Available online at http://www.journalijdr.com

IJDR

International Journal of
DEVELOPMENT RESEARCH

ISSN: 2230-9926

International Journal of Development Research
Vol. 4, Issue, 8, pp. 1491-1503, August, 2014

Full Length Research Article

RS & GIS BASED URBAN LAND USE CHANGE AND SITE SUITABILITY ANALYSIS FOR FUTURE URBAN EXPANSION OF PARWANOO PLANNING AREA, SOLAN, HIMACHAL PRADESH (INDIA)

[*1]Suraj Kumar Singh, [2]Vikas Chandel, [1]Himanshu Kumar and [3]Hemant Gupta

[1]Centre for Land Resource Management, Central University of Jharkhand, Brambe, Ranchi-835205, Jharkhand, India
[2]Aryabhatta Geo-informatics & Space Application Centre (AGiSAC), Shimla-171009, Himachal Pradesh, India
[3]State Council for Science Technology & Environment, Shimla-171009, Himachal Pradesh, India

ARTICLE INFO

Article History:
Received 21st May, 2014
Received in revised form
24th June, 2014
Accepted 13thJuly, 2014
Published online 05th August, 2014

Key words:
Site suitability analysis,
Remote Sensing, GIS,
Multi-criteria decision analysis (MCDA),
Pairwise Comparison Matrix,
Analytical Hierarchy Process (AHP),
Urbanization.

ABSTRACT

Rapid urbanization in the world is quite alarming, especially in developing countries such as India. In the present study historical change in urban area was analyzed using multi-temporal satellite images of 1980, 2000, 2010 and 2013 respectively to identify the areas where the increase or decrease has taken place over the period of last 33 years. High resolution satellite data of CARTOSAT 1 and 2 was used for base map and Digital Elevation Model generation. The goal of this study is to find potential sites in hilly terrain for urban development using site suitability analysis technique by multi-criteria decision analysis (MCDA) approach. To perform site suitability analysis, AHP technique was used for urban development in the study area. Criteria map like slope, aspect, elevation, road proximity; land use/cover and lithology were used to find new sites for urban expansion. The generated thematic layers (slope, aspect, elevation etc.) from criteria were standardized using pair-wise comparison matrix known as analytical hierarchy process (AHP). Weight for every criteria/parameter was assigned by comparing them with each other according to their importance. Final site suitability map was prepared with the help of these weights and criteria for urban expansion.

INTRODUCTION

Urbanization is a form of metropolitan growth that is a response to often random sets of economic, social, and political forces and to the physical geography of an area, through which, the productive agricultural lands, forests, surface water bodies and groundwater prospects are being irretrievably lost (Pathan *et al*., 1989). Rapid urbanization in the world is quite alarming (UNFPA, 2007), especially in developing countries such as India. It has led to serious land use problems such as loss of agricultural land, unauthorized urban sprawl, high land values, speculation in land, and other related problems. The extent of urbanization or its growth is one such phenomenon that drives the changes in land use pattern. These changes may have an adverse impact on ecology, especially on hydro-geomorphology, water resources and vegetation.

Corresponding author: Suraj Kumar Singh
Centre for Land Resource Management, Central University of Jharkhand, Brambe, Ranchi-835205, Jharkhand, India

Information on accurate urban growth is of great interest in urban and suburban areas for diverse purposes, such as urban planning, water and land resource management, market analysis & service allocation (Jat *et al*., 2008). In the last decade, more attention has been paid to urban change as the impact of human behavior is affecting urban ecosystems (Deal and Schunk, 2004). Research efforts concerned with detection and modeling of remotely sensed land cover/land use dynamics in developed countries tend to concentrate on changes driven by urban growth, particularly in large metropolitan areas (Ward *et al*., 2000; Jenerette and Wu, 2001; Wilson *et al*., 2003). Growing cities are creating an alarming situation in respect of land use, lack of proper amenities, loss of agricultural land and infrastructure facilities in all countries of the world (Manonmani *et al.,* 2012). Percentage of the world urban population is growing day by day due to wiliness of living in urban. If urban population will be grow in this way then next century will be the first urban century (United Nation, 2004). Therefore remote sensing and GIS techniques are being used for mapping and monitoring of urban growth estimation (Meaille and Wald, 1990; Westmoreland and Stow, 1992; Harris and Ventura, 1995; Yeh and Li 1996, 1997, 1999; Weng, 2001). Identification of possible sites for urban expansion in hilly terrain is one of the critical issues for planner and planning authority. Therefore, site suitability analysis has become necessary for finding appropriate site for various developmental plans, especially in the undulating landscape of the hills. Multi-Criteria Evaluation (MCE) and GIS is useful technique for site suitability because it is providing us more accuracy rather than traditional technique (Perveen *et al*., 2007; Kumar and Biswas, 2013). AHP is a multi-criteria decision-making approach introduced by Saaty (1977, 1980), in which a series of pair-wise comparisons between factors is developed to create a scaled set of preferences. This will describe the importance of each factor relative to every other factor (Saaty, 2003). The AHP is an Eigen value technique to the pair-wise comparisons approach. It provides a numerical fundamental scale, which ranges from 1 to 9 to calibrate the quantitative and qualitative performances of priorities (Saaty, 2008). In the present study historical change in urban area was analyzed using multi-temporal satellite images of 1980, 2000, 2010 and 2013 respectively to identify the areas where the increase or decrease has taken place over the period of last 33 years. High resolution satellite data of CARTOSAT 1 and 2 was used for base map and Digital Elevation Model generation. To perform site suitability analysis, AHP technique was used for urban development in the study area.

Study Area

Parwanoo is a city and a municipal council in Solan district in the Indian state of Himachal Pradesh. It is an industrial town. It borders Panchkula district of Haryana, and is after the towns of Pinjore and Kalka on the Chandigarh Shimla Highway (NH-22). The study area lies between 30°49'17"N and 30°52'20"N northern latitude and lies between 76°55‘10"E and 76°59'04"E eastern Longitude (figure.1). The town is divided into 6 different sectors spread randomly across the Shivalik Range in a radius of about 4 km. Parwanoo is essentially an industrial town with almost 80% of the local population engaged with the industries in one way or other. In the study area, elevation ranges from 725-1500 meters (figure.2).

MATERIALS AND METHODS

In this present study, base map has been prepared using high resolution satellite images (CARTOSAT-1 and 2). Base map generated includes features like administrative boundaries, water body, roads, parks, railways, ponds, playgrounds etc. (figure 3). Digital elevation model (DEM) was generated from Cartosat-1 satellite data of 30 m contour interval with the help of Leica Photogrammetry Suite 2013 (LPS) software. The present study emphasizes on the use of remote sensing and GIS in understanding the changes in the pattern of urbanization and finding new sites suitable for potential urban growth without disturbing the environmental balance. The present research is located in the Shivalik hills of Himachal and Haryana. The area has experienced rapid growth in urbanization, so the change detection in the urban area was carried using LANDSAT satellite images for the year 1980, 2000, 2010 and CARTOSAT 1 and 2 data for 2013 respectively (Table 1). Field verification was carried out using Garmin GPS to improve the accuracy of the base map. All the analysis was performed in GIS environment to identify a new site for urban development (Figure. 4).

Table 1. Satellite data used in the study

No.	Satellite data used	Resolution	Year
1.	LANDSAT-MSS	60 M	1980
2.	LANDSAT-7 ETM+	30 M	2000
3.	LANDSAT-5 TM	30 M	2010
4.	CARTOSAT-1	2.5 M	2011
5.	CARTOSAT-2	0.8 M	2013

RESULTS AND DISCUSSION

In the present study, on the basis of visual interpretation technique like tone, texture, shape, size etc. were used to identify the landuse/ landcover categories. The multi-temporal satellite images for different time periods i.e LANDSAT 1980 (figure5), LANDSAT 2000 (figure 6), LANDSAT 2010 (figure 7), CARTOSAT-1 2011 and CARTOSAT-2 2013 (figure 8) respectively were used to map urban area. In 1980, built-up area was 188189 square meters (0.72%) which has increased to 751679 square meters (8.44%) in 2000 which indicates rapid urbanization between 1980 and 2000 as various industries were establishment due to development of infrastructure and favorable industrial policy of the Government. Built-up area of Parwanoo has increased from 751679 square meters to 980943 square meters (11.01%) in 2010 because of major industrial development and 1283522 square meters (14.29%) in 2013 reflecting an increase built-up area over the decade. Change detection analysis includes a broad collection of process used to identify, differences between images of different times period. Calculation of urban growth rate of the study area was done through calculation of the total built-up area from satellite images of different time periods and then calculating the percentage of change in built-up area between these time periods. Growth of built-up area and percentage of increase in growth rate has been calculated for different time periods by using the following formula (equation 1, figure 9, Table 2);

Table 2. Trend of urban growth during 2000-2013

Year	Built-up area (m^2)	Time period	Growth(m^2)	Rate of growth (in %)	% increase in growth rate
2000	751679.21	2000-2010	229264.14	30.50	
2010	980943.35	2010-2013	302579.28	30.85	1.13
2013	1283522.63				

Built-up growth rate = present built-up area-previous built-up / previous built-up x 100……….equation 1

In the present study six criteria/parameters including slope, road proximity, land use/cover, geomorphology, elevation and aspect were used in preparation of criteria maps and multi-criteria based site suitability analysis. To perform site suitability analysis for urban expansion CARTOSAT-1 and 2 panchromatic satellite data at a resolution of 2.5 m and 1 m respectively was used for generation of Digital Elevation Model (DEM). The DEM was used to create slope and aspect map. Land use/cover and road proximity map was prepared with the help of a high resolution CARTOSAT-1 and 2. A Geomorphological map was prepared using satellite images. All these parameters were incorporated and evaluated in GIS

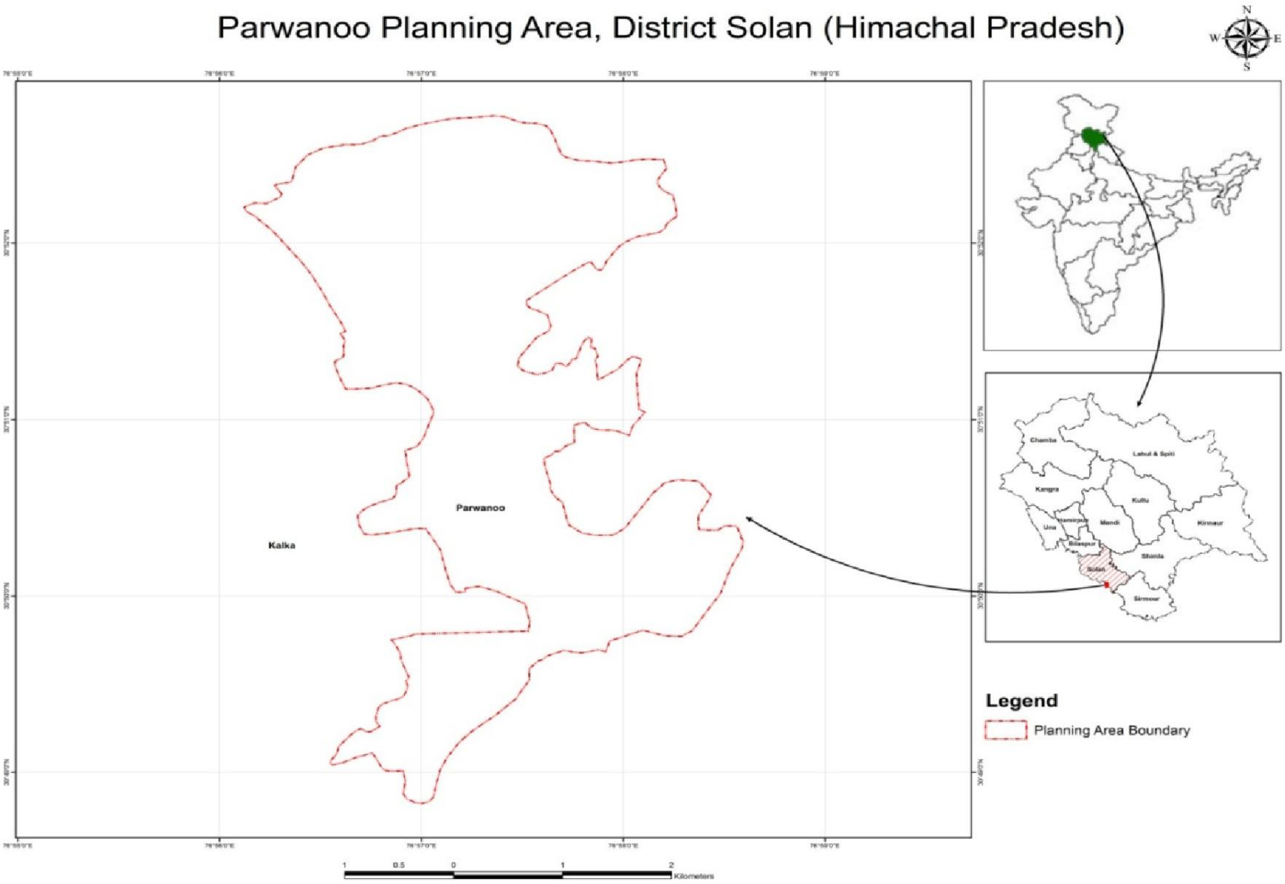

Figure 1. Location map of study area

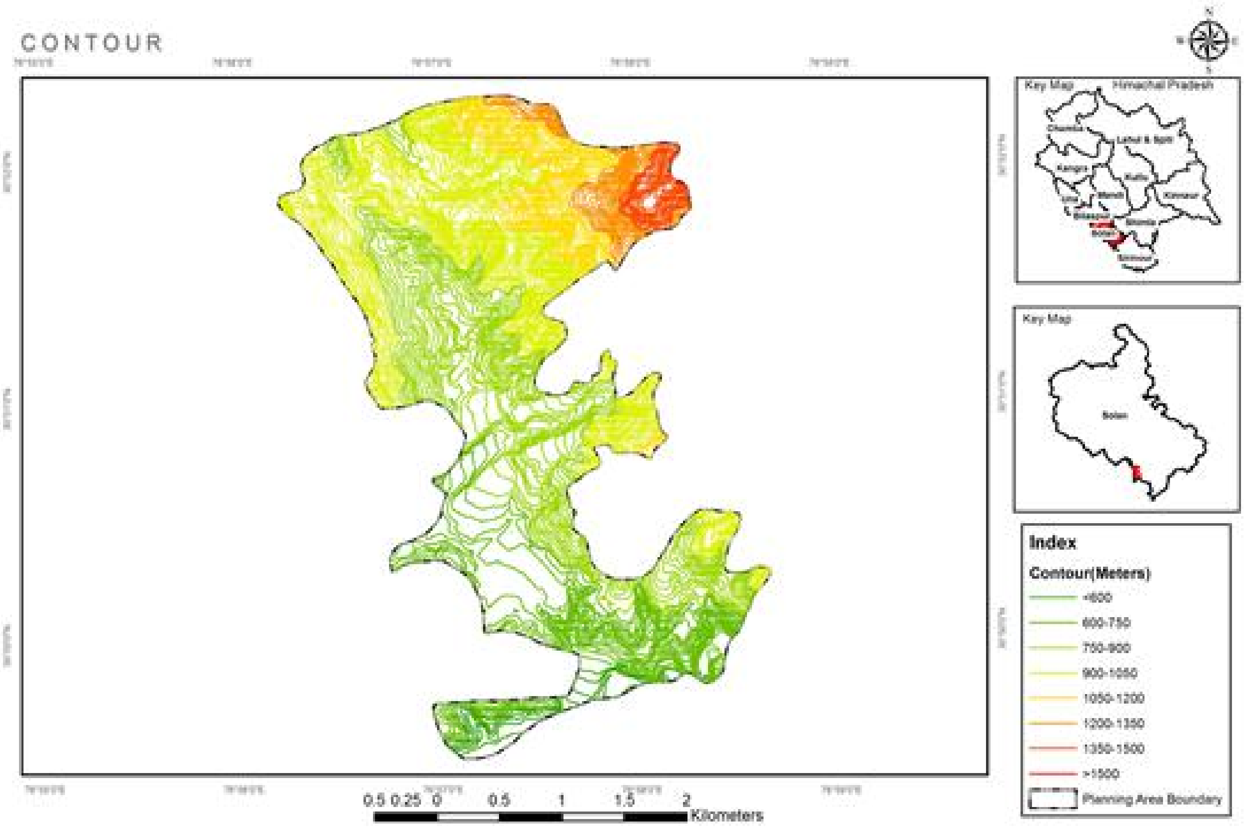

Figure 2. Elevation map of the study area

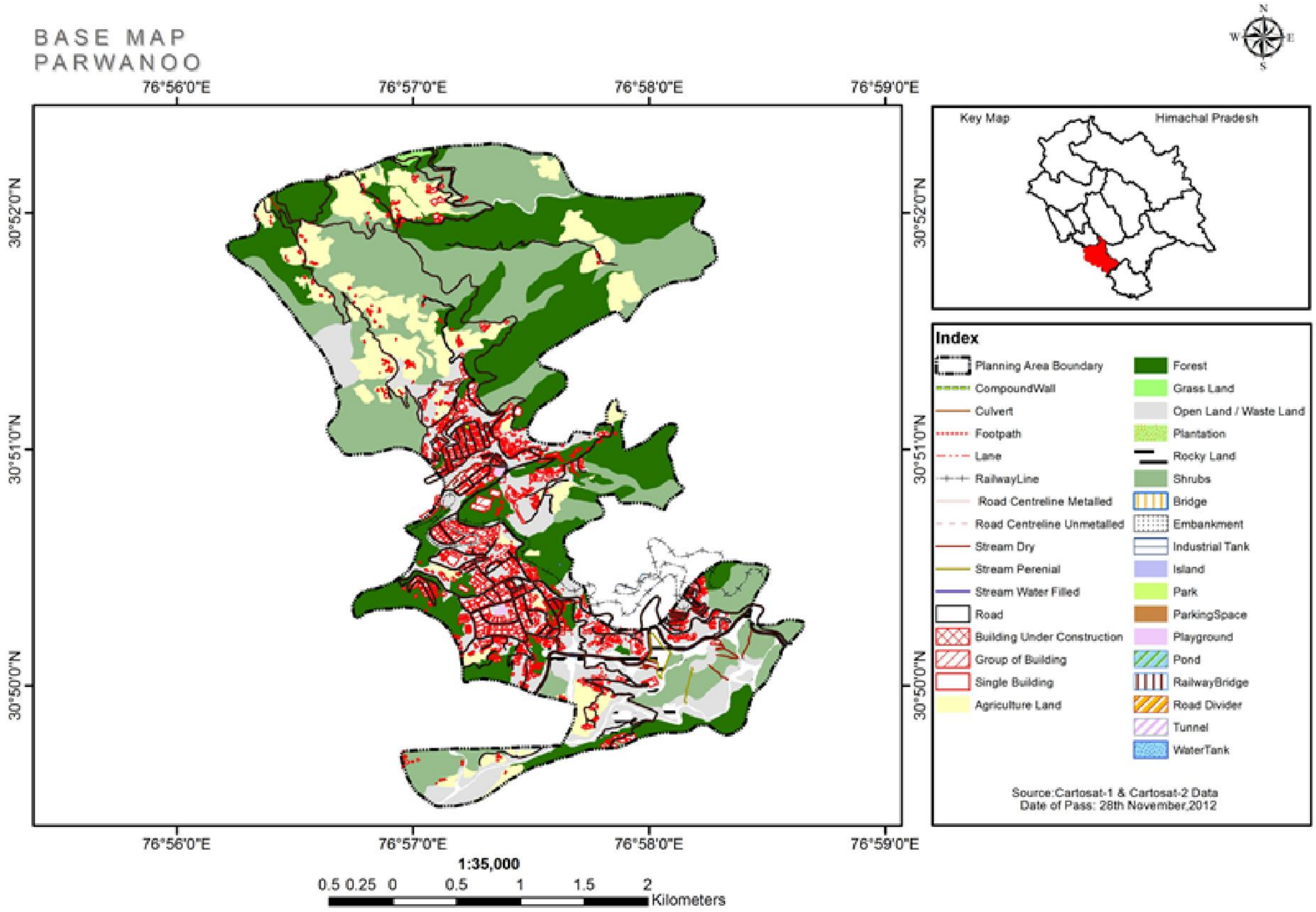

Figure 3. Base map of the study area

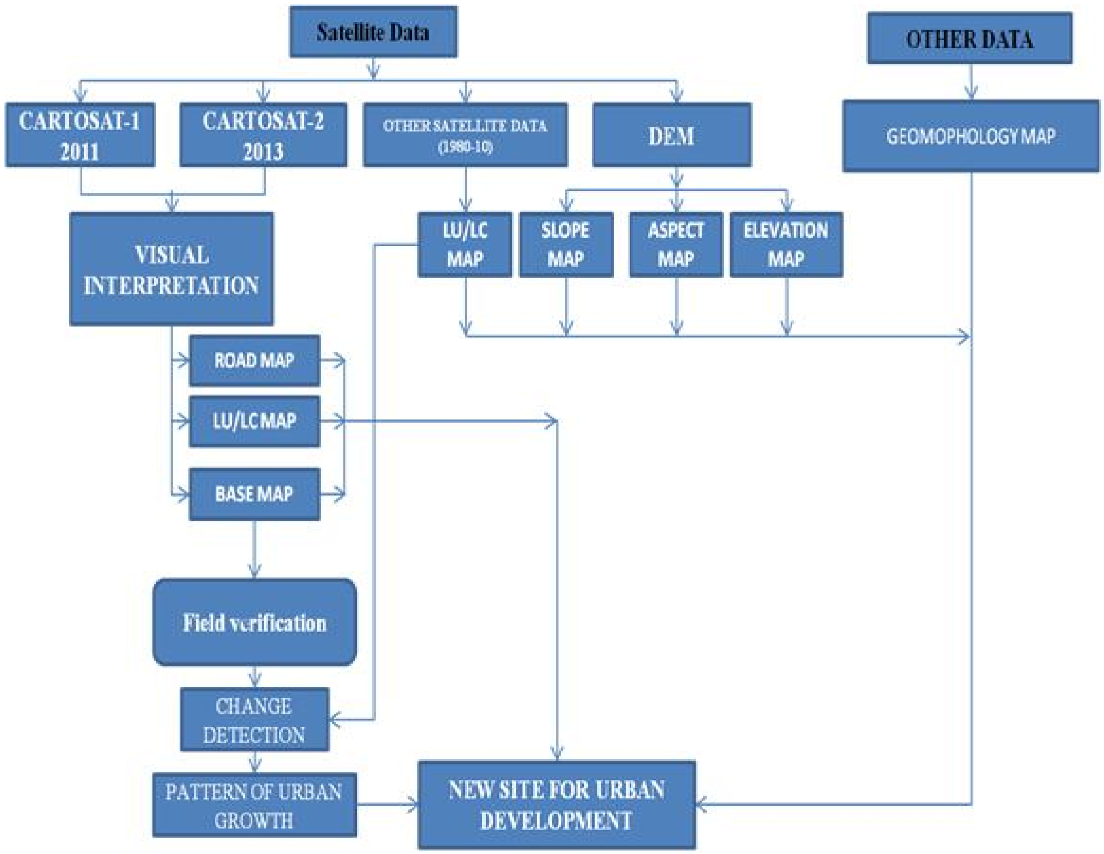

Figure 4. Flow chart of methodology

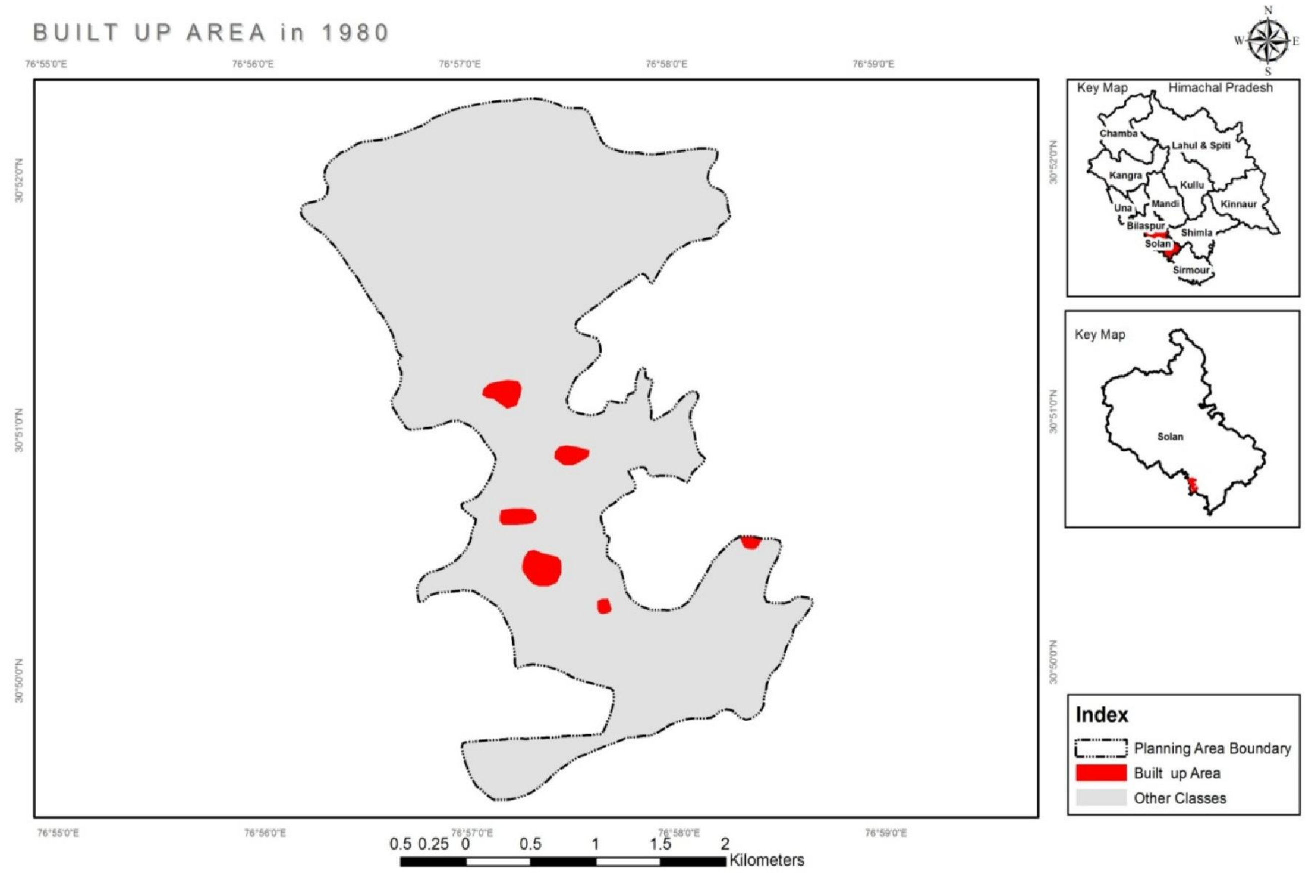

Figure 5. Built-up area in 1980

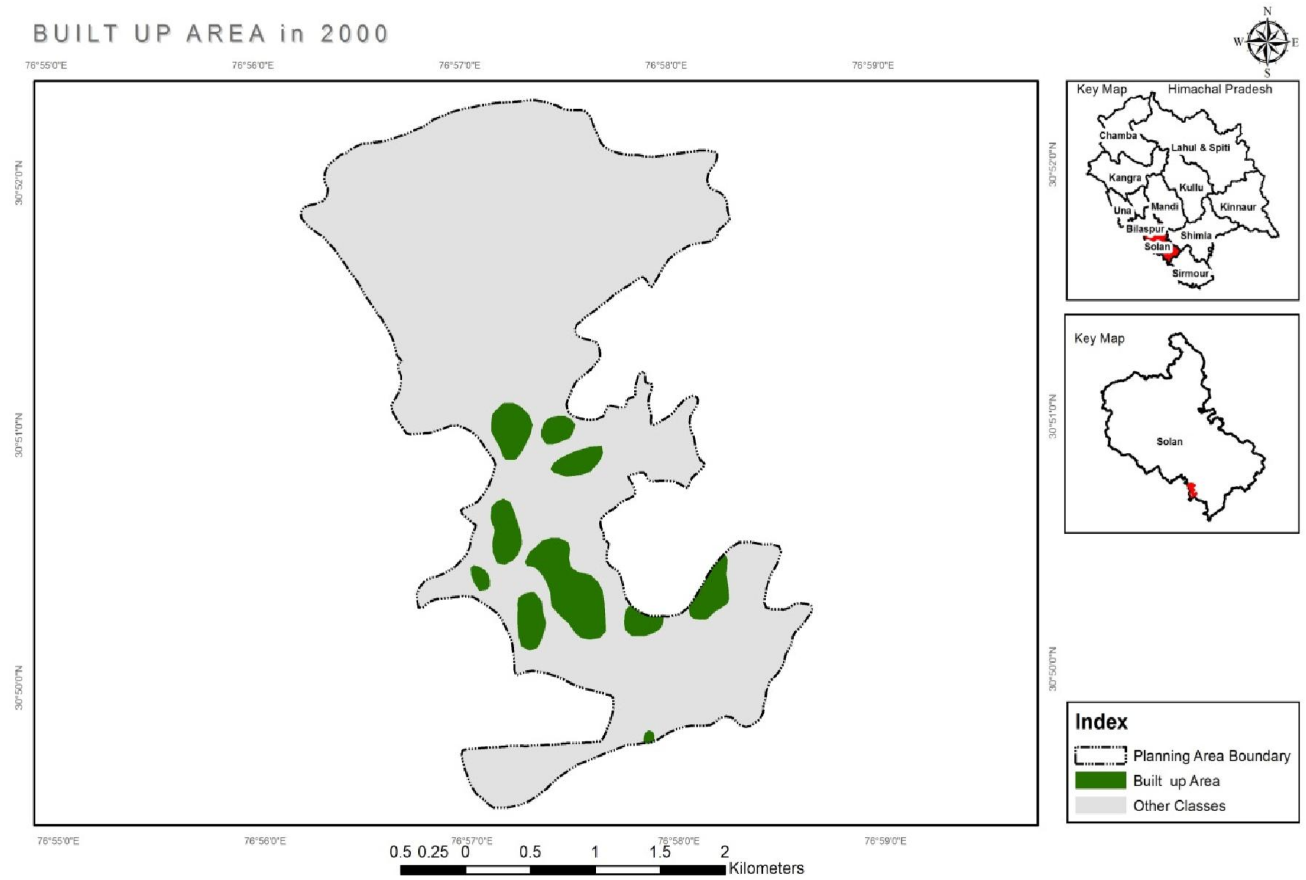

Figure 6. Built-up area in 2000

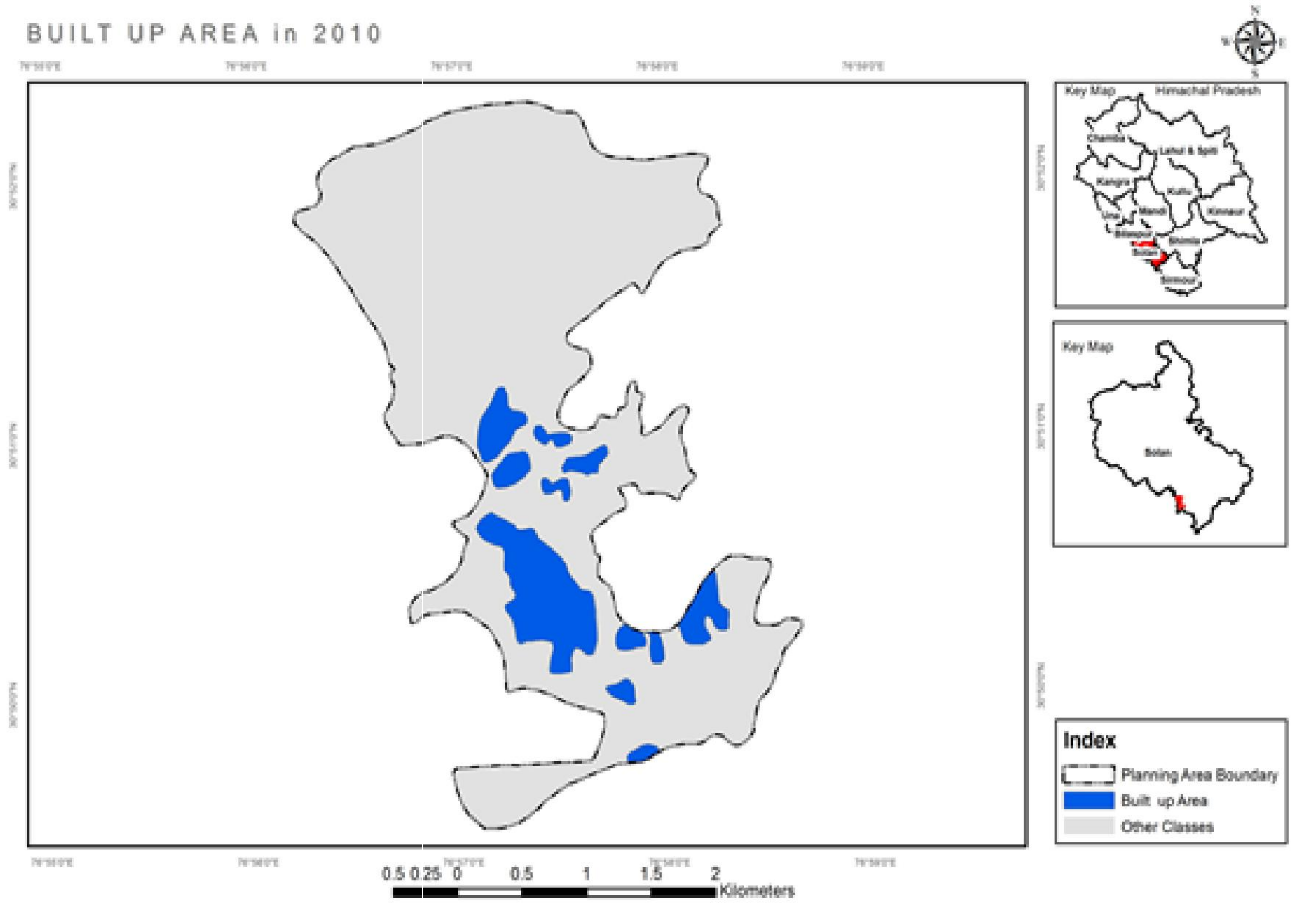

Figure 7. Built-up area in 2010

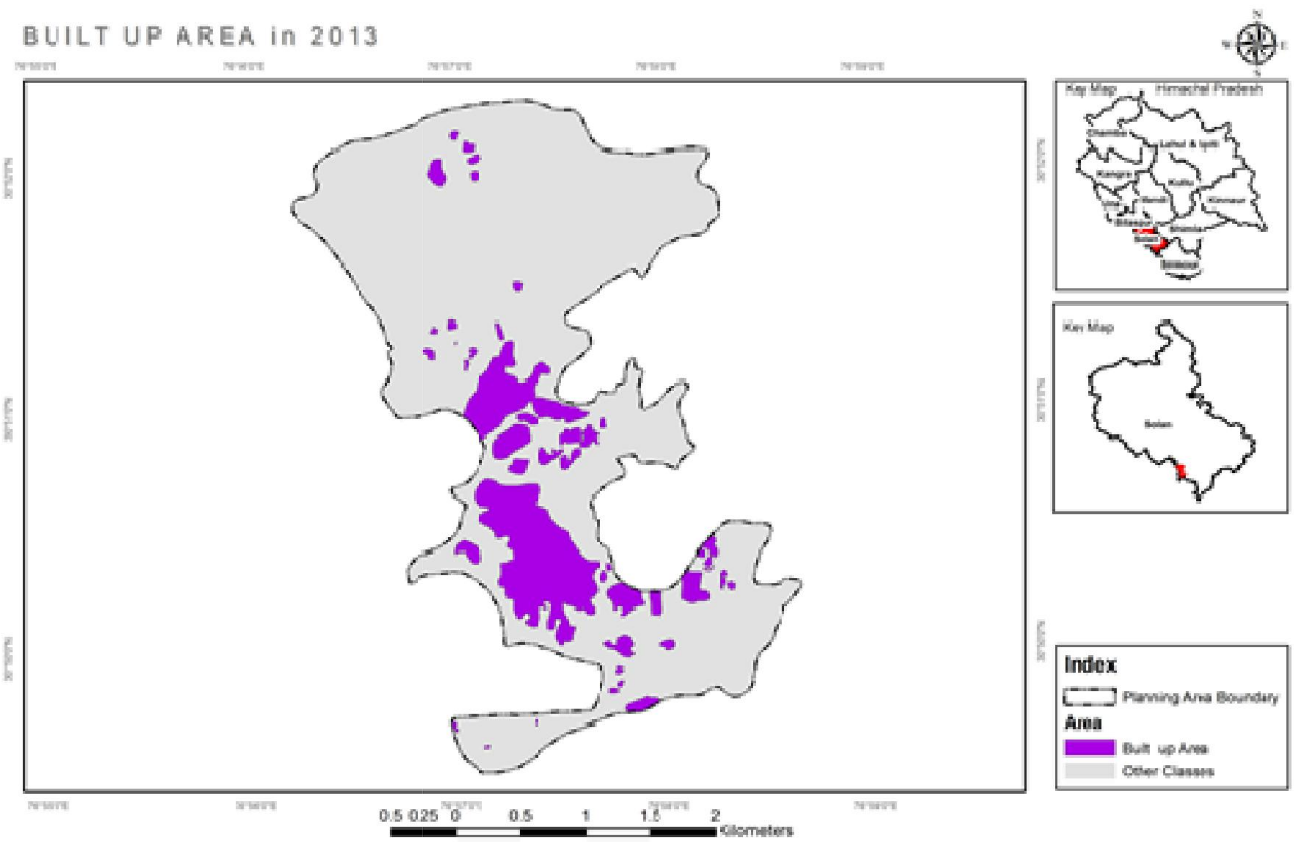

Figure 8. Built-up area in 2013

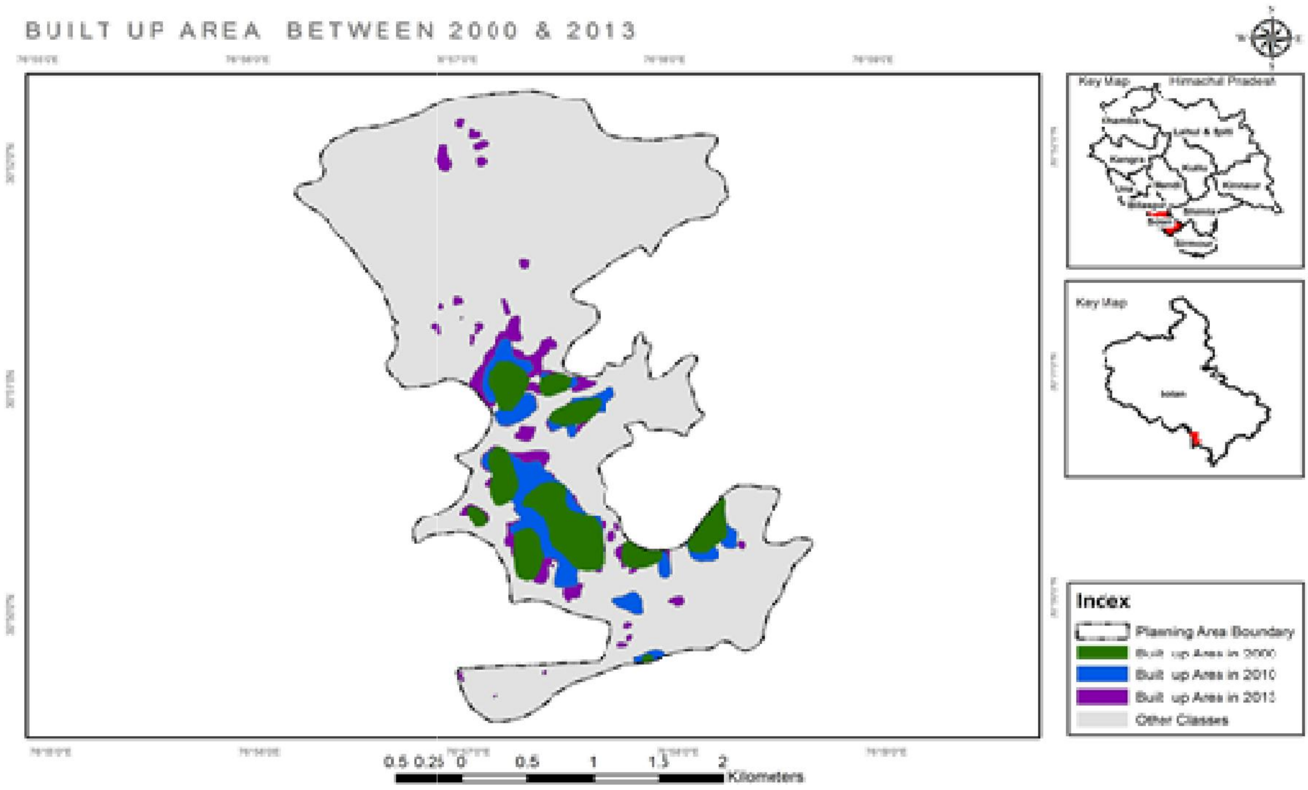

Figure 9. Built-up between 2000 and 2013

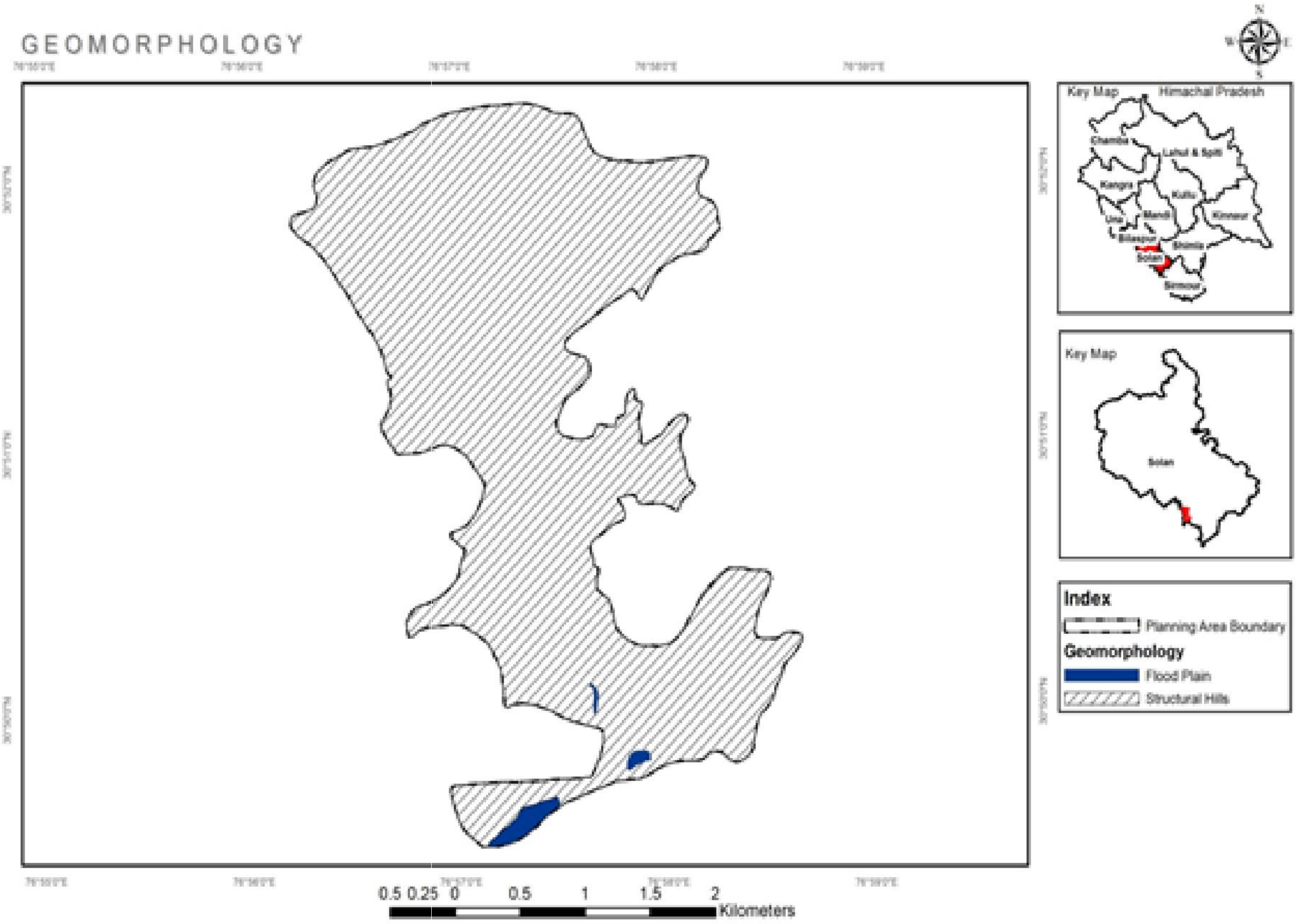

Figure 10. Geomorphology map

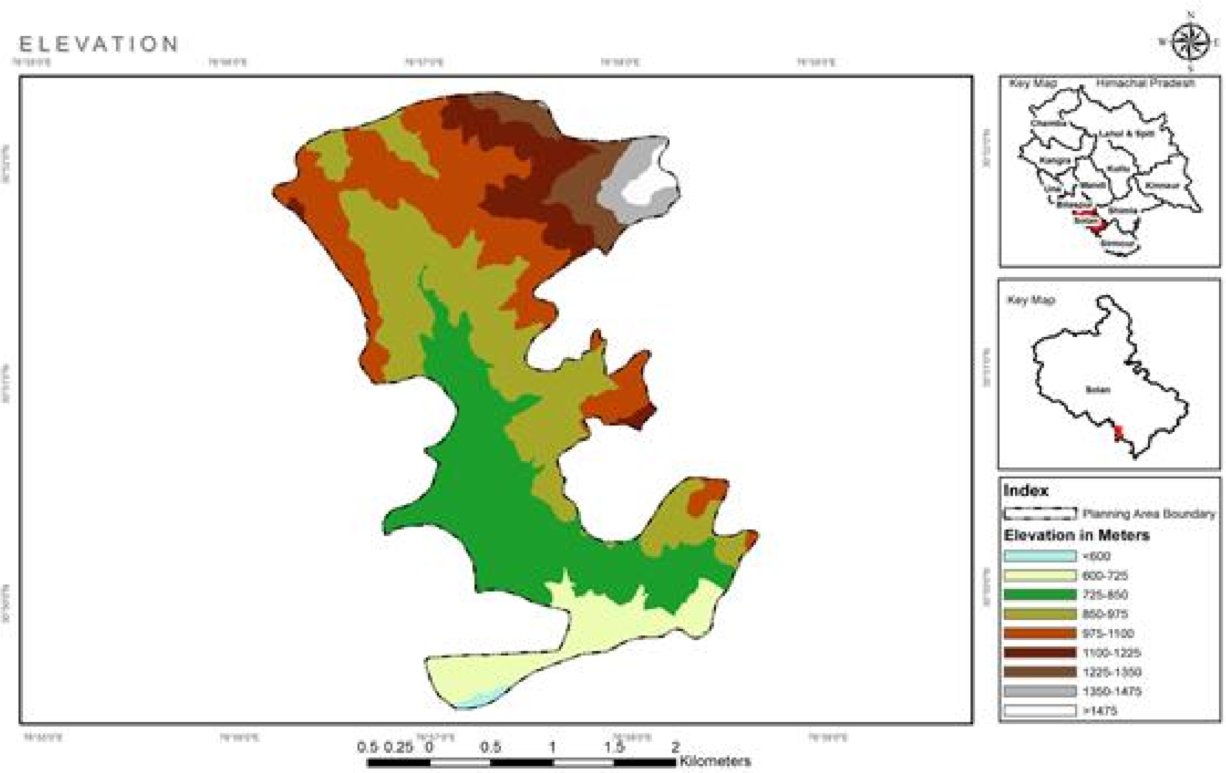

Figure 11. Elevation map

environment (ArcGIS software) to obtain final site suitability map. Geomorphology is also one of the major factors which influence the urbanization (figure 10). The geomorphological map prepared using satellite images can be broadly divide into two major type i.e flood plains and structural hills. Flood plain is considered as highly suitable for built-up because of low cost involved in construction compared to structural hills (moderate-low suitable). In this present study elevation has been considered as an important parameter in influencing the urbanization (figure 11). Majority of the area lies between elevation range 725-975 m which comes under high suitability whereas minor part lies between 975-1225 m under low suitability and above 1225 m under very low suitability for urban expansion because of expensive infrastructural development and accessibility to various distant places where the probability of natural hazards is very high. Road is also an essential parameter for site suitability analysis for the study area because transportation facility is important for carrying raw materials for industries as well as for livelihood. Construction of new roads in hilly terrain is expensive compared to plain area. For that reason, prime motto of this study is to find new site closer to any existing road for urban expansion (figure. 12). Therefore, buffer zones have been created outside the existing road for better accessibility. In the present study, areas less than 15-45 m distance from road is considered as high suitable, 45-60 m under low suitability and more than 60 m under very low suitability.

Slope is one of the most important parameter for finding new suitable sites for urban expansion (figure 13). In hilly areas people do not prefer construction on steep slopes because it increases the building costs as erosion process occurs during the construction activity in these areas and probability of natural disasters may occur. In the present study the slope of 0-10º is considered as having highest suitability, 10º-20º is considered as having moderately high suitability, 20º-30º as moderately suitable, 30º-40º as moderately low suitable, 40º-50º as low suitable, 50º-60º as very low suitable and more than 60º as least suitable for construction of new houses. Aspect has a strong influence on temperature and affects the angle of the sun rays when they come in contact with the ground. Aspect generally refers to the horizontal direction which a mountain slope faces (https://Characteristics+of+outdoor+environment.ppt). In the mid winter north facing slopes receive very little heat from the sun especially in the northern hemisphere. On the other hand, south facing slopes get much more heat rather than north facing slopes (www.fsavalanche.org/encyclopedia/aspect.html). In the present study areas with south facing slopes come under high suitability because in hilly terrain people prefer construction of houses in sun facing areas because in hilly terrain its cold during most part of the year (figure 14). Only a few a people prefer construction of houses on east facing slopes because east facing slopes receive sun heat only during morning time. Therefore in the present study higher intensity of importance has been given to southern facing slopes rather than other slopes. East facing slopes are colder than west facing slopes as east facing slopes face sun only in the morning when temperatures are colder whereas at the same time west facing slopes take the sun in the warm afternoon mostly in hilly area.

In the present study six criteria/parameters i.e. slope, road proximity, land use/cover, geomorphology, elevation and aspect were used in assigning weights based on Knowledge-based approach (Table 3). Higher weight age were assigned according to its suitability for site suitability analysis and vice versa. Further, pair wise comparison matrix using Saaty's nine-point weighing scale was calculated and applied to generate a ratio matrix (Saaty, 1996). Thereafter calculation of the criterion weights was done after the creation of pairwise

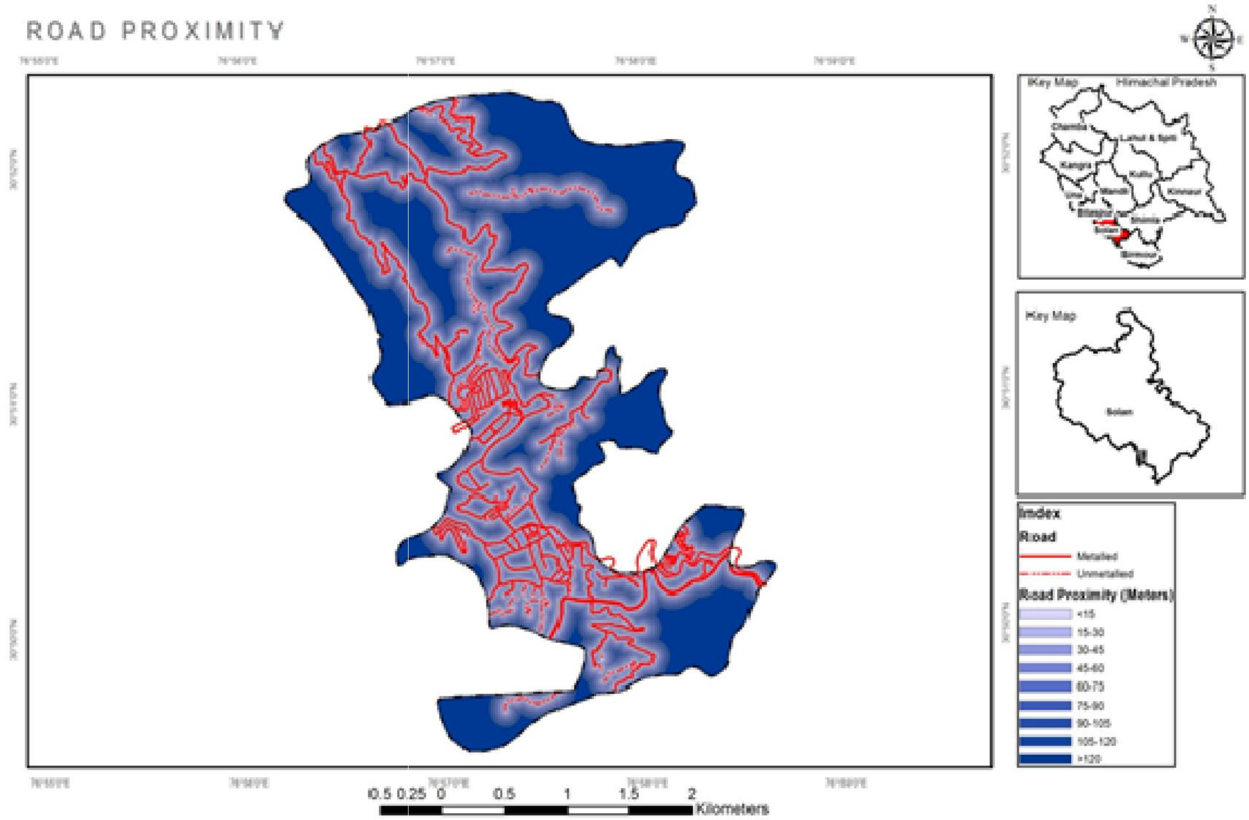

Figure 12. Road proximity map

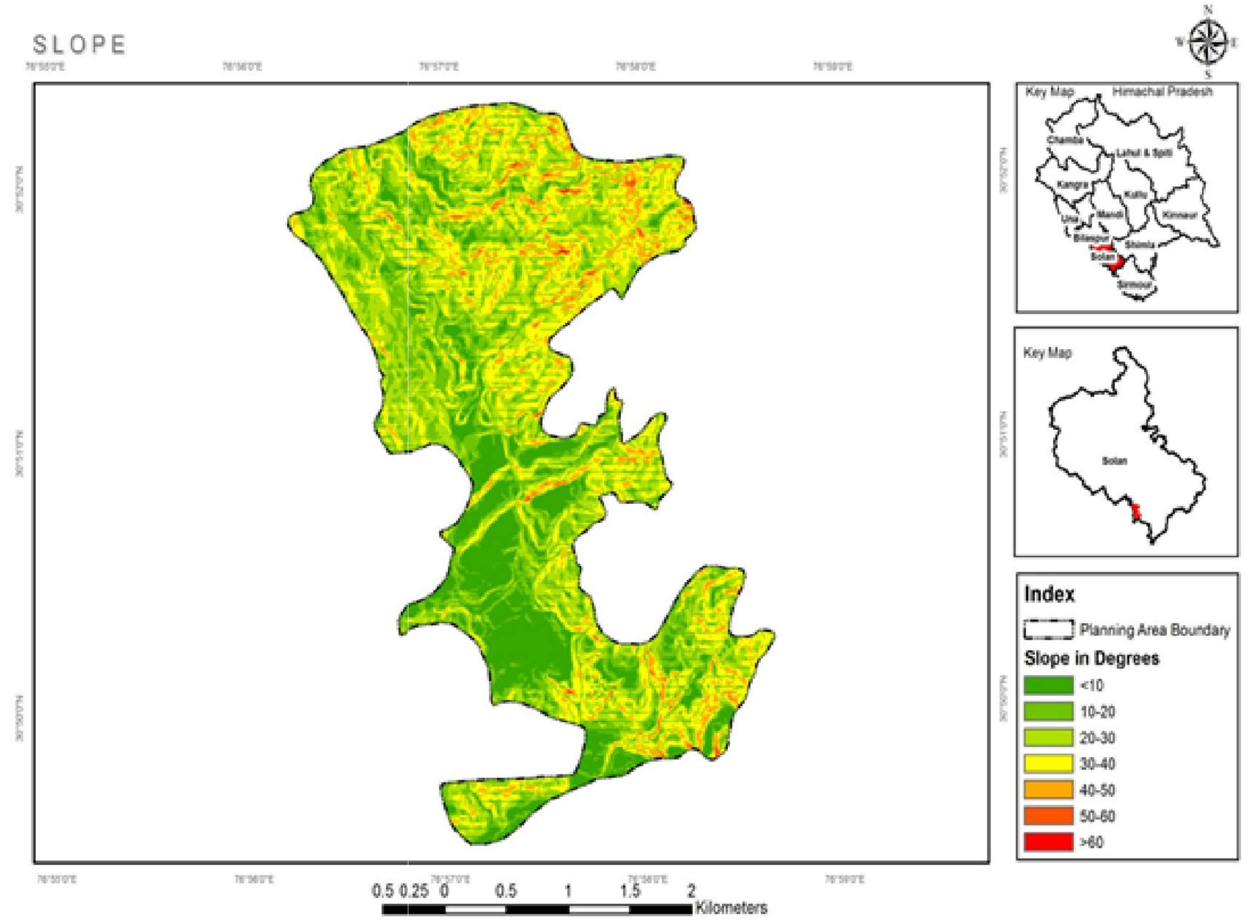

Figure 13. Slope map

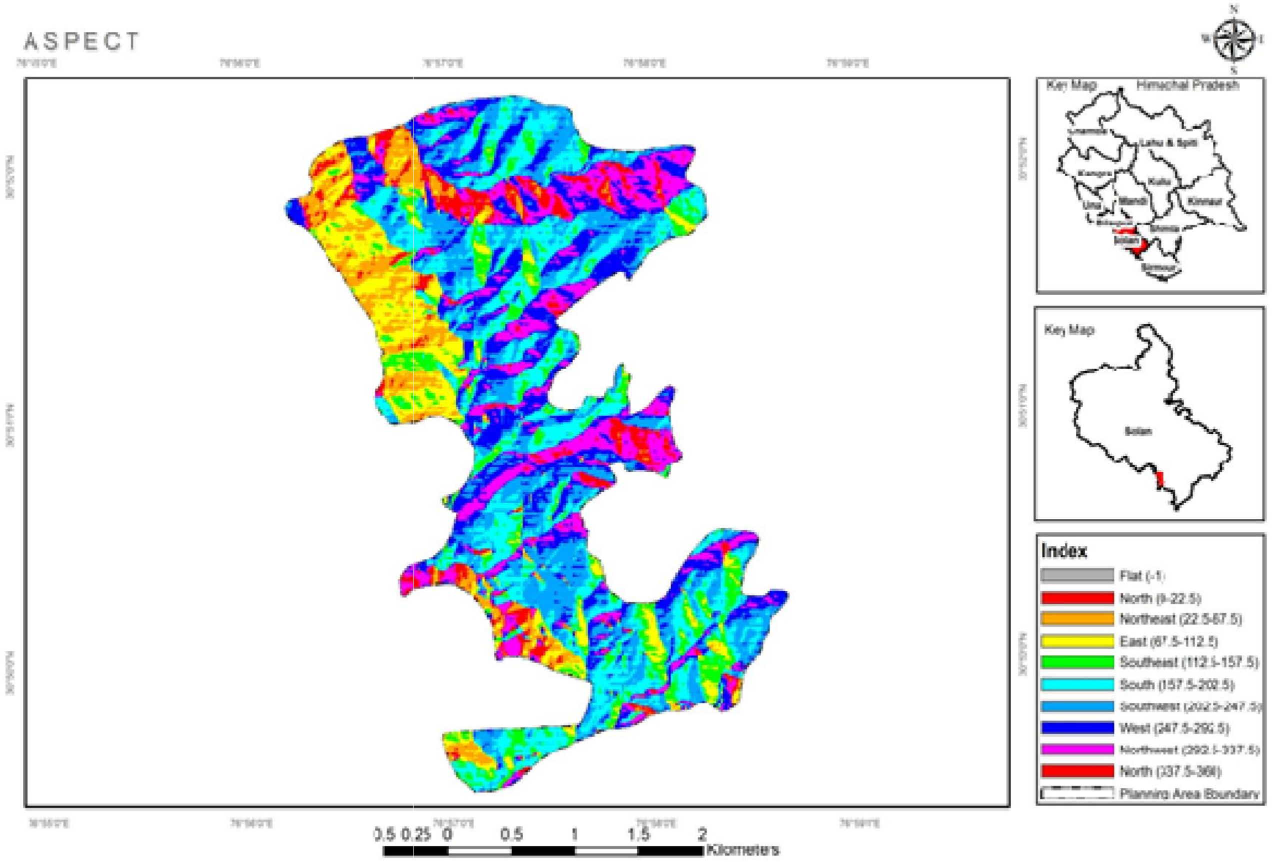

Figure 14. Aspect map

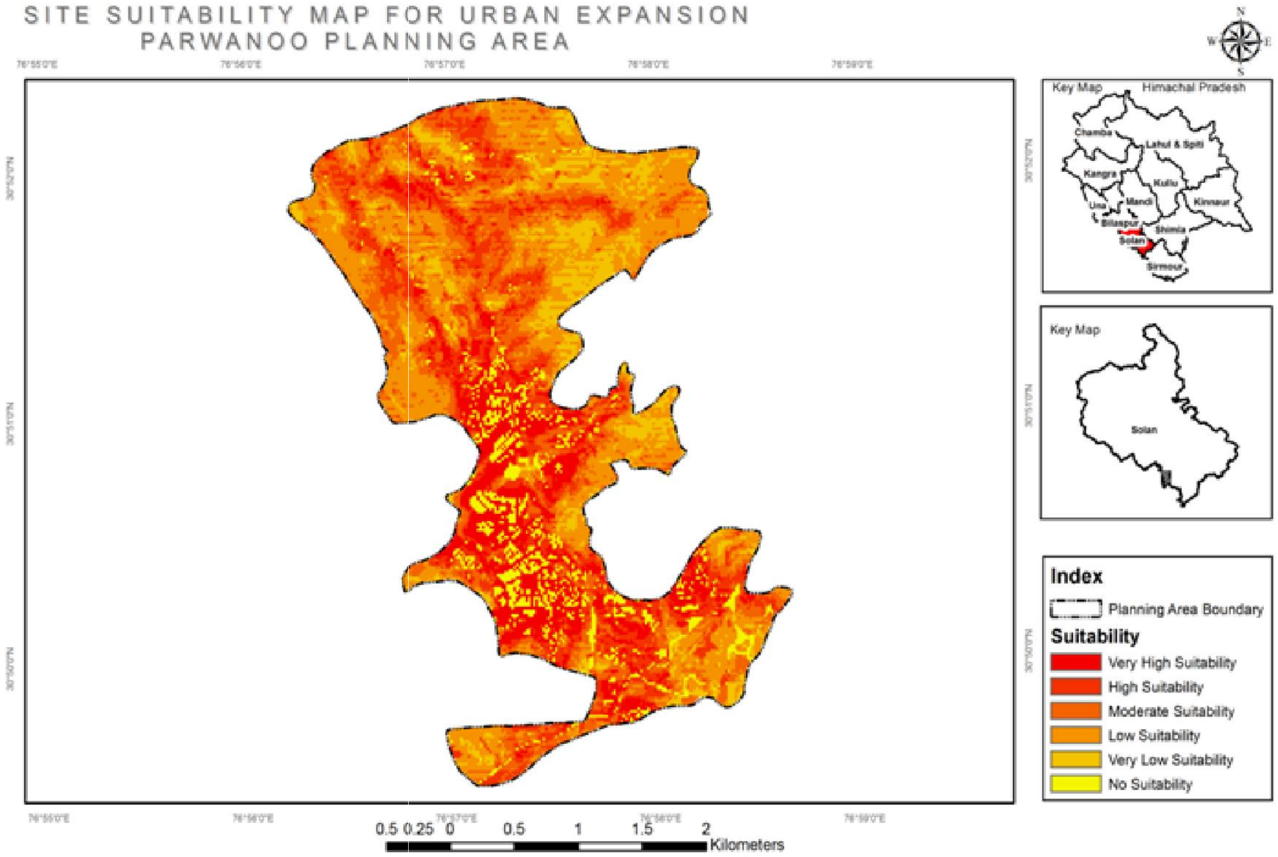

Figure 15. Site Suitability map of Parwanoo

Table 3. Weightages and parameters in determination of site suitability analysis

Slope	Road-proximity(m)	Lu/lc	Aspect	Geo-morphology	Elevation (m)	Weights	Intensity
0-10	0-15	Open land	South	Flood plain	<600	9	Highest
...	15-30	...	South-West	...	600-725	8	Very high
...	30-45	...	South-East	...	725-850	7	High
10-20	45-60	Scrub	West	...	850-975	6	Moderately high
20-30	60-75	Grassland	East		975-1100	5	Moderate
30-40	75-90	Rocky land	North-West	Structural hills	1100-1225	4	Moderately low
40-50	90-105	Forest	North-East	...	1225-1350	3	Low
50-60	105-120	Agriculture land	North	...	1350-1475	2	Very low
>60	>120	Built-up	...	...	>1475	1	Lowest

Table 4. Pairwise comparison matrix and normalized pairwise comparison matrix

Criteria	Pairwise comparison matrix						Normalized pairwise comparison matrix						Calculation of criteria weights
	Slope	Road proximity	LU/LC	Elevation	Geo-morphology	Aspect	Slope	Road proximity	LU/LC	Elevation	Geo-morphology	Aspect	
Slope	1	3	4	7	8	9	0.512821	0.619835	0.458716	0.449294	0.342906	0.28125	0.44413681
Road proximity	0.33	1	3	4	7	8	0.169231	0.206612	0.344037	0.256739	0.300043	0.25	0.25444355
Land use/land cover	0.25	0.33	1	3	4	7	0.128205	0.068182	0.114679	0.192555	0.171453	0.21875	0.14897057
Elevation	0.14	0.25	0.33	1	3	4	0.071795	0.051653	0.037844	0.064185	0.12859	0.125	0.07984440
Geomorphology	0.12	0.14	0.25	0.33	1	3	0.061538	0.028926	0.02867	0.021181	0.042863	0.09375	0.04615467
Aspect	0.11	0.12	0.14	0.25	0.33	1	0.05641	0.024793	0.016055	0.016046	0.014145	0.03125	0.02644996
Total	1.95	4.84	8.72	15.58	23.33	32	1	1	1	1	1	1	1

Table 5. Calculation of consistency vector

Criteria	Sum of weighted vector	Consistency vector
Slope	{(1*0.4441)+(3*0.2544)+(4*0.1489)+(7*0.0798)+(8*0.0461)+(9*0.0264)}	= 2.96954775/0.4441 = 6.686110273
Road proximity	{(0.33*0.4441)+(1*0.2544)+(3*0.1489)+(4*0.0798)+(7*0.0461)+(8*0.0264)}	= 1.701980532/0.2544 = 6.689029929
LU/LC	{(0.25*0.4441)+(0.33*0.2544)+(1*0.1489)+(3*0.0798)+(4*0.0461)+(7*0.0264)}	= 0.953272842/0.1489 = 6.399067891
Elevation	{(0.14*0.4441)+(0.25*0.2544)+(0.33*0.1489)+(1*0.0798)+(3*0.0461)+(4*0.0264)}	= 0.499058633/0.0798 = 6.250389245
Geomorp-hology	{(0.12*0.4441)+(0.14*0.2544)+(0.25*0.1489)+(0.33*0.0798)+(1*0.0461)+(3*0.0264)}	= 0.278014385/0.0461 = 6.023536314
Aspect	{(0.11*0.4441)+(0.12*0.2544)+(0.14*0.1489)+(0.25*0.0798)+(0.33*0.0461)+(1*0.0264)}	= 0.161886267/0.0264 = 6.120472203

comparison matrix (Table 4). AHP being a powerful tool in applying MCDA was developed by Saaty in 1980. Weights or priority vector for the alternatives or the criteria is required. For creating the pair wise comparison matrix (PCM), a system of numbers to indicate how much one criterion is more important than the other was designed by Saaty (1980). The value of λ_{max} is required in calculating the consistency ratio (CR) (Han and Tsay, 1998):

Consistency Index (C.I.) = $(\lambda max-n) / (n-1)$ (equation .2)

where n is the number of criteria and λmax is the largest eigen value (Han and Tsay, 1998; Malczewski, 1999). The final consistency ratio is calculated by comparing the C.I. with the Random Index (Malczewski, 1999).

C.R. = C.I. / R.I. (equation .3)

where R.I. depicts random index and in this case R.I. = 1.24 (Saaty, 1980). The consistency ratio is designed such a way that shows a reasonable level of consistency in the pairwise comparisons if $C.R. < 0.10$ and $C.R. \geq 0.10$ indicate inconsistent judgments (Table 5).

In the current study, the C.R. matrix of the six important parameters in site suitability assessment for urban expansion is 0.0582. Therefore the pair-wise matrix appears to have sufficient internal consistency to be considered acceptable. All criteria layers were converted into raster format for analysis because raster format is less complicated than vector data format (Chang, 2006). Thereafter all layers were multiplied by its weight for final site suitability map using raster calculator of ArcGIS. Voogd (1983) mentioned that the most relevant technique for multi-criteria evaluation is the weighted linear combination. In this technique, factors are combined by applying a weight value to each, followed by a summation of the results to yield a map of suitability (Eastman et. al. 1995) as follows;

$S = \Sigma (Wi * Xi)$ or Σ [criteria map * weight] (equation .4)

Suitability Map = ([Slope] * 0.44) + ([Road proximity] * 0.25) + ([Land use/cover] * 0.15) + ([Elevation] * 0.08) + ([Geomorphology]*0.05) + ([Aspect] *0.03)

Where S is the final suitability map, Wi is the criteria map and Xi is the weight of the parameter. The final site suitability map describes that the study area was divided into six suitability classes (Figure 15). In figure 15 dark red colour shows very highly suitable areas for urban expansion where as light orange colour shows very low suitability and yellow colour shows the areas not suitable for construction of houses and other structures.

Conclusion

The present study shows that built-up area was 2.1% of total area in 1980 which increased to 14.3 % in 2013. This clearly indicates rapid urbanization at cost of forested land. The present study shows the use of geo-informatics techniques and multi-criteria decision analysis (MCDA) technique for selection of appropriate sites for urban development in Parwanoo Planning Area, Kasauli Block, District Solan, Himachal Pradesh. The study area comprises about 14% area under very highly suitable for urban expansion, 18% area highly suitable, 22% area moderately suitable, 30% area low suitable, 9% area very low suitable and 7% area which is not suitable for urban expansion. Remote Sensing is a very useful tool to obtain different types of data required for site suitability analysis. The integration of different parameters in ArcGIS environment with the help of AHP approach can generate site suitability map having significant accuracy as shown in this study. This study can help the planners and decision makers in preparation of appropriate developmental plans for further growth of the study area. The result of the study can also be successfully applied to other areas especially in hilly areas to solve the problem of land scarcity for development of new urban areas.

REFERENCES

Chang KT, 2006. Introduction to Geographic Information System, Tata McGraw Hill, New Delhi.

Deal B and Schunk D, 2004. Spatial dynamic modeling and urban land use transformation: A simulation approach to assessing the costs of urban sprawl. E*cological Economics*, 51: 79-95.

Eastman JR., Jin W, Kyem W and Toledano P, 1995. Raster procedures for multi-criteria? Multi-objective decisions. *Photogrammetric Engineering & Remote Sensing*, 61(5): 539–47.

Han W J and Tsay W D, 1998. Formulation of quality strategy using analytic hierarchy process, Twenty Seven Annual Meeting of the Western Decision Science Institute, University.

Harris PM and Ventura SJ, 1995. The integration of geographic data with remotely sensed imagery to improve classification in an urban area. Photogrammetric Engineering and Remote Sensing, 61: 993-998.

Jat MK, Garg PK and Khare D, 2008. Monitoring and modeling of urban sprawl using remote sensing and GIS techniques. *International Journal of Applied Earth Observation and Geoinformation*, 10:26-43

Jenerette GD and Wu J, 2001. Analysis and simulation of land use change in the Central Arizona - Phoenix region. *Landscape Ecology*, 16: 611-626.

Kumar M and Biswas V, 2013. Identification of Potential Sites for Urban Development Using GIS Based Multi Criteria Evaluation Technique. A Case Study of Shimla Municipal Area, Shimla District, Himachal Pradesh, India. *Journal of Settlements and Spatial Planning*, 4(1): 45-51.

Manonmani R, Prabaharan S, Vidhya R and Ramalingam M, 2012. Application of GIS in urban utility mapping using image processing techniques. *Geo-spatial Information Science* DOI:10.1080/10095020.2012.714660

Meaille R and Wald L, 1990. Using geographic information system and satellite imagery within a numerical simulation of regional urban growth. *International Journal of Geographic Information Systems*, 4:445–456.

Pathan SK, Jothimani P and Sampat KD, 1989. Urban land use mapping and zoning of Bombay metropolitan, region using Remote Sensing data. *Journal of Indian Society of Remote Sensing*, 17(3): 11-22

Perveen F, Ryota N, Imtiaz U and Hossain KMD, 2007. Crop land suitability analysis using a multi-criteria evaluation and GIS approach, 5th International Symposium on Digital

Earth. Berkeley, USA: The University of California; pp. 1–8.

Saaty TL, 1977. A Scaling Method for Priorities in Hierarchical Structures. *Journal of Mathematical Psychology* 15: 234-281.

Saaty TL, 1980. The Analytic Hierarchy Process, Mac Gray-Hill, New York.

Saaty TL, 1996. Decision making in Complex Environments, The Analytical Hierarchy Process for decision making with Dependence and Dependence and Feedback (USA: RWS Publications).

Saaty TL, 2003. Decision-making with the AHP: Why is the principal eigenvector necessary. *European Journal of Operational Research*, 145: 85-91.

Saaty TL, 2008. Decision making with the analytical hierarchy process. *International Journal of Services Sciences*. 1(1): 83- 98

United Nations, 2004. Integration of GPS, digital imagery and GIS with census mapping. New York: United Nations Statistics Division.

UNFPA, 2007. “State of world population: unleashing the potential of urban growth” United Nations population Fund.

Voogd H, 1983. Multicriteria Evaluation for Urban and Regional Planning, Pion, Londres.

Ward D, Phinn SR and Murray AT, 2000. Monitoring growth in rapidly urbanizing areas using remotely sensed data. Professional Geographer*,* 52 (3): 371-386.

Weng Q, 2001. A remote sensing-GIS evaluation of urban expansion and its impact on surface temperature in the Zhujiang Delta, China. *International Journal of Remote Sensing*, 22(10): 1999–2014.

Westmoreland S and Stow DA, 1992. Category identification of changed land-use polygons in an integrated image processing/geographic information system. *Photogrammetric Engineering and Remote Sensing,* 58: 1593–1599.

Wilson R, Hemsley-Brown J, Easton C and Sharp C, 2003. Using Research for School Improvement: The LEA’s Role, National Foundation for Educational Research (NFER), Slough.

Yeh AGO and Li X, 1996. Urban growth management in the Pearl River delta – an integrated remote sensing and GIS approach. *The ITC Journal*, 1: 77–85.

Yeh AGO and Li X, 1997. An integrated remote sensing-GIS approach in the monitoring and evaluation of rapid urban growth for sustainable development in the Pearl River Delta, China. *International Planning Studies*, 2: 193–210.

Yeh AGO and Li X, 1999. Economic development and agricultural land loss in the Pearl River Delta, China. *Habitat International,* 23: 373–390.

****