To study land use and land cover pattern in Indrayani River watershed at Maharashtra, India: a review work

Upendra Saharkar[1,2*], S S Shahapure[3], S G Patil[4]

[*1]Department of Civil Engineering, RSCOE, Pune, Maharashtra. India.

[*2]Department of Civil Engineering, DYPIET,Ambi, Pune, Maharashtra. India.

[3]Department of Civil Engineering, RSCOE, Pune, Maharashtra. India.

[4]Ex. Executive Engineer, MIDC, Pune, Maharashtra. India.

upendra_saharkar@yahoo.co.in, https://orcid.org/0000-0002-1788-9198

Abstract

The study of water resources within a watershed is important to conserve water and maintain a balance between the demand for water and the availability of water within the watershed. Because of the growing population, economic development, urbanization, and industrialization, pressure is increasing on natural resources to meet the present demand for water. This paper is a review of the catchment area of the Indrayani River Watershed in the Upper Bhima Basin in Pune, Maharashtra, India. This area shows rapid Industrialization and fast Population growth, as per the census. This area is near the 5-Star MIDC of Talegaon Dabhade, so future water demand will increase day by day. We need to study Land use and land cover (LULC) patterns to understand past and current development of areas to avoid future water crises with the help of RS and GIS software. The assessment of Land use and land cover change (LULCC) helps identify the human influence on the natural environment.

Key words: - Watershed, Development, LULC, Water demand, RS and GIS

1. Introduction

The watershed is more than just a hydrological unit; it is also a sociopolitical-ecological entity that determines people's access to food, social and economic stability, and other essential services. The goals of the development and the slope of the land can influence these criteria for choosing a watershed size. The maintenance of any form of development requires the vigilant conservation of natural resources. In this study, an attempt will be made to use geospatial tools for estimating the spatial and temporal distribution of water, land, industry, population, etc. In this area, water demand is increasing day by day. There is also a fast-growing industrial area, which results in heavy groundwater usage due to the fact that this water is depleting per year. This area is near Mumbai, which could be developed as a third Mumbai with a new international airport near Panvel. As well as this study area having a 5-star MIDC, the water requirement for Industries is also increasing day by day. Due to this, the water requirement will definitely increase, so to avoid a future water crisis, the study may play a vital role in developing a watershed in this area with the help of water management. Analysis of identified change uses a separate data structure and thematic change information to better understand land cover and land use. Understanding human-natural interactions requires a study of the Earth's surface features.

The land use pattern has been continuously changing as a result of the population's rapid and unchecked increase, industrialization, and economic expansion (Dutta, Rahman, Paul, & Kundu, 2019). Urban expansion (Dutta & Das, 2019; Rahman, Aggarwal, Netzband, & Fazal, 2011a; Voogta&Okeb, 2003), climatic change and population growth, industrial growth and urban agglomeration, and Hassan et al. (2016) are a few probable reasons for LULC alterations.

This knowledge improves resource management and decision-making (Lu et al., 2004; Seif and Mokarram, 2012). Change detection uses multi-temporal Remote Sensing data to quantify the historical effects of an event and determine land cover and land use changes (Ahmad, 2012; Seif and Mokarram, 2012; Zoran, 2006).

Watershed change analysis has been studied worldwide using various methodologies. They are crucial to developing effective watershed management strategies worldwide (Ashraf, 2013; Bazgeera et al., 2008; Gajbhiye and Sharma, 2012; Kearns, 2005). Watershed management is crucial because a watershed is both hydrological and socio-ecological (Singh et al., 2014). It affects local residents' economic, food, and social security and life support services (Wani et al., 2008). Urbanization and deforestation in watershed areas alter water availability, surface and subsurface water interactions, and watershed ecosystems and services. Better water conservation techniques can be developed by studying a watershed's geographical and temporal fluctuations and hydrological components' interactions (Ashraf, 2013).

Remote Sensing (RS) has classified and mapped land cover and land use changes using various methods and data sets. Landsat photos have helped classify larger landscape components (Ozesmi and Bauer, 2002). Recent change detection methods use remotely sensed images. Change detection methods and algorithms have been studied for their pros and cons. Supervised classification, PCA, hybrid classification, and fuzzy classification are the most commonly used classification methods (Lu et al., 2004; Zhang et al., 2000).

Land use change analysis uses widely used supervised classification algorithms. This method relies more on background information and personal familiarity with the subject field. Using this knowledge, per-pixel signatures are taken and kept in signature files to convert the scene's raw digital numbers (DN) to radiance values (Jensen, 2007).

Boori et al. (2015) employed Remote Sensing and GIS techniques like supervised classification to investigate tourism's land use and land cover disruption. Rawat et al. (2013) used a similar method to track changes in Ramnagar town, Uttarakhand, India, between 1990 and 2010.

Due to urbanization, untreated sewage discharges, active water and soil erosion, overgrazing, tree cutting, a lack of cooperative communal structure, and diminished livelihood options, the study region was selected for change detection. Due to the rapid increase in agricultural activities and poultry farms in the Simly watershed, pesticide residues and poultry discharge in streams are also a serious problem (Butt, A., 2015; Mangrio et al., 2011). Rapid urban development in the study area has caused environmental issues like fragmentation of aquatic habitats, soil erosion, and water pollution from deforestation and municipal and industrial waste (Tanvir et al., 2006).

Thus, this study used GIS and Remote Sensing to assess changes in the watershed of the Indrayani River basin from 2001 to 2020. The objectives were (i) to identify and delineate distinct LULC categories and patterns of land use change in the watershed from 2001 to 2020(ii) to investigate the possibilities of combining GIS with RS in investigating the spatial distribution of different LULC changes in the watershed. (Butt et al., 2015)

2. **Material and methods**

2.1. Study area

For this study, a watershed of the Indrayani River has been chosen. Indrayani River originates from Kurvande village, near Lonavala town, having latitude and longitude of 18°43'56" N and 73°22'13" E and an altitude of 564 m above MSL. The Indrayani River is a tributary of the Bhima River, and both meet at Tulapur in Pune district. The total travelling distance of the river is approximately 97 KM, and the study area will be spread over an area of approx. 990 Sq. Km (i.e., 99000 Hect.). The basin is included within the Toposheet Nos. E43H5, E43H6, E43H9, E43H10, E43H13, and E43H14, which had previous numbers of 47F/5, 47F/6, 47F/9, 47 F A O, 47F/13, and 47F/14 of the Survey of India. The basin is situated approximately 18 kilometres northwest of Pune city and is well connected by National Highway No. 4 and the South-Central Broad-gauge Railway. The important townships occurring within the basin are Lonavla, Vadgaon (Taluka Place), Dehu Road, Alandi, and Chakan. A network of metalled and unmetalled roads and footpaths connects other habitations like Talegaon, Sangvi, Takve, Bhushi, Dehu, Moshi, Indori, etc. with each other.

As many as five small to moderate-capacity dams, viz., Bhushi, Lonavla, Valvan, Shirawata, and Andhra, exist along the Indrayani rivers and their tributaries within the western part of the basin. A couple of moderate- to large-scale industry belts have been developed and will be developed in the future within the basin, like Talegaon MIDC, Chakan MIDC, Talawade MIDC, etc. The industries have grown along the highway and railway axes. A variety of poultry farms and flower farms have also been developed within the basin.

Dehu Road Town is nearly entirely occupied by the military authorities. Lonavla Is a crucial summer resort, whereas Dehu and Alandi are holy shrines of Hindus. These locales receive a heavy floating population in one or the other part of the year.

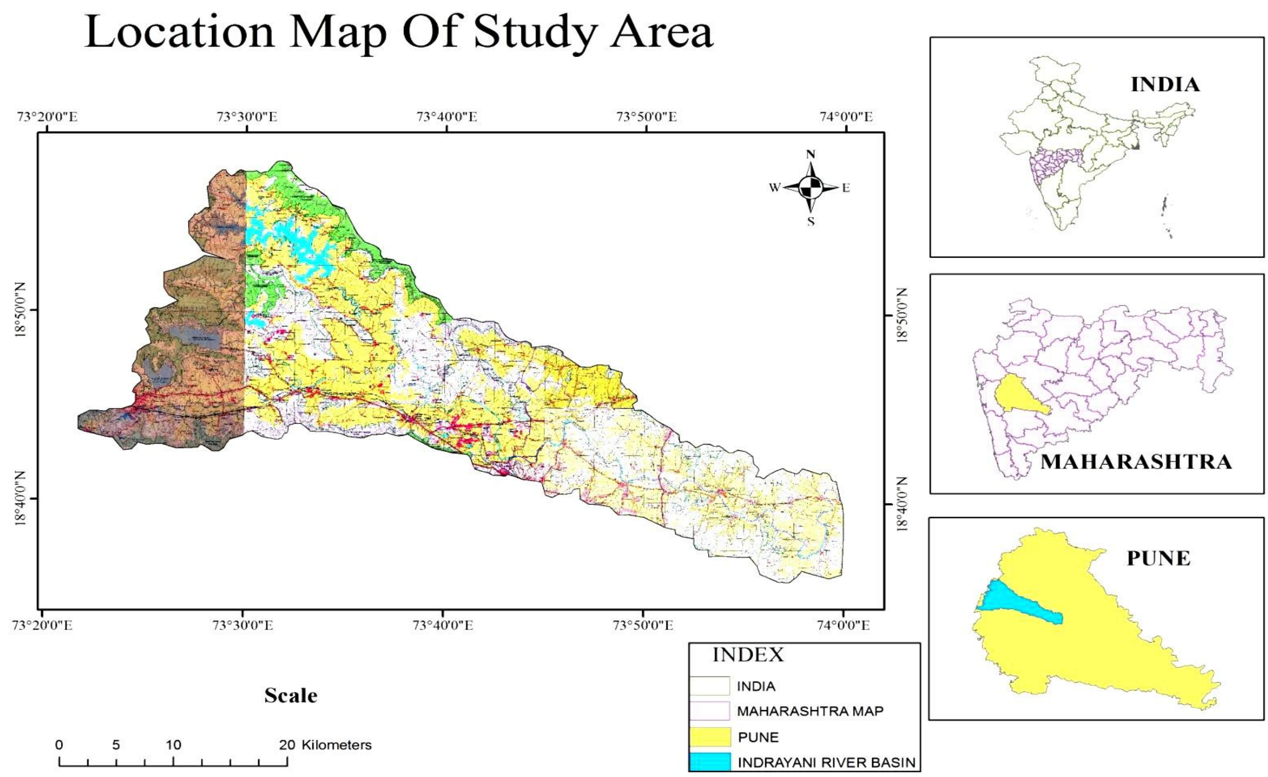


Figure1Locationmap of the study area

1.2 Data Collection and image pre-processing

Data source is one of the important elements of any research work. Researchers have gathered data from surveys in India and the National Remote Sensing Agency. The data used for land use and land cover mapping are Survey of India Toposheets. Landsat 4, Landsat 5, and Landsat 8 satellite images were used to classify the land use and land cover of the study area. All have an excellent price-quality ratio, good spectral coverage (seven bands from visible to infrared spectres), and good spatial features (30 m resolution). Images have been downloaded from the Earth Explorer platform. The land use and land cover patterns for 2001, 2010, 2015, and 2020 were mapped using Landsat 4, Landsat 5, and Landsat 8 satellite imagery. An unsupervised classification was conducted using ERDAS IMAGINE software (Version 2020). All satellite data were studied by assigning per-pixel signatures and differentiating the watershed into six classes on the basis of the specific Digital unsupervised classification value of different landscape elements. (Table 1)

Table 1.
Specification for satellite data used

Satellite	Sensor	Path/Row	Year of acquisition	Spectral Bands	Resolution
Landsat-4	MSS	146/44	1978	B, G,R. NIR, 2,3,4,5	60
Landsat-5	TM	136/44	1999	B, G, R, NIR, 1,2,3,4	30
Landsat-8	OLI/TIRS	136/44	2017	B, G, R, NIR, 4,5,8	30

1.3 LULC analysis

In order to pick training samples for each of the several types of land cover and uses that were previously defined, polygons were drawn around representative sites. The pixels that were included in these polygons were used in the recording of the spectral signatures of the various land cover categories that were extracted from the satellite images.

The spectral signature that ensures there is minimal confusion' among the land covers that are to be mapped is considered to be satisfactory. After that, the maximum likelihood algorithm was applied to the images in order to perform supervised classification. Because the analyst chooses the pixels that are most indicative of the desired classes, we have a significant amount of influence over the type of image classification that is performed. For the preparation of LULC maps, we use a satellite image that we downloaded from the USGS with unsupervised classification. The whole map is divided into six classes: water bodies, Low dense forest, Fallow land, built-up area, Barren land, and agricultural land. The following maps show LULC for 2001, 2010, 2015, and 2020 with a scale of 1:400000 (Table 2).

Table 2
Classes delineated on the basis of supervised

Sr. No.	Class of Land	Description of Class	Color Code
1	Agriculture land	Crop fields	Green
2	Barren land	Land areas of exposed soil and barren area influenced by human influence	Gray
3	Built up land / Settlements	Residential, commercial, industrial, transportation, roads, mixed urban	Red
4	Fallow land	unseeded during growing season	Yellow
5	Low dense forest	Mixed forest lands	Bottle green
6	Water bodies	River, open water, lakes, ponds and reservoirs	Blue

1.4 Accuracy assessment

Post-classification revision was used because it was simple and worked well (Harris and Ventura, 1995). This was done to improve classification accuracy and cut down on mistakes. Also, when using data with a medium spatial resolution, like that of Landsat, mixed pixels are a common problem (Lu and Weng, 2005). This is especially true for urban surfaces, which are made up of many different things, such as buildings, grass, roads, dirt, trees, and water (Jensen, 2007). Visual perception was used to solve the problem of mixed pixels. Visual perception was very important to improve the accuracy of classification and, by extension, the quality of the land cover and land use maps that were made. So, visual analysis, reference data, and local knowledge on site are used.

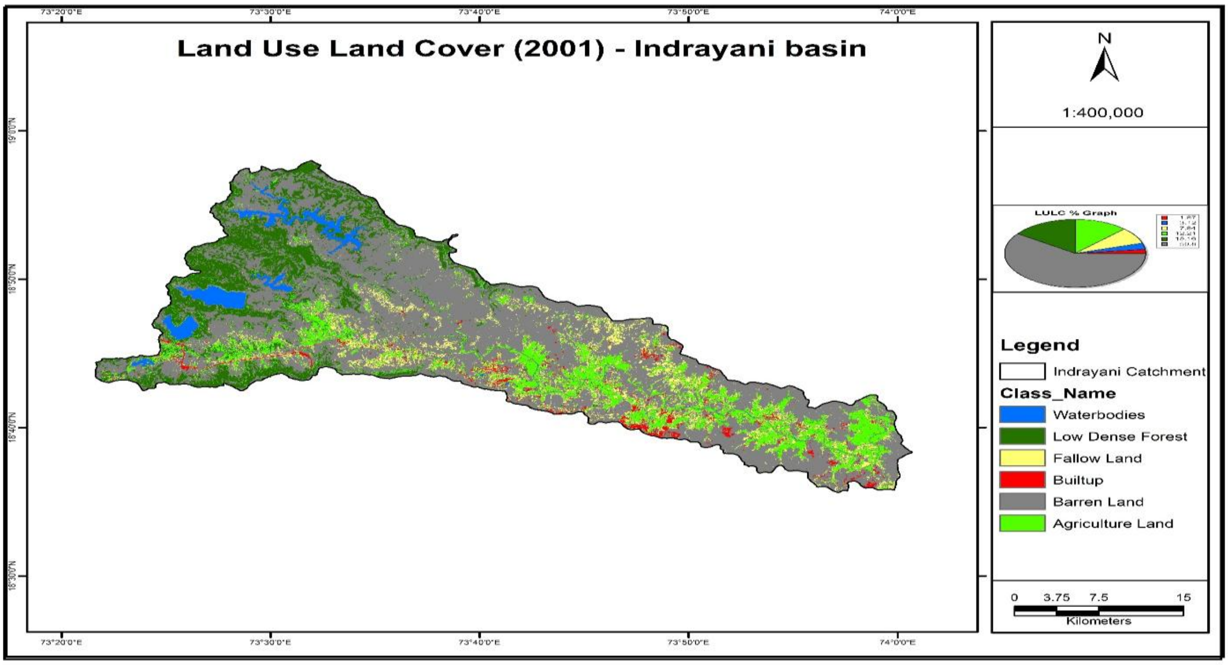


Figure 2LULC Map in Indrayani River Basin for Year 2001

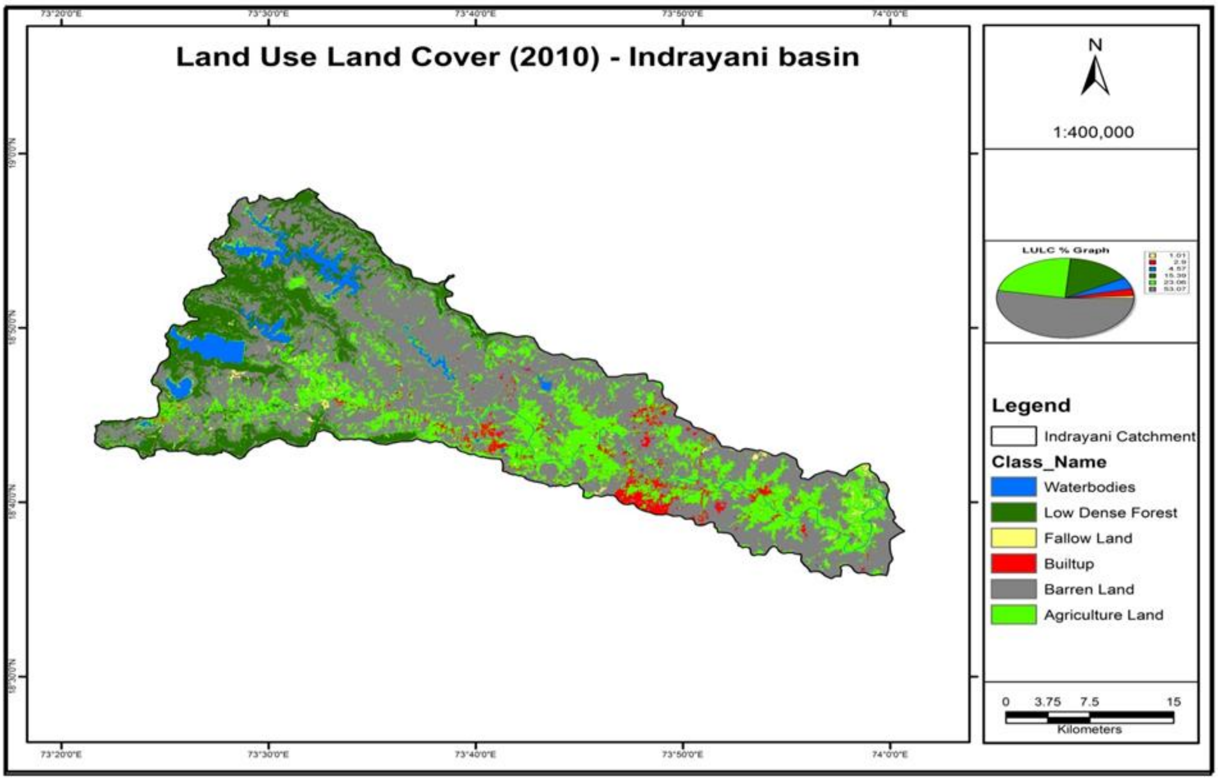


Figure 3 LULC Map in Indrayani River Basin for Year 2010

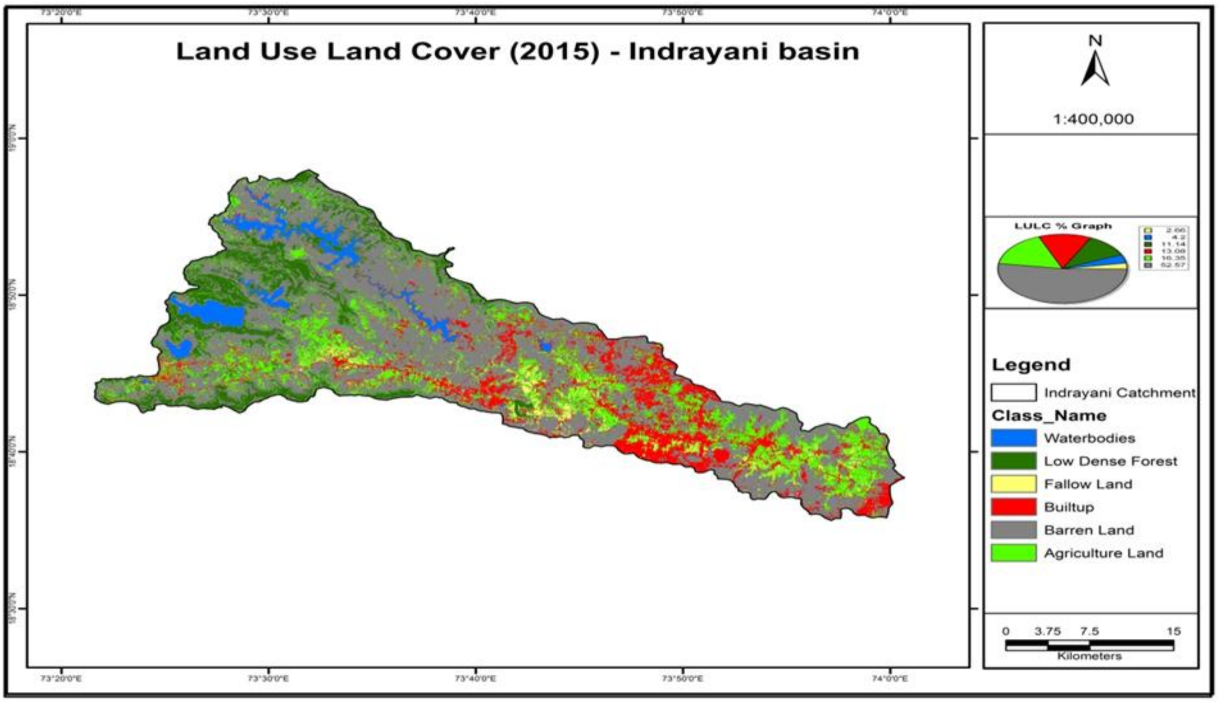


Figure 4 LULC Map in Indrayani River Basin for Year 2015

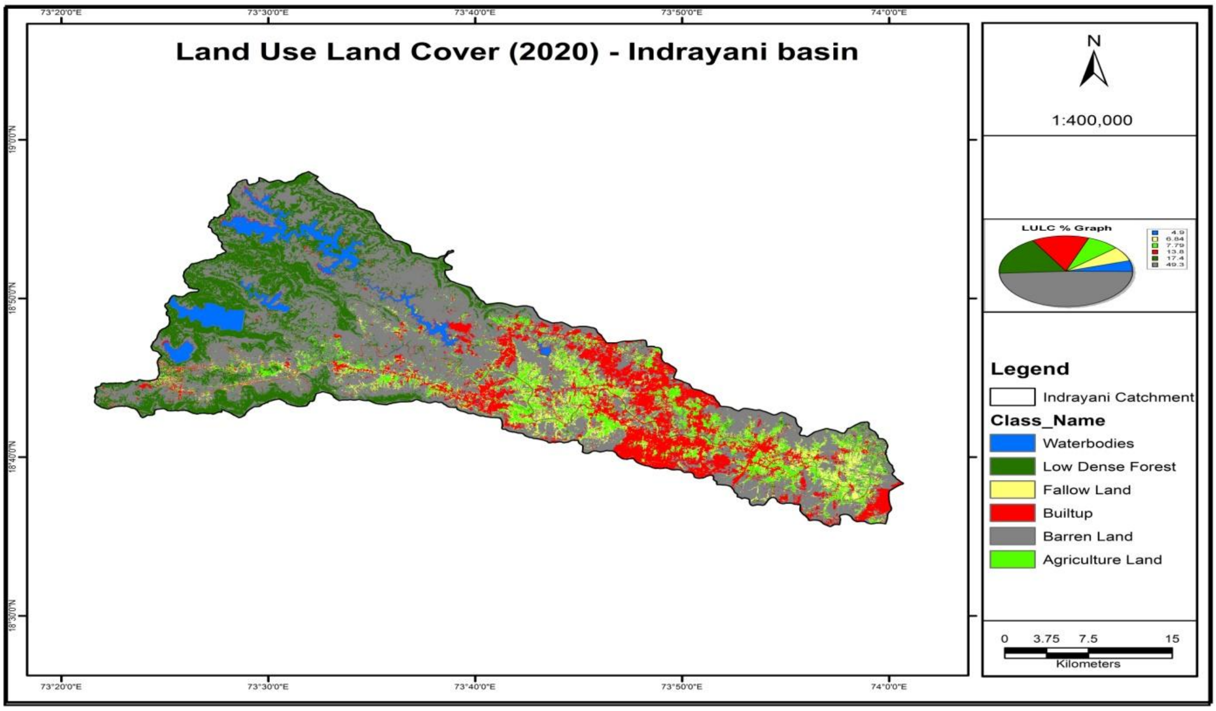


Figure 5 LULC Map in Indrayani River Basin for Year 2020

2. Results and discussion

The classified LULC map of the Simply watershed for years 2001, 2010, 2015, and 2020 is given in Figs. 2, 3, 4, and 5, respectively. Summary of Water bodies, Low dense forest, Fallow land, Builtup area, Barren land, and agricultural land is shown in Tables. 3, 4, 5, and 6 with pie charts that show LULC for 2001, 2010, 2015, and 2020, respectively.

Table 3.
LULC area and percentage summary for 2001

Sr. No.	LULC Classes	Area in (Hac)	Percentage of total area
1	Builtup	1859.04	1.87
2	Agriculture Land	12116.43	12.20
3	Fallow Land	7782.84	7.83
4	Barren Land	59362.83	59.79
5	Low Dense Vegetation	15052.77	15.16
6	Waterbodies	3100.68	3.12
	Total	**99274.59**	**100**

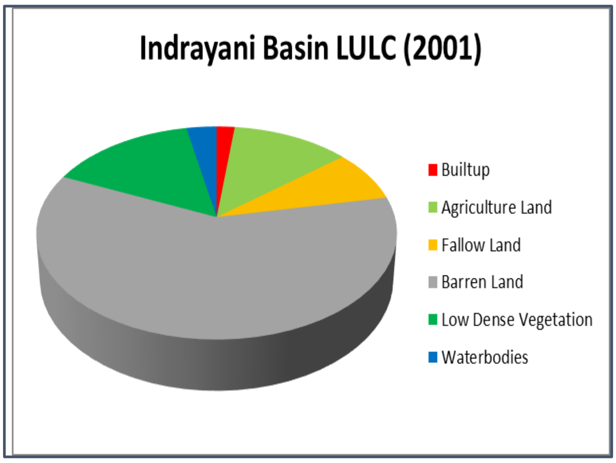


Figure 6 LULCarea and percentage summary

The Table. 3 shows thatin year 2001 the Indrayani basin having 1.87%,12.20%,7.83%,79.79%,15.16% and 3.12% of Builtup area,Agriculture Land,Fallow Land, Barren Land, Low Dense Vegetation, and Waterbodiesrespectively;the graphical representation for same are shown in Fig. 6

Table 4.
LULC area and percentage summary for 2010

Sr. No.	LULC Classes	Area in (Hac)	Percentage of total area
1	Builtup	2878.83	2.89
2	Agriculture Land	22895.46	23.06
3	Fallow Land	1004.4	1.01
4	Barren Land	52687.62	53.07
5	Low Dense Vegetation	15274.08	15.38
6	Waterbodies	4534.2	4.56
	Total	**99274.59**	**100**

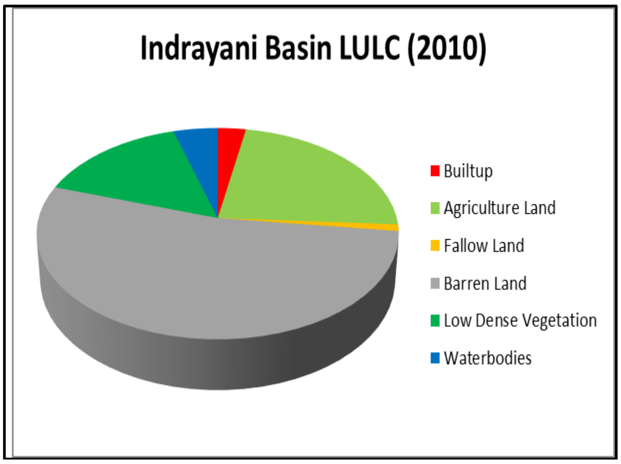


Figure 7 LULCarea and percentage summary

Table 4 shows that in 2010, the Indrayani basin had 2.89%, 23.06%, 1.01%, 53.07%, 15.38%, and 4.56% of built-up area, Agriculture Land, Fallow Land, Barren Land, low-density vegetation, and waterbodies, respectively; the graphical representation for the same is shown in Fig. 7.

Table 5.
LULC area and percentage summary for 2015

Sr. No.	LULC Classes	Area in (Hac)	Percentage of total area
1	Builtup	12985.9	13.08
2	Agriculture Land	16228.73	16.34
3	Fallow Land	2642.198	2.66
4	Barren Land	52192.49	52.57
5	Low Dense Vegetation	11056.21	11.13
6	Waterbodies	4170.285	4.20
	Total	**99275.81**	**100**

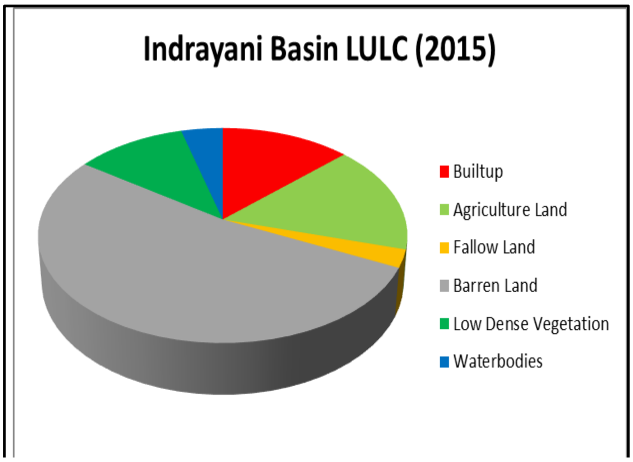


Figure 8 LULCarea and percentage summary

Table 5 shows that in 2015, the Indrayani basin had 13.08%, 16.34%, 2.66%, 52.57%, 11.13%, and 4.20% of built-up area, Agriculture Land, Fallow Land, Barren Land, low-density vegetation, and waterbodies, respectively; the graphical representation for the same is shown in Fig. 8. In this LULC, the changes are a very clear indication of the growth of built-up area from 2.89% to 13.08% from 2010 to 2015. At the same time, agricultural land percentages decreased from 23.06% to 16.34% within a 5-year span, which means a lot of agricultural land was converted to built-up area.

Table 6.
LULC area and percentage summary for 2020

Sr. No.	LULC Classes	Area in (Hac)	Percentage of total area
1	Builtup	13687.13	13.78
2	Agriculture Land	7730.82	7.78
3	Fallow Land	6785.888	6.83
4	Barren Land	48943.37	49.30
5	Low Dense Vegetation	17270.1	17.39
6	Waterbodies	4858.493	4.89
	Total	**99275.81**	**100**

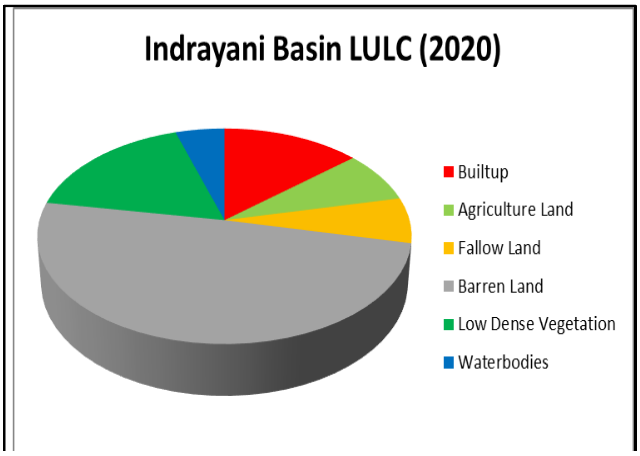
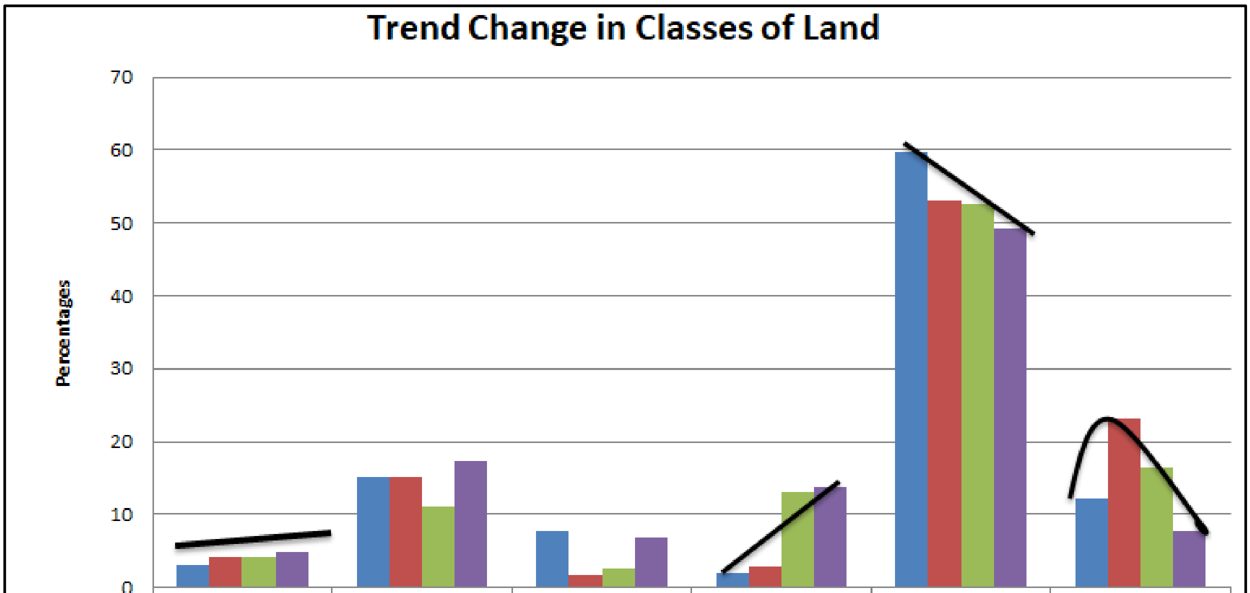


Figure 9 LULCarea and percentage summary

The Table. 6 shows that in year 2020 the Indrayani basin having 13.78%,7.78%,6.83%,49.30%,17.39%, and 4.89% of Builtup area,Agriculture Land,Fallow Land, Barren Land, Low Dense Vegetation, and Waterbodies respectively; the graphical representation for same are shown in Fig. 9.The following graph shows a small description of changes in watershed during last 20 years i.e., from 2001 to 2020. Due to this we can find out the changes in pattern of different classes of land use and land cover.



	Water bodies	Low dence forest	Fallow land	Builtup area	Barren land	Agricultural land
LULC 2001	3.12	15.16	7.84	1.87	59.8	12.21
LULC 2010	4.17	15.09	1.81	2.9	53.06	23.06
LULC 2015	4.2	11.14	2.66	13.08	52.57	16.35
LULC 2020	4.9	17.4	6.84	13.8	49.3	7.79

Figure 10 LULCtrend change in different areas and land (from 2001 to 2020)

Fig. 10 clearly shows that, during the 20-year span, water bodies did not increase notably, but at the same time, built-up area changed tremendously from 1.87% to 13.80% from 2001 to 2020, which is a clear indication that during this period, water demand increased, but water bodies increased from 3.12% to 4.90% from 2001 to 2020, which is less development against the built-up area. At the same time, from 2001 to 2020, agricultural land decreased by 12.21% to 7.79%, which is notable.

This study shows how important it is to use GIS and R to look for changes in land cover and land use in an area. This is because it gives important information about where and how land cover changes are happening. Overall, the land use and land cover maps are accurate 95% of the time. This shows that combining unsupervised classification of satellite imagery with visual analysis is a good way to record changes in how land is used and what it is used for in an area.

3. Conclusion

The Indrayani River is a tributary of the Bhima River, and both meet at Tulapur in Pune district. On the bank of the Indrayani River, Dehu Road Town is nearly entirely occupied by the military authorities. The Lonavla Is a crucial summer resort, whereas Dehu and Alandi are holy shrines of Hindus, and these locales receive heavy floating populations in one or the opposite part of the year. A couple of moderate- to large-scale industry belts have been developed and will be developed in the future within the basin, like Talegaon MIDC, Chakan MIDC, Talawade MIDC, etc. The industries have grown along the highway and railway axes. A variety of poultry farms and flower farms have also been developed within the basin. From the study of the above watershed, it is clear that the built-up area changes tremendously, which indicates population growth along with industry growth day by day. This trend will continue in the future, resulting in a significant increase in water demand and increased water stress in the watershed.

Lack of effective management and land use planning is largely to blame for the unplanned growth of Settlement and Agriculture areas in the watershed, as no Environment Impact Assessment (EIA) report is produced prior to land development in the study region. Deforestation and water scarcity are two main problems that have arisen as a result of this growth.

All these changes in land cover and land use patterns by 2020 had a negative impact on water availability, which could be a future limiting factor for both urban expansion and agricultural methods and could also be to blame for the continued decline of vegetation cover in the watershed regions. As a result, it is crucial to properly manage these water resources to prevent their depletion or degradation to the point that they no longer contribute to the area's agricultural output and social and economic growth as intended.

Having said that, the present study concludes with numerous recommendations for the appropriate management and conservation of the forest, water, and soil resources threatened by a decrease in the watershed.

- In order to make the best decisions about how to prioritise different land uses, it is important to predict the population and development needs within this watershed boundary.
- Furthermore, the Ministry of Agriculture should conduct an inventory to distinguish between productive agricultural land and unproductive land, and legislation should be enacted to prevent productive agricultural land from being converted to non-agricultural uses.
- Safeguard predetermined housing and resettlement initiatives.
- Water quantity changes as a result of changes in land use should be assessed in follow-up research.

References

Ahmad, F. (2012) Detection of change in vegetation cover using multi-spectral and multi-temporal information for District Sargodha, Pakistan SociedadeNatureza 24, 557–572.

Ashraf, A. (2013) The Changing Hydrology of the Himalayan Watershed Current Perspectives in Contaminant Hydrology and Water Resources Sustainability Intech, Islamabad.

Bazgeera, S., Sharma, P.K., Maheya, R.K., Hundala, S.S., and Sood, A. (2008). Assessment of land use changes using remote sensing and GIS and their implications on climatic variability for the Balachaur watershed in Punjab, India Desert 12, 139–147.

Boori, M.S., Vozen'lek, V., and Choudhary, K. (2015) Land use and cover disturbance due to tourism in Jesen'ky Mountain, Czech Republic: a remote sensing and GIS-based approach Egypt. J. Remote Sens. Space Sci. 18 (1), 17–26. http://dx.doi.org/10.1016/j.ejrs.2014.12.002.

Butt, A., Shabbir, R., Sheikh, S., and Aziz, s.n. (2015). Land use change mapping and analysis using Remote Sensing and GIS: A case study of the Simly watershed, Islamabad, Pakistan Egypt. J. Remote Sens. Space Sci. 18, 251–259

Ding, J., Jiang, Y., Fu, L., Liu, Q., Peng, Q., and Kang, M. (2015). Impacts of land use on surface water quality in a Subtropical River Basin: a case study of the Dongjiang River Basin, Southeastern China Water 7, 4427–4445.

Dutta, D., Rahman, A., Paul, S. K., & Kundu, A. (2019). Changing patterns of urban landscape and their effect on land surface temperature in and around Delhi Environmental Monitoring and Assessment, 191, 551.

Dutta, D., Rahman, A., Paul, S. K., & Kundu, A. (2020). Estimating urban growth in peri-urban areas and its interrelationships with built-up density using earth observation datasets The Annals of Regional Science https://doi.org/10.1007/s00168-020-00974-8.

Dutta, I., & Das, A. (2019). Application of geo-spatial indices for detection of growth dynamics and forms of expansion in English Bazar Urban Agglomeration, West Bengal. Journal of Urban Management, 8(2), 288–302.

Dutta, V. (2012) Land use dynamics and peri-urban growth characteristics: Reflections on master plans and urban suitability from a sprawling north Indian city Environment and Urbanisation in Asia, 3(2), 277–301.

Gajbhiye, S., and Sharma, S.K. (2012). Land use and land cover change detection in the Indra River watershed through remote sensing using multi-temporal satellite data Int. J. Geomatics Geosci. 3, 89–96.

Gupta, P., & Venkatesan, M. (2020). Mineral identification using unsupervised classification from hyperspectral data In P. Venkata Krishna and M. Obaidat (Vol. Eds.), Advances in Intelligent Systems and Computing: Vol. 1054 Singapore: Springer.

Hassan, Z., Shabbir, R., Ahmad, S. S., Malik, A. H., Aziz, N., Butt, A., et al. (2016). Dynamics of land use and land cover change (LULCC) using geospatial techniques: A case study of Islamabad, Pakistan Springer Plus, 5(1), 812.

Jensen, J.R., and Im, J. (2007). Remote sensing for change detection in urban environments In: Jensen, R.R., Gatrell, J.D., and McLean, D. (Eds.), Geo-spatial Technologies in Urban Environments: Policy, Practise, and Pixels, second ed., Springer-Verlag, Heidelberg, pp. 7–30.

Kearns, F.R., Kelly, N.M., Carter, J.L., and Resh, V.H. (2005) A method for the use of landscape metrics in freshwater research and management Landscape Ecol. 20, 113–125.

Lu, D., Mausel, P., Brond'zio, E., and Moran, E. (2004). Change detection techniques. Int. J. Remote Sens. 25, 2365–2407.

Lu, Q., and Weng, D. (2005). Urban classification using full spectral information from Landsat ETM imagery in Marion County, Indiana Photogramm. Eng. Remote Sens. 71 (11), 1275–1284.

Mangrio, A.G., Aslam, M., and Ikram, M.Z. (2011) Estimation and rapport between rainfall runoff and sediment load as soil loss from the Rawal sub-watershed (Satramee) Pak. J. Agric. Agril. Eng. Vet. Sci. 27 (1), 27–38.

Mohamed, A., & Worku, H. (2019). Quantification of the land use and land cover dynamics and the degree of urban growth goodness for sustainable urban land use planning in Addis Ababa and the surrounding Oromia special zone Journal of Urban Management, 8(1), 145–158.

Ozesmi, S.L., and Bauer, M.E. (2002) Satellite remote sensing of wetlands Wetlands Ecol. Manage. 10, 381–402.

Qasim, M., Hubacek, K., Termansen, M., and Khan, A. (2011). Spatial and temporal dynamics of land use patterns in District Swat, Hindu Kush Himalayan region of Pakistan Appl. Geogr. 31, 820–828.

Rahman, A., Aggarwal, S. P., Netzband, M., & Fazal, S. (2011a). Monitoring urban sprawl using remote sensing and GIS techniques in a fast-growing urban centre in India IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, 4(1), 56–64

Rawat, J.S., Biswas, V., and Kumar, M. (2013). Changes in land use and cover using geospatial techniques: a case study of the Ramnagar town area, district Nainital, Uttarakhand, India Egypt. J. Remote Sens. Space Sci. 16, 111–117.

Seif, A., and Mokarram, M. (2012. Change detection in Gil Playa in the Northeast of Fars Province. Iran Am. J. Sci. Res. 86, 122–130.

Singh, P., Gupta, A., and Singh, M. (2014) Hydrological inferences from watershed analysis for water resource management using remote sensing and GIS techniques Egypt. J. Remote Sens. Space Sci. 17, 111–121.

Singh, P., Gupta, A., and Singh, M. (2014) Hydrological inferences from watershed analysis for water resource management using remote sensing and GIS techniques Egypt. J. Remote Sens. Space Sci. 17, 111–121.

Talukdar, S., Singha, P., Shahfahad, Mahato, S., Praveen, B., & Rahman, A. (2020). Dynamics of ecosystem services (ESs) in response to land use and land cover (LU/LC) changes in the lower Gangetic plain of India Ecological Indicators, 112, 106–121.

Tanvir, A., Shahbaz, B., and Suleri, A. (2006). Analysis of myths and realities of deforestation in northwest Pakistan: implications for forestry extension Int. J. Agric. Biol. 8, 107–110.

Turner, B. L., Meyer, W. B., & Skole, D. L. (1994). Global land-use and land-cover change—towards an integrated study Ambio, 23(1), 91–95.

Voogta, J. A., &Okeb, T. R. (2003). Thermal remote sensing of urban climates Remote Sensing of the Environment, 86(3), 370–384.

Walker, R. (2001). Industry builds the city: The suburbanization of manufacturing in the San Francisco Bay Area, 1850–1940Journal of Historical Geography, 27(1), 36–57.

Wani, S.P., Sreedevi, T.K., Reddy, T.S.V., Venkateswarlu, B., and Prasad, C.S., 2008. Community watersheds for improved livelihoods through a consortium approach in drought-prone rain-fed areas J. Hydrol. Res. Dev. 23, 55–77.

Wentz, E. A., Nelson, D., Rahman, A., Stefanov, W. L., & Roy, S. S. (2008). Expert system classification of urban land use and cover for Delhi, India International Journal of Remote Sensing, 29(15), 4405–4427.

Zhang, S., Zhang, S., and Zhang, J. (2000). A study on the wetland classification model of remote sensing in the Sangjiang Plain Chin. Geog. Sci. 10, 68–73.

Zoran, M.E. (2006) The use of multi-temporal and multispectra satellite data for change detection analysis of the Romanian Black Sea Coastal Zone J. Optoelectron. Adv. Mater. 8, 252–256.