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"Patch Characterization in Bidalna Micro-watershed, DehraDun: A time Series Analysis using Remote Sensing and GIS"

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ABSTRACT: The present study aims to find out the changes in land use land cover (LULC) classes and patch metrics for bidalna micro-watershed, Dehradun, Uttarakhand by using satellite data. Such studies are essential for monitoring the changes in a holistic manner and also provide a scientific basis for anticipating the future development. The study area was classified into six LULC classes using Landsat-TM imageries of year 1990, 2000 and 2013. LULC change pattern over the span of 23 years was also analyzed. LULC maps were further used to derive patch indices namely NP (Number of Patches), PD (Patch density), LPI (Largest Patch Index), ED (Edge Density), JI (Interspersion and juxtaposition index), SPLIT (Split Index), SIDI (Simpson's Diversity Index) and SIEI (Simpson's Evenness Index) for the corresponding years to understand the patch dynamics in bidalna micro-watershed. The most dominant LULC type of bidalna micro watershed was forest of sal and pine, occupying 1,724.5 ha in 1990 and 1,278 ha and 1,234 ha in 2000 and 2013 respectively. There was drastic increase in scrubs from 463 ha in 1990 to 672 ha and 744 ha in next 2000 and 2013 respectively. The area under khair-kanju plantations, settlement and dry river bed had continuously increased in due course of time. Number of Patches (NP) and patch density (PD) showed the trend of increasing from 1990 to 2013 for bidalna watershed indicating very high fragmentation primarily driven by anthropogenic factors. Thus increased resource extraction from the entire watershed may not be sustainable in the long run. Remote sensing is of immense scope in the mapping and monitoring natural resources at watershed level and below by providing real time temporal datasets if classified and compared judiciously. It equips decision makers with providing the baseline data for monitoring and evaluation of the interventions at the ground level.

Keywords: Landscape analysis, Bidalna micro-watershed, Fragmentation, Remote sensing.

INTRODUCTION

The world around us is undergoing numerous alterations. There is nearly no habitat or natural ecosystem across the landscape not experiencing change. This is due to human activities and it has never been a cause of major concern to human until past few decades. Natural landscapes are becoming fragmented at an alarming rate as forest patch are shrinking and even getting vanished. Thus identification of individual patches and their boundaries are important steps in characterizing the structure of a landscape and thus their sustainability. The measurement of patch area include total area of habitat suitable for a particular species, maximum patch size, and mean patch size and are often the simplest to calculate and interpret (Saunders *et al*. 1991). Landscape patterns are influenced by the composition and development of vegetation following disturbances, as well as the juxtaposition of these disturbances (Oliver 1981).

Landscape ecology has now improved in recent years and turned into an applicable approach for land use planners and landscapers. The assessment of land use and land cover is an extremely important activity for contemporary land management. The recent literature suggests that human land-use practices (including type, magnitude, and distribution) are the most important factor influencing natural resource management at local, regional, and global scales (McDonnell and Pickett 1993). Nowadays, environmental management is increasingly confronted with the problem of managing and planning entire landscapes which often consist of complex, interacting mosaics of different habitat patches and ecosystems. Landscape metrics are useful for the application of the concepts of landscape ecology to sustainable landscape planning and landscape monitoring (Herzog and Lausch, 1999). A possible approach to account for fragmentation analysis and their impact on landscape structure related might be the use of landscape metrics (Feld *et al.*, 2007). Because ecological system operates at multiple scales, understanding the spatial configuration and temporal trajectory of patch structure is central to understanding the ecology of landscape (Forman 1995).

During the past decade, important advances in the integration of remote images, computer processing and spatial analysis methodologies have been linked to the study of distribution patterns of communities and ecosystems that affect changes in pattern and process over time. Satellite remote sensing provides an excellent source of data from which updated land use / land cover (LULC) changes can be extracted and analyzed in an efficient way. Several techniques have been reported to improve classification results in terms of land use discrimination and accuracy of resulting classes (Eiumnoh and Shrestha, 2000). In addition, effective monitoring and simulating of the urban sprawl phenomenon and its effects on land-use patterns and hydrological processes within the spatial limits of a watershed are essential for effective land-use and water resource planning and management (Hongga *et al*., 2010). Landscapes are conceptual units for the study of spatial patterns on the physical environment and the influence of these patterns on important environmental endpoints. Land use decision are generally made at an individual or local scale, however, the impacts are often manifested cumulatively as change in spatial pattern. Integration of structure and function of landscaped can be perceived and measured by patterns and scales (Dehkordi *et al.*, 2010). Lin *et al*. (2007) combined a land use change model, landscape metrics and a watershed hydrological model with an analysis of the impacts of future land use scenarios on land use pattern and hydrology for a landscape management plan. However, the interpretation of specific watershed characteristics is dependent on the particular phenomena being investigated. The quantified differences in landscape characteristics of each watershed provide important information that can aid in making management decisions in our ecologically and sociologically complex forests (Tappe *et al* 2004).

Remote sensing (RS) and geographic information systems (GIS) have been shown to be promising tools for investigating landscape pattern changes at various scales. Unique capabilities of remote sensing images such as providing an extensive, consistent perspective of an area, employing electromagnetic range to register phenomena, recurrent spatial and temporal patterns, pace of transmission, diversity of images, and applicability of professional application software have made it an effective tool for assessment, monitoring, and sustainable management of natural resources such as soil, air, water, forest, crops, rangelands, and is gaining a broader range of application. Considering the importance of the watershed and its constituents at both upper and lower levels and its significant control over the landscape the present study was undertaken to work out the changes in LULC in 1990, 2000 and 2013 in bidalna –micro watershed, Dehradun. It is a model watershed to study the different LULC change over time as case study for the future use. Specifically, different approaches such as construction of Land Use /Land Cover (LULC) maps, optimization of classification methodologies and calculation of landscape metrics are presented to highlight the contribution of satellite remote sensing in addressing the issues affecting the overall catchment area. Two main objectives are-

(i) To prepare the temporal LULC map for bidalna micro- watershed, Dehradun.

(ii) To evaluate landscape characterization by using FRAGSTATS- v 4.2

Study Area. The bidalna micro watershed comes in Doon Valley, state of Uttaranchal, India. The geographic extent of the study area is 30º 10" 00' to 30º 18" 36' north latitude and 78º 07" 48' to 78º 18" 00' east longitude in the district of Dehradun (Fig. 1).

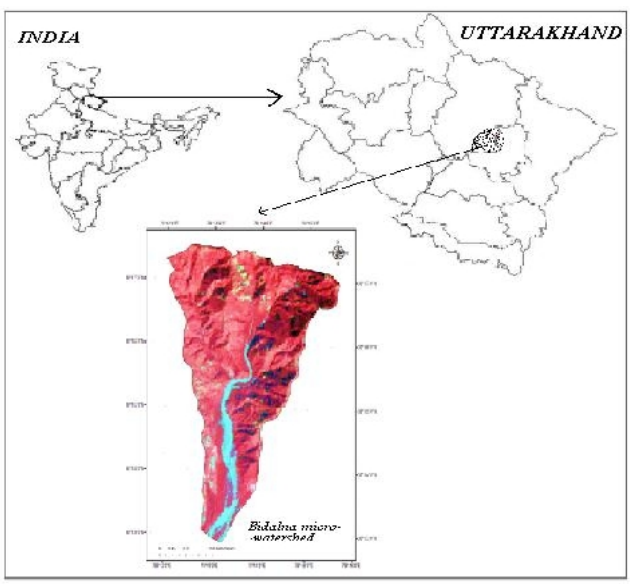

Fig. 1. Study site location and boundary.

It is located under the administrative boundary of Thano Forest Range, East Dehradun forest division. The total geographic is 2,553 ha. It receives average annual rainfall of 2,073.3 mm during June to September. There is a great variation in the temperature; it is hot during the summer and drops to freezing point during the winter. The average annual temperature is 20°C (Max. 27.8 ºC and Min. 3.3ºC).

The thano forest area consists mostly of the Moist Shiwalik Sal Forests. The Moist Bhabar and Moist Shiwalik Sal are found in patches in the souther slopes of this area. Pine (*Pinus roxburghii*), Sal (*Shorea robusta*), Khair (*Acasia catechu*), Shisham (*dalbergia* sisso), Chamror (*Ehretia laevis Roxb*.) Kanju (*Holoptelea integriflora (Roxb.) Planch*.) and Rohini (*Mallotus philippensis (Lamk) Muell.-Arg*.) are the tree species that are mainly found in this forest type. Lantana (*Lantana camara*) is a weed that has greatly affected the rejuvenation of the forest in this area and is especially harmful for Bidalna micro watershed is important part of this area.

MATERIALS AND METHODS

A. Images and ancillary data used

A geographic information system (GIS) was utilized to help characterize the study area. Remotely sensed and GIS data sets had been collected for this study while basic equipment such hardware and software were employed for data collecting and data analysis (Table 1).

Framework : Research methodology was designed to meet the objective of the work, which were involved data acquisition and land-cover land-use (LULC) classification and patch analysis. The detailed methodology is presented in Table 2. The information was then used to categorise the unsupervised 255 spectral classes into 10 LULC classes.

Table 1: Dataset and equipments.

Dataset/equipment	Descriptions		Source
Satellite data	LANDSAT TM images (FCC) of 1990, 2000 and 2013		www.usgs.org.in
Spatial Resolution	30 meter		--
Bands	Landsat 4-5	Wavelength (micrometer)	--
	Band 1	0.45- 0.52	--
	Band 2	0.52- 0.60	--
	Band 3	0.63- 0.69	--
	Band 4	0.76- 0.90	--
	Band 5	1.55- 1.75	--
Ancillary data	Bidalna micro-watershed topographic map and Land-use map		Watershed directorate of Uttarakhand and ground truth
Instrument	magnetic compass, GPS		Forestry and ecology department, Forestry and Ecology Department (FED), IIRS, Dehradun
Software	ERDAS Imagine 2014, Arc GIS 10.2.2, Frag-stats v 4.2 and MS office		

Table 2: Methodology framework.

Landscape analysis and landscape metrics	
INPUT	
RS data set acquisition- Landsat images of 1990, 2000 and 2013 of study site	2.GIS data sets- Topographic map Landuse map
PROCESS	
1.Data preparation and preprocessing -Image mosaic, image color enhancement, unsupervised classification with ground truth	
2.Visual image interpretation and digitization -On screen digitize in Arc view interface tool using basic key elements of visual interpretation and in cooperate with ancillary data -Digital classification of 10 LULC classes in 1900, 2000 and 2013	
3.Landscape Indices analysis -Calculation for landscape indices values at landscape and class levels using FRAGSTAT under ERDAS grid file -Class level: (Indices: NP,PD,LPI, SPLIT,CLUMP and IJI)	
OUTPUT	
1.LULC class map (1990, 2000 and 2013) 2.Landscape temporal change analysis (1990- 2000 and 2000- 2013) 3.Landscape indices measurement and change (1990, 2000, 2013) -at class level	

Patch matrices: Study of patches at a spatial level gives crucial information on spatial phenomenon that are guided by various drivers. FRAGSTATS v 4.2 developed by the Oregon State University (Mc Garigal *et al* 2002) quantifies the areal extent and spatial configuration of patches within a landscape; it is incumbent upon the user to establish a sound basis for defining and scaling the landscape (including the extent and grain of the landscape) and the scheme upon which patches are classified and delineated (McGarigal *et al* 2002). The short summary of metrics description for interpretation of patch dynamics are in Table 3.

Table 3: Range and descriptions of the metrics (McGarigal *et al* 2002).

NP (Number of Patches)	NP≥1, without limit. NP = 1 when the landscape contains only 1 patch.
LPI (Largest Patch Index)	0 < LPI □ 100 PLI approaches 0 when the largest patch of the corresponding patch type is increasingly small. LPI = 100 when the entire landscape consists of a single patch of the corresponding patch type; that is, when the largest patch comprises 100% of the landscape.
PD (Patch density)	PD>0, constrained by cell size. PD is ultimately constrained by the grain size of the raster image, because the maximum PD is attained when every cell is a separate patch. Therefore, ultimately cell size will determine the maximum number of patches per unit area.
SPLIT (Split Index)	1 □ SPLIT □ number of cells in the landscape area squared SPLIT = 1 when the landscape consists of single patch. SPLIT increases as the focal patch type is increasingly reduced in area and subdivided into smaller patches. The upper limit of SPLIT is constrained by the ratio of landscape area to cell size and is achieved when the corresponding patch type consists of a single one pixel patch.
CLUMPY	1 ≤ CLUMPY ≤ 1 , equals -1 when the patch size is maximally disaggregated; equals 0 when the patch is disturbed randomly, and approaches 1 when patch is maximally aggregated. It equals 1 when landscape consists of single patch.
IJI (Interspersion and juxtaposition index)	0 < IJI □ 100 IJI approaches 0 when the corresponding patch type is adjacent to only one other patch type and the number of patch types increases. IJI = 100 when the corresponding patch type is equally adjacent to all other patch types (i.e., maximally interspersed and juxtaposed to other patch types). IJI is undefined and reported as "N/A" in the "base-name" if the number of patch types is less than 3.

RESULTS AND DISCUSSON

Class indices separately quantify the amount and spatial configuration of each patch type and thus provide a means to quantify the extent and fragmentation of each patch type in the landscape.

Two levels of ecological landscape measurements including LULC classes and patch levels were conducted using landscape indices for bidalna landscape pattern measurement and evaluation. The year wise LULC map of bidalna micro watershed is shown in Fig. 2.

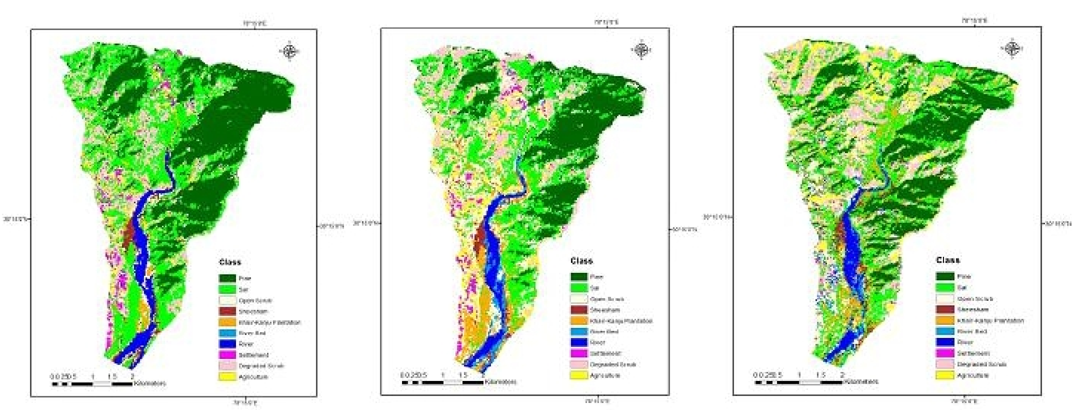

Fig. 2. Year wise (1990, 2000 and 2013) LULC map of bidalna micro watershed, Dehradun.

A. Land Use Land Cover (LULC) classification and change analysis

The most dominant LULC type of bidalna micro watershed was forest of sal and pine, occupied by the area of 1,724.5 ha in 1990 and 1,278 ha and 1,234 ha in 2000 and 2013 respectively (Table 4). The 864 ha of sal and 860 ha of pine forests was decreased up to 652.3 ha and 581.5 ha respectively from 1990 to 2013. There was drastic increase in scrubs by 463 ha in 1990 to 672 ha and 744 ha in next 2000 and 2013 respectively. Open and degraded shrub followed the opposite trends to that of sal and pine forest. The khair- kanju plantation had increased from 70 ha to 222 ha from 1990 to 2000 respectively. The area of river and river bed had continuously increased in due course of time. There was continuous decrease in percent area covered by sal forest as well as pine forest since 1990 to 2013, while this trend was reversed for scrub, agriculture and river. From 1990 to 2000, there was decrease in the sal and pine forested area which was probable mainly occupied by the scrub and khair- conju plantation (Table 5). For metrics measurement Sutthivanich and Ongsomwang (2015) found that the landscape pattern variations occurred in increasing of fragmentation and diversity whereas decreasing occurred in core area and shape complexity at landscape level in Sakaerat Biosphere Reserve, Thailand. Concurrently, at class level the indices indicated distinctively the trend of fragmentation, isolation, aggregation and extent of core area in the urban, forest plantation, agriculture, and the disturbed forest class.

Table 4: Evaluation of LULC and changes in 1990, 2000 and 2013.

	1990		2000		2013		CHANGES IN	
LULC- CLASSES	Ha	%	Ha	%	Ha	%	1990-2000	2000-2013
Sal Forest	864.5	33.9	683.5	26.8	652.3	25.6	-165.2	-47
Pine Forest	860	33.7	578.6	22.6	581.5	22.7	-281.4	-3.1
Khair_kanju Plantation	70	2.7	222.5	8.7	181.1	7.1	152.5	-41.4
Degraded Scrub	360	14.1	379.4	14.8	298.1	11.6	19.4	-81.3
Agriculture	68	2.7	118.4	4.7	131.5	5.2	50.4	13.1
Settlement	51.7	2.0	51.8	2.0	53.0	2.1	0.1	0.2
Shisham Plantation	53.2	2.1	73.5	2.9	53.2	2.1	20.3	-20.3
River	122.6	4.8	90.6	3.6	86.6	3.4	-32	-4
Open Scrub	103	4.0	292.8	11.5	446.4	17.5	189.8	153.6
Total Area (Ha)	2553		2553		2553			

Table 5: Landscape matrix measurement at landscape level in 1990, 2000 and 2013.

LANDSCAPE	YEAR			CHANGES IN	
INDICES	1990	2000	2013	1990-2000	2000-2013
NP	2438	2477	4456	39	**1979**
PD	45.8	46.5	83.7	0.7	**37.2**
LPI	11.7	6.4	2.8	-5.3	**-3.6**
ED	105	121	158	16	**37**
LSI	20.1	23.2	29.7	3.1	**6.5**
IJI	70.8	71.3	76.6	0.5	**5.3**
SPLIT	53.0	156.3	429.9	103.3	**273.6**
SIDI	0.75	0.83	0.83	0.08	0
SIEI	0.84	0.92	0.92	0.08	0

As shown in table 5, in the first period between 1990 and 2000, the sal and pine forest were two classes that decreasing in their area per annum at 18.1 and 28.1 ha respectively. The khair- kanju plantation and open scrub, on the other hand, was most increasing 15.2 and 19.0 ha per annum respectively. In the second time period between 2000 to 2013 the sal forest continually decrease in its area, contrast to agriculture, settlement and river bed were constantly increasing in its area. In this time period plantations (Shisham and khair- kanju) and degraded scrub decreased very much.

Patch Analysis: It was found that largest patch index (LPI) decreased continuously from 1990 to 2000 up to 2013 for forest vegetation. This notified that lower the LPI approaches largest patch of the corresponding patch type is increasingly small. The very high fragmentation in this region is contributed mostly by the anthropogenic factors. Regular increase in LSI (Landscape Shape Index) reveled that landscape shape becomes more irregular and/ or as the length of edge within the landscape of the corresponding patch type increases. Due to high human pressure the IJI (Interspersion and Juxtaposition Index) followed the same pattern as patch density (PD). Increase in the value showed that interspersion was increasing and was more juxtaposed to other patch type. The change in IJI was more vigorous during 2000 to 2013.

IJI indicated the aggregation of the patches in the landscape. Regular increase in split index revealed that landscape in regularly splitting into smaller patches. The split index varied was very high from 2000 to 2013 period. As population concentrations grew and economic activities intensified, the demand for developed land (e.g., agriculture, settlement etc.) increased, and the consequent growth in urban areas appeared as "settlement expansion", or urbanization (Weng, 2007).

LULC Class level

Area/edge metrics. It was found that NP in bidalna micro watershed for Sal and Pine forest significantly revealed high changed from 510, 634 and 974 patches, similarly the scrubs showed increasing pattern of NP from 939, 1121 and1201 patches in 1990, 2000, and 2013 respectively. Contrast to the forest, scrubs and plantations the agricultural landscapes in which decreasing in NP from 1990 to 2013. However, LPI followed the reverse trend for sal and pine forests as compare to PD. Splitting Index varies with time period for different LULC classes. In general, for the forest it was generally increased from 1990 to 2013 (Table 6,7). Changes in landscape pattern through fragmentation or aggregation of natural habitats can alter patterns of abundance for single species and entire communities (Quinn and Harrison 1988). Thus, there is empirical justification for managing entire landscapes, not just individual habitat types, in order to insure that native plant and animal diversity is maintained (Mc Garigal *et al* 2002).

Table 6: Landscape Indices Values (NP and LPI) at class level in 1990, 2000 and 2013 Year.

	Number of Patches (NP)			**Largest Patch Index**		
LULC- CLASSES						
	1990	2000	2013	1990	2000	2013
Sal Forests	331	411	759	5.1	2	1.2
Pine Forests	179	223	215	11.7	6.4	2.8
Khair-kanju	300	351	1004	0.3	1.3	0.5
Degraded scrub	505	770	431	0.94	0.6	0.7
Open scrub	434	351	770	0.01	1.4	0.05
Agriculture	349	271	256	0.03	0.11	0.14
Settlement	133	298	133	0.1	0.1	0.01
Shisham	181	181	347	0.3	0.3	0.23
River	26	92	10	2.2	1.2	1.1

Table 7: Landscape Indices Values (PD and Clumpiness) at class level in 1990, 2000 and 2013.

	Patch Density			**Clumpiness**		
LULC-CLASSES	1990	2000	2013	1990	2000	2013
Sal Forests	6.2	7.7	14.2	0.62	0.59	0.41
Pine Forests	3.4	4.2	4.04	0.85	0.80	0.76
Khair-kanju	5.6	6.6	18.8	0.35	0.53	0.26
Degraded scrub	9.5	4.7	8.1	0.51	0.62	0.54
Open scrub	8.2	10.5	14.5	0.31	0.48	0.37
Agriculture	6.6	5.1	5.9	0.25	0.4	0.49
Settlement	2.5	2.5	5.3	0.46	0.46	0.11
Shisham	3.4	0.2	6.5	0.46	0.46	0.31
River	0.5	0.2	1.7	0.85	0.84	0.71

LSI in the Khar-kanju, pine forest and river landscapes had the same trend of increasing in their class from1990 to 2013. This indicated those of landscape type had gained more amount of their area. Except the degraded shrub all the other LULC classes landscape had tendency of increasing in IJI values from 1990 to 2013. This indicated that aggregation of the patches in this was increased. On the other hand, IJI in the pine forest showed low degree of changes from 1990 to 2000. This implied that the forest plantation patches were sparsely distributed from each other in the landscape. A decrease in the size and number of natural habitat patches increases the probability of local extirpation and loss of diversity of native species, whereas a decline in connectivity between habitat patches can negatively affect species persistence (Fahrig and Merriam 1985).

Thus, there is empirical justification for managing entire landscapes, not just individual habitat types, in order to insure that native plant and animal diversity is maintained (McGarigal *et al* 2002).

CONCLUSION

This revealed that different spots or land uses emerged in recent years. These uses followed an abnormal development pattern across the area, leading to destruction of the area's natural ecosystems. Expansion of human dominated uses such as roads, buildings, and facilities resulted in destruction and fragmentation – a factor that can wreak havoc on the natural resources in the area. The focus needs to be placed on removing some patches and replacing others. Growth of some uses threatens the existing diversity and the nature. Human dominated use, for example, developed extremely heterogeneously in the western parts of the area, whose irregular patches may extend to the eastern hill side where good patches of sal and pine forests exist.

The approach to watershed management should be participatory in nature; people friendly, location specific, process based and geared to cater to the problems and needs of the rural communities. Remote sensing is of immense scope in the mapping and monitoring natural resources at watershed level by ensuring the best possible balance in the environment between natural resources on the one side, and human and other living beings on the other. Landscape analysis at watershed level equips the decision makers with appropriate unit for monitoring and evaluation of project intervention by providing the baseline data.

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