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## Quantitative and spatial assessment of watershed management based on land use land cover dynamics in Western Himalaya

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### ABSTRACT

Present study focuses on analyzing the spatial and temporal land use land cover change in a typical Himalayan mountain river basin. The land use land cover classification of Juni basin covering an area of 207.29 sq.km, has been prepared by calculating the area change of different land use land cover classes from satellite images of 1972 (MSS) and 2009 (LISS III). Here the conflict between social and natural forces has brought significant changes in the fragile mountain ecosystem. Monitoring and assessing the nature of changes brought over four decades in the basin is essential to maintain and restore the sustainable development of Juni basin. In the present study geospatial tools have been used to capture the changes brought in different land use land cover classes. The analysis of land use land cover change shows significant decrease in forest and sparse vegetation cover in the basin. Forest and sparse vegetation cover has recorded 4.12 and 2.58 percent negative growth in area over the study period. While, agricultural and built up land had experienced 28.55 and 24.81 percent positive growth in areal coverage from 1972 to 2009. The high rate and intensity of land use land cover changes from primary vegetation cover to secondary man made land cover has introduced several important changes in the local ecosystem. The growing population, expansion of agricultural land and built up land, sand mining, construction of roads and various development activities like construction of hydro project at Chachiot are the major pushing factor responsible for reduction of vegetation cover.

Keywords: Land Use Land Cover Change, Change Matrix, Confusion Matrix, Remote Sensing & GIS.

### 1. Introduction

Land use and land cover is a dynamic and accelerating process which varies at different rate corresponding human civilization. Anthropogenic activities and natural forces are the agents of land use and land cover change in any region. Accurate assessment of land use and land cover change is essential to generate information for sustainable development of natural resources and implementing various planning and monitoring agendas. Land use land cover change assessment provides valuable information regarding forest cover, agricultural land use, built up areas and hydrology etc. (Panigrahy, et al., 2010; Turner, et al., 2004). Heathcote, 2009 has stated that land degradation due to rapid land use land cover change has become one of the major global problem since last century. The Juni basin is tectonically unstable, densely populated, underdeveloped and ecologically fragile mountain ecosystem. As a result the issue of survival has led to extensive pressure on available natural resources. Agriculture is the main occupation of local population which puts immense pressure on available limited arable land with increasing population (Tiwari, 2008). The traditional subsistence agriculture

system in the Himalayan mountain region are dependent on animal husbandry and forest resources to sustain their livelihood (Chakraborty, et al., 1984; Gautam, et al., 2003). The growing population, extension of agricultural lands and built up areas, deforestation, construction of roads, hydro-projects, etc. has brought significant changes in the basin. Therefore, it is essential to assess the changes and implement required measures to curtail the degradation of natural resources (Biswas, et al., 1999; Jayappa, et al., 2006; Reddy, et al., 2009; Sen, et al., 2002)

## **2. Study Area**

Juni river is the south bank tributary of Beas river in Mandi district of Himachal Pradesh (Fig.1). It joins Beas river near Pandoh. Juni basin is primarily a hilly basin with altitude varies from 840 meters to 3223 meters, situated in lesser Himalayan ranges. The mean altitude and slope of basin is 2016 meters and 44.5 degrees. There is gradual increase in elevation from north to south. The valley floor of the basin is demarcated with undulating low alluvial plains, hillocks and terraces. The geological rock formations in the basin varies from Pre-Cambrian to Quaternary period. The mountainous terrain in the basin are mostly made of igneous and metamorphic rocks belonging to the Jutogh, Shali and Shimla group (Mandi District Information Booklet, 2007). Mountainous soil is mostly found in the basin which is brown in colour and have medium potash & nitrogen content. The climate of the basin is sub-tropical in the valley and temperate in higher altitude. The average minimum and maximum temperature of the Juni basin varies from 2<sup>o</sup> C to 35<sup>o</sup> C. The Monsoon season starts from early July and continues till the middle of September. The average annual rainfall of the basin is about 1124 mm with 60 to 78 average rainy days. The winter season starts from mid-November and continues till mid-March.

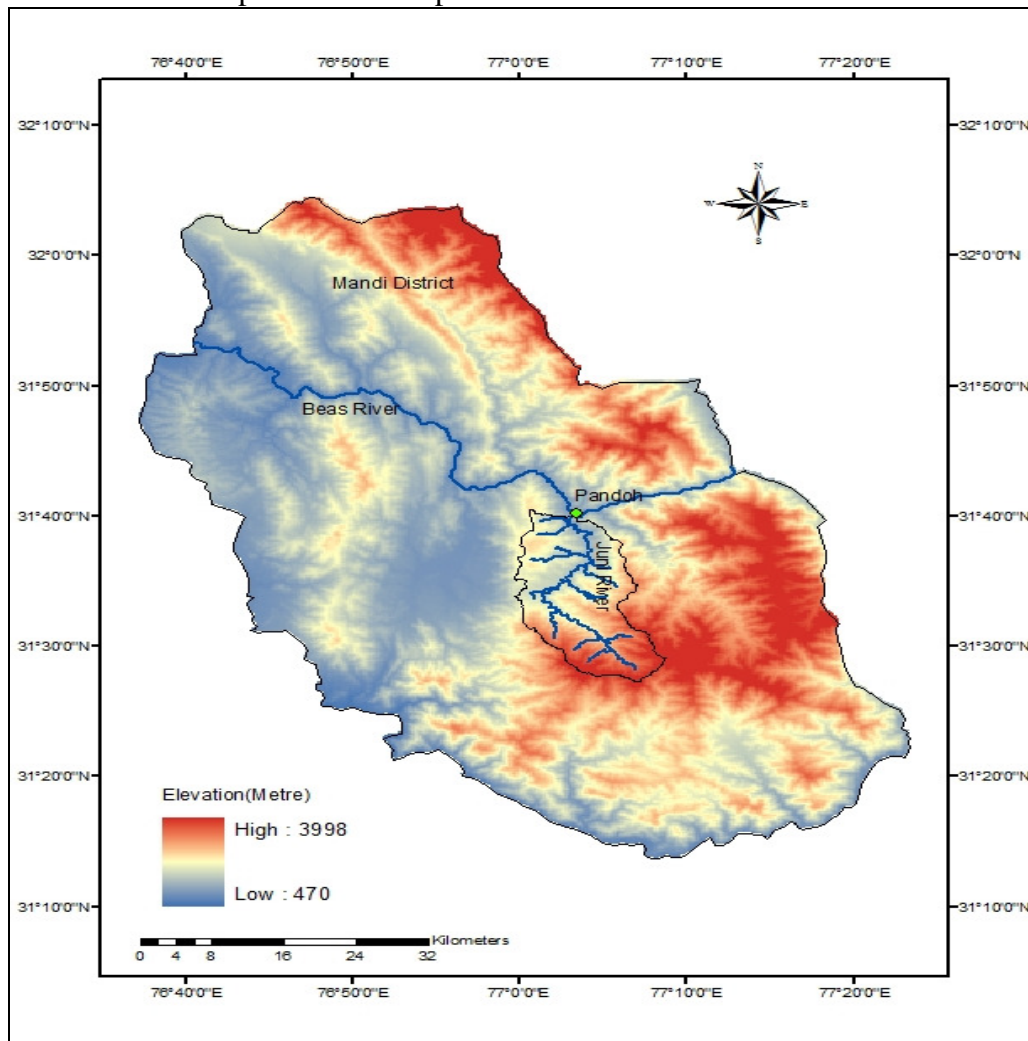
### **2.1 Methodology**

The data and information for the land use and land cover change assessment has been created from various primary and secondary data sources. The field survey of the study area for ground truth assessment constitutes the primary source of information. In the present study secondary sources are- multi-temporal satellite images and forest cover map from Forest Survey of India (FSI), have been used to assess the land use land cover change in the Juni basin over the past four decades. The satellite data products used in the study are- Multi-spectral Scanner (MSS) 1972 and Linear Imaging Self Scanning Sensor (LISS-III) 2009. After obtaining the required data sources several image enhancement techniques like radiometric and geometric correction of the satellite imagery was performed to obtain the maximum level of land use land cover classification accuracy in ERDAS 10. In Himalayan region shadows of mountain ranges causes' source of confusion in correct assessment of the land cover type. To overcome this problem, the Normalized Difference Vegetation Index (NDVI) of the study area was estimated. However, NDVI is also not completely able to remove the shadow effect of the satellite imagery (Saha et al. 2005; Eiumnoh, et al. 2000). The Normalized Difference Vegetation Index was estimated for the LISSIII image using Near Infrared and Red band as follows-

$$NDVI = (NIR - Red) / (NIR + Red)$$

There are two methods of land use land cover classification – unsupervised and supervised classification. In the present study the land use land cover classification of the multi-temporal

satellite images was performed using supervised classification. First of all, the training samples which are the representative of particular land cover class are collected.



**Figure 1:** Location Map of Juni Basin within Mandi district, Himachal Pradesh.

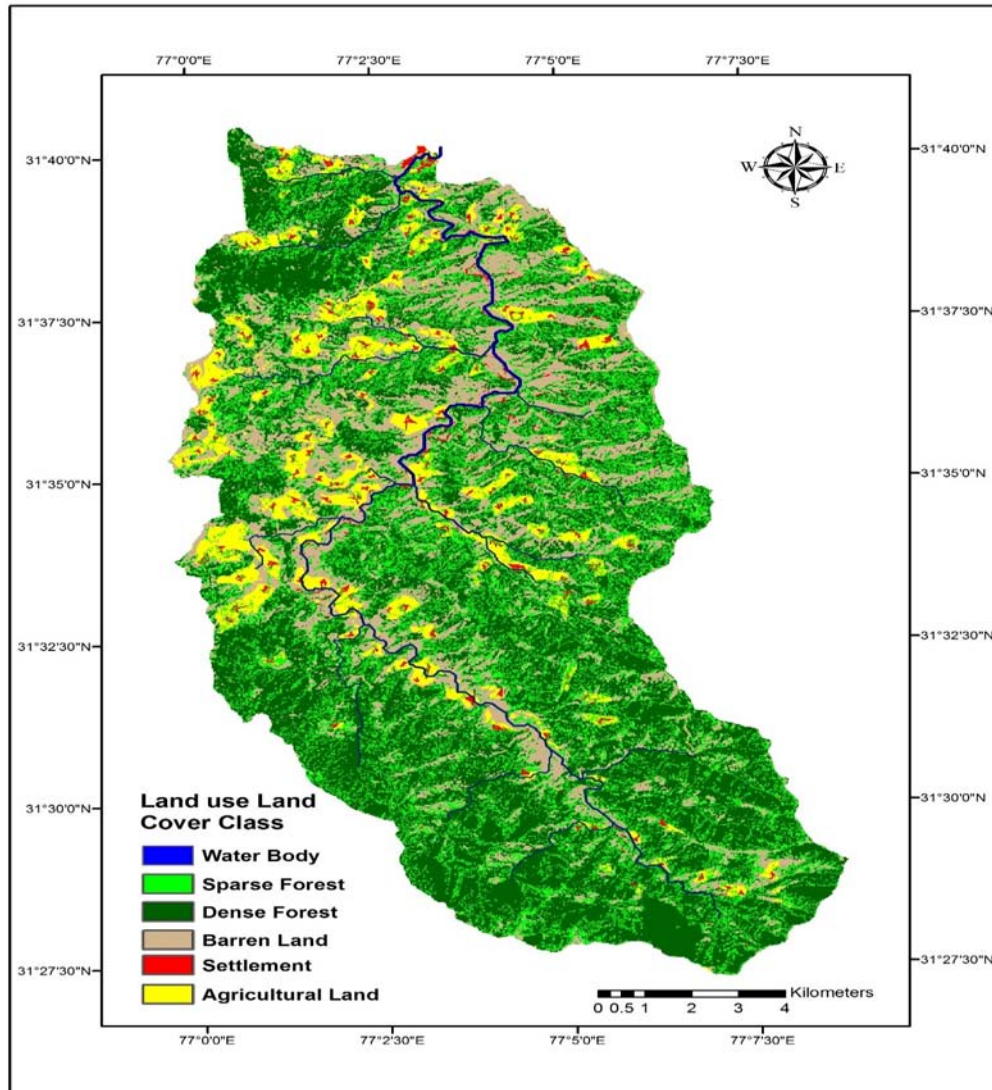
The training samples were collected for identified land cover type by marking with polygon. The training samples was collected for all land use land cover class- forest cover, sparse vegetation, agricultural land, built up land, barren land and water body. After that signature files were generated for each land cover class from training site. Finally, the maximum likelihood classifier was used to run the supervised classification. Land use and land cover classification of any area is incomplete until its accuracy has been assessed. The accuracy assessment of the land use and land cover map was done using the reference ground truth data collected during the field survey of study area (Smith, 2003). Simple random sampling method was used to perform the ground truth survey. The accuracy assessment was performed in ERDAS 10 and confusion matrix was prepared to access the accuracy level (Arora, et al. 2002; Foody, 2002; Jensen, 1986).

### **3 Result and discussion**

#### **3.1 Land use land cover pattern 1972**

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The land use land cover classification of the study area shows significant vegetation cover. The total forest cover in the Juni basin in 1972 was 94.99 sq.km which, constituted about 45.82 percent of total area. The upper reaches of the basin are full of infinite varieties of grasses studded with flower, rhododendron, olive green oak forest and black fir trees. Most of the forest cover extends beyond 2000 meters. Most of the forest cover area comes under State forest Department, and is managed by it. The density of forest cover high at higher altitude and decreases with the altitude. The dense forest cover in the southern, south eastern and south western part of the basin protects from soil erosion as many small streams originated in this area from higher altitude. Some of the most common species of trees found in the Juni basin are- Deodar, Chir, Oak, Walnut and Kail. These forests serve as very important source of natural resources like- timber, firewood, medicinal plants, dyes, etc. Sparse vegetation which constitutes grasses, shrubs and sparse tree cover extends for 49.69 sq.km which covers 23.97 percent of total area. These are mostly found in the fringe areas of dense forest cover or on the steep slope areas. The agricultural land covers 17.94 sq.km that constitutes 8.66 percent of the total area of Juni basin. Agriculture is the dominant economic activity of the people living in Juni basin. Major cereal crops grown in the basin are maize, barley, paddy and wheat. Some fruits like- walnut, plum and pears are grown in those pockets of basin which have appropriate agro-climatic conditions. Agricultural lands are generally concentrated in flat fertile valley floors. Barren land constitutes 19.83 percent of the total area of basin. These areas are devoid of vegetation cover, undulating terrain and rocky.



**Figure 2:** Land use land cover map of Juni basin, 1972. (Source- MSS 1972 Satellite Image).

### **3.2 Land use land cover pattern in 2009**

The land use land cover pattern shows significant change in forest cover, agricultural land and built up area (Fig.3). The total forest cover has experienced negative growth with 3.92 sq.km decrease in area from 1972 to 2009. The pressure on existing forest resource has increased manifold in past four decades due growth of population. Forest cover areas that are not protected under state forest department has recorded high rate of deforestation. Deforestation mostly occurs due to high demand of timber, medicinal plants and other valuable forest products. In upper reaches of the basin forest has been cleared for agricultural purposes. Sparse vegetation cover has also recorded negative growth of 2.58 percent (Table.1). Area gained from deforestation and sparse vegetation has mostly been diverted for agricultural uses and construction purposes. Increase in connectivity and incoming of modern technology has enabled the human population to find suitable utilization of these land. The agricultural land area has marked highest positive growth during the study period of 28.55 percent, followed by built up land cover which recorded 24.81 percent positive growth. These statistics shows the nature of land use land cover change dynamics. The increasing population pressure has expanded its influence on available natural wealth of the basin.

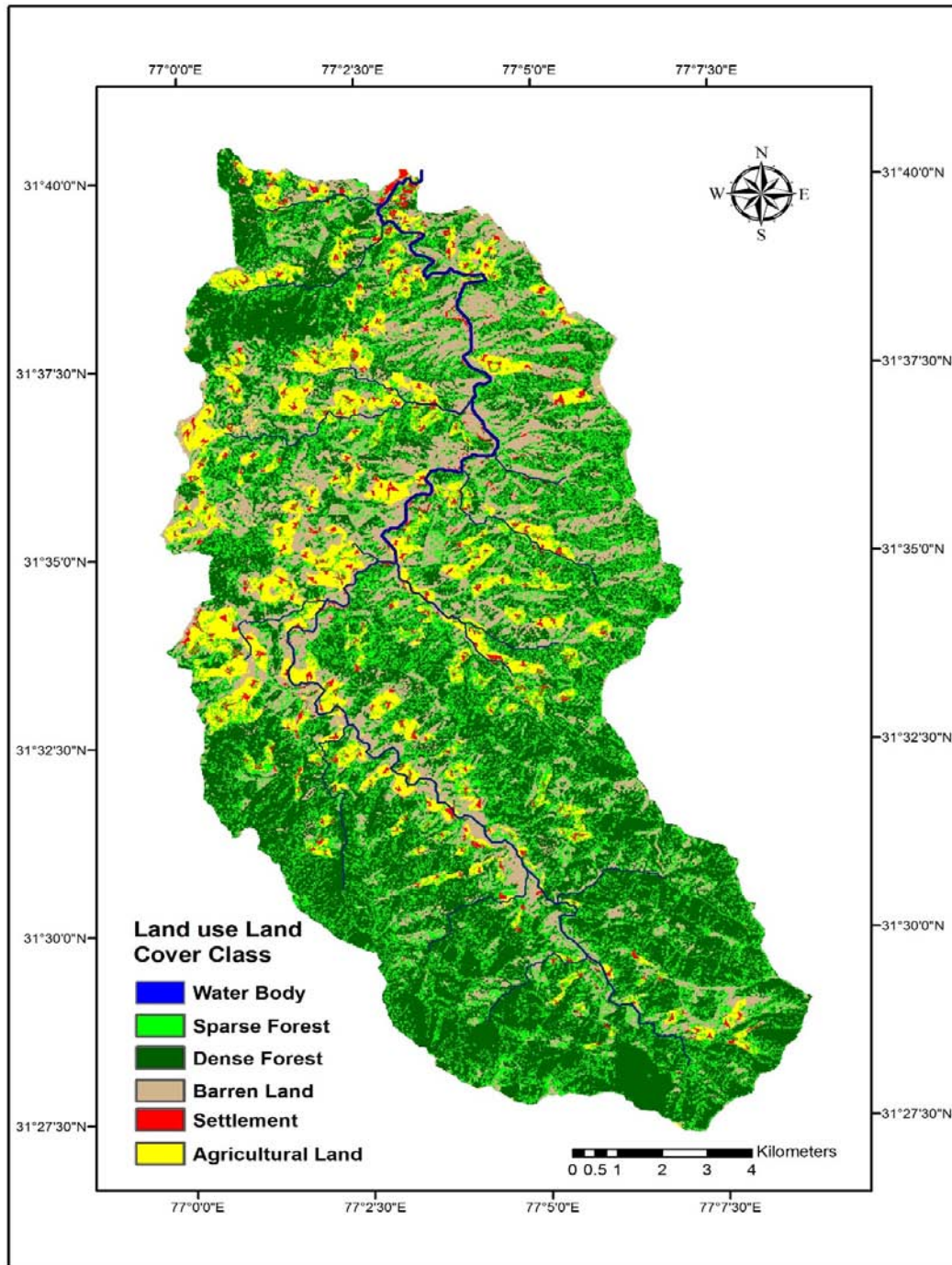
**Table 1:** Land use land cover change statistics between 1972 and 2009.

LULC Class	1972		2009		1972-2009	
	A (sq.km)	A (%)	A (sq.km)	A (%)	AD (sq.km)	AD (%)
FC	94.99	45.82	91.07	43.93	-3.92	-4.12
SV	49.69	23.97	48.40	23.35	-1.28	-2.58
BUL	3.56	1.72	4.01	1.93	0.45	24.81
BL	37.31	18.00	39.06	18.84	1.75	-0.58
AL	17.94	8.66	20.95	10.11	3.00	28.55
WB	3.80	1.83	3.80	1.83	0.00	0.00
Total	207.29		207.29			

Accuracy assessment of land use land cover map has been performed to assess the accuracy level of classified map. This serves the purpose to quantify the error and practical utilization of land use land cover map. The overall classification accuracy is 71.32 percent and the overall Kappa statistics for analysis is .67 (Table.2). The Kappa of .67 states that there is 67 percent better agreement of land use land cover classification than by chance.

**Table 2:** Confusion Matrix for Land use land cover accuracy assessment (2009).

LULC Class	Reference Total	Classified Total	Number Correct	Producer Accuracy	User Accuracy
Forest Cover	24	28	16	66.67	57.14
Sparse Vegetation	22	20	18	81.82	90.00
Agricultural Land	27	23	16	59.26	69.57
Built up Land	21	20	15	71.43	75.00
Barren Land	24	29	19	79.17	65.52
Water Body	11	9	8	72.73	88.89
Total	129	129	92		



**Figure 3:** Land use land cover map of Juni basin, 2009. (Source- LISS III 2009 Satellite Image).

#### 4. Land use land covers dynamics

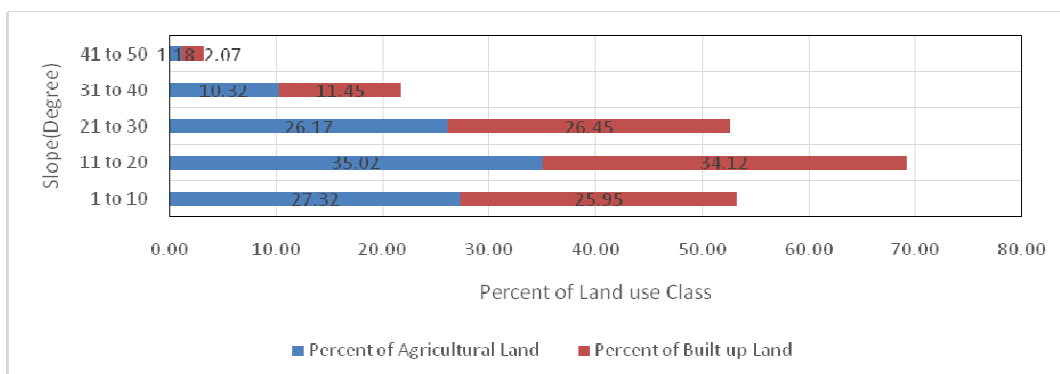
The land use land cover map prepared for two time period were overlaid to generate change maps of different classes. The land use land cover change matrix was done to analyze the different processes like- conversion of forest cover and sparse vegetation cover to non-vegetation cover, conversion from primary land cover class to secondary covers. The interpretation of different land use land cover class transformation statistics during past four decades reveals that the high population growth and rapid process of development have been largely responsible for land use changes in the Juni basin. The main factors responsible for

population growth are- growth of settlements in the periphery of Pandoh, Sarandah and Surah, increase in road connectivity to remote areas, building of Chachiot Hydroelectric Project, introduction of modern and advanced agricultural technologies, etc. Around 1.94 sq.km of forest cover and 1.02 sq.km of sparse vegetation cover has been transformed into agricultural land (Table.3). Agricultural expansion has mostly taken place in low slope valley floor of several tributaries of Juni river. With increase in connectivity it has become easy to settle in upper reaches of basin which was earlier unhabituated eg. Gohar, Gadhiman, Kandah, Jahal and Chachiot. The 3.5 MW Hydroelectric plant at Chachiot has provided efficient and regular electric supply in the Upper remote reaches of the basin. And 1.54 sq.km of forest cover and 0.26 sq.km of sparse vegetation has been converted into barren land. Unsustainable development plans, sand mining, and indiscriminate cutting of forest land has led to generation of barren land. Several patches of forest which was earlier covering undulating and rocky surface has been left over open after cutting the forest, which accelerated the high rate of soil erosion. Due to this these open high slope land areas has been gradually converted into barren land.

**Table 3:** Land use land cover change matrix between 1972 and 2009.

LULC Class	FC	SV	BUL	BL	AL	WB	Total(1972)
FC	91.07	0.00	0.44	1.54	1.94	0.00	94.99
SV	0.00	48.40	0.01	0.26	1.02	0.00	49.69
BUL	0.00	0.00	3.56	0.00	0.00	0.00	3.56
BL	0.00	0.00	0.00	37.26	0.05	0.00	37.31
AL	0.00	0.00	0.00	0.00	17.94	0.00	17.94
WB	0.00	0.00	0.00	0.00	0.00	3.80	3.80
Total(2009)	91.07	48.40	4.01	39.06	20.95	3.80	207.29

The land use land cover dynamics in Juni basin is dependent upon altitude and slope. Human activities are concentrated primarily between 1300 to 1800 meter altitude and 11 to 20 degree slope. Anthropogenic activities are mostly concentrated in areas having low slope and undulating surface because it favors agricultural practices and construction. Human settlement is restricted and seems to be very less in areas having slopes more than forty degree.

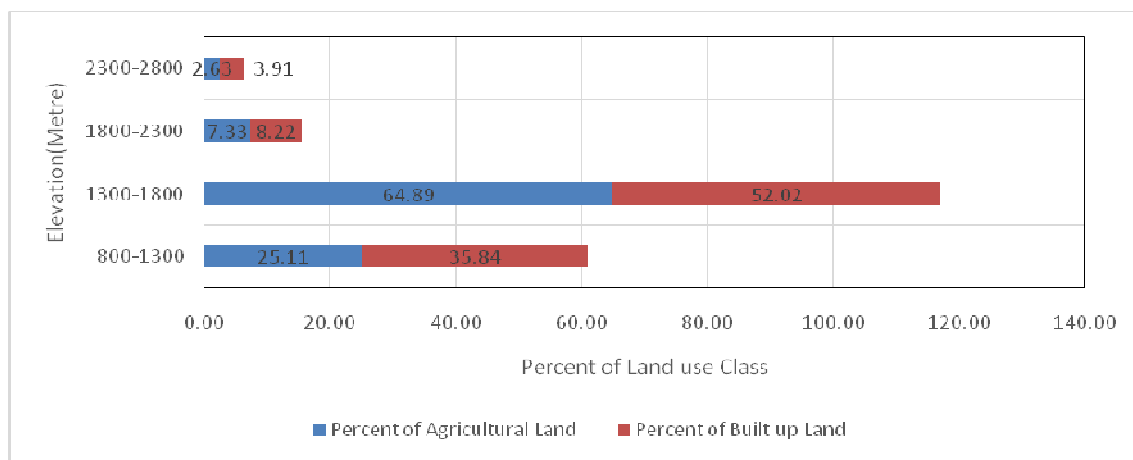


**Figure 4:** Percent of agricultural and built-up cover area under different slope categories.

Around 36.49 percent of agricultural land and 37.90 percent of built up area are situated in between 20 to 40 degree slope in the basin. Human activities in these areas increases the risk of severe soil erosion because of high slope and devoid of vegetation cover the running

surface water erodes the land surface easily. So even the agricultural practices needs to be well managed and regulated in these parts to stop the loss of top fertile soil.

Similarly, the parts of Juni basin above 2000 meter have very low anthropogenic activities. The land use land cover change analysis shows that the forest cover and sparse vegetation are left concentrated in the areas having altitude above 2400 meter mostly. During 1972 the agricultural and built-up land in upper reaches of Juni basin was less and small, but their areas has expanded and new human settlements and related activities can be marked in 2009 (Fig.2 & 3). The need and expanding demand of the population is continuing imposing a potential threat to these natural resources. So need, of time is to understand the delicate and vulnerable mountain ecological system of the Juni basin. Indiscriminate utilization of natural resources has to be curtailed and proper sustainable development models and plans need to be implemented in the basin.



**Figure 5:** Percent of agricultural and built-up cover area under various elevation categories.

## 5. Conclusion

The spatial and temporal variation in land use land cover class allows us to characterize the nature of changes that occurred in four decades. The dynamics of land use land cover change matrix reveals the noticeable change of primary land cover class to secondary land cover class. This study gives important insights into dynamics of shifts that occurred in forest and sparse vegetation cover between 1972 and 2009. Large areas of forest and sparse vegetation cover were affected and converted to other man made land use class. Around 3.92 sq.km of forest cover and 1.28 sq.km of sparse vegetation cover was cleared to satisfy the growing demand of land. Land area recovered from deforestation was principally done for providing land area for agricultural practices, building houses, construction of roads and hydro-projects. The construction of roads has improved the accessibility to those parts of basin which was earlier hard to settle, remote and unconnected. Agriculture is the main source of livelihood for most of the people. Increasing population, fragmentation of existing agricultural land with each generation, the demand of agricultural land has raised manifold. The only available and possibility to expand the agricultural and built up area is to clear land with vegetation cover. Further, the introduction of modern and advanced agricultural practices has enabled to practice agriculture in relatively low productive land. The construction of hydro project at Chachiot to generate electricity has improved the lifestyle and facility in the basin. But on the other hand, these anthropogenic activities and development had taken place at the cost of destruction of local biodiversity.

The need of time is to protect and restore the fragile ecosystem of our mountain to sustain our livelihood. The database generated from the study can be used to characterize the nature of land use land cover change taking place in the Juni basin. The indiscriminate cutting of forest and vegetation cover, intensive utilization of land for agricultural practices has led to land degradation in several parts of basin. The development plans in the basin should consider the direction and nature of growth to achieve sustainable development of Juni basin. The land use land cover change which is shaped by various social and nature interaction processes needs to be properly examined to enable the sustainable growth of basin.

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