STUDIES ON LAND USE LAND COVER CHANGE IN HAMIRPUR DISTRICT OF HIMACHAL PRADESH

Thesis

by

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CERTIFICATE- I

This is to certify that the thesis titled, **‘‘Studies on land use land cover change in Hamirpur district of Himachal Pradesh’’** submitted in partial fulfilment of the requirements for the award of degree of Master of Science **(Forestry)** in the discipline of **Environment Management** of Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan (HP) - 173 230 is a bonafide research work carried out by **Mr. Rajneesh Jaswal (F-2020-22-M)** son of Shri Desh Raj under my supervision and that no part of this thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of investigations have been fully acknowledged.

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Major Advisor

CERTIFICATE-II

This is to certify that the thesis entitled, **"Studies on land use land cover change in Hamirpur District of Himachal Pradesh"** submitted by **Mr. Rajneesh Jaswal (F-2020-22-M)** s/o Shri Desh Raj to Dr Yashwant Singh Parmar University of Horticulture and Forestry, (Nauni) Solan (HP) -173 230, India in partial fulfilment of the requirements for the degree of M.Sc (Forestry) Environmental Management in the discipline of **Environmental Science** has been approved by the Advisory Committee after an oral examination of the student in collaboration with the External Examiner.

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ABBREVIATIONS USED

$\widehat{K}$	:	Kappa
%	:	Percent
AGiSAC	:	Aryabhatta Geo-informatics & Space Application Centre
BRB	:	Brahmaputra River Basin
ETM+	:	Enhanced Thematic Mapper Plus
FGDs	:	Focus Group Discussions
GIS	:	Geographic Information System
GPS	:	Global Positioning System
ha	:	Hectare
IRS	:	Indian Remote-sensing Satellite
IRS P6 LISS-III	:	Indian Remote-sensing Satellite P6 Linear Imaging Self-Scanner-III
IRS-LISS-I	:	Indian Remote-sensing Satellite Linear Imaging Self-Scanner-I
km^2	:	Kilometer Square
Landsat-MSS	:	Landsat-Multispectral Scanner
LISS-III	:	Linear Imaging Self-Scanner-III
LULC	:	Land Use Land Cover
LULCC	:	Land Use Land Cover Change
m	:	Meter
MRB	:	Mahanadi River Basin
MSS	:	Multispectral Scanner
N.E.	:	North East
NTR	:	Nameri Tiger Reserve
OLI	:	Operational Land Imager
RS	:	Remote Sensing
sq	:	Square
TM	:	Thematic Mapper
USGS	:	United States Geological Survey

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Chapter-1

INTRODUCTION

Land use and land cover are two distinct terms that are sometimes used interchangeably (Dimyati *et al.*, 1996). The land is a major natural resource that includes soil, water, forest, and related flora and fauna and it is important for the development and expansion of a region or country (Rahman *et al.*, 2012; Chen *et al.*, 2019). Human civilization has a close interaction with the environment and is heavily reliant on land resources for survival and advancement, resulting in land use land cover (LULC) changes over time (Walker and Homma 1996; Jaiswal *et al.*, 1999). Land cover refers to the physical characteristics of the earth's surface, such as vegetation, water, soil, and other significant features on the land, whereas land use refers to land modifications caused by anthropogenic activities related to economic development, such as agriculture and infrastructure development (Dimyati *et al.*, 1996; Mukherjee *et al.*, 2009; Rawat and Kumar, 2015).

LULC is a major driver of global change and has a significant impact on ecosystem processes, biological cycles, and biodiversity (Basommi *et al.,* 2016; Behera *et al.,* 2012). Land use and land cover change (LULC) is the conversion of different land use types and is the result of complex interactions between humans and the physical environment (Pielke *et al.*, 2011). Land use research programs at a global scale have become central to international climate and environmental change research. In past studies, global environmental changes such as emissions of greenhouse gases, global climate change, loss of biodiversity, and loss of soil resources have been closely linked to LULC changes. Moreover, LULC change detection is very important for a better understanding of landscape changes over a specified time period with sustainable management as LULC is closely related to the social economy (Yin *et al.,* 2011). With rapid economic development, Vast areas of the earth’s terrestrial surface have undergone LULC (Galicia and Garcia,2007).

Various techniques of LULC change detection analysis were discussed by (Lu *et al.,* 2004). An accurate and up-to-date land cover change information is necessary for understanding and assessing LULC changes. Today, data from earth resource satellites is now widely applicable and useful for investigations of land use and land cover change (Yuan *et al.*, 2005). Remote sensing (RS) and geographic information system (GIS) are essential tools in obtaining timely spatial data on land use and land cover, as well as analyzing the changes in a study area (Pervez *et al.,* 2016; Srivastava *et al.,* 2013). LULC mapping using RS and GIS techniques has been a helpful and detailed tool to improve the selection of areas planned for agricultural, urban, and industries of a region (Selcuk *et al.,* 2003). The use of remotely sensed data allowed researchers to analyze changes in land cover in less time, at a lower cost, and with more precision (Kachhwala, 1985). The introduction of high-resolution satellite photography, as well as enhanced image processing and GIS technology, has resulted in as part of a shift to more routine and consistent monitoring and reporting of LULC patterns being modeled. Furthermore, the complete Landsat archive is now available to the scientific community for free, providing a wealth of data for identifying and monitoring changes in artificial and natural environments (Chander *et al.,* 2009; El Bastawesy, 2014). According to many studies pre-processing (data selection, co-registration, radiometric calibration, and normalizing) is critical for accurate and reliable change detection analysis (Jensen, 2005; Lu *et al.,* 2004; Scheidt *et al.,* 2008).

The trend of LULC alterations is influenced by a variety of factors, sometimes known as drivers or driving forces, which cause the changes to take place (Burgi *et al*. 2005). Researcher's focus has recently turned to the factors influencing urban expansion (Paul *et al*. 2021; Shaw *et al*. 2020; Li *et al*. 2018). However, there is currently a lack of a widely accepted scientific framework for quantifying the factors that contribute to urban growth. Institutional, sociopolitical, and economic variables influence urban and sub-urban LULC variances on a worldwide scale of urbanization (Seto *et al*. 2011). In order to effectively manage land and make better decisions, it is crucial to identify these drivers and connections between human activity and natural events.

Various researchers in India have conducted LULC, particularly using remote sensing data, which is fairly significant. Hamirpur district of Himachal Pradesh is situated at 31.6798 N latitude and 76.5026 E longitudes. The altitude of the district varies from 400 to 1100 meters above particularly mean sea level. The total geographical area of the district is 1118 sq. km. Various development activities have taken place in the district over the period which has resulted in remarkable LULC changes The Hamirpur district generally is the fast-growing education hub of Himachal Pradesh. No studies have taken place to generally monitor the Land use Land specifically Cover change hence, analysis of land use land cover changes particularly is required.

Keeping in view the above facts, the present study investigates "**Studies on land use land cover change in Hamirpur district of Himachal Pradesh**" using GIS tools to map out the status of land use land cover in the Hamirpur block of Hamirpur district of Himachal Pradesh in order to discover the land consumption rate and changes that have occurred over the previous two decades with the following objectives:

OBJECTIVES:

i) To estimate changes in land cover using remote sensing and GIS techniques

ii) To investigate drivers for land use land cover changes

Chapter-2

REVIEW OF LITERATURE

This chapter reviews the research work done in the field related to the objectives of the present study. No comprehensive studies were taken to monitor the land use land cover change in district Hamirpur. A few studies conducted on land use and cover change elsewhere have been reviewed and presented under the following heads:

2.1 To estimate changes in land cover using remote sensing and GIS techniques

2.2 To investigate drivers for land use land cover changes

2.1 TO ESTIMATE CHANGES IN LAND COVER USING REMOTE SENSING AND GIS TECHNIQUES

Xian and Mike (2005) worked on urban growth in the Tampa Bay watershed and found that impervious surface area increased three-fold from 1991 to 2002. Tampa Bay watershed has experienced a large change, especially in medium to high urban density areas.

Long *et al.* (2007) carried out research in the Jiangsu province, China to examine the primary driving forces for land-use change using remote sensing maps Two change matrices were generated and pixel-to-pixel comparison demonstrated that industrialization, urbanization, population increase, and China's economic reform policies are the four key driving forces contributing to land-use change in Kunshan.

Carmelo *et al.* (2011) conducted research in the Province of Avellino (Southern Italy) related to the analysis and characterization of LULC changes. And the study has shown that LULC patterns and their changes are linked to both natural and social processes whose driving role has been clearly demonstrated: after the disastrous Irpinia earthquake (1980), local specific zoning laws and urban plans have significantly addressed landscape changes.

Datta and Deb (2012) conducted research in Indian Sundarbans using remote sensing data and concluded that a considerable reduction of open mangrove stands and associated biodiversity mainly in the forest-habitation interference zones of Sundarbans and an increase in the coverage of dense mangroves in the reserved forests had been observed indicating the existence of proper centralized management regimes. Overall, a cumulative loss of approximately (0.42%) of its original mangrove cover between 1975 and 2006 had been estimated for this part of the Sundarbans which was at parity with the findings of other studies in the Sundarbans or similar mangrove ecosystems of the tropics.

Deka *et al.* (2014) studied land cover dynamics in the Kamrup district of Assam (1991 to 2011) using Remote sensing and GIS and found that land cover change has occurred in a respective way built up (+45.82%), wetland (-9.45%), cropland (+4.16%) and forest cover (-3.09%).

Saikia *et al.* (2014) conducted a study in the Nameri Tiger Reserve (NTR) in Assam, India using Landsat imageries. The studies showed that dense forest decreased sharply while open forest increased marginally. The increase in the degraded and open forest categories occurred at the expense of dense forests, which decreased at an average annual rate of 288 hectares per year, or at 0.56 percent annually. The number of patches in the NTR landscape recorded a five-fold increase indicating a high degree of fragmentation of the habitat while the number of patches of the dense forests increased by 338 percent from 270 hectares in 1973 to 1138 hectares in 2007 at an annual rate of increase of 9.9 percent per annum, their mean patch area declined from 19.09 to 12.82 hectares.

Teixeira *et al.* (2014) did a study on the Mondego River in Central Portugal to characterize the driving forces linked both to LULC and LULC change, with potential impacts on the condition of water bodies. Results showed that agricultural areas and artificial surfaces, which are the driving forces that pose the most challenges to aquatic systems, are also the ones whose representative increases in downstream regions.

Rawat and Kumar (2015) conducted research in Hawalbagh block of the district Almora, Uttarakhand, India. The results indicated that during the last two decades, vegetation and built-up land have increased by 3.51 percent (9.39 km^2) and 3.55 percent (9.48 km^2) while agriculture, barren land, and water body have decreased by 1.52 percent (4.06 km^2), 5.46 percent (14.59 km^2) and 0.08 percent (0.22 km^2), respectively.

Agaton *et al.* (2016) studied LULCC detection in an urban watershed in West Java Province, Indonesia. researchers used GIS and RS approaches to detect LULCC in the Upper Citarum Watershed. The study revealed that between 2005 and 2014 forest cover declined by (41%) and by (35%). Agricultural land increased by (2%) built-up land by (65%) Bare land decreased by (15%), Bushland cover declined by (4%) and water bodies shrunk by (12%).

Bansal *et al.* (2016) conducted research in the Yamuna River basin of India to gain a better understanding of the LULC dynamics and potential driving forces. The LULC maps on 1:250,000 scales created using satellite images at decadal intervals (1985, 1995 and 2005) were used to study the LULC dynamics. During the study period, the major LULC changes observed were an increase in cropland from 65.7 percent to 67.9 percent, built-up 0.9 percent to 1.9 percent, and a decrease in the forest from 17.1 percent to 16.4 and water bodies from 2.3 percent to 1.9 percent.

Khan and Jhariya (2016) carried out research in the Raipur municipal corporation, using multi-temporal remote sensing data (LANDSAT of years 1999 and 2016). The study concluded that anthropogenic activities like settlement, roads, and industrial areas were largely broadened.

Lakshmi and Yarrakula (2016) carried out research in the Anantapur and Kadapa districts located in the state of Andhra Pradesh, India using MSS (1973), TM (1992), ETM+ (2001), and IRS RESOURCESAT-II Landsat satellite photos (2012). According to the research, mining and agricultural activities were on the increase. The water bodies, woodland, and barren rock decreased from 3.11 to 1.40 percent, 58.73 to 29.89 percent, and 0.60 to 0.18 percent, respectively, between 1973 and 2012.

Pasha *et al*. (2016) studied the Land Cover Change hot spots in the Gulf of Kachchh, India using multi-temporal remote sensing data and GIS from 1977 to 2015. According to the results, mangroves, salt pans, and built-up land have risen by 79.9 percent, 84 percent, and 93.8 percent, respectively, during the last four decades. Between 1977 and 2015, approximately 21.4 km^2 of mangroves were converted to salt pans and developed land.

Zope *et al.* (2016) studied the impact of land use land cover change and urbanization on floods are investigated an expanding urban catchment of the Oshiwara River in Mumbai, India. The LULC analysis revealed a 74.84 percent increase in the built-up area with a 42.8 percent decrease in open spaces between the years 1966 and 2009, with a substantial increase in urbanization.

Batar *et al.* (2017) studied the Garhwal Himalayan Region of India with the aim to analyse the observed changes in land cover and forest fragmentation that occurred between

1976 and 2014. The results indicated that anthropogenic activities are the main causes of the loss of forest cover and forest fragmentation, but that natural factors also contributed. An increase in the area of scrub and barren land also contributed to the accumulation of wasteland or non-forest land in this region.

Kaliraj *et al.* (2017) carried out research on the South West coast of Kanyakumari to estimate the decadal changes and their transformations in land use and land cover. It was observed that areas on beach face landforms, plantations, cultivable lands, fallows and barren lands have been converted into settlements and built-ups and it increased twice in spatial extent from 2000 to 2011 due to human encroachment and urban expansion activities.

Viedma *et al.* (2017) investigated recent LULC changes in southwestern Turkey by focusing on those that could affect fire and the factors driving them. The results showed that the most important LULC changes were deforestation followed by afforestation. Deforestation was positively related to high livestock density and proximity to villages and increased forest interfaces with other LULC types. They found no evidence that LULC changes were making the landscape more hazardous as there was a net decrease in fuel biomass and the landscape became more fragmented over time. However, despite the area being heavily used and relatively fragmented, large fires can occur driven by severe weather.

Behera *et al*. (2018) studied the deforestation pattern in Mahanadi and Brahmaputra River basins (BRB). The LULC maps were derived from Landsat pictures at three decadal intervals, namely 1985, 1995 and 2005, for two important river basins in India the Mahanadi River basin (MRB) and Brahmaputra River basins (BRB). The study concluded that though the forest land conversion for agricultural operations was the most significant LULC change in both basins, BRB had a greater rate than MRB. While the development of reservoirs and aquaculture farms contributed to the growth of water bodies in MRB, snow and ice melting contributed to the production of additional water bodies in BRB. In BRB, scrub land served as an intermediary class for forest conversion to barren land, but in MRB, the scrub area was converted directly to wasteland and agricultural land.

Chebli *et al.* (2018) studied forest and silvopastoral cover changes and their drivers in northern Morocco. Farmers and local institutions all agreed that drought, fire, soil erosion and population growth are the most striking drivers of forest and silvopastoral decreases.

Chowdhury *et al*. (2018) conducted research to examine land use land cover change (LULCC) in the Halda Watershed over the last 40 years. Agriculture, bare soil, settlements, vegetation and water bodies were the five major land use land cover classifications in the watershed. The LULC and overlay map that result show a major change away from vegetation (35.1%) and water class (85.47%) and toward agriculture, bare soil and settlements.

Khan and Jhariya (2018) carried out research in Raipur City, Chhattisgarh, India to study land use and land cover changes using remote sensing and GIS techniques. The study area's LULC maps were created using satellite images between 1999 and 2016, which were visually interpreted using ERDAS IMAGINE and ArcGIS software. The revealed that the settlement (net growth of 16.2%), road (net increase of 0.8%), open land (net increase of 14.8%) and industry (net increase of 3.1%) areas have shown a significant increase.

Abdullah *et al.* (2019) did land use and land cover analysis across the coastal region of Bangladesh (1990 to 2017) to study human-environment interaction and for the first time used the XG Boost methodology to address high landscape heterogeneity and spectral complexities in image data. The study found that in 28 years of period coastal areas have experienced a net increase in agricultural land (5.44%), built up (4.91%), rivers (4.52%) and vegetation decreased by 8.26 percent. This study also signifies that the use of powerful XG Boost and Random Forest can be useful in inscribing the complexities in land use land cover (LULC) classification.

Adhikary *et al*. (2019) studied the LULC dynamics in the Eastern Ghats highlands of India using remote sensing data and GIS. Historical topographic sheets, IRS P6 LISS-III and Landsat TM photos were used in this work to assess recent and historical LULC conditions in east India's Eastern Ghats Highlands. The study concluded that Forest cover declined from 52.7 percent to 29.6 percent of the total area between 1931 and 2008. During the period, the scrub area increased from 874 km^2 10.4 percent to 1269 km^2 (15.2%), while agricultural land increased from 978 km^2 11.7 percent to 2864 km^2 34.2 percent.

Alam *et al*. (2019) carried out research in the Kashmir valley Using Landsat satellite data for assessing the land use and land cover change. The study revealed that build-up (198.45%), plantation (87.98%), pasture (71%), water (48%) and agriculture had the most variation (28.85%). Anthropogenic actions have mostly caused the massive land transformation, which has been mostly negative in character.

Berihun *et al*. (2019) studied the land use/land cover changes, drivers and their implications in contrasting agroecological environments of Ethiopia. They used field observations, remote sensing data and extremely high resolution (0.5–3.2 m) satellite pictures, as well as GIS to investigate variations in LULC. The study revealed that Forest land was the most common LULC class in Guder and Aba Gerima, accounting for 40.9 percent and 32.0 percent respectively, whereas bushland 36.6 percent was the most common LULC class in the Debatie watershed. Forest land, bushland and pasture land declined by 70 percent, 50 percent and 27 percent in Guder, 65 percent, 49 percent and 63 percent in Aba Gerima and 63 percent, 59 percent and 38 percent in Debatie, respectively, from 1982 to 2016-2017. Cultivated land rose by 40 percent, 129 percent and 704 percent in Guder, Aba Gerima and Debatie, respectively, during the same time.

Berihun *et al.* (2019) examined the trends, driving factors and implications of LULC dynamics over the past 35 years (1982–2017) in the upper Nile basin. Results revealed that Population growth and associated changes in farming practices were the major driving forces for the observed LULC changes in the study watersheds.

Betru *et al.* (2019) carried out research in Western Ethiopia to assess the trends of Land use Land cover and its drivers. The study showed that the expansion of agricultural land was the major driver showing a radical increase of 13 pp between 2013 and 2016. The forest was first changed to shrub/grasslands and finally end up in agriculture showing that degradation is leading to deforestation.

Deka *et al*. (2019) studied the land-use and land-cover change dynamics in Eastern Arunachal Pradesh, N.E. India using remote sensing and GIS. The land use land cover (LULC) map was prepared at 1:250K using Landsat-MSS, IRS-LISS-I and LISS-III data for the years 1985, 1995 and 2005. The study revealed that Between 1985 and 2005, cropland and built-up area rose by 665.41 km^2 and 16.72 km^2, respectively. Forest area, on the other hand, has decreased by 699.37 km^2 over the same time period.

Hussain *et al*. (2019) studied the land use land cover changes over forty years in Lodhran District of Pakistan. Supervised classification was used to detect LULC variations observed over the Lodhran district. The study revealed that the conversion of barren land into vegetation and built-up areas has been a notable development in the Lodhran district over the last 40 years.

Meer and Mishra (2019) studied the land cover and land use changes in the Baramulla district of Kashmir valley by using geospatial technology. Land-use and land-cover classification were generated via on-screen digitizing, utilizing the satellite data from 1979, 2001 and 2018. The study concluded that the agricultural area decreased by 54.99 percent from 1979 (401.81 km^2) to 2018 (180.87 km^2). Horticulture has also grown by 35.52 percent from 334.38 km^2 in 1979 to 518.65 km^2 in 2018. From 1979 (777.54 km^2) to 2018 (563.99 km^2), the area of dense forest has decreased by roughly 27.46 percent.

Verma and Raghuvanshi (2019) studied the rural development and land use land cover change in a rapidly developing Varanasi district. The study revealed that during the period 1993–2013, agricultural land, which accounted for roughly half of all land cover, expanded by 37%, whereas built-up land increased by 236 percent.

Dhanaraj and Angadi (2020) did the land use land cover mapping and monitored the urban growth using remote sensing and GIS techniques in Mangaluru, India. The study revealed that the percentage of built-up area has risen from 3.68 percent in 1972 to 18.79 percent in 2018. Agricultural land, on the other hand, declined from 36.51 to 11.22 percent between 1972 and 2018.

Elagouz *et al*. (2020) conducted research in the Egyptian Nile Delta using remote sensing, to evaluate the impact of land cover change and urban sprawl. The study revealed that there was a steady growth in agricultural, urban, fish farm and natural vegetation areas, as well as a steady decline in water bodies and sand areas.

Mishra *et al*. (2020) studied the changes in LULC patterns of the Rani Khola watershed of Sikkim Himalaya for the periods 1988–1996, 1996–2008 and 2008–2017. The watershed's LULC maps were created using supervised classification utilizing the maximum likelihood classifier (MLC). According to the findings dense woodland, built-up areas and water bodies all increased by 16.40 percent (41.76 km^2), 2.13 percent (5.41 km^2 and 0.11 percent (0.28 km^2), respectively. Open forest, farmland and barren terrain have been reduced by 13.98 percent (35.59 km^2), 2.83 percent (7.22 km^2) and 1.82 percent (0.4.64 km^2), respectively.

Prokop (2020) studied the LULC changes of severely degraded land using high-resolution remote-sensing data from the last 50 years in the Meghalaya Plateau, northeast India. LULC mapping was done using a visual interpretation approach along with field surveys. Based on satellite pictures from the US Corona programme in 1965, pan-sharpened Indian Remote Sensing (IRS) images IRS-1D in 1998 and Google Earth in 2017. The study concluded that in 2017, grassland had a dominance of 73.2 percent, with forests (17.6%), towns (5.8%), mining (2.3%), agriculture (0.7%) and water bodies (0.4%) making minor contributions.

Singh *et al*. (2020) studied the temporal land use land cover and water quality changes in the Harike wetland ecosystem, Punjab, India. The map was generated by visually interpreting multispectral Resources at 2 LISS-IV satellite data (2014 and 2018) with a spatial resolution of 5.8 m on-screen. The study revealed that during 2014–18, agricultural, forest and built-up land increased, while wasteland, water bodies and wetland land decreased. Agricultural land increased at a rapid rate of 18.87 hectares per year from 2006 to 2014 but then fell to 3.53 hectares per year from 2014 to 2018.

Somvanshi *et al*. (2020) studied the spatial LULC changes and their growth prediction based on statistical models and earth observation datasets of Gautam Budh Nagar, Uttar Pradesh, India. The results revealed that Increased urbanization favoured a significant decrease in agricultural land and rural built-up areas. The simulation model found that by 2019, 14.7 percent of urban built-up areas will have increased, followed by 15.7 percent in 2022 and 18.68 percent in 2031.

Thakur *et al*. (2020) did a study on land use land cover change detection through geospatial analysis in an Indian Biosphere Reserve. The study revealed that Sal mixed forest has shrunk by 2.88 percent (5.23 km^2), the dense mixed forest has shrunk by 4.02 percent (9.54 km^2) and teak plantations have shrunk by 6.77 percent (2.61 km^2) and bamboo brakes have shrunk by 7.66 percent (2.34 km^2).

Kumar *et al.* (2021) studied the change of land use land cover in the Jhansi district of Uttar Pradesh over the past 20 years using LANDSAT TM, ETM+ and OLI sensors. The result revealed that cropland, built-up area and water bodies grew by 27.16 percent (1367.26 km^2), 0.58 percent (29.4 km^2) and 0.3 percent (15.26 km^2), respectively, whilst fallow/barren land and forest dropped by 27.55 percent (1386.58 Km^2) and 0.5 percent (25.34 Km^2), respectively.

Rasool *et al*. (2021) conducted a study in the Southern part of Kashmir Himalaya. The research determined that large land use changes occur in a few select classes, with cropland agriculture losing the most (5%) and economically productive horticulture gaining the most (+4.29%), during the study period.

Baig *et al*. (2022) examined LULC variations in Selangor, Malaysia and predicted future developments. The resulting maps depicted region changes from 1991 to 2021 in various classes, with developed, barren and water lands increasing by 15.54 percent, 1.95 percent and 0.53 percent respectively and agricultural, forest and wetlands decreasing by 3.07 percent, 14.01 percent and 0.94 percent respectively.

Cui J *et al.* (2022) conducted research in the Yellow River Basin, Shandong Province, China to examine the land cover change patterns and their underlying reasons in the Shandong section of the Yellow River Basin. The results revealed that over the last two decades, the LULC types in the study area have primarily been farmland and construction land, with the proportion of farmland area decreasing and the proportion of construction land area increasing from 19.4 percent to 29.7 percent.

Kuma *et al*. (2022) studied the LULC changes and related effects in the Bilate catchment from 1986 to 2018. The study of Landsat imagery from 1986, 2002 and 2018 revealed significant changes in LULC in the Bilate basin. From 1986 to 2018, the continuous-time series expansion of cultivated land at 9.27 percent, barren land at 1.36 percent, built-up areas at 0.97 percent and water bodies at 0.13 percent was accompanied by a decline in forest wood at 8.56 percent from 1986 to 2002 and grazing lands 3.18 percent from 1986 to 2018. The main consequences of the LULC shift in the basin were a decrease in agriculture yields, animal products and numbers and Lake Abaya fish population. It is recommended that all responsible entities have the commitment and engage closely with communities through participatory ways to achieve sustainable land use.

2.2 TO INVESTIGATE DRIVERS FOR LAND USE LAND COVER CHANGES

Belay and Mengistu (2019) studied the LULC patterns and drivers in the Muga watershed, Upper Blue Nile basin and Ethiopia. Watersheds in the study were identified using digital image analysis tools and their socioeconomic and biophysical drivers were examined using descriptive statistics. According to the results of the socioeconomic data analysis, the most prominent drivers of LULC changes in the research watershed were an extension of cultivated land, removal of trees for firewood and construction reasons, population increase, land tenure policy and climate variability.

Betru *et al*. (2019) studied the trends and drivers of land use land cover change in Western Ethiopia. MSS (1978), TM (1986, 1991 and 2010), ETM+ (1999) and OLI (2013 and 2016) Landsat images were used to investigate the dynamics of LULC. The study revealed that small-scale subsistence agriculture as well as large-scale commercial agriculture, population pressure from a multi-source, ongoing intake of immigrants, a lack of coordinated institutional frameworks and unsustainable exploitation of forest resources are the major underlying drivers for deforestation.

Degife *et al*. (2019) conducted research in the Lake Hawassa watershed of Ethiopia to study LULC dynamics, its drivers and environmental implications in the Lake Hawassa Watershed of Ethiopia. To analyse the change and examine the underlying determinants and its implications, the study triangulated data from Landsat images (1972, 1992 and 2017), focus group talks, interviews and farmers' lived experiences through a household survey. The study revealed the growth of agricultural operations, urban and infrastructural expansion, timber extraction, biophysical variables, demographic considerations and land tenure policies.

Munthali *et al*. (2019) studied the local perception of drivers of LULC change dynamics across the Dedza District in the Central Malawi Region. This study assessed LULC dynamics and related LULC change factors using remote sensing and Geographic Information System (GIS)-based analyses, focus-group discussions, key informant interviews and semi-structured interviews with 586 households. The study revealed that the primary causes of these observed LULC changes in the research region were identified as firewood collecting, charcoal production, population increase and poverty.

Sharma *et al*. (2019) carried out research in the Taunggyi District, Shan State of Myanmar to study the forest cover change and its drivers. The study revealed that the potential deforestation driver is infrastructure, elevation, slope, deforested area and population.

Dibaba *et al*. (2020) carried out research in Finchaa Catchment, Northwestern Ethiopia to find drivers and implications of LULC Dynamics. Landsat images from 1987, 2002 and 2017 were utilised to create the land use maps and quantify the changes. The study revealed that several causes, including ecological, socioeconomic, institutional, technical and demographic aspects all contributed to the observed LULCC in the research region. The main implications of LULCC in the Finchaa watershed were a decrease in agricultural productivity, loss of biodiversity, prolonged aridity, drought, land and soil degradation and a decrease in water supplies.

Hailu *et al*. (2020) studied the dynamics of the LULC change trend and its drivers in Jimma Geneti District, Western Ethiopia. The study revealed that Population expansion, legislative and institutional changes, poverty and a lack of understanding about the necessity of natural resource protection for sustainable lifestyles are among the key underlying causes of LULC changes.

Mills *et al*. (2020) studied the trends and drivers of land cover changes in a tropical urban forest in Ghana. For this study, they used Landsat satellite images using ENVI to detect trends of land cover changes from 1991 to 2015. The major cause of land cover change, according to survey respondents, is urbanization. Other variables influencing land cover change cited included fuel wood exploitation and logging, agriculture, a lack of forest guards and a lack of enforcement of forest and yearly fire legislation and a lack of forest guards. Based on these data, the study concluded that human activities were causing significant changes in land cover in the urban forest.

Li *et al*. (2020) studied the driving factor and predicted LULC by using remote sensing. The study revealed that natural forces influenced changes in land use and covers in Gansu the most, whereas socioeconomic influences had little impact due to the gradual development of the economy.

Hishe *et al*. (2021) studied the LULC patterns and driving factors in Desa’a Forest in Northern Ethiopia. Landsat images from 1973 (MSS), 1986 (TM) and 2015 (OLI) were used, as well as maximum likelihood supervised classification. A pixel-to-pixel comparison after categorization was also performed to discover variations from year to year. The study revealed that the main causes of deforestation in the Desa'a forest include fire, agricultural expansion, grazing and browsing effects, drought, timber exploitation and a lack of government attention.

Chapter-3

MATERIALS AND METHODS

The present investigation entitled “**Studies on land use land cover change in Hamirpur district of Himachal Pradesh**” was conducted from 2021-2022. The details regarding the experimental sites, material and methodology adopted for undertaking this study objective-wise are presented below.

3.1 TO ESTIMATE CHANGES IN LAND COVER USING REMOTE SENSING AND GIS TECHNIQUES

3.1.1 STUDY AREA

3.1.1.1 Location

The study was carried out in the Hamirpur block, district Hamirpur of Himachal Pradesh located between 31°44 to 31°36' N latitude, 76°35' to 76°26' E Longitude and elevation varies from 400 meters to 1000 meter covering an area of 108 km^2 (Fig 1).

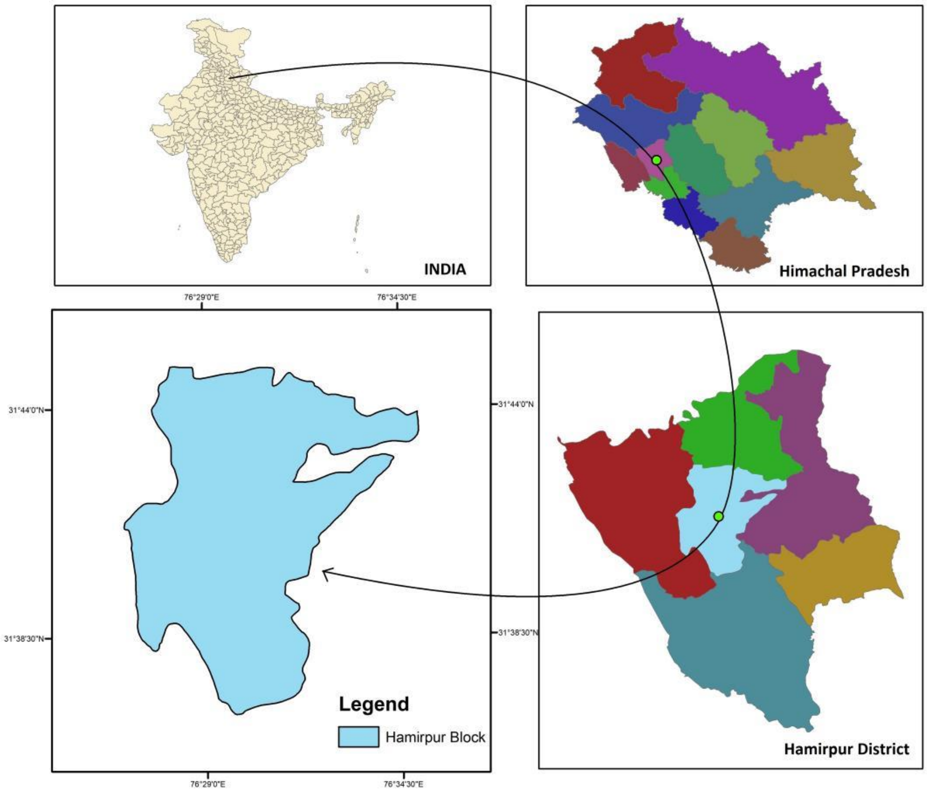


Fig. 3.1: Map of the study area

3.1.1.2 Climate

The climate of the study area falls in the humid sub-tropical zone. The temperature during the winter months is too cold. The district receives plentiful rains during the monsoon. The maximum rainfall is observed in the district from July to August and a minimum in the months of April and October. The district's hottest month is May and the coldest month is January. The average maximum and minimum day temperature recorded in the district ranges from 6˚C to 40˚C.

3.1.2 Preparation of land cover map of the Hamirpur block

The land use land cover (LULC) in the Hamirpur block was mapped to analyze 19 years of changes (2002-21) using the supervised image classification technique and multi-sensor satellite data for different years. The details of the methodology adopted for the present study are discussed below (Fig 3.2).

3.1.3 Data used

In this study, three cloud-free satellite images from Landsat 7 (Enhanced Thematic Mapper), Landsat 8 (Operational Land Imager) and Sentinel 2 (Operational Land Imager) from the United States Geological Survey (USGS) server for land cover maps were used (Fig 3.3, Fig 3.4 and Fig 3.5). These images were selected on the basis of their availability and the quality of the datasets required for the study area. Table 3.1 summarized the details of the satellite data used in the study area.

Table 3.1: Details of the satellite data used in the Hamirpur block

Satellite	Sensor	Spatial Resolution (M)	Date of Acquisition	Sources
Landsat 7	ETM	30	22-05-2002	USGS
Landsat 8	OLI	30	20-05-2013	USGS
Sentinel 2	MSI	10	27-05-2021	USGS

MSI: Multi-Spectral Imager; ETM: Enhanced Thematic Mapper; OLI: Operational Land Imager.

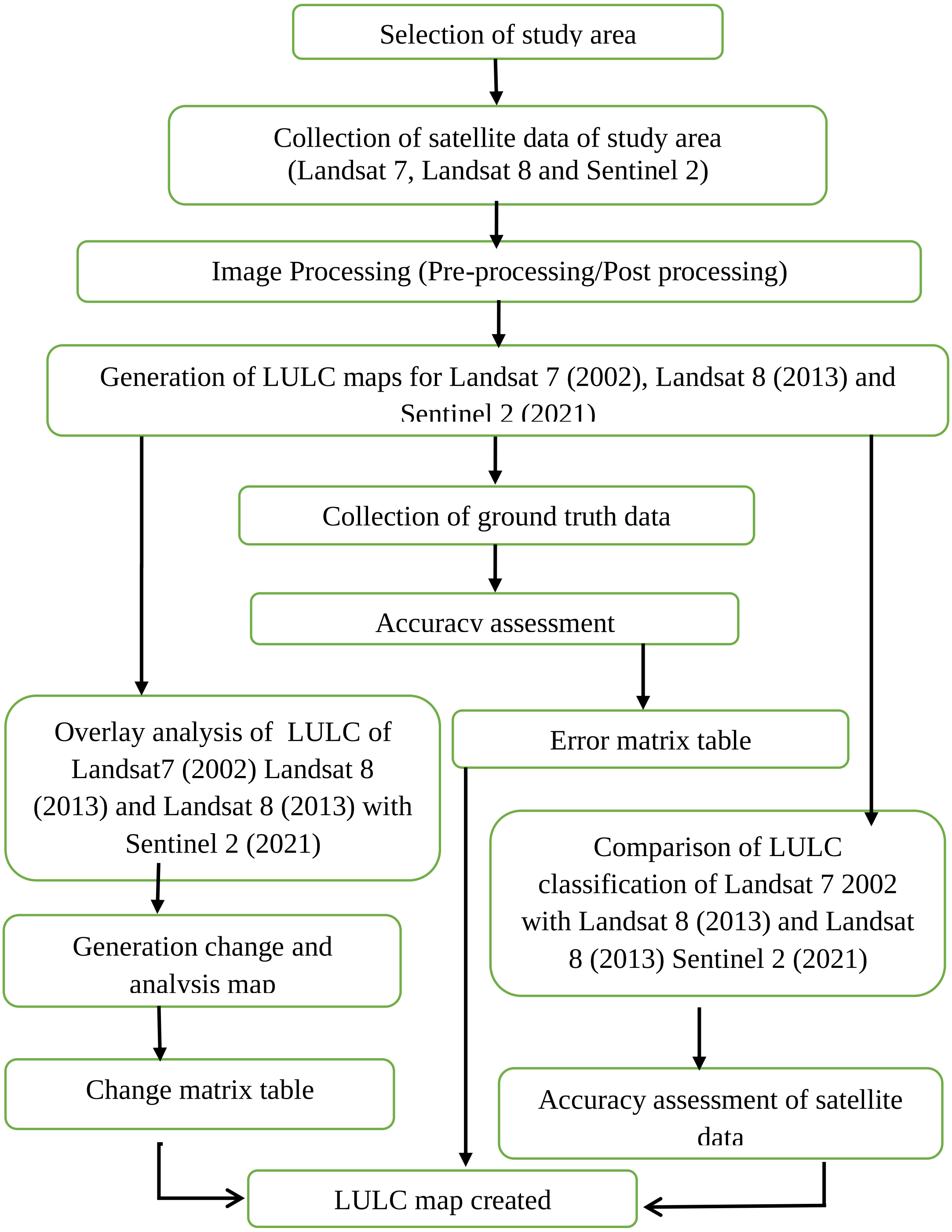
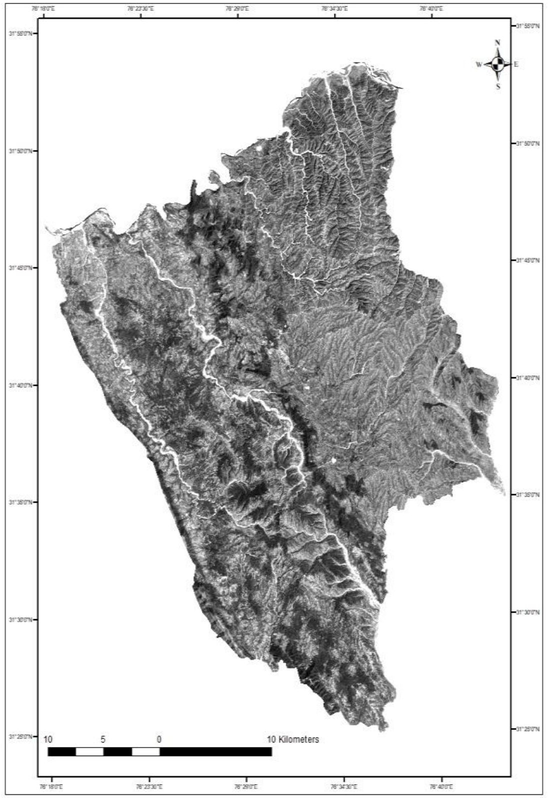
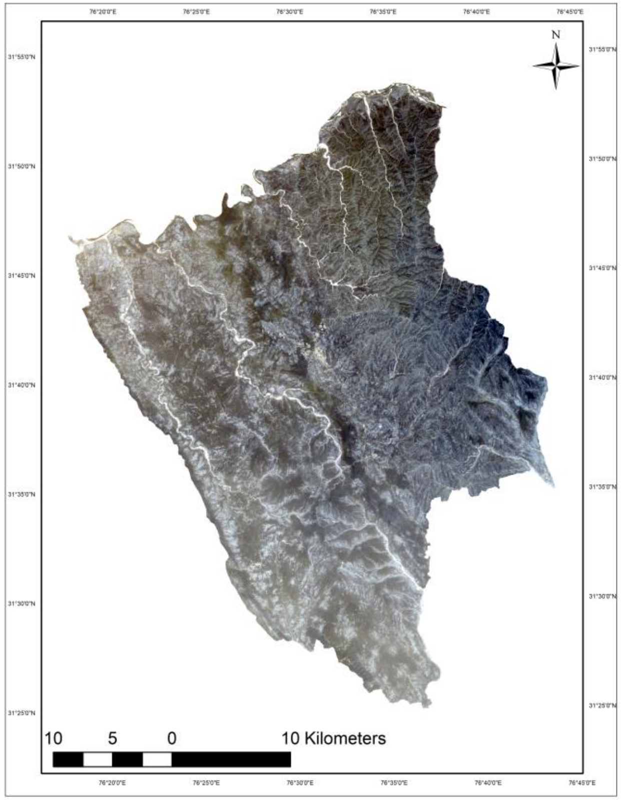


Fig 3.2: Flow chart of the methodology adopted in the present study





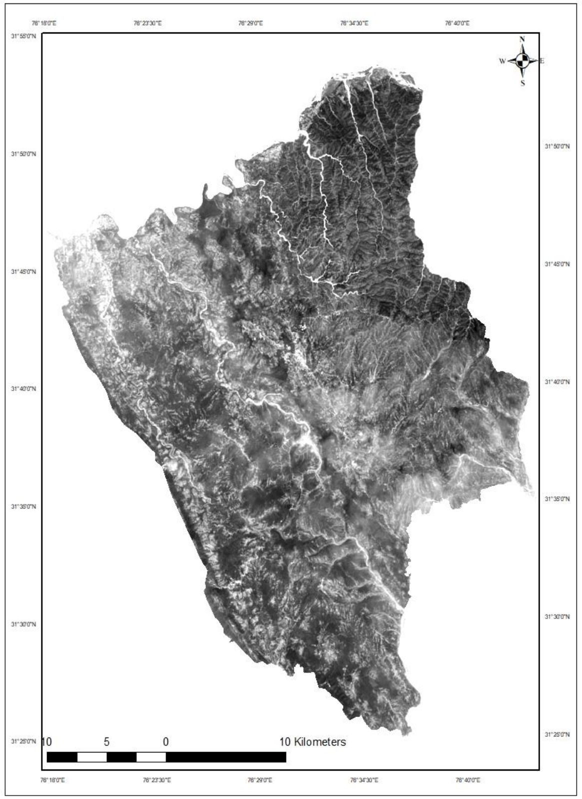


Fig. 3.3: Satellite image from Landsat 7 in the year 2002 of the Hamirpur district

Fig. 3.4: Satellite image from Landsat 8 in the year 2013 of the Hamirpur district

Fig. 3.5: Satellite image from Sentinel 2 in the year 2021 of the Hamirpur district

3.1.4 Software and Tools used

In the present study the under-mentioned software and tools were used:

1) ArcGIS Version 10.8
2) Digital camera to capture the pictures of different LULC classes in the study area during ground truthing.
3) Global Positioning System (GPS) to take geo-coordinates at the time of ground truth data collection.

3.1.5 Pre-processing

Boundary shape file (.shp) of district Hamirpur was obtained from Aryabhatta Geo-informatics & Space Application Centre (AGiSAC), Department of Science & Technology, Shimla which was further used for clipping out the study area (Fig 3.6). The satellite images for the years 2002 (Landsat 7), 2013 (Landsat 8) and 2021 (Sentinel 2) were downloaded from the USG server. Band number 1, 2 and 3 of Landsat 7 and band number 5, 4 and 3 of Landsat 8 satellite were used for the study for the years 2002 and 2013 respectively and they were stacked using the layer stacking feature of Arc-map software. After that, false colour composite bands were generated from the stack layer feature (Fig. 3.7 and Fig. 3.9) of the Hamirpur block. Landsat 7 and 8 stacked images of Hamirpur block were re-sampled from 30 m to 10 m resolution (Fig 3.8 and Fig 3.10). Similarly, band numbers 2, 3 and 4 of Sentinel 2 were also taken for the study and they were stacked using the layer stacking feature of Arc-map software and false colour composite bands were generated with the help of the stacked layer feature (Fig 3.11) of Hamirpur block. Stacked images for the years 2002, 2013 and 2021 were clipped using the clip feature of Arc map. Mishra *et al* (2020) have adopted the same process to extract the study area.

3.1.6 Land use and land cover classifications of Hamirpur block

Land use and land cover (LULC) classification were based on Anderson *et al* (1976) classification system. The numbers of LULC classes exist in the classification system out of which seven LULC classes viz. Agriculture land, Barren/Shrub/Waste Land, Built-up Land, Forest Land and Drainage were selected according to the topography of the study area. The details are given in Table 3.2

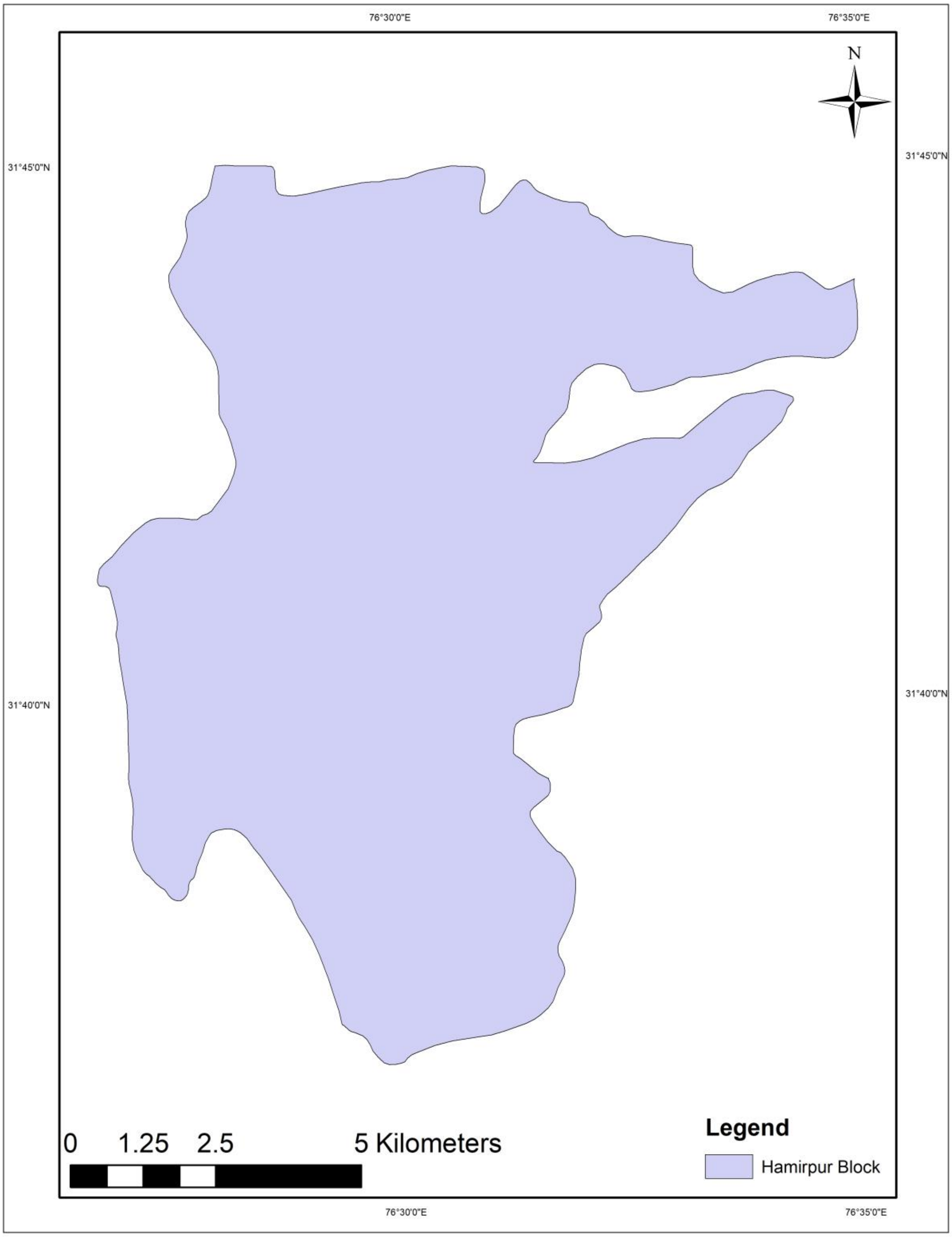


Fig. 3.6: Shape file of the study area

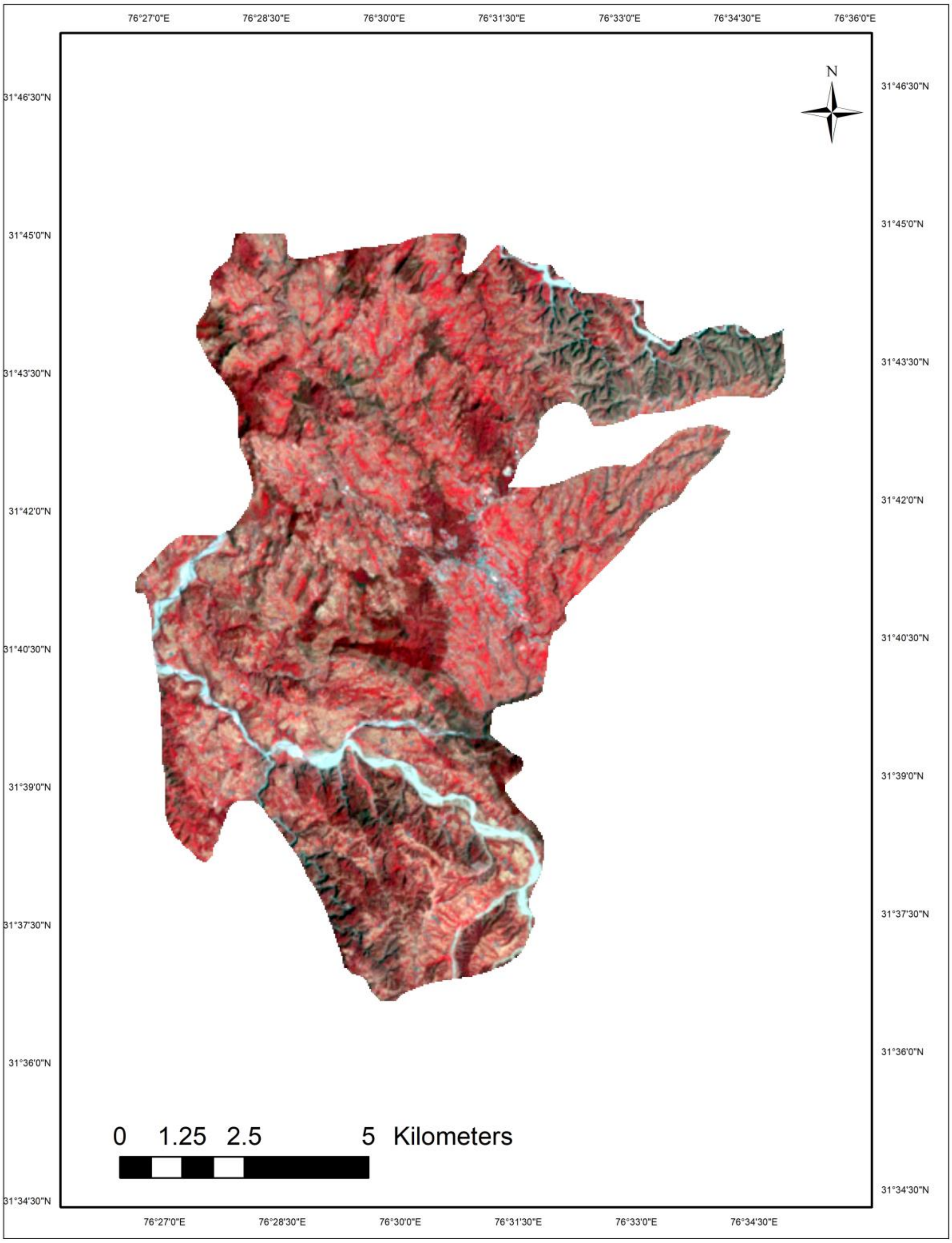


Fig. 3.7: Standard false colour composite of a satellite image from Landsat 7 in the year 2002 of the Hamirpur block

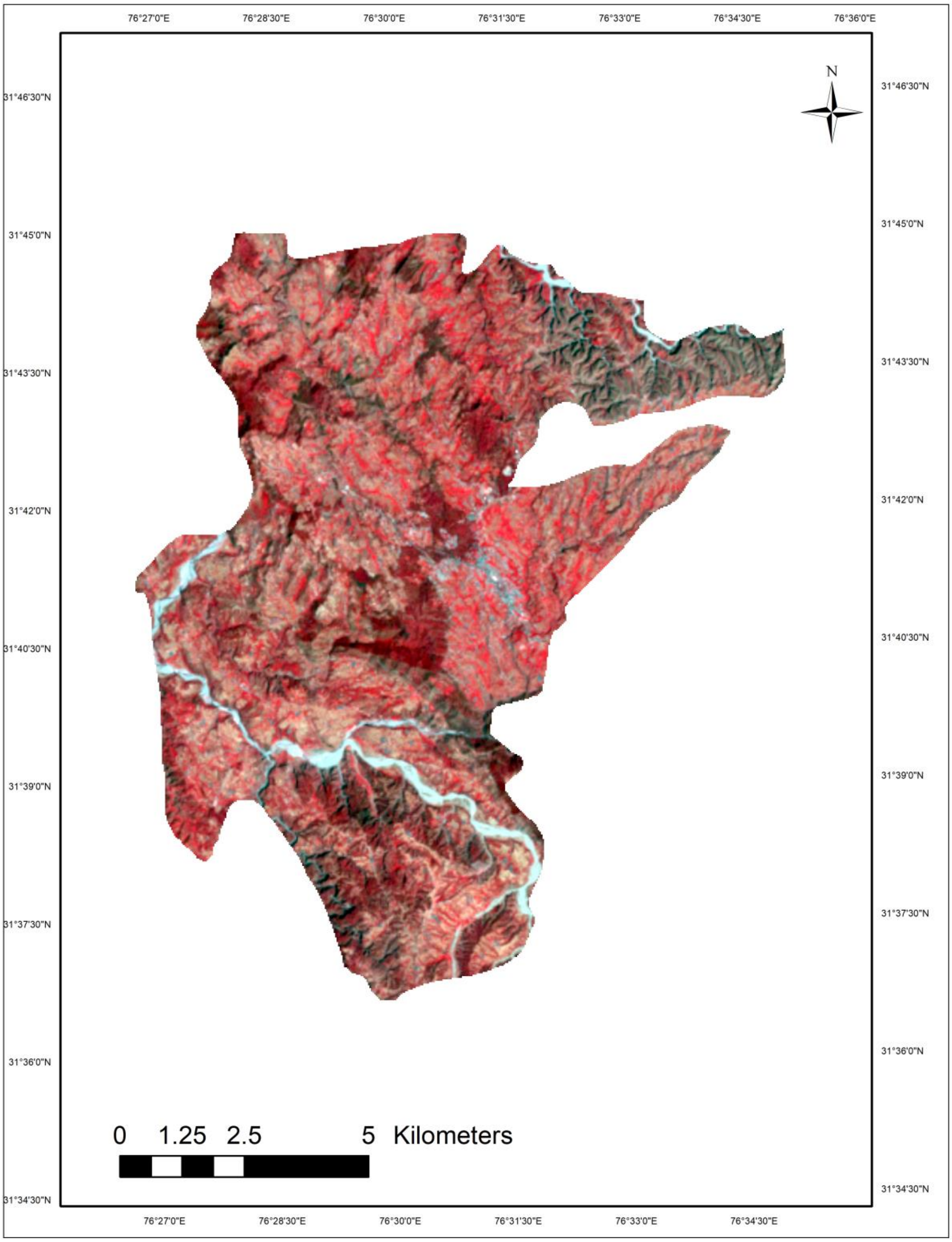


Fig. 3.8: Re-sampled (10m) standard false colour composite of a satellite image from Landsat 7 in the year 2002 of the Hamirpur block

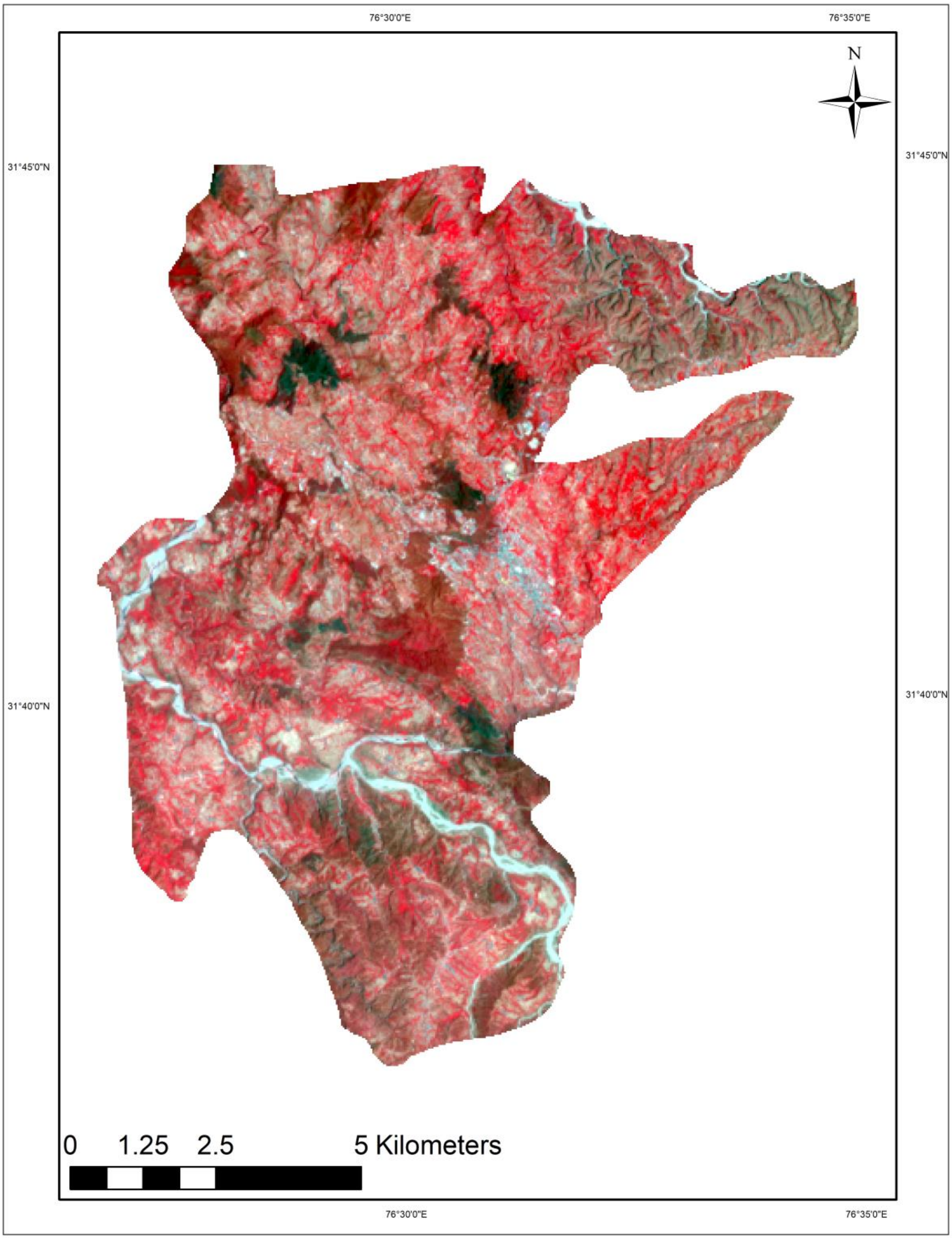


Fig. 3.9: Standard false colour composite of a satellite image from Landsat 8 in the year 2013 of the Hamirpur Block

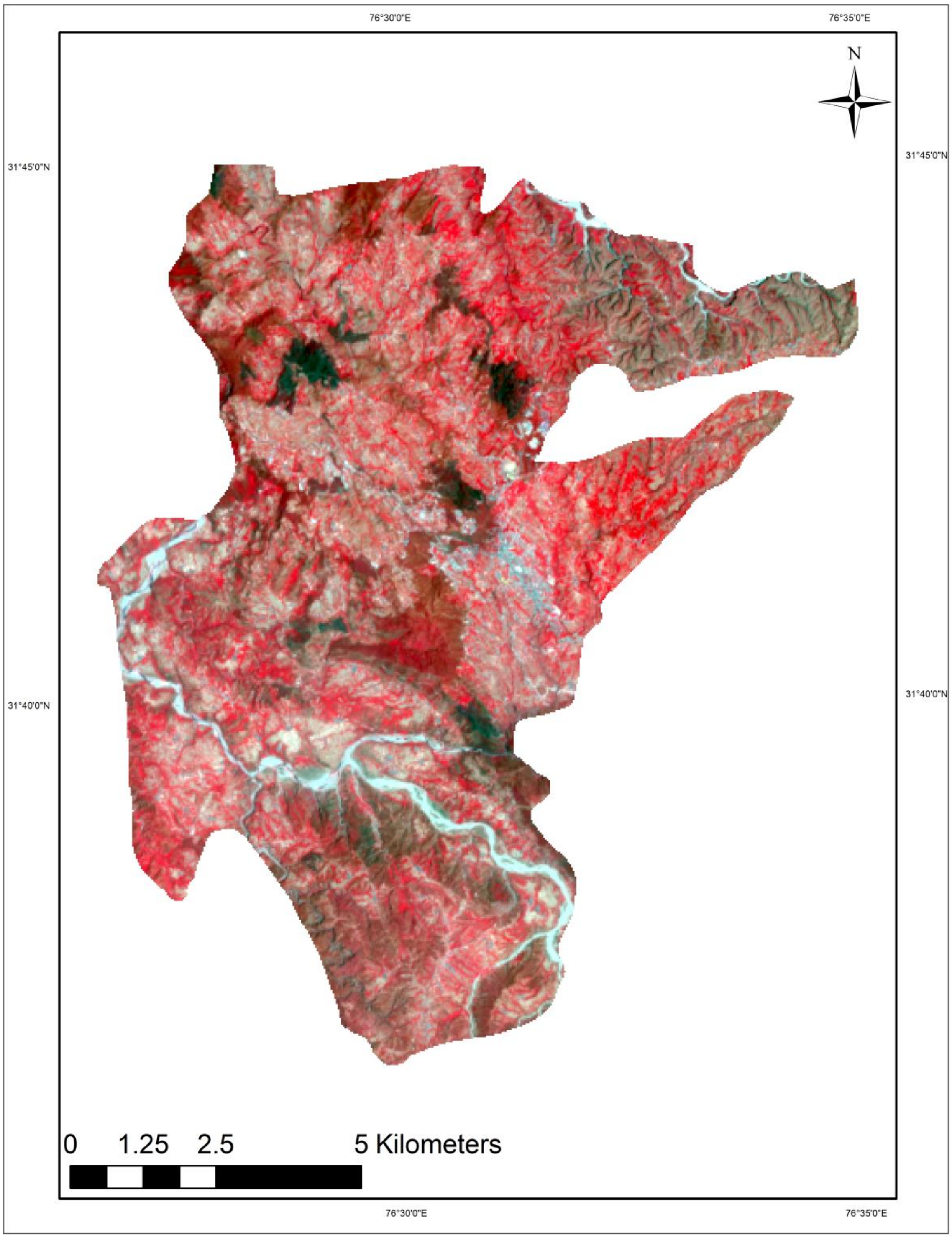


Fig. 3.10 Re-sampled (10m) standard false colour composite of a satellite image from Landsat 8 in the year 2013 of the Hamirpur block

Fig. 3.11: standard false colour composite of a satellite image from Sentinel 2 in the year 2021 of the Hamirpur block

Table 3.2: Land use and land cover classification for the Hamirpur Block

Sr. No.	Level 1	Description
1	Agriculture Land	Cropland – 3 cropping seasons Kharif (June/July-Sep/Oct), Rabi (Nov/Dec-Feb/Mar) and Zaid (Apr-May) exist in India. Agriculture land with an alternation between a cropping period of several years and a fallow period
2	Barren/Shrub/Waste Land	Bare rock – Rock faces, Rock slides, Cliffs, exposed rocks, etc. and land which is not under cultivation
3	Built-up Land	Urban – Compact (When urban structures and transport networks occupied > 80 percent of surface area), Sparse (Buildings, area associated with vegetated and bare soil and covers about 30 percent to 80 percent of surface area). Rural – Human settlements of size relatively less than the urban settlements where > 80 percent of the people are involved in agricultural activities.
4	Forest Land	Lands with 70 percent or more tree canopy density. Lands with 40 percent to 70 percent tree canopy density. All lands with tree canopy density of 10 percent and more but less than 40 percent. Degraded forest lands with a canopy density of less than 10 percent. Lands are not included in any of the above classes.
5	Drainage	Natural drains

There was a total of five LULC classes demarcated and presented in Table 3.2. The attribute information, tables and maps of classifications were prepared for all three satellite imageries.

3.1.7 Post-processing

3.1.7.1 Supervised classification

After the preparation of classification one of the most widely used image classification techniques, i.e., maximum likelihood classification was adopted for mapping all the LULC classes. Before the selection of training samples, empirical analysis of satellite imagery, google earth images were investigated carefully. For most of the classes, the fair number of training samples taken specifically was 50-100, which is essentially significant (Mishra *et al.* 2020).

3.1.7.2 Detection of land use and land cover change

To study the LULC changes over time, the vector layer of Landsat 7 for the year 2002 was intersected with the vector layer of Landsat 8 for the year 2013.

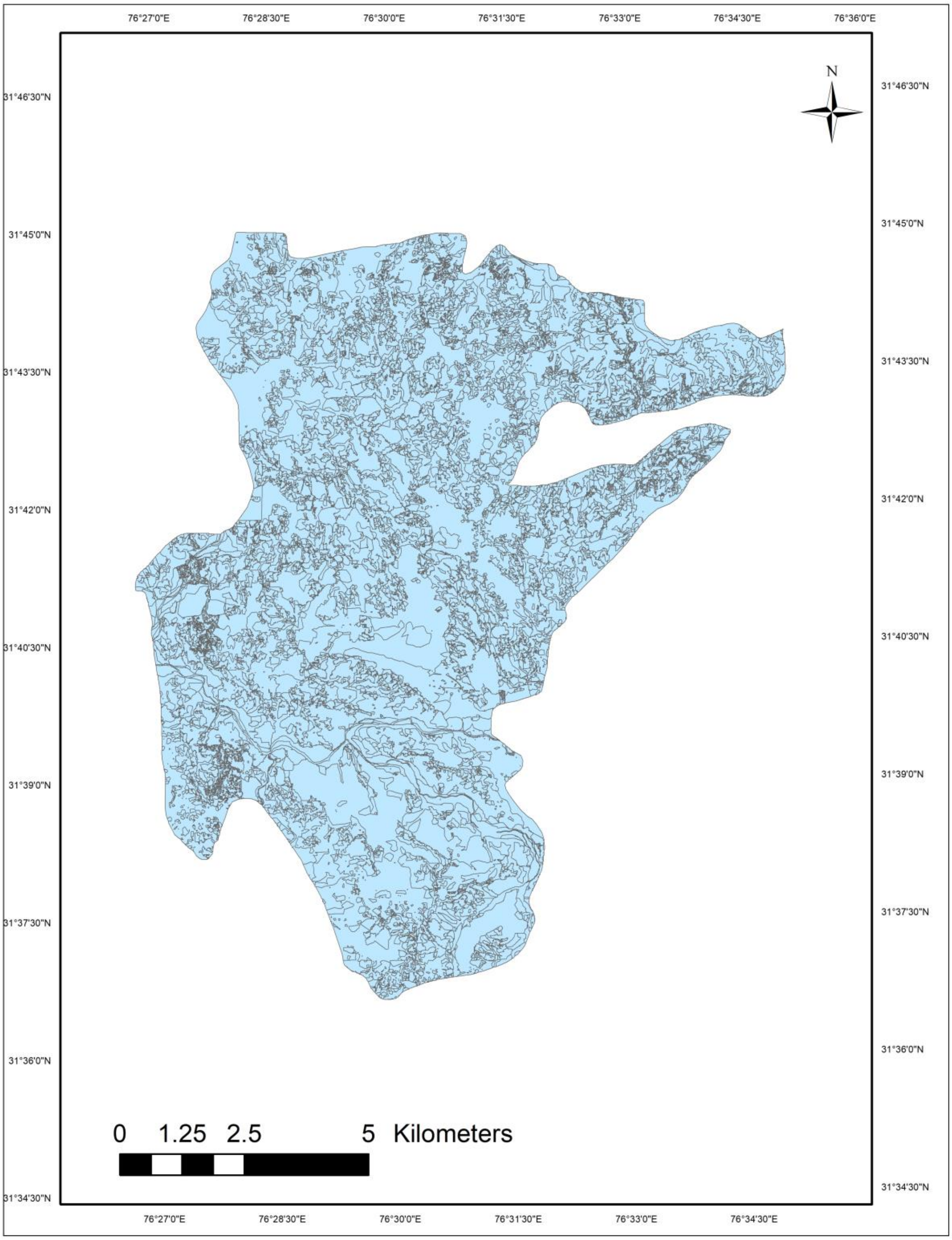


Fig. 3.12: Intersect vector layers of Landsat 7 in the year 2002 and Sentinel 2 in the year 2021 of the Hamirpur block

The Landsat 8 for the year 2013 was intersected with the vector layer of Sentinel 2 for the year 2021. Singh and Khanduri, 2011; Tiwari and Saxena, 2011 followed the same methodology. Both layers were combined using the intersect tool, which is included in ArcGIS (Version 10.8) software (Fig. 3.12). By comparing the categorised shape data of Landsat 7 from the year 2002, Landsat 8 from the year 2013 and Sentinel 2 from the year 2021, locations were extracted where changes had occurred. In MS Excel, the area of all the categorised LULC classes was exported and computed. Area computed for each class were then subtracted from one another (Landsat 7 for the year 2002 minus Landsat 8 for the year 2013 and Landsat 8 for the year 2013 minus Sentinel 2 for the year 2021) and percentage changes were calculated. A change matrix table was created.

3.1.7.3 Accuracy assessment of land use and land cover classification of Hamirpur block

The review of classification with ground truth data to improve how well the classification represents the real world is known as accuracy assessment. In the current study, the accuracy of the generated classified satellite imageries, namely Landsat 7 for the year 2002, Landsat 8 for the year 2013 and Sentinel 2 for the year 2021, was assessed using a random sample approach to measure the quality of information derived from satellite data. An error matrix was used to conduct this evaluation. A point feature shape file was constructed in ArcGIS software by picking 140 points that correspond to the main areas of change as well as other places in the study area (Fig. 3.13). The shape file of 140 randomly selected sites was superimposed on Google Earth to verify the Landsat 7 ground truth data for the years 2002 and 2013. The ground truth data for the year 2021 was also checked physically by visiting the 35 selected locations (Table 3.3). A field survey was conducted for ground verification of doubtful areas with the help of GPS and local guides in different parts of the block covering all the LULC classes.

3.1.7.4 Accuracy assessment

The error matrix, also known as the contingency/confusion matrix table, is one of the most frequent means of expressing classification accuracy. Error matrices compare and express numerous criteria concerning classification performance on a class-by-class basis (Weslati *et al.* 2020). Ground truthing data was obtained and combined with LULC categorised images for verification (Chowdhury *et al.* 2020). The categorised images were confirmed by viewing historical satellite images for the years 2002 and 2013 on Google Earth (Fig. 3.14), as described by Rwanga and Ndambuki (2017).

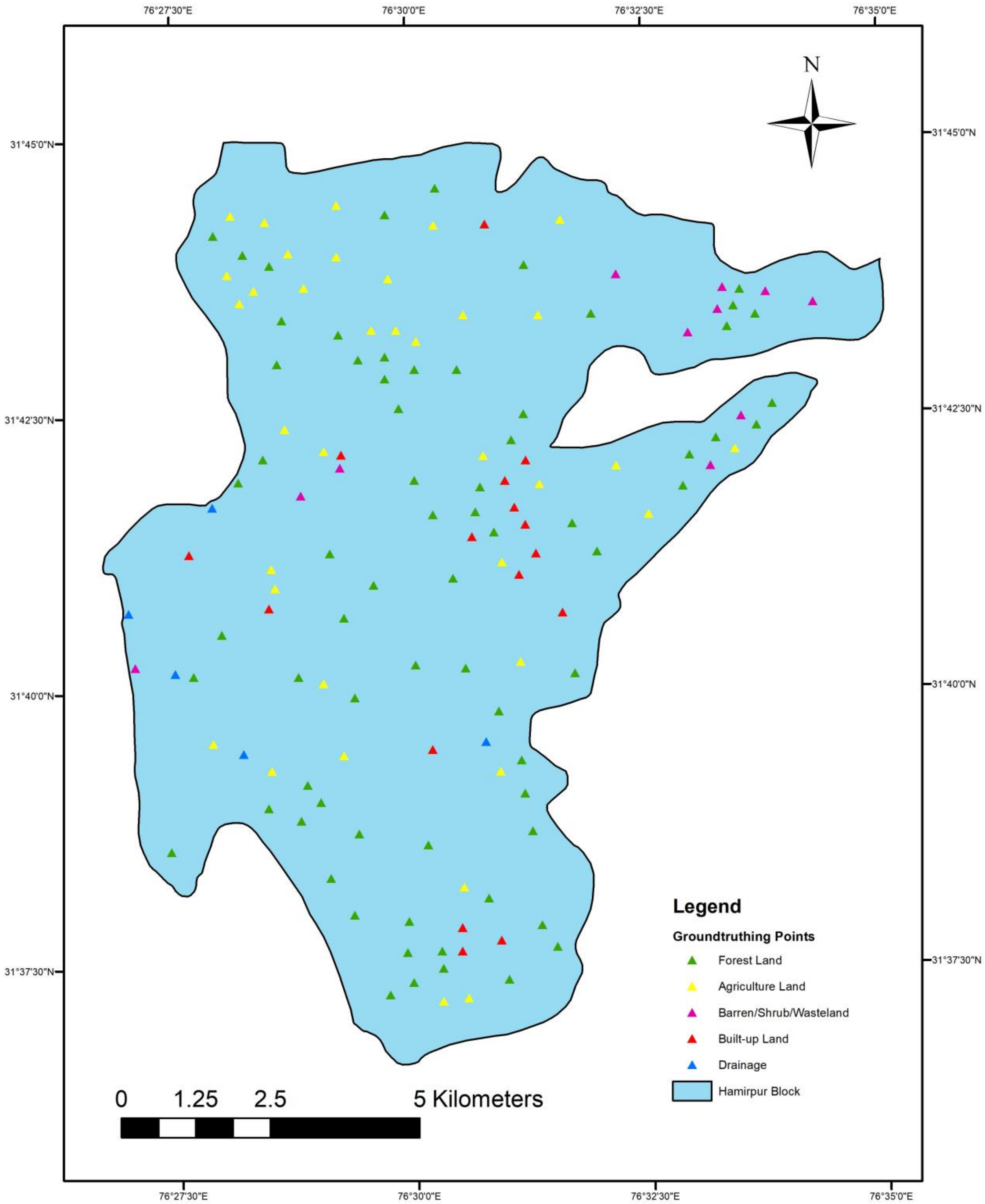


Fig. 3.13: Ground truthing points in the study area

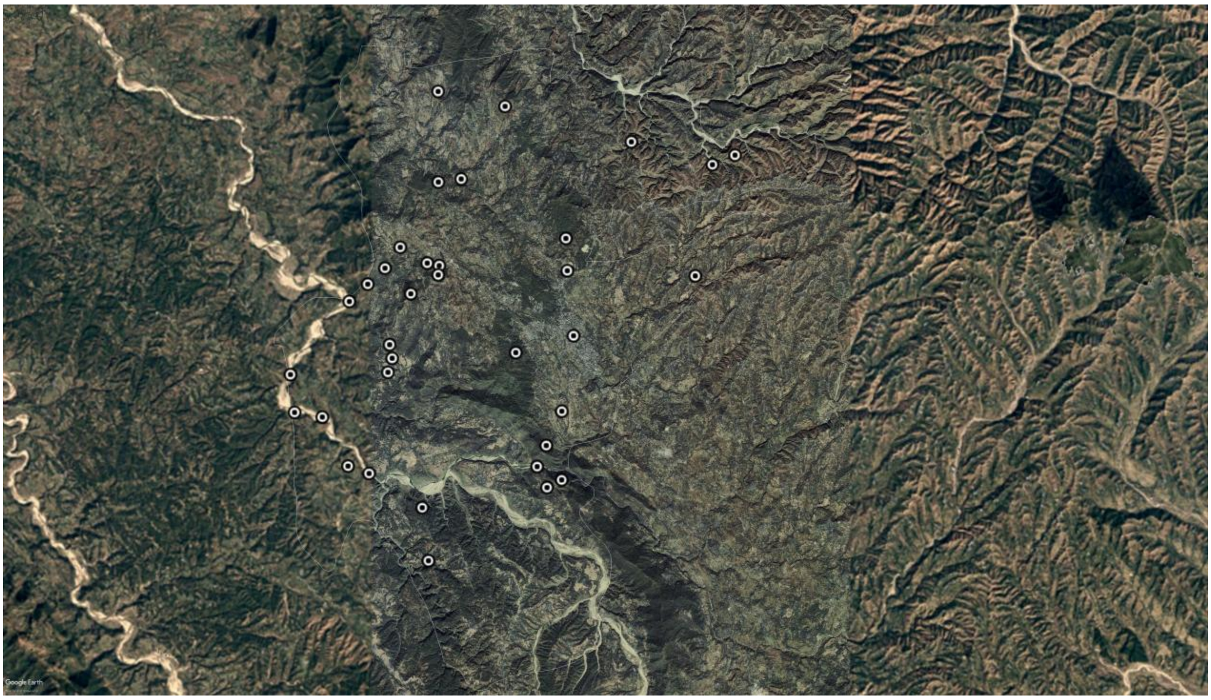


Fig. 3.14: Verification of selected points using Google Earth

Ground truthing data was used to examine the accuracy of the LULC categorization of Landsat 7 in the year 2002 Landsat 8 in 2013 and Sentinel 2 in 2021. For each LULC classified satellite data set, error matrix tables were created. For each LULC classification, the producer, user and overall accuracy, as well as the Kappa (K) coefficient, were computed.

Producer accuracy was calculated by using equation 3.1 (Congalton, 1991 and Yuan *et al.* 2005).

$$\text{Producer Accuracy} = \frac{\text{Total no.of correct points in each class}}{\text{Total no.of points used for that class (Classified Total)}} \qquad 3.1$$

User accuracy was calculated by using the formula given by Rujoiu-Mare and Mihai (2016).

$$\text{User Accuracy} = \frac{\text{Total no.of correct points in each class}}{\text{Total no.of points used for that class (Reference Total)}} \qquad 3.2$$

Overall accuracy was calculated by using the method of Rwanga and Ndambuki (2017).

$$\text{User Accuracy} = \frac{\text{Total no.of correct points}}{\text{Total no.of selected points}} \qquad 3.3$$

Kappa ($\widehat{K}$) coefficient was calculated by using the formula of Tilahun and Teferie (2015).

$$\hat{K} = \frac{N\sum_{i=1}^{k} x_{ii} - \sum_{i=1}^{k}(x_{i+} * x_{+i})}{N^2 - \sum_{i=1}^{k}(x_{i+} * x_{+i})} \qquad 3.4$$

where,

x_{i+} and x_{+i} are the marginal totals for the row I and column I

x_{ii} number of observations in row I and column I

N is the total number of observations

3.2 To investigate drivers for land use land cover changes.

The methodology adopted to achieve objective 2 is depicted in Fig 3.15.

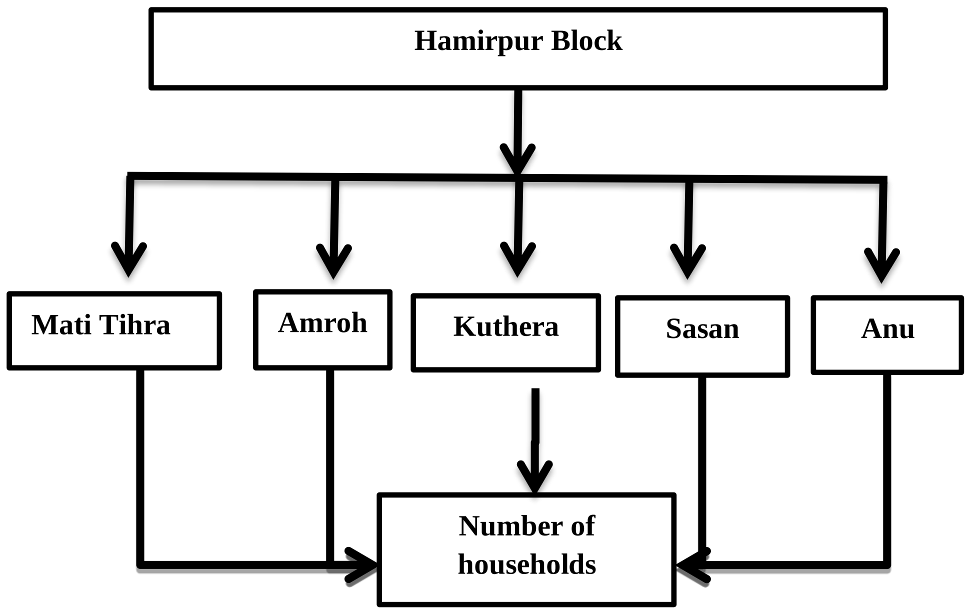


Fig 3.15: Methodology adopted for drivers for land use land cover changes

3.2.1 Household Surveys

In this study, face-to-face key informant interviews and a semi-structured household pre-tested questionnaire (Appendix A) were used. The questionnaire included both open-ended and closed-ended questions intended to evoke information about local community views of LULC changes and the drivers of these changes in the Hamirpur block during the study period (2002 to 2021) as it provides insight into the determinants of LULC alterations. (Munthali *et al.* 2019). To select respondents for the household interviews, a random sampling procedure was used under study. A questionnaire was distributed to 100 households. In addition, the questionnaire was distributed to respondents who (i) were aged 20 years and above, (ii) had lived in the respective area for at least 25 years and (iii) were implicit decision-makers in the household and/or, in the absence of a family head, it was made with appropriate representative and knowledgeable member of the household. The questionnaire contained five sections that covered the socioeconomic aspects of the home, local community perceptions of LULC changes and their reasons.

3.2.2 Focus-Group discussions and key informant interviews

Focus-group discussions (FGDs) and key informant interviews were conducted to triangulate the information acquired from the household interviews and get an in-depth and detailed understanding of local people's perspectives of LULC changes that had occurred in the investigated landscape, as well as the linked underlying factors considered to have contributed to the changes. A total of four focus groups discussion were held in five panchayats where home interviews were also done during the same time period. Each focus group had 10–15 participants. Key informants were identified using a purposive sampling strategy based on their expertise in the study area. Key informants in this study were exclusively technical members from the Hamirpur block who was familiar with the challenges in the study region.

3.2.3 Statistical Analysis

The study employed a variety of data-analytical tools and techniques, such as descriptive statistics, GIS-based processing and regression analysis. The LULC change analyses were carried out using ArcGIS software. The questionnaire's socioeconomic data was input, processed, coded and analysed using Microsoft Excel 2016 before being subjected to additional analysis. Descriptive statistics were used to describe the socioeconomic factors of the families, as well as to summarise their responses and rank the drivers of LULC changes. The ranking of the causes of LULC changes seen by respondents (household surveys) was derived using the weighted average principle and the ranking index adopted by (Munthali *et al. 2019)*:

$$\text{Index} = \frac{R_n C_1 + R_{n-1} C_2 \ldots\ldots + R_1 C_n}{\sum R_n C_1 + R_{n-1} C_2 \ldots\ldots\ldots + R_1 C_n} \qquad 3.5$$

where Rn = value given for the least-ranked level (for example, if the least rank is the 10th, then $R_n = 10$, $R_{n-1} = 9$, $R_1 = 1$; C_n = counts of the least ranked level (in the above example, the count of the 10th rank = Cn and the count of the 1st rank = C_1).

Chapter-4

RESULTS AND DISCUSSIONS

This chapter deals with the results which are obtained from the present study after analyzing the data related to the Land Use and Land Cover (LULC) classification for the Hamirpur block of Hamirpur district during the period 2002 to 2021 using remote sensing and Geographic Information System (GIS). This chapter is discussed under the following subheads:

4.1 To estimate changes in land cover using remote sensing and GIS techniques

- **4.1.1 Land use and land cover classification of the Hamirpur block**
- **4.1.2 Accuracy assessment of LULC classification of the Hamirpur block**
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4.2 To investigate drivers for land use land cover changes

- **4.2.1 Socioeconomic and demographic characteristics of sampled households**
- **4.2.2 Local-community perceptions on the impact of LULC Changes**
- **4.2.3 Ranking of drivers of LULC Changes**

4.1.1 Land use and land cover classification of the Hamirpur block

The land use land cover (LULC) map of the Hamirpur block was prepared using the supervised classification of satellite data obtained from Landsat 7 for the year 2002, Landsat 8 for the year 2013 and Sentinel 2 for the year 2021 (Fig. 4.1, 4.2 and 4.3).

Table 4.1: Temporal distribution of area (km^2) under different land use land cover classes in Hamirpur block

LULC Class	Year		
	2002	**2013**	**2021**
Agriculture Land	28.87	28.81	27.52
Barren/Shrub/Waste Land	9.37	9.25	7.70
Built-up Land	8.45	8.80	10.84
Drainage	0.45	0.39	0.36
Forest Land	61.49	61.38	62.20
Total	**108.63**	**108.63**	**108.63**

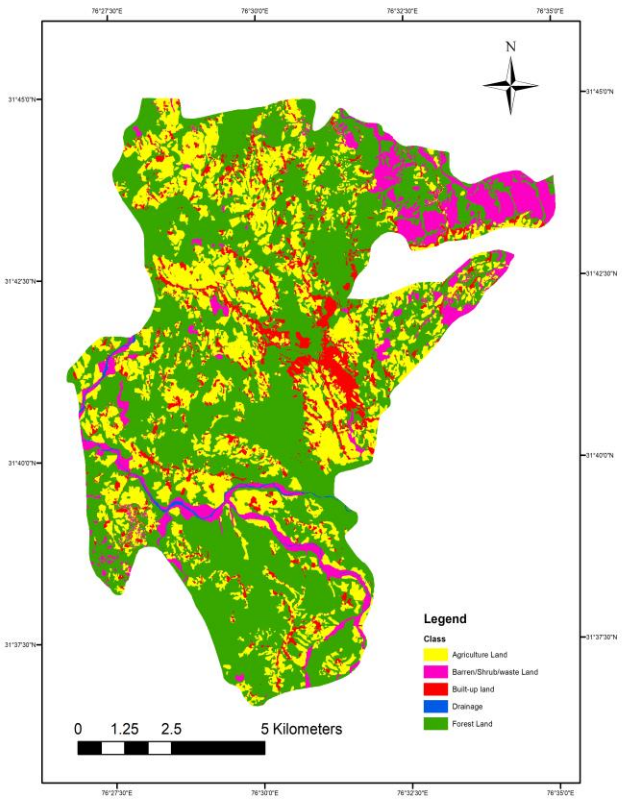

Fig. 4.1: Land use land cover classification of Hamirpur block for the year 2002

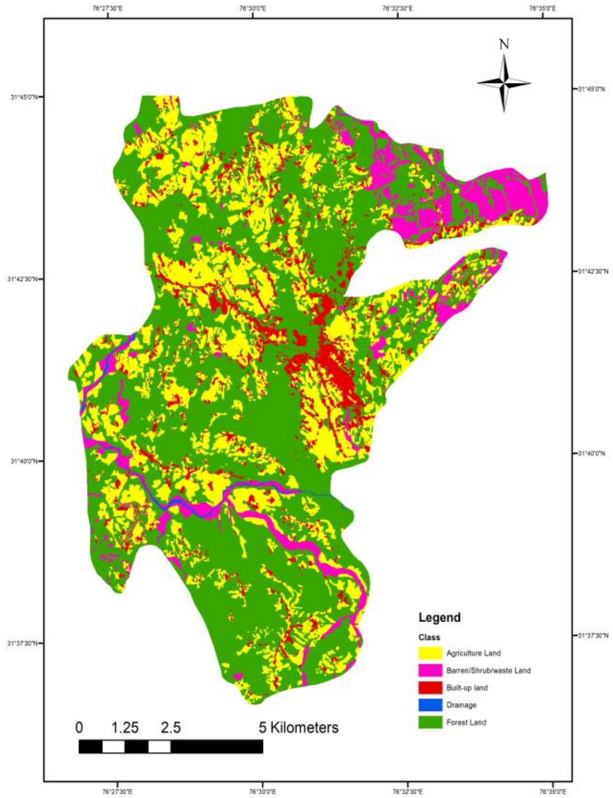

Fig. 4.2: Land use land cover classification of Hamirpur block for the year 2013

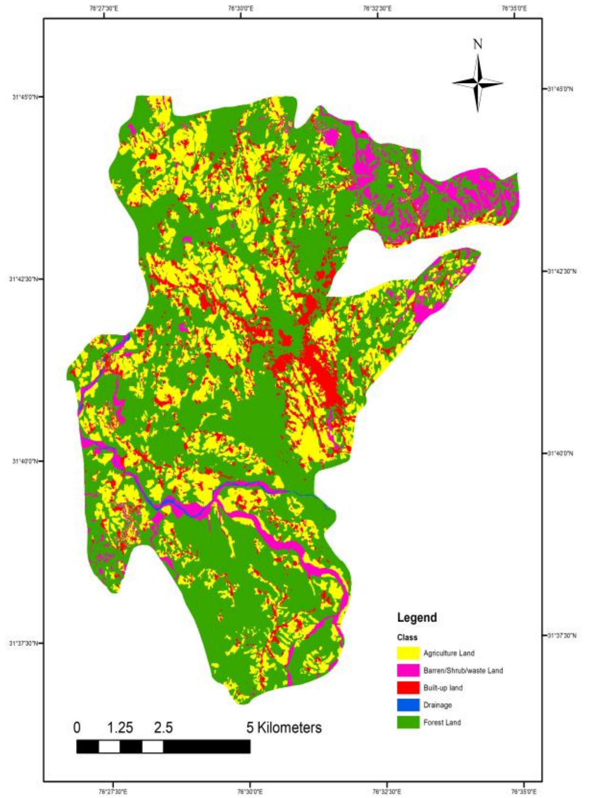

Fig. 4.3: Land use land cover classification of Hamirpur block for the year 2021

The temporal distribution of LULC covering five major classes: agriculture land, barren/shrub/wasteland, built-up land, drainage and forest land of the years 2002, 2013 and 2021 are shown in Table 4.1. According to area statistics for LULC using Sentinel 2, the largest area was covered under forest land amounting to 62.20 km^2 in the year 2021 followed by 61.49 km^2 (2002) and 61.38 km^2 in the year 2013, whereas agriculture land ranks second with an area of 28.87 km^2 in the year 2002 followed by 28.81 km^2 in 2013 and 27.52 km^2 in 2021 while minimum in drainage with an area of 0.36 km^2, 0.39 km^2 and 0.45 km^2 in 2021, 2013 and 2002 respectively of the total geographical area in the Hamirpur block. The built-up area increased from 8.45 km^2 in the year 2002 to 10.84 in the year 2021. The barren/shrub/wasteland decreased from 9.37 km^2 in the year 2002 to 7.70 km^2 in the year 2021. Table 4.1 revealed that forest land decreased during the period 2002-2013 but sharply increased from the year 2013 to 2021. Wang *et al*., (2021) noted a similar classification in the Thimphu city of Bhutan such as built-up area, forest land, agriculture land and bare land.

4.1.2 Accuracy assessment of LULC classification of the Hamirpur block

The accuracy of the generated classified satellite imageries, namely Landsat 7 the year 2002, Landsat 8 the year 2013 and Sentinel 2 the year 2021, was assessed using the random sampling approach to determine the quality of information derived from satellite data. A few ground truthing pictures in the Hamirpur block conducted for the year 2021 have been presented in Fig 4.4 to 4.8.

Fig. 4.4: Ground truthing points in the forest area of Hamirpur block (31°41'16.31"N, 76°30'54.17"E)

Fig. 4.5: Ground truthing points in agriculture land in Hamirpur block (31°41'1.61"N, 76°32'36.41"E)

Fig. 4.6: Ground truthing points of barren/shrub/waste land of Hamirpur block, (31°38'45.18"N, 76°30'31.68"E)

Fig. 4.7: Ground truthing points of built-up area of Hamirpur block, (31°41'7.45"N, 76°31'24.03"E)

Fig. 4.8: Ground truthing points of the drainage area of Hamirpur block, (31°39'31.75"N, 76°30'38.58"E)

4.1.2.1 Error matrix tables for land use and land cover classifications

Tables 4.2, 4.3 and 4.4 present the error matrix for all the LULC categories of Landsat 7 in the year 2002, Landsat 8 in the year 2013 and Sentinel 2 in the year 2021 respectively.

Table 4.2 revealed that in the case of the agriculture land, there was a total of 38 points selected from classified data out of which 35 points were found correct when compared with reference data and 3 points showed an error that belongs to forest land. Similarly, in the case of class built-up, there, was a total of 19 points selected from classified data out of which 19 points were found correct when compared with reference data. In the case of class forest land, 69 points were selected from classified data out of which 68 points were found correct when compared with reference data and 1 point showed an error that belongs to built-up.

Table 4.2: Error matrix table of LULC classification in the year 2002 using Landsat 7 in the Hamirpur block

	Agriculture Land	Barren/ Shrub/ Waste Land	Built-up Land	Forest Land	Drainage	Total (Users)
Agriculture Land	35			3		**38**
Barren/ Shrub/ Waste Land		9				**9**
Built-up Land			19			**19**
Forest Land			1	68		**69**
Drainage					5	**5**
Total (Producers)	**35**	**9**	**20**	**71**	**5**	**140**

Table 4.3 indicated that in the case of forest land there was a total of 67 points selected from classified data out of which 65 points were found correct when compared with reference data and 2 points showed an error that belongs to barren/shrub/wasteland. Similarly, in the case of class agriculture land, there were a total of 41 points selected from classified data out of which 41 points were found correct when compared with reference data. In the case of class drainage, a total of 5 points were selected from classified data out of which all 5 points were found correct when compared with reference data.

Table 4.3: Error matrix table of LULC classification in the year 2013 using Landsat 8 in the Hamirpur block

	Agriculture Land	Barren/ Shrub/ Waste Land	Built-up Land	Forest Land	Drainage	Total (Users)
Agriculture Land	41					**41**
Barren/ Shrub/ Waste Land		13				**13**
Built-up Land		1	13			**14**
Forest Land		2		65		**67**
Drainage					5	**5**
Total (Producers)	**41**	**16**	**13**	**65**	**5**	**140**

Table 4.4 revealed that in the case of a class forest land there was a total of 63 points selected from classified data out of which 63 points were found correct when compared with reference data. Similarly, in the case of the class agriculture land, there was a total of 38 points selected from classified data out of which 38 points were found correct when compared with reference data. In the case of class drainage, there was a total of 5 points selected from classified data out of which all 5 points were found correct when compared with reference data.

Table 4.4: Error matrix table of LULC classification in the year 2021 using Sentinel 2 in the Hamirpur block

	Agriculture Land	Barren/ Shrub/ Waste Land	Built-up Land	Forest Land	Drainage	Total (Users)
Agriculture Land	38					**38**
Barren/ Shrub/ Waste Land		11				**11**
Built-up Land		1	22			**23**
Forest Land				63		**63**
Drainage					5	**5**
Total (Producers)	**38**	**12**	**22**	**63**	**5**	**140**

4.1.2.2 Producer and user accuracy for land use and land cover classifications

The producer, user and overall accuracy, as well as the kappa (K) coefficient, were computed using equations 3.1, 3.2, 3.3 and 3.4 for all the LULC classifications of Landsat 7 (2002), Landsat (2013) and Sentinel 2 (2021) and the derived values are shown in Tables 4.5, 4.6 and 4.7. In the case of LULC classification for the year 2002 using Landsat 7 satellite, it can be seen from Table 4.5 that producer’s accuracy was maximum in classes: agriculture land, barren/shrub/waste land and drainage as 100 percent and minimum in class forest land and built-up as 95 percent, while user’s accuracy was maximum in classes: built-up, drainage and barren/shrub/waste land as 100 percent and minimum in class agriculture and forest land as 92.11 percent and 98.55 percent respectively. The LULC for 2002 using Landsat 7 satellite showed that the overall accuracy was 97.86 percent with a Kappa coefficient of 0.95. In the case of LULC classification for the year 2013 using Landsat 8 satellite, table 4.6 indicated that producer accuracy was maximum in all classes except one class i.e., barren/shrub/waste land (81.25%) while user accuracy was maximum in classes: agriculture land, drainage and barren/shrub/waste land as 100 percent and minimum in class built-up as 92.86 percent and forest land 97.01 percent. The LULC for 2013 using Landsat 8 satellite showed that the overall accuracy was 98.57 percent with a Kappa coefficient of 0.94. Similarly, in the case of LULC classification for the year 2021 using Sentinel 2, it can be seen from Table 4.7 that producer’s accuracy was maximum in all classes except one class barren/shrub/wasteland 91.66 percent while the user accuracy was maximum in all classes except built-up land as 95.55 percent. The LULC for 2021 using Sentinel 2 satellite showed that the overall accuracy was 87.86 percent with a Kappa coefficient of 0.96. Faruque *et al*. (2022) found similar accuracy results in human-induced mangrove forests areas in Bangladesh

Table 4.5: Producer and user accuracy (%) of LULC in the year 2002 using Landsat 7 in the Hamirpur block

S. No.	LULC classes	Accuracy	
		Producer	User
1	Agriculture Land	100	92.11
2	Barren/ Shrub/ Waste Land	100	100.00
3	Built-up Land	95	100.00
4	Forest Land	95.77	98.55
5	Drainage	100	100.00
Overall Accuracy = 97.86			
Kappa Coefficient = 0.95			

Table 4.6: Producer and user accuracy (%) of LULC in the year 2013 using Landsat 8 in the Hamirpur block

S. No.	LULC classes	Accuracy	
		Producer	User
1	Agriculture Land	100	100.00
2	Barren/ Shrub/ Waste Land	81.25	100.00
3	Built-up Land	100	92.86
4	Forest Land	100	97.01
5	Drainage	100	100.00
Overall Accuracy = 98.57			
Kappa Coefficient = 0.94			

Table 4.7: Producer and user accuracy (%) of LULC in the year 2021 using Sentinel 2 in the Hamirpur block

S. No.	LULC classes	Accuracy	
		Producer	User
1	Agriculture Land	100	100.00
2	Barren/ Shrub/ Waste Land	91.66	100.00
3	Built-up Land	100	95.65
4	Forest Land	100	100.00
5	Drainage	100	100.00
Overall Accuracy = 87.86			
Kappa Coefficient = 0.98			

4.1.3 Land use land cover change detection in the Hamirpur block (2002-21)

Tables 4.8, 4.9 and 4.10 exhibit the change outcomes where it is clear that there have been significant positive (e.g., an increase in built-up land area) and negative (e.g., a decrease in drainage area) changes in various land use and land cover classifications from 2002 to 2021. According to the findings, the area under agriculture and barren/shrub/waste land has decreased in 2021, whereas the area under built-up and forest land has increased.

Table 4.8: Temporal distribution of the area under different land use land cover classes in the Hamirpur block (2002-2013)

LULC Class	Year		Change	
	2002	2013	km^2	%
Agriculture Land	28.87	28.81	-0.06	-0.21
Barren/Shrub/waste Land	9.37	9.25	-0.12	-1.30
Built-UP land	8.45	8.8	0.35	3.98
Drainage	0.45	0.39	-0.06	-15.38
Forest Land	61.49	61.38	-0.11	-0.18

The change in the Hamirpur block varied significantly from the year 2002 to 2013. During the last 11 years from 2002 to 2013, the built-up area has increased from 8.45 km^2 in 2013 to 8.80 km^2 in 2002 which accounts for 3.98 percent of the total study area. A significant decrease in the area was observed in other classes viz. agriculture land, barren/shrub/waste land, drainage and forest land. Agriculture land has decreased from 28.87 km^2 in the year 2002 to 28.81 km^2 in 2013 which accounts for 0.21 percent. The barren/shrub/waste land decreased from 9.37 km^2 in the year 2002 to 9.25 km^2 in the year 2013. This decrease in barren/shrub/waste land accounts for 1.31 percent. The overall loss of drainage land was found to be 15.39 percent which was 0.45 km^2 in the year 2002 and 0.39 km^2 in the year 2013. The forest land of the study area slightly decreased from 61.49 km^2 in the year 2002 to 61.38 km^2 in the year 2013 which accounts for 0.18 percent. Mishra *et al*. (2019) noted the major changes in the built-up area along the periphery of Gangtok city due to urban sprawl and expansion of the town area.

Table 4.9: Land use land cover changes in the Hamirpur block (2013-2021)

LULC Class	**Year**		**Change**	
	2013	**2021**	**km^2**	**%**
Agriculture Land	28.81	27.52	-1.29	-4.69
Barren/Shrub/Waste Land	9.25	7.70	-1.55	-20.13
Built-up Land	8.80	10.84	2.04	18.82
Drainage	0.39	0.36	-0.03	-8.33
Forest Land	61.38	62.20	0.82	1.32

During the last 8 years from 2013 to 2021, a drastic change was observed in the built-up area which increased from 8.80 km^2 in the year 2013 to 10.84 km^2 in the year 2021 which accounts for 18.82 percent of the total study area while forest land increased from 61.38 km^2 in the year 2013 to 62.20 km^2 in the year 2021 accounts for 1.32 percent. A significant decrease in the area was observed in other classes viz. agriculture land, barren/shrub/waste land and drainage. The agriculture land has decreased from 28.81 km^2 in the year 2013 to 27.52 km^2 in the year 2021 which accounts for 4.69 per cent. The extreme change in barren/shrub/waste land was found to be 20.13 percent which was 9.25 km^2 in the year 2013 and 7.70 km^2 in the year 2021. The drainage decreased from 0.39 km^2 in the year 2013 to 0.36 km^2 in the year 2021 which accounts for 8.33 percent. Somvanshi *et al*. (2018) noted the major changes in the built-up and drainage areas in Gautam Budh Nagar, Uttar Pradesh due to urban sprawl and expansion of the town area.

Table 4.10: Land use land cover changes in the Hamirpur block (2002-2021)

LULC Class	Year		Change	
	2002	2021	km^2	%
Agriculture Land	28.87	27.52	-1.35	-4.91
Barren/Shrub/Waste Land	9.37	7.7	-1.67	-21.69
Built-up Land	8.45	10.84	2.39	22.05
Drainage	0.45	0.36	-0.09	-25.00
Forest Land	61.49	62.2	0.71	1.14

The data depicted in table 4.4 evinced the overall change in area from the years 2002 to 2021. During the last two decades, the overall increase in the built-up area and forest land was observed while a significant decrease in agriculture land, barren/shrub/waste land and drainage. The built-up area which increased from 8.45 km^2 in the year 2013 to 10.84 km^2 in the year 2021 accounts for 22.06 percent of the total study area while forest land increased from 61.49 km^2 in the year 2002 to 62.20 km^2 in the year 2021 accounts for 1.1498 percent. A significant decrease in the area was observed in other classes i.e., agriculture land, barren/shrub/waste land and drainage. The agriculture land decreased from 28.87 km^2 in the year 2002 to 27.52 km^2 in the year 2021 which accounts for 4.91 percent. The extreme change in barren/shrub/waste land was found to be 21.7 percent which was 9.37 km^2 in the year 2002 and 7.70 km^2 in the year 2021. The drainage land decreased from 0.45 km^2 in the year 2002 to 0.36 km^2 in the year 2021 which accounts for 25.00 percent. Rawat and Kumar (2015) found similar results in the Almora district of Uttarakhand due to mainly expansion of the Almora town area during the last two decades.

4.1.4 LULC change matrix from 2002 to 2021

Data pertaining to change in matrix area from 2002 to 2021 are presented in Table 4.11. Forest and built-up areas showed an increasing trend during this time period, in contrast, to a decrease in the change rate of other land use classes. About 2.40 km^2 area was converted from agriculture land (1.24 km^2), barren/shrub/waste land (0.31 km^2), drainage land (0.01 km^2) and forest land (0.83 km^2) into built-up land due to the expansion of the study area during the last two decades. Similar results were obtained by Rawat and Kumar, 2015. A minute growth in forest land (0.7 km^2) was seen due to changes in agriculture land (0.31 km^2), barren/shrub/waste land (1.49 km^2) and drainage land (0.01 km^2) due to afforestation and natural regeneration. Similar findings were obtained by Mishra *et al.* 2019.

About 1.4 km^2 of agriculture land, 1.7 km^2 ^{b}arren/shrub/waste land and 0.1km^2 drainage land were reduced during the last two decades.

Table 4.11: Transformation matrix of different land use land cover classes (km^2) from 2002 to 2021

LULC Classes		2021					
		Agriculture Land	**Barren/Shrub /Waste land**	**Built-up Land**	**Drainage**	**Forest Land**	**Grand Total**
2002	Agriculture Land	**27.21**	0.1	1.24		0.31	**28.9**
	Barren/Shrub/ Waste land	0.07	**7.5**	0.31		1.49	**9.4**
	Built-up Land			**8.45**			**8.4**
	Drainage	0.02	0.07	0.01	**0.35**	0.01	**0.5**
	Forest Land	0.22		0.83		**60.44**	**61.5**
	Grand Total	**27.5**	**7.7**	**10.8**	**0.4**	**62.2**	**108.6**

4.1.5 Land use land cover transformation in the Hamirpur block (2002-2021)

Fig 4.11 indicated the major areas where alterations have been identified and classified between 2002 and 2021 where the total land cover change in the Hamirpur block was 4.06 km^2 out of which an increase of 2.39 km^2 (22.05%) was in built-up land and a decrease of 0.09 km^2 (25.00%) was in drainage. Various developmental activities have taken place near the city 'Hamirpur' over a period of time. The existing educational institutes have been expanded while several new NIT, COHF, HM and HPTU, have been established which has led to the overall development of the region, especially in the vicinity of the existing as well as the newly established educational institutes. Consequently, there has been an increase in road connectivity in the region to facilitate developmental activities and provide more accessibility to the remote and so far not so well connected areas of the state. The Mahatma Gandhi National Rural Employment Guarantee Act and several other government schemes have also contributed significantly to the development of the region and provided employment opportunities to the local people who have been involved in the building of roads, bridges, watersheds, check dams, etc. All these factors have resulted in the conversion of the barren/shrub/waste land into built-up land in the Hamirpur block. A look at the data concerning the same reveals that approximately 2.39 km^2 of combined agriculture land, barren/shrub/waste land forest land area in Hamirpur has been converted into built-up land. In addition to these, the state government has implemented afforestation policies which have led to an increase in the overall forest cover of the state (0.71 km^2).

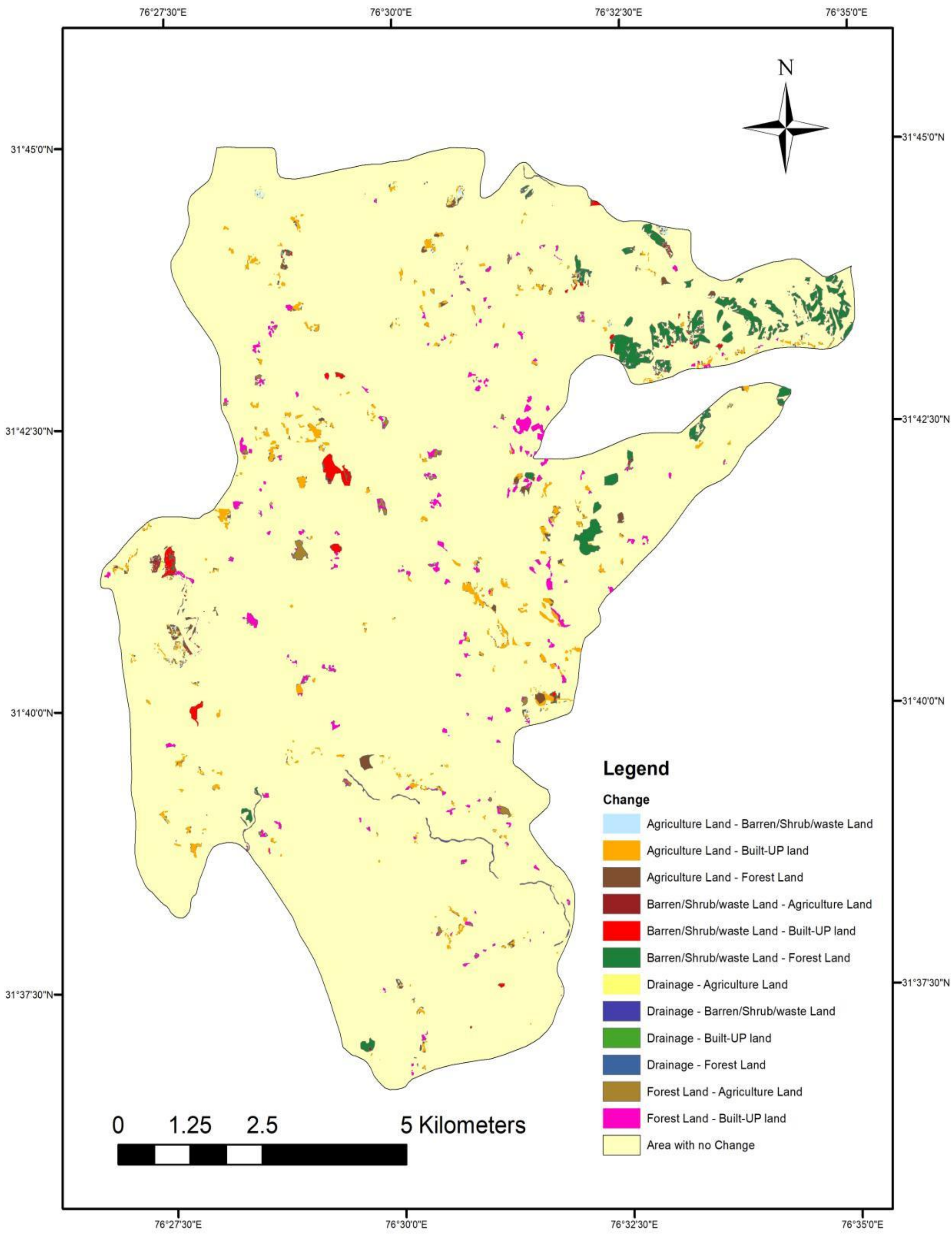

Fig. 4.11: Land use land cover transformation from 2002 to 2021

4.2 TO INVESTIGATE DRIVERS FOR LAND USE LAND COVER CHANGES

4.2.1 Socioeconomic and demographic characteristics of sampled households

The socioeconomic and demographic attributes of the sampled households were analysed to investigate drivers for land use land cover changes. The results revealed that the age of the respondents ranged from 20 to 70 years, with an average of 39.2 years. About 93.3 percent of the interviewees lived in the study area throughout the study period (2002-2021). The majorities (54%) of the respondents were married, about 55 percent of the sampled households were female and 71.7 percent of the households were male-headed. The results also indicated that household size ranged from one person to 10 people, with an average of 4.5 persons. With respect to their education status, 77.8 percent of the respondents were literate (64.3% and 13.5% attended primary and secondary school, respectively) and 22.2 percent had never attended school. Approximately 95 percent of the sampled households were engaged in farming activities and a small portion of the respondent, 5 percent were involved in non-farm activities, such as businesses and professional work. The mean household income of the respondents was 2.50 lakh per year. Government jobs and private jobs were ranked as the most important source of income in the Hamirpur block. Income from self-employment opportunities, such as businesses were ranked second.

4.2.2. Local-community perceptions on the impact of LULC changes

Significant differences were found among the interviewed households in perceptions regarding LULC changes. Respondents perceived that LULC changes have a negative impact on agriculture production in the Hamirpur block. Results showed that 60 percent of local communities perceived a positive impact of LULC changes on livelihood and employment generation as shown in Fig 4.12. Almost half of the respondents (54%) perceived a negative impact for the next 10 years. 43 percent of respondents perceived a positive impact on rural areas. Key informants from different institutions and Focus Group Discussions (FGDs) also correctly perceived that the Hamirpur block has changed drastically from the year 2002 to 2021.

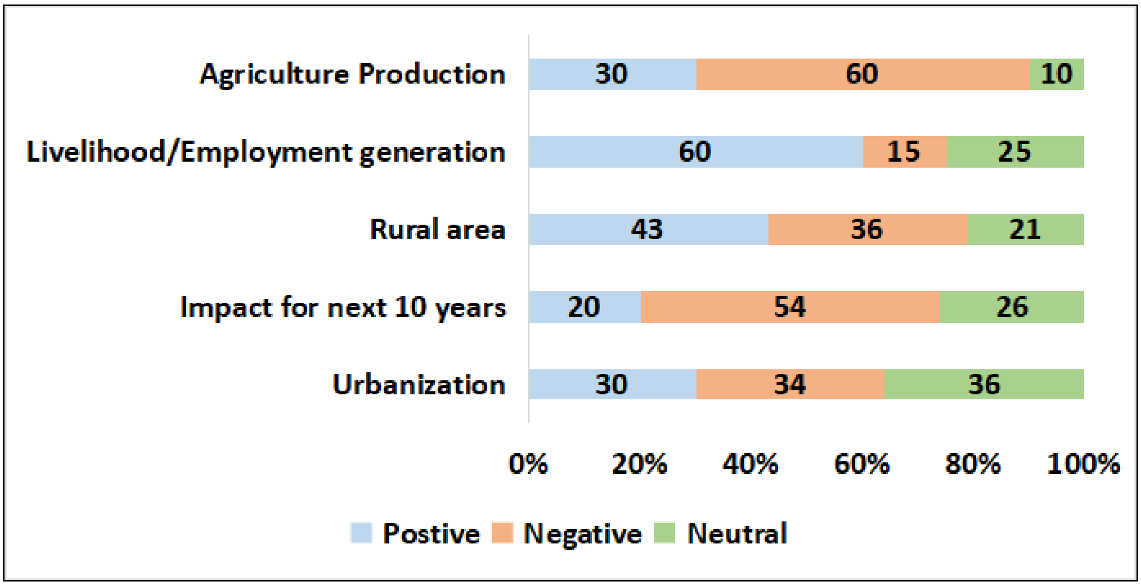

Fig 4.12: People's perception of the impact of land use land cover changes in the Hamirpur block

4.2.3 Ranking of drivers of LULC changes

The respondents identified 13 factors (6 proximate drivers and 7 underlying drivers) as important drivers contributing to LULC changes in the Hamirpur block, especially during the period under review (Tables 4.12 and 4.13).

Population increase, urbanization, adoption of new technology, climate change, accessibility to the public distribution system (PDS) and increase in income were the top six ranked proximate drivers for LULC changes in the study area, with population increase and urbanization ranked first and second, respectively (Table 4.12). Similar results were also revealed during key informant interviews and FGDs in which population increase and urbanization were identified as the main causes of LULC in the Hamirpur block. This finding is in line with the findings of Hailu *et al.* (2020), Long *et al.* (2007) and Dibaba *et al.* (2020) who reported that population increase and urbanization are major drivers of LULC dynamics.

Table 4.12: Major proximate drivers of land use land cover changes in the Hamirpur block

LULC Proximate drivers	**No. of respondents/Rank**			**Weight**	**Index**	**Rank**
	3	2	1			
Population Increase	90	5	5	285	1.00	**1**
Urbanization	88	5	7	281	0.98	**2**
Adoption of new technology	84	4	12	272	0.95	**3**
Climate Change	77	10	13	264	0.92	**4**
Accessibility to PDS	67	9	24	243	0.85	**5**
Increase in income	52	21	27	225	0.78	**6**
				1570		

With respect to underlying causes of LULC drivers in the study area, the interviewed households identified business for local shops or traders as the most important underlying driver contributing to LULC followed by economic benefits, change in the area, water availability for all uses and employment (Table 4.13). With regard to business for local shops or traders, respondents (71%) perceived that the population had increased over the studied period. FGDs and key informant interviews indicated a change in the area, as the main underlying cause of LULC changes. Betru *et al.* (2009) who reported the economic benefit and market demand as major underlying drivers of LULC dynamics.

Table 4.13: Major underlying drivers of land use land cover changes in the Hamirpur block

LULC underlying drivers	No. of respondents per Rank			Weight	Index	Rank
	3	2	1			
Business for local shops or traders	71	21	8	263	0.92	**1**
Economic benefits	68	21	11	257	0.90	**2**
Change in Area	73	8	19	254	0.89	**3**
Water availability for all uses	60	33	7	253	0.88	**4**
Employment	59	29	12	247	0.86	**5**
People living in a smaller town	59	22	19	240	0.84	**6**
Native vegetation	38	41	21	217	0.76	**7**
				1731		

Chapter-5

SUMMARY AND CONCLUSIONS

Land use land cover (LULC) studies have long been recognized as the greatest planning unit for landscape planning resource management. As a result, evaluating land use land cover patterns is important for change detection and assessment. Remote sensing and geographic information systems (GIS) have shown to be quite valuable in assessing and interpreting LULC changes. Remote sensing and image processing advancements provide great opportunities to perceive changes in LULC more accurately over progressively large areas while reducing cost and time. Multi-temporal high-resolution satellite data from several years are being used as the source of information and this information is used to determine changes in the LULC pattern. There was limited information available on the temporal LULC change of the Hamirpur block in the Hamirpur district of Himachal Pradesh, therefore the present study was conducted to meet the following objectives:

1. To estimate changes in land cover using remote sensing and GIS techniques.
2. To investigate drivers for land use land cover changes.

The Hamirpur block was classified using multi-temporal satellite images from Landsat 7 (the year 2002), Landsat 8 (the year 2013) and Sentinel 2 (the year 2021). The maximum likelihood supervised classification technique was used in ArcGIS software (Version 10.8) to classify land use and land cover maps for all three satellite images. Other instruments used in this study were a digital camera, GPS and Google Earth. The Hamirpur block was divided into five LULC classes: agriculture land, built-up land, forest land, barren/shrub/waste land and drainage. From the years 2002 to 2021, the same classification technique was used to create LULC classification maps for all three satellite images. A point feature shape file was built in Arc GIS software by choosing 140 points that corresponded to distinct feature classes in the study area. To examine the accuracy of LULC maps of Landsat 7 in the year 2002 and Landsat 8 in the year 2013, 140 randomly selected sites were overlaid on Google Earth. The ground truthing of the year 2021 was also checked by physically visiting the 140 sites. Error matrix tables containing producer, user and overall accuracy, as well as the Kappa coefficient, were created. Overlay analysis employing satellite imagery was used to examine LULC trends over a decade, from the years 2002 to 2021. For each year, the areas of all main classes were determined and a change matrix table was created. Driver's analysis was done by using indexing of responses from 100 households in the Hamirpur block. Their responses were analyzed using the ranking formula. Major proximate and underlying drivers were identified for LULC change. Based on the present study "Studies on land use land cover change in Hamirpur district of Himachal Pradesh" the results are summarized in this section.

5.1. SUMMARY

- LULC classification in the year 2002 using Landsat 7 satellite imagery showed an area under agriculture land as 28.87 km^2, built-up (8.45 km^2), forest land (61.49 km^2), drainage (0.45 km^2) and barren/shrub/waste land as 9.37 km^2.
- LULC classification in the year 2013 using Landsat 8 satellite imagery showed an area under agriculture land as 28.81 km^2, built-up (8.80 km^2), forest land (61.38 km^2), drainage (0.39 km^2) and barren/shrub/waste land as 9.25 km^2.
- LULC classification in the year 2013 using Landsat 8 satellite imagery showed an area under agriculture land as 28.81 km^2, built-up (8.80 km^2), forest land (61.38 km^2), drainage (0.39 km^2) and barren/shrub/waste land as (9.25 km^2).
- Overall accuracy for LULC classification for Landsat 7 in the year 2002, Landsat 8 in the year 2013 and Sentinel 2 in the year 2021 were 98.86 percent, 98.5 percent and 87.86 percent with a Kappa coefficient of 0.95, 0.94 and 0.98 respectively.
- LULC change analysis (2002-21) showed that the total area under agriculture land, drainage and barren/shrub/waste land decreased by (1.35 km^2), (0.09 km^2) and (1.67 km^2) respectively which was 4.91 percent, 21.69 percent and 25.00 percent respectively.
- The area under built-up land and forest land increased by (2.39 km^2) and (0.71 km^2) respectively from 2002-21 which was 22.05 percent and 1.14 percent respectively.
- The major proximate driver of LULC changes was population increase, urbanization, adoption of new technology, climate change, availability of public distribution system (PDS) and increase in income with the index value of 1, 0.98, 0.95, 0.92, 0.85, 0.78.
- The major underlying driver of LULC change was business for local shops or traders. The index value of the business for local shops or traders, economic benefits, changes in the area, water availability for all uses, employment of people living in a smaller

town and native vegetation with the index value of 0.92, 0.90, 0.89, 0.88, 0.86, 0.84, 0.76 respectively.

5.2. CONCLUSION

From the study, it is concluded that the area under built-up land in Hamirpur block increased by 22.05 percent from the years 2002 to 2021 which may be due to rapid urbanization taking place in the city area and an increase in forest land by 1.14 percent was observed due to afforestation policies established by Government of Himachal Pradesh from April 2005. A decrease in drainage by 25 percent, barren by 21.69 percent and agriculture by 4.91 percent.

Rapid urbanization has increased business opportunities for local shopkeepers and improved their livelihood. The establishment of education institute activities has resulted in improving the education level of the district. Government policies such as National Rural Livelihood Mission and Mahatma Gandhi National Rural Employment Guarantee Act and various other schemes have helped in the employment generation of people living in smaller towns.

5.3. SUGGESTION

Advancement in technology and further, this type of study would help in the development, planning and conservation of natural resources on a land use basis. The study showed that continuous monitoring using Remote Sensing may serve as a vital tool for the assessment of temporal changes in LULC.

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APPENDIX-I

DEPARTMENT OF ENVIRONMENTAL SCIENCE
DR. Y. S. PARMAR UNIVERSITY OF HORTICULTURE AND FORESTRY
NAUNI, SOLAN, HIMACHAL PRADESH

TOPIC: "People perception for LULC drivers"

Questionnaire No.	
Date	
District	
Block	
Panchayat	
Village	
Name of the respondent	

1. Gender: [ ] Male [ ] Female
2. Status in the household (HH): [ ] HH head [ ] House wife [ ] others (specify) ______
3. Age ________________Years or Year of Birth ______________
4. Marital status: [ ] Single [ ] Married [ ] Widowed [ ] Separated/Divorced
5. Farming experience:
   a) <10 yrs ( ) b) 10- 30 yrs ( ) c) >30 yrs ( )
6. How long have you lived in this region?
   a) <5 years ( ) b) 5-10 years ( ) c) 10-20 years ( ) d) >20 ( )

A) SOCIOECONOMIC STRUCTURE OF HOUSEHOLDS

1. PHYSICAL ASSETS

1.1 Type of house of the respondent

S No.	Type of house	Present	10 years ago	20 years ago
1.	**Traditional grass thatched house/mud walled house**			
2.	**Iron-sheet/ slate roofed with mud walls**			
3.	**Semi permanent house (Iron roofed with mud walls but plastered)**			
4.	**Permanent house (bricks/stones/tiles/ iron-roofed)**			

1.2 Type of family:

	Present	10 years ago	20 years ago
Nuclear/ Joint			
Household Size (Total persons)			

1.2.1 Highest level of education of the HH head [ ] None [ ] Primary [ ] High School
[ ] Intermediate [ ] Graduate [ ] Post Graduate

1.2.2 Give details on educational levels of HH members.

Education Level	Number in the category	Occupation	
		Main	Subsidiary
None			
Primary			
High School			
Intermediate			
Graduate			
Post Graduate			

1.2 What is the primary source of income/livelihood of your household?

	Agriculture	Livestock	Tourism / Hotel	Nonfarm income	Business	Govt. Job
Present						
10 years ago						
20 years ago						

B) VULNERABILITY STUDY

1.1 PERCEPTION ON impact of LAND USE CHANGE IN LAST 10 YEARS

(Exposure)

S No.		Positive	Neutral	Negative
1.1	**Agriculture Production**			
1.2	**Livelihood and Employement generation**			
1.3	**Rural Area**			
1.4	**Impact for Next 10 year**			
1.5	**Urbanization**			

1.2 REASON FOR LAND USE CHANGE

Reasons	
Climate change	
Increase revenue/returns	
Adoption of new technology	
Accessibility to PDS	
Urbanization	
Population	

1.3 REASON FOR LAND USE CHANGE

Reasons	
Business for local shops or traders	
Economic benefits	
Change in Area	
Water availability for all uses	
Employment	
People living in smaller town	

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ENVIRONMENTAL SCIENCE

Title of Thesis	:	**Studies on land use land cover change in Hamirpur district of Himachal Pradesh**
Name of the Student	:	Rajneesh Jaswal
Admission Number	:	F-2020-20-M
Major Advisor	:	Dr R K Aggarwal
Major Field	:	Forestry
Minor Field(s)	:	Environment Management
Degree Awarded	:	Master of Science in Forestry
Year of Award of Degree	:	2022
No. of pages in Thesis	:	59 +iii
No. of words in Abstract	:	421

ABSTRACT

The present study entitled "**Studies on land use land cover change in Hamirpur district of Himachal Pradesh"** was carried out in Hamirpur district, Himachal Pradesh with the aim to estimate changes in land use land cover using remote sensing and GIS techniques and investigating drivers for LULC. The study was carried out by selecting the Hamirpur block of the Hamirpur district. High-resolution satellite data of Landsat 7 for the year 2002, Landsat 8 for the years 2013 and Sentinel 2 for the year 2021 were analyzed for LULC mapping using a supervised classification technique. Results were verified through 1409 ground truthing points and accuracy assessment. To investigate drivers for LULC changes, data was collected by a detailed questionnaire-based survey. The study area was classified into five LULC classes: agriculture land, barren/shrub/waste land, built-up land, forest land and drainage and it was found that the maximum area in 2002 was covered by forest land (56.60%) followed by agriculture land (26.57%), while the minimum area was covered by drainage (0.41%) out of the total area of 108.63 km^2. while the maximum area in 2021 was covered by forest land (57.25%) followed by agriculture land (25.33%), while the minimum area was covered by drainage (0.33%) out of the total area of 108.63 km^2. Overlay analysis of Landsat 7 of the year 2002 over Sentinel 2 of the year 2021 was done to analyze changes. The result also showed that area under agriculture land, barren/shrub/waste land and drainage decreased by 4.91 percent, 21.69 percent and 25.00 percent respectively, while built-up and forest areas increased by 22.05 percent and 1.14 percent respectively. The overall accuracy for classified imageries i.e., Landsat 7 (the year 2002), Landsat 8 (the year 2013) and Sentinel 2 (the year 2021) was obtained as 97.86 percent, 98.57 percent and 87.86 percent with Kappa coefficients of 0.95, 0.94 and 0.98 respectively. As per people's perception increasing population and urbanization emerged as the major proximate drivers and business for local shops or traders and economic benefits emerged as the major underlying drivers for the land use changes as perceived by 60 percent of the respondents see the positive impact of change dynamics in case of livelihood and employment generation. The study revealed that various developmental activities have taken place near the city 'Hamirpur' over a period of time and all these factors have resulted in the conversion of the barren/shrub/waste land into built-up land in the Hamirpur block. However, afforestation policies have led to an increase in the overall forest cover of the state.

Signature of Major Advisor **Signature of the student**

Countersigned

Professor and Head
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BRIEF BIO-DATA

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Date of Birth : 12-06-1997

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Educational qualifications:

Standard/Degree	**Name of Institute**	**Board/ University**	**Year of passing**	**Percentage received (%) or OGPA**
10	Gurukul Public Sen. Sec. School Hamirpur	HPBOSE	2012	83
12	Gurukul Public Sen. Sec. School Hamirpur	HPBOSE	2014	78.60
B.Sc (Forestry)	College of Horticulture and Forestry, Neri, Hamirpur	Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Solan	2019	71.1

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Any other Information : NO

(Rajneesh Jaswal)