International Journal of Advanced Research in Engineering and Applied Sciences

ISSN: 2278-6252
Impact Factor: 4.817

ANALYSIS OF LAND USE/LAND COVER IN RELATION TO GEOMORPHOLOGICAL FEATURES ALONG SATLUJ RIVER, HIMACHAL PRADESH, INDIA

Sandeep Kumar*

Santosh**

Abstract: *Land use/land cover is obviously constrained by environmental factors such as climate, soil characteristics along with geological and geomorphological features of the area. In this study, an attempt has been made to delineate the LULC categories with reference to geomorphological features along the course of Satluj River. The relationship was explored by investigating the area using remote sensing and GIS. Statistical analysis shows that major part of the area is covered by forests followed by agriculture, barren rocky area and land with/without scrub. The various geomorphic features are dominant accordingly, especially in the upper two climatic zones but in the lower climatic zone, due to modifications by human beings for socio-economic activities, the LULC and geomorphology are inconsistent with each other. This clearly indicates that the land covered by various forests is diverted for settlement, agriculture/horticulture and other developmental activities. This study may prove significant for policy makers and planners in their planning efforts which help in establishing sustainable development strategies in the region.*

Keywords: *Climatic zone, Geomorphology, Land use/land cover, Remote sensing, River.*

*Department of Environment Studies, Panjab University, Chandigarh

**Department of Environmental Sciences, MDU, Rohtak (Haryana)

1. INTRODUCTION

Land is one of the most important natural resources on which all activities of human beings are based in one way or the other. Geomorphology is the science of landforms which generally consist of the linear, areal and relief aspects of the drainage network. A typical landform is formed due to the interaction of processes of tectonic activities, erosion and deposition, that is well exemplified by the geomorphic features of the area. The surface configuration of an area is due to continuous spatial variability of landforms, each of which possesses a distinct morphologic expression and characterised by some clearly defined physical properties and some dominant geomorphic processes (Jog, 1995). Factors, like the stage and pattern of development, climatic conditions, type of land, physical features and the texture are important for determining the LULC of an area. Land use/land cover is obviously constrained by environmental factors such as climate, soil characteristics along with geological and geomorphological features of the area. Though, land use practices and land cover categories are directly related to geomorphology of the area but unlike geological and geomorphological features, land use is seasonally dynamic in nature. The land use/land cover can be critically viewed in light of the existing physical environment like geology, geomorphology, hydrology, tectonics and the agro-climatic conditions of the area (Thapa and Sood, 2004). Land use/land cover features are controlled by geomorphic units, which are further altered by human modifications.

It is difficult to get real time information for the delineation of land features through conventional means, which are time consuming and expensive. The remote sensing and GIS techniques are more important to interpret the features, which provide time and cost effective solutions. Hence remote sensing integrated with GIS provides an effective tool for analysis of LULC and geomorphology, together with ground truth surveys to collect information on the qualitative and quantitative status.

The Satluj River along its course is geomorphologically diverse. The area shows uneven topography with varying drainage density, geomorphic features of regional extent and genetic significant. The objective of this study is to compare and analyse the land use/land cover pattern in relation to geomorphological features along the Satluj River i.e. to understand the relationship between land use/land cover and geomorphology of the area.

2. STUDY AREA

2.1 Location and drainage

The study area comprised the parts of Satluj River catchment, Khab to Bhakra dam i.e. 5 km stretch on both side, which falls in Kinnaur, Shimla, Kullu, Mandi, Solan and Bilaspur districts of Himachal Pradesh. The Satluj River (Vedic name - Satudri and Sanskrit name - Shatadru), also known as the Langqên (Chinese) and Sutlej (Indian), is the principal and easternmost tributary of the Indus River system. It originates from the southern slopes of Kailash Mountains i.e. from Rakas Lake as Longcchen Khabab River, at an elevation of about 4,572 meters (15,000 feet), above mean sea level (msl). It enters India from east of Shipki La (altitude-3048 m, above msl) after traversing a length of about 320 km (200 miles) in the Tibetan province of Nari Khorsam, through a narrow gorge in the Kinnaur district of Himachal Pradesh and flows in southwesterly direction. Before leaving the Himachal Pradesh, it cuts a gorge in Naina Devi Dhar and mingles with the water of Govind Sagar Lake. The geographical limits of the study area lie between 31°10′ N to 31°50′ N latitude and 76°30′ E to 78°40′ E longitude in the western Himalayas. It falls in the toposheet no. 53 I/9, 53 I/10, 53 I/6, 53 I/2, 53 I/3, 53E/14, 53E/15, 53E/10, 53E/11, 53E/7, 53E/8, 53E/3, 53E/4, 53A/15 and 53A/11 on 1:50,000 scale. The distance covered by river, from Khab to Bhakra Dam, is approximately 320 Kilometers. The gradient of river is very steep near its source and gradually reduces downstream. A gross fall of 2180 m is available in the river bed from Shipki La to Bhakra dam (EIA, Luhri HEP, 2006). The river flows through different areas, having varying climatic and topographic features. It is an antecedent, Trans-Himalayan River and generally follows the dendritic pattern (Gupta and Sah, 2008). Along with its major and minor tributaries, it drains over 40% of NE and SE parts of Himachal Pradesh (Bartarya *et al*., 1996). Discharge of river comprises monsoonal rainfall, glacier and snowmelt. It is supported by number of mighty tributaries on either side. Main tributaries are Spiti, Bhaspa and Gambhar at Khab, Karchham and Kangri respectively.

2.2 Geological and geomorphological set up

The study area has a complex geological and tectonic setup, incorporated in Indian Standards as a high damage risk zone. It comprises a variety of rocks belonging to different lithotectonic groups. The higher Himalaya consists of medium to high grade metamorphic and sedimentary cover of Tethyan sediments. These have been intruded by granite

intrusions. The lesser Himalaya consists of low grade metamorphic and sedimentary thrust sheets (Bartarya *et al*., 1996). The rocks of lesser and higher Himalayas are highly folded and faulted with axial cleavage. At its lower reaches, the river cuts through fragile layers of sedimentary rocks of Shiwalik range. Apart from wide variation in lithology, the area comprises the extreme cover of glacial, glacio-fluvial, old slided mass, fluvial, talus deposits and other sediments of Quaternary age (Gupta and Sah, 2008). The river crosses a number of thrusts and faults, separating the Rampur, Jutogh, Vaikrita and Haimanta formations.

The river along its course has curved out a variety of geomorphic features in different micro-climatic zones. It shows immature topography as indicated by active erosional processes, high relief, deep gorges and high channel gradient. Among the various geomorphic processes, the glacial and fluvial have played a dominant role in shaping the present landscape. Fluvial terraces, debris fans and talus cones are other features (Gupta and Sah, 2008). It makes steep gradient along its longitudinal profile in the first phase i.e. at its source and gradually decreases as it descends downstream.

2.3 Climate and seasons

The river channel can be divided into different climatic zones, having diversity in orographic settings and physiographic features. This zonation is primarily based on the amount of annual rainfall and variation in temperature. From North to South, it has been divided into three broad climatic zones i.e. semi-arid to arid temperate zone (upstream from the Morang), sub-humid to humid temperate zone (between the Wangatoo and Morang) and wet temperate or Monsoonal zone (downstream of Wangatoo). Each zone is characterised by its own peculiarities of climatic factors, geomorphic and topographic features (Gupta *et al*., 1994; Bartarya *et al*., 1996). The average annual precipitation in the semi-arid to arid temperate, sub-humid to humid temperate and wet temperate or monsoonal zone is <200 mm, 200-800 mm and >800 mm respectively. The mean minimum temperature recorded in each zone is -11, -8 and -5°C, whereas, mean maximum temperature is 15, 28, and 30°C respectively (Gupta and Sah, 2008).

ISSN: 2278-6252
Impact Factor: 4.817

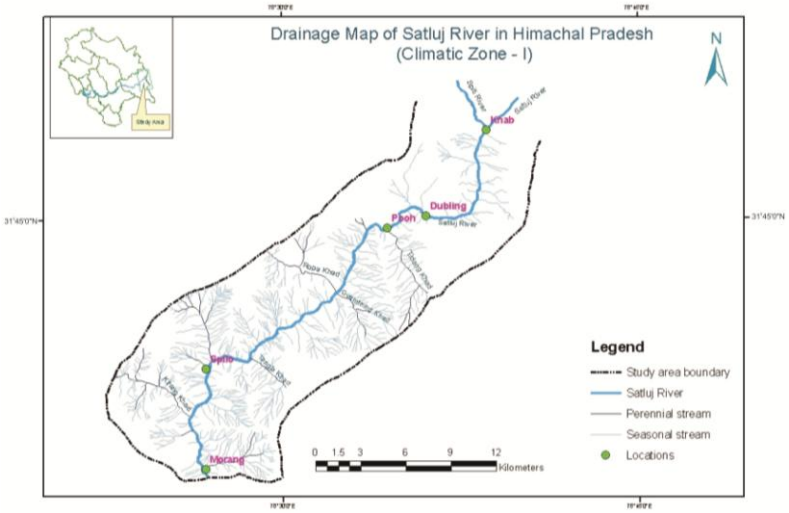

Figure 1. Map showing the climatic zone - I of Satluj River

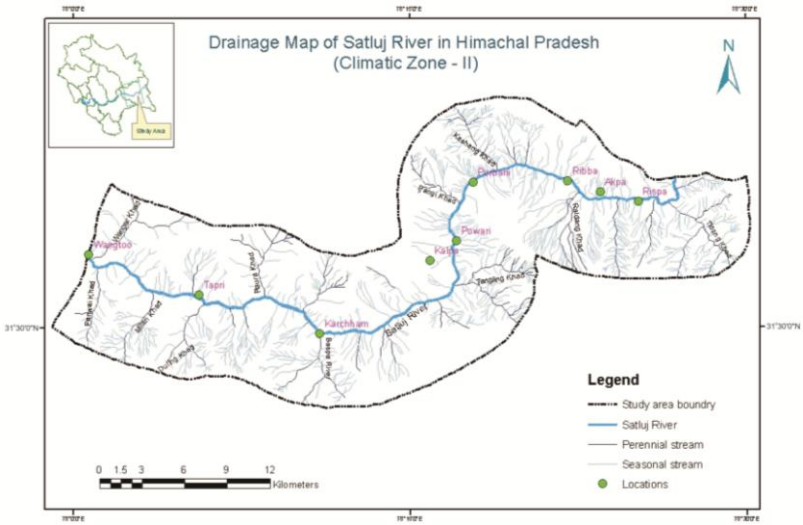

Figure 2. Map showing the climatic zone - II of Satluj River

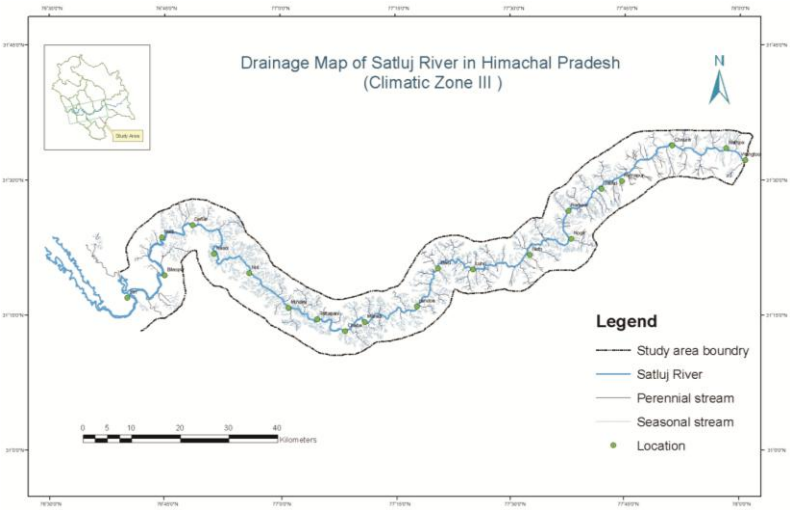

Figure 3. Map showing the climatic zone - III of Satluj River

Based on broad climatic conditions, the area has following four seasons: winter (December to March), pre-monsoon (April to June), monsoon (July to September) and post-monsoon (October, November).

3. MATERIALS AND METHODS

The study was predominantly based on primary data and the information available from secondary sources. Broadly two types of approaches were being adopted for classifying land use/land cover and geomorphology into various categories i.e. remote sensing and GIS. The classification system developed by National Remote Sensing Agency (NRSA, 1990) was followed to generate land use/land cover map. The published thematic maps were consulted for delineating geomorphological features. False colour composite (FCC) imageries of LISS – III (scale- 1:50,000 and bands- 2, 3, 4) were used for the visual interpretation. Moreover, these were fused with IRS-Panchromatic to produce PAN sharpened images. Whole study area was not covered in a single imagery; therefore investigation was carried out using data from number of closest year of adjoining imageries of IRS satellites. The satellite data used was IRS-1D **(**PAN + LISS III merged**)** for the entire study area.

Survey of India (SOI) topographical maps numbers; 53 I/9, 53 I/10, 53 I/6, 53 I/2, 53 I/3, 53E/14, 53E/15, 53E/10, 53E/11, 53E/7, 53E/8, 53E/3, 53E/4, 53A/15 and 53A/11 on 1:50,000 scale were used in the preparation of base maps. In LULC study, Level II classification was used, suitable for mapping on 1:50,000 scale. The smallest mapping unit of size 3X3 under this classification on this scale covers 11.25 hectares of area on the ground. Processed digital satellite data was procured from National Remote Sensing Agency by SCST&E, Shimla (H.P.) where the hardware and software facilities were provided. The satellite imageries used for preparation of LULC maps were acquired on 6th February, 21st September, 3rd, 28th, 31st October 2000; 21st September 2001 and 18th February, 28th October, 20th November 2002 (Path- 94 to 97 & Row- 49). The geomorphological sheets on 1:50,000 scale were supplied by Irrigation and Public Health (I & PH) department, Una, Himachal Pradesh. These sheets were prepared from the satellite imageries provided by National Remote Sensing Centre (NRSC), Hyderabad. The FCC imageries used for the preparation of sheets were of IRS-1D satellite with LISS III, dated 28th October 2000, 4th May 2002 and 9th May 2003.

ISSN: 2278-6252
Impact Factor: 4.817

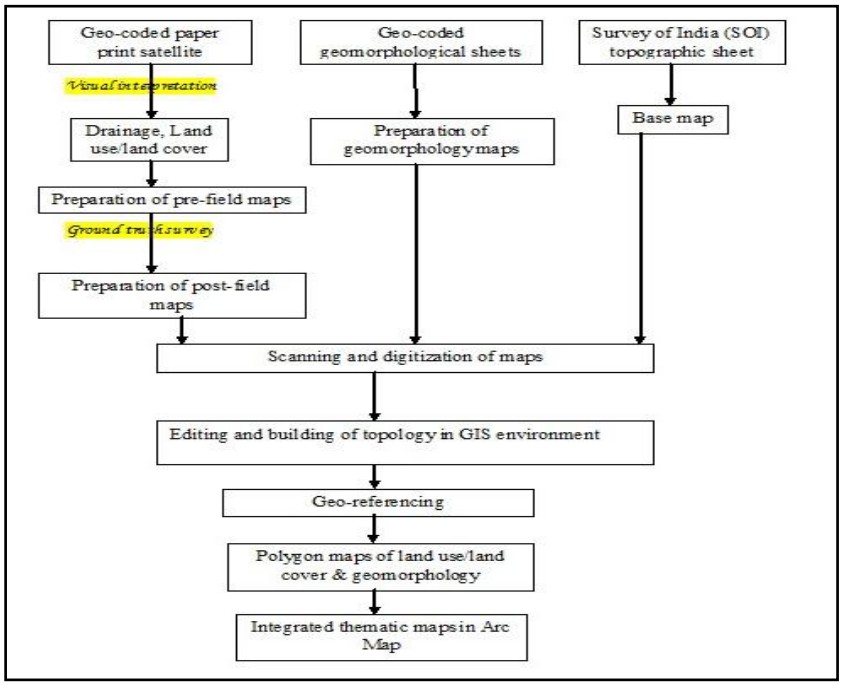

Figure 4. Procedure for the preparation of land use/land cover and geomorphology maps

Statistics of all maps i.e. length of river along with its perennial and seasonal tributaries, area of different categories of land use/land cover and geomorphology were calculated using Arc info GIS software.

4. RESULTS AND DISCUSSION

On the basis of these studies, various geomorphological units and land use/land cover have been mapped and statistically analysed.

Figure 5

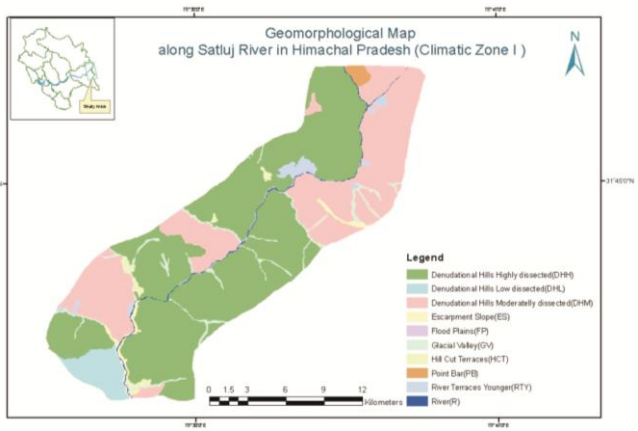

Figure 6

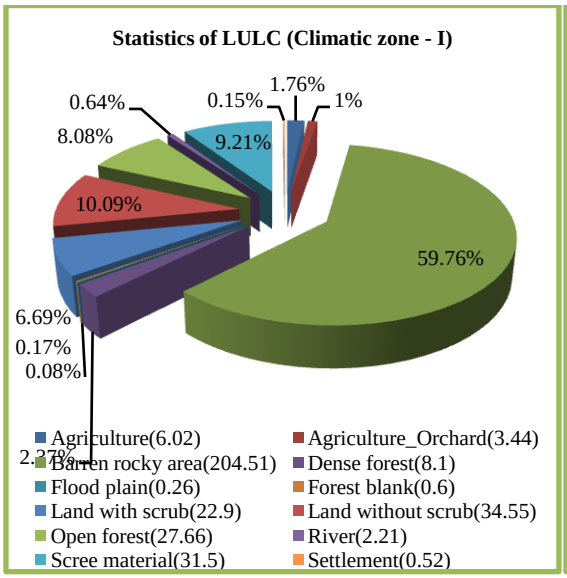

Figure 7

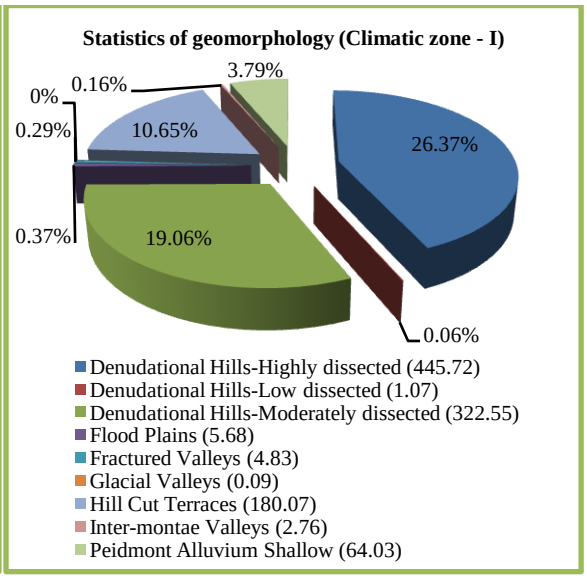

Figure 8

Figure 5-8. Map and statistics (area in Km^2) of land use/land cover and geomorphology in climatic zone – I (Semi arid to arid temperate)

Table 1. Quantitative distribution of major LULC categories and dominant geomorphic units in climatic zone – I

LULC categories	% of total area	Dominant geomorphic units
Agriculture	1.76	Hill cut terraces, river terraces younger
Agriculture_orchard	1.00	Hill cut terraces, river terraces younger
Barren rocky area	59.76	Denudational hills-moderate and highly dissected
Dense forest	2.37	Denudational hills-low and moderately dissected
Forest blank	0.17	Denudational hills-moderately dissected
Land with scrub	6.69	Denudational hills-low, moderate & highly dissected
Land without scrub	10.09	Denudational hills-moderate and highly dissected
Open forest	8.08	Denudational hills-low, moderate & highly dissected
Scree material	9.21	Denudational hills-moderate and highly dissected, escarpment slopes
Settlement	0.15	Hill cut terraces, river terraces younger

In climatic zone – I, the major area is covered by barren rocks (59.76%), generally devoid of vegetation and unsuitable for human settlement, where the dominant geomorphic features are moderate and highly dissected denudational hills. The area under agriculture, horticulture and settlement accounts for 2.91%, which generally occurs in hill cut and younger river terraces. The scree material (9.21%) is generally present along the river and dominated by escarpment slopes, moderate and highly dissected denudational hills. The forest types identified are dense and open forest, which along with forest blank accounts for 10.62%, where dominant geomorphic units are low, moderate and highly dissected denudational hills. Apart from these features, the land area of 16.78% is covered by land

with/without scrub where low, moderate and highly dissected denudational hills are dominant.

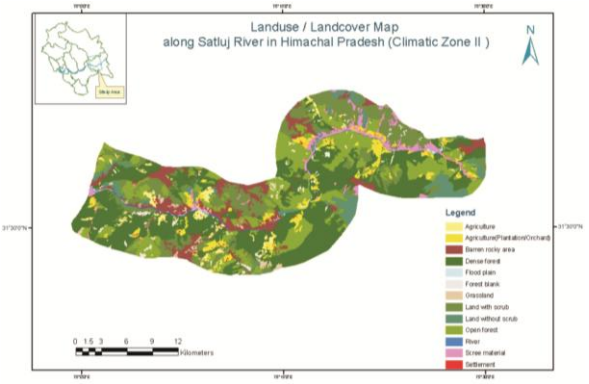

Figure 9

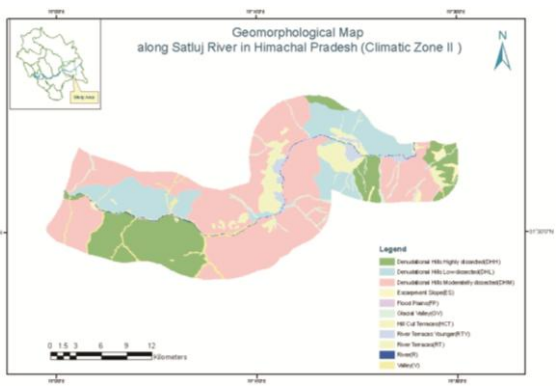

Figure 10

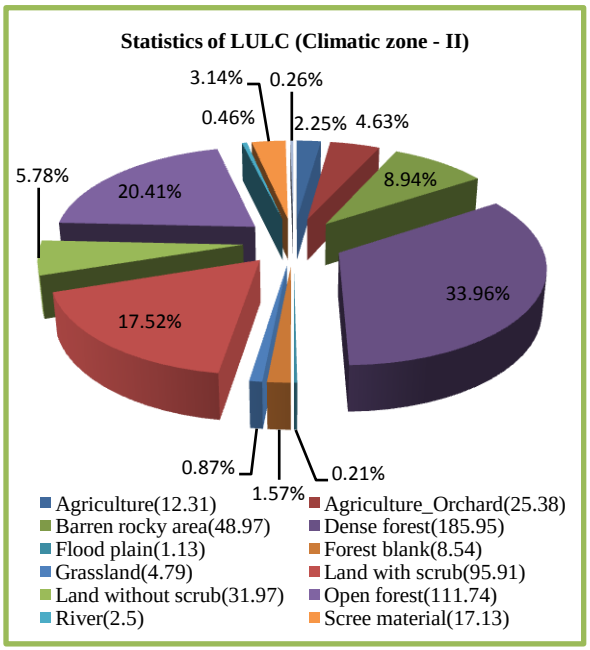

Figure 11

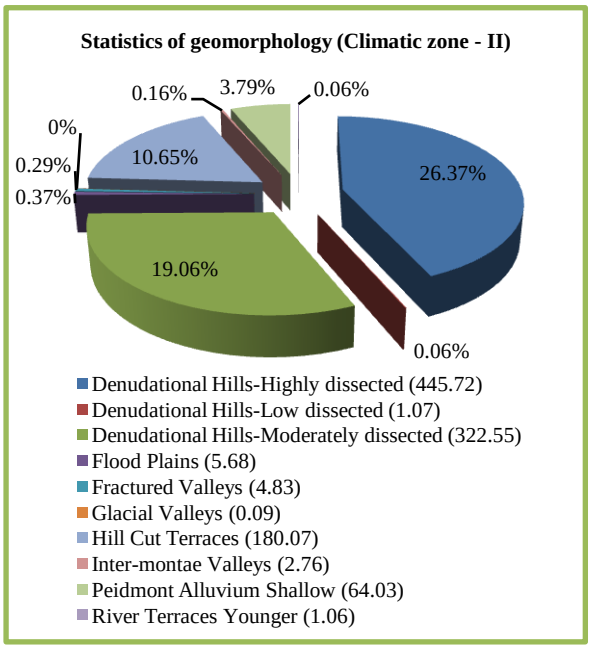

Figure 12

Figure 9-12. Map and statistics (area in Km^2) of land use/land cover and geomorphology in climatic zone – II (Sub humid to humid temperate)

Table 2. Quantitative distribution of major LULC categories and dominant geomorphic units in climatic zone – II

LULC categories	% of total area	Dominant geomorphic units
Agriculture	2.25	Hill cut terraces, river terraces
Agriculture_orchard	4.63	Hill cut terraces, river terraces
Barren rocky area	8.94	Denudational hills-low, moderate & highly dissected
Dense forest	33.96	Denudational hills-low, moderate & highly dissected
Forest blank	1.57	Denudational hills-low, moderate & highly dissected

Grassland	0.87	Denudational hills- moderately dissected
Land with scrub	17.52	Denudational hills-low, moderate & highly dissected
Land without scrub	5.78	Denudational hills-moderately dissected
Open forest	20.41	Denudational hills-low, moderate & highly dissected
Scree material	3.14	Denudational hills-moderate and highly dissected, escarpment slopes
Settlement	0.26	Hill cut terraces, river terraces

In climatic zone – II, the LULC data shows that the major land cover type is dense forest (33.96%), followed by open forest (20.41%) and a few forest blank patches are present, which accounts for 1.57%. In all types, the dominant geomorphic features are low, moderate & highly dissected denudational hills. The area falling under land with scrub is 17.52% and the land without scrub is 5.79%, which occurs on low, moderate, high and moderate dissected denudational hills respectively. Barren rocky area (8.94%) lies over low, moderate & highly dissected denudational hills. Settlement is generally present in the terraces of river where agriculture (2.25%) along with orchard/plantation type of agriculture (4.63%) is generally practiced and encountered by hill cut terraces, river terraces geomorphic units. The scree material accounts for 3.14%, which is present on escarpment slopes, moderate & highly dissected denudational hills. Few grassland patches are present in the forest cover area, accounting for 0.87%, where moderately dissected denudational hills are dominant.

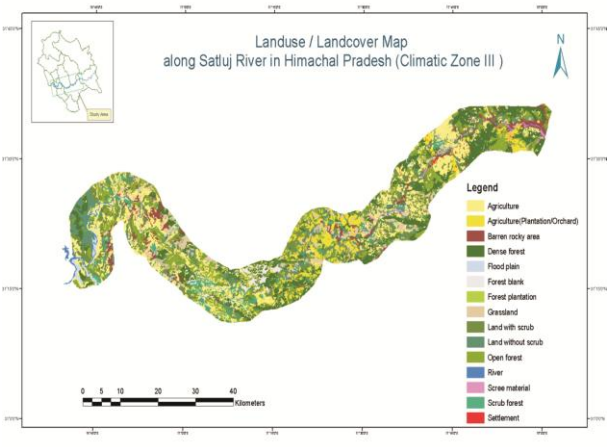

Figure 13

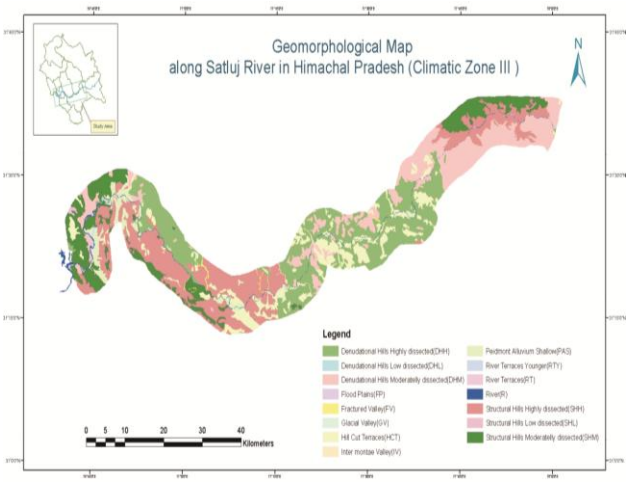

Figure 14

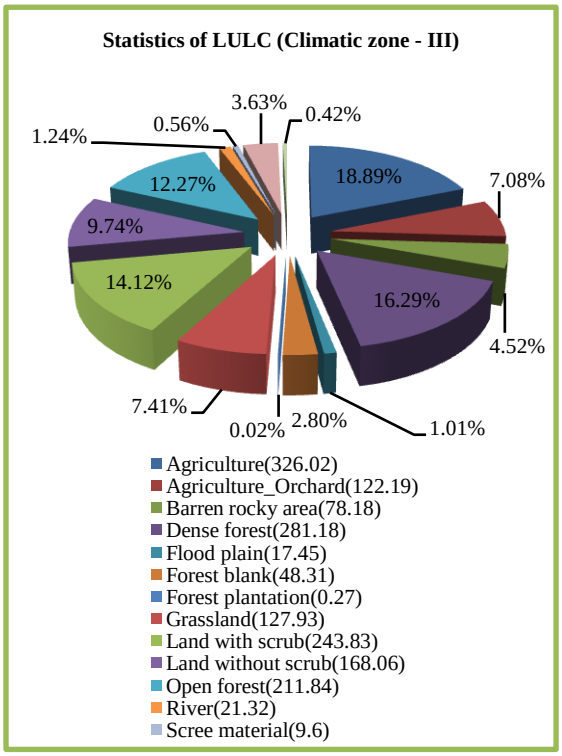

Figure 15

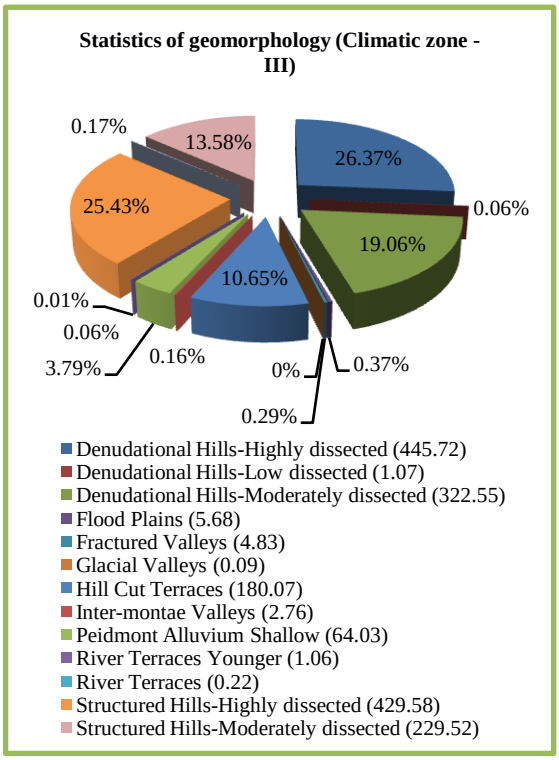

Figure 16

Figure 13-16. Map and statistics (area in Km^2) of land use/land cover and geomorphology in climatic zone – III (Wet temperate or monsoonal)

Table 3. Quantitative distribution of major LULC categories and dominant geomorphic units in climatic zone – III

LULC categories	% of total area	Dominant geomorphic units
Agriculture	18.89	Hill cut terraces, river terraces, peidmont alluvium shallow, structured hills-moderately dissected, denudational hills-highly dissected
Agriculture_orchard	7.08	Hill cut terraces, structured hills-low dissected
Barren rocky area	4.52	Denudational hills- moderate & highly dissected
Dense forest	16.29	Structured hills-low dissected, denudational hills-moderate & highly dissected
Forest blank	2.80	Structured hills-highly dissected
Grassland	7.41	Structured and denudational hills-highly dissected
Land with scrub	14.12	Denudational hills- highly dissected
Land without scrub	9.74	Denudational hills- moderate & highly dissected
Open forest	12.27	Structured hills-highly dissected, denudational hills-moderate & highly dissected

Scree material	0.56	Structured hills-highly dissected, denudational hills-moderately dissected
Scrub forest	3.63	Structured hills-moderate & highly dissected
Settlement	0.42	Hill cut terraces, river terraces

In climatic zone – III, the primary land use category identified is agriculture (18.89%) where hill cut terraces, river terraces, peidmont alluvium shallow, structured hills-moderately dissected, denudational hills-highly dissected are dominant geomorphic units. Hill cut terraces, structured hills-low dissected are prominent in orchard/plantation type of agriculture, which accounts for 7.08%, whereas the dense population is settled over hill cut terraces and river terraces. The area under forest is classified as dense (16.29%); open (12.27%); scrub (3.63%); forest plantation (0.02%) and forest blank (2.80%) along with grasslands (7.41%), which are encountered by structured hills low, moderate & highly dissected and denudational hills-moderate & highly dissected. The land with/without scrub accounts for 23.86% along with barren rocky (4.52%), which are dominated by moderate & highly dissected denudational hills. The area falling under scree material is just 0.42%, where the structured hills-highly dissected and denudational hills-moderately dissected are prominent geomorphic features.

The land use/ land cover categories are directly related to geomorphological features of an area. In the upper reaches of the river, the barren rocks are pre-dominant, generally devoid of vegetation. As one goes down, the area under these rocks decreases. In all the climatic zones of the study area, moderate and highly dissected denudational hills are common geomorphic units. The terraces have provided an ideal geo-environment for human activities such as agriculture, horticulture, settlements and other civil establishments. The area under such activities increases down the stream. It was observed that apart from terraces, the low and moderately dissected structural hills are other encountered geomorphic units, especially in the lower reaches of river. The forests are classified under various categories. The low, moderate and high dissected denudational hills are dominant in upper two climatic zones whereas low, moderate and high dissected structured hills are dominantly encountered in the lower zone. The land with/without scrubs is generally dominated by low, moderate and high dissected denudational hills in the study area. The

study clearly indicates that the geomorphic divisions are well correlated with the distribution of different LULC in the area.

5. CONCLUSIONS

It was observed that land use/land cover categories are directly related to geomorphological features of the study area. This clearly indicates that the geomorphic divisions are well correlated with the distribution of different LULC, especially in the upper two climatic zones. But comparison in the climatic zone – III shows that severe deforestation activities are occurring, where the land is diverted for other socio-economic activities, which is geomorphologically inconsistent. The relationship acts as a basis for further land evaluation and land use planning by finding out areas suitable for developmental activities**.** It is further imperative to suggest that such studies may be useful for policy makers and planners in their planning efforts, which help in establishing sustainable development strategies in the region.

ACKNOWLEDGEMENTS

Authors are thankful to Indian Council of Medical Research (ICMR) and University Grant Commission (UGC), New Delhi for providing financial assistance in the form of research fellowship. The State Council for Science, Technology and Environment (SCST&E), Shimla and Ground Water Organisation, Una are greatly acknowledged for providing requisite research facilities, cooperation and precious support.

REFERENCES

1. Bartarya S.K., Virdi N.S. and Sah M.P. 1996. Landslide hazards: Some case studies from the Satluj Valley, Himachal Pradesh, *Himalayan Geology*, 17: 193-207.
2. Bocco G., Mendoza M. and Velazquez A. 2001. Remote sensing and GIS-based regional geomorphological mapping-A tool for land use planning in developing countries, *Geomorphology*, 39:211-219.
3. EIA. 2006. Environmental Impact Assessment on Luhri Hydropower Project by Satluj Jal Vidyut Nigam Limited, Shimla, Himachal Pradesh, India.
4. Gupta V. and Sah M.P. 2008. Impacts of the Trans-Himalayan Landslide Lake Outburst Flood (LLOF) in the Satluj catchment, Himachal Pradesh, India, *Natural Hazards*, 45: 379-390.

5. Gupta V. and Sah M.P. 2008. Spatial variability of mass movements in the Satluj valley, Himachal Pradesh during 1900~2006, *Journal of Mountain Science*, 5: 38-51.
6. Gupta V., Sah M.P., Virdi N.S. and Bartarya S.K. 1994. Landslide hazard zonation in the Upper Satluj Valley, District. Kinnaur, Himachal Pradesh, *Journal of Himalayan Geology*, 4(1): 81-93.
7. Jog S.R. 1995 (ed.) Indian Geomorphology: Landforms and Processes, Rawat Publication.
8. NRSA. 1990. Manual of Nationwide land use/land cover mapping using digital techniques, part II, RRSSC, Nagpur, Department of Space, Government of India, pp. 1-78
9. Thapa R.S. and Sood S.K. 2004. Environment and ecological impact due to river bed mining in Chakki Khad, District Kangra, Himachal Pradesh, A technical report.