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RESEARCH PAPER

Monitoring land use/cover change using remote sensing and GIS techniques: A case study of Hawalbagh block, district Almora, Uttarakhand, India

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Abstract Digital change detection techniques by using multi-temporal satellite imagery helps in understanding landscape dynamics. The present study illustrates the spatio-temporal dynamics of land use/cover of Hawalbagh block of district Almora, Uttarakhand, India. Landsat satellite imageries of two different time periods, i.e., Landsat Thematic Mapper (TM) of 1990 and 2010 were acquired by Global Land Cover Facility Site (GLCF) and earth explorer site and quantify the changes in the Hawalbagh block from 1990 to 2010 over a period of 20 years. Supervised classification methodology has been employed using maximum likelihood technique in ERDAS 9.3 Software. The images of the study area were categorized into five different classes namely vegetation, agriculture, barren, built-up and water body. The results indicate that during the last two decades, vegetation and built-up land have been increased by 3.51% (9.39 km^2) and 3.55% (9.48 km^2) while agriculture, barren land and water body have decreased by 1.52% (4.06 km^2), 5.46% (14.59 km^2) and 0.08% (0.22 km^2), respectively. The paper highlights the importance of digital change detection techniques for nature and location of change of the Hawalbagh block.

1. Introduction

Land use/cover is two separate terminologies which are often used interchangeably (Dimyati et al., 1996). Land cover refers to the physical characteristics of earth's surface, captured in the distribution of vegetation, water, soil and other physical features of the land, including those created solely by human activities e.g., settlements. While land-use refers to the way

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in which land has been used by humans and their habitat, usually with accent on the functional role of land for economic activities. The land use/cover pattern of a region is an outcome of natural and socio-economic factors and their utilization by man in time and space. Information on land use/cover and possibilities for their optimal use is essential for the selection, planning and implementation of land use schemes to meet the increasing demands for basic human needs and welfare. This information also assists in monitoring the dynamics of land use resulting out of changing demands of increasing population.

Land use affects land cover and changes in land cover affect land use. Changes in land cover by land use do not necessarily imply degradation of the land. However, many shifting land use patterns driven by a variety of social causes, result in land cover changes that affects biodiversity, water and radiation budgets, trace gas emissions and other processes that come together to affect climate and biosphere (Riebsame et al., 1994). Land use/cover change detection is very essential for better understanding of landscape dynamic during a known period of time having sustainable management. Land use/cover changes is a widespread and accelerating process, mainly driven by natural phenomena and anthropogenic activities, which in turn drive changes that would impact natural ecosystem (Ruiz-Luna and Berlanga-Robles, 2003; Turner and Ruscher, 2004). Understanding landscape patterns, changes and interactions between human activities and natural phenomenon are essential for proper land management and decision improvement. Today, earth resource satellites data are very applicable and useful for land use/cover change detection studies (Yuan et al., 2005; Brondizio et al., 1994).

With the invent of remote sensing and Geographical Information System (GIS) techniques, land use/cover mapping has given a useful and detailed way to improve the selection of areas designed to agricultural, urban and/or industrial areas of a region (Selcuk et al., 2003). Application of remotely sensed data made possible to study the changes in land cover in less time, at low cost and with better accuracy (Kachhwala, 1985) in association with GIS that provides suitable platform for data analysis, update and retrieval (Chilar, 2000). The advent of high spatial resolution satellite imagery and more advanced image processing and GIS technologies, has resulted in a switch to more routine and consistent monitoring and modeling of land use/land cover patterns. Remote-sensing has been widely used in updating land use/cover maps and land use/cover mapping has become one of the most important applications of remote sensing (Lo and Choi, 2004).

Landsat-TM images represent valuable and continuous records of the earth's surface during the last 3 decades (USGS, 2014). Moreover, the entire Landsat archive is now available free-of-charge to the scientific public, which represents a wealth of information for identifying and monitoring changes in manmade and physical environments (Chander et al., 2009; El Bastawesy, 2014). Several studies acknowledged the importance of pre-processing (i.e., data selection, co-registration, radiometric calibration and normalization) in performing accurate and reliable change detection analysis (Jensen, 2005; Lu et al., 2004; Mas, 1999; Scheidt et al., 2008; El Bastawesy et al., 2013).

Some extensive research efforts have been made by international scholars for land use/land cover change detection using remotely sensed images. Daniel et al. (2002) have compared land use/ land cover change detection methods and made use of 5 methods, viz., traditional post-classification cross tabulation, cross correlation analysis, neural networks, knowledge-based expert systems and image segmentation and object-oriented classification. They observed that there are merits to each of the five methods examined and that, at the point of their research, no single approach can solve the land use change detection problem. Yuan et al. (2005) developed a methodology to map and monitor land cover change using multi-temporal Landsat TM data in the seven-county Twin Cities Metropolitan Area of Minnesota for 1986, 1991, 1998 and 2002. Their result showed that between 1986 and 2002 the amount of urban land increased from 23.7% to 32.8% of the total area, while rural cover types of agriculture, forest and wetland decreased from 69.6% to 60.5%. Adepoju et al. (2006) examined the land use/land cover changes that have taken place in Lagos for the last two decades due to the rapid urbanisation. A post-classification approach was adopted by Adepoju with a maximum likelihood classifier algorithm. El Gammal et al. (2010) have used several Landsat images of different time periods (1972, 1982, 1987, 2000, 2003 and 2008) and processed these images in ERDAS and ARC-GIS softwares to analyze the changes in the shores of the lake and in its water volume. Bhagawat (2011) presented the change analysis based on the statistics extracted from the four land use/land cover maps of the Kathmandu Metropolitan by using GIS. According to him, land use statistics and transition matrices are important information to analyze the changes of land use. El-Asmar et al. (2013) have applied remote sensing indices, i.e., normalized difference water index (NDWI) and the modified normalized difference water index (MNDWI) in the Burullus Lagoon, North of the Nile Delta, Egypt for quantifying the change in the water body area of the lagoon during 1973 to 2011.

In India, researches on land use/land cover have been done by various scholars, especially by using remote sensing data. Pooja et al. (2012) have quantified land use/cover of Gagas watershed, district Almora using survey of India topographic sheet of the year 1965 and LISS III satellite data for the year 2008 over a period of 43 years. Rawat et al. (2013a–d, 2014) have carried out a study on land use/land cover of five major towns (i.e., Ramnagar, Nainital, Bhimtal, Almora and Haldwani) of Kumaun Himalaya in Uttarakhand (India). Based on 20 years of satellite data from 1990 to 2010 of land use/land cover change, they found that built up area has sharply increased due to construction of new buildings in agricultural and vegetation lands. Amin et al. (2012) carried out a study on land use/land cover mapping of Srinagar city in Kashmir Valley. They observed that the Srinagar city has experienced significant changes during 1990 to 2007. The analysis also showed that changes in land use pattern have resulted in the loss of forest area, open spaces, etc. Mehta et al. (2012) presented an integrated approach of remote sensing and GIS for land use and land cover study of arid environment of Kutch region in Gujarat in between year 1999 and 2009. Sharma et al. (2012) introduced land consumption rate (LCR) and Land Absorption Coefficient (LAC) to aid in the quantitative assessment changes between the years 1976 and 2008 in Bhagalpur city in the state of Bihar in India. Pandey et al. (2012) presented the implementation of a Geospatial approach for improving the Municipal Solid

Waste (MSW) disposal suitability site assessment in growing urban environment. Kumar et al. (2013) carried out study on biomass estimation of Sariska Wildlife Reserve using forest inventory and geospatial approach to develop a model based on the statistical correlation between biomass measured at plot level and the associated spectral characteristics. Singh et al. (2014) have used recent freely available satellite data of Landsat-8 for assessing the land use pattern and their spatial variation of Orr watershed Ashok Nagar district, M.P., India.

An attempt is made in this study to map out the status of land use/cover of one of the development blocks of the Uttarakhand state, viz., Hawalbagh block of District Almora in view to detect the land consumption rate and the changes that has taken place during the last two decades using geospatial techniques.

2. Study area

The study area (Fig. 1), viz., the Hawalbagh block is one of the eleven development blocks of District Almora of the Uttarakhand state lies in the Lesser Himalayan terrain in India. It extends between 29° 32′ 30″ N to 29° 44′ 23″ N latitudes and 79° 31′ 11″ E to 79° 43′ 50″ E longitudes and encompasses an area of 267.53 km^2. Geologically, the Hawalbagh block is made-up of the rocks of two tectonic units. These are the Almora Group in the central and southern part which consists of three formations, i.e., Saryu Formation, Almora Gnessies and Gumalikhet Formation and the Damtha Group in the northern part having Rauthgarh Formation (Valdiya, 1980). Climatically, the study area enjoys cool temperate climatic conditions. On an average, the study area receives about 1065.01 mm of rainfall per year. The annual mean maximum, minimum and average temperature of the study area stands at 23.3 °C, 11.9 °C and 17.6 °C, respectively. The master stream of Hawalbagh block is Kosi river which flows from north to south and divides the block into two halves. The total length of streams in the Hawalbagh block is about 1047.59 km. Out of the total streams of Hawalbagh block, 84.54% (885.73 km) are non-perennial streams while only 15.46% (161.86 km) stream are perennial. The Hawalbagh block consists of 10 nayaypanchyats, 124 gram-panchyats and 234 villages. The block has a total population of 59,227.

3. Material and methods

3.1. Database preparation

Landsat Thematic Mapper at a resolution of 30 m of 1990 and 2010 were used for land use/cover classification. The satellite data covering study area were obtained from global land cover facility (GLCF) (http://glcfapp.glcf.umd.edu:8080/esdi/) and earth explorer site (http://earthexplorer.usgs.gov/). These data sets were imported in ERDAS Imagine version 9.3 (Leica Geosystems, Atlanta, U.S.A.), satellite image processing software to create a false colour composite (FCC). The layer stack option in image interpreter tool box was used to generate FCCs for the study areas. The sub-setting of satellite images were performed for extracting study area from both images by taking geo-referenced out line boundary of Hawalbagh block map as AOI (Area of Interest). For better classification results some indices such as normalized difference vegetation index (NDVI), normalized difference water index (NDWI) and normalized difference builtup index (NDBI) were also created to classify the Landsat images.

3.2. Land use/cover detection and analysis

To work out the land use/cover classification, supervised classification method with maximum likelihood algorithm was applied in the ERDAS Imagine 9.3 Software. Maximum likelihood algorithm (MLC) is one of the most popular supervised classification methods used with remote sensing image data. This method is based on the probability that a pixel belongs to a particular class. The basic theory assumes that these probabilities are equal for all classes and that the input bands have normal distributions. However, this method needs long time of computation, relies heavily on a normal distribution of the data in each input band and tends to over-classify signatures with relatively large values in the covariance matrix. The spectral distance method calculates the spectral distance between the measurement vector for the candidate pixel and the mean vector for each signature and the equation for classifying by spectral distance is based on the equation for Euclidean distance. It requires the least computational time among other supervised methods, however, the pixels that should not be unclassified become classified, and it does not consider class variability. Ground verification was done for doubtful areas. Based on the ground truthing, the misclassified areas were corrected using recode option in ERDAS Imagine. The error matrix and Kappa Khat methods were used to assess the mapping accuracy. Five land use/cover types are identified in the study area viz., (i) vegetation (ii) agricultural land (iii) barren land (iv) built-up land (v) water body.

3.3. Land use/cover change detection and analysis

For performing land use/cover change detection, a post-classification detection method was employed. A pixel-based comparison was used to produce change information on pixel basis and thus, interpret the changes more efficiently taking the advantage of "-from, -to" information. Classified image pairs of two different decade data were compared using cross-tabulation in order to determine qualitative and quantitative aspects of the changes for the periods from 1990 to 2010. A change matrix (Weng, 2001) was produced with the help of ERDAS Imagine software. Quantitative areal data of the overall land use/cover changes as well as gains and losses in each category between 1990 and 2010 were then compiled.

4. Results and discussions

The results obtained through the analysis of multi-temporal satellite imageries were diagrammatically illustrated in Figs. 2–4 and data are registered in Tables 1 and 2. Fig. 2 depicts land use/cover status, Fig. 3 depicts land use/cover change in different land use categories and Fig. 4 illustrates magnitude of change in different land categories. A brief account of these results is discussed in the following paragraphs.

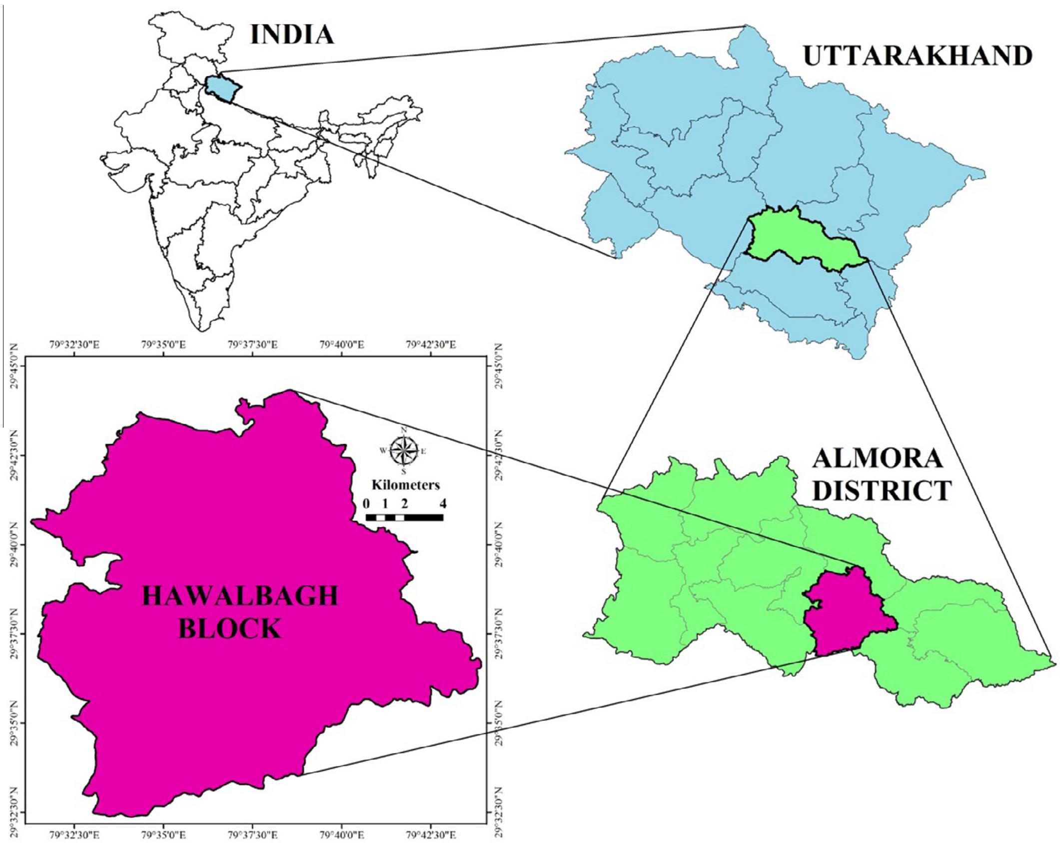

Figure 1 Location map of the study area.

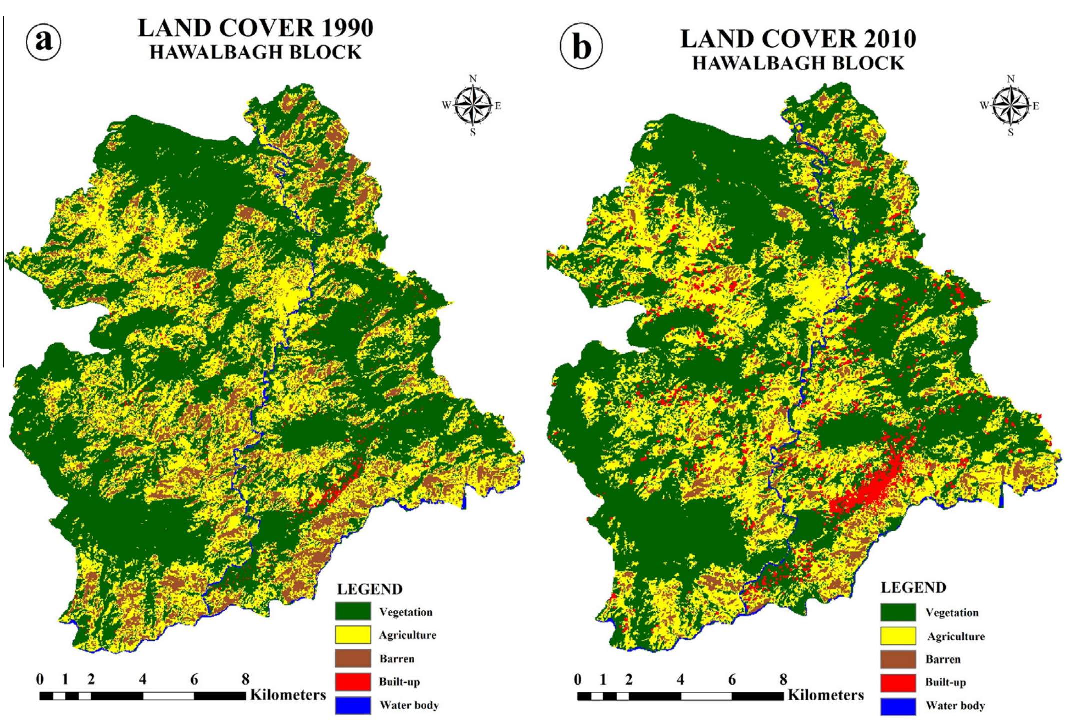

Figure 2 Land use/cover status of the Hawalbagh block; (a) in 1990, (b) in 2010 (based on Landsat Thematic Mapper Satellite Imagery).

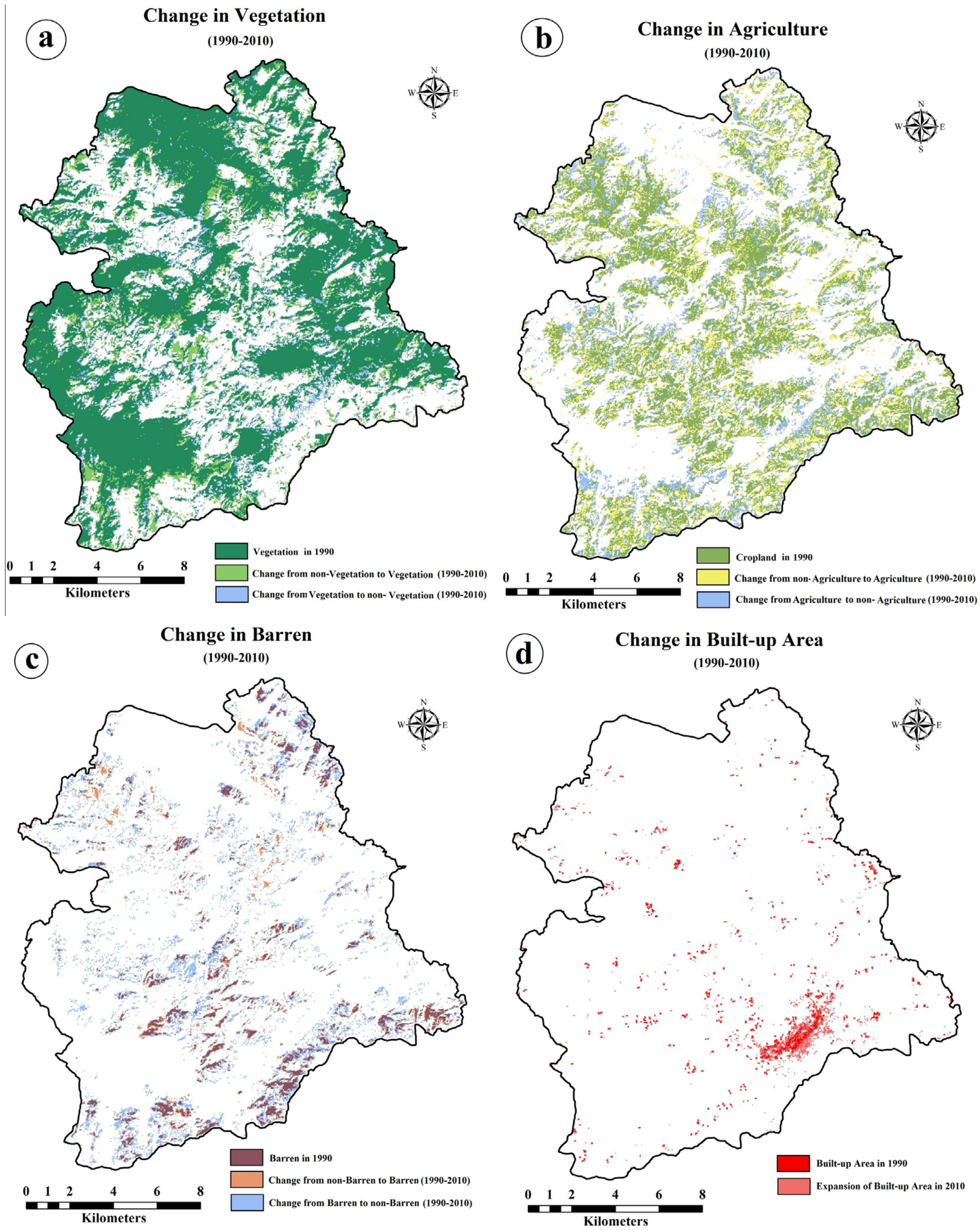

Figure 3 Land use/cover change in different categories during the last two decades in the Hawalbagh Development Block (1990–2010); (a) vegetation (b) agriculture (c) barren (d) built-up (based on Landsat Thematic Mapper Satellite Imagery).

4.1. Land use/cover status

Accuracy assessment of the land use/cover classification results obtained showed an overall accuracy of 90.29% for 1990 and 92.13% for 2010. The Kappa coefficients for 1990 and 2010 maps were 0.823 and 0.912 respectively.

Fig. 2(a) depicts spatial distributional pattern of land use/cover of the Hawalbagh block for the year 1990 while Fig. 2(b) for the year 2010. These data reveal that in 1990, about 54.75% (146.49 km^2) area of Hawalbagh block was under vegetation, 31.69% (84.73 km^2) under agriculture land, 11.65% (31.17 km^2) under barren, 1.01% (2.72km^2) under built-up land and 0.90% (2.42 km^2) under water body. During 2010 the area under these land categories was found about 58.26% (155.88 km^2) under vegetation, 30.17% (80.67 km^2) under agriculture land, 6.19% (16.58 km^2) under barren, 4.56% (12.2 km^2) under built-up land and 0.82% (2.22 km^2) under water body (Table 1).

4.2. Land use/cover change

Data registered in Table 1 and Figs. 3 and 4 reveal that both positive and negative changes occurred in the land use/cover pattern of the Hawalbagh block. During the last two decades

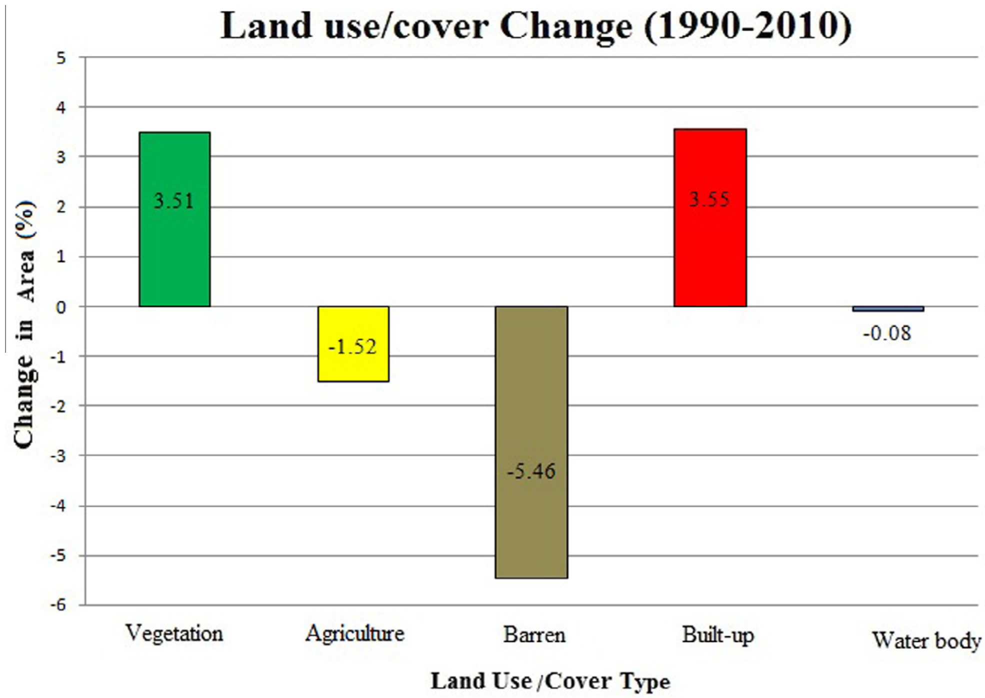

Figure 4 Diagrammatic illustration of land use/cover change in percent during the last two decades (1990–2010) in the Hawalbagh block.

Table 1 Area and amount of change in different land use/cover categories in the Hawalbagh block during 1990 to 2010.

Land use/cover categories	1990		2010		Change 1990–2010	
	km^2	%	km^2	%	km^2	%
Vegetation	146.49	54.75	155.88	58.26	9.39	3.51
Agriculture	84.73	31.69	80.67	30.17	−4.06	−1.52
Barren	31.17	11.65	16.58	6.19	−14.59	−5.46
Built-up	2.72	1.01	12.2	4.56	9.48	3.55
Water body	2.42	0.9	2.2	0.82	−0.22	−0.08
Total	267.53	100	267.53	100	0.00	0.00

Table 2 Land use/cover change matrix showing land encroachment (in %) of Hawalbagh block.

Land use/cover categories		Year 1990				
		Vegetation	Agriculture	Barren	Built-up	Water body
Year 2010	Vegetation	83.54	32.24	16.07	0.0	22.25
	Agriculture	11.91	55.14	52.72	0.0	7.68
	Barren	0.44	8.14	28.62	0.0	3.34
	Built-up	4.11	4.23	2.15	100	0.53
	Water body	0	0.25	0.44	0.0	66.2
	Class total	100	100	100	100	100

the vegetation in the study area has increased from 146.49 km^2 in 1990 to 155.88 km^2 in 2010 which accounts for 3.51% of the total study area. The agriculture has decreased from 84.73 km^2 in 1990 to 80.67 km^2 in 2010 which accounts for 1.52%. The built-up area has increased from 2.72 km^2 in 1990 to 12.20 km^2 in 2010 which accounts for 3.55%. The barren land has been decreased from 31.17 km^2 in 1990 to 16.58 km^2 in 2010. This decrease in barren land accounts for 5.46%. The water body of the study area has slightly decreased from 2.42 km^2 in 1990 to 2.20 km^2 in 2010 which accounts for −0.08%.

To understand land encroachment for different land categories during the last two decades, a change detection matrix (Table 2) was prepared which reveals that:

i. about 11.91% area of vegetation covered has been converted into agriculture, 4.11% area under built-up area and 0.44% area under barren land;
ii. about 32.24% area of agriculture has been converted into vegetation, 8.14% into barren and 4.23% in built-up;
iii. about 52.72% of area of barren has been converted into agriculture, 16.07% area under vegetation and 2.15% area under built-up land; and
iv. about 22.25% area of water body has been converted into vegetation, 7.68% in agriculture, 3.34% in barren and 0.53% into built-up land.

5. Conclusion

The study conducted in one of the development blocks of Almora district in Uttarakhand state (India) advocates that multi temporal satellite imagery plays a vital role in quantifying spatial and temporal phenomena which is otherwise not possible to attempt through conventional mapping. The study reveals that the major land use in the study area is vegetation. The area under vegetation has increased by 3.51% (9.39 km^2) due to afforestation work during 1990 to 2010. The second major category of land in the study area is agriculture which was decreased by 1.52% (4.06 km^2) due to conversion in vegetation, barren land and built-up land. The third major category of land in the study area is barren which has also decreasing. During the study period (i.e., 1990–2010), barren land has been decreased by 5.46% (14.59 km^2) due to conversion in agriculture, vegetation and built-up land. The area under fourth category of land, i.e., the built-up land has increased by 3.55% (9.48 km^2) due to mainly expansion of the Almora town area during the last two decades. Thus, the present study illustrates that remote sensing and GIS are important technologies for temporal analysis and quantification of spatial phenomena which is otherwise not possible to attempt through conventional mapping techniques. Change detection is made possible by these technologies in less time, at low cost and with better accuracy.

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