Georgian Geographical Journal 2023, Vol.3 (2)

Analysis of Forest Cover Changes in the Dharchula Alpine Ecosystem, Western Himalayas, India: in the context of the governance of protected areas

Bhanwar Vishvendra Raj Singh[1]*, Ravi Mishra [2], Shailesh Yadav[3]

Abstract

The heart of biodiversity conservation initiatives are biosphere reserves, national parks, wildlife reserves, and other protected areas (PAs). PAs are permanent institutions, according to protection policy and practice, although the fragmentation forest habitat indicator is downgrading, downsizing, and degazettement (PADDD). In the current context, India has 514 wildlife sanctuaries, while the Himalayas have approximately 35 wildlife sanctuaries. However, wildlife sanctuaries in the Himalayan range have not been extensively studied using space technology (such as geospatial techniques), so Dhar Chula Tehsil, which is part of the Pithoragarh district in Uttarakhand, India, was chosen as the study area due to the high density of forests and proximity to the Askot Wildlife Sanctuary. This research will aid in tracking changes in wildlife habitats and demonstrating options for greater biodiversity restoration. The examination of land cover and land-use change includes a substantial concentration of forest habitat change. This study seeks to examine changes in the LULC of Dharchula utilising multitemporal satellite data, e.g., Landsat 2 and Sentinel 2b for 1975 and 2020, respectively, to assess the understanding of forest changes at Dhar Chula Tehsil. The adjustments were validated using numerous indices, including the normalised difference vegetation index (NDVI), the normalised difference vegetation index (RDVI), and the weighted analysis method. As a result, the forest area has expanded marginally over the last five decades, from 130455 hectares to 157140.2 hectares. This is good news for the forest environment.

Keywords: Forest Ecosystem, Protected Areas

Introduction

India is the 7th-largest country in the world. The vastness and complexity of Indian landscapes contribute to a diverse ecosystem that faces many problems.

Forests are home to many species, mostly flora and fauna, and provide abundant resources to our environment [1]. The forest is not only a place to enjoy nature's beauty but also a phenomenon that provides essential needs for humans and society, such as fuelwood, edible materials such as fruits and vegetables, and housing for many herders and farmers [2]. Forest areas in India range from temperate to coniferous, evergreen to shrub and deciduous forests, and from tropical forests to cool temperate forests [3]. With different climatic conditions, India is home to a diverse range of flora and fauna, including lions, Bengal tigers, white tigers, panthers, one-horned rhinoceros, and lion-tailed macaques. The flora of India ranges from the western Himalayas to the country's plains and includes species such as chirping, blue pine, silver fir, and dwarf willow.

India is dealing with enormous issues in the forest sector, such as deforestation, degradation, and loss of habitat for both flora and wildlife, as well as extreme climatic conditions and the consequences of forest fires across enormous areas, resulting in carbon escapes back into the atmosphere [4]. Forests are critical for ecosystem survival and biodiversity [5]. Because of the substantial asset externalities involved at both the global and local levels, deforestation and degradation in the Himalayan regions are of considerable concern to all policymakers [6].

The Himalayas are the only source of India's three major river systems, which include the Ganges, the Brahmaputra, and the Indus [7]. Along with the abovementioned main rivers, there are several tributaries that originate in the Himalayas. The Himalayas are among the most tectonically unstable, undeveloped, ecologically vulnerable, and dense mountains on the planet [8]. Because of continuous uplift, this mountain range is extremely vulnerable to large-scale tectonic movements and landslides [9, 10]. They are the world's most unstable and vulnerable mountain ranges [6].

[1] Department of Geography Mohanlal Sukhadia University, Udaipur, India
[2] Kumaun University, Almora, Uttarakhand, India
[3] Sahariya Govt. College, Kaladera, Jaipur, India
* Corresponding author: bhanwarsa28@gmail.com

This study is based on locating areas in the Askot Wildlife Sanctuary, which are protected areas that serve as a reservoir of biodiversity in a biogeographical unit; they serve as a refuge for native plants, animals, and microorganisms; and they serve as a laboratory [11], where forest degradation and deforestation have occurred or are on the verge of occurring. Conservation of the world's wild genetic resources is becoming increasingly dependent on a limited percentage of land area in natural reserves, particularly as natural areas rapidly deplete [12, 13].

Our study is based on the detection of changes in the forest region of Dhar Chula Tehsil (near Askot Wildlife Sanctuary), which is located in the Pithoragarh district of Uttarakhand, India, in the western Himalayan range. There are 279 kinds of fodder, including trees, shrubs, and herbs, according to Samant 1998 [14, 15]. The research is carried out using multitemporal satellite data. The primary focus of the research is the application of remote sensing and GIS [16, 17].

Remote sensing (RS) data, in conjunction with geographic information systems (GIS), aid in the analysis, mapping, and monitoring of earth resources for effective and sustainable forest landscape management. Remote sensing is a method of gathering data or information about an area without physically coming into contact with an object or study area [17]. GIS is a computer system that has been expanded to gather data, store it, analyse it, and then present it as an output result to aid in the solution of a real-world problem [18, 19].

Methods and Materials

Dharchula is a tehsil and a Nagar panchayat in the Uttarakhand district of Pithoragarh. In the mediaeval period, Dharchula was a key trade town for the Trans-Himalayan trade routes. The Dharchula is surrounded by Himalayan peaks and is located at an elevation of 915 metres above sea level. It is located in a valley on the Kali River's banks. This city is named Dharchula because it is situated on a hill that resembles a stove. Pithoragarh is 90 kilometres away. It is located at a distance and is surrounded by mountains. In regard to tourism, the most prominent tourist attraction in this city is Manas Lake, also known as Manasa Sarovar.

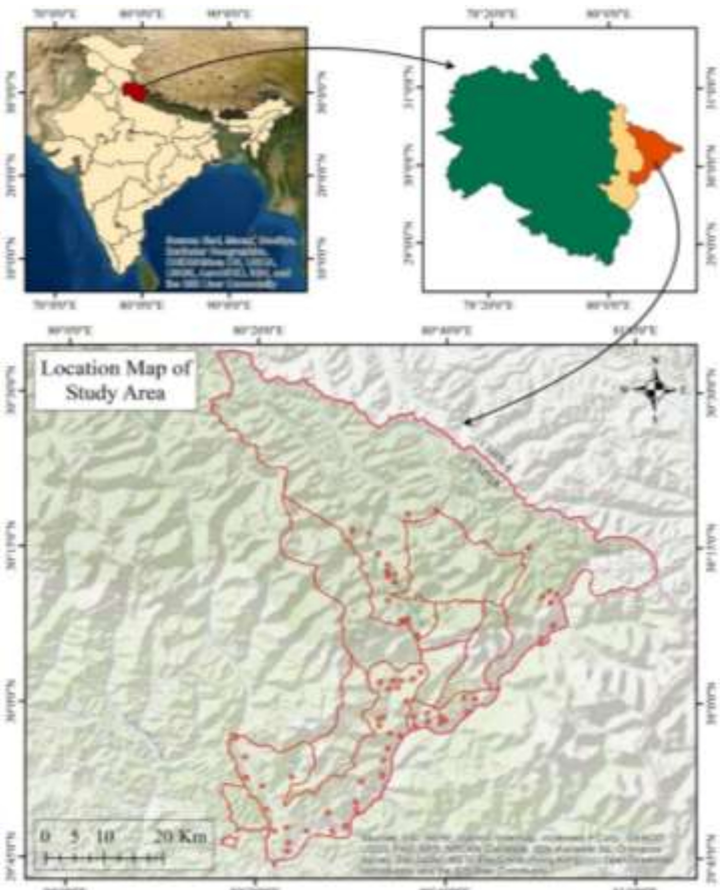

Figure 1. Study Area. Source- Prepared by researchers, GOI.

Askot Wildlife Sanctuary is also included in this tehsil and is located in Pithoragarh district on the longitude of 29°46'45"N to 30°27'45"N and latitude of 81°01'53"E to 80°16'25"E. Uttarakhand. Pithoragarh is approximately 1514 m tall, or 4967 ft [20]. In 1960, the district was separated from the Almora district. This is the easternmost district of Uttarakhand, which shares borders with Nepal in the east and Tibet in the north. Pithoragarh is another name for "Little Kashmir" [21]. It is a historical site since it served as the Chand Kings' seat of authority in the Kumaon region. The months of March to June and September to December are ideal for visiting the Pithoragarh district [22].

Askot was established to protect the endangered musk deer, but it is also rich in flora such as herbs and shrubs. "Green Paradise" is another name for the Askot Wildlife Sanctuary. This location is 3629 feet above sea level. Along the different river streams, the region is covered in a dense forest of deodar and pine. It is also reported to be a significant terrain feature for pilgrims travelling to Bhanar, Nirikot, Kalapani, and Adi Kailash. The sanctuary region includes passes such as Lumpia Lekh, Lipu Lekh, and Mankshang Lekh.

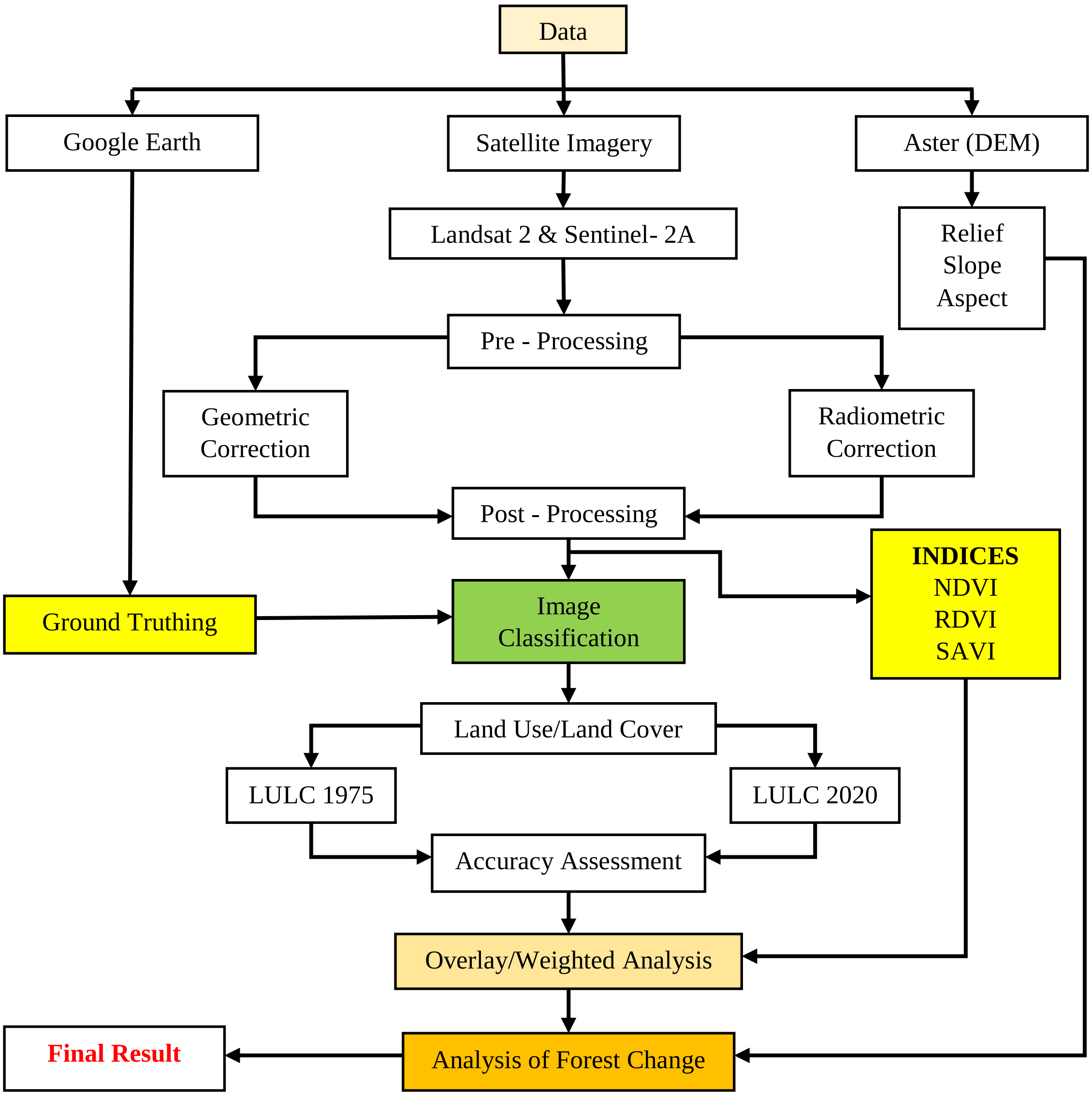

Chart 1: Methodology Chart

Dharchula tehsil is our research study region because, despite its never-ending natural beauty, it is being degraded by the consequences of forest degradation and deforestation. Our research is based on identifying profiles of places where degradation and deforestation have occurred, as well as analysing the impact on biodiversity.

This study used a combination of quantitative and qualitative methods of research with geospatial technologies to explore the spatiotemporal dynamic change in the Askot Wildlife Sanctuary.

Methodology Charts

This study employed remote sensing data to track changes in forest cover in the study area between 1975 and 2020. ERDAS Imagine 2015 software and ArcGIS 3.1.0 were used for image processing. This study made use of both primary and secondary data. In the research process, every piece of data is useful and important. Landsat MSS data image acquisition date 06/12/1975 with four bands; Sentinel 2-A data image acquisition date 24/10/2020; and ASTER DEM data 30 m resolution were the major data used in the study. (Table 1).

Table 1. Data Set Used

Sr. No.	Data type	Source	Spatial resolution (m)
1	Landsat 2 MSS (1975) & Sentinel 2-A (2020)	United States Geological Survey (USGS)	80 10
2	Digital Elevation Model	ASTER	30

For forest cover change detection approaches, Landsat imaging preprocessing and supervised classification algorithms were used. Images were classified into five LULC groups (Table 2): dense forest, shrubland, grassland, companion land, and water body.

Table 2. Land use and land cover classes

Sr. No	Land use/land cover type	Description
1	Dense Forest	Area covered by dense forest with high pixels
2	Shrub Land	Open Forest and bushes, Agriculture, and grassland
3	Fellow land	Not in use lands, bank of rivers
4	Barren Land	Hilly features and low fertile areas
5	Water bodies	Every pixel contains water like rivers, lakes, streams & ponds, etc.

Forest cover change detection technique

The detection of change entails the use of multitemporal datasets to distinguish areas of land cover change between imaging dates. It is commonly utilised in remote sensing techniques that analyse multitemporal datasets.

For any given period, remote sensing technology has the potential to identify numerous types of land cover change. Multitemporal Landsat data were gathered to track changes in forest ecosystems in 1975, 1990, 2005, and 2020.

The raster data were then transformed to vector layers with Arc GIS 10.2.2 software, and the LULC classes were identified. Following the classification of LULCs, maps were created, and the changes in forest cover in the research region were analysed.

Normalised Difference Vegetation Index

This process is used to calculate the NDVI value of the forest between 1975 and 2020 and to compare the NDVI value of each image. NDVI levels indicate forest quality and health. To assess the health of the forest, the NDVI process was used for both images. The difference between near-infrared (NIR) and visible red reflectance values normalised to reflectance is the NDVI.

The vegetation category's NDVI value varies from 0.1 to 1. A dense woodland region is usually linked with an NDVI value of 0.4 to 1. The NDVI formula is as follows:

$$\text{NDVI} = \frac{(NIR-Red)}{(NIR+Red)} \tag{1}$$

Classification Accuracy Assessment using the Error Matrix

An error matrix was used in the study to examine classification accuracy. It is a square array of integers organised in rows and columns that expresses the number of sample units assigned to each category relative to the real range as revealed by reference data.

The accuracy assessment reflects the actual difference between the categorisation and the reference map or data. The evaluation may imply that the categorisation results are bad if the reference data are extremely erroneous.

To compute the percentage of LULUC (%), Garai and Narayan (2018) compared the original and end LULC area coverage, as indicated in Eq. 2 [23].

$$\% \text{ Change } = \frac{(V_2 - V_1)}{V_1} \times 100 \tag{2}$$

where % change is the LULC change percentage, V2 represents the final value, and V1 represents the initial value. The kappa coefficient shows the percentage of agreement obtained after removing the chances of agreement that are likely to occur by chance [24]. The kappa statistic can be used to calculate the degree of agreement between value categories and reference data [8, 25].

Landis and Koch (1977) classified kappa values ranging from 1 to 1 into three categories: (1) greater than 0.80 indicates robust agreement, (2) between 0.40 and 0.80 indicates mild agreement, and (3) less than 0.40 indicates poor agreement [26]. There is agreement between the classification and reference data.

The kappa coefficient typically varies from 0 to 1.00, with the latter indicating sufficient agreement and often being multiplied by a hundred to produce a percentage degree of classification accuracy.

Land Use Dynamic Degree

To evaluate the temporal and spatially shifting aspects of land use, this study used a single dynamic degree index. The single dynamic degree of land refers to the entire amount of change in certain forms of land use in the research area over a specific time period [27]. A single dynamic degree index can be used to quantify the changing rate of regional land usage. This allows for the comparison of regional differences in land-use change as well as the analysis of the changing trend of land use [28].

This can be calculated as follows:

$$\left\{ LC(K) = \frac{u_b - u_a}{u_a} * \frac{1}{T} * 100 \,\% \right\} \tag{3}$$

In this formula, u_b represents the area of a specific land use category at the end of the research period, and u_a represents the area of a specific land use type at the start of the research period. T denotes the length of the research period. The dynamic degree of certain types of land use within the study period or time is represented by LC. If the dynamic degrees are positive, it indicates that the number of land use types is increasing with time. Similarly, if the dynamic degree is negative, the land use types decrease with time.

Terrain Mapping

Digital Elevation Model/Elevation: The elevation of the study area is depicted on the elevation map. The elevation ranges from 212 metres to 6461 metres. The elevation map is shown in Figure 2 below.

Aspect: The study area's aspect map in the figure below indicates flat areas with values of 0-39, 40-79 as North, 80-120 as North–East, 130-160 as East, 170-200 as South–East, 210-240 as South, 250-280 as South–West, 290320 as West, and 330-360 as North–West. The slope's orientation is measured clockwise in degrees from 0-360, with 0 being north, 90 being east, 180 being south, and 270 being west. Aspect values determine the physical slope face direction. The aspect directions are supported by the slope angle. The aspect map was prepared with the help of the digital elevation model (DEM).

Relief: The relief map depicts the contours of landmarks and landscape as a function of size and elevation. They are the most sophisticated type of topographic map. A location's relief is the difference between its highest and lowest altitudes. The study region relief map depicts the shaded region of the slopes using azimuth and sun angular directions. The relief map above displays a low value of 0 and a high value of 254 m.

Drainage Pattern: The drainage map of the study region depicts the river network's streams and flow patterns. The topography of the land, whether a certain area is dominated by hard or soft rocks, as well as the slope of the ground, governs streams and networks. A system is said to conform if its pattern is tied to the structure and relief of the terrain, it flows through. The drainage map is created using DEM data and the Arc GIS software hydrology function. Five different stream orders have been discovered. (See Fig. 2(d)).

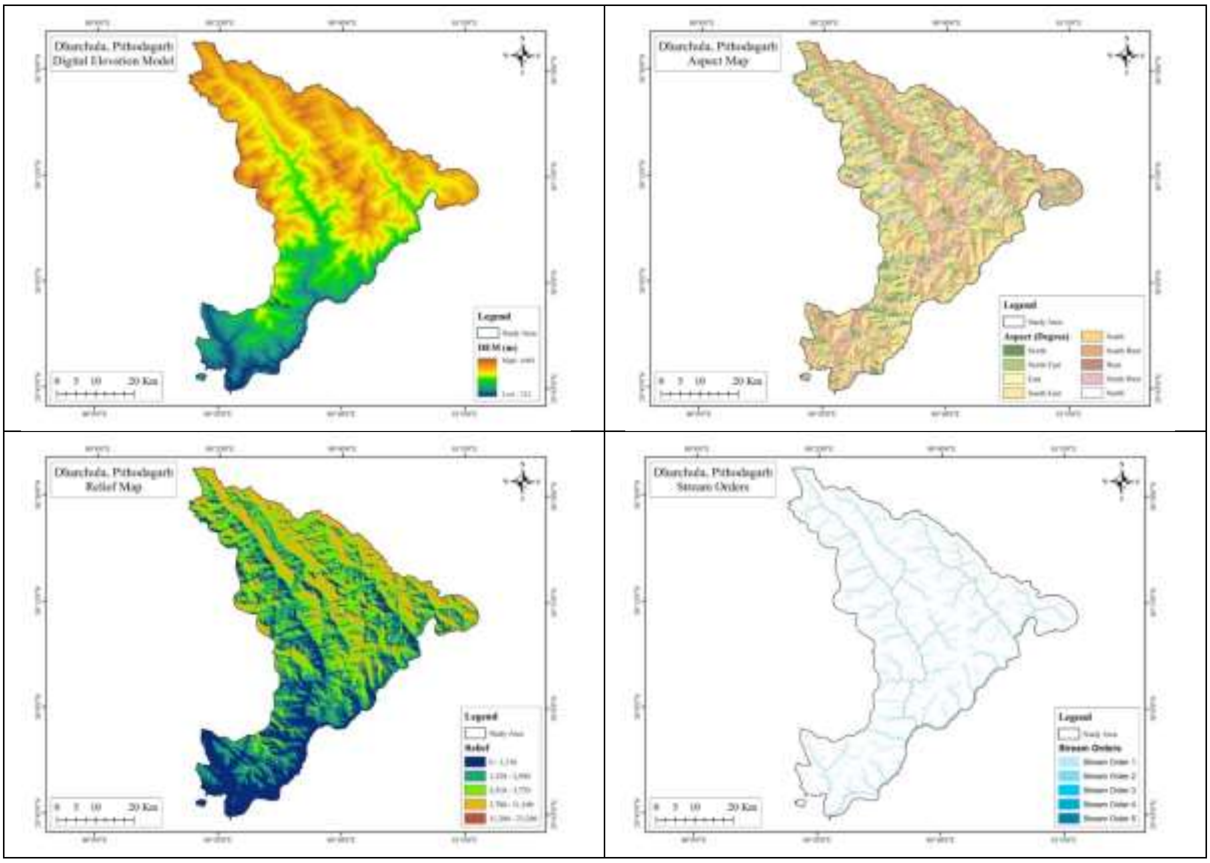

Figure 2: Terrain Map of Askot Wildlife Sanctuary A. Digital Elevation Model, b. Aspect Map, c. Relief Map, d. Stream Orders

Results

Land Use/Land Cover

The area naturally covered by the natural environment, such as forest, farmland, water bodies, and wetlands, is referred to as land cover. Whereas land use refers to the development of places by humans for their lives, whether for conservation, hospitals, schools, residential, or other purposes. Land cover analysis is the analysis of satellite and aerial data that aids in the identification of terrain across time.

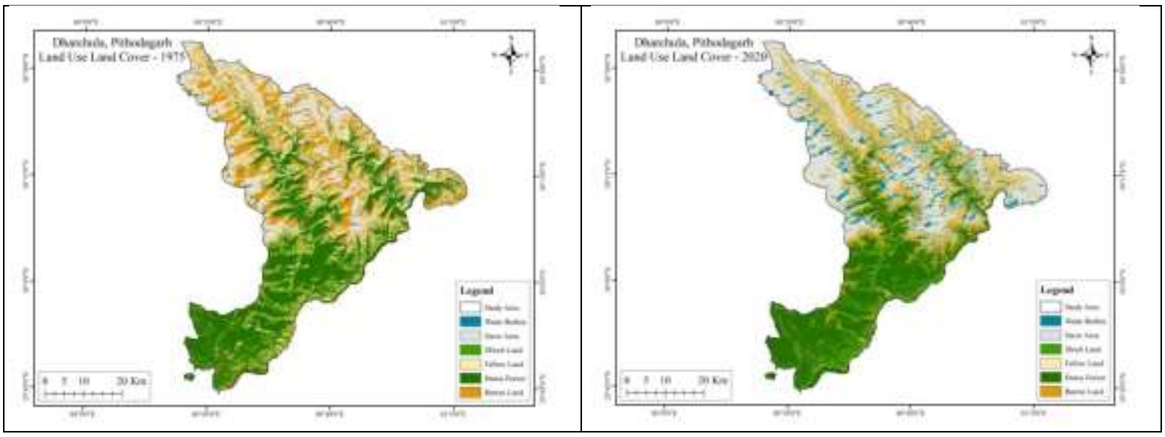

Figure 3: LULC of 1975 & 2020

Figure 3 represents the land use and land cover area of the Dhar Chula Area for the years 1975 and 2020. This figure represents all six classes' areas and their changes. In 1975, the area of forest was approximately 92528.64 hectares, and it drastically changed in another image of 2020, with 82363.22 hectares.

Table 3. Area of classes and changes in hectares

Sr. No.	Class Name	Area, 1975	Area, 2020	Change (2020 - 1975)
1	Dense Forest	92528.64	82363.22	-10165.4
2	Water Bodies	8642.88	24572.98	15930.1
3	Fellow Land	56541.96	57057.61	515.65
4	Barren Land	66653.28	43757.34	-22895.9
5	Shrub Land	15746.76	13240.45	-2506.31
6	Snow Area	457365.6	56986.81	-400379

Shrubland also decreased by over 2506 hectares. Water bodies and neighbouring land have only witnessed good changes.

Because there is no such high-resolution image available, it is probable that the classification does not clearly define it. As a result, the study selected another depiction method, such as indices, for further investigation and verification.

Change Detection and Error Matrix

Change detection aids in the observation of changes over time [29]. Table 5 compares the change detection to the years 1975-2020 (Figure 10) as well as its accuracy assessment. The study area covers a total of 277985.44 hectares.

For accuracy testing, 4000 random points are generated to be checked against Google Earth for ground truthing. After calculation, it is discovered that the research has an accuracy of 92.85%, which is derived from the following formula:

$$\textbf{Overall Accuracy} = \frac{\textbf{Diagonal total}}{\textbf{Overall total}} * \mathbf{100} \tag{3}$$

where the diagonal total is 3713 and the overall total is 4000. The kappa coefficient is also calculated by using producer accuracy and user accuracy. The Kappa value is 0.89 here, which is very much affected, as it is quite close to 1.

Table 4: Accuracy Assessment of LULC (1975-2020)

		2020							
	LULC Classes	Dense Forest	Water Bodies	Fellow Land	Barren Land	Shrub Land	Snow Area	Row Total	User Accuracy
	Dense Forest	1767	0	0	0	76	0	1843	95.87
	Water Bodies	0	75	0	0	0	0	75	100
	Fellow Land	16	0	682	0	0	0	698	97.707
	Barren Land	5	0	59	158	58	36	316	50
1975	Shrub Land	12	1	0	20	942	3	978	96.319
	Snow Area	0	1	0	0	0	89	90	98.88
	Column Total	1800	77	741	178	1076	128	4000	
	Producer Accuracy	98.16	97.402	92.03	88.76	87.54	69.53	Diagonal Total: 3713	
	AC	0.31		kappa	0.896	Overall Accuracy		0.92 (92.85%)	

Land Use/Land Cover Change % and Single Land Use Dynamic Degree (k %)

Table 5. LULCC in % & Single Land Use Dynamic Degree (k %)

Land use/Land cover categories	Change Area (%)	Single Land Use Dynamic Degree (k %)
Dense Forest	-10.9862	-0.24414
Water Bodies	184.3147	4.095883
Fellow Land	0.911978	0.020266
Barren Land	-34.3508	-0.76335
Shrub Land	-15.9164	-0.3537
Snow Area	-87.5402	-1.94534

From LULCC% 1975 to 2020, forest changed by -10.98%, while shrubland and snow area also changed negatively by -15.91% and 87.54%, respectively. With 184.31% and 0.91%, respectively, other land and water bodies had a good positive rate.

The declining rates of forest and shrubland over 45 years are slightly lower for the single land use dynamic degree, with -0.24% and -0.35%, respectively. Snow area has a significantly negative trend of approximately -1.94% every year, which is rather high when compared to other classes. Land and water bodies have increased at a healthy rate of 0.02% to 4.09% every year.

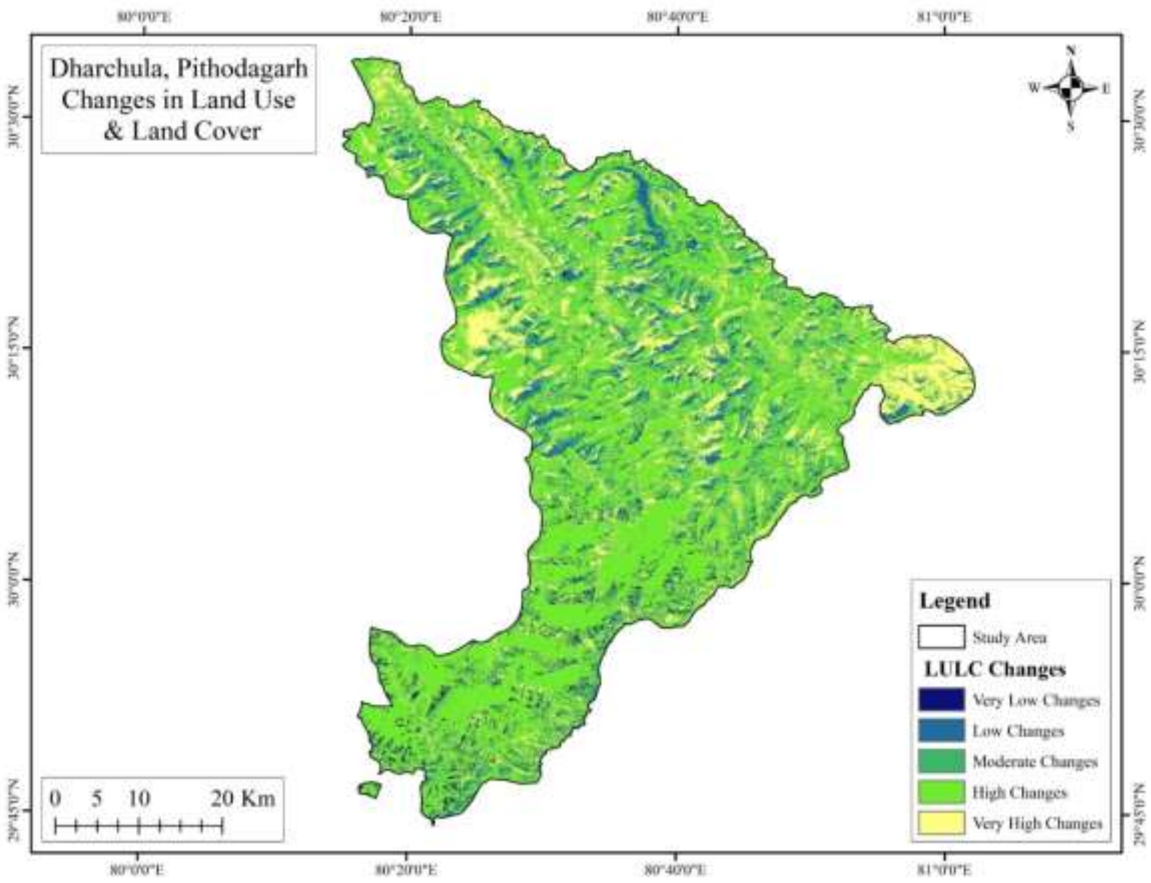

Figure 4: Change over Land Use/Land Cover (1975-2020)

To check and verify the land use land cover outcome, research has used other indices to rectify and be sure of the result.

Normalised Difference Vegetation Index (NDVI)

The normalised difference vegetation index (NDVI) is a popular metric. It has a value between +1 and -1. The vegetation index is a satellite image indicator that describes the health of vegetation as well as the number of greens. The NDVI calculates the difference between the near-infrared light reflected by vegetation and the red light absorbed by vegetation.

The highest vegetation index values decreased from 0.97 in 1975 to 0.82 in 2020 (Table 6). The darker the green hue in the image is, the higher the NDVI values and the greater the vegetation cover. Similarly, the minimum values increased from -0.97 in 1975 to -0.56 in 2020. This suggests that the vegetation conditions in 1975 were better than those in 2020. The outcome can be seen as a dark red colour on the map (Fig. 5). The lower the NDVI values and the less vegetation, the darker the red colour, and vice versa. According to this comparison, the highest vegetation cover was recorded in 1975, while the average vegetation cover was observed in 2020.

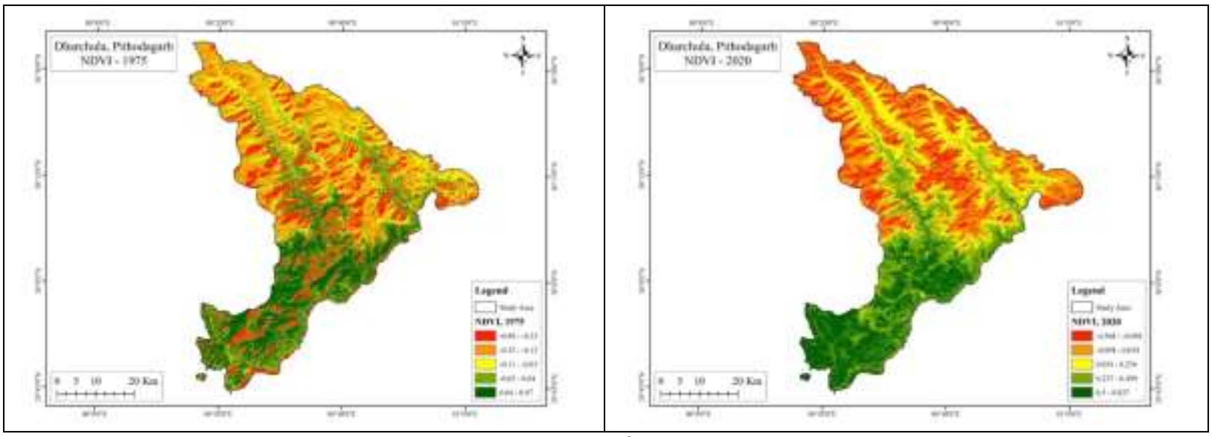

Figure 5: NDVI of 1975 & 2020

Table 6: NDVI statistics of 1975 and 2020

Sr. No.	NDVI	1975	2020
1	Minimum	-0.976	-0.568
2	Maximum	0.97	0.827
3	Mean	-0.171	0.209
4	Standard deviation	0.277	0.247

The mean and standard deviation of the two-period images can better explain this comparison. Table 6 shows that the mean values grew from -0.171 in 1975 to 0.209 in 2020. This means that the lowest NDVI value in the 1975 satellite image has the least vegetation coverage, while the highest mean NDVI value in the 2018 image has the most vegetation. The standard deviation of the NDVI score, on the other hand, indicates a minor reduction from 0.27 in 1975 to 0.24 in 2020. This suggests that the condition of vegetation changes from its mean NDVI value varies more in the 1975 image than in the 2020 satellite image. Hence, the change in vegetation is more average in the 2020 satellite image than the change in vegetation in 1975, according to the NDVI.

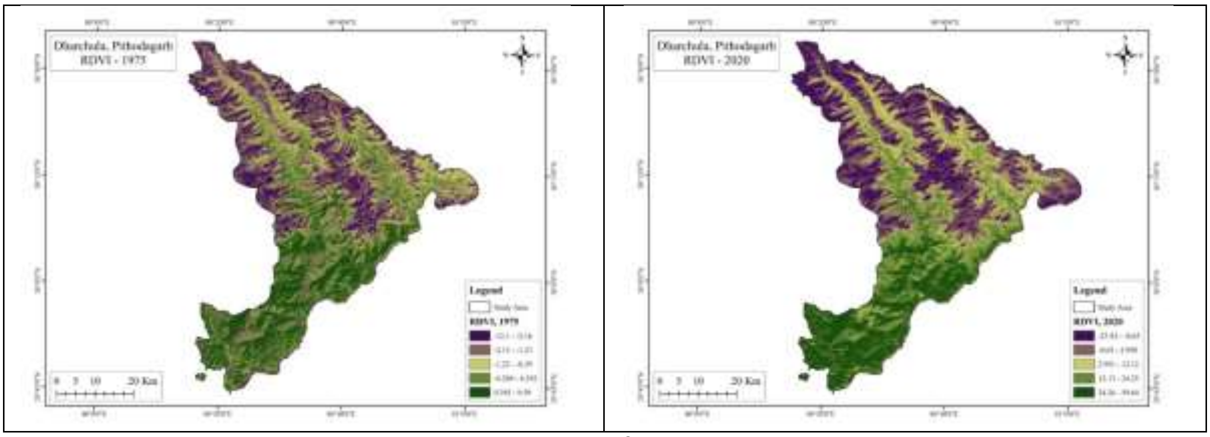

Figure 6: RDVI of 1975 & 2020

Renormalised Difference Vegetation Index (RDVI)

The Renormalised Difference Vegetation Index (RDVI) uses the difference between near-infrared and therefore red wavelengths with the NDVI to focus on healthy vegetation. It is used for the most effective result, which is applied to heavily vegetated areas.

The maximum renormalised difference vegetation index values grew from 9.6 in 1975 to 59.6 in 2020 (Table 7). The darker the green hue in the image is, the higher the RDVI values and the greater the vegetation cover. Similarly, the minimum values fell from -12.1 in 1975 to -23.9 in 2020. This suggests that the state of the environment in 2020 will be better than it was in 1975. The outcome is also visible in the map (Fig. 6) as a dark purple colour. The darker the purple is, the lower the RDVI and the less vegetation there is, and vice versa. According to this comparison, the highest vegetation cover was observed in 2020, while the average vegetation cover was observed in 1975.

Table 7: RDVI statistics of 1975 and 2020

Sr. No.	RDVI	1975	2020
1	Minimum	-12.1	-23.9
2	Maximum	9.59	59.6
3	Mean	-0.89	10.6
4	Standard deviation	1.33	12.8

The mean and standard deviation of the two period images can better explain this comparison. Table 7 shows that the mean values grew from -0.89 in 1975 to 10.6 in 2020. This means that the lowest RDVI value in the 1975 image has the least vegetation coverage, while the highest mean RDVI value in the 2020 image has the most vegetation. The standard deviation of the RDVI value, on the other hand, shows an increase from 1.33 in 1975 to 12.8 in 2020. This signifies that the state of vegetation changed from its mean RDVI value in 1975 to 2020. In general, the RDVI values show that vegetation cover has increased in general, and forests in particular have increased throughout time. Even if the change was minor, the trend indicated an increase in natural vegetation.

Soil Adjusted Vegetation Index

SAVI is an abbreviation for the soil-adjusted vegetation index, which depicts the unequal variation within the saturation effect caused by soil moisture, soil colour, and high-density vegetation. Huete, A. R. (1988) developed a vegetation index that took into consideration changes in red and near-infrared destruction via the forest canopy [30].

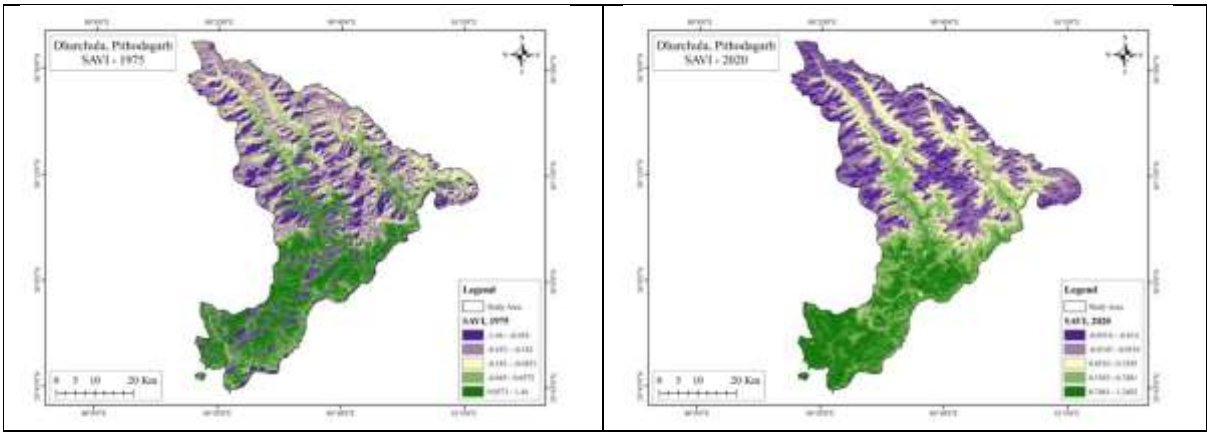

Figure 7: SAVI of 1975 & 2020

The maximum soil-adjusted vegetation index values declined significantly from 1.44 in 1975 to 1.24 in 2020 (Table 8). The darker the green colour in the photograph is, the higher the SAVI values and the greater the vegetation cover. However, the minimum values also decreased, from -1.46 in 1975 to -0.851 in 2020. This signifies that the status of vegetation in 2020 is better than the status of vegetation in 1975. The outcome is also visible in the map (Fig. 7) as a dark purple colour. The lower the SAVI values and the lesser the vegetation, the darker the purple colour, and vice versa. According to this comparison, the highest vegetation cover was recorded in 2020, while the average vegetation cover was reported in 1975.

Table 8: SAVI statistics of 1975 and 2020

Sr. No.	SAVI	1975	2020
1	Minimum	-1.46	-0.851
2	Maximum	1.44	1.24
3	Mean	-0.246	0.314
4	Standard deviation	0.397	0.37

The mean and standard deviation of the two-period images can better explain this comparison. Table 8 shows that the mean values grew from -0.246 in 1975 to 0.314 in 2020. This means that the lowest SAVI value in the 1975 image has the least plant coverage, while the highest mean SAVI value in the 2020 image has the most vegetation. The standard deviation of the SAVI value, on the other hand, shows a minor reduction from 0.39 in 1975 to 0.37 in 2020. This signifies that the status of vegetation changed from 1975 to 2020 based on the SAVI mean value. In general, the SAVI values show that vegetation cover has increased in general, and forests in particular have increased throughout time. Even if the change was minor, the trend indicated an increase in natural vegetation.

Because there have been some conflicting results, researchers have decided to aggregate all of the indicators using weighted methods and examine the real forest cover change.

Weighted Analysis

The Weightage Sum Tool in ArcGIS was used to produce the weighted analysis of the indices and variables indicated above. The weighted sum tool allows weighing variables by combining various inputs and integrated analysis. Weightage sum analysis, such as overlay analysis, includes numerous inputs with various components for combined weighing analysis. The multiplication of field values for each input in the raster is designed using weighted sum analysis. We aggregate all of the raster inputs to generate the output data for certain weights.

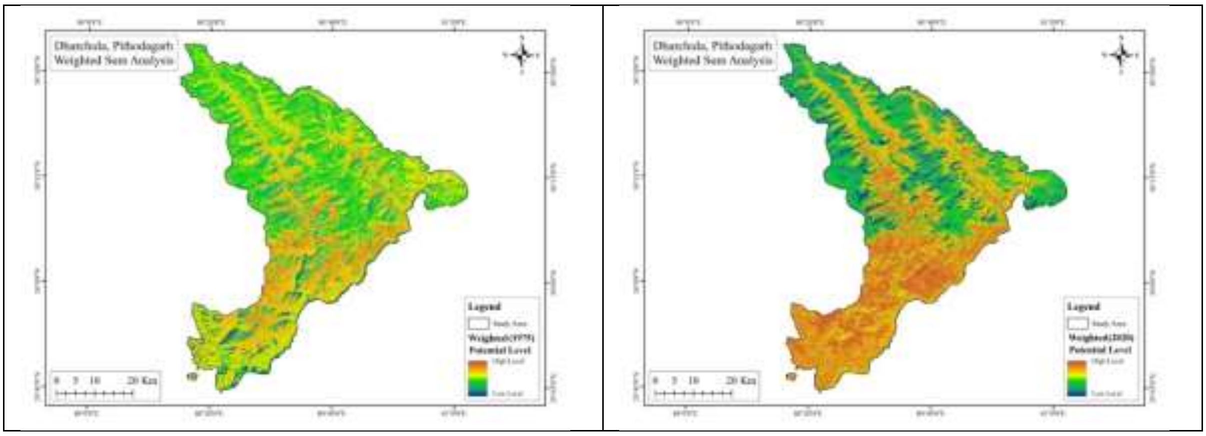

Figure 8: Weighted Sum Analysis of Indices

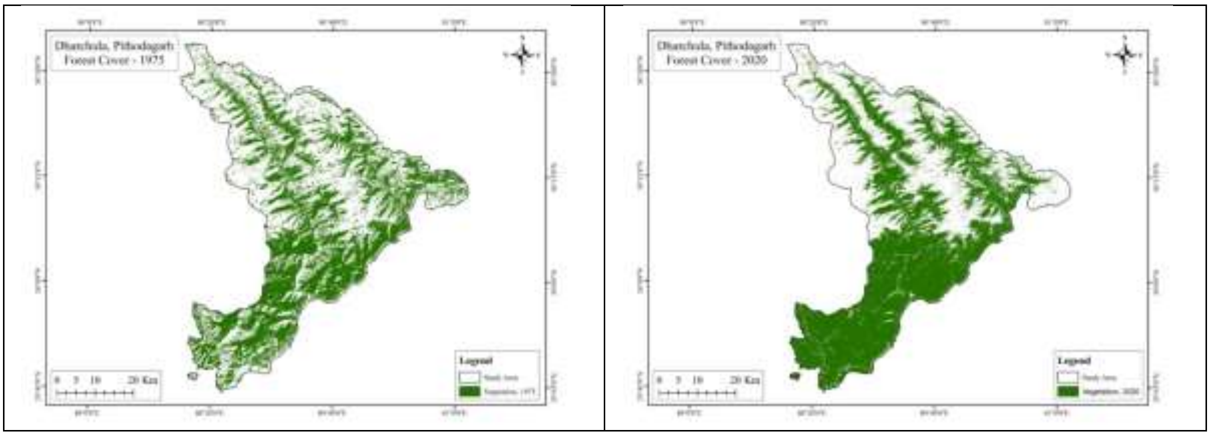

Figure 9: Final Forest Cover Map

Table 9: Forest Cover of 1975 and 2020

	1975	2020
Forest Cover	130455	157140.2

For weighted sum analysis, the LULC classification, normalised difference vegetation index, normalised difference vegetation index, soil adjusted vegetation index, and digital elevation model were also utilised. Following the weighted sum computation, the result is computed using a raster calculator and the output's mean value. After re-examining other criteria, it is determined to be a forest area if it is more than the mean value.

Discussion

Community composition patterns, as well as forest composition and diversity, are significant for ecological and anthropogenic variables [31-32]. It is also tied to the current environment. The nature of the forest community is determined by ecological variables such as location, species variety, and the renaissance state of various species [33-34].

The main issues that forests face are erosion and deforestation, which are the primary causes of reduced forest cover and biodiversity loss. As a result, the necessity for a wildlife sanctuary is critical for the protection of endangered species as well as the prevention of natural resources from becoming extinct in the future, which is critical for both animals and humans [35-36].

The Himalayas, a global biodiversity hotspot, have undergone substantial changes in forest cover in recent decades, necessitating the establishment of numerous protected areas (PAs) to prevent forest degradation. The spatiotemporal characteristics of this forest cover change throughout the region, as well as the effectiveness of its PAs, are unknown.

Governance can be defined as a set of processes, procedures, resources, institutions, and stakeholders that govern how decisions in protected areas (PAs) are made and implemented. Forest PA governance is currently multilayered and convoluted, encompassing a diverse set of actors, many levels of power sharing, a plethora of statutory and informal regulations, and entrenched interests. However, there is little extensive data on how different local governance structures and day-to-day decision-making processes inside forest PAs affect PA performance in terms of attaining targeted conservation outcomes.

Governance mechanisms and structures that drive social-ecological systems and in situ forest conservation measures such as protected areas (PAs) can be crucial for effective management and development of conservation outcomes. Despite this, little is known about how different types of local administration and decision-making mechanisms affect the conservation outcomes of forest-protected areas. This is mostly due to a dearth of studies on the relationship between governance regimes and environmental or social effects, and understanding is based on case studies.

This research study examines changes in the forest environment in Dhar Chula Tehsil, which is close to the Askot Wildlife Sanctuary. According to the findings of the research study, the southern and southwest parts of this area are the most vulnerable, while the eastern and northeast parts are less vulnerable. The study's findings revealed that a holistic and complete approach can lessen anthropogenic strain by expanding the usage of eco-friendly technology and raising local people's knowledge.

The maps were created using remote sensing and GIS techniques for the years 1975 and 2020. Various indicators, such as LULC, SAVI, RDVI, NDVI, relief, slope, and aspect maps, have been employed in research. These maps were developed and examined to improve scientific outcomes. Others explain the forest covering, height, features, and overall environmental health of this wildlife sanctuary, while others highlight improved utilisation of forest resources for biodiversity richness.

This area's forest ecosystem provides a variety of services as well as a significant function in human welfare and subsistence. This research project relied on satellite-collected statistical data. The data analysis demonstrates that the adjacent areas have a tribal and rural population that is directly and indirectly dependent on forest resources. They are almost in touch with nature.

It is insufficient to be pleased with a positive result in one region. There are many more areas that are under threat and must be protected. At the government, forest department, and local levels, a three-tier sustainable, holistic, and inclusive management plan should be adopted and interconnected. With the collective effort of governments and nongovernmental organisations, the awareness, socioeconomic, and employment levels should be raised so that people understand how important forest resources are in the overall development of humans, which will aid in the achievement of sustainable development goals.

Meanwhile, there are numerous advantages to protecting forest ecosystems. Forest conservation includes promoting cultural services, increasing carbon storage and segregation, lowering greenhouse gas emissions, poverty alleviation, watershed protection, natural hazard regulation, maintaining food security and agricultural services, improving medical services, and ecotourism.

Conclusion

Forests offer many farmers and herders shelter, food items such as fruits and vegetables, fuelwood, and other essentials for human existence. Natural forests are used for mining, oil extraction, dam construction, logging, farming, housing, manufacturing, cattle grazing, and the purchase of wood for fuel and furniture.

Although determining the specific extent of changes in a hilly terrain such as the study location can be difficult, past research has revealed a favorable trend in vegetation. Despite the initial trend of falling taxonomic research in LULC, it was determined after combining all the indicators and classification methodologies that high-density forests still exist in the study region and are developing with rising afforestation. Time-series Landsat and Sentinel images show that the area's forest density has increased over time in terms of NDVI, indicating a positive trend across all regions of study. A 45-year investigation revealed a significant rise in vegetated areas. The amount of forest cover increased over the five decades between 1975 and 2020. From 130455 hectares in 1975 to 157140.2 hectares in 2020, the forest area has risen.

The findings of this study are based on an initial assessment enabled by time-series data analysis and other relevant and well-known indicators. In-depth surveys and fieldwork are needed to corroborate the findings and improve the study's accuracy.

Competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Authors' contribution

The offered concept was considered by Bhanwar Vishvendra Raj Singh. Ravi Mishra and Shailesh Yadav led the composition of the manuscript and performed the analytic computations, methodology, and results. All other authors contributed constructive criticism and assisted in shaping the research, analysis, and paper.

Acknowledgements

It is my proud privilege to express my gratitude to many people who helped me directly or indirectly conduct this scientific research work. I express my heartfelt indebtedness to ness and owe a deep sense of gratitude to my colleagues and my well-wishers for their encouragement. I am extremely thankful to Mr. Ravi Mishra and every member of my family for their sincere guidance and inspiration in completing this project. I also thank all my friends who have more or less contributed to the preparation of this project report. I will always be indebted to them.

The study has indeed helped me to explore more knowledgeable avenues associated with my topic, and I am sure it will help me to grow more in the future.

References

[1] Pierotti, R., & Wildcat, D. (2000). Traditional ecological knowledge: the third alternative (commentary). *Ecological applications*, *10*(5), 1333-1340.

[2] Coates, P. (2013). *Nature: Western attitudes since ancient times*. John Wiley & Sons.

[3] Agarwal, B. (2009). *Environmental issues in India: a reader*. Pearson Education India.

[4] Palo, M., & Uusivuori, J. (Eds.). (2012). *World forests, society and environment* (Vol. 1). Springer Science & Business Media.

[5] Putz, F. E., Blate, G. M., Redford, K. H., Fimbel, R., & Robinson, J. (2001). Tropical forest management and conservation of biodiversity: an overview. *Conservation Biology*, *15*(1), 7-20.

[6] Ives, J. D., & Messerli, B. (2003). *The Himalayan dilemma: reconciling development and conservation*. Routledge.

[7] Sarin, M. M., Krishnaswami, S., Dilli, K., Somayajulu, B. L. K., & Moore, W. S. (1989). Major ion chemistry of the Ganga-Brahmaputra river system: weathering processes and fluxes to the Bay of Bengal. *Geochimica et cosmochimica acta*, *53*(5), 997-1009.

[8] Wang, X., Zheng, D. and Shen, Y., 2008. Land use change and its driving forces on the Tibetan Plateau during 1990–2000. *Catena*, 72(1), pp.56-66.

[9] Valdiya, K. S. (1985). Accelerated erosion and landslide-prone zones in the central Himalayan region. *Environmental regeneration in Himalaya: concepts and strategies/edited by JS Singh*.

[10] Whipple, K.X., 2009. The influence of climate on the tectonic evolution of mountain belts. *Nature geoscience, 2(2), p.97.*

[11] Sharma, V., & Chaudhry, S. (2013). An overview of Indian forestry sector with REDD. *International Scholarly Research Notices*, *2013*.

[12] IA, M. (1989). Wildlife conservation and the invasion of nature reserves by introduced species: a global perspective. *Biological invasions: a global perspective*, 215-255.

[13] Macdonald, I. A. W., Loope, L. L., & Usher, M. B. Hamann, 0. 1989. *Wildlife conservation and the invasion of nature reserves by introduced species: a global perspective. -In: Drake, JA, Mooney, HA, DiCastri, F. et al.(eds), Biological invasions: a global perspective. John Wiley, Chichester*, 215-255.

[14] Samant, Rawal, & Dhar. (2006). Diversity, extraction and status of fodder species in Askot wildlife sanctuary, west Himalaya, India. *The International Journal of Biodiversity Science and Management*, *2*(1), 29-42.

[15] Samant, S. S. (1998). Diversity, distribution and conservation of fodder resource of west Himalaya, India. *Proceedings of the Third Temperate Pasture and Fodder Network (TAPAFON), Pokhra, Nepal*, *9*, 9-13.

[16] Jaiswal, R. K., Saxena, R., & Mukherjee, S. (1999). Application of remote sensing technology for land use/land cover change analysis. *Journal of the Indian Society of Remote Sensing*, *27*, 123-128.

[17] Jensen, J.R., 2009. Remote sensing of the environment: An earth resource perspective 2/e. *Pearson Education India*.

[18] Longley, P.A., Goodchild, M.F., Maguire, D.J. and Rhind, D.W., 2005. *Geographic information systems and science. John Wiley & Sons*.

[19] Maguire, D.J., 1991. An overview and definition of GIS. *Geographical information systems: Principles and applications, 1,* pp.9-20.

[20] Kumar, F. and Singh, G.S., 2001. Net. Symp. Role of E. Sci. Integrated Development End Related Societal issues GSI Spl. Pub. No. 65 (Ill) 2001: 109-116 Geology and Geomorphology of Quaternaries Along Kailash-Mansarovar Route, UPPER KALI VALLEY, PITHORAGARH DISTRICT, UTTARANCHAL. In National Symposium Role of Earth Sciences in Integrated Development and Related Societal Issues, 2-4 November, 2001, Lucknow (Vol. 1, No. 65, p. 109). *Geological Survey of India*.

[21] Sharma, S. and Sharma, S., 2015. Understanding Pithoragarh's cultural jewels: its fairs and festivals. *Worldwide Hospitality and Tourism Themes, 7(4),* pp.331-346.

[22] Tyagi, N., 1991. Hill resorts of UP Himalaya: a geographical study. *Indus Publishing*.

[23] Garai, D., & Narayana, A. C. (2018). Land use/land cover changes in the mining area of Godavari coal fields of southern India. *The Egyptian journal of remote sensing and space science*, 21(3), 375-381.

[24] Foody, G. M., Campbell, N. A., Trodd, N. M., & Wood, T. F. (1992). Derivation and applications of probabilistic measures of class membership from the maximum-likelihood classification. *Photogrammetric engineering and remote sensing*, 58(9), 1335-1341.

[25] Mishra, P., Pandey, C. M., Singh, U., Gupta, A., Sahu, C., & Keshri, A. (2019). Descriptive statistics and normality tests for statistical data. *Annals of cardiac anaesthesia*, 22(1), 67.

[26] Landis, J. R., & Koch, G. G. (1977). An application of hierarchical kappa-type statistics in the assessment of majority agreement among multiple observers. *Biometrics*, 363-374.

[27] Chunxiao, Z., Zhiming, L., & Nan, Z. (2008). Using remote sensing and GIS to investigate land use dynamic change in western plain of Jilin province. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Science*, 37, 1685-1690.

[28] Li, P., Zuo, D., Xu, Z., Zhang, R., Han, Y., Sun, W., ... & Yang, H. (2021). Dynamic changes of land use/cover and landscape pattern in a typical alpine river basin of the Qinghai-Tibet Plateau, China. *Land Degradation & Development*, 32(15), 4327-4339.

[29] Prenzel, B. (2004). Remote sensing-based quantification of land-cover and land-use change for planning. *Progress in planning*, 61(4), 281-299.

[30] Huete, A. R. (1988). A soil-adjusted vegetation index (SAVI). *Remote sensing of environment*, 25(3), 295-309.

[31] Ahmad, I., Ahmad, M.S.A., Hussain, M., Ashraf, M., Ashraf, M.Y. and Hameed, M., 2010. Spatiotemporal aspects of plant community structure in open scrub rangelands of submountainous Himalayan plateaus. *Pak. J. Bot*, 42(5), pp.3431-3440.

[32] Gairola S, Rawal RS, Todaria NP (2008) Forest vegetation patterns along an altitudinal gradient in subalpine zone of west Himalaya, India. *African Journal of Plant Science* 2(6):42-48.

[33] Criddle RS, Church JN, Smith BN, *et al*. (2003) Fundamental causes of the global patterns of species range and richness. Russ J Plant Physiol. *Russian Journal Plant Physiology* 50:192-199. DOI: 10.1023/A: 1022969029867.

[34] Todaria NP, Pokhriyal P, Uniyal P, *et al*. (2010) Regeneration status of tree species in forest of Phakot and Pathri Rao watersheds in Garhwal Himalaya. *Current Science* 98(2): 171-175.

[35] Balmford, A., Bruner, A., Cooper, P., Costanza, R., Farber, S., Green, R.E., Jenkins, M., Jefferiss, P., Jessamy, V., Madden, J. and Munro, K., 2002. *Economic reasons for conserving wild nature.science*, 297(5583), pp.950-953.

[36] Groves, C.R., Jensen, D.B., Valutis, L.L., Redford, K.H., Shaffer, M.L., Scott, J.M., Baumgartner, J.V., Higgins, J.V., Beck, M.W. and Anderson, M.G., 2002. Planning for Biodiversity Conservation: Putting Conservation Science into Practice: A seven-step framework for developing regional plans to conserve biological diversity, based upon principles of conservation biology and ecology, is being used extensively by the nature conservancy to identify priority areas for conservation. *AIBS Bulletin*, 52(6), pp.499-512.