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Morphological Assessment and Land Use Land Cover Change Detection of Hindon River Basin on Geospatial Platform

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Abstract: The present study is carried out the morphometrical analysis of River Hindon basin by linear, areal and relief aspects and land use land cover analysis of the basin by supervised classification technique. The basin occupies 6940 km^2 geographical area and it's boundary perimeter is 1081.88 km. The minimum and maximum elevation of the basin was 190 m and 868 m and average elevation of entire basin is 528.5 m from mean sea level. The land use land cover by supervised classification, indicated that total 4047.93 km^2 area about 58.32 % of total area of basin used for agriculture purpose and covered by vegetation, 953.81 km^{2}i.e. 1.37 % of basin area is covered by water bodies like river, streams, ponds, canals etc., 647.43 km^2 i.e. 9.32 % of basin area is barren land and 2149.94 km^2 i.e. 30.97 % of basin area is covered by build-up. There are also carried out the analysis of NDVI and NDVI ranges of the basin during 1990 was -0.13 to + 0.47 and in 2022 was -0.10 to +0.48.

Keywords: Morphometry, GIS & Remote Sensing, LANDSAT, SRTM Digital Elevation Model, LULC, NDVI

Morpho-metrical analysis is important for any watershed to address water erosion prone areas, flood prone areas, highly affected sediment transport areas and sediment accumulated areas of river (Haokip et al., 2022). It is important to know about morpho-metrical parameters of the basin in terms of linear, areal and relief aspects for watershed management planning and hydrological studies of the basin (Avijit Mahala 2020). The watershed management projects can be designed, such as establishment of gully control and flood control structures like spillways, grassed waterways, reservoirs, barrages, dams, soil and water conservation structures like bunds, terraces etc., water supply and disposal units like canal distributaries and watercourses, culverts, surface and sub-surface drainage systems and can also address water logging affected areas in the basin through morphometrical analysis (Sinha and Eldho 2021). The morphometric analysis of watershed is useful to investigate the erosion status of basin, flood prone areas and critical area suffering to soil erosion within drainage basin (Bajirao et al., 2019). The morphological analysis is generally performed for planning and implementing soil and water conservation and quality measures, groundwater development and management and erosion control measures (Agrawal et al., 2022). Hydrological and geomorphic processes occur within the watershed, and morphometric characterization at the watershed scale reveals information about formation and development of land surface processes and thus provides a holistic insight into the hydrological behaviour of a watershed (Shekhar et al., 2022). Morphological parameters affect the various hydrological characteristics of the basin such as runoff, peak discharge, time of concentration, depression storage, flow velocity etc (Anand et al.,2020). The parameters required for the morphometrical analysis of the basin from linear, areal and relief aspects are area, perimeter, stream order, stream length, number of streams, maximum length of the main channel of the basin, maximum and minimum elevation from mean sea level and slope etc (Annayat et al., 2022). Using morphological parameters, different hotspot locations which may be expected to have extreme events such as drought, flood etc. can be identified (Joy et al., 2023). This will helps in selection of particular site for the prevention of the area by constructing different structures such as spillways, grassed waterways, artificial water harvesting structures and dams. It also helps to address the erosion affected areas and for prevention of that adopted various erosion control temporary and permanent structures.

Most of the industrial and municipal waste are dissolving in the river therefore degree of contamination of the river is increasing day by day and their adverse effect on groundwater quality and groundwater contamination is also increasing in Hindon river basin due to dissolving toxic elements (Sharma et al., 2021). Most of the farmers nearby the villages of Hindon river use that polluted water for irrigation purpose for their agricultural land, which also affects the crop yield and productivity. For the rejuvenation of river Hindon, it is important that the study of morphometrical parameters for the quantitative and qualitative assessment of the basin must be carried out. The national mission for clean Ganga (NMCG) approved 4 projects worth rupees 407 crore in April 2023 to rejuvenate river Hindon in the district Shamil of Uttar Pradesh state (https://pib.gov.in/PressRelease Page). Prabhakar et al. (2019) and Gupta et. al. (2023) highlighted the morphometric analysis with land use and land cover (LULC) changes and hydrologic performance over the watershed. This study is carried out for the morphometrical analysis in linear, areal and relief aspects and temporal variation of land use land cover in river Hindon basin and their applications in the basin for management & planning of watershed.

MATERIAL AND METHODS

Site location: Hindon river is an important tributary of river Yamuna. It originates from Shivalik hills of Saharanpur district and joins to river Yamuna near village Tilwada of Gautam Buddha Nagar district in Uttar Pradesh. It travels the total distance from origin to confluence point of 312 km and many of streams, drains and rivers joins the path of Hindon river main stream. The extent of the basin is from 28° 24' 9" N to 30°17'18" N latitude and 77° 12' 30" E to 77° 55' 4" E longitude. The minimum and maximum elevation of the basin from mean sea level is 190 m and 868 m respectively and average elevation of the basin is 528.5 m. The Kali River, Krishni River, Nagdev nala, Dhamola Nala, budhana drain, dasna drain, star paper mill drain, Jonney escape are the important tributaries of river Hindon, passing through 6 districts of UttarPradesh, Saharanpur, Muzaffarnagar, Bagpat, Ghaziabad, Meerut and Gautam Buddha Nagar and some area of the basin is occupied by Haridwar District Uttarakhand and Union Territory Delhi (Fig. 1).

Data-sets and methodology: All morphometrical parameters of Hindon river basin has been evaluated and secondly the change detection of land use land cover analysis in the gap of 30 years by supervised classification techniques as well as NDVI analysis has been performed. Shuttle Radar Topography Mission (SRTM) Digital elevation model (DEM) data downloaded from USGS earth explorer and thereafter the elevation map, flow direction, flow accumulation, stream order, aspect, and slope map were prepared. LANDSAT-8-9 C2 L2 and LANDSAT 4-5 C2 L2 all 7 bands (30 m resolution) were downloaded from USGS earth explorer for the land use land cover analysis of Hindon river basin. For the preparation of NDVI maps LANDSAT 4-5 (for 1990) and LANDSAT 8-9 (for 2022) 30 m resolution data is acquired from USGS earth explorer. The Arc GIS 10.3 software used for preparation, analysis and representation of data through maps. The flowchart of the methodology has been depicted in the Figure 2-a & 2-b.

RESULTS AND DISCUSSION

Linear Aspects

Stream order (U): Stream ordering is the first step to be performed for the quantitative study of the river basin (Rai et al., 2019). According to Strahler Stream Ordering System, smallest stream designated as 1st order stream and confluence of two 1st order streams derive 2nd order stream.

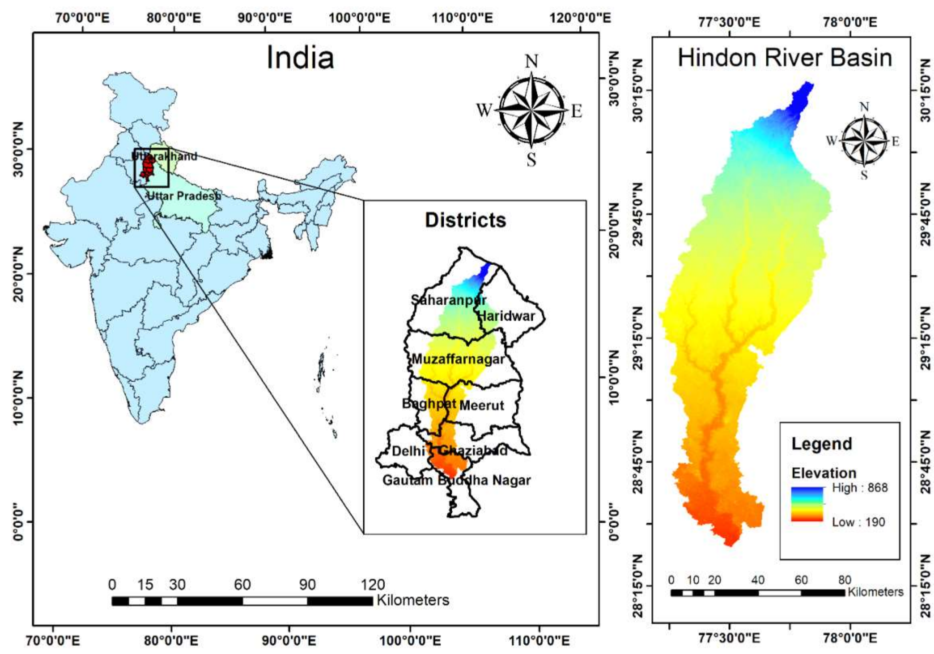

Fig. 1. Location map of Hindon River Basin

Similarly the confluence of two 2nd order stream makes 3rd order stream and so on till the end of stream outlet. Stream order map of the basin is created by SRTM DEM of 30 m resolution. Hindon river basin was have maximum 5th order stream.

Stream number (Nu): Stream number is the count of individual streams in the basin of each order. There are total 758 streams found in Hindon river basin. Out of these, 658 streams of 1st order, 84 streamsof 2nd order, 13 streams of 3rd order, 2 streams of 4th order and 1 stream of 5th order were determined by calculation.

Stream length (Lu): Total sum of all stream length of Hindon river basin was 2047 km in which 1124 km length of 1st order, 471 km length of 2nd order, 156 km length of 3rd order, 155 km of 4th order and 141 km of 5th order stream werefound.

Bifurcation ratio (Rb): In Hindon river basin, the mean bifurcation ratio is found to be 5.69, which indicates that there are very less number of stream branches in Hindon basin (Table 1). Lower the mean bifurcation ratio, greater the branching in the stream network within a watershed and vice-versa (Prabhakaran and Jawahar Raj 2017).

Stream length ratio (R_L): The R_L values between streams of different order in the basin reveal that there are variations in slope and topography (Waikar and Nilawar 2014).

Areal Aspects

Form factor (R_f): The present study of Hindon river basin, basin area (A) was calculated 6950 km^2 and length of main stream (L) was as 312 km so the form factor will be 0.065 thus confirm that either visually or numerically Hindon basin is an elongated basin.The form factor less than 0.78 indicates an

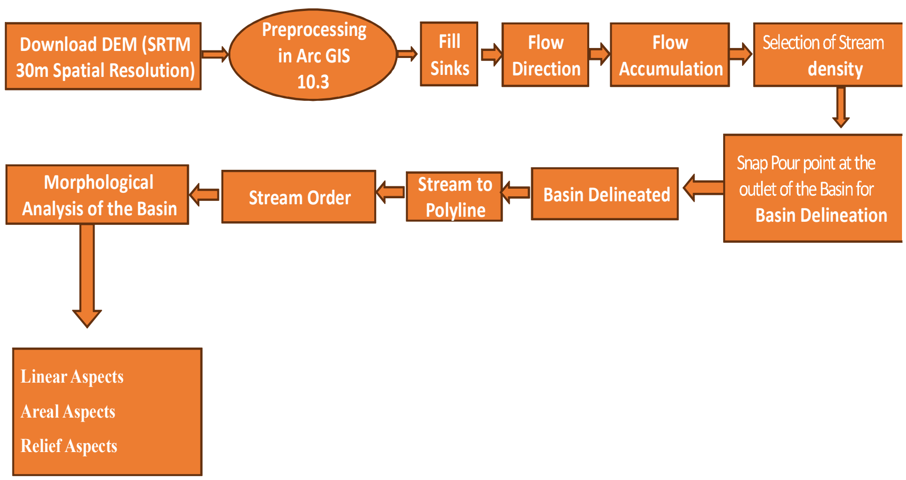

Fig. 2a. Methodology of flowchart for linear, aerial & relief aspect analysis of Basin

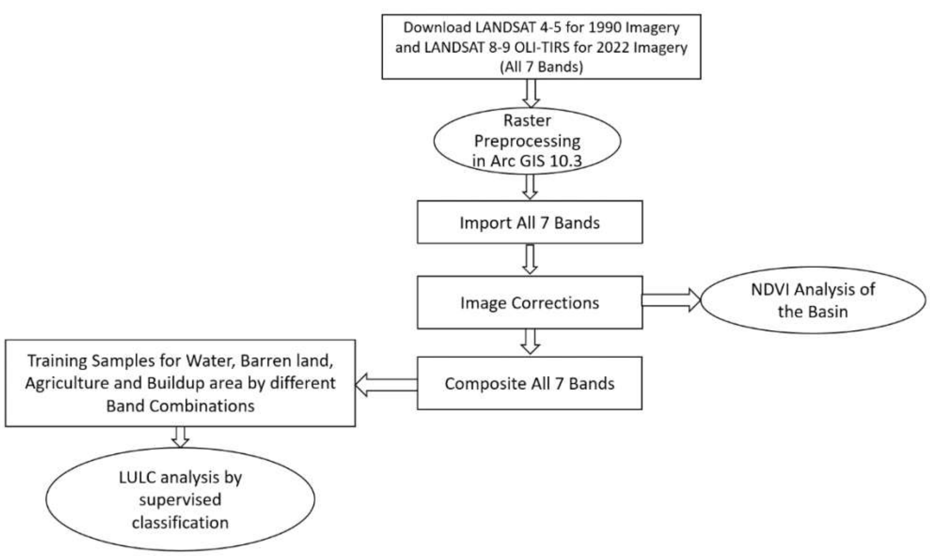

Fig. 2b. Methodology of flowchart for land use land cover & NDVI analysis

elongated basin, and greater than 0.78 indicates a circular basin (Farhan et al., 2016).

Shape factor (S_f): The shape factor of Hindon river basin was 14.The greater the circular character of the basin, the greater is the rapid response of the watershed after a storm event (Altaf et. al., 2013).

Compactness coefficient (Cc): The compactness coefficient value is independent of size of watershed and dependent only on the slope (Rai et. al., 2017). The compactness coefficient of Hindon river basin was 3.66.

Elongation ratio (R_l): In Hindon river basin, the elongation ratio was obtained as 0.301and states that the basin is much elongated.The varying slopes of watershed can be classified with the help of the index of elongation ratio, i.e. circular (0.9-0.10), oval (0.8-0.9), less elongated (0.7-0.8), elongated (0.5-0.7), and more elongated (< 0.5) (Pareta and Pareta, 2011).

Circulatory ratio (Rc): The circulatory ratio was 0.074.Circulatory ratio (Rc) is influenced by the length and frequency of the stream, geological structures, land use/land cover (LULC), climatic variability, relief and slope of the sub-watersheds (Patel et al. 2013). The high value of circularity ratio shows the late maturity stage of topography.

Drainage density (D_d):. In Hindon river basin, the drainage density was found to be as 0.29 km per km^2.It indicates that how many streams are there per unit area of the basin generally represented as km/km^2

Stream frequency (S_f): The stream frequency of Hindon river basin was 0.119 per km^2. The higher stream number indicates the higher stream density in the basin so probability of extreme events by runoff accumulation like a flood on a particular site of the basin may be increased.

Constant of channel maintenance (C): The constant of channel maintenance value of Hindon river basin was 3.395.The constant of channel maintenance indicates the relative size of landform units in a drainage basin and has a specific genetic connotation

Relief Aspects

Relief ratio (R_r): The relief ratio of the Hindon river basin was 3.2285 and maximum relief of the basin is 684 m. In general, the relief ratio (R_r) indicates the overall slope of watershed surface (Prabhakar et. al., 2019). The rate of potential energy to kinetic energy of flowing water is dependent on relief ratio due to slope and elevation characteristics of the basin.

Ruggedness number (R_n): The ruggedness number (R_n) of Hindon river basin was 0.201 which indicates that smoother topography of the basin. Most of the area of Hindon basin are flatter or less slopy, only some parts of the basin area are having a steep slope like Shivalik hills where Hindon originates, other areas of the basin are not having a steep slope. The ruggedness number is the product of relief and drainage density and both parameters should be in same units. It indicates that the structural complexity of the terrain in association with the relief and drainage density (Altaf et al., 2013). The extremely high values of ruggedness number occur when slopes of the basin are not only steeper but also longer (Umrikar 2016). The values range from 0 to 1. The values close to 0 show relatively smoother topography, and ruggedness number (R_n) close to 1 shows rough topographical characteristics (Nath et. al., 2022).

Land use land cover (LULC), change detection and NDVI analysis of basin: Land use land cover analysis of Hindon river basin is carried out by supervised classification

Table 2. Areal aspects of Hindon river basin

Areal aspects	Value
Total area of the basin (sq. km)	6950
Form factor	0.07
Shape factor	14.00
Compactness ratio	7.32
Drainage density	0.29
Circulatory ratio	0.07
Elongation ratio	0.30
Constant of channel maintenance	3.39
Stream frequency	0.10

Table 3. Relief aspects of Hindon river basin

Relief aspects	Value
Maximum relief	678
Relief ratio	3.22
Ruggedness number	0.20

Table 1. Linear aspects of Hindon River Basin

Stream order	Stream number (N_u)	Total no. of streams	Stream length (L_u)	Total stream length (KM)	Stream length ratio (R_L)	Bifurcation ratio (R_b)	Mean bifurcation ratio (R_{bm})	Length of overland flow
I	658		1124			7.84		
II	84		471		0.91	6.46		
III	13	758	156	2047	0.99	6.5	5.69	1.55
IV	2		155		0.33	2		
V	1		141		0.42			

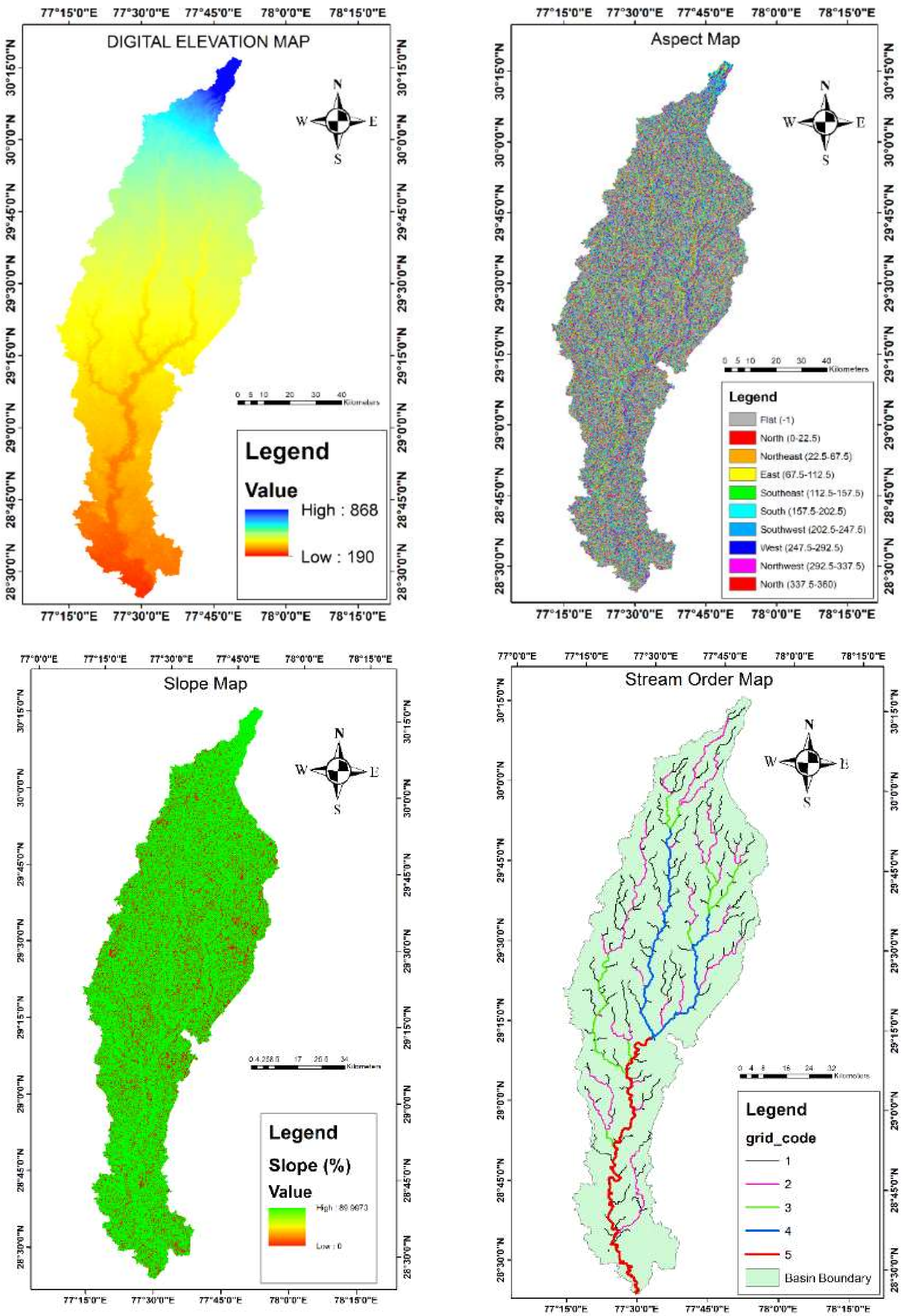

Fig. 3. Hindon basin digital elevation, aspect, slope and stream order maps

technique. The large water bodies in the entire basin are extended in the area of about 953.81 km^2 i.e., approximately 1.37 % of the total area and the largest area of the basin accounts to be as 4047.93 km^2,approximately 58.32% of total area, covered by agriculture land and vegetation (Table 6). The LULC map for the years 1990 and 2022 has been shown in Figure4 and the NDVI maps in Figure 5. Figure 4 and Figure 5, indicate land use land cover changes decade wise. Before the 1990 most of the area of basin was agricultural and pastoral land and during the 1990 to 2022 urbanisation and industrialisation started and it is increasing continuously with respect to time. About 30.97 % of total basin area has been converted into built-up in 2022.This indicates the continuous encroachment of the rivers by built-up in the basin. Most of the area in 1990's that lay nearby the river Hindon and their tributaries was barren land and after three decades we can see the significant changes in the basin and barren land is converted into agriculture and pastoral land during the past three decades due to green revolution and climate change (Mishra et al., 2018). Total built-up area in the basin was 15.72 % during 1990 and now total built-up area is 30.97 % increased about 15.25 % whereas total barren land 21.93% during 1990 which is now only 9.32% and decreased about 12.61%. Similarly water bodies like stream channels, canals, rivers, ponds has increased from 0.24 % to 1.37 % due to changes in several meteorological and climatic conditions. The study of normalized difference vegetation index (NDVI) of the basin was carried out for understanding land cover characteristics and their changes in the basin during 1990 and 2022. The ranges of NDVI in 1990 varies from - 0.13 to 0.47 whereas in 2022 it ranges from -0.10 to 0.48. Negative NDVI values indicates that clouds and water bodies of the basin and those values which are positive and close to zero up to 0.1 indicates the exposed surface such as

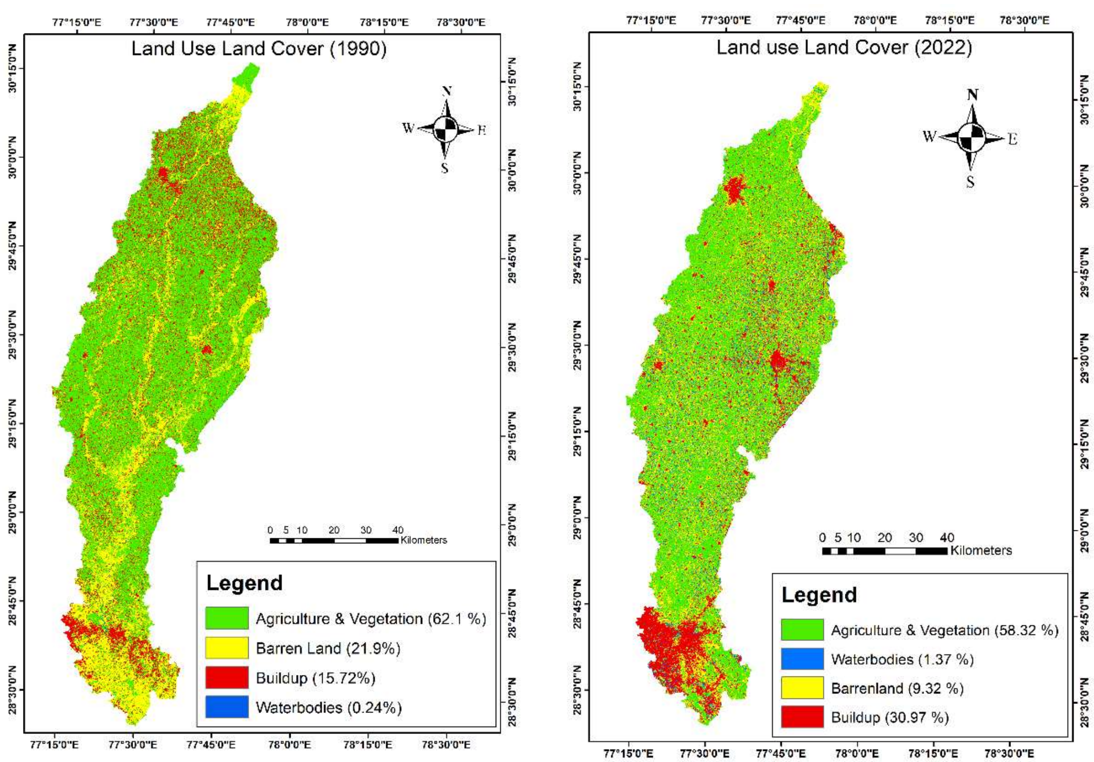

Fig. 4. Temporal changes of land use land cover by supervised classification technique

Table 4. Land use land cover classification of the basin (1990 and 2022)

Class	Area (1990)	Percentage (1990)	Area (2022)	Percentage (2022)
Agriculture land and vegetation	4309.74	62.10	4047.93	58.32
Build up	1090.96	15.72	2149.94	30.97
Barren land	1521.94	21.93	647.43	9.32
Water	16.65	0.24	95.38	1.37
Total			6940	100

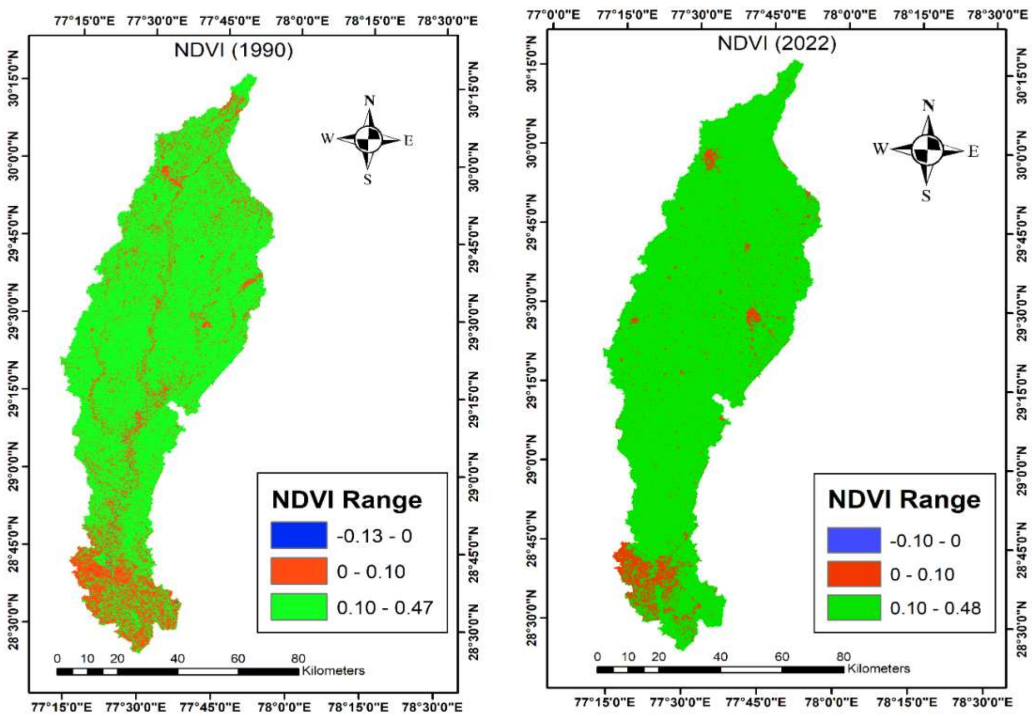

Fig. 5. Temporal variation in normalized difference vegetation index

bare soil, over grazed land, barren land etc. as well as built-up area and the value of NDVI from 0.1 to 0.5 indicates sparse vegetation over the basin (Jeevalakshmi et. al., 2016). The barren land is transformed into agricultural and pastoral land. During 1990 most of the area of the basin was barren land, after 3 decades now most of the area is converted into either built-up or agricultural and pastoral land. After the study of NDVI it is also concluded that basin does not contains dense forest and large water bodies such as reservoirs and lakes.

CONCLUSION

The morphometric analysis is essential for overall watershed investigation and management. It also plays an important role in hydrological investigations of a river basin or watershed. The geographical area of the basin is 6940 km^2, perimeter is 488 km, consisting the total of 758 streams (including small and large streams) of 2047 km length and the length of main stream channel which originates from Shivalik hills, Saharanpur to its outlet at Tilwada, is 312 km. The basin is drained by the highest 5th order stream. The elevation of the basin varies from 190 m to 868 m withan average elevation of 528.5 m.The built-up area and water bodies increased 15.25 and 1.13% respectively whereas agriculture and vegetative area and barren land decreased to 3.78 and 12.61 % respectively from 1990 to 2022 andthe NDVI analysis also concludes the same results.

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AUTHORS CONTRIBUTION

All authors contributed significantly to the development of this workShivam Kumar Dwivedi conceptualized the study design and supervised the research process. Vikash Singhcollected and processed the data. Mukesh Kumar Sharmaperformed the data analysis and interpretation. Anjali Bhagwat contributed to the literature review, analysing results and writing of the final manuscript draft. All authors reviewed, edited, and approved the final version of the manuscript.

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