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Land-Use/ Land-Cover Change Detection and Analysis in Aglar Watershed, Uttarakhand

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Authors' contributions

This work was carried out in collaboration between all authors. Authors AIS designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author SS is the author under whose guidance work was carried out author MUDD managed the analyses of the study. Author VK managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Land-Use and Land-Cover (LULC) change has a significant impact on watershed processes such as hydrology, soil erosion, carbon sequestration, etc. While analyzing the interactions of various natural and human activities and assessing their impacts, the Land-Use/ Land-Cover change plays an important role. It forms an important component whose interaction with environment and humans need to be assessed. Although LULC change is a result of both natural and human activities, they are often linked to human activities. Natural activities for e.g. flash floods, earthquake, rain triggered landslides, etc., play an important role in changing the LULC of an area and may also result in drastic changes in watershed characteristics. One major example of this kind is the extreme rainfall events which occurred in June 2013. After these events, there are regions (or watersheds) of Uttarakhand, where significant agricultural land got converted to bare land. Due to advancement in the field of Remote Sensing and GIS techniques with the use of high-resolution satellite imagery, it

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has become possible to evaluate before and after scenarios of a landscape. The present study aims at detecting the Land-Use/ Land-Cover change from the year 1993 to 2015 and analysis of possible causes of change using multispectral satellite imagery from Landsat ETM+, Landsat Thematic mapper, and SRTM DEM. The LULC change analysis results were evaluated in relation to the geology, slope, and soils of the region to ascertain possible factors responsible for the change.

Keywords: LULC; Remote Sensing; GIS; Landsat Thematic mapper.

1. INTRODUCTION

Land use/ land cover of a watershed is a result of various environmental, natural and anthropogenic factors. The quick shrinking of the arable land resources due to various natural and anthropogenic factors has become a serious concern of development of land resources. Hence, for planning and management of land resources, it is necessary to have a deep understanding in the field of Land-Use/ Land-Cover (LULC).Though both the terms, Land-Use and Land-Cover are used inter-changingly, however in reality both the terms are different in meaning. Land Cover is the area of land covered by Wetlands, Agriculture, Forests, Grass lands and water-bodies, while as Land-use means the use for which the land is put to – whether the land is used for construction, conservation, or mixed uses [1]. India is a fast developing economy with population growth rate of 1.23% change per year [2]. Adequate and reliable information on various complex interrelated aspects is hence needed for proper management with LULC being one such aspect. With the rapid degradation of environment resulting in problems such as worsening environmental quality, destruction of important wetland, sedimentation of reservoirs, erratic floods and rainfall, and loss of wildlife habitat, the focus on the filed of LULC has increased significantly.

Land-use/ Land-Cover change is the change in the physical as well as biological characteristics of land [3]. Land-Cover change detection has become an essential component, while studying any area for conservation and recovery purposes. The field of LULC change detection has been drawing the attention of many researchers with the advancement in the field [4]. The knowledge of LULC changes is very important in understanding natural resources, their utilization, conservation and management [5]. Though very essential for planning and management of watersheds, the LULC classification is subject to errors and discrepancies. The traditional methods of evaluation, including referencing of images and topographic sheets for stratifying vegetation result in errors and subjectivity in interpretation. Such interpretation discrepancies can be solved by applying recent approaches of using digital satellite data with digital terrain modeling for classification of vegetation [1].

The change in the LULC can be attributed to various natural and man-made factors the most of which are related to human activities such as urbanization, Intensive agriculture, deforestation, overgrazing etc. The changes may be due to complex interactions between various social, economic and biophysical elements of a system. While in research works related to LULC change, most of the changes are attributed to human activities, much less emphasis is laid on the natural components although less in magnitude. The natural causes may be different varying from a slow continuous change taking place over a time or an abrupt catastrophic event where both differ in magnitude and time although contribute to the change. The development of different LULC may also be a result of heterogeneous climate and physiographic conditions of an area all of which need to be evaluated [5]. The temporal differences in the LULC of an area can be evaluated and monitored with the availability opportunely processed and elaborated remote sensing data [6]. From watershed planning and management point of view, it is very important to have a deep understanding of the location, magnitude and factors affecting LULC of a watershed. The hypothesis behind this work is that there are certain intrinsic natural forces which cause a LULC of an area to undergo a gradual change that needs to be evaluated for the study area in addition to the assessment of change that has occurred in the past.

1.1 Objectives

Keeping in view the points discussed above, the research work was carried with the following two objectives:-

1. Detect the change in Land-Use/ Land-Cover (LULC) in the study area.

2. Analyze the magnitude, nature and possible causes of the LULC change.

1.2 Study Area

The study area of Aglar watershed lies in Tehri-Garhwal and Dehradun districts of Uttarakhand state of India and is located in the outer Garhwal Himalayan range. The area is located geographically at 30°35'27.8" N to 30°25'6.7" N and 78°0.68' E to 78°17'40.92" E (Fig. 1). The area is also known for frequent landslide and is also erosion prone. The maximum and minimum elevation in the study area varies between 3015-700 meters above MSL. The area of watershed is approximately 295 Km^2.

The climate of the area which is cooler than the rest of India can be defined as a subtropical climate (Koppen C*f*a). Higher elevations have climate close to temperate. The average monthly temperature varies between 6°C and 20°C. The mean annual precipitation of the area is around 2023 mm. The Aglar watershed is majorly a forested area, but there is a different LULC distribution in the northern and southern aspect of the watershed. While the northern aspect mostly comprises of thick and dense forests, the southern aspect is inhabited and degraded.

2. METHODOLOGY

2.1 Input Data Preparation and Processing

The first step involved is the preparation of data inputs. In the present study, ArcGIS 10.2.2, and ERDAS Imagine 9.3 interface were used to meet the objectives of the study. Landsat multispectral imageries for Year 1993, 1999 and 2015 with a spectral resolution of 30m were acquired from earth explorer interface of USGS (USGS, 2014). The input data hence acquired was imported into ERDAS Imagine version 9.3. The different bands were stacked using layer stack in order to generate a FCC image of the area. The area of Interest was much smaller than the area for which data was acquired. So an AOI

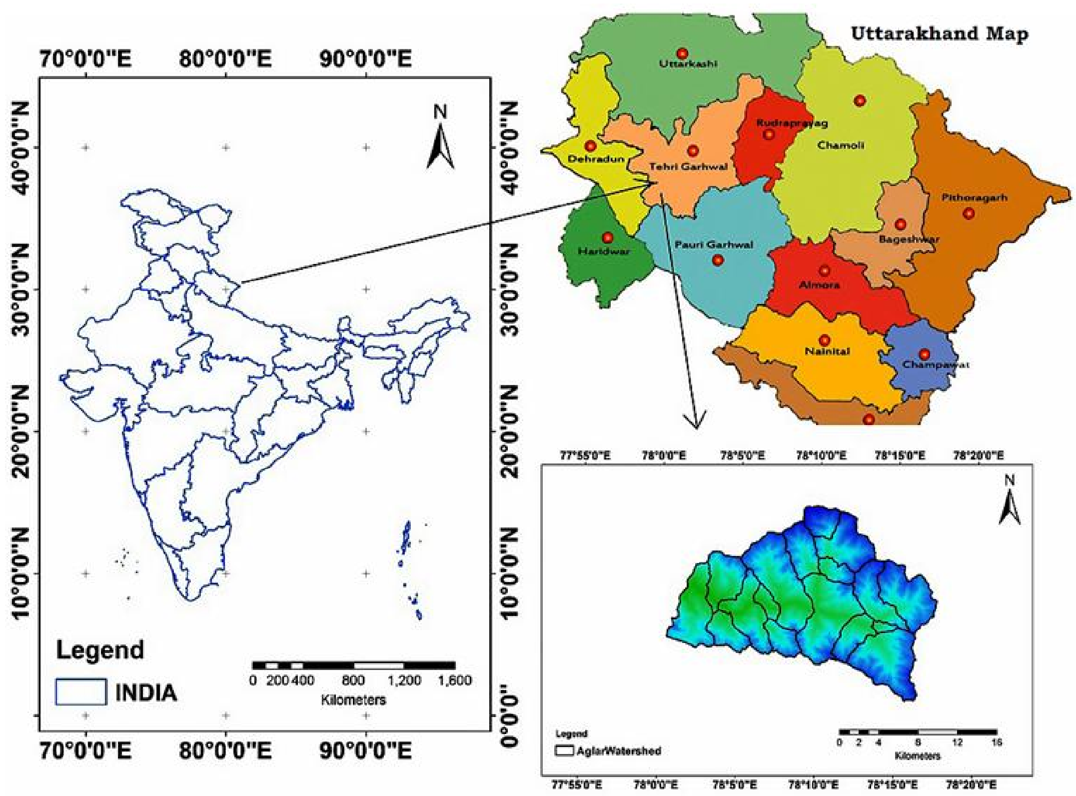

Fig. 1. Location and hill-shade map of study area

(Area of Interest) file created from shape file of the study area was used to subset the area of interest from all the geo-referenced images of different time periods. On the basis of the major types of Land-Cover/ Land-Use (LULC) in the area, a classification scheme consisting of six classes (viz. Forests, Shrubs/ Grasslands, Agriculture, Bare, Water-body and Buildup) was adopted for the study area. Supervised classification method with maximum likelihood algorithm was used to classify the images of three different time periods. Once the spectral signatures were created for each class, the images were classified. Any errors in classification were corrected by using recode function in ERDAS which is based on intensive ground truthing. Kappa statistics was used to find the accuracy of the classification.

2.2 LULC Change Detection

The changes map was produced from the two images of different time periods in Erdas using Images Highlight option in Erdas 9.3 which highlights the areas where there is increase or decrease in the pixel values above a specified limit. In order to quantify the change in LULC, a pixel based method was used where areas under different pixels belonging to different classes were estimated. The classified images were compared to produce a change matrix in ERDAS Imagine.

2.3 Factors

The digital elevation map (DEM) of the study area was obtained from earth explorer site of USGS. The DEM was projected and a slope map was prepared for the study area. A soil map of the study area was also prepared by digitizing the soil map for the Uttar Pradesh state of National Bureau of Soil Survey and Land-Use planning of scale 1: 50,000.

The general Methodology of the study can also be illustrated by a flow chart for better understanding.

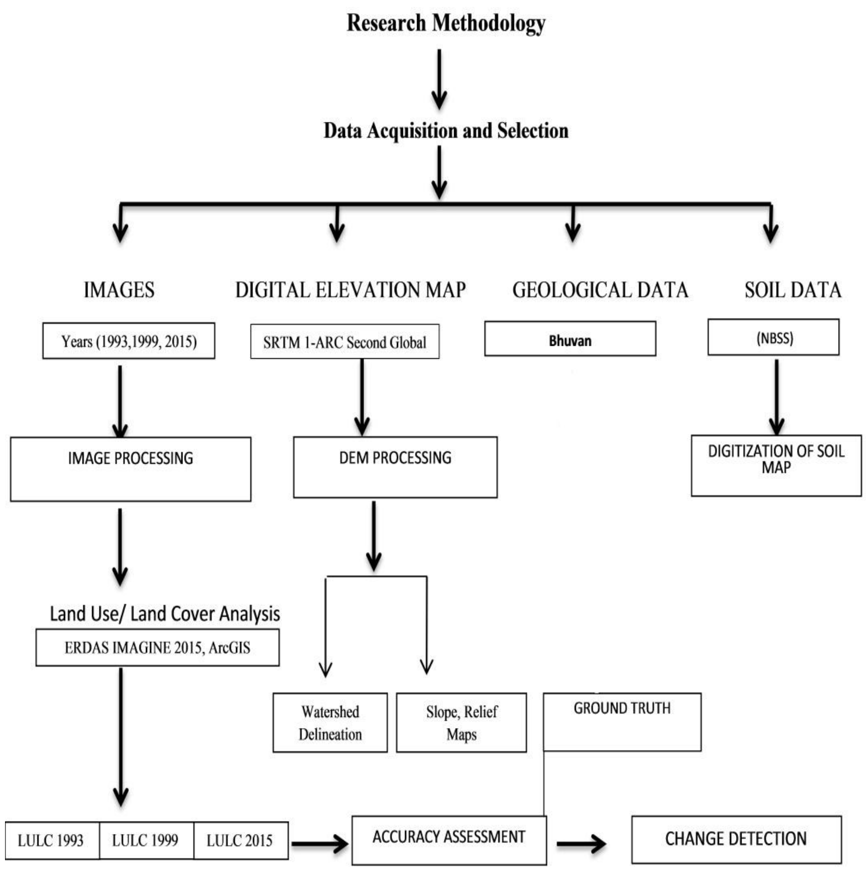

Fig. 2. Methodology of the research

3. RESULTS AND DISCUSSION

The whole of the watershed was divided into six Major Land-Use/ Land-Cover classes occurring in the watershed based on a simple classification scheme. A classification scheme was adopted for the study area in which classified Land use/ Land cover (LULC) maps of the selected classes scheme were developed (viz. Forests, Shrubs/ Grasslands, Agriculture, Bare, Water-body and Buildup) based on the adopted classification. The LULC maps were developed for the year 1993, 1999 and 2015. The year 1999 was selected to act as a reference for trend detection. Following the classification, it was observed that forests form a major part of land with the northern aspect of the watershed. The forest cover also showed a major variation with altitude with high altitude areas having more and dense forest cover. The LULC maps also revealed a dense forest on the eastern side of the northern aspect of the watershed especially in the higher altitudes. In the same aspect, shrubs occupy more area on the eastern side of the watershed, especially in the lower slopes. It was also found that a minor area in the southern side of the watershed is inhabited. Agriculture is mainly practiced on the slopes where the land is divided in the terraces. Shrubs and agriculture are prominent Land-Cover especially in the north aspect and southwest direction of the watershed. The land along the river draining Aglar watershed in its floodplains is cultivated where the slope is less and covered by shrubs in the steep sloped area. Lower reaches of the southern aspects along the streams are suitable for cultivation and hence used for agriculture. The area under different LULC classes along with their spatial variability is shown for two different time periods viz. 1993 and 2015.

It can be observed from the initial results of the year 1993 and 1999 that Aglar watershed is mainly a forested area with lot of vegetation especially in the north aspect. It was observed for the year 1993 that Forests covered an area of 12095 ha, Shrubs/ Pastures covered an area of 4637.4 ha, bare land was about 2770 ha and Agriculture was practiced on an area of 7900 ha. A very small area of the watershed was occupied by Build-Up and Water-bodies. The percentage of the total areas under different Land-Use/ Land-Cover classes was calculated for the year 1993, 1999 and 2015. The results are tabulated Table 1.

The results for the year 1993 were compared with that of 2015 with the year 1999 serving as a base for comparison and trend observe trend, if found. It was observed that though the Forest cover remained almost constant, the Bare Land however showed a positive trend and the

Table 1. Land use/ land cover classes for selected 3 years of study

LULC class	Percentage of area (%)	Percentage of area (%)	Percentage of area (%)
	1993	**1999**	**2015**
Forest	41.00	40.96	41.44
Agriculture	26.78	24.30	19.34
Bare	9.39	11.60	13.90
Water-Body	4.16	4.20	5.09
Shrubs	15.72	15.73	16.12
Build-Up	2.94	3.20	4.10
Total	**100**	**100**	**100**

Table 2. Area under different LULC classes and comparison between 1993 and 2015

LULC class	AREA (Km^2) (1993)	AREA (Km^2) (2015)	Changed Area as %age of total Area	Change in LULC class
Forests	41.0	41.4	+0.44	+1.06
Agriculture	26.8	19.4	-7.44	-27.78
Shrubs/pasture	15.7	16.1	+0.39	+2.47
Bare	9.4	13.8	+4.51	+48.01
Build-up	2.9	4.1	+1.16	+39.45
Water-body	4.1	5.0	+0.93	+22.35

agricultural area showed negative trend with continuous decrease of the years. It was observed that, while Forests cover remained almost constant, the agricultural area decreased by 27.78%. Also there was an increase in the Bare Land which increased by 48.01%. Both the Water-bodies and the Build-Up areas also showed a positive trend showing an increase of 22.35% and39.45% respectively.

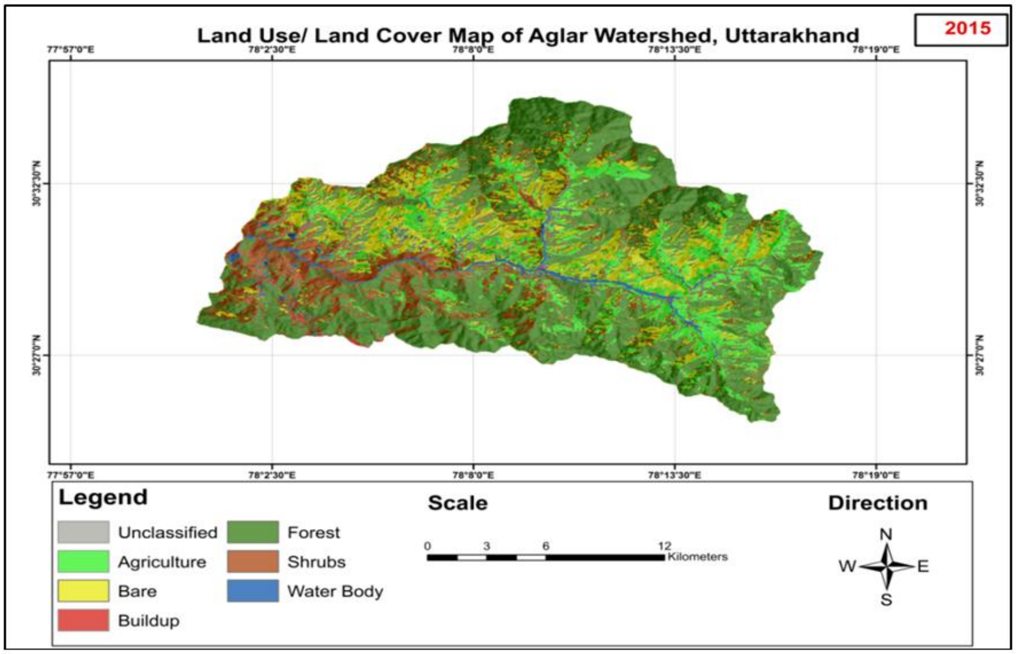

Fig. 3. Land use/ land cover map for the year 2015

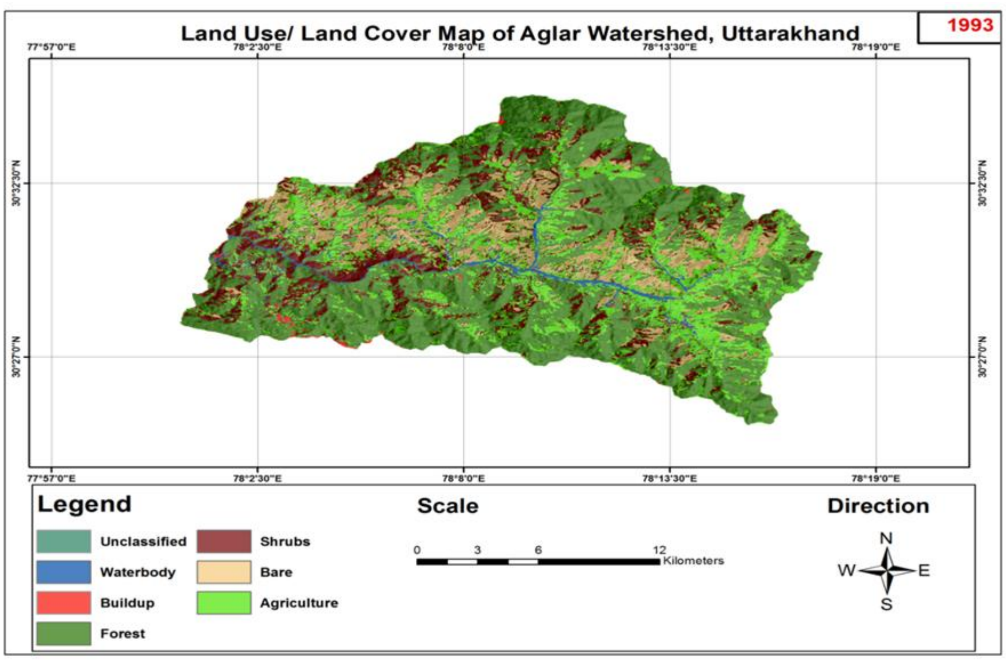

Fig. 4. Land use/ land cover map for the year 1993

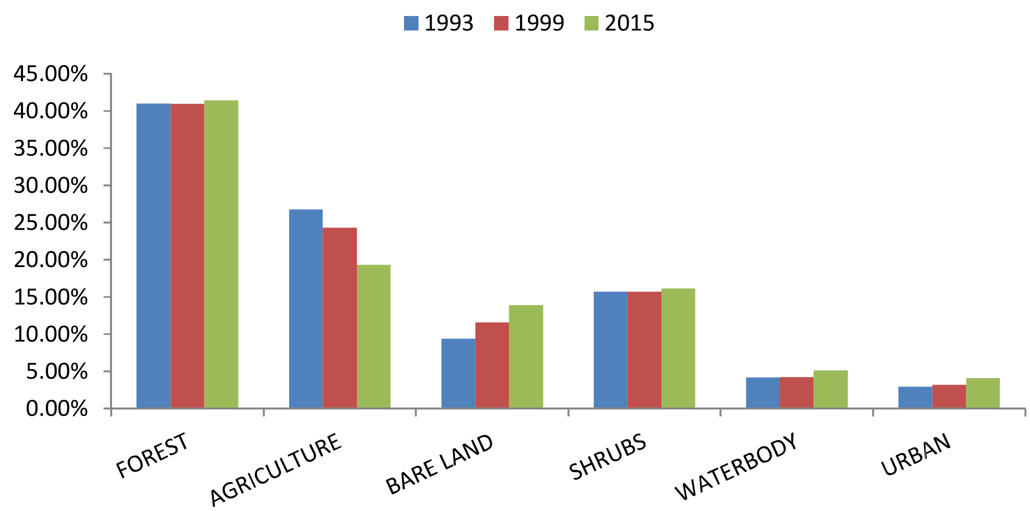

Fig. 5. Bar chart diagram of the percentage of different LULC in Aglar watershed

Following the classification of an image, accuracy assessments were performed on the thematic information. The accuracy assessment of the classification was carried using Reference ground truth data with GPS and GIS layers collected with Simple Random Sampling method. In this method the reference observations are randomly placed and the random location points in the classified image are compared with the actual LULC in the area by ground truthing. The user's accuracy determines the probability accuracy with which a classified pixel from the (LULC) map accurately corresponds with the actual referenced data [7]. The difference between the true agreement and the chance agreement of classified map of random classifier are compared to reference data is measured by the Kappa statistics [8]. The Kappa values range between 0 and 1. For good classification results, the kappa values should be greater than 0.80. The classification is said to be moderate when the Kappa values lie between 0.40 and 0.80 and poor when the Kappa values of less than 0.40 [7]. Keeping in view those numbers this study has been on high accuracy side with kappa statistic for different years tabulated below.

Table 3. Kappa statistic values of the classification.

Year	Kappa Coefficient	Accuracy
1993	0.81	83.88%
1999	0.82	85.62%
2015	0.84	88.14%

To analyze the possible causes of land degradation various factors were taken into account and analyzed for their possible effect on LULC. It was observed and derived from the LULC maps and data analysis that between 1993 and 2015, it is mainly agricultural land that has got converted into bare land. In order to evaluate the effect of slope on soil erosion on a particular LULC class, the slope map of the catchment was divided into 8 different classes with slope (>10°) to slope (70°). Distinct slope categories, i.e., steep slope to very steep slope lands (50°), which occurred in the southern aspect of the watershed; moderate slope lands were present in the northern aspect, and the central part of the watershed was relatively flat area. The moderate to steep sloped lands were mostly either cultivated or bare and these were the areas where significant change in the LULC was observed. Steep sloped areas which were covered by forests did not experience much change possibly because of the plantation drives carried by Uttarakhand forest task force. It was found that around 10.81% of the total area of the watershed has a slope >45° and 89.35% of the total area has a slope>15°. Based on the detailed survey of the maps and local survey, it was found that prolonged cultivation of the steeply sloped lands lead to reduction in the nutrient content which hence became unsuitable for cultivation. Soils in steep sloped areas cultivated without any required soil conservation measures lead to soil erosion and nutrient depletion. The presence of steep slopes land coupled with cultivation and the climate of the area is one of the possible causes of land degradation.

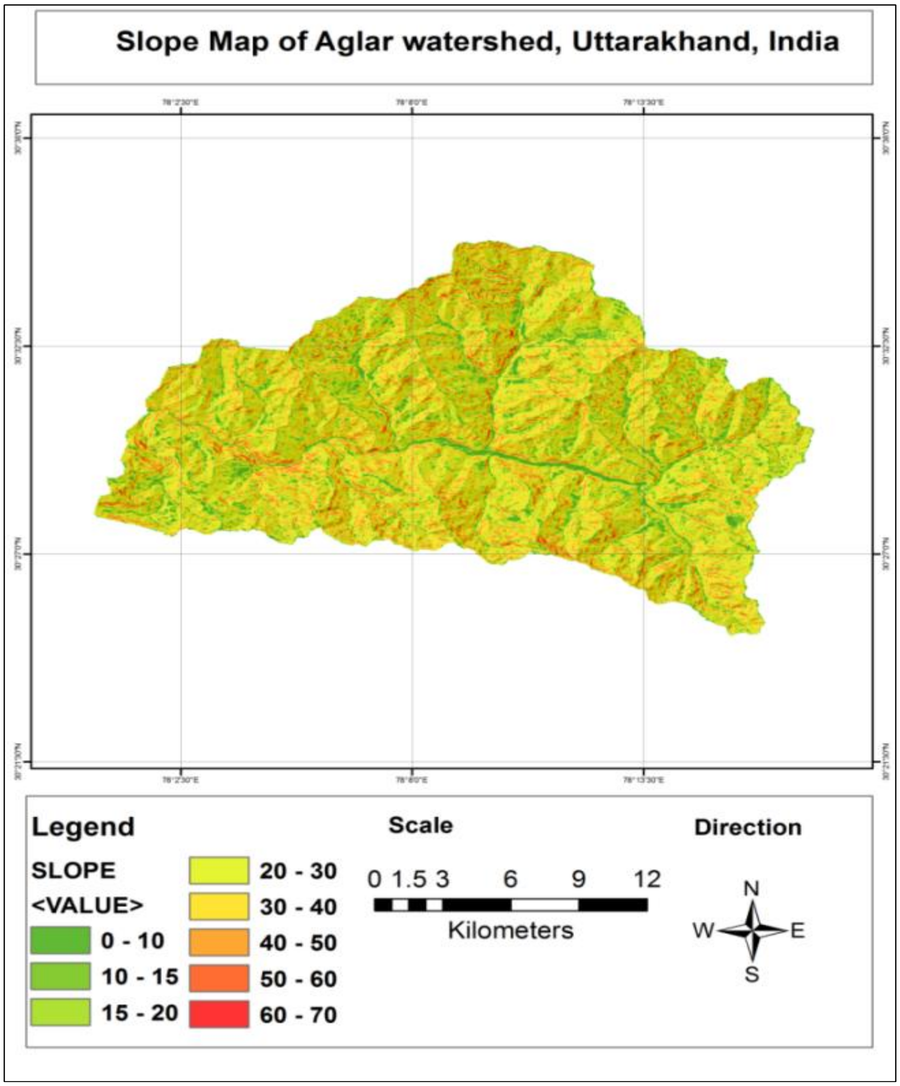

Fig. 6. Slope map of Aglar Watershed

The forests remained almost unchanged showing a change of nearly 1%. Some of the forest area had been cleared for settlement in watershed and a certain area of forest land has undergone degradation due to erosion especially in the degradation prone southern aspect, but the decrease was balanced by afforestation. Eco Task Forces 127 battalion began working in Aglar Micro Watershed area from 1994 onwards and planted an area of 2400 hectares till 2007-08 from 2002-03.Aspect gives the direction to which a cell is facing and hence the direction of the slope. The aspect has an impact on the type of vegetation growing on the area. In fact, it is one of the major factors determining the Land-Cover of Aglar watershed. Aspect affects the moisture retention, weathering and soil structure of a watershed and hence has a profound effect on the Land-Cover of the area. [9] applied an analytical approach in a semi-arid area in southeast Spain using simple modeling and found that aspect plays an important role in controlling the distribution of plants and vegetation communities. It was also concluded that the variation in the vegetal cover with the aspect is a result of difference in the soil moisture rates and hence it can be derived that aspect plays an important role in the plant diversity and hence land cover. The aspect hence has an impact on the type of vegetation growing on the area since it affects the moisture retention, weathering and soil structure. Hence it was observed that north aspect is much more vegetated owing to availability of plenty of sunshine and moisture. The soil resource map of the area was developed with reference to National Bureau of Soil Survey. The soils in the south aspect with soil association number 26, where most of the change and degradation has taken place are classified as Lythic Udorthents. These soils belong to very steeply to steeply sloped hills. These soils are slightly to moderately acidic, very severely eroded with high percentage of stoniness (>40%). Moderate to steeply sloping hills consists of moderately shallow to moderately deep, excessively drained, coarse- loamy/ loamy-skeletal classified as Typic Cryorthents. These soils are highly susceptible to degradation. T-factor or Tolerance factor which is described as the ability of a soil to resist degradation varies from 1 to 5 with 1 being the soils least tolerant to erosion [10]. The T-Factor for these soils is 1 which indicates that these soils are fragile and highly susceptible to degradation.

Table 4. Soil classification table showing types of soil in Aglar watershed

Soil association number	Soil type	Erosion Intensity
22	Typic Udorthents	Very Severe
48	Lithic Udorthents	Moderate
11	Typic Udorthents	Severe
14	Typic Hapludolls	Moderate
25	Dystric Eutrudepts	Moderate
45	Typic Dystrudepths	Moderate
55	Typic Udorthents	Severe
26	Typic Udorthents	Moderate

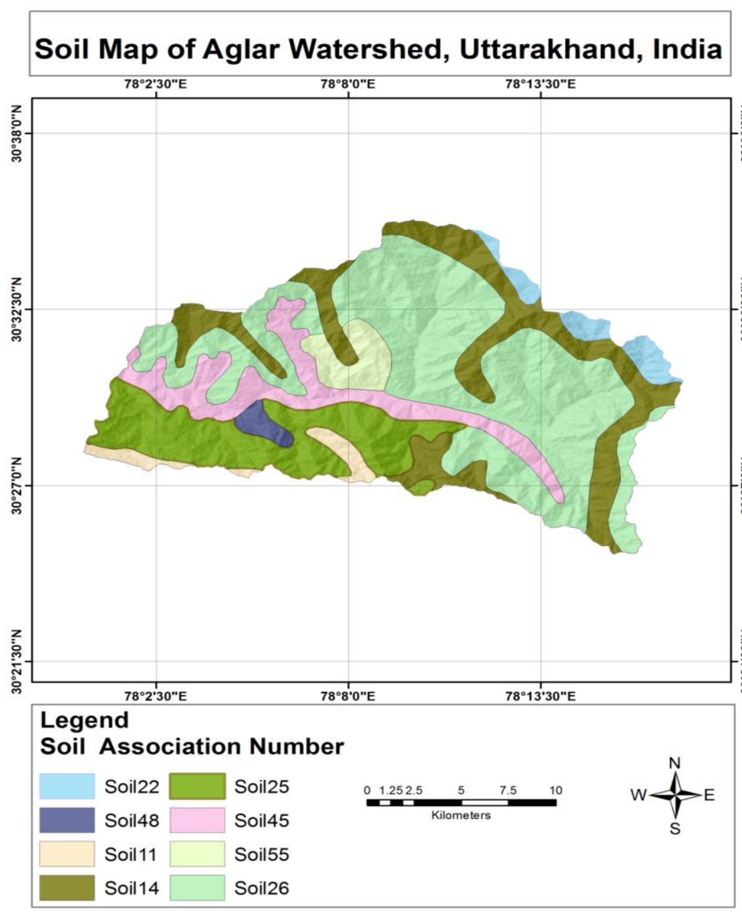

Fig. 7. Classified soil map of Aglar watershed

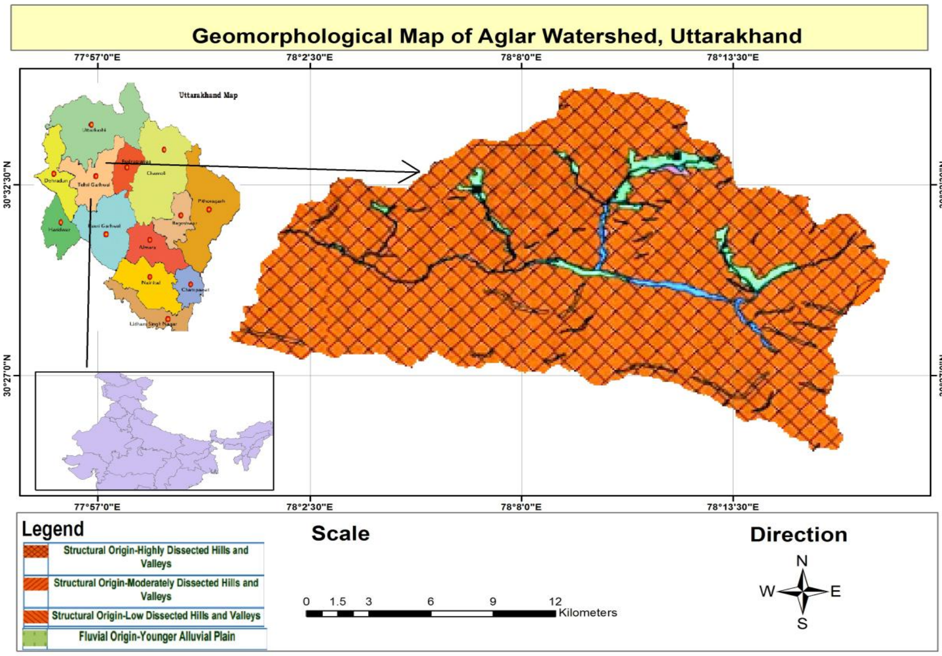

Fig. 8. Geomorphological map of Aglar watershed, Uttarakhand

A geo-morphological map of the study area of scale 1:50000 was prepared from Bhuvan Indian Geo-platform of ISRO prepared under a National Level Mapping project of ISRO's (Indian Space Research Organization). The mapping shows that most of the area comprises of highly dissected hilly although structural in origin which may be another reason for the changing landscape and degradation in the area. The geomorphology was studied on the basis of the visual interpretation of satellite data along-with the DEM of the Aglar watershed. Two major geomorphic units can be broadly delineated from the map which includes highly dissected structural hills in the major part of watershed and younger alluvial plains. Other minor landforms can also be found dotting the two major geomorphic units. The major part of the watershed is highly dissected leading to the extensive erosion through fluvial action and mass movement. The erosional dissection is found to be controlled by the fracture pattern of the bedrock or the lineaments. In general, the higher degree of dissection leads to increase the intensity of degradation and loss of cultivable soil. A high degree of dissection by gullies on hill-slopes and mass movement due to landslides all contribute to the changing landscape. [11] found that fractures control the erosion of the rock and thereby the landforms, e.g. the relation between the drainage system and the fracture configuration in bedrock.

Another most important reason for the change in the Land-Cover/ Land-Use in the study area is the series of high intensity rainfall events that occurred in 2013. Since most of the soil around the water bodies was of fluvial origin and hence fertile, most of the agriculture was practiced. It has been observed that most of the agricultural land around the rivers was washed off and these lands are bare on the basis of the digital data analysis, ground truth and survey with locals of the area. Utilizing the steep sloped lands for agricultural purposes without any management practice also renders the land vulnerable to degradation.(Reply to HC16 Ahm A:-This watershed has a river centered between north and south aspect which is mountainous and rough terrain. The area lying in the flood plain got washed off during Uttarakhand floods. The cultivation on slopes discussed here can be related to the rest of area including those cultivated steep slopes)

4. CONCLUSION

It can be concluded from the initial results that the Aglar watershed has indeed undergone a change in Land use/ Land cover (LULC) from year 1993 to 2015. Out of all six LULC classes, major changes have occurred in bare land areas which showed a continuous increase and at the same time agricultural land showed a decrease of 27.78%. All these results infer and establish the apprehensions of the locals that the area is turning more into a barren and uncultivable area. It is basically the apprehensions of the local community about the changing landscape that lead to this research work. The results were thus analyzed for the causes which could be responsible for the changes in LULC of the area. Nature of the soils occurring on the moderate to steeply sloped lands combined with cultivation of those slope played an important role in LULC change in the area. The nature of the soils occurring on the moderate to steeply sloped lands combined with cultivation of those slope have played an important role in the degradation. In the low lying areas of the watershed agriculture was the principle source of income and economy. Frequent high intensity rains, flash flood and lack of proper soil conservation measures lead to degradation of soil. It can be also inferred from the results that it is not always the human factors that are responsible for degradation. There are several natural intrinsic factors which actually favor the land degradation in the area though not accounted for, which were studied under the present work. The whole set of changes are the result of complex interaction between various factors. This study shows that, remotely sensed data combined with ground truth data makes it possible to explore the LULC management problems associated with the future growth of the Aglar watershed population. Several Land use plans should be prepared in accordance with a protection strategy. In order to stop further degradation the local administration should work in tandem with planning and environmental protection agencies and hence preserve this precious natural reserve i.e. Land.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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