sufficient percolation time for the infiltration and so surface runoff increases due high intensity of rainfall which causes sudden flood in the basin and downstream of the basin.

The maximum and average of daily peak temperature data is plotted as shown in Fig. 9.8. The peak temperature is one of the main parameters of climate change. Both the trend lines show that the maximum and average of peak temperature increase with nonlinear temporal pattern as shown in Fig. 9.8. Here also it is observed that the values of coefficients of the regression equation and R^2 are very small. However, the increase in peak temperature is a matter of concern although it is gradual. The data shows that there is 8.6% and 4.6% increase in maximum and average of daily peak temperature respectively from year 1979 to year 2014. This increase in temperature can be correlated with deforestation and hence with LULC in the local and global

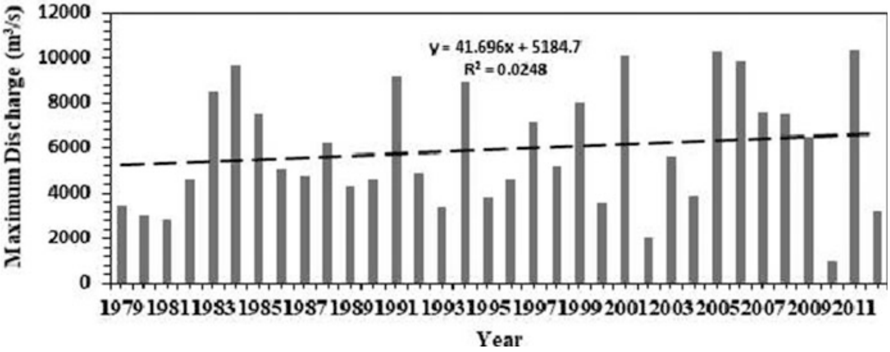


Fig. 9.10 Change in annual maximum flood at Jenapur gauging station

scale. Similarly, the maximum and average of daily peak relative humidity is plotted as shown in Fig. 9.9. Here also similar trend of temporal change is found in both maximum and average of peak relative humidity. The data shows that there is 9.9% and 1.14% increase in average and maximum values of daily peak relative humidity from year 21,978 to 2014, respectively. The temperature rises over the region which increases evaporation in the basin and water body of Bay of Bengal at downstream of the Brahmani River Basin, having an effect on relative humidity largely. Therefore, there is indirect effect of LULC and deforestation on the relative humidity.

The streamflow data of Jenapur gauging station which is located toward downstream of Brahmani River is collected from Central Water Commission (CWC). The annual maximum discharge is plotted from year 1978–2014. The trend line shows that the peak flood at the Jenapur gauging station varies linearly with time. Here also the value of R^2 is only 0.0248. Low R^2 value doesn't show strong linear correlation of peak flood with time. Although all climate parameters such as maximum temperature, relative humidity, and precipitation changes with the LULC change over the region in local as well as global scale, the streamflow data depends indirectly on change in LULC. It is evident that in a basin, the change in streamflow at any gauging station depends upon many factors such as LULC change, precipitation, soil type, water demand, etc. Due to increase in agricultural and industrial growth along with human settlement in the Brahmani River Basin, the demand of water also increased drastically. Therefore, the peak flood data is likely to be biased if only the effect of LULC change is considered. Therefore, peak flood data at Jenapur station is considered to be not following any trend line. Although LULC change have major impact on the peak flood, other important factor like water demand needs to be taken into consideration in the study.

9.5 Conclusion

The LULC study reveals that there are major changes in the LULC over the years 1975–2018 in the study area especially dense forest cover. The area under dense forest decreased by 57% due to an increase in urbanization and agriculture. The second major category of land in the study area is barren/crop land, which was increased by 30% due to development in agricultural technology, irrigation, transportation facilities, etc. The third major category of land in the study area is built-up area which is increasing by 32.73%. During the study period (i.e., 1975–2018), built-up area has been increased due to advancement of communication, transportation, and agricultural activities. The area under fourth category of land, i.e., the sand, has increased at the first stage by 6.57%, and in the later stage it is decreased by 7.05%. Hence, the present study proves that remote sensing technology can be efficiently used for the spatio-temporal changes in catchment cover no cost and in real time.

From this study, we clearly found the decrease in about 56.85% of forest land in just 36 years and its serious impact on climate, temperature, rainfall, relative humidity, and discharge by analyzing the previous 36 years (1979–2014) data. So, we have to stop the rapid deforestation and to increase afforestation to reduce the unwanted weather change and hence to reduce global warming and other calamities. The climate parameters maximum and average of daily peak temperature and relative humidity data from year 1978–2014 shows an increasing trend. Similarly, maximum of daily peak rainfall data over the study area shows increasing trend. In this study, it is proved that the change in LULC and deforestation have direct impact on these climate parameters. The streamflow data is also studied at Jenapur gauging station and the change in peak flood also is observed. However, the change in peak flood is also affected by change in agricultural, industrial, and municipal water demand. Therefore, due to all these different factors, the trend in peak flood could not be defined.

However, the LULC change is not only responsible for change in climate change parameters. The climate change parameters also affected by global climate change which is due to large-scale pollution and deforestation globally as well as locally. This study is carried out on a regional scale. Therefore, there is a need to analyze the impact of global LULC changes along with pollution on the climatic parameters which can be addressed in future study. Additionally, the changes in river streamflow are largely affected by various local demands such as municipal, industrial, and agricultural demand. Therefore, these demand factors should take into consideration along with LULC to detect the impact on streamflow. These research gaps can be addressed in a future study.

Acknowledgments The authors would like to thank the USGS research team for allowing us to download the surface reflectance products of Landsat from their website http://www.earthexplorer.usgs.gov.

References

Babar, S., & Ramesh, H. (2015). Streamflow response to land use-land cover change over the Nethravathi River Basin, India. *Journal of Hydrologic Engineering, 20*(10), 05015002.

Chanapathi, T., & Thatikonda, S. (2020). Investigating the impact of climate and land-use land cover changes on hydrological predictions over the Krishna river basin under present and future scenarios. *Science of the Total Environment, 721*, 137736.

Comber, A., Fisher, P., & Wadsworth, R. (2005). What is land cover? *Environment and Planning B: Planning and Design, 32*(2), 199–209.

Costa, M. H., & Pires, G. F. (2010). Effects of Amazon and Central Brazil deforestation scenarios on the duration of the dry season in the arc of deforestation. *International Journal of Climatology, 30*, 1970–1979.

Das, P., Behera, M. D., Patidar, N., Sahoo, B., Tripathi, P., Behera, P. R., et al. (2018). Impact of LULC change on the runoff, base flow and evapotranspiration dynamics in eastern Indian river basins during 1985–2005 using variable infiltration capacity approach. *Journal of Earth System Science, 127*(2), 1–19.

Garg, V., Aggarwal, S. P., Gupta, P. K., Nikam, B. R., Thakur, P. K., Srivastav, S. K., & Kumar, A. S. (2017). Assessment of land use land cover change impact on hydrological regime of a basin. *Environmental Earth Sciences, 76*(18), 1–17.

Ge, J. (2010). MODIS observed impacts of intensive agriculture on surface temperature in the southern Great Plains. *International Journal of Climatology, 30*, 1994–2003.

Hengade, N., & Eldho, T. I. (2016). Assessment of LULC and climate change on the hydrology of Ashti Catchment, India using VIC model. *Journal of Earth System Science, 125*(8), 1623–1634.

Hord, R. M. (1982). *Digital image processing of remotely sensed data*. Elsevier.

Khan, M., Sharma, A., & Goyal, M. K. (2019). Assessment of future water provisioning and sediment load under climate and LULC change scenarios in a peninsular river basin, India. *Hydrological Sciences Journal, 64*(4), 405–419.

Kishtawal, C. M., Niyogi, D., Tewari, M., Pielke, R. A., Sr., & Shepherd, J. M. (2010). Urbanization signature in the observed heavy rainfall climatology over India. *International Journal of Climatology, 30*, 1908–1916.

Kumar, N., Singh, S. K., Singh, V. G., & Dzwairo, B. (2018). Investigation of impacts of land use/land cover change on water availability of Tons River Basin, Madhya Pradesh, India. *Modeling Earth Systems and Environment, 4*(1), 295–310.

Lawrence, P. J., & Chase, T. N. (2010). Investigating the climate impacts of global land cover change in the Community Climate System Model (CCSM). *International Journal of Climatology, 30*, 2066–2087.

National Research Council. (2005). *Population, land use, and environment: Research directions*. National Academies Press.

Nilawar, A. P., & Waikar, M. L. (2019). Impacts of climate change on streamflow and sediment concentration under RCP 4.5 and 8.5: A case study in Purna river basin, India. *Science of the Total Environment, 650*, 2685–2696.

Petchprayoon, P., Blanken, P. D., & Ekkawatpanit, C. (2010). Hydrological impacts of land use/land cover change in a large river basin in central-northern Thailand. *International Journal of Climatology, 30*, 1917–1930.

Sertel, E., Robock, A., & Ormeci, C. (2010). Impacts of land cover data quality on regional climate simulations. *International Journal of Climatology, 30*, 1942–1953.

Sinha, R. K., & Eldho, T. I. (2018). Effects of historical and projected land use/cover change on runoff and sediment yield in the Netravati river basin, Western Ghats, India. *Environmental Earth Sciences, 77*(3), 1–19.

Sinha, R. K., Eldho, T. I., & Subimal, G. (2020a). Assessing the impacts of land use/land cover and climate change on surface runoff of a humid tropical river basin in Western Ghats, India. *International Journal of River Basin Management*, 1–12.

Sinha, R. K., Eldho, T. I., & Subimal, G. (2020b). Assessing the impacts of land cover and climate on runoff and sediment yield of a river basin. *Hydrological Sciences Journal, 65*(12), 2097–2115.

Strengers, B., Müller, C., Schaeffer, M., Haarsma, R., Severijns, C., Gerten, D., Schaphoff, S., van den Houdt, R., & Oostenrijk, R. (2010). Assessing 20th century climate–vegetation feedbacks of land-use change and natural vegetation dynamics in a fully coupled vegetation–climate model. *International Journal of Climatology, 30*, 2055–2065.

Swain, R., & Sahoo, B. (2015). Variable parameter McCarthy-Muskingum flow transport model for compound channels accounting for distributed non-uniform lateral flow. *Journal of Hydrology, 530*, 698–715. https://doi.org/10.1016/j.jhydrol.2015.10.030

Swain, R., & Sahoo, B. (2017a). Mapping of heavy metal pollution in river water at daily time-scale using spatio-temporal fusion of MODIS-Aqua and Landsat satellite imageries. *Journal of Environment Management, 192*, 1–14. https://doi.org/10.1016/j.jenvman.2017.01.034

Swain, R., & Sahoo, B. (2017b). Improving river water quality monitoring using satellite data products and a genetic algorithm processing approach. *Sustainability of Water Quality and Ecology, 9–10*, 88–114. https://doi.org/10.1016/j.swaqe.2017.09.001

Swain, R., Sahoo, B., & Perumal, M. (2018). An embedded VPMM-AD model for riverine transient flow and non-reactive contaminant transports. *Journal of Hydrology, 563*(2018), 711–725. https://doi.org/10.1016/j.jhydrol.2018.06.025

Takahashi, H. G., Yoshikane, T., Hara, M., Takata, K., & Yasunari, T. (2010). High-resolution modelling of the potential impact of land-surface conditions on regional climate over Indochina associated with the diurnal precipitation cycle. *International Journal of Climatology, 30*, 2004–2020.

Tokairin, T., Sofyan, A., & Kitada, T. (2010). Effect of land use changes on local meteorological conditions in Jakarta, Indonesia: Toward the evaluation of the thermal environment of mega cities in Asia. *International Journal of Climatology, 30*, 1931–1941.

Townshend, J. R. (1992). *Improved global data for land applications. A proposal for a new high-resolution data set*. Report of the Land Cover Working Group of IGBP-DIS. Global Change Report (Sweden).

Xiao, C., Yu, R., & Fu, Y. (2010). Precipitation characteristics in the Three Gorges Dam vicinity. *International Journal of Climatology, 30*, 2021–2024.