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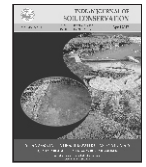

Land use/ land cover change analysis in treated watershed using RS and GIS

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ABSTRACT

Watershed management is a special entity for development of an area. During last four decades a large number of watersheds were treated under various schemes implemented by different Departments and NGOs. Monitoring and evaluation of watershed projects are as important as their implementation. Hence, an attempt was made to study the changes in land use/land cover (LU/LC) in Bino watershed of Uttarakhand to find out the effects of watershed treatment measures and human interference over 30 years (1976-2006) using integrated approach of remote sensing (RS) and geographic information system (GIS). The study has been done through RS approach using Survey of India (SoI) toposheet and satellite imageries of Landsat Multi Spectral Scanner satellite image for 1976, a Landsat Thematic Mapper satellite image for 1999 and an Indian Remote Sensing satellite image for 2006 (IRS-1C, LISS-III) and unsupervised classification was employed. GIS software was used to prepare the thematic maps. Ground truth observations were also performed to check the accuracy of the classification. The classified LU/LC images for 1976, 1999 and 2006 have overall accuracy of 89.1, 89.4 and 90.3% with KAPPA statistic of 86.1, 86.3 and 87.7%, respectively. Results revealed that area under agriculture land and waste land increased while area under open forest and water body declined continuously over the study period. Dense forest area increased during the first (1976-1999) period but decreased slightly during the second (1999-2006) period, whereas the magnitude of shape complexity indices increased substantially. The study reveals that there is the need of further watershed treatment or desilting in the upstream of soil conservation measures and water bodies and preventing the expansion of settlements in the area.

1. INTRODUCTION

Natural resources are the foundation of a healthy and prosperous nation. The long-term sustainability of production and ecological services of these resources is essential for the sustenance of life on the earth. However, excess population is forcing misutilization of natural resources leading to their depletion, pollution and degradation. The Government of India (GoI) has employed watershed management approach to address the foregoing issues, the outcome of which has been fruitful (Sharda *et al.,* 2008; Sudhishri *et al.,* 2014a; Sudhishri *et al.,* 2006; Sudhishri and Kumar, 2011 and Sudhishri and Dass, 2012).

Land use/land cover (LU/LC) change is one of the important factors that determine the impacts of implementation of watershed interventions. Land use is the intended employment of land management strategy placed on the land cover by human agents or land managers to exploit the land cover and reflects human activities. On the other hand, land cover is defined by the attributes of the earth's land surface captured in the distribution of vegetation, water, desert and ice and the immediate subsurface, including biota, soil, topography, surface and groundwater and it also includes those structures created solely by human activities such as mine exposures and settlement (Lumbin *et al.,* 2003).

LU/LC change is a dynamic process owing mainly due to implementation of different conservation measures and afforestation/reforestation as well as socio-economic environment in the watershed (Bisht and Kothyari, 2001), which has also been observed by Hu *et al.* (2012) in Jiuxiang river watershed showing the great change in the watershed land use structure and need for initiating different watershed measures to achieve land resources sustainable use. Therefore, LU/LC dynamics are important elements for monitoring, evaluating, protecting and planning for watershed resources. These are major issues and challenges for the eco-friendly and sustainable development for the economic growth of any area. Chakraborty (2001) studied the LULC change in Birantiya Kalan watershed in the district of Pali, western Rajasthan to observe the changes over a span of 1988-1996 using Indian Remote Sensing Satellite Data and ARC/INFO-Geographic Information System (GIS). Some studies (Mahajan *et al.*, 2001; Mahajan and Panwar, 2005; Sarma *et al.*, 2001; Gautam *et al.*, 2003; Joshi and Gairola, 2004; Chauhan and Nayak, 2005; Jianchu *et al.*, 2005; Raju and Kumar, 2006; Bhandari and Grant, 2007; Sharma *et al.,* 2007 and Bansal *et al.,* 2012 and Kumar *et al.,* 2011) have shown the use of Remote Sensing (RS) and GIS in LULC change detection.

RS data because of its synoptic, multi-spectral and multi-temporal nature made possible to understand landscape dynamics-detect, identify, map, and monitor differences in LU/LC patterns over time, irrespective of the causal factors. Analysis and presentation of such data, on the other hand, can be greatly facilitated through the use of GIS technology. A combined use of RS and GIS technology, therefore, can be invaluable to address a wide variety of resource management problems including LU/LC changes (Gangopadhyay *et al.*, 2014).

The Himalayan region (51.3 M ha) has steep slopes and yields the average soil loss of 20 t ha^{-1} yr^{-1}; in some cases as high as 80 t $ha^{-1}yr^{-1}$ (Samra, 2002). The state of Uttarakhand has 92.57% area under hills and 7.43% under valleys and plains (Sudhishri *et al.,* 2014b). The net cropped area of the state is about 1.26 M ha of which 26.9% is irrigated. The state has a forest cover of 65% which is under tremendous biotic pressure. Most of the catchment area of Ramganga river falls in the outer Himalayan ranges and only a small portion is in the Himalayan foothills and the Shiwaliks. The Ramganga reservoir (Kalagarh Dam) constructed during 1974-75 across the river Ramganga, serves the nation through power generation, flood mitigation, irrigation and water supply, recreation and holding wild life habitats and parks. But, high erosion and degradation/depletion of natural vegetation have caused heavy siltation in the reservoir. Therefore, for natural resource conservation and reducing high sediment rate in the Ramganga catchment, the programme on intensive afforestation and soil conservation measures have been undertaken starting from 1962 under various nationally and internationally funded watershed management programmes (Consultancy Report, 1989). The current study was carried out to know the effects of these watershed measures implemented since 1962 and demonstrates the application of multi-temporal satellite images along with GIS in defining LU/LC dynamics of Bino watershed located under Ramganga catchment of Uttarakhand state in outer Himalayan region over a span of 30 years (1976-2006).

2. MATERIALS AND METHODS

Study Area

River Ramganga, a major tributary of the river Ganga, originates in the outer Himalayas in Chamoli district of Uttarakhand. It travels through the districts of Chamoli, Almora, Nainital and Pauri Garhwal and then enters the plains near Kalagarh after coursing through about 168 km in hilly terrain. The watershed area of the Ramganga river and its tributaries up to Kalagarh dam site is 3339.26 km^2 (Sharda *et al.*, 2008) in a shoe like shape and lying between $78^0 35'$E to 79^0 $34'$E longitude and $29^0 30'$N to $30^0 6'$N latitude. Out of this watershed area, 45.8, 11, 41.4 and 1.8% is under Almora, Chamoli, Pauri Garhwal and Nainital districts, respectively. Most of the catchment area falls in the outer Himalayan ranges and only a small portion is in the Himalayan foothills and the Shiwaliks. The elevation of the catchment above mean sea level (msl) varies from 260-2950 m (Consultancy Report, 1989). Out of 11 sub-watersheds of Ramganga catchment, Bino sub-watershed has been selected to conduct various investigations in the present study.

Location and Climate

The study area, Bino sub-watershed (hereafter will be referred to as Bino watershed) of the river 'Bino' with an area of 29617.75 ha is situated in North-Eastern part of Ramganga catchment in middle and outer ranges of Himalayas between $79^0 6' 14.4''$ to $79^0 17' 16.8''$ E longitude and $29^0 47' 6''$ to $30^0 02' 9.6''$ N latitude in Almora and Pauri Garhwal district of Uttarakhand. The watershed drains into Bino (a tributary of Ramganga river) through its outlet. Climate of the watershed varies from Himalayan sub-tropical to sub-temperate having mean annual maximum and minimum air temperature of 30^0C and 18^0C, respectively. The daily mean temperature remains high during months of May and June, and minimum in December and January. The area experiences three distinct seasons, *viz.,* long winter (October-March), summer (April-mid-June) and monsoon (mid-June-September). The mean annual rainfall in the area is 931.3 mm (Sudhishri *et al.,* 2014b and Sudhishri *et al*., 2016). Severe frost occurs during nights from mid-December-February and more than 70% of the rainfall occurs from south-west monsoons.

Soils and Physiographical Characteristics

The Bino watershed with mean length of 28.46 km and mean width of 17.27 km has undulating and irregular slopes varying from moderate to steep in valley areas on either sides of the Bino river. The maximum and minimum elevations in the watershed are respectively 2884 m and 802 m above msl. Based on general slope in different portions of watershed, the land may be categorized as valley, moderate and steep hill areas. More than 75.31% of the watershed area falls under a medium to steep slope class of more than 25% with an average slope of 37.43% (Sudhishri *et al.,* 2014b). Soils are coarse textured varying from sandy loam, loam and sandy clay loam, stony and are highly erodible. At higher elevations, mostly sandy loam soils are found with 32-68 cm depth and containing about 21.96 to 45.45% gravel. Soil depth at lower altitudes varies from 43-110 cm, while deep soil belts occur in the alluvial deposits of the river bed. Soil pH is mostly on acidic side ranging from 4.52-6.6. Soils under the reserved forest are fairly good, medium to deep and rich in organic matter, but soils under pastures, waste lands and poorly managed civil and vanpanchayat forests are severely overgrazed and eroded.

Land Use and Cropping Pattern

About 49.7% of the watershed area is under forest and 29.4% under agricultural land in 2006. The forested area is mainly covered with chir pine (*Pinus roxburghii)* and *banj* oak (*Quercus leucotrichophora*) forest trees. Oak species are fire susceptible, nutrient demanding and sensitive to disturbances. The cultivable lands, in general, are under poorly managed terraces and are susceptible to severe erosion. The pasture lands and waste lands have a poor vegetation cover and are severely eroded. Fruit trees like apple, pears, plum, walnut and apricot are found at higher elevations and whereas citrus, guava, mango, litchi trees are found at lower and medium elevations of the watershed. The commonly found grasses are *Chrysopogan Heteropogan* and *Eragrostis curvula*.

On rainfed terraced fields, crops like paddy, finger millet (*mandua*), barnyard millet (*jhingora*), maize, pulses, buck wheat, amaranths, potato are grown in *kharif*, while wheat, lentil are grown in *rabi*. Whereas, on irrigated terraces crops like paddy and vegetables in *kharif* and wheat, berseem and vegetables in *rabi* are grown. In rainfed areas of mid-hills, the most prevalent cropping sequences are spring rice/barnyard millet/spring chilli (March/April-September)-wheat (October-May)-finger millet (June-October)-fallow (November-February) *i.e.* 3 crops are taken in two years which has a cropping intensity of 150%. In irrigated valley areas, rice (June-October)-wheat (November-May) and rice (June-October)-fallow (November-January)-potato (February-May) are the most commonly practiced cropping sequences.

Data Extraction Using GIS

Various steps and techniques involved to extract required data using GIS are described in the following sections.

Geo-referencing and Mosaicing of Toposheets

Survey of India (SoI) toposheets no. 53 N/4, 53 N/8, 53 O/1, and 53 O/5 of the scale 1:50,000, which comprised total watershed area were collected from SoI, Dehradun and Central library of GB Pant University of Agriculture and Technology library and used for delineation of watershed. These toposheets were scanned (*.jpeg format*) and geo-referenced and these were joined to form complete image of the study area using ERDAS Imagine 9.0 software. Watershed boundary, and its area and perimeter calculation were done using ArcGIS (ArcView) 9.3 software and found to be 29617.75 ha and 83.243 km, respectively.

Pre-processing of Remote Sensing Data

The main data used in the study included a Landsat Multi Spectral Scanner satellite image (hereafter MSS image) for 1976, a Landsat Thematic Mapper satellite image for 1999 (hereafter TM image) and an Indian Remote Sensing satellite image from 2006 (IRS-1C, LISS-III; hereafter IRS image).

Satellite type	Sensor	Number of bands	Path/Row	Pixel spacing (m x m)	Observation date
Landsat 2	MSS	4	156/39	57 × 57	19 November 1976
Landsat 4	TM	7	145/39	28.5 × 28.5	15 October 1999
IRS-1C	LISS-III	4	-	23.5 × 23.5	*rabi* season, 2006

Layer stacking and subsetting of satellite images were done and then false colour composite (FCC) of images was prepared using ERDAS IMAGINE 9.0 software. A brief description of the satellite images used is given below.

Land Use/ and Land Cover Classification

To identify various land features by digital analysis of satellite data, an unsupervised classification was done using ERDAS 9.0 software assigning 150 numbers of classes initially. Finally these classes were reclassified using ArcGIS and clubbed into six classes for 2006 and five classes for 1976 and 1999 each based on similarity in texture and tone of images and the information available from landuse reports and field surveys. The ground-truth information required for the classification accuracy assessment was collected from the field during July 2008 and October 2009. The LU/LC classes present in the study area included dense forest, open forest, agriculture land, waste land, and water bodies for 1976 and 1999. For 2006 landuse were classified as dense forest, open forest, rainfed agriculture land, irrigated agriculture land, waste land, and water bodies. But in reality it has been classified into five classes and as mentioned for 2006, agricultural land was divided into rainfed agricultural land (simply written as agricultural land in map) and irrigated agricultural land as this map was used for further erosion assessment (Sudhishri *et al.,* 2014) study. So overall, the LU/LC classes were divided into five classes *i.e.* dense forest, open forest, agriculture land (*i.e.* total of rainfed and irrigated agricultural land), waste land, and water bodies. When the maps of 1976/1999 overlaid on the map of 2006, the merging of rainfed or irrigated land with agricultural land of 1976/1999 were considered under agricultural land only.

Accuracy Assessment

The increased usage of RS data and techniques has made geospatial analysis faster and more powerful, but the increased complexity also creates increased possibilities for error. In the past, accuracy assessment was not a priority in image classification studies. Because of the increased chances for error presented by digital imagery, however, accuracy assessment has become more important than ever (Congalton 1991). Classification accuracy was calculated by preparing the classification error matrix and assessment was made using the field data *i.e.* ground truthing. Error matrices were generated to assess the producer's accuracy, user's accuracy and overall classification accuracy. The overall accuracy was calculated by summing the number of pixels classified correctly and dividing them by the total number of pixels. The producer's accuracy was computed by dividing the number of correctly classified pixels in each category by the number of training set pixels used for that category. Whereas, user's accuracy was computed by dividing the number of correctly classified pixels in each category by the total number of pixels those were classified in that category (Iqbal *et al.,* 2014). Using the same error matrices developed for the year 1976, 1999 and 2006. Another discrete multivariate technique of use in accuracy assessment is called KAPPA. The result of performing a KAPPA analysis is a KHAT static (an estimate of KAPPA), which is another measure of agreement or accuracy. KAPPA coefficient or KHAT statistic was computed for each year using following eq. 1 (Congalton, 1991).

$$K^{\wedge} = \frac{N\sum_{i=1}^{r} x_{ii} - \sum_{i=1}^{r}(x_{i+} * x_{+i})}{N^2 - \sum_{i=1}^{r}(x_{i+} * x_{+i})} \qquad ...(1)$$

Where, r is the number of rows in the matrix, x_{ii} is the number of observations in row i and column i, x_{i+} and x_{+i} are the marginal totals of row i and column i, respectively, and N is the total number of observations.

Detection of LU/LC Changes and Quantification of Landuse Change Index

Classified images for 1976, 1999 and 2006 were exported to ArcView GIS version 9.3 (ESRI, Redlands, USA) from ERDAS IMAGINE and rest of the analysis was performed in GIS environment. The images were first converted to grid in Arcview and then to the shape format. The polygon themes were generated and used for further analysis. The degree of individual LU/LC change (LC) was calculated by using eq. 2 as proposed by Wang (2000).

$$LC = \frac{U_b - U_a}{U_a} \times \frac{1}{T} \times 100 \qquad ...(2)$$

Where, LC represents the degree of percentage LULC change, U_a the amount of the particular landuse at beginning of year 'a', U_b the amount at the end of year 'b' and T represents the length of period in years of the study. When the unit of T is set as a year, LC indicates the degree of annual individual landuse dynamics.

Detection and Analysis of Year Wise Trend and LU/LC Change Pattern

The land use polygons themes for 1976 and 2006, obtained from the digital classification of satellite data and subsequent GIS analyses using the method described above were overlaid by 'union' option two at a time in ArcGIS and the area converted from each of the classes to any of the other classes was computed from attribute table. The number of land use plots under each LU/LC class, their areas and perimeters in the year 1976 and 2006 were determined using information contained in the LU/LC maps developed for respective periods. The degree of irregularities of different land use plots described in terms of a shape complexity index (SCI) was then calculated using eq. 3 as proposed by Kammerbauer and Ardon (1999).

$$SCI = \frac{\textit{Average perimeter of a particular landuse plots}}{\textit{Average area of the same landuse plots}} \quad ...(3)$$

A higher value of the SCI indicates more irregular patch forms (Gautam *et al.,* 2003).

3. RESULTS AND DISCUSSION

To determine temporal landuse change indices for the study watershed, the LU/LC maps were generated for the years 1976, 1999 and 2006 based on FCC of downloaded satellite imageries and are shown in Fig. 1, Fig. 2 and Fig. 3, respectively.

Accuracy Assessment

For accuracy assessment the producer's accuracy, user's accuracy, overall accuracy and KAPPA statistics were calculated for all the three images by generating error matrices. The overall accuracy of the LU/LC information for 1976, 1999 and 2006 were found to be 89.1, 89.4 and 90.3%, whereas, KAPPA statistics were 86.1, 86.3 and 87.7%, respectively (Table 1). This accuracy level is in agreement with the standard

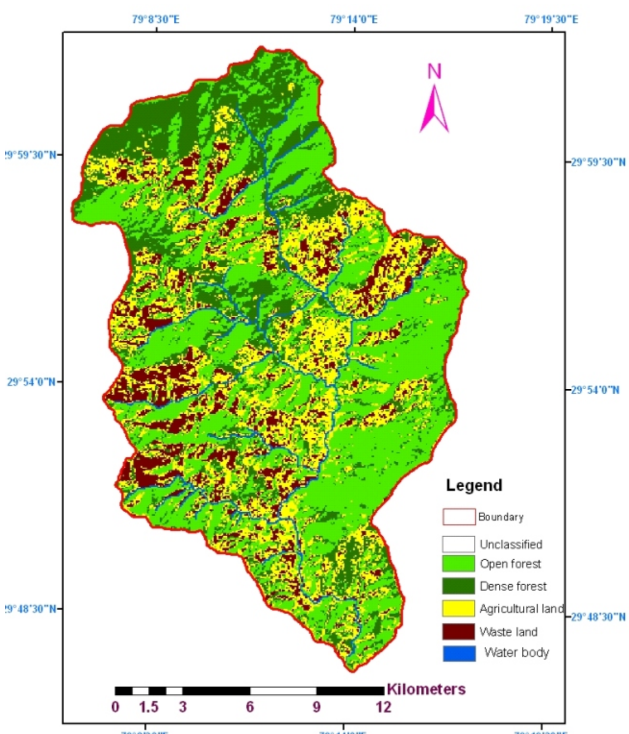

Fig. 1. Land use/ land cover map for the year 1976 in the study watershed

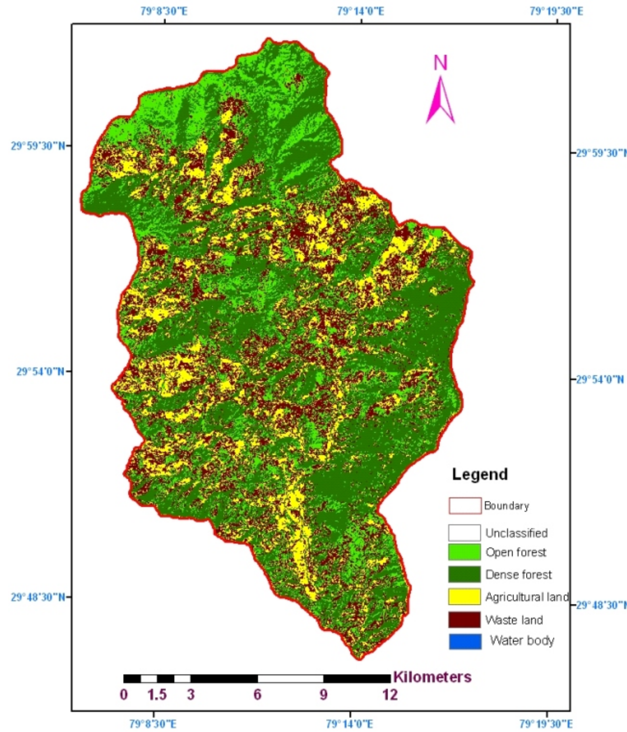

Fig. 2. Land use/land cover map for the year 1999 in the study watershed

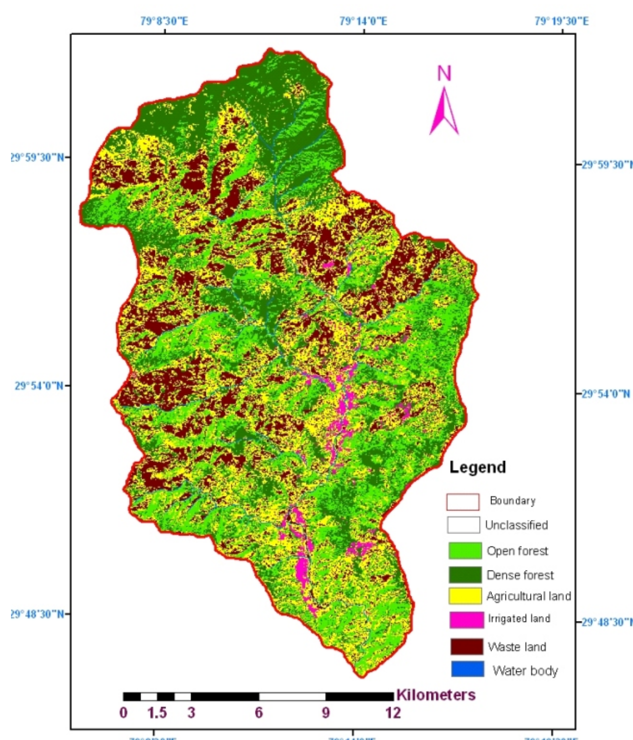

Fig. 3. Land use/ land cover map for the year 2006 in the study watershed

accuracy of 85-90% for LU/LC mapping studies as recommended by Anderson *et al.* (1976).

Change Detection

The LU/LC classes present in the study area include dense forest, open forest, agriculture land, waste land, and water bodies for 1976 and 1999. For 2006 LU/LC were classified as dense forest, open forest, rainfed agriculture land, irrigated agriculture land, waste land, and water bodies. The area under different LU/LCs was given in Table 2 and Fig. 4. It was found that in the year 1976, the watershed was having 70.12 (23.68%), 116.77 (39.43%), 67.16 (22.67%), 34.88 (11.78%), and 7.25 (2.45%) km^2 under dense forest, open forest, agriculture land, waste land and water body, respectively, whereas, area under

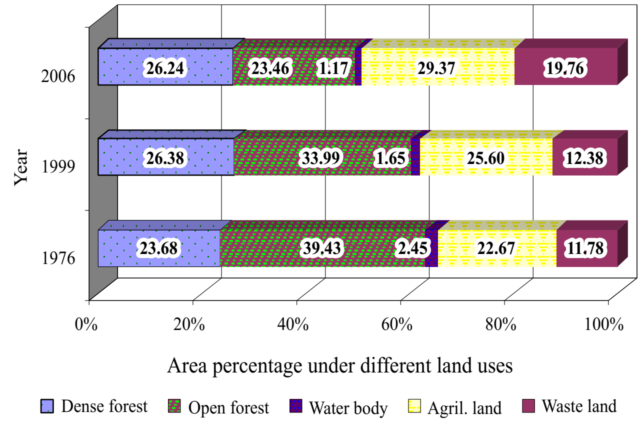

Fig. 4. Land use/ land cover dynamics (1976-2006) in the study watershed

Table: 1
Classification accuracy assessment using error matrix for different years under study

Classification	Dense forest	Open forest	Agril. land	Waste land	Water body	Row total	Producer's accuracy %	User's accuracy %
Classification accuracy assessment for the year 1976								
Dense forest	79	6	4	3	0	92	84.9	85.9
Open forest	10	68	2	0	0	80	85.0	85.0
Agril. Land	4	0	80	9	0	93	87.9	86.0
Waste land	0	6	5	42	0	53	77.8	79.2
Water body	0	0	0	0	132	132	100.0	100.0
Column Total	93	80	91	54	132	450		
Overall accuracy % = 89.1, Kappa coefficient= 86.1%								
Classification accuracy assessment for the year 1999								
Dense forest	81	2	8	4	0	95	82.7	85.3
Open forest	9	74	2	0	0	85	88.1	87.1
Agril. Land	8	2	73	4	0	87	85.9	83.9
Waste land	0	6	2	33	0	41	80.5	80.5
Water body	0	0	0	0	134	134	100.0	100.0
Column Total	98	84	85	41	134	442		
Overall accuracy % = 89.4, Kappa coefficient = 86.3%								
Classification accuracy assessment for the year 2006								
Dense forest	94	10	0	2	0	106	89.5	88.7
Open forest	2	68	8	0	0	78	84.0	87.2
Agril. Land	9	0	76	4	0	89	83.5	85.4
Waste land	0	3	7	46	0	56	88.5	82.1
Water body	0	0	0	0	137	137	100.0	100.0
Column Total	105	81	91	52	137	466		
Overall accuracy % = 90.3, Kappa coefficient = 87.7%								

Table: 2
Temporal changes in different landuse classes and their indices in the study watershed

Landuse	Area (ha)			Area change (ha)			Area change (%)			Annual landuse change index		
	1976	1999	2006	1976-1999	1999-2006	1976-2006	1976-1999	1999-2006	1976-2006	1976-1999	1999-2006	1976-2006
Dense forest	7012.04	7813.40	7771.68	801.36	-41.72	759.64	2.71	-0.14	2.56	0.50	0.08	0.36
Open forest	11676.98	10066.27	6949.21	-1610.71	-3117.06	-4727.77	-5.44	-10.52	-15.96	0.60	4.42	1.35
Agril land	6715.68	7580.87	8697.49	865.18	1116.62	1981.80	2.92	3.77	6.69	0.56	2.10	0.98
Waste land	3488.45	3667.69	5852.04	179.24	2184.36	2363.59	0.61	7.38	7.98	0.22	8.51	2.26
Water body	724.60	489.52	347.33	-235.07	-142.19	-377.27	-0.79	-0.48	-1.27	1.41	4.15	1.74

these land uses in the year 1999 were 78.13 (26.38%), 100.66 (33.99%), 75.81 (25.60%), 36.68 (12.38%) and 4.9 (1.65%) km^2, respectively. Area under above LULC classes, during the year 2006 were 77.72 (26.24%), 69.49 (23.46%), 86.97 (29.37%), 58.52 (19.76%), and 3.47 (1.17%) km^2, respectively. During the year 2006 out of total agriculture land, 80.50 and 6.47 km^2 was under rainfed and irrigated land, respectively. Results showed that area under agriculture land and waste land increased while area under open forest and water body declined continuously over the study period. Dense forest area increased during the first (1976-1999) period but decreased slightly during the second (1999-2006) period. A detailed losses and gains among the five landuse classes over the study period (1976-2006) are given in Table 3 and Table 4.

Among the major landuse groups, around 45.56% of open forest, 47.35% of dense forest, 49.10% of agriculture, 62.27% of waste land and 36.70% of the water body area in 1976 remained unchanged until 2006. Open forest and water body area shrunk by about 31.68% and 50.02% of 1976 area, respectively in between 1976 and 2006. Open and dense forest lost 54.44% and 52.65% of its 1976 area to other classes and gained 22.76% and 57.97% (Table 3) from other classes. The very high losses from dense forest and agricultural lands were only partially compensated by gains from other classes.

It was found from Table 4 that about 30.67% of open forest area was converted to dense forest due to increase in plantation by Forest and Horticulture Department. About 30.84% of the dense forest area was also converted into agricultural land due to encroachment of forest area for agriculture. Due to migration of local people and decreased interest in rainfed farming about 34.05% of the agricultural land also was converted into waste land. It was observed that some of the waste land was also changed to agricultural land (30.85%). The area under various water bodies was found to be reduced by about 50% as water body area was converted to open forest (25.36%), agricultural land (20%) and waste land (6%) due to boulder and sediment deposition, plantation on stream banks and implementation of soil conservation programs in the area.

Above analysis indicated that the changes in landuse pattern from 1976 to 2006 were quite diverse. The change index ranged from 0.22 (waste land) to 1.41 (water body) during 1976-1999, 0.08 (dense forest) to 8.51 (waste land) during 1999-2006 and 0.36 (dense forest) to 2.26 (waste land) during 1976 to 2006. Other significant changes included a 5% decrease in open forest and a 3% increase in agricultural land during 1976-1999, 11% decrease in open forest and a 7% increase in waste land during 1999-2006, 16% decrease in open forest and an 8% increase (Table 2) in waste land during 1976-2006.

LU/LC Change Pattern

Change in LU/LC pattern was studied using LU/LC maps

Table: 4
Percent change of land uses among landuse classes in study watershed

Landuse class		Class wise per cent change	Total Change (%)
Changed from	Changed to		
Open forest	Dense forest	30.67	54.44
	Agril Land	18.22	
	Waste land	5.46	
	Water body	0.09	
Dense forest	Open forest	11.70	52.65
	Agril Land	30.84	
	Waste land	9.96	
	Water body	0.14	
Agril. land	Open forest	7.37	50.90
	Dense forest	9.22	
	Waste land	34.05	
	Water body	0.27	
Waste land	Open forest	2.01	37.73
	Dense forest	4.66	
	Agril Land	30.85	
	Water body	0.21	
Water body	Open forest	25.36	63.30
	Dense forest	11.88	
	Agril Land	20.05	
	Waste land	6.01	

Table: 3
Overview of change in major landuse groups from 1976-2006

Landuse	Percent of landuse in 1976			Net gain/loss (%)
	Unchanged in 2006	Lost to other classes in 2006	Gained from other classes in 2006	
Open forest	45.56	54.44	22.76	-31.68
Dense forest	47.35	52.65	57.97	5.32
Agril Land	49.10	50.90	59.40	8.50
Waste land	62.27	37.73	62.58	24.85
Water body	36.70	63.30	13.28	-50.02

Table: 5
Patchiness of different land uses in the year 1976 and 2006

Landuse	Average area (ha)		Average perimeter (m)		Shape complexity Index (m ha^{-1})	
	1976	2006	1976	2006	1976	2006
Open forest	9.89	0.72	1160.40	342.70	117	479
Dense forest	2.47	0.85	545.28	324.63	221	382
Agril Land	2.64	0.60	693.00	341.26	262	573
Waste land	3.27	0.69	717.07	287.62	220	416
Water body	851.46	358.62	246789.14	253889.70	290	708

of 1976 and 2006 through its patchiness calculated by using a SCI. An analysis of changes in shape of the above five LU/LC plots revealed that the number of patches under all the LU/LC classes increased continuously over the period. As shown in Table 5, average area and average perimeter of each LU/LC plots (*i.e.* patch) decreased substantially over the study period, whereas shape complexity indices increased substantially. Increase in SCI values was due to the fact that there was random heterogeneity in landscape (Table 4) which might be due to expansion of settlements, infrastructural development, plantations and implementations of other conservation works by different Government Departments and NGOs in the area.

4. CONCLUSIONS

The study was attempted to know the effects of different watershed interventions carried out in Bino watershed since 1962-63 and demonstrates the application of multi-temporal satellite images in defining LU/LC dynamics over a span of 30 years (1976-2006). Integrated approach of RS and GIS application was applied for detecting the temporal change in land use/land cover using generated land use/land cover maps for the year 1976, 1999 and 2006. The overall accuracy and KAPPA statistics of the classified images were 89.1, 89.4, 90.3% and 86.1, 86.3, 87.7% for 1976, 1999 and 2006, respectively. Variation in different LU/LC classes during 1970-1999, 1999-2006 and 1976-2006 showed that the implementation of various conservation measures in the study watershed had diversified impacts on its LU/LC dynamics. The area under agriculture and waste lands increased while area under open forest and water body declined continuously over the study period (1976-2006). Increase in waste land may be due to conversion of 34.05% of the agricultural land to waste land and this may be due to migration of local people and decreased interest in rainfed farming and also part of the area under various water bodies was converted to waste land (6%) due to boulder and sediment deposition. Dense forest area was found to be increasing during 1976-1999 period but decreased slightly during 1999-2006 period. However, the very high losses from dense forest and agricultural lands were only partially compensated by gains from other classes. Increase in SCI values shows the random heterogeneity in landscape and this may be due to expansion of settlements, infrastructural development and non-functional of soil and water conservation measures due to silting in upstream of the structure. This study emphasizes further implementation of watershed interventions with desilting of water harvesting structures. The approach adopted in this study clearly demonstrated the potential of integration of RS and GIS techniques in measuring the change pattern of LU/LC in Ramganga catchment of Uttarakhand.

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REFERENCES

Anderson, J.R., Hardy, E.E., Roach, J.T., and Witmer, R.E. 1976. A land use and land cover classification system for use with remote sensor data. Washington, DC: Government Printing Office (US Geological Survey, Professional Paper 964). 28 p.

Bansal, Amit, Karwariya, Sateesh and Goyal, Sandip. 2012. Change detection in land use/land cover in sewan watershed using remote sensing and GIS technique. *IJARSG.*, 1(2): 208-217.

Bhandari, B. and Grant, M.R. 2007. Landuse and population dynamics in Kalikhola watershed of Nepal. *J. Rural Community Dev.*, 2: 100-109.

Bisht, B.S. and Kothyari, B.P. 2001. Land cover change analysis of Garur Ganga watershed using GIS/Remote sensing technique. *J. Indian Soc. Remote,* 29(3): 165-174.

Chakraborty, D. 2001. Characterization and spatial modelling for hydrological response behaviour of Birantiya Kalan watershed in western Rajasthan-remote sensing and GIS approach. Ph.D. Thesis. IARI, New Delhi, India.

Chauhan, H.B. and Nayak, S. 2005. Land use / land cover changes near Hazira region, Gujarat using Remote sensing satellite data. *J. Indian Soc. Remote,* 33(3): 413-420.

Congalton R.G. 1991. A review of assessing the accuracy of classifications of remotely sensed data. *Remote Sens. Environ.,* 37:35-46.

Consultancy Report. 1989. Evaluation of effects of soil conservation measures in sedimentation and hydrology of the Ramganga catchment. Project sponsored by Central Water Commission (Govt. of India). Department of SWCE, GBPUAT, Pantnagar, Uttarakhand, India. 219 p.

Gangopadhyay, S.K., Reddy, G.P. Obi and Sarker, Deepak. 2014. Erosion risk mapping in Peruguda micro-watershed of semi-arid mapping using remote sensing and GIS. *Ind. J. Soil Cons.,* 42(1): 29-38.

Gautam, A.P., Webb, E.L., Shivakoti, G.P. and Zoebisch, M.A. 2003. Land use dynamics and land scape change pattern in a mountainous watershed in Nepal. *Agric. Ecosyst. Environ.,* 99: 83-96.

Hu He Bing, Liu Hong Yu, Hao Jing Feng and An Jing. 2012 Analysis of land use change characteristics based on remote sensing and GIS in the Jiuxiang river watershed. *Int. J. Smart Sens. Intelligent Sys.,* 5(4): 811-823.

Iqbal, M.F. and Khan, I.A. 2014. Spatiotemporal land use land cover change analysis and erosion risk mapping of Azad Jammu and Kashmir, Pakistan. *The Egyptian J. Remote Sens. Space Sci.,* 17: 209-229.

Jianchu, X., Xihui, A. and Xiqing, D. 2005. Exploring the spatial and temporal dynamics of land use in Xizhuang watershed of Yunnan, southwest China. *Int. J. Applied Earth Observation Geoinformation.* 7: 299-309.

Joshi, P.K. and Gairola, S. 2004. Land cover dynamics in Garhwal Himalayas- A case study of Balkhilla sub-watershed. *J. Indian Soc. Remote,* 32(2): 199-208.

Kammerbauer, J. and Ardon, C. 1999. Land use dynamics and landscape change pattern in a typical watershed in the hillside region of central Honduras. *Agric. Ecosyst. Environ.,* 75: 93-100.

Kumar, A., Sharma, H.C. and Kumar, S. 2011. Planning for replenishing the depleted groundwater in upper Gangetic plains using RS and GIS. *Ind. J. Soil Cons.,* 39(3): 195-201.

Lambin, E.F., Geist, H.J. and Lepers, E., 2003. Dynamics of land use/cover change in tropical regions. *Annu. Rev. Environ. Resour*., 28: 205-241.

Mahajan, S. and Panwar, P. 2005. Land use changes in Ashwani Khad watershed using GIS techniques. *J. Indian Soc. Remote,* 33(2): 227-232.

Mahajan, S., Panwar, P. and Kaundal, D. 2001. GIS application to determine the effect of topography on landuse in Ashwani Khad watershed. *J. Indian Soc. Remote,* 29(4): 243-248.

Raju, K. and Anil Kumar, R. 2006. Land use changes in Udumbanchola taluk, Idukki district- Kerala: An analysis with the application of Remote sensing data. *J. Indian Soc. Remote,* 34(2): 162-169.

Samra, J.S. 2002. Watershed management: A tool for sustainable production. In: Resource conservation and watershed management technology options and future strategies. Dhyani, S.K., Tripathi, K.P., Singh, R., Raizada, A., Sharam, N.K., Mishra, A.S., Shrimali, S.S., Dhyani, B.L., Sharma, A.R. and Khola, O.P.S. (eds.). Indian Association of Soil and Water Conservationists, CSWCRTI, 218 Kaulagarh Road, Dehradun-248195. Uttaranchal, India. pp. 1-10.

Sarma, V.V.L.N., Muralikrishna, G., Hemamalini, B. and Rao, K.N. 2001. Landuse/land cover change detection through remote sensing and its climatic implications in the Godavari delta region. *J. Indian Soc. Remote,* 29(1&2): 85-91.

Sharda, V.N., Juyal, G.P. and Naik, B.S. 2008. Watershed development in India: Status and perspective. Central Soil and Water Conservation Research and Training Institute (ICAR), Dehradun-248195, India. pp. 172-186.

Sharma, E., Bhuchar, S, Xing, M.A. and Kothyari, B.P. 2007. Land use change and its impact on hydro-ecological linkages in Himalayan watersheds. *Tropical Ecology.* 48(2): 151-161.

Sudhishri, S., Kumar, A. and Singh, J.K. 2016. Comparative Evaluation of Neural Network and Regression Based Models to Simulate Runoff and Sediment Yield in an Outer Himalayan Watershed. *JAST.* 18: 681-694.

Sudhishri, S., Dass, Anchal, Choudhury, P.R., Kumar, Pramod, Lenka, N.K. and Patnaik, U.S. 2014a. People's participation and convergence of Institutions in watershed development in eastern ghats of India: An experience. *Ann. Agric. Res.*, 35(4): 435-444.

Sudhishri, S., Kumar, A., Singh, J.K., Dass, A. and Nain, A.S. 2014b. Erosion tolerance index under different land use units for sustainable resource conservation in a Himalayan watershed using remote sensing and geographic information system (GIS). *Afr. J. Agric. Res.,* 9(41): 3098-3110.

Sudhishri, S. and Dass, A. 2012. Study on the impact and adoption of soil and water conservation technologies in eastern ghats of India. *Journal Agric. Eng.,* 49(1): 51-59.

Sudhishri, S. and Kumar, A. 2011. Comparison of methodologies for prioritization of sub-watersheds considering techno-social aspects: Development of an integrated new approach. *Ind. J. Soil Cons.,* 39(1): 80-87.

Sudhishri, S, Patnaik, U.S., Dass, A. and Dash, B.K. 2006. Participatory water resource development for sustainable tribal agriculture- A case study. *Ind. J. Soil Cons.,* 34(1): 60-64.

Wang, X.L., 2000. The analysis of population factors in land use/land cover change. *J. Resour. Sci. Beijing*., 22(3): 39-42.