LAND USE/ LAND COVER DYNAMICS STUDY AND PREDICTION IN GARHWAL REGION OF WESTERN HIMALAYA

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ABSTRACT

Analysis of Land Use Land Cover (LULC) dynamics is important and should be done regularly. It brings LULC changes into attention which can be managed before they turn into unmanageable calamities/conditions. In this study, LULC change analysis was carried out for Garhwal region of western Himalaya for years 1995, 2005 and 2015. Garhwal region covers 7 districts of Uttarakhand. The LULC maps were prepared using visual interpretation technique at 1:50,000 scale using LISS III satellite data. It was categorised into Built Up, Cropland, Plantation, Evergreen forest-dense, Evergreen forest-Open, Deciduous forest-dense, Deciduous forest-Open, grassland, Snow cover, Scrub land, Barren land and water bodies. The current LULC change trend was extrapolated and used to predict LULC map of years 2025 and 2035 using Cellular Automata-Markov Chain Model (CA-Markov). The validation of the method was done by predicting LULC change for 2015 and comparing it with the actual LULC map of 2015. Analysis of LULC change revealed that there is a decrease in evergreen forest-dense (4.57%), deciduous forest-open (9.38%), plantation (12.77%), scrub forest (4.92%) and Glacier/ Snow cover (35.08%). on the other hand, area under built up (30.98%), cropland (6.64%), evergreen-open (1.33%), deciduous-dense (8.84%), grassland (38.70%), barren land (34.69%) and water bodies (14.16%). The study of LULC dynamics extracts the negative and positive changes which may be natural or anthropogenic. It helps to prioritize the areas of management and conservation.

1. INTRODUCTION

Land Use/ Land Cover Change (LULCC) is an alarm to keep check on activities which degrade the environment and also highlights the result of environment conservation activities such as afforestation. Activities such as clearing of forest, degradation of forest quality or health and invasion can be identified from LULCC analysis. For decades, LULCC is used to track forest health and spread (Coppin and Bauer, 1996; Emch et al., 2005; Iverson, 1988; Kilic et al., 2006; Ramachandran and Reddy, 2017; Viedma et al., 2006). LULCC can be linked to different causes such as human invasion and climate change. LULCC can be used to extrapolate the trend of change to give LULC maps for future. The maps which are prepared for future can be used by managers, conservationists and policy makers. The predicted maps help the most for finding the suitable areas for introduction of species under conservation. Hence it is recommended that LULC maps for every area on Earth should be prepared at regular intervals say for every 10 years and change analysis should be done. It will help in covering all the areas and highlighting the areas which have gone under rapid change.

Himalaya, despite having fragile ecosystem is not away from the human disturbance. The people living in Himalayan mountains are deteriorating the natural landform and inviting calamities. Hence, LULCC studies are must for Himalayan region to keep track on changes. LULCC studies guides conservation planning which saves time, money and man power.

This study is an attempt to analyze LULCC in part of western Himalaya and predicting the trend of changes for future.

Aims of this study are as following:

- LULCC map preparation for 1995,2005 and 2015 for Garhwal region of western Himalaya.
- LULC change analysis for the above mentioned years (2 decades)
- Prediction of LULC maps for years 2025 and 2035.

2. STUDY AREA

Garhwal Himalaya (part of western Himalaya) is spread in seven districts of Uttarakhand namely Haridwar, Dehradun, Pauri garhwal/Pauri, Tehri Garhwal/Tehri, Uttarkashi, Chamoli and Rudraprayag (Figure 1). It covers an area of 33,412 km^2. The altitude ranges from 195 m to 7,816 m asl. Due to enormous difference in topography, forest types found in the study area are dry deciduous forest, Moist deciduous forest, Sal forest, Pine forest, Temperate and Sub-alpine broadleaf forest, alpine scrub and alpine pastures (Roy et al., 2002).

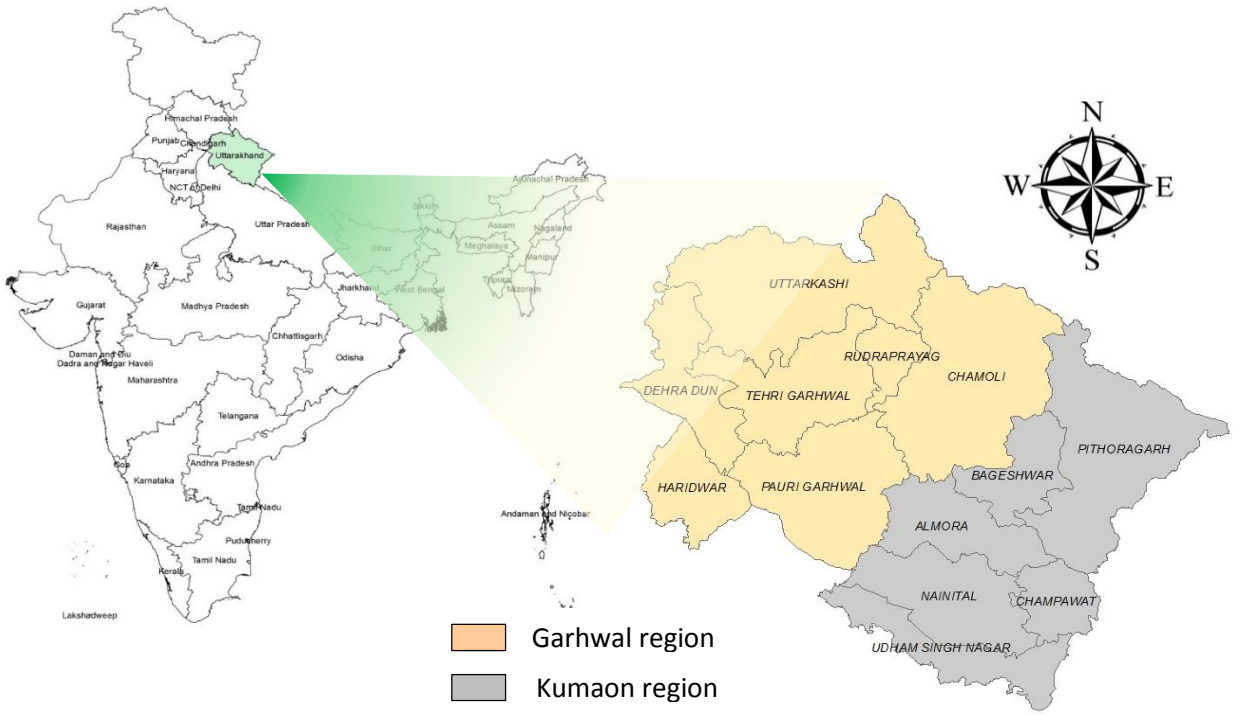

Figure 1: Garhwal Region of Uttarakhand

3. MATERIALS AND METHOD

3.1. Data used

For preparing LULC map of 1995, Landsat 4-5 TM was used. Landsat 4-5 TM data was obtained from USGS. 7 satellite images were used with path-row combination as 145-39, 146-38 and 146-39. For 2005 and 2015, ResourceSat 1-LISS III data was used. For 2005 and 2015, 29 cloud-free satellite images for each year, of the three seasons were used.

3.2. Satellite Image Processing and Classification

False Colour Composite (FCC) of the satellite images were used for classification. The maps were prepared at 1:50,000 scale. Hybrid (supervised and visual) classification scheme was adopted to prepare LULC maps. LULC classes for classification were Built Up, Cropland, Plantation, Evergreen forest-Dense, Evergreen forest-Open, Deciduous forest-Dense, Deciduous forest-Open, Grassland, Snow cover, Scrub land, Barren land and Waterbodies. ERDAS IMAGINE, IDRISI Taiga and ArcGIS were used for classification, image interpretation, spatial analysis, change detection and future prediction of LULC.

3.3. Change Detection and Prediction for Future

The change analysis was done using Matrix Union, Summary report of Matrix and Zonal change tools of ERDAS IMAGINE. The change matrices were prepared for LULC classes for 1995-2005, 2005-2015 and 1995-2015. For future prediction, MARKOV and CA-MARKOV tool of IDRISI Taiga were used. For validation of the method, 1995 and 2005 maps were used to predict 2015 map. Validation was done using actual LULC 2015 map. Using the same method, 2005 and 2015 maps were used to predict 2025 map. Similarly, 1995 and 2015 maps were used to predict 2035 map. Change analysis was again done for 2025 and 2035 maps using 2015 map.

4. RESULTS

4.1. LULC maps for 1995, 2005 and 2015

The LULC maps for 1995, 2005 and 2015 are shown in Figure 2. Some changes can be captured by comparing the maps visually. It can be seen that the area under Barren Land (brown), Cropland (yellow) and Built Up (red) has increased whereas Glacier/Snow cover (sky blue) has decreased prominently.

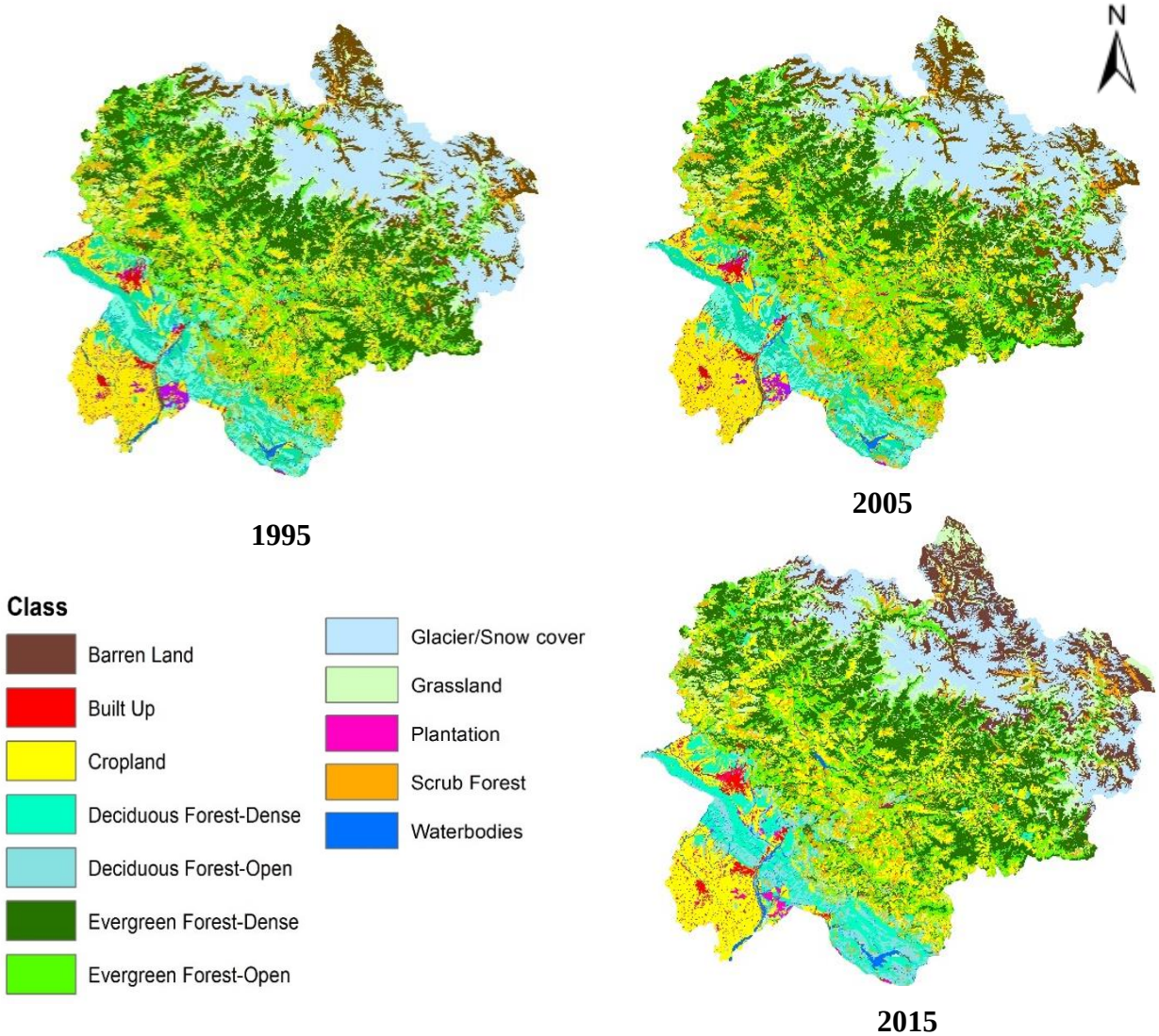

Figure 2: LULC maps for 1995,2005 and 2015

4.2. Change analysis

The summary of the change matrix is shown in Table 1. The percentage increase was highest for Barren land (58.95%), followed by Grassland (40.43%) and Built Up (30.98%). Whereas, the percentage decrease was highest

for Glacier/Snow cover (35.08%), followed by Plantation (12.56%) and Deciduous forest-Open (9.38%). Waterbodies increase (14.17%) was due to classification error.

Change matrix was generated for 1995-2015. Change matrix for 1995-2015 is shown in Table 2. Change matrix shows how much area of one class is converted into other class. There was increase in the areas under Built Up, Cropland, Evergreen forest-Open, Deciduous forest-Dense, Grassland and Barren Land and decrease for Evergreen forest-Dense, Deciduous forest-Open, Scrub Forest, Plantation and Glacier/Snow cover. Built Up and Cropland area increased at the expense of forests and plantation. Barren land increased in glacial area whereas the lower area of barren land was covered up by grassland. The quality of Evergreen forest decreased as large area of dense forest (73056.80 ha) got converted to open forest. A reverse of this trend was found for deciduous forest where open forest converted to dense forest. Area under Waterbodies also showed increase.

Classes	Year 1995 Area(ha)	Year 2015 Area(ha)	Change %
Built Up	24205.89	31704.66	30.98
Cropland	581035.56	619646.79	6.65
Evergreen forest-Dense	699527.24	667553.92	-4.57
Evergreen forest-Open	397338.27	402615.67	1.33
Deciduous forest-Dense	165207.69	179802.30	8.83
Deciduous forest-Open	170545.68	154556.89	-9.38
Plantation	20860.96	18240.22	-12.56
Scrubland	197408.34	187746.97	-4.89
Grassland	223559.84	313955.16	40.43
Barren land	218041.48	346569.02	58.95
Waterbodies	54836.86	62606.67	14.17
Glacier/Snow cover	500510.48	324931.40	-35.08

Table 1: Change Matrix summary 1995-2015

2015 / 1995	Built Up	Cropland	Evergreen forest-Dense	Evergreen forest-Open	Deciduous forest-Dense	Deciduous forest-Open	Plantation	Scrubland	Grassland	Barren land	Waterbodies	Snow/ Glacier	Grand Total
Built Up	22764.20	986.63	10.14	11.46	35.14	76.20	91.41	83.12	5.70	20.97	120.90	0	24205.87
Cropland	7230.70	533055.00	3368.56	9710.84	874.89	1296.81	1853.91	10666.90	5944.03	418.12	6616.28	0	581036.03
Evergreen forest-Dense	55.30	4853.49	608118.00	73056.80	4313.95	980.18	13.08	3518.44	3431.00	267.73	904.49	14.46	699526.91
Evergreen forest-Open	123.49	19379.30	45181.30	280552.00	3266.09	9956.45	12.84	27941.50	8939.00	800.18	1169.91	15.72	397337.79
Deciduous forest-Dense	50.11	1256.95	3170.42	3301.29	127241.00	26169.20	1292.20	2150.73	75.63	34.44	447.26	0	165189.24
Deciduous forest-Open	567.65	6214.52	1004.03	6712.93	38726.60	108023.00	1328.03	6525.27	471.51	199.64	772.99	0	170546.18
Plantation	301.77	3047.44	0	71.65	3319.26	387.99	13383.60	96.83	151.78	0	100.63	0	20860.94
Scrubland	427.16	36475.30	2392.59	14855.20	1479.63	7194.70	74.02	112058.00	19294.70	2170.25	986.86	0	197408.41
Grassland	62.78	9421.86	2928.10	10792.50	233.05	8.52	68.77	16333.60	166848.00	15630.60	708.25	523.87	223559.92
Barren land	11.23	396.29	346.12	1569.89	76.03	53.63	0	4509.62	60482.70	145804.00	3641.30	1150.68	218041.49
Waterbodies	110.25	4554.14	678.76	323.14	232.70	392.83	78.16	898.62	494.04	289.61	46780.80	3.74	54836.79
Glacier/Snow cover	0	6.05	355.91	1657.96	0	0	0	2964.10	47817.40	180933.00	354.07	266422.00	500510.49
Grand Total	31704.64	619646.97	667553.92	402615.66	179798.34	154539.52	18196.02	187746.72	313955.49	346568.54	62603.75	268130.48	3253060.04

Table 2: Change Matrix for 1995-2015

4.3. Prediction maps for 2025 and 2035

The trend for changes from 1995 to 2015 was further projected to get the predicted maps for 2025 and 2035. For validation, map for 2015 was predicted and compared with the classified map. The Kappa accuracy was 0.74. The predicted maps for 2025 and 2035 are provided in Figure 3.

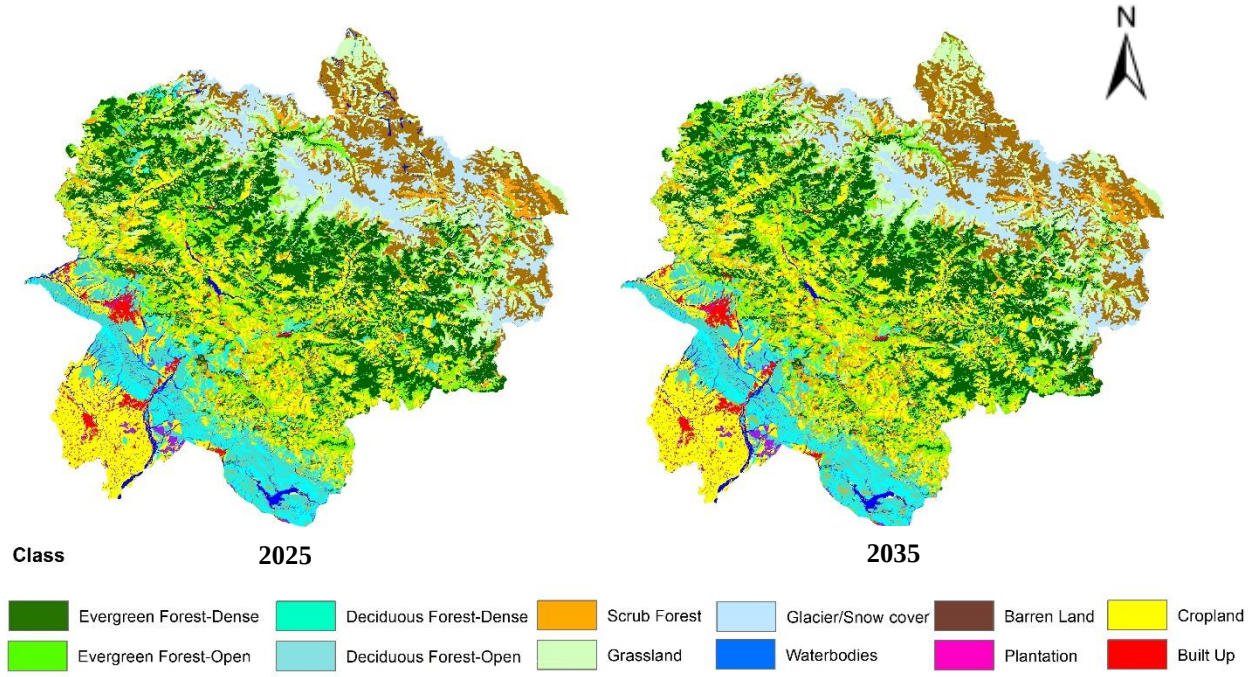

Figure 3: Predicted map for 2025 and 2035

For 2025 compared with 2015, highest percentage decrease was predicted for Glacier/Snow cover (29.51%), followed by Barren Land (18.08%) and Scrub Forest (9.18%). Highest percentage increase was predicted for Waterbodies (25.70%), followed by Built Up (20.60%) and Grassland (15.13%) (Table 3).

Classes	Year 2015 Area(ha)	Year 2025 Area(ha)	Change %
Built Up	31704.66	38234.3	20.60
Cropland	619646.79	651694.4	5.17
Evergreen forest-Dense	667553.92	653876.8	-2.05
Evergreen forest-Open	402615.67	415568.6	3.22
Deciduous forest-Dense	179802.30	201187	11.89
Deciduous forest-Open	154556.89	151719.9	-1.84
Plantation	18240.22	17232.88	-5.52
Scrub forest	187746.97	170501.5	-9.18
Grassland	313955.16	361461	15.13
Barren land	346569.02	283904.4	-18.08
Waterbodies	62606.67	78697.32	25.70
Glacier/Snow cover	324931.40	229050.1	-29.51

Table 3: Change Matrix summary 2015-2025

Similarly, for 2025- 2035, The percentage increase was highest for Scrub forest (15.63%), followed by Barren Land (7.71%). Whereas, the percentage decrease was highest for Deciduous forest-Open (14.15%), followed by Plantation (13.09%) (Table 4).

Classes	Year 2025 Area(ha)	Year 2035 Area(ha)	Change %
Built Up	38234.3	38435.21	0.53
Cropland	651694.4	662837.7	1.71
Evergreen forest-Dense	653876.8	643748.9	-1.55
Evergreen forest-Open	415568.6	418132.6	0.62
Deciduous forest-Dense	201187	182165.1	-9.45
Deciduous forest-Open	151719.9	130249.4	-14.15
Plantation	17232.88	14977.73	-13.09
Scrub forest	170501.5	197146.1	15.63
Grassland	361461	379012.1	4.86
Barren land	283904.4	305787.1	7.71
Waterbodies	78697.32	61672.38	-21.63
Glacier/Snow cover	229050.1	218964	-4.40

Table 4: Change Matrix summary 2025-2035

5. DISCUSSION

The changes from 1995-2035 were not favouring greenness. Evergreen forests were losing their area to agriculture and urban expansion. Settlement does not affect the natural environment much but the associated activities such as agriculture, extraction of wood etc. do. All the classes have lost some area to cropland. The quality of forests is also decreasing as the density of forests is decreasing. An opposite to it was found for Deciduous forest where a large area of open forest got converted into dense forest. From the field, it was observed that thick shrub cover underneath the tree canopy makes the forest appear denser in satellite image. Besides forest areas, area under waterbodies showed large difference (14.7% increase). This was due to different river boundaries in different seasons. The banks of the rivers are used for agriculture in dry season which in wet season is taken up by river water. Hence, waterbodies area change was not considered. Another major concern is that as per the predicted map, 105967.4 ha Glacier/Snow cover area would be lost which further support the fact that the glaciers are melting due to climate change. Since, glaciers are melting, the soil or rock below gets exposed. This land remains barren and gets converted to grassland later. For 2025, an increase in waterbodies was found in Glacier/Snow cover area which disappeared in 2035. This can be related to the prediction that the glaciers on melting will release large volume of water which will be further followed by scarcity of water in the upstream (IPCC, 2001). The prediction in this study does not encase abrupt or new addition such as large scale afforestation or changes that may occur due to natural calamities.

6. CONCLUSION

The analysis of LULCC in the study area indicate that the natural landforms are degrading and the human dominance in increasing. The result of this study can be used by the managers and planners to prioritize the areas for management. Besides, it is also recommended that there should be a check on the human encroachment into natural landforms.

7. ACKNOWLEDGEMENT

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