INNOVATIONS

Content available on Google Scholar

www.journal-innovations.com

Mapping the Land Use and Land CoverChanges and Hydrological Regime of Rishikesh City in Uttarakhand Using Geo-Spatial Techniques

PankajGautam[1], Subhash Anand[2], Harish Kumar[3]

Corresponding Author: ***Subhash Anand***

Abstract

The intergovernmental panel for climate change (IPCC) Fourth Assessment Report discussed about the negative impacts of climate change on water resources around the world (IPCC Climate Change 2007). The land use and land cover changes are the results of the utilization of resources by the human being in time and space for various purposes. These changes could be taken place because of natural causes also. The seasonal variation in rainfall affects the variability in soil moisture that influences the wetness or dryness of monsoon season and which also affect the hydrological system. The study focused on mapping out Landuse and Land Cover (LULC) changes through processing topographic sheets and Landsat satellite data for different years with the help of GIS in Rishikesh city, Dehradun district, Uttarakhand, India; realizing the importance of LULC monitoring in the management and planning of the land resources. The study has been conducted based on three situations according to the time when 1990, 1998, 2007 and 2017. In order to study the change in LULC, and Landsat data (1990-2017) were used to generate different layers of maps. Spatial-temporal information on the LULC and its changes were determined by GIS and RS techniques. The change was more than 32.75 percent in water bodies' area after monsoon season in city in 1990. The other water bodies were also rejuvenated because of stagnation of water which also contributed in increasing of water bodies' area. In 2017, water bodies further increased after monsoon season with 35.44 per cent change in the area. Water bodies are only class which has positive change to its area after the monsoon season.

Keywords*: 1 Land use and land cover;2 hydrological regime; 3 monsoonvariability;*

[1]**Research Associate**, National Council of Educational Research and Training (NCERT), New Delhi- 110016, India.
[2]**Professor**, Department of Geography, Delhi School of Economics, University of Delhi, Delhi- 110007, India.
[3]**PhD. Research Scholar**, Department of Geography, Delhi School of Economics, University of Delhi, Delhi- 110007, India.

1. Introduction

The intergovernmental panel for climate change (IPCC) Fourth Assessment Report discussed about the negative impacts of climate change on water resources around the world (IPCC Climate Change 2007). India is prevalently agrarian economy with immense population and it is totally depends on the monsoon rainfall for their food and endurance and even little change in precipitation can influence the hydrology and water level which can additionally effects on economy and social arranging of India (Shukla, 1985).The land use and land cover change is main drivers for global environmental change (Zhai, et al., 2020) and are the results of the use of natural resource by the human being in existence for different purposes (Asselman and Middelkoop, 1995). These changes could be taken place because of natural causes also (Reed and Stringer, 2016). To understand the human interference in the natural pattern, this method becomes relevant or viable to trace various features that have been changed (Pinto et al, 2013). Land use change always occurs under certain circumstances and these circumstances affect the whole ecosystem of that region (BMZ, 2012)the factors which are responsible for land use land cover change can be categorized into direct and indirect factors (Brouwer, 1991; Blaikie and Brookfield, 1987). Some activities or factors are known to directly influence or modify the proportion of utilization of land such as agriculture expansion, industrialization or urbanization etc. (Turner and Meyer, 1994). Physically, the direct factors are more importance than the indirect factors but indirect factors are responsible for influencing these factors which culminates into changes in the landscape (Taylor et al., 2002). These indirect factors have very complex structures which controls the change on land use and human activities (Alonso-Pérez et al., 2003; Wijitkosum, 2012).

The land use and land cover have direct impact on the hydrology of Rishikesh city (Zhou, 2020). Urbanization and industrialization affect the size and durability of small streams and flow of hydrology (Trudeau and Richardson, 2016). It also leads to drying up of wetlands for agriculture use which affects the runoff (Mccauley et al., 2015). All these land use elements individually or altogether affect the hydrology (Sisay, 2020). There is uniform relationship found between rainfall and soil moisture which in non-linear in character (Douville et al. 2001). The aim of the study is to assess the impact of monsoon rainfall over the hydrological pattern of Rishikesh city and surrounding areas (Thomas et al., 2014). These land use and land cover maps represents the spatial distribution of land in the pre monsoon and post monsoon periods which are then used for understanding the hydrological change in different season in the year. The seasonal variation in rainfall affects the variability in soil moisture that influences the wetness or dryness of monsoon season and which also affect the hydrological system (Douville 2002).

The hydrology is one of the physical elementsin land use and land cover which is directly or indirectly affected by human activities (Zhang et al., 2001; Cigizoglu et al., 2005). The hydrology at Rishikesh is controlled by slope gradient, and it is the first point where a complete form of Ganga River appears first after meeting with river Alaknanda at DevPrayag (Misra, 2010). The Rishikesh city is lined by rivers from three sides namely Chandrabhaga in the northwest, Song River in the southwest and Ganga River in southeast.

2. Study Area

2.1 Location

Rishikesh city is municipal board in Dehradun district in the northern state of Uttarakhand in India. Rishikesh city is situated at 30° 10' 33" N latitude and 78° 29' 47" E longitude (Figure 1). Rishikesh city has average height of 372 meters (1,745 feet) (Statistical Abstract of Dehradun, 2016).

2.2 Drainage

The Ganga, one of the most ancient and sacred rivers of India shapes the central seepage channel of the study area (Central Pollution Control Board, 2000). The river enters the area from north of LaxmanJhula and Munni-Ki-Reti, at a height of 500 meters above mean sea level, close which it gets the waters of Song and Suswa, the two primary rivers of the eastern Dun and of Chandrabhaga in Rishikesh city (Figure 1). Subsequently, dispersing its water into a few rivers surrounding lush islands and it leaves towards Rishikesh city shaping the limit between the Dun and Garhwal (Census of India, 1991).

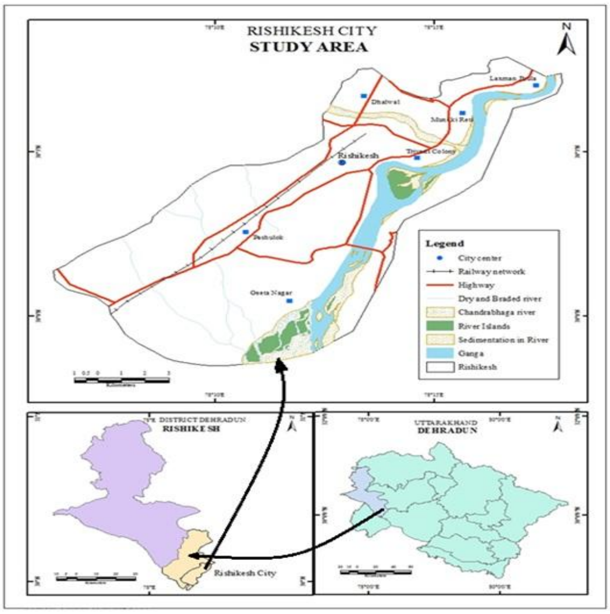


Figure: 1 Study Area

3. Database and Methods

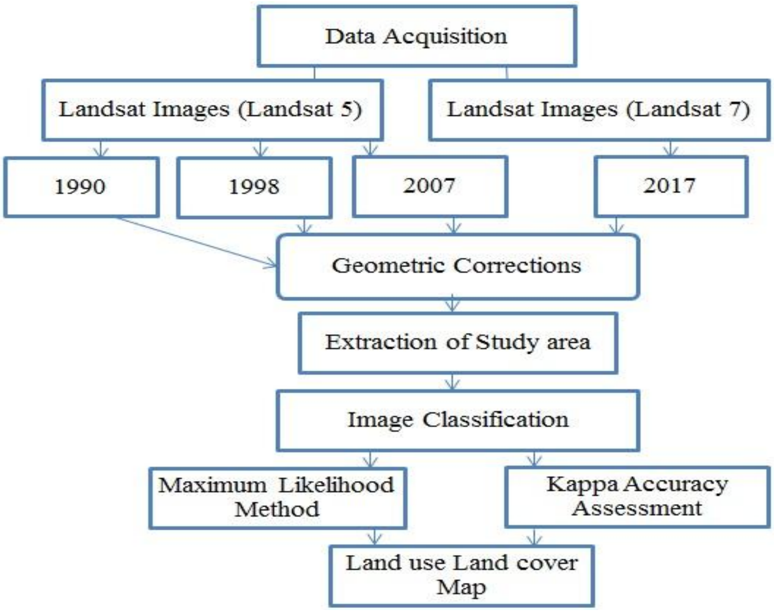
3.1 Database

The backbone of any kind of research is data. The study focused on mapping out LULC changes through processing topographic sheets and Landsat satellite data for different years with the help of GIS (Merchant, 2001) in Rishikesh city, Dehradun district, Uttarakhand, India; realizing the importance of LULC monitoring in the management and planning of the land resources (Gumma et al., 2019). The study has been conducted based on three situations according to the time when 1990, 1998, 2007 and 2017.

- The first situation is the pre monsoon *i.e.* before the monsoon of 1990, 1998, 2007 and 2017.

- The second is the post monsoon situation *i.e.* after the monsoon of 1990, 1998, 2007 and 2017.

The data required for the study comprised of topographical maps, satellite images and secondary data. In order to study the change in LULC, and LANDSAT data (1990-2017) were used to generate different layers of maps. Spatial-temporal information on the LULC and its changes were determined by Geographic Information System (GIS) and Remote Sensing techniques (Figure 2).



Source: Prepared by Authors

Figure: 2 Data Source and Methodology

3.2 Remote Sensing Data

A series of Landsat Multi spectral scanner (MSS) and Enhanced Thematic Mapper (ETM) multispectral images acquired for the years 1990, 1998, 2007 and 2017 (for the Monsoon and non-Monsoon season) have been used for the identification of different LULC classes and preparation of LULC map. These datasets are produced by the United States Geological Survey (USGS) with the spatial resolution of 30m x30m (path 132 and row 46 and are freely available from USGS Earth (Table 1). ETM+ imagery was chosen for this research due to its rich spectral information, the stability of data availability and the fact that the imagery is available at no cost.

Table 1 Technical Specification of Satellite Images

Type	Mechanical Scanner
Spatial Resolution	30 m
Spectral Range	0.45 µmto 12.5 µm
No. of Bands	08
Temporal Resolution	16 days

Year	***Path and Row***	***Spatial Resolution***	***Description***	***Satellite Sensor***
1990	*132/46*	*30 m*	*LANDSAT-5*	*Thematic Mapper (TM)*

1998	*132/46*	*30 m*	*LANDSAT-5*	*Thematic Mapper (TM)*
2007	*132/46*	*30 m*	*LANDSAT-5*	*Thematic Mapper (TM)*
2017	*132/46*	*30 m*	*LANDSAT-7*	*Enhanced Thematic Mapper (ETM)*

Source: Prepared by Authors

3.3 Image Preparation Analysis

In case of LANDSAT sensor, it collects information in the form of different bands in Tagged Image Format File (TIFF) format which is needed to obtain multispectral imagery from the raw data obtained from USGS (Rawat and Kumar, 2015; Risky et al., 2017; Firozjaei et al., 2019). To get detailed information from remotely sensed images, multispectral data is extracted from the imagery. For this layer, layer stacking of seven bands out of eight was done except thermal band since it has no application in LULC process and then based on the requirement, one of the classification techniques was applied for the preparation of the maps (Far, 2003; Pandy and Nathawat, 2006).

The temporal satellite data Landsat 7 ETM+ for the Monsoon and post- monsoon season have been used for the preparation of LULC maps except for the year 1990, 1998, 2007 and 2017. For the classification of the images, we have applied unsupervised classification in our study (Jansen and Gregorio, 2003; Thenkabail, 2016). Image classification can be divided into supervised and unsupervised classification. It is defined as the process by which pixels are assigned to their respective classes (Jensen and Coven, 1999). The user has to perform quality check on the results. In this process, several spectral classes can be assigned to few land cover types (Jensen and Coven, 1999).

4. Results

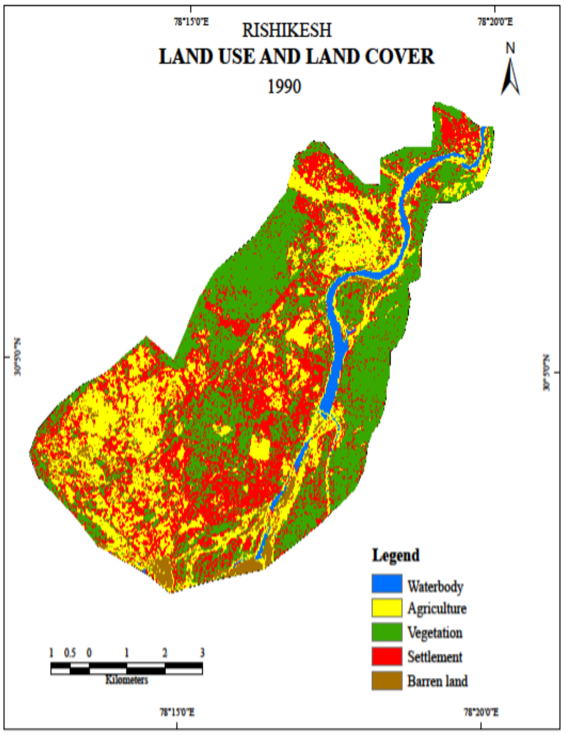
4.1 Land Use Land Cover Change Detection Analysis for the year 1990 (Pre Monsoon)

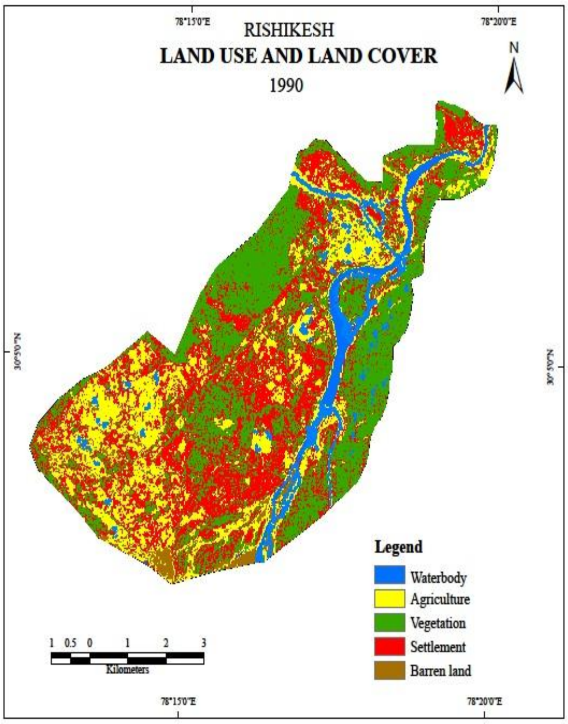
In 1990, the water bodies had occupied second smallest part of this study area after barren land 3.11 and 3.09 per cent respectively. These were mostly concentrated in river catchment and barren land is associated with river catchment and little bit towards the agriculture field. This region had enough vegetation cover and it occupied the 37.38 per cent area (Figure 3). The settlements are concentrated in three areas in this study area, which is Nagar Palika area, Nagar Nigam area and near the LakshmanJhula. Settlement occupied 32.46 per cent of land in the study area in 1990. The third largest occupant in this study area was agriculture which had covered the 23.09 per cent of total study area. Overall, vegetation, settlement and agriculture had occupied the almost 96 per cent of total study area together (Table 2).

4.2 Land Use and Land Cover for the year 1990 (Post Monsoon)

In the year of 1990, the water bodies had occupied almost 4.88 per cent of total study area. The barren land had decreased to 1.79 per cent and this partially decreased in 1990. This barren land had associated with the catchment and agriculture field (Figure 4). The vegetation cover had marginally reduced to 36.38

per cent and settlement had also reduced to 31.61 per cent (Table 2). But agriculture had increased to 24.89 per cent. Monsoon season deeply affect the socio-economic character of Rishikesh because of excess amount of water brought number of problem in the city.





Source: Prepared by Authors using Landsat images
Figure 3 and 4 Land Use Land Cover map of 1990, Pre-Monsoon and Post-Monsoon

Table 2 Land Use Land Cover Class for the Years 1990

S. No.	LULC Classes	Area (in Sq. Kms (pre-monsoon)	Area (in sq. kms) (Post-monsoon)	Area (in Per cent) (pre-monsoon)	Area (in per cent) (Post-monsoon)
1	Water bodies	0.498	0.781	3.11	4.88
2	Agriculture	3.833	3.982	23.96	24.89
3	Vegetation	5.982	5.893	37.38	36.83
4	Settlement	5.192	5.058	32.46	31.61
5	Barren Land	0.495	0.286	3.09	1.79
6	Total	16	16	100	100

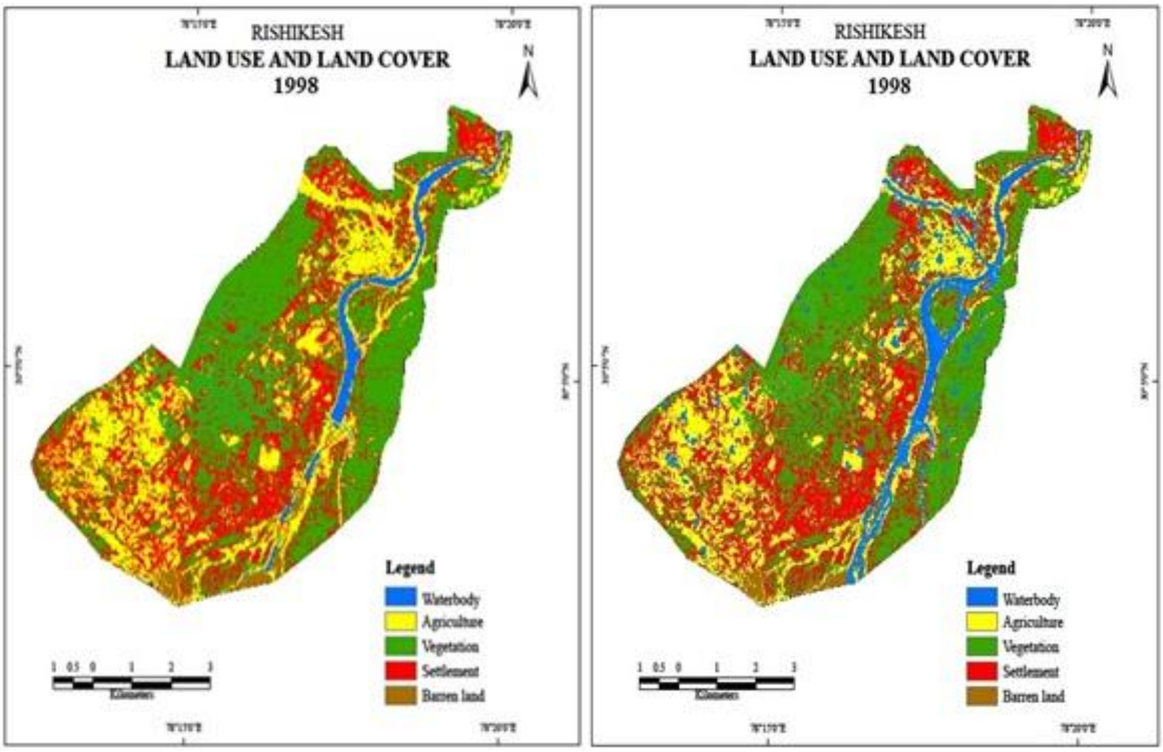
Source: Prepared by Authors

4.3 Land Use and Land Cover for the year 1998 (Pre Monsoon)

Land use and land cover does not observe such drastic change, such as cities in plains. Similarly, this kind of change had taken place in Rishikesh city, most of the settlement and agriculture areas were converted into vegetation cover which comprises the 42.77 per cent area of study area. In the year of 1998, the vegetation covered the most of the built and usable area and even water bodies and barren land. The vegetation cover extended to western part of the city and spread in the semi urbanized area of Pashulok area. Settlement was reduced to 29.14 per cent and agriculture was also reduced to 21.45 per cent. The water bodies had occupied second smallest part of this study area after barren land 3.15 per cent but it was little bit more than the previous one. Barren land was reduced to 0.6 per cent and which was occupied by vegetation (Figure 5).

4.3 Land Use and Land Cover for the year 1998 (Post- Monsoon)

The vegetation cover had marginally decreased to 41.83 per cent, it happened because of water bodies which occupy some small part of vegetation cover on the map. Settlement had also reduced to 28.24 per cent. The water bodies expand in dimensions during the monsoon season in 1998 (Table 3).



Source: Prepared by Authors using Landsat images
Figure 5 and 6 Land Use Land Cover map of 1998, Pre-Monsoon and Post-Monsoon

Table 3 Land Use Land Cover Class for the Years 1998

S.NO.	LULC Classes	Area (in Sq. Kms (pre-monsoon)	Area (in sq. kms) (Post- monsoon)	Area (in Per cent) (pre-monsoon)	Area (in per cent) (Post-monsoon)
1	Water bodies	0.558	0.889	3.49	5.56
2	Agriculture	3.432	3.604	21.45	22.53
3	Vegetation	6.843	6.693	42.77	41.83
4	Settlement	4.663	4.519	29.14	28.24
5	Barren land	0.504	0.295	3.15	1.84
	Total	16	16	100	100

Source: Prepared by Authors

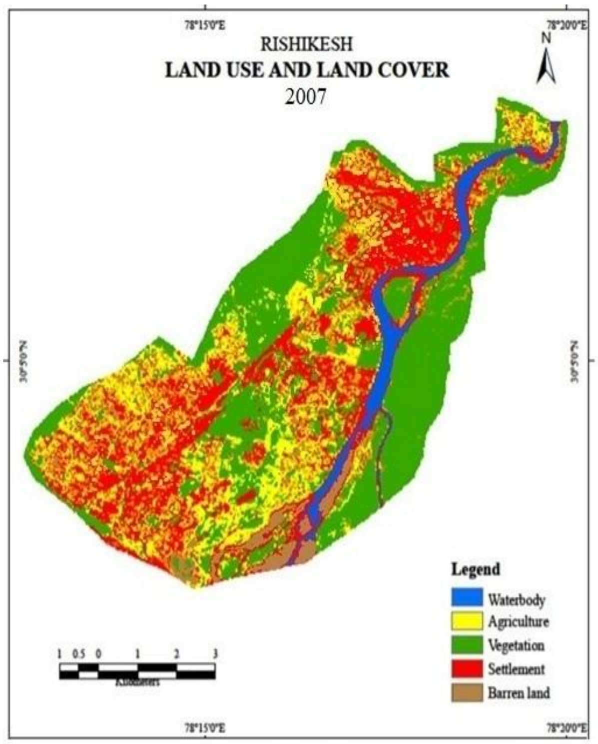
The barren land had also decreased to 1.84 per cent total area because of retaining by river water during the monsoon season (Figure 6). The agriculture has been increased to 22.53 per cent after the monsoon period in 1998 because of sowing and cultivation of seasonal crops after monsoon.

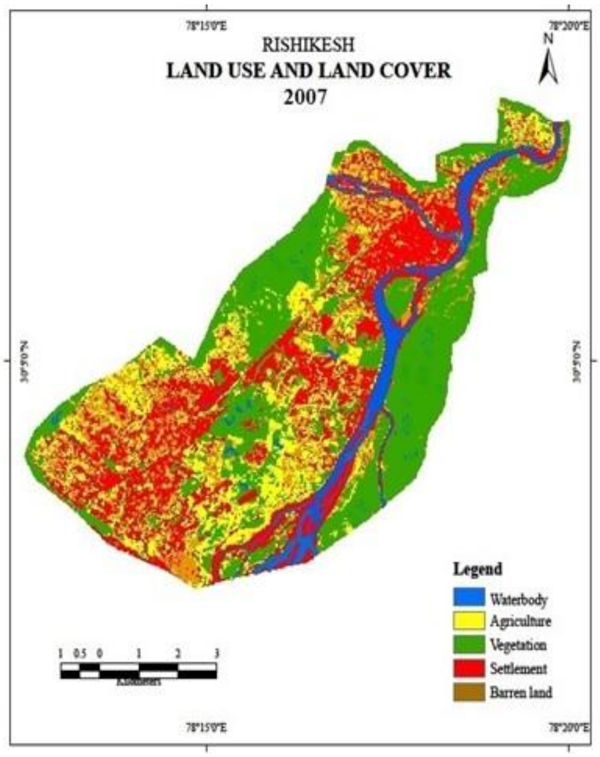
4.5 Land Use and Land Cover for the year 2007 (Pre Monsoon)

The barren land has increased to 4.22 per cent which is river catchment or cross sectional area and some spots visible between the agriculture fields in the map. Most of the catchment is observed to be dry and barren land can be easily demarcated on the map in the southern part of river Ganga. The water bodies have partially increased to 3.85 per cent and are continuously increasing according to the prepared maps from the last 1990s in the study area. The vegetation is partially reduced to 41.45 per cent and it is mostly visible near by the settlement and catchment areas (Figure 7). The eastern and western part of the Rishikesh city is covered with the vegetation. The settlement has also increased to 30.41 per cent which reflects the growing trend of city (Table 4). The settlements are growing in the area previous occupied by agriculture; in Rishikesh city.

4.6 Land Use and Land Cover for the year 2007 (Post-Monsoon)

There have settlements which are looking like emerging from agriculture area nearby the Chandrabhagariver. The water bodies are continuously increasing in area in both the seasons. The water bodies almost 6.09 per cent area which is almost twice of its percentage in the pre monsoon area. The agriculture also increased partially but is mostly concentrated in western margins of the maps. The agriculture is 20.16 per cent which is little bit more than pre monsoon season area. The barren land is decreased to 1.89 per cent because of extension of river water on dry land areas of river catchment (Table 4). The settlement which occupies the 30.37 per cent of total area of Rishikesh city is pre dominantly concentrated along the river Ganga and ChandrabhagaRiver (Figure 8).





Source: Prepared by Authors using Landsat images

Figure 7 and 8 Land Use Land Cover map of 2007, Pre-Monsoon and Post-Monsoon

Table 4 Land Use Land Cover Class for the Years 2007

S.NO.	**LULC Classes**	**Area (in Sq. Kms (pre- monsoon)**	**Area (in sq. kms) (Post-monsoon)**	**Area (in Per cent) (pre-monsoon)**	**Area (in per cent) (Post-monsoon)**
1	Water bodies	0.616	0.974	3.85	6.09
2	Agriculture	3.211	3.226	20.07	20.16
3	Vegetation	6.632	6.638	41.45	41.49
4	Settlement	4.866	4.859	30.41	30.37
5	Barren land	0.675	0.303	4.22	1.89
	Total	16	16	100	100

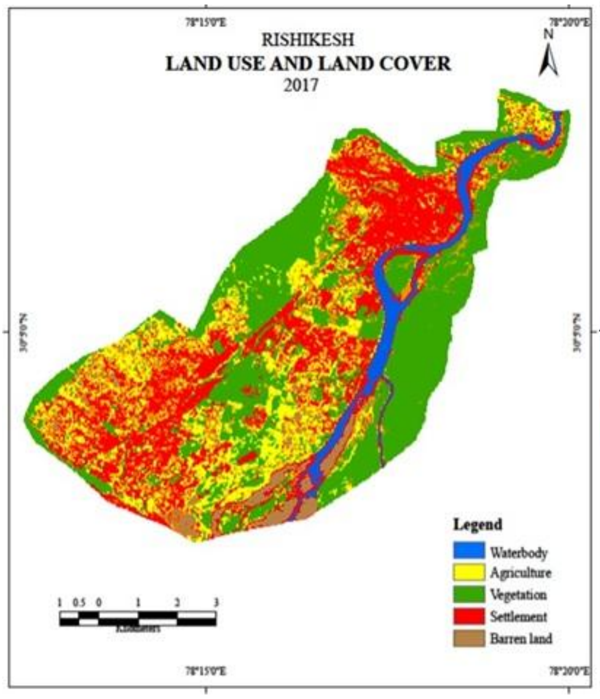
Source: Prepared by Authors

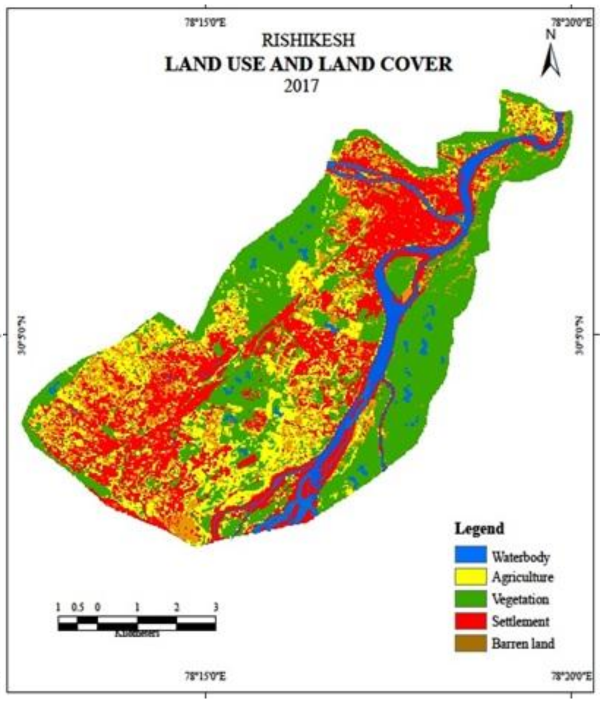
4.7 Land Use and Land Cover for the year 2017 (Pre Monsoon)

The agriculture is seen to have reduced in the land use land cover map of 2017 to 11.73 which reflect the change in economic activities in the area. The barren land is increased to 17.3 per cent which is river catchment or cross sectional area and some spots visible between the agriculture fields in Shyampur area of southern part of the map. Most of the catchment is observed to be looking dry and barren land can easily be observed on the map in southern part near river Ganga ((Figure 9). The area under water bodies category has partially increased to 4.29 per cent and is continuously increasing as per maps from the in the last decades map of study area. This time the flow is almost continuous. Therefore, it looks linear in spite of a dissected form. The vegetation has reduced to 38.86 per cent and it is mostly visible near by the settlement and catchment areas (Table 5).

4.8 Land Use and Land Cover for the year 2017 (Post-Monsoon)

The water bodies area increased to 7.08 per cent in 2017 after monsoon this reflect the huge flow of water in the city during this season which influences the hydrology of this city (Figure 10). The settlements have marginally decreased in periphery of the city and near by the banks of river because of flood and rainy drains. The settlements are 29.82 per cent which is slightly decreased (Table 5).





Source: Prepared by Authors using Landsat image

Figure 9 and 10 Land Use Land Cover map of 2017, Pre-Monsoon and Post-Monsoon

Table 5 Land Use Land Cover Class for the Years 2017

S.NO.	LULC Classes	Area (in Sq. Kms (pre-monsoon)	Area (in sq. kms) (Post-monsoon)	Area (in Per cent) (pre-monsoon)	Area (in per cent) (Post-monsoon)
1	Water bodies	0.687	1.133	4.29	7.08
2	Agriculture	3.028	2.49	18.92	15.56
3	Vegetation	6.216	5.942	38.86	37.14
4	Settlement	5.361	4.771	31.01	29.82
5	Barren land	0.708	1.664	6.92	10.4
	Total	16	16	100	100

Source: Prepared by Authors

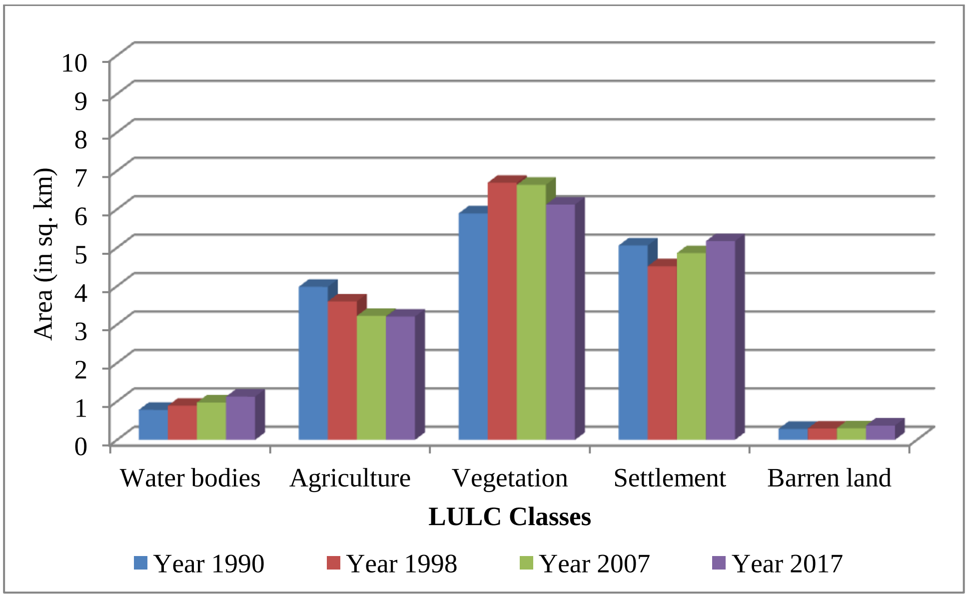
The agriculture is increased to 15.56 and barren land has been decreased to 10.4 per cent. Barren land has been used for agriculture which was present along with the agriculture margins. Barren land which was present in river channel is also submerged under river water which can be seen on the map of 2017 after monsoon period. The vegetation cover has increased to 37.14 per cent which occupies the area near Pashulok area in the city.

5. Discussion

5.1 The Land Use Change during the Period of 1990 to 2017 (Pre- Monsoon)

The analysis satellite images of Rishikesh city have provided different outcomes which show change in all the classes. Water bodies was only gainer in the whole period and it is the only increasing category of land use land cover reflected by the increase in the area of water bodies in this region. During the 1990 it was 3.11 per cent of total area of the study but in 1998 it slightly increased to 3.49 per cent and further in the year of 2007 it increased to 3.85 per cent and in 2017 it increased to 4.29 per cent in area of the study. It reflects growing size of water in Rishikesh city (Table 11). The area of water bodies increased from 0.498 sq. km to 0.687 sq. km (Figure 11). The agriculture has decreased in the whole period. The agriculture decreased to 21.45 per cent in 1998 from 23.96 per cent in 1990. And it further decreased to 20.07 per cent in 2007 per cent and in 2017 it was decreased to 18.92 per cent of total area of Rishikesh which is almost one fourth of area of agriculture in the period of 1990. The agriculture is reduced from 3.833 sq. km to 3.028 sq. km from 1990 to 2017. The vegetation and settlement fluctuated during this period with positive and negative change in area. The vegetation and settlement had occupied the 37.38 and 32.46 per cent respectively. But in the year of 1998, the settlement declined to 29.14 per cent and vegetation occupied some area of settlement and agriculture and gained 42.77 per cent area of total study area. In the year 2007, the vegetation declined to 41.45 per cent and settlement increased to 30.41 per cent. In 2017, the vegetation and settlement occupies the areas with 38.86 and 31.01 respectively. The vegetation and settlement occupied 5.982 and 5.192 sq. km area of total land in 1990 which changed to

6.843and 4.663 sq. km in 1998. But afterward vegetation starts to decline in upcoming years. It declined to 6.632 sq. km in 2007 and further in 6.216 sq. km in 2017 (Figure 11).

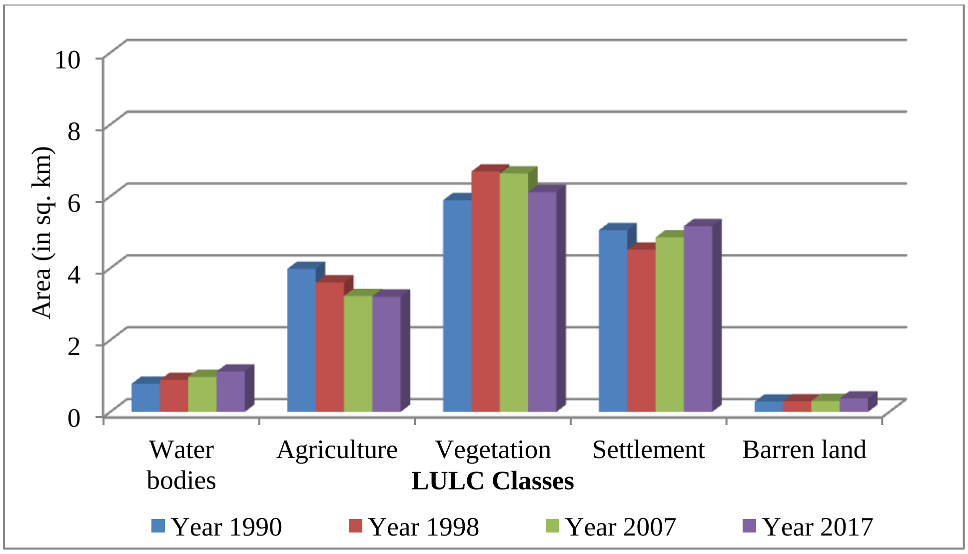


Source: Prepared by Authors

Figure: 11 The Land Use Change during the Period of 1990 to 2017 (Pre-Monsoon)

5.2 The Land Use Change during the Period of 1990 to 2017 (Post-Monsoon)

The trend of land use land cover in Rishikesh is very different from the pre monsoon condition. The major changes were taken place in water bodies, it was the lone gainer in monsoon season and it achieved it larger area during this season because of an excess amount of water in river streams and other water bodies. It was high as compared to the pre monsoon conditions. During 1990 it was 4.88 per cent of the total study area but in 1998 it slightly increased to 5.56 per cent and further in the year of 2007 it increased to 6.09 per cent and in the year 2017, it occupied 7.03 per cent of the study area. The area of water bodies increased from 0.781 sq. km to 1.125 sq. km (Figure 12). The agriculture decreased to 22.53 per cent in 1998 from 24.89 per cent in 1990. And it further decreased to 20.16 per cent in 2007 per cent and in the year 2017, it was 20.05 per cent of total area of Rishikesh (Table 12). The vegetation and settlement had occupied the 36.83 and 31.61 per cent respectively in 1990. But in the year of 1998, the settlement declined to 28.24 per cent and vegetation increased to 41.83 per cent area of total study area. In the year 2007, the settlement increased to 30.37 and vegetation decreased to 41.49 per cent and in 2017, the vegetation further declined to 38.26 per cent and settlement increased to 32.32 per cent. The agriculture land also declined during 1990 to 2017 from 24.89 per cent to 20.05 per cent. In the year 2017, barren land was 2.34 per cent of total land of the study area and it never lose their area during the period of 1990 to 2017.



Source: Prepared by Authors

Figure: 12. Land Use Change during the Period of 1990 to 2017 (Post-Monsoon)

6. Kappa Accuracy Assessment

The Kappa accuracy assessment is used to check the quality of map output after completion of map (Congalton, 1991; Richards, 2014; Rwanga and Ndambuki, 2017). This process used by various scientists and scholars for assessment of accuracy of the maps (Fielding and Bell, 1997; Manandhar et al., 2009). It is used through reality check of actual positioning of features and element which plotted or identified on the maps and on the basis of Geographical Control Points (GCPs) it has been cross checked with pixels (Scott and Ritchie, 2006; Ceccarelli et al., 2013; Malik et al., 2019). It was introduced by Cohen in 1960s.The Kappa provides the reader as quantitative measure for the agreement between observers. Kappa assessment has been done with very simple formula:

$$\frac{\text{Sum of the observation on which the class occur}}{\text{Total number of Observation}} \text{ X 100}$$

There are overall accuracy and kappa Coefficient which described the accuracy level of maps in study area. The accuracy rate 1990, 1998, 2007 and 2017 map are 90.40, 89.05, 90.25 and 91.10 with 0.82, 0.86 kappa coefficient respectively (Table 6).

Table 6 Accuracy Assessment by Kappa Coefficient from 1990 to 2017

Year	Overall Accuracy (in per cent)	Kappa Coefficient
1990	90.40	0.82
1998	89.05	0.86
2007	90.25	0.86
2017	91.10	0.86

Source: Prepared by Researcher

7. Normalized Difference Water Index

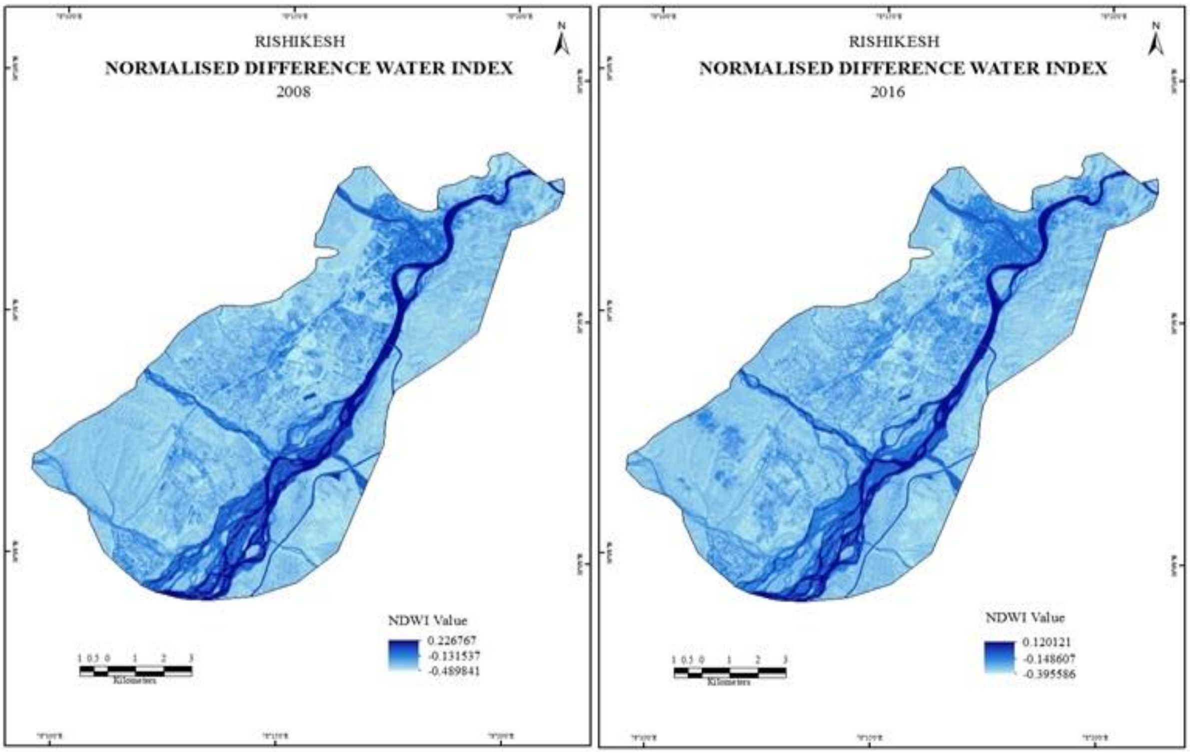
Normalized Difference Water Index (NDWI), presented without precedent for 1996 in (Gao), reflects moisture content in plants and soil and is controlled by similarity with NDVI as:

$$\mathbf{NDWI} = \frac{NIR - SWIR}{NIR + SWIR}$$

NIR - close infrared range with wavelengths in the scope of 0.841 - 0.876 nm
SWIR - a piece of the range with wavelengths in the scope of 1.628-1.652 nm

7.1 NDWI of Rishikesh for 2008 and 2016

The NDWI of Rishkesh city in 2008 described that the water content is high in area represented by dark blue and shade of blue. The catchment area has high content of NDWI value and it is positive and near the 0.227 and the region which has bluish white color represents the low content of NDWI index with the value of -0.49 which represent less content of water or moisture (Figure 13).The NDWI of Rishkesh city in 2016 has been observed that water content reduces all over the area in Rishikesh city. Blue dark colour representing the high water content and bluish white colours have represented no water or less water content (Figure 14).



Source: Prepared by Authors with help of Landsat images

Figure 13 and 14Normalized Difference Water Index

The catchment area has high content of NDWI value and it is positive and near the 0.120 but it is less than the value of images of year of 2008 and the lowest value which has observed at -0.39 are also low as compare to image of the year 2008 (Figure 14).

8. Conclusions

The hydrological regime of Rishikesh is mostly dependent on flowing river which renders this city as attraction for its scenic beauty, spiritual importance and tourist spots etc. This area comprises of one main river which flows in the east of the city and two tributaries of this main river. The tributaries are Chandrabhaga and Song river, both bring the huge amount of water during the rainy season. This city has also received water from numbers of rainy drains which passes through the city and meet the tributaries and the main river. Therefore, the water bodies have increased in study area. The change was more than 32.75 percent in water bodies area after monsoon season in city in 1990. The other water bodies were also rejuvenated because of stagnation of water which also contributed in increasing of water bodies area. During 1998, the water bodies had 32.90 per cent changed, it means it had been added some area in water bodies in 1998. During the year of 2007, the water bodies again increased and added 47.23 per cent area in water bodies. In 2017, water bodies further increased after monsoon season with 35.44 per cent change in the area. Water bodies are only class which has positive change to its area after the monsoon season in study area.

Author Contributions

Writing—original draft, Pankaj; Writing—review & editing,Harish Kumar, Supervision, prof. Subhash Anand.All authors have read and agreed to the published version of the manuscript.

Funding

This work was partially supported by the Non-NET fellowship by University of Delhi.

Conflicts of Interest

The authors declare no conflict of interest.

References

1. Alonso-Pérez, F., Ruiz-Luna, A., Turner, J., Berlanga-Robles, C. A., &Mitchelson-Jacob, G. (2003). Land cover changes and impact of shrimp aquaculture on the landscape in the Ceuta coastal lagoon system, Sinaloa, Mexico. *Ocean & Coastal Management,46*(6-7), 583-600. Asselman, N. E., &Middelkoop, H. (1995). Floodplain sedimentation: Quantities, patterns and processes. *Earth Surface Processes and Landforms,20*(6), 481-499.
2. Blaikie P. and Brookfield H. (1987). Land Degradation and Society. 296 pp. London: Routledge.
3. BMZ, (2012). Land use planning: concepts, tools, applications. Deutsche GesellschaftfürInternationaleZusammenarbeit. Eschborn, Germany, Federal Ministry for Economic Cooperation and Development (available at www.giz.de).

4. Brouwer, F. M. (1991). *Land use changes in Europe: Processes of change, environmental transformations and future patterns:*. Dordrecht: Kluwer Acad. Publ.
5. Ceccarelli, T., Smiraglia, D., Bajocco, S., Rinaldo, S., Angelis, A. D., Salvati, L., & Perini, L. (2013). Land cover data from Landsat single-date imagery: An approach integrating pixel-based and object-based classifiers. *European Journal of Remote Sensing,46*(1), 699-717.
6. Census of India, (2011), Directorate of Census of India, *Census of India*, Delhi, India.
7. Central Pollution Control Board (2000). "Water Quality status of Yamuna River," New Delhi, www. cpcb.nic.in
8. Cigizoglu, H. K., Bayazit, M., &Önöz, B. (2005). Trends in the Maximum, Mean, and Low Flows of Turkish Rivers. *Journal of Hydrometeorology,6*(3), 280-290. doi:10.1175/jhm412.1
9. Congalton, R. G. (1991). A review of assessing the accuracy of classifications of remotely sensed data. *Remote Sensing of Environment,37*(1), 35-46. Douville, H. (2002). Influence of soil moisture on the Asian and African monsoon. Part II: Inter annual variability. *Journal of Climate*, *15*, 701–720.
10. Douville, H., Chauvin, F., &Broqua, H. (2001). Influence of soil moisture on the Asian and African monsoons. Part 1: Mean monsoon and daily precipitation. Journal of Climate, 14, 2381–2404.
11. Far, M. G. (2003). Assessing land-use/land-cover mapping of agriculture area using high-resolution satellite data and GIS techniques. *Remote Sensing for Agriculture, Ecosystems, and Hydrology IV*.
12. Fielding, A. H., & Bell, J. F. (1997). A review of methods for the assessment of prediction errors in conservation presence/absence models. *Environmental Conservation,24*(1), 38-49.
13. Firozjaei, Sedighi, Kiavarz, Qureshi, Haase, &Alavipanah. (2019). Automated Built-Up Extraction Index: A New Technique for Mapping Surface Built-Up Areas Using LANDSAT 8 OLI Imagery. *Remote Sensing,11*(17), 1966.
14. Gumma, M. K., Thenkabail, P. S., Teluguntla, P., & Whitbread, A. M. (2019). Indo-Ganges River Basin Land Use/Land Cover (LULC) and Irrigated Area Mapping. *Indus River Basin,7*(5), 203-228.
15. IPCC. Climate Change, 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change Solomon S, Qin D, Manning M, Chen Z, Marquis M, Averyt KB, Tignor M, Miller HL, (eds.)], Cambridge University Press, Cambridge, United Kingdom and New York, USA. 2007; 996.
16. Jansen, L. J., & Gregorio, A. D. (2003). Land-use data collection using the "land cover classification system": Results from a case study in Kenya. *Land Use Policy,20*(2), 131-148.
17. Jensen, J. R. and Coven, D. C. (1999). Remote Sensing Of Urban/Suburban Infrastructure and Socio-Economic Attributes. Photogrammetric engineering and remote sensing, Vol. 65, pp. 611-622.
18. Khajuria, A., &Ravindranath, N. (2012). Climate Change Vulnerability Assessment: Approaches DPSIR Framework and Vulnerability Index. *Journal of Earth Science & Climatic Change,03*(01).
19. Li, S., Yeng H., Lacayo M., Liu J. and Lei G. (2018). Impact of Land Use and Land Cover Change on Water Yield: A Case Study in Jing-Jin-Ji, China, Sustainability, Vol. 10 (4), p. 960.
20. Malik, A., Pandey, S. K., Kumar, H., & P. (2019). Measuring of Deforestation Rate Using Pixel Based Approach. *International Journal of Innovative Knowledge Concepts,7*(5), 167-177.
21. Manandhar, R., Odeh, I., &Ancev, T. (2009). Improving the Accuracy of Land Use and Land Cover Classification of Landsat Data Using Post-Classification Enhancement. *Remote Sensing,1*(3), 330-344.

22. Mccauley, L. A., Anteau, M. J., Burg, M. P., &Wiltermuth, M. T. (2015). Land use and wetland drainage affect water levels and dynamics of remaining wetlands. *Ecosphere,6*(6), 1-22.
23. Merchant, J. W., &Narumalani, S. (2001.). Integrating Remote Sensing and Geographic Information Systems. *The SAGE Handbook of Remote Sensing,* 257-268.
24. Misra, A. K. (2010). A River about to Die: Yamuna. *Journal of Water Resource and Protection,02*(05), 489-500.
25. Pandy, A. C. and Nathawat, M. S. (2006). Land Use Land Cover Mapping Through Digital Image Processing of Satellite Data-A Case Study from Panchkula, Ambala and Yamuna Nagar District, Haryana, India.
26. Pinto, R., Jonge, V. D., Neto, J., Domingos, T., Marques, J., &Patrício, J. (2013). Towards a DPSIR driven integration of ecological value, water uses and ecosystem services for estuarine systems. *Ocean & Coastal Management,72*, 64-79.
27. Rawat, J., & Kumar, M. (2015). Monitoring land use/cover change using remote sensing and GIS techniques: A case study of Hawalbagh block, district Almora, Uttarakhand, India. *The Egyptian Journal of Remote Sensing and Space Science,18*(1), 77-84. doi:10.1016/j.ejrs.2015.02.002
28. Reed, M. S., & Stringer, L. C. (2016). Land degradation, desertification, and climate change: Anticipating, assessing, and adapting to future change. London: Routledge, Taylor & Francis Group.
29. Richards, J. A. (2014). *Remote Sensing Digital Image Analysis An Introduction*. Berlin: Springer Berlin.
30. Risky, Y. S., Aulia, Y. H., &Widayani, P. (2017). Spatiotemporal Built-up Land Density Mapping Using Various Spectral Indices in Landsat-7 ETM+ and Landsat-8 OLI/TIRS (Case Study: Surakarta City). *IOP Conference Series: Earth and Environmental Science,98*, 012006.
31. Rwanga, S. S., &Ndambuki, J. M. (2017). Accuracy Assessment of Land Use/Land Cover Classification Using Remote Sensing and GIS. *International Journal of Geosciences,08*(04), 611-622.
32. Scott, J., & Ritchie, N. (2006). Measuring Pixel Classification Accuracy Using Synthetic Spectrum Images. *Microscopy and Microanalysis,12*(S02), 1394-1395.
33. Shukla, J. (1985). Predictability. In Advances in geophysics, Academic Press. Vol. 28B, pp. 87–122.
34. Shukla, J. (1985). Predictability. In Advances in geophysics, Academic Press. Vol. 28B, pp. 87–122.
35. Sisay, E., Teshome, A., &Halefom, A. (2020). Potential implications of land use/land cover change and climate variability on ungauged watershed hydrology. *International Journal of Hydrology Science and Technology,10*(2), 167.
36. Taylor, C., Lambin, E., Stephenne, N., Harding, R. and Essery, R., (2002). The Influence of Land Use Change on Climate in the Sahel. *Journal of Climate*, 15(24), pp.3615-3629.
37. Thenkabail, P. S. (2016). *Remotely sensed data characterization, classification, and accuracies*. Boca Raton, Fl: Taylor & Francis.
38. Thomas, T., Gunthe, S. S., Ghosh, N. C., &Sudheer, K. P. (2014). Analysis of monsoon rainfall variability over Narmada basin in central India: Implication of climate change. *Journal of Water and Climate Change,6*(3), 615-627.

39. Trudeau, M., & Richardson, M. (2016). Empirical assessment of effects of urbanization on event flow hydrology in watersheds of Canada's Great Lakes-St Lawrence basin. *Journal of Hydrology,541*, 1456-1474.
40. Turner, B. L. and Meyer, W. B. (1994), Changes in Land Use Land Cover: A Global Perspective, Cambridge University Press, Vol. 4, pp. 88-96.
41. Uddin, M., Akter, S., Uddin, M., &Diganta, M. (2018). Trend Analysis Variations and Relation Between Discharge and Rainfall: A Study on Kushiyara River. *Journal of Environmental Science and Natural Resources,10*(2), 121-132.
42. USGS (2018. Earth Explorer, United State Geological Survey, Federal Govt. of United States, Washington DC. earthexplorer.usgs.gov
43. Verbyla, D. L. (1995). *Satellite remote sensing of natural resources*. Boca Raton, FL: Lewis.
44. Wijitkosum, S. (2012). Impacts of land use changes on soil erosion in Pa Deng sub-district, adjacent area of KaengKrachan National Park, Thailand. *Soil and Water Research,7*(No. 1), 10-17.
45. Zhai, R. et al., (2020) Evaluation of Driving Forces of Land Use and Land Cover Change in New England Area by a Mixed Method, ISORS Int Jr. Geo-Inf. 9(6), 350,
46. Zhang, X., Harvey, K. D., Hogg, W. D., &Yuzyk, T. R. (2001). Trends in Canadian streamflow. *Water Resources Research,37*(4), 987-998.
47. Zhou, Y. (2020). Watershed Hydrology and Land-Use and Land-Cover Change (LULCC). *Fresh Water and Watersheds,* 221-224.