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Identifying Suitable site for Urban Development using Multi Criteria Decision Making model {Analytic Hierarchy Process (AHP)}: Case of Shillong and its Agglomeration area

B.Swer.[1], **B.S.Mipun.**[2]

research scholar, Department of Geography, Nehu University, shillong Professor, Department of Geography, Nehu University, shillong, India [2]

Abstract

Shillong is the capital city of the state of Meghalaya, India. It was the capital of Assam until 1972 when Meghalaya constituted into a state. Shillong is one of the many hill stations in India. It seemed an ideal place to start the investigation in this hill station since this research was partly rooted in a field based study. Shillong has its roots in the British colonial era. Most of the structures seen today in Shillong are British type or the commonly associated Assam type. Shillong has grown from a small village to a sprawling city. Today Shillong is viewed as the education hub of the North East.

Shillong is the capital city of Meghalaya and is located at 25.57° N and 91.88° E. It lies in the Khasi hills in Meghalaya and is also the headquarters of the East Khasi Hills district. To the north of the state of Meghalaya lies the state of Assam and the plains of Bangladesh lie to the south.

The Khasi hills consists of a range of hills ranging from 1500 to 2000 mt above sea level. In generalShillong is bounded by a range of hills with undulating downs broken by deep ravines through which larger hill streams flow. The Khasi uplands are rich in tropical forests and coniferous forests in the higher altitudes. Sal, oak and bamboo are predominant in the lower slopes and fir and pine trees are found on the higher slopes. Shillong is surrounded by three hills-Lum Sohpetbneng, Lum Diengiei and Lum Shillong. The major rivers are the Umshyrpi and the Umkhrah, which finally merge and form the Umiam river.

The final suitability map was obtained from both weighted sum overlay and Spatial Analyst Tools covering an area of 656.02 sq. km. After suitability analysis it was found that from the available area 3 sq km falls under not suitable.

67 sq km under low suitable, 199 sq.km under moderately suitable, 275 sq. km under high suitable and 106 sq. km under very highly suitable. The result shows that highly suitable areas for urban development is either agricultural or mostly forest type.

City growth and sprawl are due to rapid urban development and migration of population from rural to urban areas are global phenomena. Compact urban centers are rapidly changing and leading to congestion , thus most natural land are being converted to urban use (Hauser *et al*., 1982). The planning on the hills is very restrictive as compared to the plains. The major factors that govern the planning are topography, climatic conditions, orientation, traffic movement, available usable spaces, sources of water supply, natural drains and paths.According to United Nation's Population Division report published in 1975, about 38% of the earth's population is living in urban areas and by 2025; this proportion is expected to rise to 61%. This implies that about 5 billion people out of a total world population of 8 billion will be living in urban areas (UNPD, 1995; http://www.wri.org/wri/wr-96-97).

Shan (1999) applied remote sensing and GIS technologies for analyzing the dynamics of the urban spatial structure in Shanghai. Multi-temporal landuse information of the central city of Shanghai was obtained by the interpretation of aerial photos of 1958, 1984 and 1996. Based on Arc/View GIS concentric and sector methods, a conceptual model of the spatial structure of Shanghai was brought forth. Sao (2000) carried out a study to prepare location map of selected urban facilities and services using GPS technology and to identify the service areas of different facilities and services, which will be the inputs for preparation of comprehensive development plan of the city.

Ashraf (2001) carried out a study to find out the historical urban development of Kharga city, Egypt and used it for defining the main direction of city's development. Amarsaikhan and Ganzorig (2000) carried out study to investigate the urban changes that have occurred in central part of Ulaanbaatar area, Mongolia over the past few decades and describe the socio-economic reasons for the changes. In this study a topographic map of 1969 at 1:25.000 scale, SPOT XS image of 1986, SPOT PAN image of 1990 and SPOT XS image of 1997 were used. A survey showed that the GIS based multi-criteria approaches are most often used in site suitability analysis (Malczewski, 2006).

• Gentle slopes are required so that the cost of site development is lessened. The roads for traffic movement are of gradual gradient. Less excavation is required to be done to maintain the ecological balance.

• Slope of the ground should not be more than 30º as far as possible even in rocky reaches to avoid instability problems, especially during severe earthquakes.

• Suitable clearance around buildings is necessary. Foundation of any part of building should not rest on filled up ground. On hills there should be clearance of about 40º in case of soil, soil mixed boulder, fractured rock zone, soft rock zone having outward dip, so that any slip, if occurs may not hit the building. • Due to the cold climate, the southern slopes are preferred.

• The orientation of the houses is to maximize the penetration of the sun rays.

• The stress is also laid on the preservation of the green cover. The site should be developed in such a way that felling of trees is avoided as far as possible.

• Site susceptible to high winds, storms, floods and landslides should be avoided. • Since the inner side of the cut slope may have higher bearing capacity, building should be so oriented and planned so as to enhance that higher load comes on inner side. Where the site seems to undergo unequal settlement, the site should be so planned and designed that the higher load comes on harder part of foundation and soil.

• Terrace in all around the building should have proper slope for efficient drainage. During the site development, terrace may be cut at 1:30 to 1:50 slope and may be trimmed at suitable slope after the completion of the building work.

In the steep hilly zones, the stepped terraces will be much beneficial environmentally and economically, as they result in the least hill cutting and disturbance to the hill stability.

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Keywords

Shilling urban Agglomeration , Geographic Information System (GIS); Multi-criteria Evaluation (MCE); Overlay Weightage Average (OWA); Weighted Linear Combination (WLC); Analytic Hierarchy Process (AHP); Urban Development; Spatial Analysis

STUDY AREA:

Shillong, started with a small town of moderate size in the district of East Khasi Hills (Meghalaya State), Shillong is the capital city of Meghalaya and is located at 25.57° N and 91.88° E. It lies in the Khasi hills in Meghalaya and is also the headquarters of the East Khasi Hills district. To the north of the state of Meghalaya lies the state of Assam and the plains of Bangladesh lie to the south.

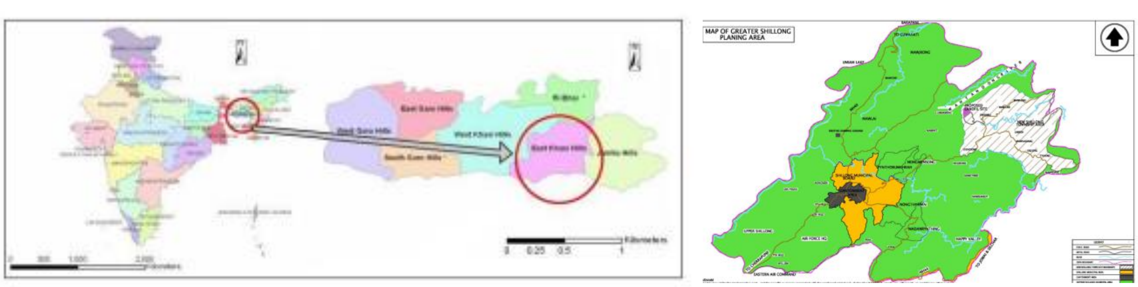
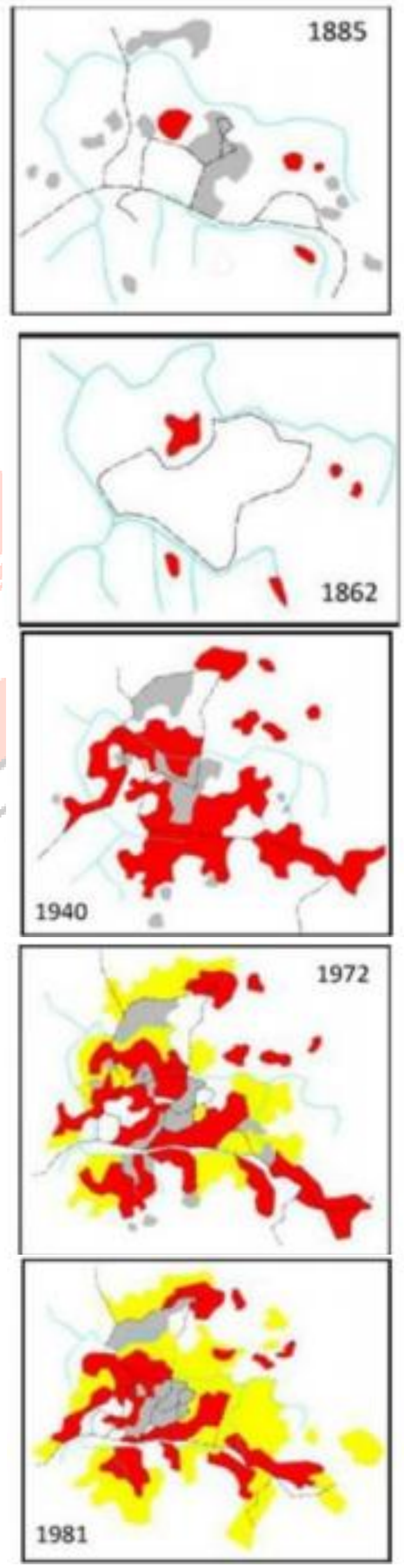


FIGURE 1

METHODOLOGY:

Different attribute layers such as slope, LULC, forest area drainage and waterbodies are generated by using ArcGis 10.8. These layers were prepared using ArcGis and results were generated to identify the possible suitable site for urban expansion. For suitability analysis, different parameters such as land use, roads, drainage and water bodies are considered and categorized with various attribute layers by using ArcGis analytical tools. Methodology is shown as flow diagram, shown in Fig. 1.

Expansion trends during 1885-2006:



1862: Shillong and Iewduh, two distinct sites were considered as the H.Q station and military cantonment by British.

1874: Assam province was constituted and Shillong was made the Headquaters.

1878: Shillong constituted into a station

1886: Total transfer of land from SyiemMylliem to the British.

1909: Municipality constituted under Bengal Municipal Act.

1940: Rapid Urban growth due to formation of Municipality and due to establishment of state and government offices.

1961: Since Mawlai and Nongthymmai became census towns they were included in the urban agglomeration.

1981: Further expansion of urban area to the towns of Pynthorumkhrah and Madanryting.

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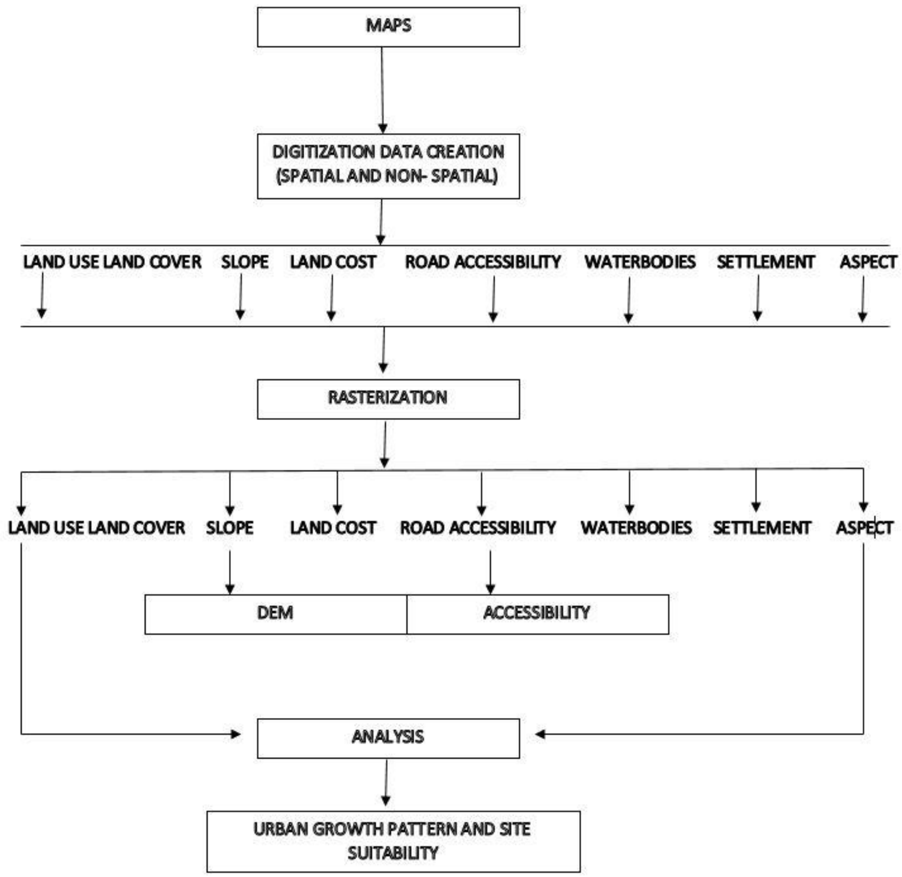
GIS BASED SITE SUITABILITY ANALYSIS

Local criteria have been identified for the selection of suitable sites. The physical character of the site such as the slope, LULC, road proximity, cost, drainage waterbodies etcdetermine the suitability for the type of use of a particular area. Assessment based on ranking and weightage have been worked out to determine the overall suitability or to identify the potential sites for urban expansion and development.

The analysis may also determine how those factors will fit into the design process to evaluate site suitability (Hofstee and Brussel, 1995).The different land qualities, which can be considered for suitability modeling are, present land-use/land-cover, slope, proximity of transportation network, flood hazard, groundwater condition etc. (Sunil, 1998).



Methodology to study the urban pattern and for site suitability analysis
Fig.1

Parameters for suitability: Following parameters have been considered for the suitability analysis.

1. Slope
2. Land Use Land Cover
3. Road Accessibility
4. Land Cost
5. Waterbodies
6. Settlement
7. Aspect

Slope: The criteria slope describes the elevation change on a certain area of terrain. In the analysis it was determined that the flatter the slope of the terrain the better. To obtain a suitable location with the best possible slope, a reclassification of the slope data was made.

The reclassification of the slope grouped the data into five classes. These classes were based on the slope degree and used to determine the most promising sites. Lesser is the degree flatter is the area and most suitable for urban development. The map Slope of Elevation (Fig. 2) shows how the data looked after reclassification.

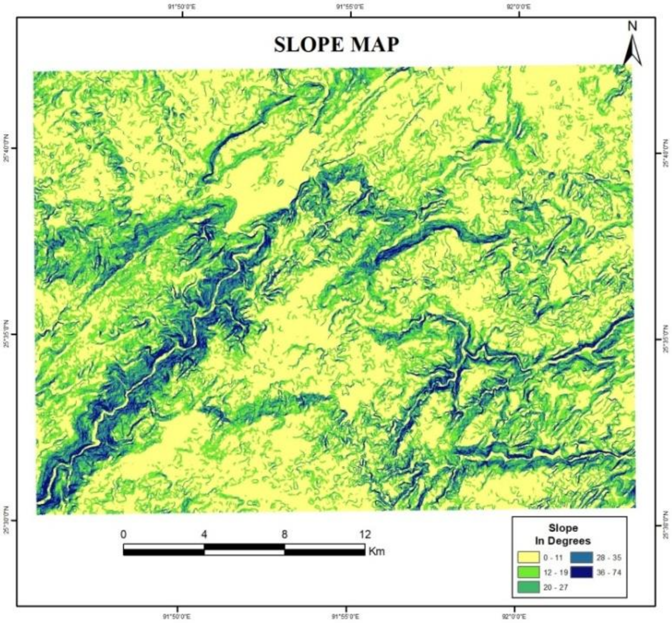


Fig.2 Slope Map.

Existing land use: Identification of land cover establishes the baseline information for activities like thematic mapping and change detection analysis. It generally refers to the categorization or classification of human activities and natural elements on the landscape within a specific time frame based on established scientific and statistical methods of analysis of appropriate source materials. This map has been shown in Fig.3. The main classes considered here and the arecovered is given in Table 1.

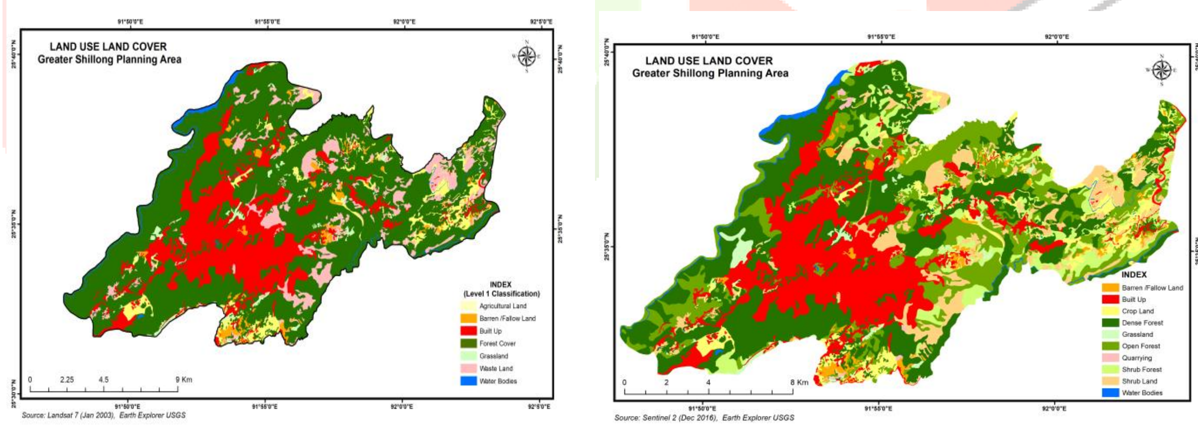
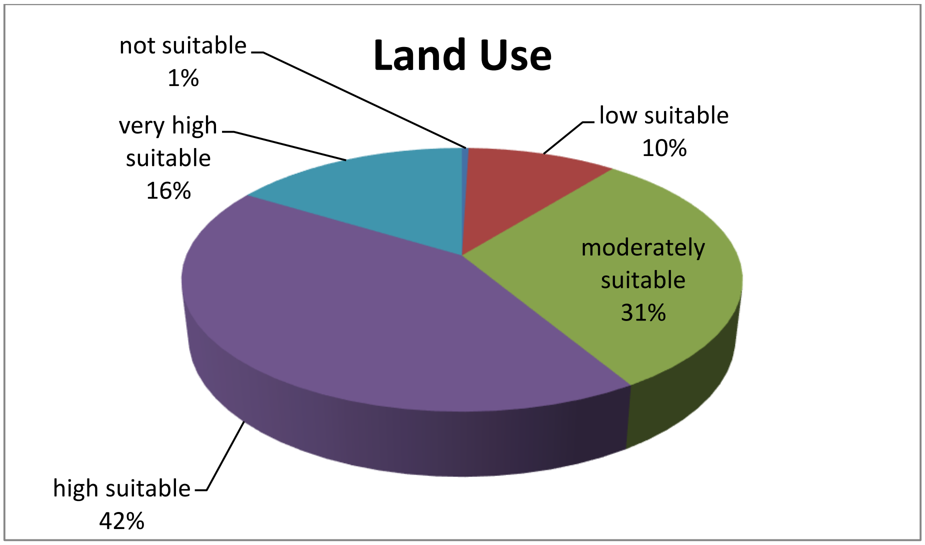


Fig.3,4 Land use Land Cover (2003,2016)

Classification	**Area in sq.km**
Agricultural land	125.06
Built up	63.88
Forest	327.58
Grassland & Grazing land	15.93
Shifting cultivation	0.44
Wastelands	113.34
Water bodies	9.78

Grand Total	**656.02**

Table 1



Land use Distribution Chart

Water Bodies: Major waterbodies have been extracted from the LULC map. This is to understand the channel and the source and area covered by water bodies so as not to have so much impact on urban development .

Road accessibility: In this study, major roads, which are connecting to different areas have been digitized and buffer zones have been created by taking different distances from the road to generate road accessibility map. This way, buffer zones have been categorized accordingly, as given in Fig. 6 shows the buffer zones for the road accessibility.

Settlement: The settlements or the built environment within the GSPA area have been digitized. Individual built up have been digitized to understand the density and concentration in a particular area, as given in figure 7 and also to see the spread or pattern of growth.

Land Cost: Land cost is another important criteria considered as this will determine the type of project to be identified in the particular area. Land cost is dertermined by creating buffer zones and categorized accordingly.

Aspect : Aspect is considered taking the slope map into consideration. This criteria plays an important role in determining the orientation of the site with respect to the slope so that it will give a better use of the land for a particular purpose.

For suitability analysis, a score to each of the criteria as per their suitability for urban development is given since each criteria will not have the same weightage or importance for urban development. The suitability scoring used in this study for each of the map and their category at 10 point scale.

All the Seven thematic maps have been converted in raster form, so that for each pixel, a score can be determined. These maps are then combined into a composite suitability map by simple addition of recorded maps with weight system.

In this study, higher weightage has been assigned to slope and landuse as they play a very important role in the urban development.

Next important criteria considered is the road proximity to the particular area. Distance to and from the main roads and other roads from the sites, may not affect strongly, but longer distance may involve some extra costs. Moreover, new road might be required to change the situation. Considering this situation, weightage is assigned to the accessibility. Also as there are already built environment in and around the area urban settlements have also been considered a criteria so as to not come in conflict with the results to be obtained.

Least priority has been given to water bodies.

SITE SUITABILITY : This study performs a GIS Spatial analysis in which models are represented as a set of spatial processes, such as, classification, and reclassification and overlay techniques. Each of the input is assigned a weight influence based on its importance, then the result is successively multiplied with their factors. This process is often used in site suitability studies where several factors affect the suitability of a site (ESRI, 2000). The result is summed up producing a site suitability map asshown by the formula;

Site Suitability =∑ [factor map (Cn) x weight (Wn)] Where, Cn=standardized raster cell, Wn=weight derived from AHP pair wise comparisons

Table 2. Pairwise comparison matrix

Criteria	Slope	LU/LC	Settlement	Road proximity	Waterbodies	Land Cost	Aspects
Slope	1	2	3	4	5	6	7
LU/LC	0.50	1	2	3	4	5	6
Settlement	0.67	0.50	1	2	3	4	5
Road proximity	0.75	0.67	0.50	1	2	3	4
Waterbodies	0.80	0.75	0.67	0.50	1	2	3
Land Cost	0.83	0.80	0.75	0.67	0.50	1	2
Aspects	0.86	0.83	0.80	0.75	0.67	0.50	1
Total	5.41	6.55	8.72	11.92	16.17	22	28

Table 3. Normalized Matrix and Criterion Weights

	Slope	LU/LC	Settlement	Road proximity	Waterbodies	Land Cost	Aspects	Computational criterion weights
Slope	0.18	0.31	0.34	0.34	0.31	0.28	0.25	0.29
LU/LC	0.09	0.15	0.23	0.25	0.25	0.23	0.21	0.20
Settlement	0.12	0.08	0.11	0.17	0.19	0.19	0.18	0.15
Road proximity	0.14	0.10	0.06	0.08	0.12	0.14	0.14	0.11
Waterbodies	0.15	0.11	0.08	0.04	0.06	0.09	0.11	0.09
Land Cost	0.15	0.12	0.09	0.06	0.03	0.05	0.07	0.08
Aspects	0.16	0.13	0.09	0.06	0.04	0.02	0.04	0.08
Total	1	1	1	1	1	1	1	1

Criterion	**Weighted sum vector**	**Consistency vector**
Slope	**[(1)(0.29)+(2)(0.20)+(3)(0.15)+(4)(0.11)+(5)(0.09)+(6)(0.08)+(7)(0.08)= 3.07/0.29**	**10.59**
LU/LC	**[(0.50)(0.29)+(1)(0.20)+(2)(0.15)+(3)(0.11)+(4)(0.09)+(5)(0.08)+(6)(0.08)= 2.22/0.20**	**4.14**
Settlement	**[(0.67)(0.29)+(0.50)(0.20)+(1)(0.15)+(2)(0.11)+(3)(0.09)+(4)(0.08)+(5)(0.08)= 1.65/0.15**	**3.92**
Road proximity	**[(0.75)(0.29)+(0.67)(0.20)+(0.50)(0.15)+(1)(0.11)+(2)(0.09)+(3)(0.08)+(4)(0.08)= 1.28/0.11**	**3.87**
Waterbodies	**[(0.80)(0.29)+(0.75)(0.20)+(0.67)(0.15)+(0.50)(0.11)+(1)(0.09)+(2)(0.08)+(3)(0.08)= 1.03/0.09**	**3.45**
Land Cost	**[(0.83)(0.29)+(0.80)(0.20)+(0.75)(0.15)+(0.67)(0.11)+(0.50)(0.09)+(1)(0.08)+(2)(0.08)= 0.87/0.08**	**2.71**
Aspects	**[(0.86)(0.29)+(0.83)(0.20)+(0.80)(0.15)+(0.75)(0.11)+(0.67)(0.09)+(0.50)(0.08)+(1)(0.08)= 0.80/0.08**	**1.72**

λ = (10.59+4.14+3.92+3.87+3.45+2.71+1.72)/7=30.39/7=4.34 Consistency Index, CI = (λ-n)/(n-1)=(4.34-7)/(7-1)=0.44/6=0.07 Consistency Ratio (CR)=CI/RI=0.07/1.24=0.06, (RI-1.24 for n=7), (Source: Adopted from Saaty, 1980).

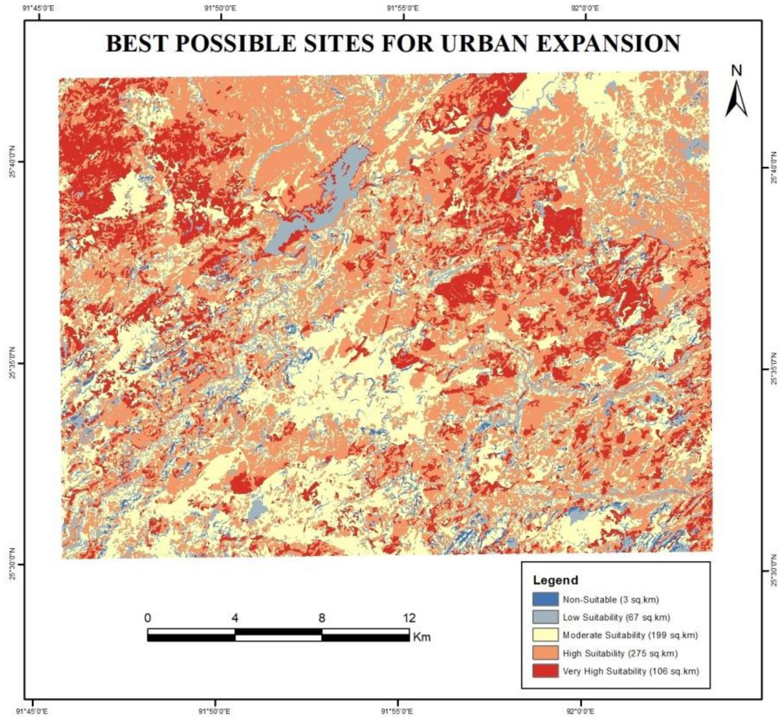
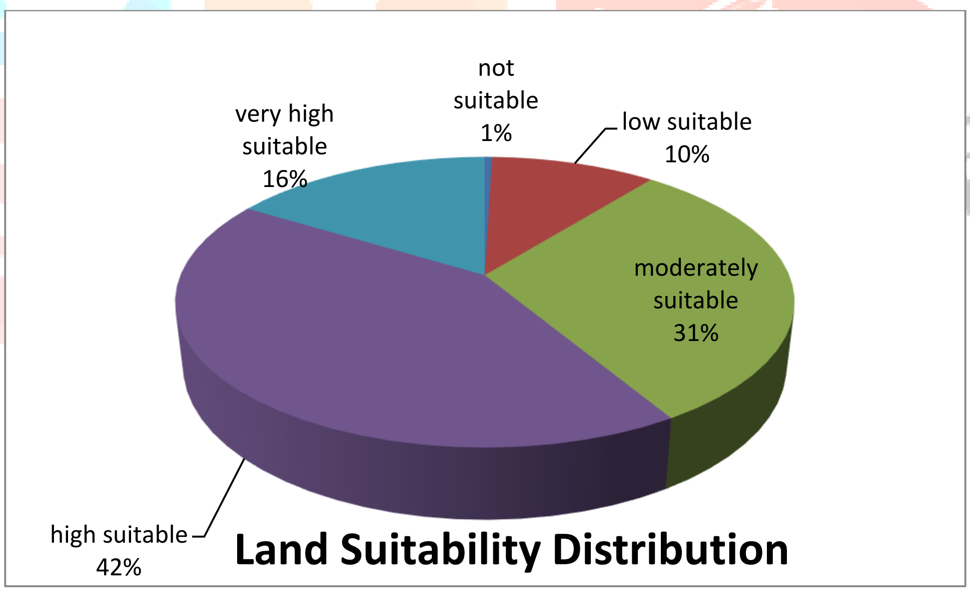


Fig: 5 Best Possible Sites for Urban Development



Land Suitability Distribution

The final suitability map (Fig.5) was obtained from both weighted sum overlay and Spatial Analyst Tools covering an area of 656.02 sq. km. After suitability analysis it was found that from the available area 3 sq km falls under not suitable.67 sq km under low suitable, 199 sq.km under moderately suitable, 275 sq. km under high suitable and 106 sq. km under very highly suitable. The result shows that highly suitable areas for urban development is either agricultural or mostly forest type.

CONCLUSIONS

Land use suitability analysis for urban development is necessary to overcome the problem with limited land availability against drastic growth of urbanization. As per the suitability map, the growth is being projected towards the North Eastern side which matches with the development taken place in the present scenario. This direction could be because of the proximity to NEIGHRIMS and other institutional and office areas which has been shifted to that side of the land and also because of availability of land. This study will be helpful for urban planners and urban development authorities to plan future development and future expansion of the city.

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