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Spatio-Temporal Dynamics of Almora Town Area, India

J.S. Rawat[1], Manish Kumar[1], and Ravindra Nath Pathak[2]

[1]Centre of Excellence for NRDMS in Uttarakhand, Department of Geography, Kumaun University, SSJ Campus, Almora, Uttarakhand, India
[2]Haryana Space Applications Centre (HARSAC), CCS Haryana Agriculture University Campus, Hisar, Haryana, India

Correspondence should be addressed to J.S. Rawat, jsrawat1955@gmail.com

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Abstract The present study illustrates an integrated approach of remote sensing and GIS (Geographical Information System), i.e., Geospatial techniques for measuring physical growth of Almora town of district Almora in the Kumaun region of Central Himalaya. Landsat satellite imageries of three different time periods, i.e., Landsat TM of 1990, Landsat TM 1999 and Landsat TM of 2010 were acquired and quantify the changes in the Almora town from 1990 to 2010 over a period of 20 years. Supervised Classification methodology has been employed using Maximum Likelihood Technique in ERDAS 9.3. The images of the study area were categorized into three different classes, viz., built-up area, vegetation and others. The results indicate that during the last two decades (i.e., 1990-2010), built-up area of the Almora town area has been increased about 80.73% (i.e. 2.04 km^2) while areas under vegetation and other land categories have decreased about 43.42% (i.e. 1.32 km^2) and 37.31% (i.e. 0.72 km^2), respectively. The results of the paper on digital change detection techniques shall be helpful in proper land use planning for a sustainable and uniform urban growth of the Almora town area.

Keyword *Land Use/Cover; Spatio-Temporal; Multi-Temporal Satellite Imagery; Remote Sensing*

1. Introduction

Land is becoming a scarce resource due to immense urban development and demographic pressure. Hence, information on land use/cover and possibilities for their optimal use is essential for the selection, planning and implementation of land use schemes to meet the increasing demands for basic human needs and welfare. This information also assists in monitoring the dynamics of land use resulting out of changing demands of increasing population. The Land use/cover pattern of a region is an outcome of natural and socio-economic factors and their utilization by man in time and space. Information on land use/cover is important to support urban management and planning, sustainable management of natural resources and socio-economic development (Kontes et al., 2000). Land cover is a fundamental parameter describing the Earth's surface. This parameter is a considerable variable

that impacts on and links many parts of the human and physical environments (Foody, 2002). On the other hand, land use refers to man's activities which are directly related to the land (Clawson and Stewart, 1965). Land use involves the management and modification of natural environment or wilderness into built environment such as fields, pastures, and settlements. Land use/cover change has become a central component in current strategies in managing natural resources and monitoring environmental changes. Land use/cover dynamics are widespread, accelerating and significant process driven by human action but also producing changes that impact humans (Agarwal *et al*., 2002). Land use/cover change, as one of the main driving forces of environmental change, is central to the sustainable development debate. Land use/cover changes have impacts on a wide range of environment and landscape. The change in land cover occurs even in the absence of human activities through natural processes where as land use change is the manipulation of land cover by human being for multiple purposes-foods, fuel wood, timber, fodder, leaf, litter, medicine, raw materials and recreation. Many socio-economic and environmental factors are involved for the change in Land use/cover. Land use/cover change has been reviewed from different perspectives in order to identify the drivers of land use/cover change, their process and consequences. The advent of high spatial resolution satellite imagery and more advanced image processing and GIS technologies, has resulted in a switch to more routine and consistent monitoring and modeling of land use/cover patterns. Using remote sensing techniques to develop land use classification mapping is a useful and detailed way to improve the selection of areas designed to agricultural, urban and/or industrial areas of a region (Selçuk, 2003). Remote-sensing has been widely used in updating land use/cover maps and land use/cover mapping has become one of the most important applications of remote sensing (Lo, 2004). The mapping of land use/cover can be performed in a cost-effective manner using Earth observation remote-sensing technologies in conjunction with geographical information systems (Weng, 2002) and GI Science (Wilson, 2008).

The present study demonstrates the application of multi-temporal satellite imageries in defining land use/cover dynamics of a Himalayan town, viz. Almora located in the Uttarakhand State in the Central Himalayan region of Kumaun Himalaya.

2. Study Area

The study area, viz., Almora town (Figure 1) in Uttarakhand, India extends between 29°05’16”N to 29°17’28”N latitudes and 79°24’07”E to 79°37’05"E longitudes and encompasses an area of 7.27 km². The average height of the town stands at 1,651 meters above mean sea level. Almora town enjoys the cool temperate climatic conditions.

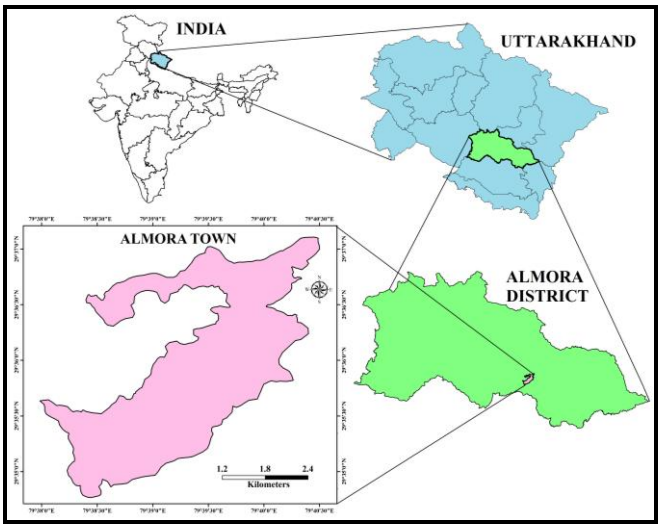

Figure 1: *Location Map of the Study Area*

3. Methodology

3.1. Land Use/Cover Detection and Analysis

To work out the land use/cover classification, Landsat TM at a resolution of 30 m of 1990, 1999 and 2010 using bands 2 (green), 3 (red) and 4 (near-infrared) were used. The satellite data covering study area were obtained from Global Land Cover Facility (GLCF) site. These data sets were imported in ERDAS Imagine version 9.3 (Leica Geosystems, Atlanta, U.S.A.), satellite image processing software to create a False Colour Composite (FCC). The layer stack option in image interpreter tool box was used to generate FCCs for the study areas. The sub-setting of satellite images were performed for extracting study area from both images by taking geo-referenced out line boundary of Almora town map as AOI (Area of Interest). The FCC images of the study area were then digitally processed for land use/cover identification and mapping. Image classification procedure is used to classify multispectral pixels into different land cover classes. The Maximum Likelihood Algorithm of Supervised Classification was used for pixel clustering. Three land use/cover types are identified in the study area viz., (i) vegetation (ii) built-up land (iii) others.

3.2. Land Use/Cover Change Detection and Analysis

For performing land use/cover change detection, a post-classification detection method was employed. A change matrix (Weng, 2001) was produced with the help of ERDAS Imagine software. Quantitative areal data of the overall land use/cover changes as well as gains and losses in each category were determined between 1990 and 2010 and then compiled.

3.3. Land Use/Cover Status

Figure 2 depicts spatial distributional pattern of land use/cover of the Almora town area for the year 1990, Figure 3 for the year 1999 and Figure 4 for the year 2010. These data reveal that in 1990, about 31.63% (2.30 km^2) area of Almora town was under built-up land, 41.82% (3.04 km^2) under vegetation and 26.55% (1.93 km^2) under others land categories. During 1999 the area under these land categories was found 40.85% (2.97 km^2) area of Almora town was under built-up land, 38.97% (2.82 km^2) under vegetation and 20.36% (1.48 km^2) under others land categories. During 2010 the area under these land categories was found 59.68% (4.34 km^2) area of Almora town was under built-up land, 23.66% (1.72 km^2) under vegetation and 16.66% (1.21 km^2) under others land categories.

Table 1: *Distribution of Land Use/Cover during 1990, 1999 and 2010*

Land use/cover	1990		1999		2010	
	Km^2	%	Km^2	%	Km^2	%
Vegetation	3.04	41.82	2.82	38.79	1.72	23.66
Built up Area	2.30	31.63	2.97	40.85	4.34	59.68
Others	1.93	26.55	1.48	20.36	1.21	16.66
Total	7.27	100	7.27	100	7.27	100

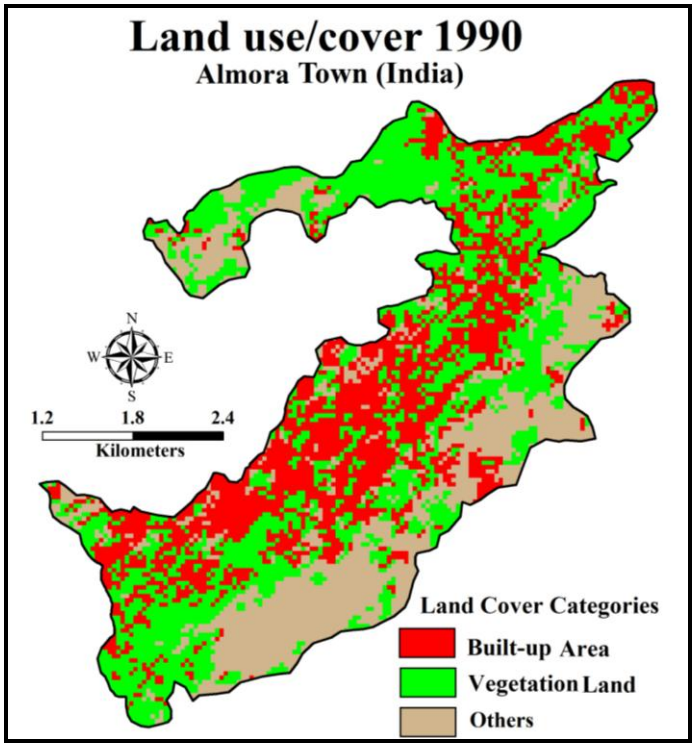

Figure 2: *Land Use/Cover Map of 1990 of the Almora Town, District Almora (Based on Landsat Thematic Mapper Satellite Imagery)*

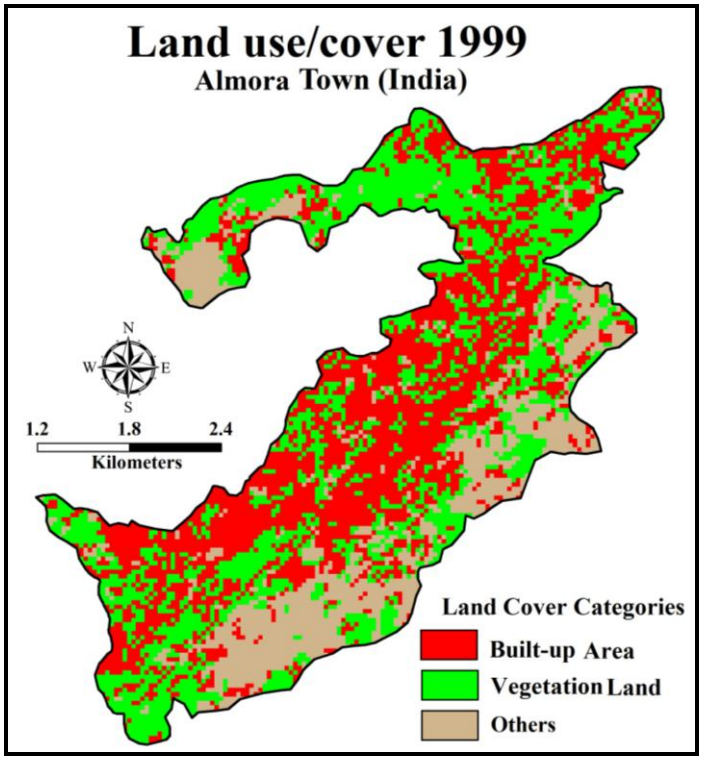

Figure 3: *Land Use/Cover Map of 1999 of the Almora Town, District Almora (Based on Landsat Thematic Mapper Satellite Imagery)*

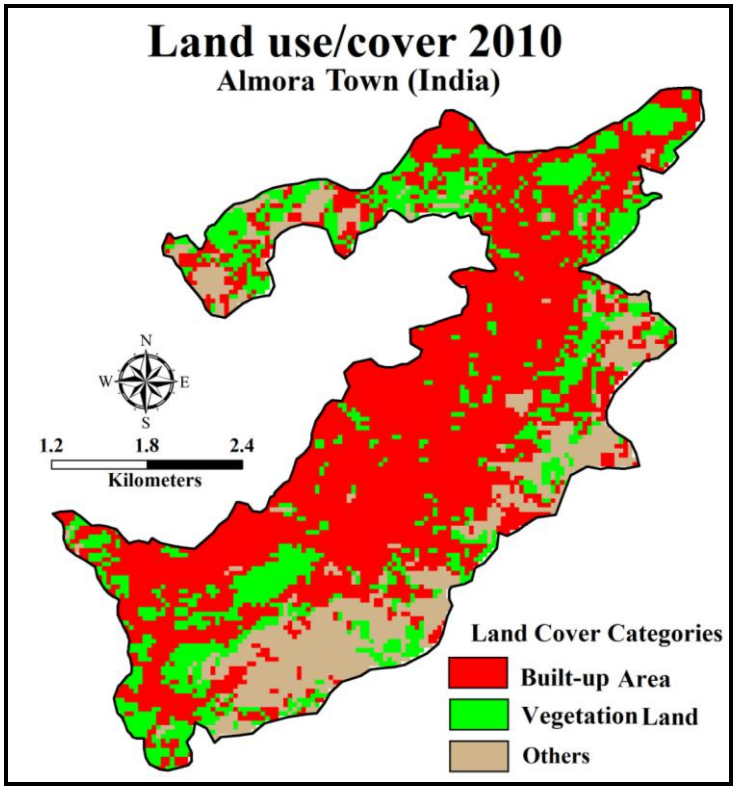

Figure 4: *Land Use/Cover Map of 2010 of the Almora Town, District Almora (Based on Landsat Thematic Mapper Satellite Imagery)*

3.4. Land Use/Cover Change

The data registered in Table 2 & 3 and Figure 5 & 6 depict that both positive and negative changes occurred in the land use/cover pattern in the Almora town area. During the last two decades the built-up area has increased from 2.30 km^2 in 1990 to 2.97 km^2 in 1999 and 4.34 km^2 in 2010 which accounts for 80.73% of the total sprawl area. The vegetation cover has been decreased from 3.04 km^2 in 1990 to 2.82 km^2 in 1999 and 1.72 km^2 in 2010. This decreased in vegetation accounts for 43.42% of the total town area. The land under other categories has been decreased from 1.93 km^2 in 1990 to 1.48 km^2 in 1999 and 1.21 km^2 in 2010. This decreased in other land category accounts for 37.31 % of the total town area.

The study reveals that in between 1990 to 1999 and 1999 to 2010 Almora town is increasing at the rate of 0.07 km^2/year and 0.12 km^2/year, respectively which was 0.10 km^2/year increased during the two decades (i.e., 1990-2010) (Table 3).

Table 2: *Area and Amount of Change in Different Land Use/Cover Categories in the Almora Town Area during 1990 to 2010*

Land use/cover Categories	1990-1999		1999-2010		1990–2010	
	km^2	%	km^2	%	km^2	%
Vegetation	-0.22	-7.24	-1.10	-39.00	-1.32	-43.42
Built Up Area	0.67	30.56	1.37	47.24	2.04	80.73
Others	-0.45	-23.32	-0.27	-18.24	-0.72	-37.31

Table 3: *Area and Amount of Change in Different Land Use/Cover Categories in the Almora Town Area during 1990 to 2010*

Land use/cover category	1990-1999	1999-2010	1990-2010
	Km^2/year	Km^2/year	Km^2/year
Vegetation	-0.02	-0.1	-0.06
Built up Area	0.07	0.12	0.10
Others	-0.05	-0.02	-0.03

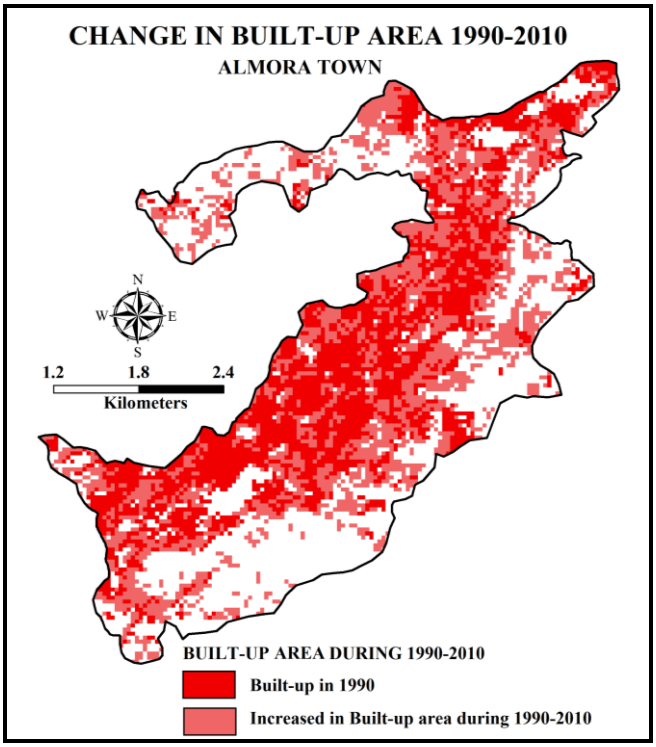

Figure 5: *Change in Built-Up Area during 1990-2010 of the Almora Town, District Almora (Based on Landsat Thematic Mapper Satellite Imagery)*

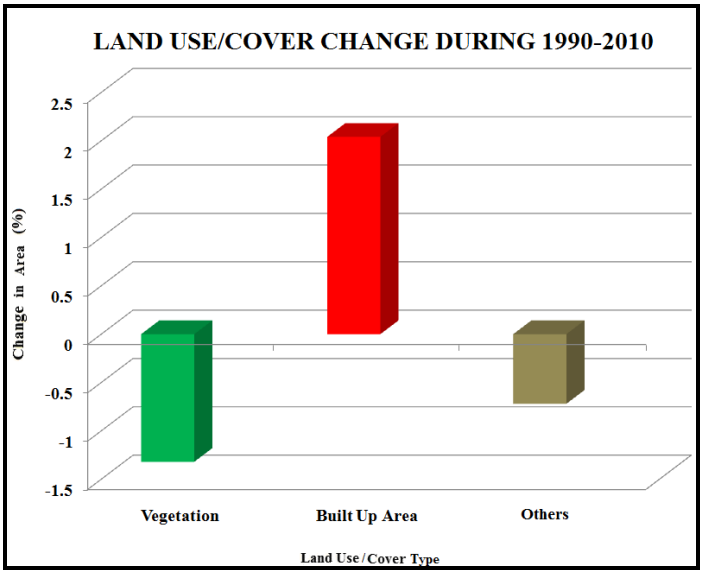

Figure 6: *Diagrammatic Illustration of Land Use/Cover Change during the Last Two Decades (1990-2010) in the Haldwani Town Area*

3.5. Land Use/Cover Change Matrix

To understand land encroachment in different land use/cover categories, change detection matrix (Table 4) was prepared which reveals that during the last two decades (1990–2010)

i) About 49% of vegetation covered has been converted into built-up land and about 08.11% into others land category;
ii) About 25.76% of land into others category has been converted into vegetation cover and 24.39% into built-up land.

Table 4: *Land Use/Cover Change Matrix Showing Land Encroachment (in %) in Almora Town Area during 1990–2010*

	Land Use/Cover Categories	Year 1990		
		Vegetation	Built-up Area	Others
Year 2010	Vegetation	42.89	0.00	25.76
	Built-up Area	49.00	100.00	24.39
	Others	08.11	0.00	49.85
	Class Total	100.00	100.00	100.00
	Class Change	57.11	0.00	50.15

4. Conclusion

The study conducted in one of the towns of the Uttarakhand state located in the Central Himalaya, India, viz., Almora advocates that multi-temporal satellite imagery are very useful to detect the changes in land use quickly and accurately. The study reveals that the major land use in the Almora town area is built-up area. During the last two decades the area under built-up land has been increased 80.73% (2.04 km^2) due to construction of new buildings on agricultural and vegetation land while the area under vegetation and others land category have decrease by 43.42% (i.e. 1.32 km^2) and 37.31% (i.e. 0.72 km^2), respectively. The approach adopted in this study clearly demonstrated the potential of GIS and remote sensing techniques in measuring change pattern of land use/cover in town area which is otherwise not possible to attempt through conventional mapping. Change detection is made possible by these technologies in less time, at low cost and with better accuracy.

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