Monitoring of Land Use and Land Cover Changes Using Remote Sensing and Geographic Information System

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Abstract

The Land use Land cover (LULC) change due to rapidly growing population is a common feature of urban area. This research aims to detect the variations in LULC from 1991-2017 of Malakand Division in the Khyber Pakhtunkhwa province of Pakistan. The study relies on secondary dataset downloaded from United State Geological Survey (1991, 2001, 2011 & 2017 imageries) and UN OCHA website. Maximum Likelihood technique under supervised image classification was adopted to analyze the LULC changes in between 1991 and 2017. Total six land use classes were generated including agriculture built-up area, vegetation cover, water bodies, snow cover and barren land. The results from 1991 to 2017 show a substantial reduction in snow cover and barren land which is consequence of climate change. Whereas the areas underbuilt-up, vegetation cover, and water bodies were increased. The vegetation cover increased from 28.89% to 44.67% while barren land decreased from 45.68% to 40.29 of the total area. Furthermore, the built-up area increased from 1.02% to 6.2%, whereas water covers increased from 0.63% (1991) up to 0.86% (2017) of the total area. The study concludes that there is immense need of planning to preserve natural habitat for sustainable development in the area.

1. Introduction

The change in land use land cover (LULC) has a key role in reduction of biodiversity and ultimately affects the climate in an area at both local as well as regional level(Yohannes et al., 2020). The LULC is determined mainly by analyzing the ecological situation, geological structure, altitudes, and slope accompanied by socio-economic, technological, and institutional set-up, which have greater influences on land-use pattern in an area (Mishra et al., 2019). The change in landscape can play an important role in changing environment at local as well as global scale(Rudel, 2009). Moreover, from last few decades, the men are disturbing the natural environment rapidly to fulfil their needs for resources (Berihun et al., 2019). Detecting the change in LULC pattern is a significant tool to detect the human association with geographical dynamics(Liping et al., 2018).

The rapidly growing human activities including population growth, industrialization and urbanization provoking large scale changes in LULC pattern around the Globe. (Mishra et al., 2019). In particular, with reference to developing countries, the rapid changes in LULC pattern is causing reduction in key resources such as vegetation cover, water bodies and soil (Cheruto et al., 2016; Twisa & Buchroithner, 2019). Moreover, these anthropogenic interruptions play vital role in changing the climate and triggering disasters by exposing slopes to precipitation and increasing water runoff(Haindongo et al., 2020). As the water runoff increases along slope, the erosive power of water also increases. Thus, the bare slopes work as agents to trigger disasters like floods and mass movement(Bibi et al., 2019; Bibi et al., 2017). An important implication of transformation in land-cover is that it has drastic impact on energy fluxes, bio-geochemical cycles, climate, and human as well as animals livelihood (Mishra et al., 2019). LULC is a significant element to understand the association between human activities and environment, therefore, monitoring and detecting of LULC changes are essential steps towards a sustainable environment (SENSING, 2014). Then there is an immense need of LULC information to maintain the environment along with living conditions (Chowdhury et al., 2020). The change detection in detection of land use and land cover (LULC) have a vital significance in the process of global change detection analysis at various spatio-temporal scales (Islam et al., 2018). These analyses involve the computation of multi-temporal datasets under a framework to collect the information of thematic change. This process could lead to understand the basic mechanism engaged in upbringing of LULC changes (Mishra et al., 2019). To have an understanding with this mechanism is essential for better management of resource and decision making process (Butt et al., 2015). Additionally, these analysis offers a valued tool to boost the efficiency of LULC, and to reduce the adverse societal and environmental impacts linked to LULC(SENSING, 2014).

The Geographic Information System (GIS) along with Remote Sensing technology are significant tools to monitor the changes of LULC (Rai & Sweta). Specifically the high temporal resolution of Remote Sensing data (4D) boost the analysis capacity of GIS to find not only the rate of change but could also help out to identify the causative factors of change (Ramachandra & Kumar, 2004). In general the Landsat images have served enormously to classify various types of landscapes at regional scale (Butt et al., 2015). Moreover, to detect the change it is crucial to involve the multi-temporal dataset obtained from Remote Sensing to examine the past and find the changes related to LULC properties (Butt et al., 2015). Thus, the importance of remotely sensed spatio-temporal data cannot be denied in patterns mapping of LULC changes over time. In addition, it is possible to quantify such changes with the help of GIS techniques even with the dataset having multiple resolutions/ scales(SENSING, 2014). Furthermore, the combined use of Remote Sensing and GIS technologies make the process of detecting LULC changes simple and faster as compared to customary surveying and mapping methods (Da Costa & Cintra, 1999; SENSING, 2014). Additionally, it is only possible due to remote sensing data to observe the variations of LULC in short time, at less cost and greater accuracy.

In recent years, numerous techniques have been developed to detect the change using remotely sensed data for example supervised classification, clustering or unsupervised classification, Hybrid classification PCA, neural network and Fuzzy classification etc. (Butt et al., 2015). There are various methods of supervised classification applied extensively to compute LULC changes around the globe. However, this method of classification is greatly dependent on expert knowledge and exposure to the area under observation (Butt et al., 2015). Thus, this method works by using signature and digital numbers (DN) of each individual pixel in the image and convert them in to radiance values (Butt et al., 2015).

Pakistan, like other developing countries, is facing a rapid growth in country population and urban sprawl in past few years and this trend is reported to continue in future as well. According to the reports of the World Bank, approximately one half of the overall population of Pakistan will be urban by 2015 (Dawn, 2007). High population growth rates and lack of employment opportunities in rural areas have resulted in urban sprawl and change in LULC pattern such as agricultural land into built-up area and forests into agricultural or built-up land. As a consequence, Pakistan faced a widespread land use change in past few years due to advancement in educational level, social life and urbanization. The percentage of the total population resident in urban areas of Pakistan is showing a rapid increase which was around 17.8% in 1951, 32.5% in 1998 and increased up to 37% in 2011 (GoP, 2011). However, a negative consequence of this change in the land use pattern comes forward in form of food shortage, lack of pure drinking water, low ground water table and poor drainage system which sometimes leads to other related problems such as floods in urban area when it rains heavily.

Khyber Pakhtunkhwa (KP), a province of Pakistan is facing the threats of urban sprawl and rapidly growing population which have ultimately a great impact on land use pattern change (Anderson, 1976). Therefore, the present study aims to identify and analyze changes in LULC in Malakand Division, KP, Pakistan because there has been no systematic and detailed study about LULC in Malakand Division so far (please see Figs. 1 and 2). A few studies on LULC have been conducted in India (see for examples (Kaliraj et al., 2017; Lakshmi & Yarrakula, 2016; Rawat & Kumar, 2015; Salghuna et al., 2018; SENSING, 2014; Thakkar et al., 2017)), Iran (see for example (Halimi et al., 2018)), Bangladesh (see for example (Islam et al., 2018)), China (see for example (Liping et al., 2018)), Egypt (see for example (Abd El-Kawy et al., 2011; Halmy et al., 2015)). In Pakistan, however, there have been only few studies about LULC change detection (Butt et al., 2015) conducted land use change mapping and analysis using remote sensing and GIS of Simply watershed, Islamabad, Pakistan. In order to fill this gap in the literature, this study aims to identify and analyze changes in LULC from 1991–2017 in Malakand Division in the Khyber Pakhtunkhwa province of Pakistan.

2. Study Area

Malakand Division is an administrative unit of Khyber Pakhtunkhwa province; Pakistan situated at 34° 33' 56" North and 71° 55' 52" East**.** The total covered area of the division is 32007 Sq.kms with 8.7 million population. Malakand Division is one of the largest divisions of KP and join its boundaries with Gilgit Baltistan in north, Afghanistan in northwest, Hazara Divisions in east and Mardan in south. The area is characterized with many attractive features such as snow-covered peaks, whistling rivers, fruit orchards, and lush green pastures. The beauty of the area is a great source of attraction for national and international tourists. The areas also have historical importance being center of ancient Ghandhara and Aryan civilizations.

The area lays under subtropical dry climatic zone of Hindukush Range having one of the largest coniferous and broadleaved forest in Pakistan. The minimum elevation of the study area is approximately 700 m and extends up to 7708 m with rough terrain, medium to steep slopes, plains, and rivers (Hazrat et al., 2008; Khan et al., 2013). Malakand division was once characterized with huge forests and shrubs having different tree species but in last few decades most of the vegetation cover has been destroyed due to extensive human interruption.

3. Methodology

3.1. Data Collection

Various datasets (vector and raster) were collected to conduct the current study (Fig. 3) including satellite imageries and other relevant data to investigate the LULC changes in area under study over 27 years from 1991 till 2017. A total of four Landsat imageries were acquired for the years 1991, 2001, 2011 & 2017 (Table 1 for detail). The images were downloaded from United State Geological Survey (USGS). However, the district boundaries were clipped from all Pakistan district shape file downloaded from the OCHA website (https://data.humdata.org/organization/ocha-pakistan).

Table 1
Details of the satellite imageries used for image analysis.

Platform/ Sensor	Scenes (Path/Row)	Image Date	Scene ID#	Number of Bands	Spatial Resolution
LANDSAT_5	150/035, 150/036, 151/035, 151/036,	1991-11-05, 1991-11-21, 1991-06-05, 1991-10-27	TM	7	30m
LANDSAT_7	150/035, 150/036, 151/035, 151/036,	2001-10-07 2001-10-07 2001-09-28 2001-09-28	ETM	8	30m
LANDSAT_5	150/035, 150/036, 151/035, 151/036,	2011-11-12 2011-11-12 2011-10-02 2011-10-02	TM	7	30m
LANDSAT_8	150/035, 150/036, 151/035, 151/036,	2017-09-09 2017-10-27 2017-10-18 2017-10-02	OLI_TIRS	11	30m

3.2. Image *Classification*

The processing of satellite images was done in ArcMap 10.2.1 for all images. Classification is a technique in GIS for the comparative analysis to detect the changes of various types of land uses in the given period. There are three type of classification techniques a) supervised, b) unsupervised and c) object-based classification. In most of the studies supervised and unsupervised classification is used because object-based analysis requires the data of high spatial resolution. In this study, images have been classified by supervised classification using likelihood classifier to detect the change in the land use pattern from 1991 to 2017 in the study area.

3.3. *Supervised* Classification

Supervised classification method has been applied to identify the LULC changes within the given time span. Maximum Likelihood techniques in ArcGIS 10.2 have been used for classification of the images of 1991 to 2017. A maximum likelihood classifier was used to perform supervised classification. While working the classifier assumes that a) there is normal distribution of a sample class and b) this classifier considers characteristics, covariance matrix and mean vector for each individual class. Moreover, based on these characteristics of cell value the probability is calculated for each individual class the membership of each individual cell to a particular class is determined. The following algorithm has been used in this study. The steps followed for the data processing are mentioned in Fig. 3.

3.4. Post-*processing*

Subsequently, after image Pre-processing and classification, the resulting images were divided in to different LULC classes. Moreover, the area of each individual LULC class was computed from resultant images and a change detection map was developed for the period of 1991–2017.In current study a total of six categories of land uses were generated including agricultural area, water bodies, built-up area, vegetation cover, snow cover and barren land (detail is mentioned in Table 2).

Table 2
Land cover classification scheme used in this study

S. No	Land use Land Cover Classes	Description
1	Built-up Area	commercial, Residential, road network and industrial
2	Vegetation Cover	All type of vegetation including forest
3	Water Bodies	Area covered by water bodies
4	Snow	Area covered by snow
5	Barren Land	All type of barren land

4. Results

The results of current study revealed that the area under built-up class in Malakand Division was 12919.81 hectares (0.99%) in 1991 (please see Fig. 4), the water bodies and barren land area was 8273.79 hectares and 590879.28 hectares respectively; area under vegetation cover was 373748.97 hectares and 307645.21 (23.78%) was under snow cover in 1991. In 2001, the built-up area in Malakand Division was 27304.41 hectares (2.11%), vegetation covered 413206.93 hectares (29.83%), water was present on 6351.49 hectares (0.49%), Snow covered a total area of 96735.83 hectares (7.47%) and the barren land was 749883.14 hectares (57.97%) (Please see Figs. 5).

The analysis revealed that in 2011 the built-up area spanned on 54351.96 hectares, and vegetation covered 475458.5 hectares. Water spanned on 7751.6 hectares, snow covered 29893.35 hectares and barren land stretched on 725952.46 (please see Figs. 6). In 2017, however, the built-up area in Malakand Division increased in its extent from 54351.96 to 79915.44 hectares (6.17%), the vegetation covers also increased to 577842.95 hectares (43.889%). The area covered by water bodies increased to 11365.81 hectares (0.87%) and the snow cover increased by 8% (an area of 103585.11 hectares) and barren land was 521249.45 hectares (40.27%) (Please see Figs. 7).

4.1. Change Detection Analysis

The purpose of change detection analysis is to quantify the changes of an area over time(Liping et al., 2018). The classified scenes of 1991, 2001, 2011 and 2017 were utilized to compute the area of all LULC classes to examine the variations which took place over time from 1991 to 2017. In addition, these resultant classified images were very useful to detect numerous changes that occurred in all classes of land use for example the growth in urban built-up area was detected while on the other hand a substantial decrease detected in the vegetation cover (Figs. 8, 9 and 10 for more detail). Figure 8 depicts the changes in land cover in the study area from 1991–2001. The results of this study revealed that there is a substantial growth found in built-up area, vegetation cover and barren land while some decrease in snow cover area was found. In 1991 the built-up area was 12919.8 hectares whereas in 2001 it increases up to 14384.6 hectares i.e. 27304.41 hectares total in 2001. The total change in the Vegetation cover is 39457.96 hectares. The area covered by snow in 1991 was 307645 hectares, and in 2001 it was 96735.83 hectares, the percentage of snow which have changed was − 16.30%. Area under barren land in 1991 was 590879 hectares i.e. 1.99% and in 2001, it was 749883.1 hectares i.e. 12.29%, the percentage of area covered by water has changed by 0.14%.

Figures 11, 12 and 13 indicate the variation in land cover from 2001–2011. The analysis of these figures reveals that a substantial growth in built-up area and vegetation cover was detected in between 2001–2011. In 2001 the area covered by vegetation was 413206.93 hectares whereas in 2011 it increased up to 62251.57 hectares. There was a change of approximately 4.82% noticed in vegetation cover. Whereas the area covered by built-up class was 27304.41 hectares in 2001 and increased up to 27047.55 hectares in 2011, while 2.11% increase has also occurred in area under built- up class. Conversely, the barren land in 2001 was 749883.14 hectares but it decreased to 23930.68 hectares in 2011. The percentage of barren land which have changed was − 1.85% while water covered area was 6351.49 hectares in 2001 which increased to 1400.11hectares in 2011 (0.08%).
During the period from 2011 to 2017, the built-up area grew by 25563.48 hectares from 2011 to 2017 which is 1.98% but the barren land decreased during the same period by 204703.01 hectares i.e. 15.83%. Vegetation increased from 475458.5 hectares to 577842.953 hectares during the same period. Increase in

snow cover was also noticed i.e. 73391.76 hectares during 2011 to 2017. However, the covered area of water bodies too increased by 0.27% during 2011–2017 (detail in Figs. 14, 15. 16).

The overall results from 1991 to 2017 show that major decrease was observed in snow and barren land whereas, noticeable increase in vegetation cover, built-up and water bodies was detected. Land covered with vegetation increased from 28.89–44.67% while barren land decreased from 45.68% to 40.29 of the total area. The portion of built-up area was 1.02% which grew up to 6.2%. Water covers the least area in this whole time period covering an area of 0.63% of the total area in 1991 which increased up to 0.86% in 2017 (please see Figs. 17, 18 & 19).

4.2. Accuracy Assessment

In this study, the classified images have been justified by ground truth data and available open-source Google earth. The qualitative and quantitative accuracy assessment has been done for these classified images. A stratified random sampling technique was used for quantitative assessment whereas the qualitative assessment was carried out by visual interpretation technique through Google Earth Pro (open source). It is assumed that these ground truth points, and Google Earth Pro images are the most accurate data available to measure the accuracy of the prediction. For every individual land use class 40 reference point were selected and to check the accuracy, producer accuracy, user accuracy, overall accuracy and kappa coefficient were computed for the two classified scenes (please see Figs. 20, 21, 22 & 23).

5. Discussion

As land use land cover changes influence functions and processes of ecological landscape(Hietel et al., 2004). Many lands use change influences each other. Our results showed that there was a substantial increase in built-up area (commercial, residential, road network and industrial). This substantial growth in built-up area and vegetation cover along with decrease in barren land is illustrating that due to rapid growth in population most of the barren land either converted into built-up area or comes under vegetation cover to fulfill the food requirements of rapidly growing population of the district. The increase vegetation cover may also be due to the Government's billion tree tsunami project initiated in Pakistan in recent years. Increasing population leading to urbanization is one of the major factors of increased Co_2 emission(Weber & Sciubba, 2019) leading to increasing temperature (Chapman et al., 2017). Global warming is the major factor of glacier melting resulting in the glacial recreation (Rasul & Molden, 2019). As noticed in this study, the snow cover has reduced it is due to the impact of increasing temperature pattern due to climate change. There was a sudden decrease found in snow cover area in between 1991 to 2001 and 2001 to 2011 while from 2011 to 20017 again a prominent increase found in snow cover in the study area. This situation is strongly justifying the statement that Pakistan has a wet period after each 10 years and in between a dry period of 10 years exist. The decrease in the area of snow cover shows the higher melting ratio which is an open prediction of a wet period followed by extensive floods in the country.

Meteorological and hydrological processes are influenced by snow cover change. It is because snow cover can affect the surface energy, water balance, and the development of the atmospheric boundary layer(Yu et al., 2017). There was a slight increase and decrease observed in the area of water bodies. For the period of 1991 t0 2001 there was a decrease found in the area of water bodies but from 2001 to 2011 and in between 2011 to 2017 a prominent increase found in water bodies. Snow and ice melt is considered important regulators of seasonal river discharge(Jeelani et al., 2012).

The substantial LULC transformation is found in form of conversion of barren land into built-up area, followed by vegetation cover. This spatial extension didn't cause much disturbance because the barren land was not under use. There was a positive change detected in LULC pattern such as useless land comes under purposeful utilization. However, it could be a future threat because the substantial growth in the population of the district and rapid urbanization could be a disaster in future for the study area. Furthermore, in future when the barren land will be consumed for multi purposes then the next target land use will be area covered by vegetation cover to fulfill the need of growing population. This could ultimately cause a great threat to sustainability of environment and may also trigger different climate and slope related disasters such as landslide(Bibi et al., 2016; Bibi et al., 2017).

6. Conclusion

The study performed in the five districts of Khyber Pakhtunkhwa Province of Pakistan indicates that spatio-temporal data of satellites is tremendously useful to identify the changes in LULC accurately and quickly. The results reveal that the class of vegetation cover enclosed maximum area in the study area. In past few decades, the area under vegetation has increased by 204093.983 hectares i.e. 15.78%. Most of the vegetation increased in the districts of Swat and Shangla in which barren land was converted to vegetation, while the area covered by barren land is reduced by 9.41%. The increase in Built-up area indicates that most of the agricultural land was used for the developmental activities. A faster expansion ratio was noticed in built-up area along river sides as compared to mountains areas. The methodology adopted by current research is clearly supporting the capability of GIS and remote sensing techniques in computing and identifying the changes in the pattern of LULC of town areas. Therefore, it is suggested that GIS and remote sensing techniques be used to detect the change in LULC in other parts of Pakistan as well as the world.

Declarations

Author Contributions: SG & TB conceived and designed the study; TB and YG collected data, analysed and wrote the manuscript. AN, SA, SM and AAS reviewed, edited, and offered feedback. SR approved and submitted.

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Availability of data and materials: All data generated or analyzed during this study are included in this published article [and its supplementary information files]

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Figures

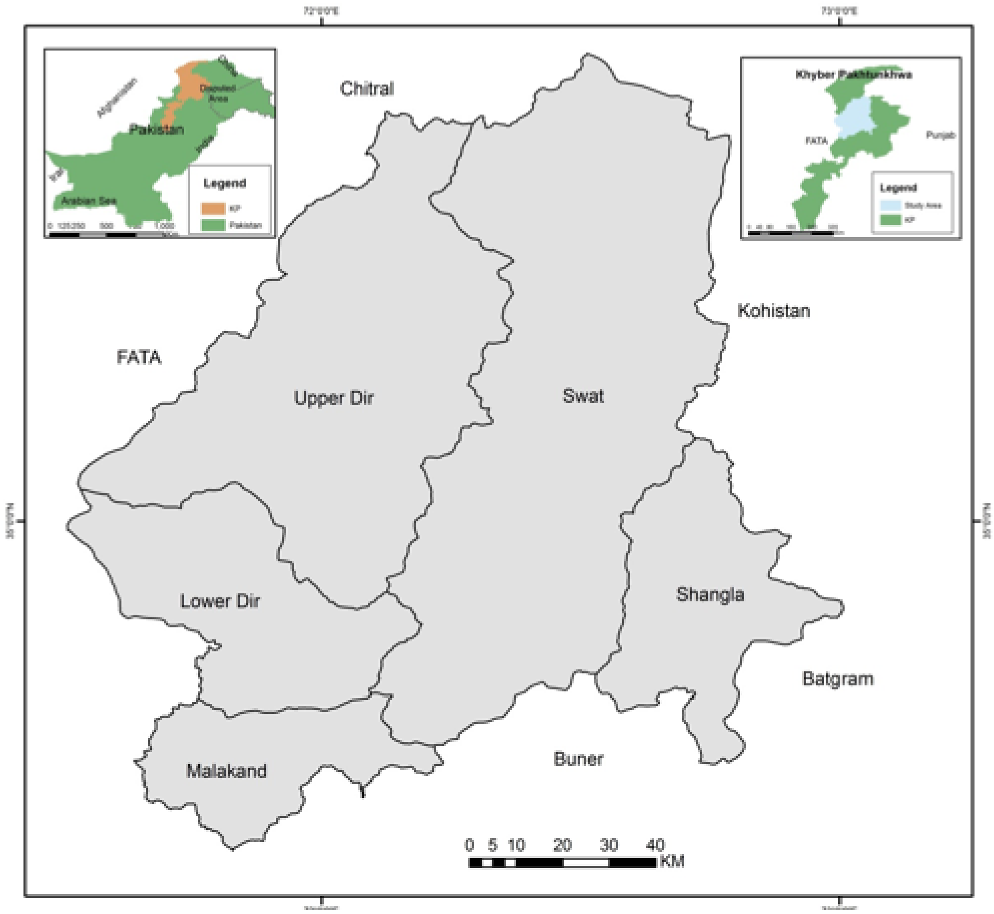

Figure 1

Map of Malakand Division, KP. Pakistan

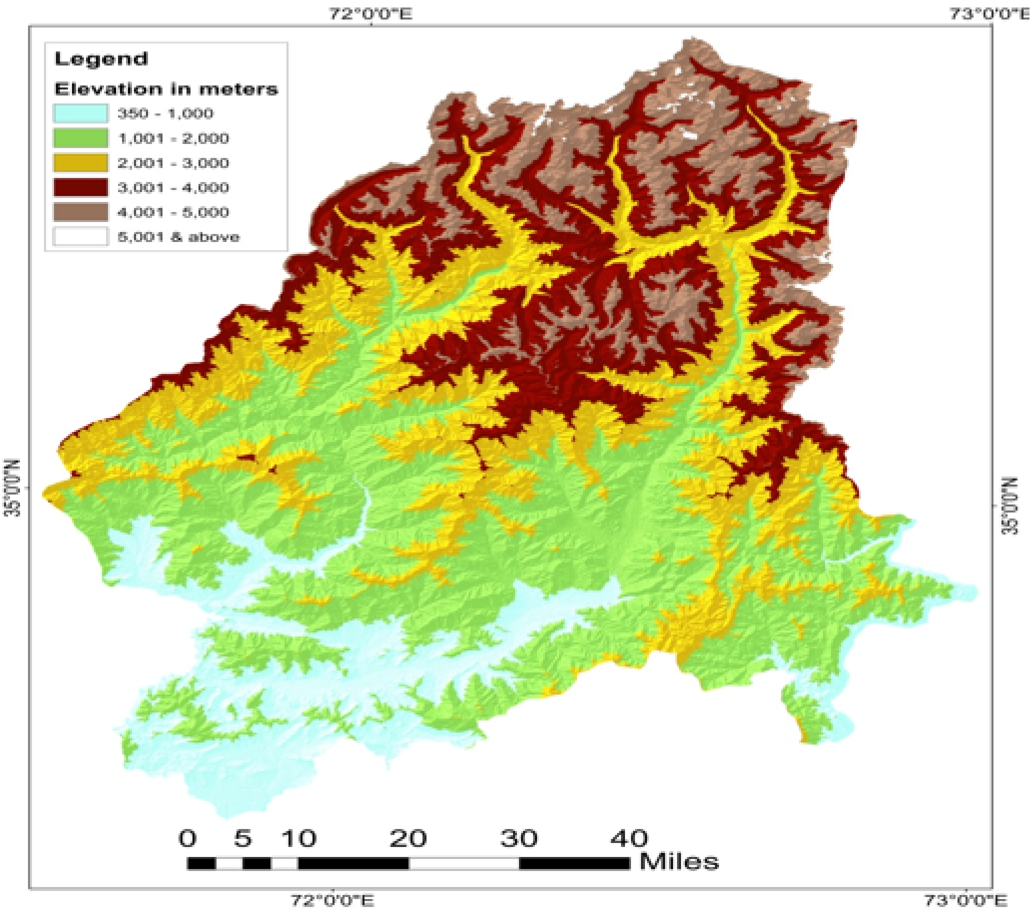

Figure 2

Elevation map of the study area

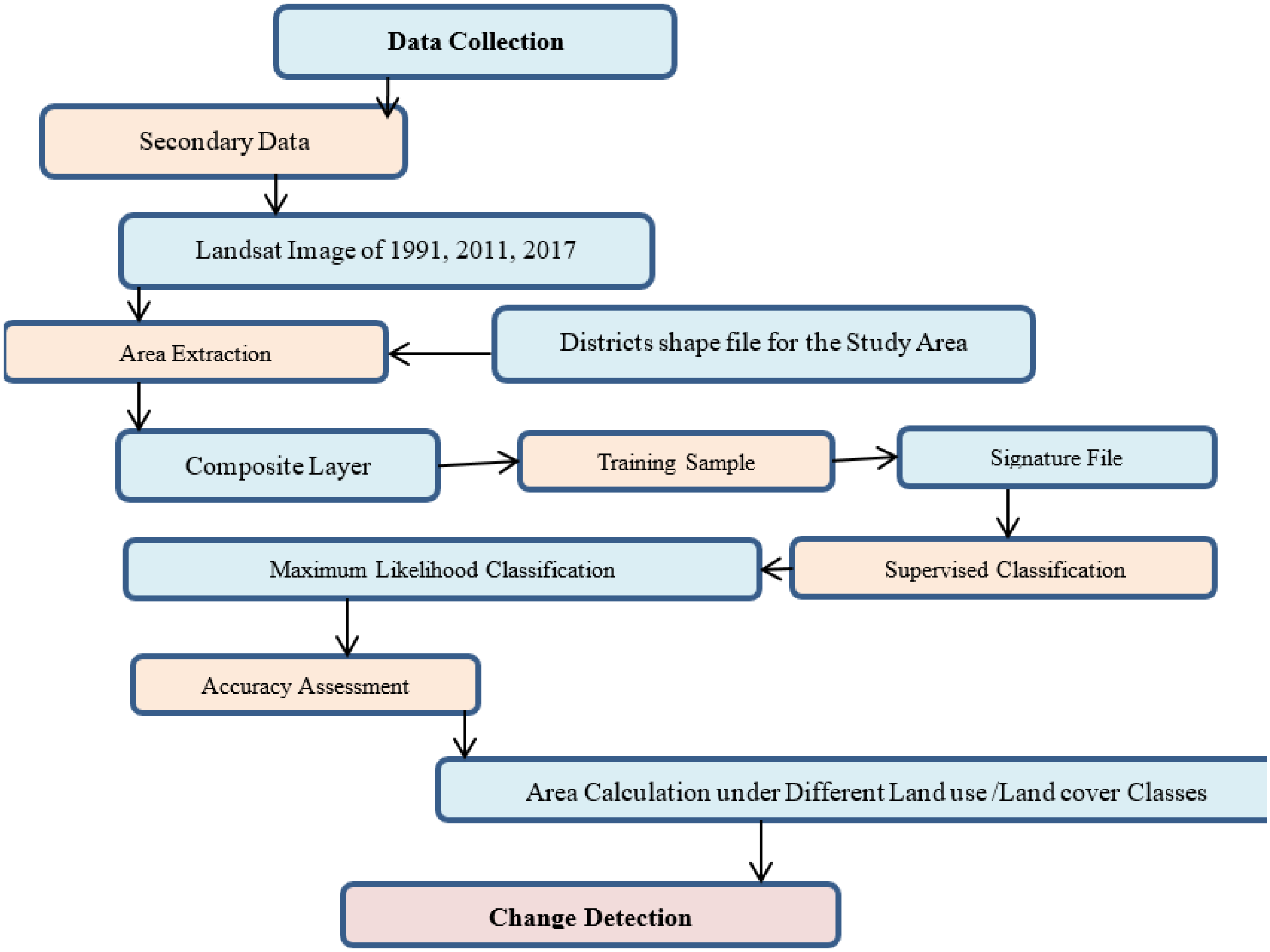

Figure 3

Work flow of the study

Figure 4

Map showing land use/land cover of the study area in 1991.

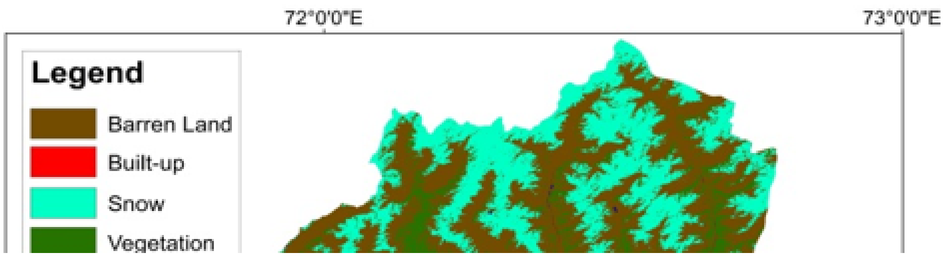

Figure 5

Land Use/Land Cover of the study area 2001.

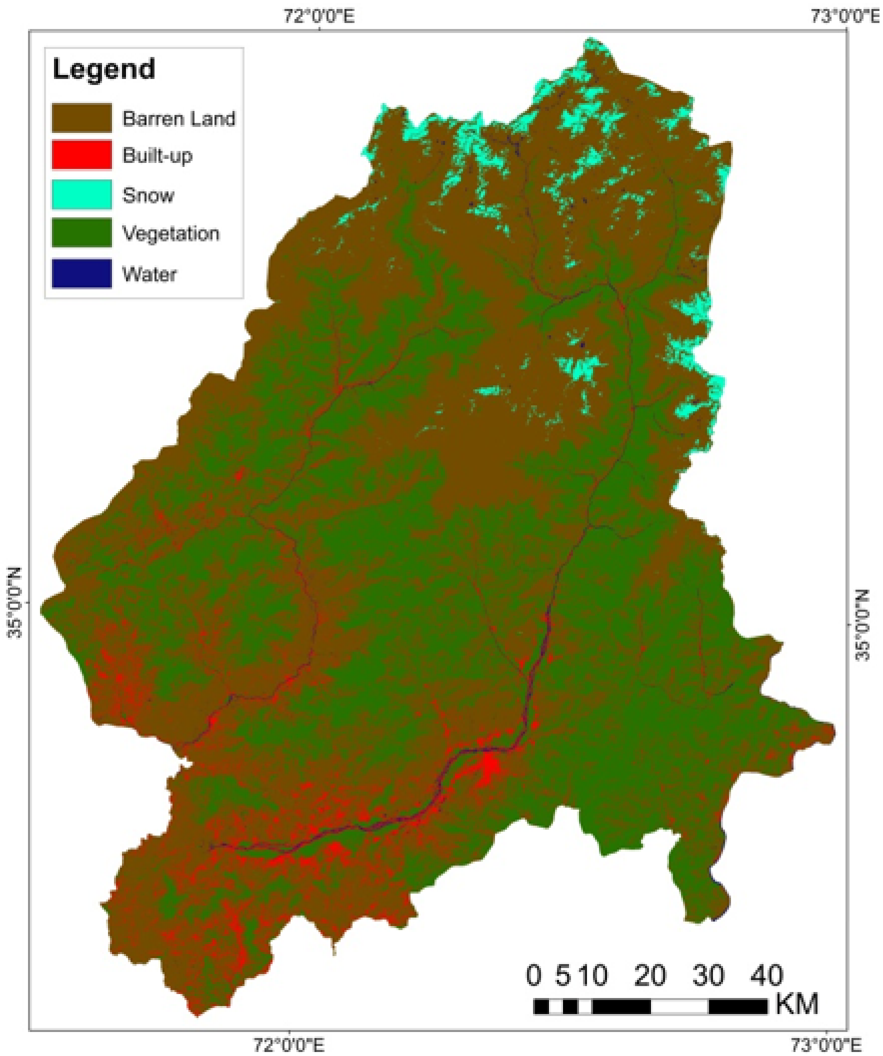

Figure 6

Land Use/Land Cover of the study area 2011

Figure 7

Land Use/Land Cover of the study area 2017

Figure 8

Land Cover Change Detection of Study Area in between 1991-2001.

Figure 9

Land Cover Changes of Study Area 1991-2001

Figure 10

Change detection of Land Cover 1991-2001

Figure 11

Shows Land Cover Change Detection of Study Area 2001-2011.

Figure 12

Land Cover Changes of Study Area 2001-2011

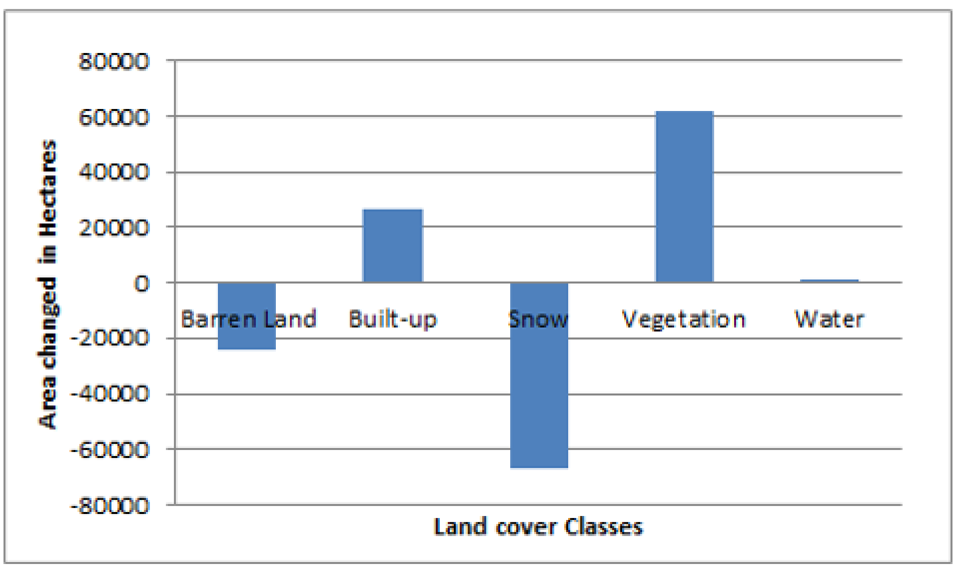

Figure 13

Change detection of Land Cover 2001-2011

Figure 14

Land Cover Change Detection of Study Area 2011-2017

Figure 15

Land Cover Changes of Study Area 2011-2017

Figure 16

Change detection of Land Cover 2011-2017

Figure 17

A comparison of all classified images a (1991), b (2001), c (2011) and d (2017).

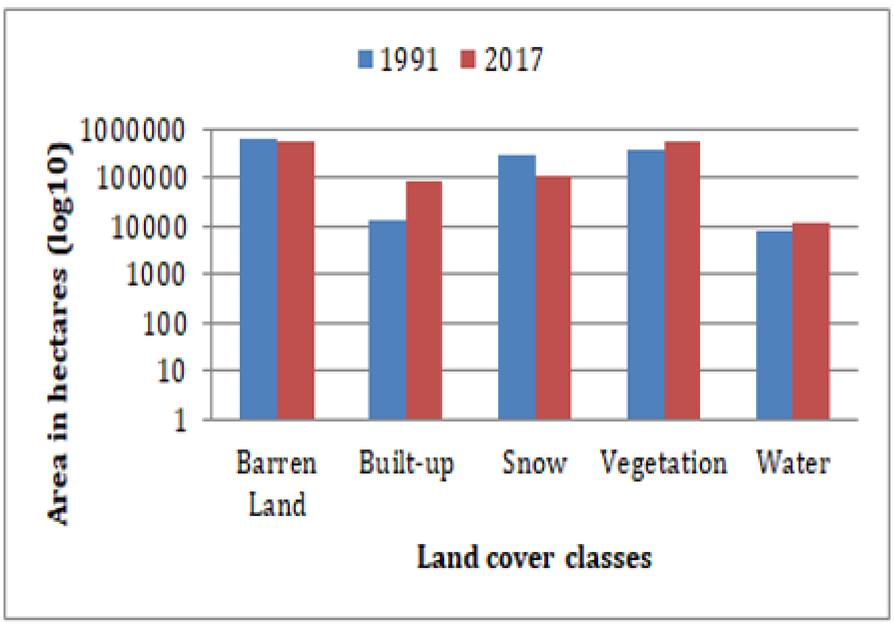

Figure 18

Land Cover Changes of Study Area 1991-2017

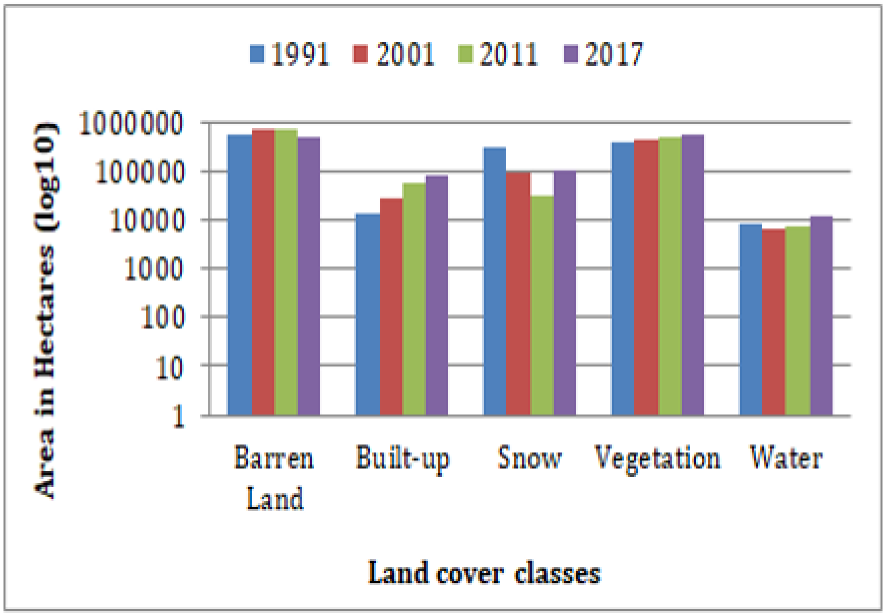

Figure 19

Area in hectares of each classified class of 1991, 2001, 2011 and 2017

Figure 20

Physical accuracy by comparing google earth image of 1991 and classified image 1991 strip.

Figure 21

Physical accuracy by comparing google earth image of 2001 and classified image 2001 strip.

Figure 22

Physical accuracy by comparing google earth image of 2011 and classified image 2011 strip.

Figure 23

Physical accuracy by comparing google earth image of 2017 and classified image 2017 strip.5.