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

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ABSTRACT

Land use/land cover (LULC) 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 geological units 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 rock types 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 geological units 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, GIS, LULC, Remote sensing, River, Rock types.

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. The factors like the stage and pattern of development, climatic conditions, type of the 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 geological and geomorphological features, but unlikely 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). The geology, rock and soil affect the vegetation of a place by influencing the moisture regime, texture and drainage of the soil. Land use/land cover features are controlled by geologic 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 geology, together with ground truth surveys to collect information on the qualitative and quantitative status.

The area along the Satluj River consists of many distinct types of geological units. The detailed geological set up of the Satluj valley has been described by Sharma (1977). The dominance of one process over another is controlled by geologic, including geomorphic settings and neotectonic activities. The objective of this study is to compare and analyse the land use/land cover pattern in relation to geological features along the Satluj River i.e. to understand the relationship between land use/land cover and rock types 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). Numerous glaciers drains directly into the river at various points along its course and many others drain into its tributaries. 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 whole 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).

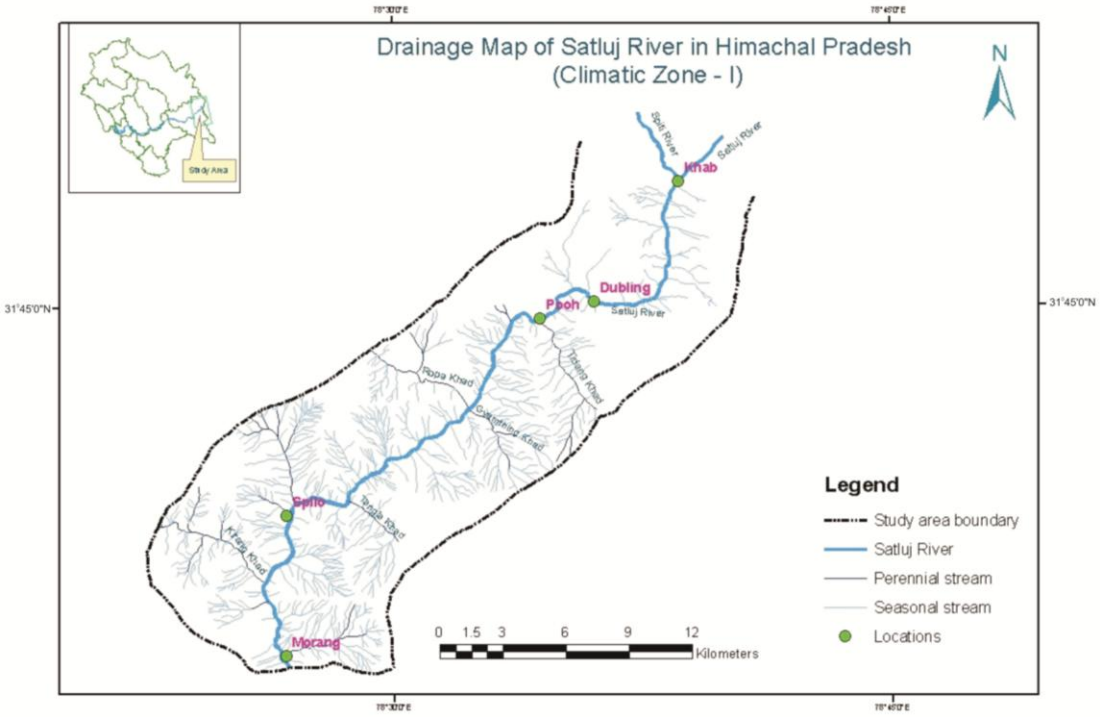


Figure 1: Map showing the climatic zone - I of Satluj River.

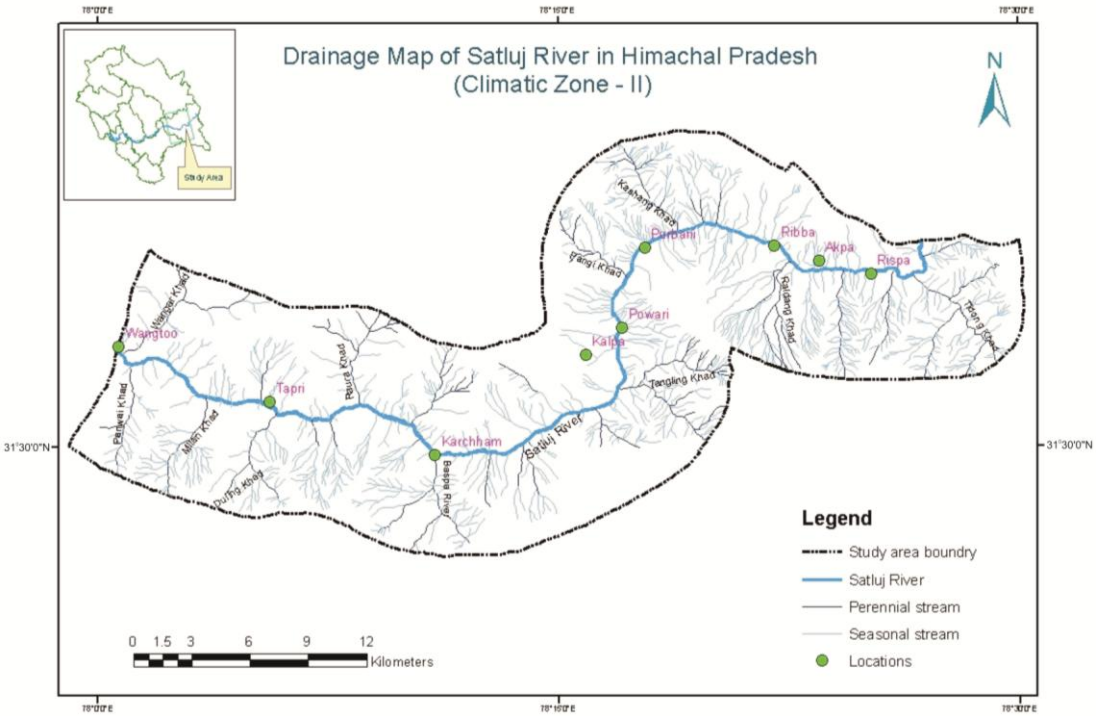


Figure 2: Map showing the climatic zone - II of Satluj River.

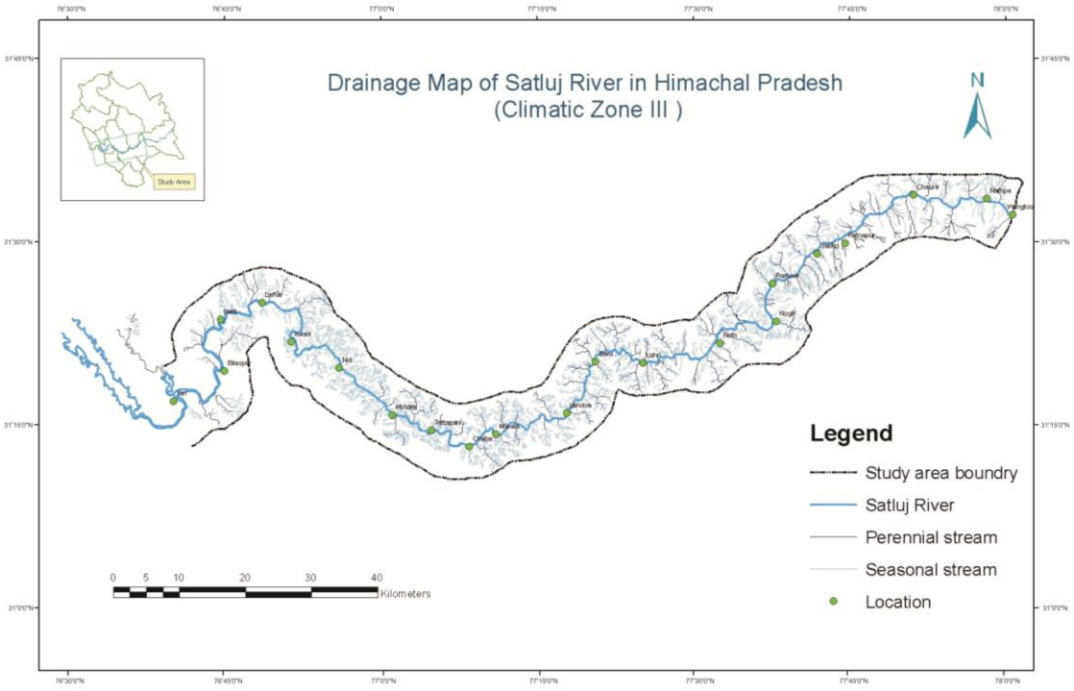


Figure 3: Map showing the climatic zone - III of Satluj River.

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. Methodology

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 geology 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 geological 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. These PAN

sharpened images help in delineating the spatial pattern present in the study area. 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.

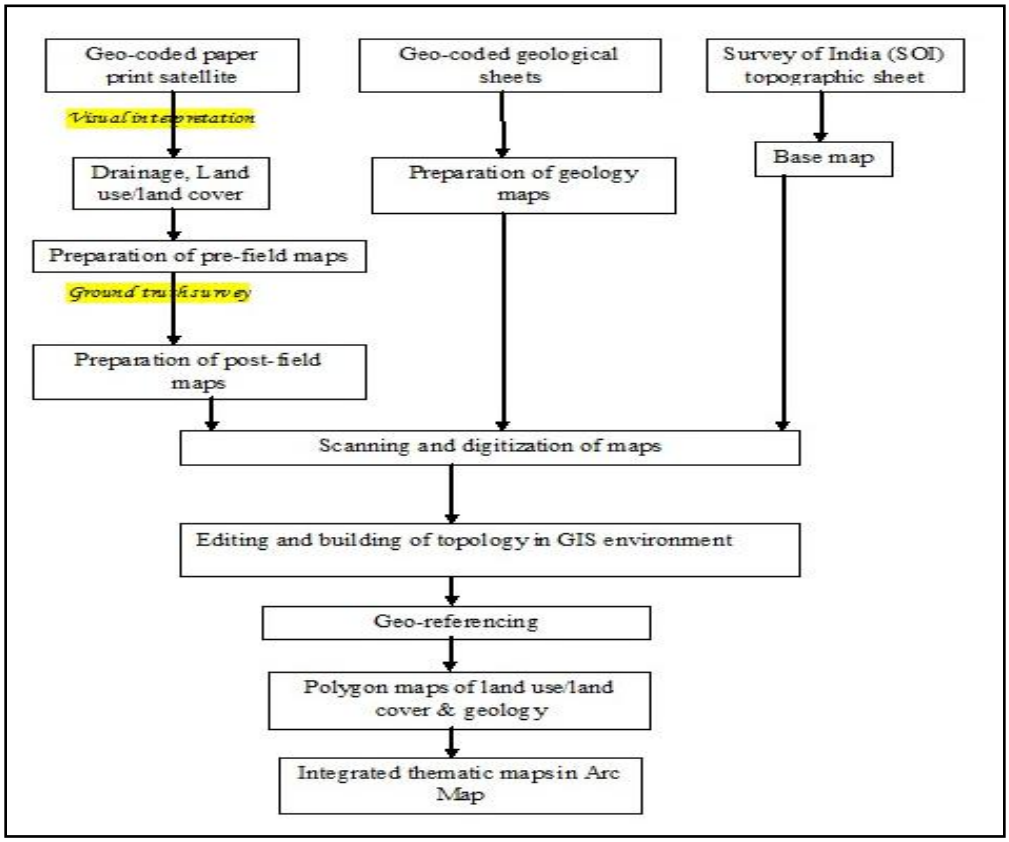
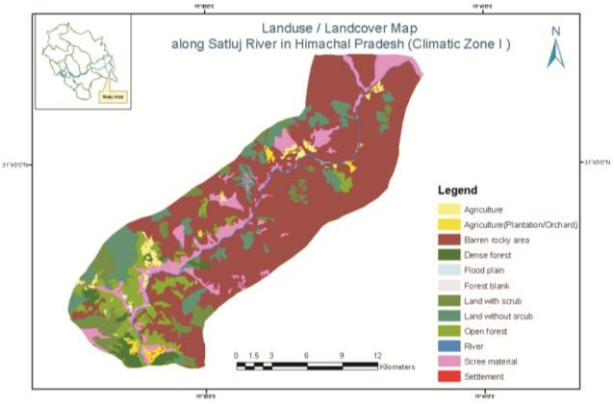


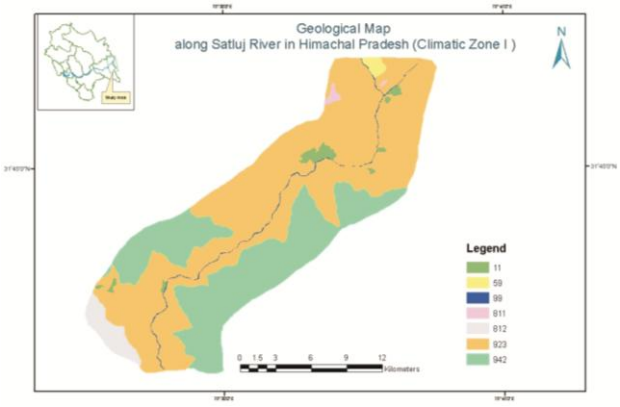
Figure 4: Procedure for the preparation of land use/land cover and geology maps.

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 geological 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. 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 geology were calculated using Arc info GIS software.

4. Results and discussion





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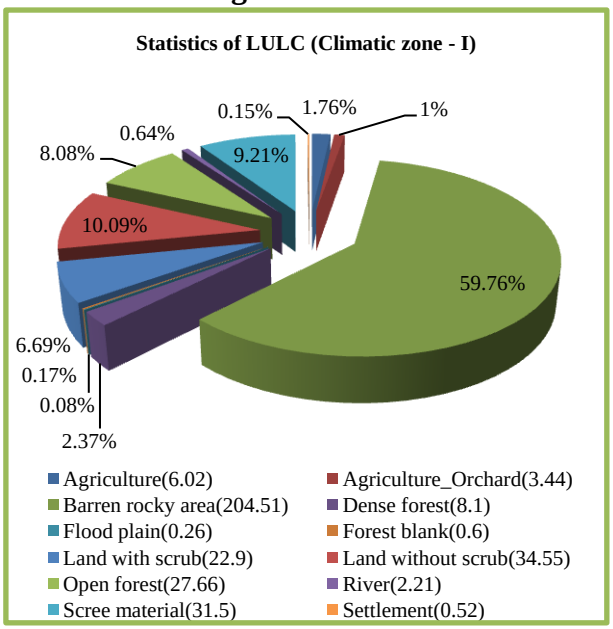

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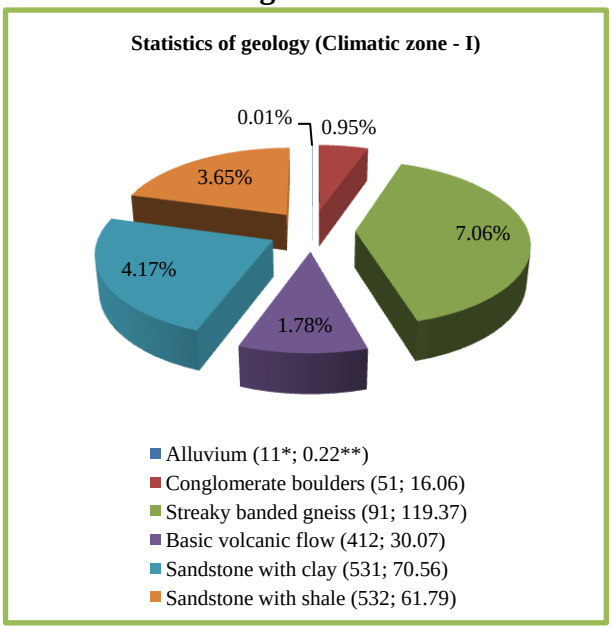


Figure 7 **Figure 8**

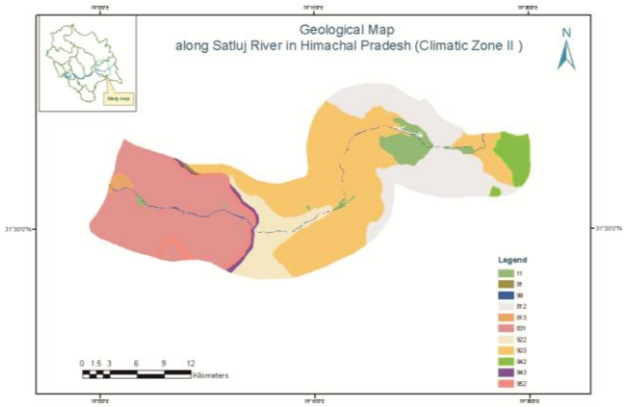
Figure 5-8: Map and statistics of land use/land cover (area in Km^2) and geology (*legend numbers;**area in Km^2) in climatic zone – I (Semi arid to arid temperate).

Table 1: Quantitative distribution of major LULC categories and dominant geologic units (rock types) in climatic zone – I.

LULC categories	% of total area	Dominant geologic units (rock types)
Agriculture	1.76	Alluvium and dominantly schist
Agriculture_orchard	1.00	Alluvium and dominantly schist
Barren rocky area	59.76	Dominantly schist, grey phyllite, carbonaceous slate
Dense forest	2.37	Dominantly schist
Forest blank	0.17	Dominantly schist
Land with scrub	6.69	Intrusive granites, grey phyllite, carbonaceous slate
Land without scrub	10.09	Dominantly schist, grey phyllite, carbonaceous slate
Open forest	8.08	Dominantly schist
Scree material	9.21	Intrusive granites and dominantly schist
Settlement	0.15	Alluvium and dominantly schist

In climatic zone – I, the major area is covered by barren rocks (59.76%), generally devoid of vegetation and unsuitable for human settlement, where dominant schist, grey phyllite and carbonaceous slate geologic features are present. The area under agriculture, horticulture and settlement accounts for 2.91%, which is generally occupied by alluvium and dominantly schist. The scree material (9.21%) is generally present along the river and dominated by intrusive granites and dominantly schist. The forest types identified occurs in dominantly schist where dense and open forests, along with forest blank (10.62%) are present. Apart from these features, the land area of 16.78% is covered by land with/without scrub, where dominantly schist, intrusive granites, grey phyllite & carbonaceous slate are dominant.

Figure 9



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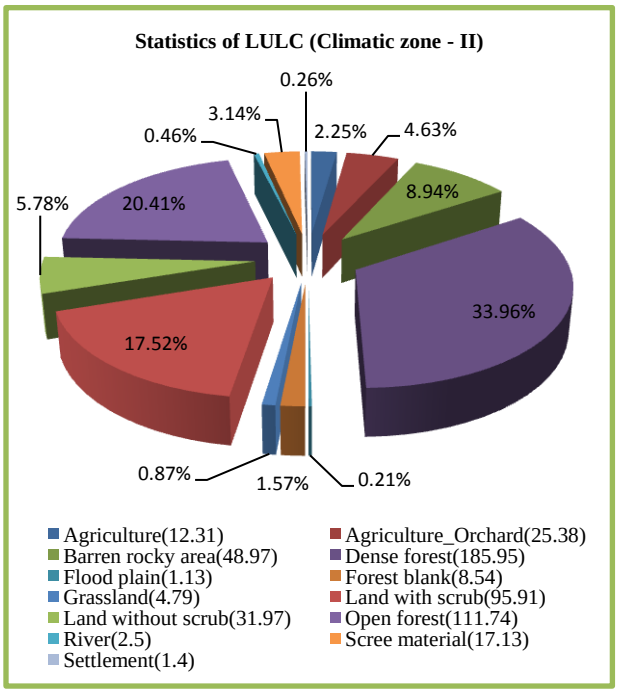


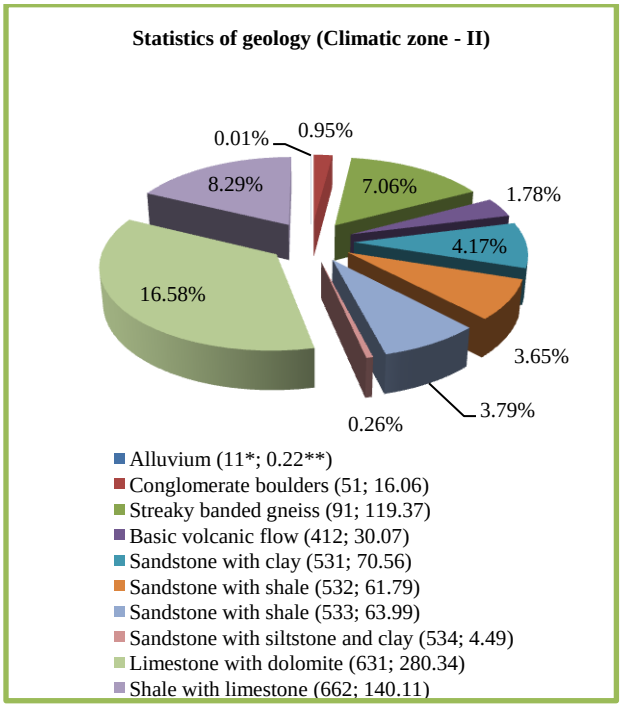


Figure 11 **Figure 12**

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

Table 2: Quantitative distribution of major LULC categories and dominant geologic units (rock types) in climatic zone – II.

LULC categories	% of total area	Dominant geologic units (rock types)
Agriculture	2.25	Alluvium and dominantly schist
Agriculture_orchard	4.63	Alluvium and dominantly schist
Barren rocky area	8.94	Dominantly schist with slate and phyllite, grey phyllite and carbonaceous slate & granitoid gneiss
Dense forest	33.96	Dominantly schist, intrusive granites, granitoid gneiss & grey phyllite and carbonaceous slate
Forest blank	1.57	Dominantly schist & granitoid gneiss
Grassland	0.87	Dominantly schist
Land with scrub	17.52	Intrusive granites, granitoid gneiss, granites & dominantly schist with slate and phyllite
Land without scrub	5.78	Intrusive granites & granitoid gneiss
Open forest	20.41	Dominantly schist, granitoid gneiss & grey phyllite

		and carbonaceous slate, dominantly schist with slate and phyllite
Scree material	3.14	Dominantly schist, intrusive granites & granites
Settlement	0.26	Alluvium and dominantly schist

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 dominantly schist and granitoid gneiss geologic units are common. But grey phyllite and carbonaceous slate are dominant units in dense and forest apart from intrusive granites and dominantly schist with slate and phyllite respectively. The area falling under land with scrub is 17.52%, where the encountered rock types are intrusive granites, granitoid gneiss, granites & dominantly schist with slate and phyllite and the land without scrub (5.79%), in which intrusive granites & granitoid gneiss are dominant rock types. Barren rocky area (8.94%) is present over dominantly schist with slate and phyllite, grey phyllite and carbonaceous slate & granitoid gneiss. Settlement along with agriculture (2.25%) and orchard/plantation (4.63%) is generally dominated by alluvium and dominantly schist. The scree material accounts for 3.14%, which is present on dominantly schist, intrusive granites & granites. Few grassland patches are present in the forest cover area, accounting for 0.87%, where dominantly schist types of rocks are present.

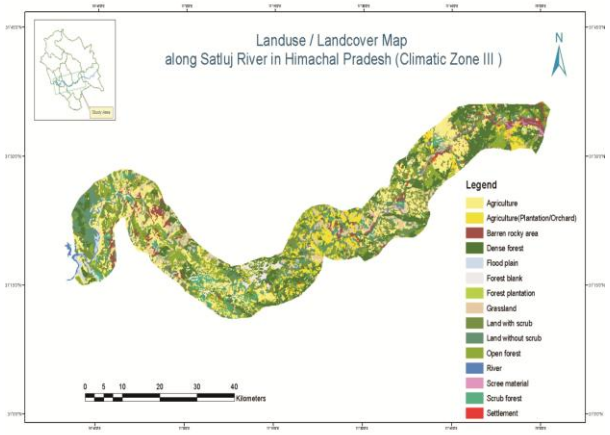
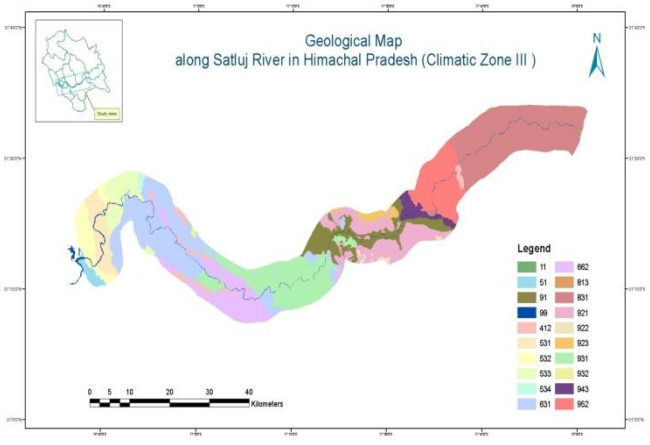


Figure 13



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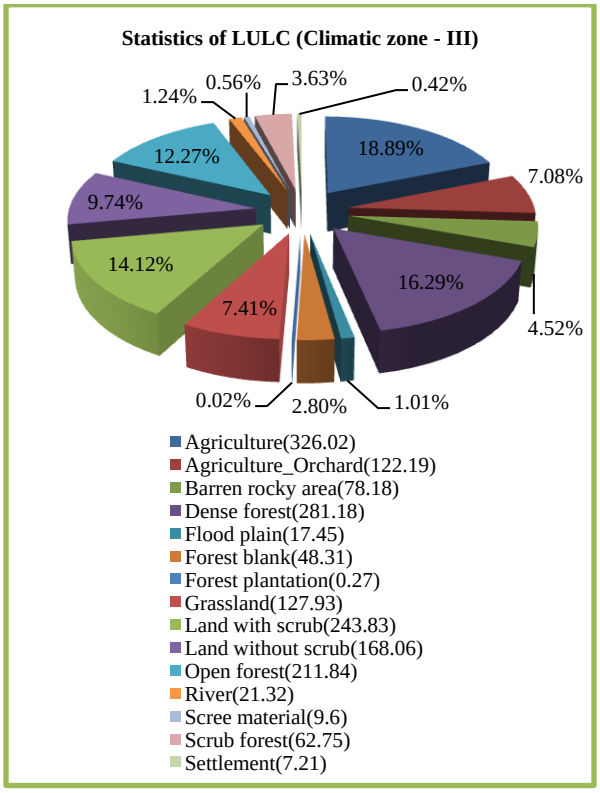

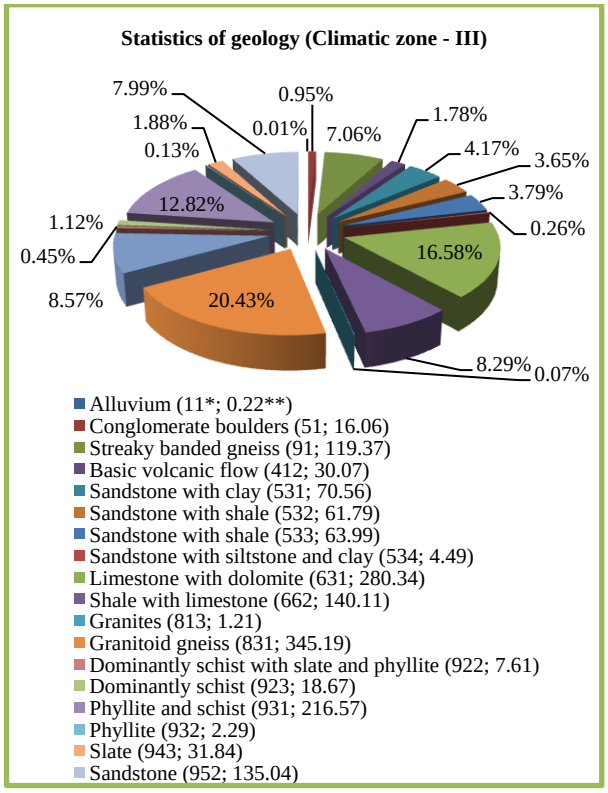

Figure 15 **Figure 16**

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

Table 3: Quantitative distribution of major LULC categories and dominant geologic units (rock types) in climatic zone – III.

LULC categories	% of total area	Dominant geologic units (rock types)
Agriculture	18.89	Alluvium, granitoid gneiss, sandstone with clay and shale, limestone with dolomite, schist with quartzite, phyllite and schist & streaky banded gneiss
Agriculture_orchard	7.08	Alluvium, granitoid gneiss, sandstone with clay and shale, limestone with dolomite, schist with quartzite, phyllite and schist & streaky banded gneiss
Barren rocky area	4.52	Limestone with dolomite & granitoid gneiss
Dense forest	16.29	Granitoid gneiss, limestone with dolomite, sandstone with shale & phyllite and schist

Forest blank	2.80	Phyllite and schist & shale with limestone
Grassland	7.41	Granitoid gneiss, streaky banded gneiss, limestone with dolomite, schist with quartzite
Land with scrub	14.12	Schist with quartzite, phyllite and schist, granitoid gneiss & sandstone with shale
Land without scrub	9.74	Sandstone with clay, shale & shale with limestone
Open forest	12.27	Sandstone with shale, limestone with dolomite, granitoid gneiss & sandstone
Scree material	0.56	Granitoid gneiss & slate
Scrub forest	3.63	Granitoid gneiss, limestone with dolomite, shale with limestone & sandstone with clay
Settlement	0.42	Alluvium, granitoid gneiss, sandstone with clay and shale, limestone with dolomite, schist with quartzite, phyllite and schist & streaky banded gneiss

In climatic zone – III, the primary land use category identified is agriculture (18.89%), orchard/plantation (7.08%), whereas the dense population is settled and the dominant geologic units are alluvium, granitoid gneiss, sandstone with clay and shale, limestone with dolomite, schist with quartzite, phyllite and schist & streaky banded gneiss. 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%), where the prominent rock types are granitoid gneiss, limestone with dolomite, shale with limestone, sandstone with clay, sandstone with shale, streaky banded gneiss, schist with quartzite, phyllite and schist. The land with/without scrub accounts for 23.86%, which are encountered by schist with quartzite, phyllite and schist, granitoid gneiss, sandstone with shale and, sandstone with clay, shale & shale with limestone rock types respectively. The area falling under baren rocky area and scree material is 4.52 and 0.42%, where the limestone with dolomite, granitoid gneiss and slate are prominent geologic units.

The land use/land cover categories are directly influenced by geological units (rock types) 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. The dominant geologic units are dominantly schist, limestone with dolomite, granitoid gneiss grey phyllite & carbonaceous slate. Quaternary deposits in the geological past generally

allow low angle of repose and are generally fertile in nature. Thus the most of settlements, agriculture/horticulture and other socio-economic activities occur on these deposits. The area under such activities increases down the stream. It was observed that apart from alluvium and dominantly schist, other encountered rock types are granitoid gneiss, sandstone with clay and shale, limestone with dolomite, schist with quartzite, phyllite and schist & streaky banded gneiss, especially in the lower reaches of river. The forests are classified under various categories where, dominantly schist, granitoid gneiss, grey phyllite and carbonaceous slate, intrusive granites, limestone with dolomite, shale with limestone, sandstone with clay, sandstone with shale, streaky banded gneiss, schist with quartzite, phyllite and schist are prominent rock types. The land with/without scrubs is generally dominated by intrusive granites, grey phyllite & carbonaceous slate, dominantly schist, granitoid gneiss, granites & dominantly schist with slate and phyllite, schist with quartzite, sandstone with shale, sandstone with clay, shale & shale with limestone types of rocks. The study clearly indicates that the rock type divisions are well correlated with the distribution of different LULC in the area.

5. Conclusions

The land use/land cover is critically viewed in light of the existing physical environment like geology. It is observed that the classification of land use/land cover categories is directly related to geological units of the study area. This clearly indicates that the rock types are well correlated with the distribution of different LULC, especially in the upper two climatic zones. But comparatively, the climatic zone – III shows that severe deforestation activities are occurring, where the land is diverted for other socio-economic activities, which is inconsistent with geologic units. The analysis of 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

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