Assessment of Habitat Dynamics of Asian Elephant in Shivalik Landscape and its Environs from 1979-2015

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KEYWORDS: Shivalik Landscape, North -Western habitat limit of Asian Elephant, Land Use/Land Cover dynamics, Satellite data, man-elephant conflict.

The updated Landscape maps are essential for management planning and strategic decision making for biodiversity conservation. These are also important for mid-course correction and directing future efforts, because ignorance should not lead to irreparable damage. The Shivalik Landscape of Uttarakhand, Haryana and south eastern Himachal Pradesh is the north-western limit of wild population of Asian elephant. Elephant habitat in this landscape is characterized by mixed moist and dry deciduous forests. Geomorphologically southern aspect is highly dissected supporting mix of dry and moist deciduous forests, while northern aspect has moist deciduous forest of *Shorea robusta* (Sal) and its associates like *Mallotus philippensis* (major fodder species of elephant) and *Lagerstoemia* spp., etc. However, demographic changes including enhanced religious activities and urbanization, patterns of forest resource utilization and cropping, certain management actions, increased industrialization and communication network in last few decades have led to the changes in land use and land cover (LULC) and forest cover density. We have attempted to analyse changes in LULC in last 35 years using satellite remote sensing data with an objective to find out changes LULC and cropping patterns for cash crops and the man-elephant conflict zones. LANDSAT images of 1979, 1991, 2003 and 2015 were used to map forest cover type by integrating dry and wet seasons data to capture phenology using unsupervised classification approach. Mapping accuracy for 1979, 1991, 2003 and 2015 was found 95.107, 94.219, 94.186 and 93.892%, respectively. From 1979 to 2015 about 424% expansion in urbanization was observed at the expense of other land use types, e.g. agriculture land, putting additional pressure on forest resources. A major changes of about 108% was observed between 2003 and 2015. It may suggest as one the major causes for increased man-elephant conflict.

INTRODUCTION

An ever increasing human population and its associated developmental activities has put a tremendous pressure on earth' renewable and non-renewable resources all across the globe. The very change in the land use pattern in recent past, including especially the conversion of forest into non forest land has largely affected the species surviving therein, either at local or the landscape level.

Due to its unique geographical location between two major biogeographic zones *i.e.*, Himalaya (North) and Tarai landscape (South), this landscape has experienced extreme pressure of urban sprawl from both the sides (Sivakumar et al., 2010). Increasing anthropogenic activities in surroundings has resulted in degradation of this ecosystem. Developmental activities like industrialisation, railway and highway construction and tourism etc. in and around the region has led to fragmentation and shrinkage of the existing wildlife corridors (Joshi & Singh, 2008). Thus, the connectivity between buffer forests and crucial corridors between protected areas are reduced. This has disrupted the movement of wildlife in the region; especially of Tiger & Asiatic Elephant, which otherwise require large contiguous area to survive. The changing land use patterns have pushed them to live in the fragmented habitats. Therefore, assessing land use change of this landscape has become a necessity.

Keeping track record of vegetation assessment (qualitative and quantitative) using traditional method like field survey alone cannot provide good insight about their changes either temporally or spatially. Earlier, aerial photographs were regularly employed by planners to detect land use alteration over a period of a time in region (Avery 1965; Faulkner 1968; Ritcher 1969). The cost of acquiring large format photography and annual interpretation of aerial photographs was high and prohibitive. In early 1970s, the advancement in computer technology and the emergence of Remote Sensing & Geographical Information System (RS & GIS) field altogether; has opened a new frontier in mapping due to the capabilities to acquire the digital data to reconstitute an image of the earth's surface. Satellites provide nearly global coverage of the earth surface with the spatial resolution and repetition rate that vary from one platform to another. These satellite images can be interpreted wrongly and can provide wrong results unless one has good ground truth knowledge. Thus, the use of Remote Sensing and Geographical Information system in combination with field survey plays a very crucial in land use change dynamics analysis.

The various capabilities *i.e.*, repetitive data acquisition, synoptic view and the digital data format appropriate for computer processing of different remote sensing satellite's sensors such as Thematic Mapper (TM), Satellite Pour I' Observation de la Terre (SPOT) and Radar And Advanced Very High Resolution Radiometer (AVHRR)) have become the major data sources for different change detection application during the past decades. Since last two decades, this method has been widely used in India by many researchers and organizations to quantify the land use land cover (Roy et al., 1995; Kushwaha, 1997; Jha et al., 2000; Kushwaha et al., 2000; Kushwaha, 2005; Nandy et al., 2007; FSI, 2011).

In India, Singh (1989) earliest used Landsat data for detecting the change in North East forest region and found it to be a very effective tool and also derives its (change detection) definition as the process to find out the changes in state of an object by observing it at different times.

The Landsat multi time series data used in this study, is freely available from 1970s' onwards and has advanced since then,spatially as well as spectrally.

STUDY AREA

With the extent of 29° 05' to 30° 43' N latitude and 77° 19'to 79° 25' E longitude, the study area covers about 10250 km^2. The altitude ranges from 160m in the south to 2230 m above MSL in the north. The climate is highly variable in this region. Temperature is governed by the elevation, varies from 23 – 46°C in summer and minimum 5°C during winter. The Mean Annual Rainfall is around 1800mm, with highest rainfall experienced between July and August. The area is sandwiched between two major physiographic regions *i.e.*, Himalayan ecosystem and Indo - Gangetic plains (Yadav et al. 2015). Geomorphologically, the landscape is characterized by highly dissected terrain in the southern aspect and gentle slope on the north aspect.Majority of area lies in Uttarakhand state with some of it being covered in other three states *i.e.*, Himachal Pradesh, Haryana, and Uttar Pradesh.

Because of the transient position between Himalayan and Indo Gangetic plain, there existing flora and faunal assemblage has affinity with both of these biogeographic regions (Rodgers and Pawar, 1988).The major vegetation types in this region are Tropical Moist Deciduous Forest (Group 3C /C2), Tropical Dry Deciduous Forest (Group 5B/C1 &C2), Subtropical Pine Forest (Group 9/C1& DS1), Subtropical Dry Evergreen Forests (Group 10/C1) and Himalayan Moist Temperate forest (Group12/C1)(Champion and Seth, 1968). Faunal species like Asian Elephant (*Elephas maximus*), Bengal Tiger (*Panthera tigris*), Leopard (*Panthera pardus*), Sloth bear(*Ursus ursus*) , Goral (Nemorhae goral), Jungle cat (*Felischaus*), Sambar deer (*Cervus unicolor*), Wild boar (*Sus scrofa*), Hyaena (*Hyaena hyaena*), Jackal (*Canis aureus*), Himalayan Yellow throated Marten (*Martes flavigula*), Common langur (*Presbytis entellus*), Rhesus Macaque (*Macaca mulatta*) Nilgai (*Boselaphus tragocamelus*), Barking deer (*Muntiacus muntjak*), Python (Python molorus) and King Cobra (Ophiophagus hannah) etc. found throughout study area.

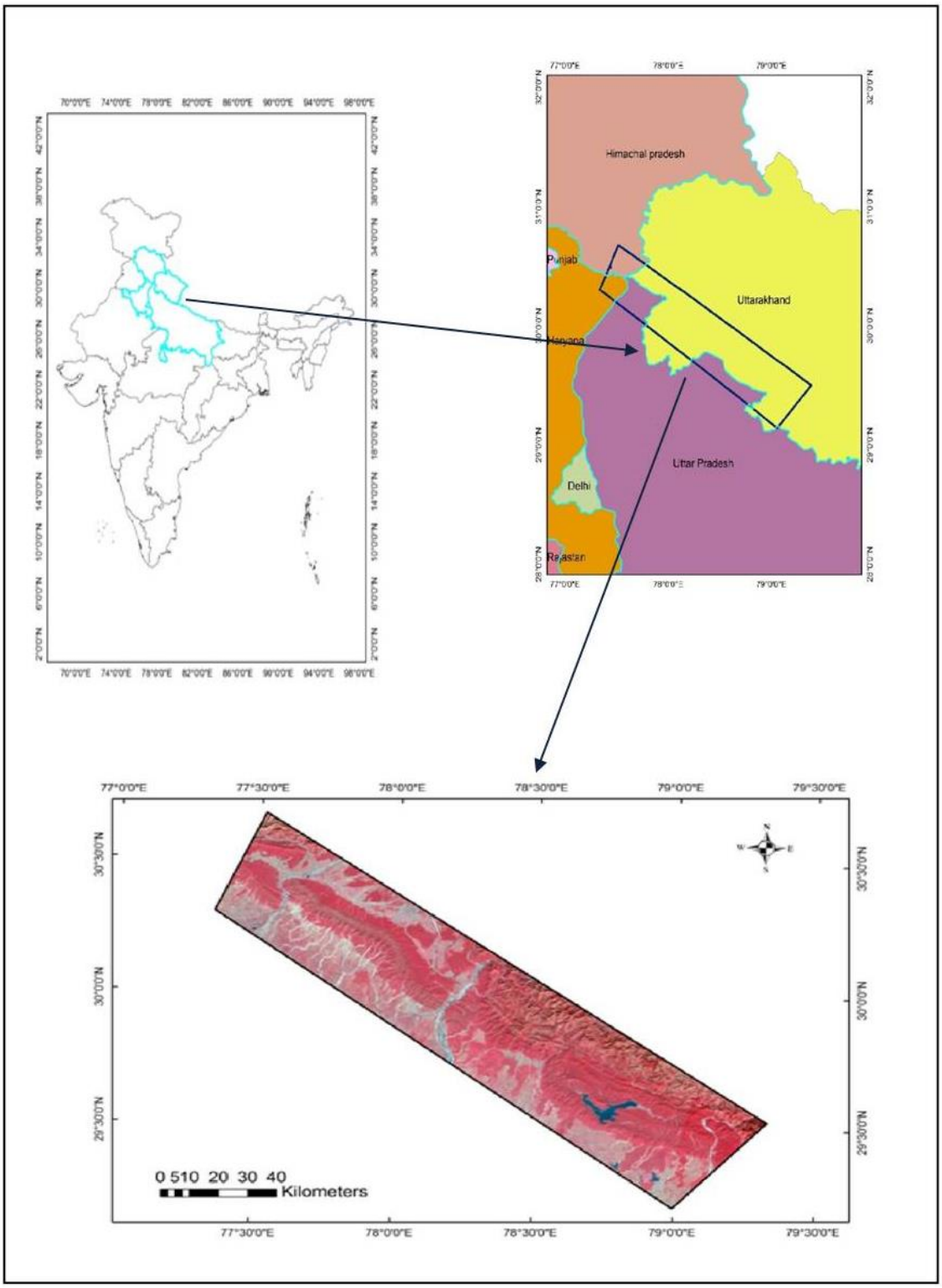

Figure 1. Location of the study area

MATERIAL AND METHODS

Satellite Images Used

The details of different time period satellite images used in the land Use & Land Cover mapping are given in table below:

Table 1. Details of the satellite data used in study

Satellite Sensor	Sensor	Path & Row	Acquired Date	Spatial Resolution	Spectral Band	Data Source
Landsat-8	OLI & TIRS	146039 & 145040	12-02-2015 11/11/2015 & 21/02/2015 13/11/2015	30m	B1 (Ultra Blue): 0.435 – 0.451 µm B2 (Blue): 0.45 – 0.512 µm B3 (Green): 0.533 – 0.590 µm B4 (Red): 0.636 - 0.673 µm B5 (NIR): 0.851 – 0.879 µm B6 (SWIR 1): 1.566 – 1.651 µm B7 (SWIR 2): 2.107 – 2.294 µm	
				15m	B8 (Panchromatic): 0.503 - 0.676 µm B9(Cirrus): 1.363 - 1.384 µm B10 (Thermal IR):10.60 – 11.19 µm B11 (Thermal IR):11.50 – 12.51 µm	
Landsat - 7	Enhanced Thematic mapper Plus (ETM+)	146039 & 145040	07/03/2003 14/10/2002 & 01/04/2003 23/10/2002	30m	B1 (Blue): 0.45 – 0.52 µm B2 (Green): 0.52 – 0.60 µm B3 (Red): 0.63 - 0.69 µm B4 (NIR): 0.76–0.90 µm B5 (SWIR 1): 1.55–1.75 µm B6 (Thermal IR):10.4–12.5 µm	http://earthexplorer.usgs.gov
				15m	B7 (SWIR 2): 2.08–2.35 µm B8 (Panchromatic) 0.52 - 0.90 µm	
Landsat 4 -5	Thmatic Mapper	146039 & 145040	04/04/1993 & 07/03/1991	30m	B1 (Blue): 0.45 – 0.52 µm B2 (Green): 0.52 – 0.60 µm B3 (Red): 0.63 - 0.69 µm B4 (NIR): 0.76 – 0.90 µm B5 (SWIR 1): 1.55 – 1.75 µm B6 (Thermal IR):10.4 – 12.5 µm B7 (SWIR 2): 2.08 – 2.35 µm	
Landsat 1 - 5	Multi-spectral Scanner (MSS)	146039 & 145040	20/04/1979 & 26/10/1979	60m	B1 (Green): 0.5 – 0.6 µm B2 (Red): 0.6 - 0.7 µm B3 (NIR): 0.7 - 0.8µm B4 (NIR) 0.8 – 1.1 µm	

Different image processing and GIS software like ERDAS IMAGINE, ENVI 5.0, PC GEOMATICA and ArcGIS were used to carry outthe analysis.

METHODOLOGY

Prior to the LULC classification, every band for each tile was radiometrically (DN to Surface reflectance) corrected, using PC Geomatica Software. Seasonal images for each respective year *i.e.*, 1979, 1991, 2003 and 2015 were stacked together, using bands 1-7for both the tiles. The two tiles covering the study area were then mosaic together and the study area was masked. Land Use Land Cover maps for each of four years were prepared using Unsupervised Classification technique. The image was classified till level II into 25 classes based on Anderson Classification System using ISODATA clustering algorithm. The pure pixels were recoded and masked with the FCC and unsupervised classification was once again run on the image. This step involved iteration till every pixel was classified. The recoded classes were then mosaicked together and LULC maps were prepared for years 1979, 1991, 2003 and 2015. A combination of Google Earth images and ground truth points collected during field survey were used for accuracy assessment.Error matrix/ Confusion matrix was generated and the overall accuracy was calculated using Kappa Statistics.

Change detection was done for the combination of years' 1979 &1991, 1979 & 2003, 1979 & 2015, 1991 & 2003, 1991 & 2015 and 2003 & 2015 respectively.

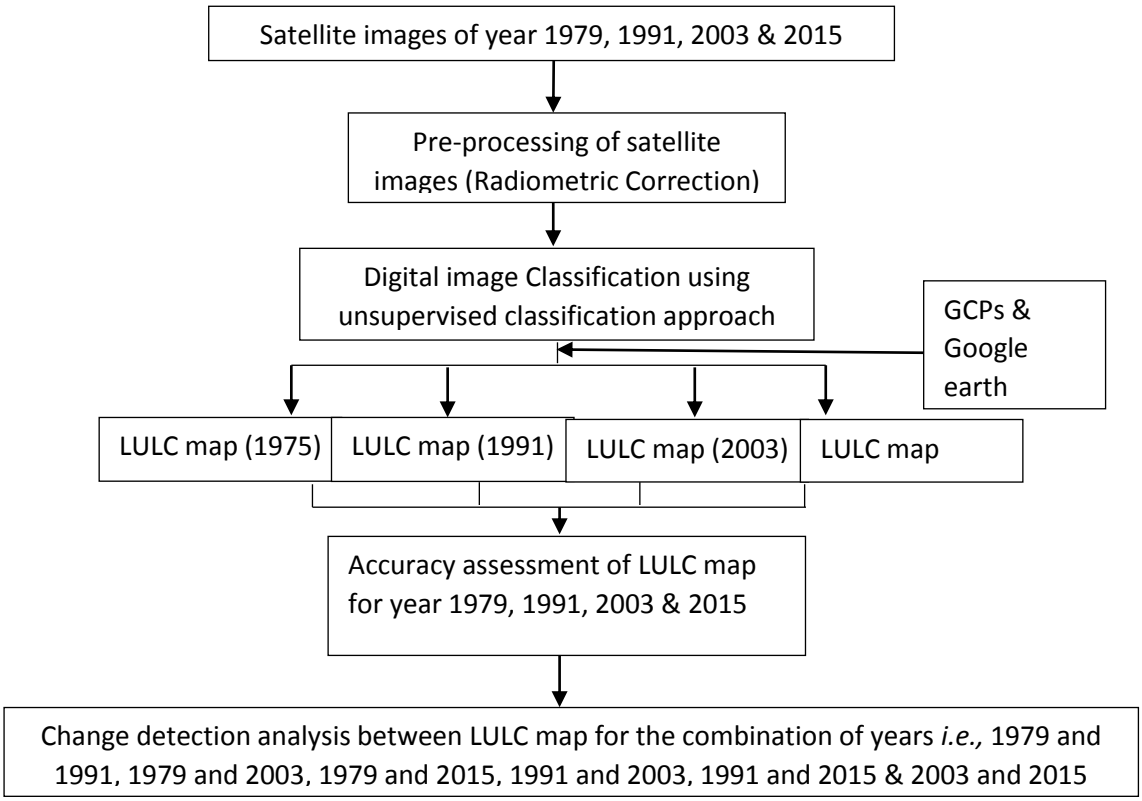

Figure 2. Flowchart shows methodology adopted for LULC mapping

RESULTS AND DISCUSSION

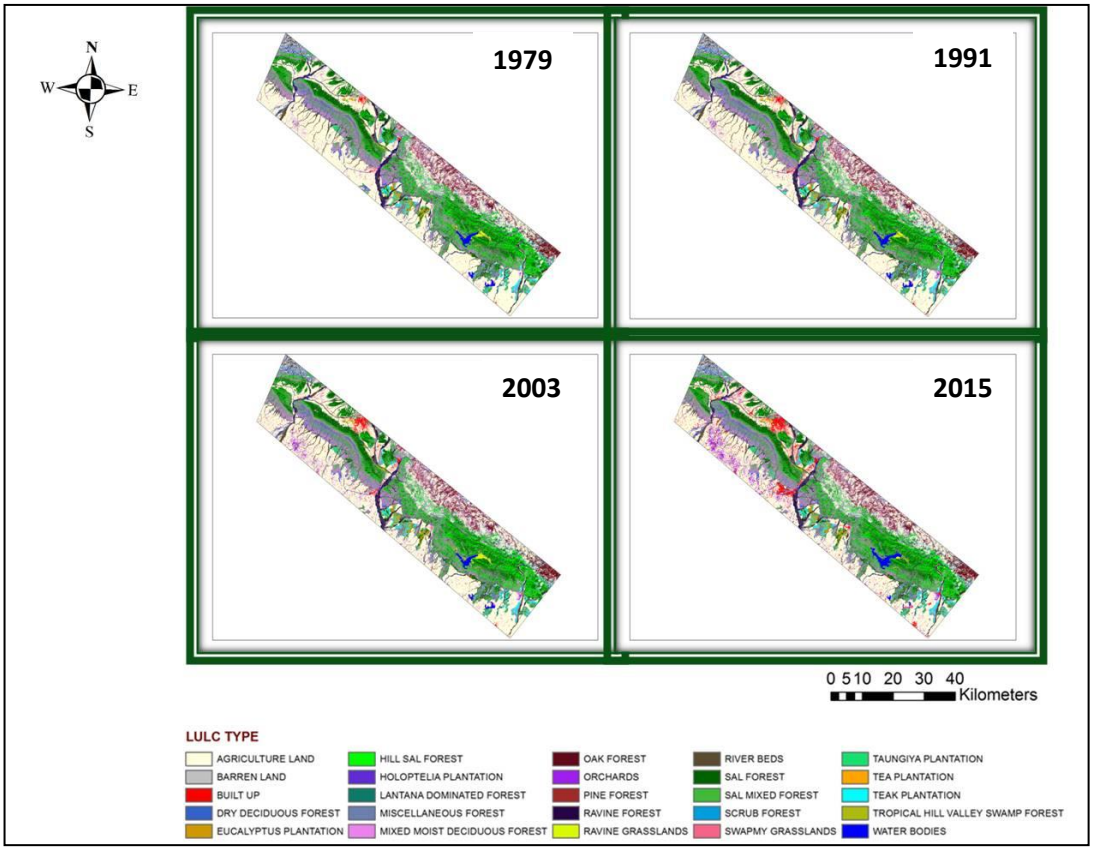

Figure 3. Land Use Land Cover Map for Year 1979, 1991, 2003 and 2015.

Table 2. Area statistics and relative change of each land use land cover categories between 1979 and 1991.

LULC TYPE	1979		YEAR	1991		% AREA CHANGE
	ha	%		ha	%	
SAL FOREST	126787	12.38		126787	12.38	0.00
HILL SAL FOREST	62561.9	6.11		62561.9	6.11	0.00
SAL MIXED FOREST	118288	11.55		118288	11.55	0.00
MIXED MOIST DECIDUOUS FOREST	135063.02	13.19		135011	13.19	-0.04
DRY DECIDUOUS FOREST	19919.94	1.95		19593.6	1.91	-1.64
PINE FOREST	27684	2.70		27684	2.70	0.00
OAK FOREST	14405.2	1.41		14405.2	1.41	0.00
TROPICAL HILL VALLEY SWAMP FOREST	1142.46	0.11		1142.46	0.11	0.00
RAVINE GRASSLANDS	5083.47	0.50		5062.41	0.49	-0.41
RAVINE FOREST	16796.6	1.64		16719.2	1.63	-0.46
SWAPMY GRASSLANDS	498.24	0.05		496.8	0.05	-0.29
SCRUB FOREST	21001.7	2.05		21001.79	2.05	0.00
LANTANA DOMINATED FOREST	5373.63	0.52		5375.25	0.52	0.03
TAUNGIYA PLANTATION	3537.63	0.35		3537.63	0.35	0.00
HOLOPTELIA PLANTATION	68.04	0.01		68.04	0.01	0.00
TEAK PLANTATION	14748.43	1.44		14855.35	1.45	0.72
EUCALYPTUS PLANTATION	7647.03	0.75		7739.46	0.76	1.21
MISCELLANEOUS FOREST	2111.31	0.21		3499.2	0.34	65.74
TEA PLANTATION	623.7	0.06		623.7	0.06	0.00
ORCHARDS	3960.81	0.39		5234.94	0.51	32.17
BUILT UP	5373.72	0.52		8528.13	0.83	58.70
BARREN LAND	3390.03	0.33		3390.03	0.33	0.00
AGRICULTURE LAND	363991.42	35.55		358580.62	35.02	-1.49
RIVER BEDS	48295.51	4.72		48261.4	4.71	-0.07
WATER BODIES	15524.75	1.52		15430.43	1.51	-0.61

Table 3. Area statistics and relative change of each land use land cover categories between 1979 and 2003

LULC TYPE	1979		YEAR	2003		% AREA CHANGE
	ha	%		ha	%	
SAL FOREST	126787.00	12.38		126787.00	12.38	0.00
HILL SAL FOREST	62561.90	6.11		62561.90	6.11	0.00
SAL MIXED FOREST	118288.00	11.55		118288.00	11.55	0.00
MIXED MOIST DECIDUOUS FOREST	135063.08	13.19		134963.00	13.18	-0.07
DRY DECIDUOUS FOREST	19919.93	1.95		19553.00	1.91	-1.84
PINE FOREST	27684.00	2.70		27684.00	2.70	0.00
OAK FOREST	14405.20	1.41		14405.20	1.41	0.00
TROPICAL HILL VALLEY SWAMP FOREST	1142.46	0.11		1142.46	0.11	0.00
RAVINE GRASSLANDS	5083.47	0.50		5602.77	0.55	10.22
RAVINE FOREST	16795.84	1.64		16202.20	1.58	-3.53
SWAPMY GRASSLANDS	498.24	0.05		564.75	0.06	13.35
SCRUB FOREST	21001.70	2.05		21001.79	2.05	0.00
LANTANA DOMINATED FOREST	5373.63	0.52		5378.49	0.53	0.09
TAUNGIYA PLANTATION	3537.63	0.35		3537.63	0.35	0.00
HOLOPTELIA PLANTATION	68.04	0.01		68.04	0.01	0.00
TEAK PLANTATION	14748.42	1.44		14563.56	1.42	-1.25
EUCALYPTUS PLANTATION	7647.03	0.75		7656.30	0.75	0.12
MISCELLANEOUS FOREST	2111.31	0.21		3499.20	0.34	65.74
TEA PLANTATION	623.70	0.06		623.70	0.06	0.00
ORCHARDS	3960.81	0.39		12842.64	1.25	224.24
BUILT UP	5373.72	0.52		13485.60	1.32	150.95
BARREN LAND	3390.03	0.33		3393.63	0.33	0.11
AGRICULTURE LAND	363992.28	35.55		347623.80	33.95	-4.50
RIVER BEDS	48290.48	4.72		49674.59	4.85	2.87
WATER BODIES	15520.92	1.52		12765.57	1.25	-17.75

Table 4. Area statistics and relative change of each land use land cover categories between 1979 and 2015.

LULC TYPE	1979	YEAR	2015		% AREA CHANGE
	ha	%	ha	%	
SAL FOREST	126787.18	12.38	126787	12.38	0.00
HILL SAL FOREST	62561.89	6.11	62561.8	6.11	0.00
SAL MIXED FOREST	118288.91	11.55	118280	11.55	-0.01
MIXED MOIST DECIDUOUS FOREST	135063.69	13.19	134952	13.18	-0.08
DRY DECIDUOUS FOREST	19919.97	1.95	19551.6	1.91	-1.85
PINE FOREST	27684	2.70	27684	2.70	0.00
OAK FOREST	14405.2	1.41	14405.2	1.41	0.00
TROPICAL HILL VALLEY SWAMP FOREST	1142.46	0.11	1140.66	0.11	-0.16
RAVINE GRASSLANDS	5083.47	0.50	3015.45	0.29	-40.68
RAVINE FOREST	16795.89	1.64	18216.45	1.78	8.46
SWAPMY GRASSLANDS	498.24	0.05	1161.9	0.11	133.20
SCRUB FOREST	21001.69	2.05	21285.91	2.08	1.35
LANTANA DOMINATED FOREST	5373.63	0.52	6140.7	0.60	14.27
TAUNGIYA PLANTATION	3537.63	0.35	3537.63	0.35	0.00
HOLOPTELIA PLANTATION	68.04	0.01	68.04	0.01	0.00
TEAK PLANTATION	14748.35	1.44	14545.76	1.42	-1.37
EUCALYPTUS PLANTATION	7647.03	0.75	7656.3	0.75	0.12
MISCELLANEOUS FOREST	2111.31	0.21	3499.2	0.34	65.74
TEA PLANTATION	623.7	0.06	623.7	0.06	0.00
ORCHARDS	3960.81	0.39	22249.66	2.17	461.75
BUILT UP	5373.72	0.52	28179.63	2.75	424.40
BARREN LAND	3390.03	0.33	3068.28	0.30	-9.49
AGRICULTURE LAND	363992.17	35.55	326208.42	31.86	-10.38
RIVER BEDS	48290.45	4.72	44510.63	4.35	-7.83
WATER BODIES	15520.95	1.52	14540.49	1.42	-6.32

Table 5. Area statistics and relative change of each land use land cover categories between 1991 and 2003.

LULC TYPE	1991	YEAR	2003		% AREA CHANGE
	ha	%	ha	%	
SAL FOREST	126787.0	12.38	126787	12.38	0.00
HILL SAL FOREST	62561.9	6.11	62561.9	6.11	0.00
SAL MIXED FOREST	118288.0	11.55	118288	11.55	0.00
MIXED MOIST DECIDUOUS FOREST	135011.1	13.19	134963	13.18	-0.04
DRY DECIDUOUS FOREST	19593.6	1.91	19553	1.91	-0.21
PINE FOREST	27684.0	2.70	27684	2.70	0.00
OAK FOREST	14405.2	1.41	14405.2	1.41	0.00
TROPICAL HILL VALLEY SWAMP FOREST	1142.5	0.11	1142.46	0.11	0.00
RAVINE GRASSLANDS	5062.4	0.49	5602.77	0.55	10.67
RAVINE FOREST	16718.5	1.63	16202.29	1.58	-3.09
SWAPMY GRASSLANDS	496.8	0.05	564.75	0.06	13.68
SCRUB FOREST	21001.8	2.05	21001.8	2.05	0.00
LANTANA DOMINATED FOREST	5375.3	0.52	5378.49	0.53	0.06
TAUNGIYA PLANTATION	3537.6	0.35	3537.63	0.35	0.00
HOLOPTELIA PLANTATION	68.0	0.01	68.04	0.01	0.00
TEAK PLANTATION	14855.3	1.45	14563.5	1.42	-1.96
EUCALYPTUS PLANTATION	7739.5	0.76	7656.3	0.75	-1.07
MISCELLANEOUS FOREST	3499.2	0.34	3499.2	0.34	0.00
TEA PLANTATION	623.7	0.06	623.7	0.06	0.00
ORCHARDS	5234.9	0.51	12842.64	1.25	145.33
BUILT UP	8528.1	0.83	13485.6	1.32	58.13
BARREN LAND	3390.0	0.33	3393.63	0.33	0.11
AGRICULTURE LAND	358581.4	35.02	347623.73	33.95	-3.06
RIVER BEDS	48256.4	4.71	49674.63	4.85	2.94
WATER BODIES	15426.6	1.51	12765.57	1.25	-17.25

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Table 6. Area statistics and relative change of each land use land cover categories between 1979 and 2015.

LULC TYPE	1991	YEAR	2015		% AREA CHANGE
	ha	%	ha	%	
SAL FOREST	126787.2	12.38	126787	12.38	0.00
HILL SAL FOREST	62561.9	6.11	62561.8	6.11	0.00
SAL MIXED FOREST	118288.9	11.55	118280	11.55	-0.01
MIXED MOIST DECIDUOUS FOREST	135011.7	13.19	134952	13.18	-0.04
DRY DECIDUOUS FOREST	19593.6	1.91	19551.6	1.91	-0.21
PINE FOREST	27684.0	2.70	27684	2.70	0.00
OAK FOREST	14405.2	1.41	14405.2	1.41	0.00
TROPICAL HILL VALLEY SWAMP FOREST	1142.5	0.11	1140.66	0.11	-0.16
RAVINE GRASSLANDS	5062.4	0.49	3015.45	0.29	-40.43
RAVINE FOREST	16718.5	1.63	18216.46	1.78	8.96
SWAPMY GRASSLANDS	496.8	0.05	1161.9	0.11	133.88
SCRUB FOREST	21001.8	2.05	21285.92	2.08	1.35
LANTANA DOMINATED FOREST	5375.3	0.52	6140.7	0.60	14.24
TAUNGIYA PLANTATION	3537.6	0.35	3537.63	0.35	0.00
HOLOPTELIA PLANTATION	68.0	0.01	68.04	0.01	0.00
TEAK PLANTATION	14855.3	1.45	14545.8	1.42	-2.08
EUCALYPTUS PLANTATION	7739.5	0.76	7656.3	0.75	-1.07
MISCELLANEOUS FOREST	3499.2	0.34	3499.2	0.34	0.00
TEA PLANTATION	623.7	0.06	623.7	0.06	0.00
ORCHARDS	5234.9	0.51	22249.6	2.17	325.02
BUILT UP	8528.1	0.83	28179.6	2.75	230.43
BARREN LAND	3390.0	0.33	3068.28	0.30	-9.49
AGRICULTURE LAND	358581.1	35.02	326208.22	31.86	-9.03
RIVER BEDS	48256.4	4.71	44510.66	4.35	-7.76
WATER BODIES	15426.6	1.51	14540.49	1.42	-5.74

Table 7. Area statistics and relative change of each land use land cover categories between 1979 and 2015.

LULC TYPE	2003	YEAR	2015		% AREA CHANGE
	ha	%	ha	%	
SAL FOREST	126787.2	12.38	126787	12.38	0.00
HILL SAL FOREST	62561.9	6.11	62561.8	6.11	0.00
SAL MIXED FOREST	118288.9	11.55	118280	11.55	-0.01
MIXED MOIST DECIDUOUS FOREST	134963.6	13.18	134952	13.18	-0.01
DRY DECIDUOUS FOREST	19553.0	1.91	19551.6	1.91	-0.01
PINE FOREST	27684.0	2.70	27684	2.70	0.00
OAK FOREST	14405.2	1.41	14405.2	1.41	0.00
TROPICAL HILL VALLEY SWAMP FOREST	1142.5	0.11	1140.66	0.11	-0.16
RAVINE GRASSLANDS	5602.8	0.55	3015.45	0.29	-46.18
RAVINE FOREST	16202.3	1.58	18216.46	1.78	12.43
SWAPMY GRASSLANDS	564.8	0.06	1161.9	0.11	105.74
SCRUB FOREST	21001.8	2.05	21285.92	2.08	1.35
LANTANA DOMINATED FOREST	5378.5	0.53	6140.7	0.60	14.17
TAUNGIYA PLANTATION	3537.6	0.35	3537.63	0.35	0.00
HOLOPTELIA PLANTATION	68.0	0.01	68.04	0.01	0.00
TEAK PLANTATION	14563.5	1.42	14545.8	1.42	-0.12
EUCALYPTUS PLANTATION	7656.3	0.75	7656.3	0.75	0.00
MISCELLANEOUS FOREST	3499.2	0.34	3499.2	0.34	0.00
TEA PLANTATION	623.7	0.06	623.7	0.06	0.00
ORCHARDS	12842.6	1.25	22249.6	2.17	73.25
BUILT UP	13485.6	1.32	28179.58	2.75	108.96
BARREN LAND	3393.6	0.33	3068.28	0.30	-9.59
AGRICULTURE LAND	347623.0	33.95	326207.82	31.86	-6.16
RIVER BEDS	49674.6	4.85	44510.67	4.35	-10.40
WATER BODIES	12765.6	1.25	14540.49	1.42	13.90

Because of the limitation of pages, results depicting accuracy assessment for each of LULC maps were discussed only. Overall map accuracy was found almost similar at 95.107, 94.219, 94.186 and 93.892% for years 1979, 1991, 2003 and 2015 respectively. A detailed examination of results by LULC class showed not very much variability for overall years, with producer's accuracies ranging from 86.154 to 100% and user's accuracies from 88.89 to 100%. Oak forest has shown the lowest user's accuracy with the value of 88.899. For some other classes like Mixed moist deciduous forest, Dry Deciduous forest and Lantana dominated forest, the overall accuracies were found below 91.0%. Factor likely to have contributed for the lower accuracy was mixed pixel spectral response, for that these classes might have been misinterpreted and produced lower accuracies. Two other classes *i.e.*, Swampy Grasslands and Holopelea plantation shown 100% accuracy for each map.

The quantitative results and spatial distribution of land use and land cover assessment resulting from digital image classification for four different years 1979, 1991, 2003 and 2015 are shown in table 2, 3, 4, 5, 6 and 7. Each classified image contains 25 LULC classes, *i.e.,* Sal Forest, Hill Sal Forest, Sal Mixed Forest, Mixed Moist Deciduous Forest, Dry Deciduous Forest, Pine Forest, Oak Forest, Tropical Hill Valley Swamp Forest, Ravine Grasslands, Ravine Forest, Swapmy Grasslands, Scrub Forest, Lantana Dominated Forest, Taungiya Plantation, Holopelea Plantation , Teak Plantation, Eucalyptus Plantation, Miscellaneous Forest, Tea Plantation , Orchards, Built Up, Barren Land, Agriculture Land, River Beds and Water Bodies. The validation for each land use/land cover map and for their components were done independently using strata wise randomly generated GCPs in ERDAS software.

The classified maps have two broad classes *i.e.,* forest (from Sal forest to Miscellaneous forest) and non – forest classes (From Tea plantation to water bodies). The total study area is about 1023886 ha or 10250 km^2. LULC map of year 1979 shows that nearly 363991.42 ha (35%) area is covered by Agriculture Land which is followed by Mixed Moist Deciduous Forest (13.19), Sal Forest (12.38%) and Sal Mixed Forest 118288 ha (11.55%). The LULC classes *i.e.,* Holopelea Plantation, Tea plantation & Tropical Hill Valley Swamp Forest Covers the lowest % of study area with 68.08 ha (0.01%), 623 ha (0.06%) and 1142 ha (0.11%) respectively and their area have remain same for LULC map for year 1979, 1991, 2003 and 2015 .

In year 1991, LULC classes like Agriculture Land and Mixed Moist Deciduous Forest despite of losing its fraction of area accounted with (-1.49%) and (-0.04%), covered the highest amount of area. Two other highly occupied LULC classes *i.e.,* Sal Forest and Hill Sal forest remain unchanged.

In terms of % of area change between 1979 and 1991, the gain was highest for miscellaneous forest 65% followed by Built up (58%) and orchards (32.17%). The loss were highest for Dry deciduous forest (1.64%) followed by agriculture land (1.49%).

Comparisons were made in terms of relative changes for different LULC classes between 1979 – 2003 & 1979 – 2015. LULC classes like Agriculture Land and Mixed Moist Deciduous Forest, continue to lost its fraction of area in year 2003 & 2015 with (-3.06% & -9.03%) and (-0.04%) respectively, but still covered the highest amount of area. Two other highly occupied LULC classes *i.e.,* Sal Forest and Hill Sal forest remain unchanged. The highest gain was observed for Orchard (224% & 461%) and built up (150% & 424%) between year 1979 – 2003 & 1979 – 2015 respectively. Like other part of the world, this area has been witnessed to the increasing urban population and its associated developmental activities like industrialisation, construction of highways and roads, Tourism etc. since last four decade, especially post to the Uttarakhand division in year 2000. This urban expansion was found mainly in the cities/towns of Haridwar, Dehradun, Kotdwar and Ramnagar and these changes can easily be spotted in LULC maps.

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