Site Suitability Analysis for Urban Expansion and its Development in a Hill Town using Gis and Multi criteria decision making along with AHP: A Case Study of New Shillong Township, Meghalaya, India.

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Abstract — New Shillong Township appears to be an ideal location for urban development and expansion due to its undulating landscape, slope, and high land cost. GIS-based multi-criteria evaluation of slope, road proximity, land usage, property valuations, and other features are used to identify potential areas for urban expansion and development in New Shillong Township. ArcGIS 10.8 software assessed six thematic information layers and merged and pan-sharpened spatial data (Cartosat-1 and Kompsat) to choose suitable locations in New Shillong Township. It focuses on the Weighted Linear Combination and Overlay Weighted Average (OWA) Sum, both based on the GIS (WLC). Six criteria—drainage, aspect, cost, slope, road proximity, and land use—were assessed and given weights in this study. Using visual interpretation of satellite data, various thematic information layers were created for each characteristic, showing site suitability on an ordinal scale. The pair-wise comparison matrix method was used to normalize the maps based on various criteria. We have determined the weights of each criterion by comparing their importance to one another.

OWA and WLC were used to combine criterion weights and maps. The joint comparison matrix displays the weights for the following: slope (=0.34), road proximity (=0.16), land use (=0.23), land cost (=0.12), drainage (=0.09), and aspect (=0.07). Consistency Ratio (CR =0.0117) of 0.10 suggested that the joint comparisons were reasonably consistent. The final suitability map, which covers an area of 40.8 square kilometers, was created using both weighted sum overlay and spatial analysis tools. Following suitability research, it was discovered that 0.03 sq km of the available area is not suitable. 1.18 square kilometres were classified as low suitable, 3.68 square kilometres as moderately suitable, 12.77 square kilometres as highly suitable, and 25.26 square kilometres as extremely highly suitable. The results revealed that agricultural or forest areas are appropriate for urban growth.

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

I. Introduction

A method for organizing and assessing decision alternatives based on several attributes and objectives is called multicriteria decision analysis (MCDA) (Voogd, 1983). MCDA techniques can incorporate a variety of decision problem concepts. They speed up agreeing, improve communication, and identify the best options (Boroushaki and Malczewski, 2010). Geographic information systems (GIS) give decision-makers powerful tools for gathering, modifying, organizing, and managing spatial data. GIS was utilized to identify the best locations for land development. Twenty years ago, the use of GIS was essentially restricted to the use of preexisting digital map data, which was overlaid to define areas that could simultaneously satisfy the established criteria. When working with properly defined siting criteria, overlays are a useful tool; however, they may not be as effective when working with non-deterministic data (Craver, 1991). GIS-integrated multicriteria decision analysis "transforms and combines spatial data and value judgments—the decision-makers preferences—to evaluate a set of alternatives based on relevant criteria. This method" shows on a map the best location for a given land use by combining all the significant spatial criteria.

It has been suggested that by offering flexibility for the analysis, understanding, and reevaluation of a decision problem, GIS-based multicriteria decision analysis could increase cooperation amongst stakeholders in the decision-making process (Boroushaki and Malczewski, 2010).

II. Study Area

The proposed New Shillong Township has an average elevation of 4,908 feet (1,496 meters) above sea level and is located 13 kilometers northeast of Shillong City at 25° 59' North Latitude and 91° 94' East Longitude. Its coordinates are 25° 59'N latitude and 91° 94'E longitude. It has an area of 20.30 square kilometers as indicated in Fig 1a. There are about 21 communities where land has been purchased, and a motorable road leads to it. Mawdiang-diang, Umroh, Mawlong, Diengiong, Umsawli, Mawkasiang, Madansaisiej, Mawpdang, Siejiong, and Tynring existed up to the Shillong Bye Pass. The Proposed Township region, which is in the early stages of development and is part of the Master Plan 2011-2031, is an ideal location for using the land-use site suitability analysis model.

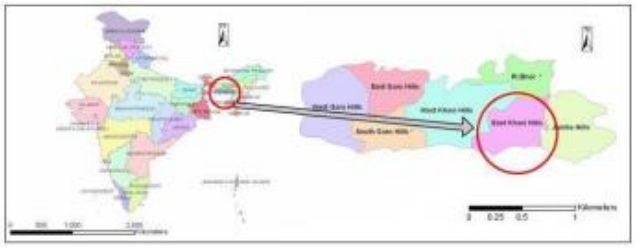


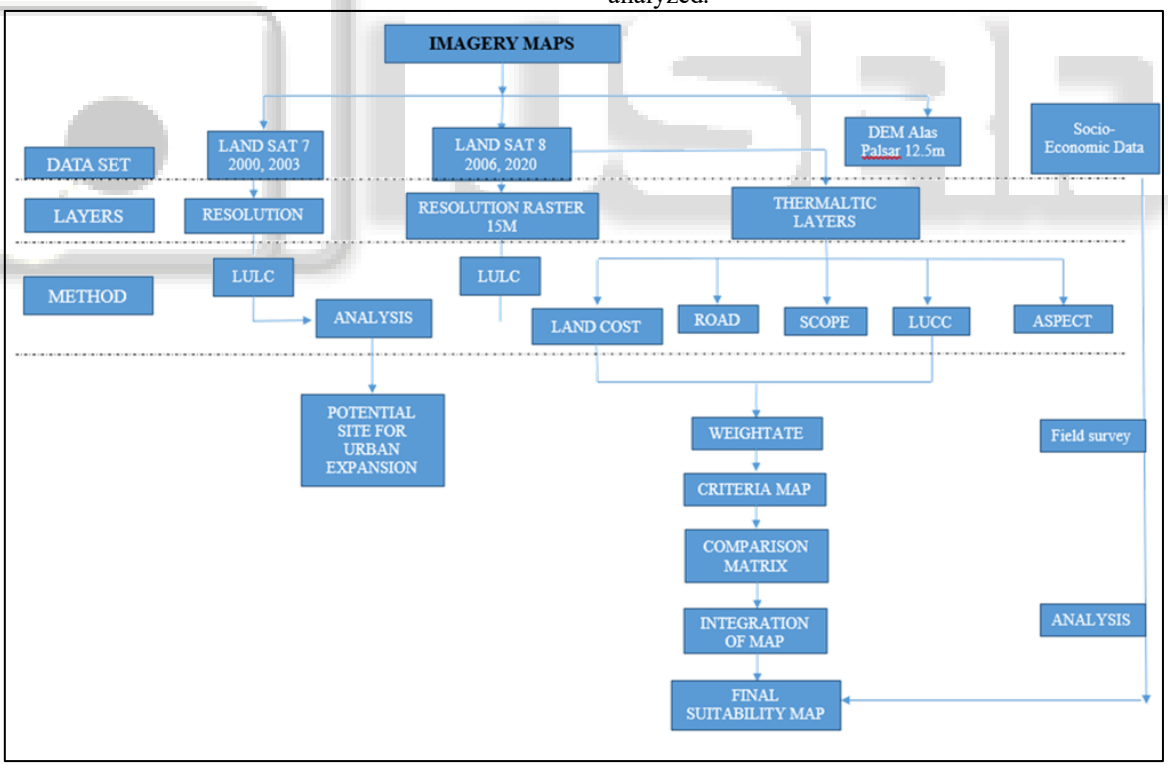
Fig. 1: The Location of The Study Area
Source: https://theshillongtimes.com/2021/05/31/6-labourers-from-assam-suspected-to-be-trapped-in-ejh-mine/meghalaya-districts-map/

III. MATERIALS AND METHOD:

The "purpose of this project is to demonstrate a decision support system model for site appropriateness evaluations. Potential urban development sites were identified using GIS and numerical approaches. For this aim, ArcGIS 10.8 was used to build thematic (information) layers like slope, road proximity, land use/cover (LU/LC), land cost, and aspect maps. Each layer was given internal weights" and rankings; the attribute field weight values varied from 1 to 9. Weight was used as a feature class in the rasterisation of each vector layer. Forests, bodies of water, and regions used for business, residential, recreational, as well as industrial purposes were all assigned zero weights.

With slopes of under fifteen percent, depleted or open spaces were given more weight, and riparian buffer factors for highways were taken into account. The criteria map was created using these theme layers as factors, using the Spatial Analytic Hierarchy Process (AHP). In this study, we created various situations by assigning different preference values to the choice criteria.

Based on the assessment, the scenarios were ranked from least to most advantageous locations We found the best option by optimizing the simulated scenarios presented in this work, based on six competing criteria. An example of a decision support system is the Spatial Analytic Hierarchy Process (AHP), which combines GIS and AHP to find and rank locations appropriate for urban development based on knowledge-based user preferences. The approach was demonstrated with a case study that evaluated whether a hill town was suitable for urban growth and development using a multi-criteria assessment tool based on geographic information systems. To make assessments about urban expansion and how well the results fit into it, the data were analyzed.



IV. SITE SUITABILITY:

The identification of suitable locations for urban development and expansion in mountainous terrain is a critical component of urban planning. Site appropriateness research has become inevitable in topographical and undulating areas to determine appropriate and suitable sites. In addition to mapping techniques like GIS tools that make it easier to process geographical databases that show areas of the site that are ideal for different planning goals and alternatives, site appropriateness requires a detailed analysis of a site's natural resources and processes. When deciding whether a hill town is suitable for urban development, terrain information is essential. One of the most important elements in assessing whether an area is viable for development operations is its topographic quality. On slopes of more than 20%, the

development is severely limited. Slopes of less than 5% are preferable for industrial parks and commercial parks. In addition, mountainous topography increases construction expenses therefore, steep slopes are undesirable. Site suitability is further influenced by the soil texture and drainage characteristics. In cases where buildings lack basements and municipal sewage disposal is available, 1 to 2 meters may be adequate (Lillesand M. Thomas, Kiefer W. Ralph, and Chipman W. Jonathan in Kumar and Kumar, 2014). The site's various characteristics (such as its aspect, cost, slope, and current land use) will all play a role in determining whether or not it is suitable for a given use. Many suitability factors can be ranked or scored using a ranking or scoring system to determine an urban use's overall suitability. Certain qualities may render a location unsuitable for urban land use. Site appropriateness analysis offers value to research by assisting in the identification of appropriate sites that match particular criteria (Kumar and Kumar,2014)

Presenting a model for a decision support system for site appropriateness evaluation is the aim of this analysis. To find possible sites for urban growth, numerical techniques and geographic information systems (GIS) were applied. For this aim, GIS was employed to construct "thematic (information) layers for slope, road proximity, land use/cover (LU/LC), land cost, DEM, settlement, and aspect maps. For every layer, internal weights and rankings were determined; attribute field weight values varied from 1 to 9. Water bodies, woods, and residential, recreational, commercial, and industrial locations were all assigned zero weights" when rasterizing each vector layer using the weight as a feature class.

We found the best option by optimizing the simulated scenarios suggested in this work based on seven competing criteria. The scenarios were graded from least to most beneficial areas for urban growth based on the assessment. One kind of decision support system that uses both GIS and AHP to identify and prioritize areas suitable for urban development is the Spatial Analytic Hierarchy Process (AHP). It uses user preferences based on knowledge to do this. A case study utilizing a GIS-based multi-criteria assessment tool to determine whether a hill town was suitable for urban growth and development served as an example of the methodology. The results were analyzed to draw judgments about urban expansion and how well they fit into it.

Seven parameters were employed in the analysis to determine areas that would be good for urban development and city expansion: built-up elevation, road, aspect, LULC, and slope "employing AHP. Following the analysis of the weight assignment and weight normalization of each parameter with each of its features, a suitability map was utilized to produce the result:

A. The Assignment of Weights to The Thematic Layers

In the current investigation, the joint comparison matrix of the six parameters was generated in the square matrix, and each characteristic of the parameters in the diagonal matrix is always" 1. Roads, LULC, slope, aspect, elevation, cost of land, and settlement were the study's parameters that were assigned for joint comparisons. As indicated in Tables 1.2 and 1.3, respectively, the normalized pair-wise matrix and consistency analysis were computed for the joint comparison matrix.

Criteria	Aspect	Land Cost	settlement	LU/LC	Roads	Elevation	Slope
Aspect	1	3	4	5	6	7	8
Land Cost	0.33	1	2	4	4	5	6
Built-Up	0.25	0.50	1	3	4	6	7
LU/LC	0.20	0.25	0.33	1	3	4	6
Roads	0.17	0.25	0.25	0.33	1	3	4
Elevation	0.14	0.20	0.20	0.25	0.33	1	3
Slope	0.13	0.17	0.14	0.17	0.25	0.33	1
Total	2.22	5.37	7.92	13.75	18.58	26	35

Source: Primary data 2021-22

Table 1.1: Joint Comparison Matrix

Criteria	Aspect	Land Cost	Built up	LU/LC	Roads	Elevation	Slope	Computational criterion weights
Aspect	0.45	0.56	0.51	0.36	0.32	0.27	0.23	0.39
Land Cost	0.15	0.19	0.25	0.29	0.22	0.19	0.17	0.21
Built-Up	0.11	0.09	0.13	0.22	0.22	0.23	0.20	0.17
LU/LC	0.09	0.05	0.04	0.07	0.16	0.15	0.11	0.10
Roads	0.08	0.05	0.03	0.02	0.05	0.11	0.11	0.07
Elevation	0.06	0.04	0.03	0.02	0.02	0.04	0.09	0.04
Slope	0.06	0.03	0.02	0.01	0.01	0.01	0.03	0.02
Total	1	1	1	1	1	1	1	1

Source: Researcher Primary data 2021-22

Table 1.2: Normalised Weights Criterion Weights Calculation

B. Calculation

$$CI = \frac{\lambda - n}{n-1} = \frac{7.72-7/7-1}{} = 0.12$$

$$Cr = \frac{CI}{RI} = \frac{0.12}{1.32} = 0.09$$

In this case, the consistency vector's value (λ) is determined to be 7.72. An acceptable further consistency ratio of (0.09) was determined.

Criterion	Weighted sum vector	Consistency vector
Aspect	[(1)(0.39)+(3)(0.21)+(4)(0.17)+(5)(0.10)+ (6)(0.07)+(7)(0.04)+(8)(0.02)= 3.06/0.39]	7.85
Land Cost	[(0.33)(0.39)+(1)(0.21)+(2)(0.17)+ (4)(0.10)+(4)(0.07)+(5)(0.04)+(6)(0.02)= 1.68/0.21]	8.00
Built-Up	[(0.25)(0.39)+(0.50)(0.21)+(1)(0.17)+ (3)(0.10)+(4)(0.07)+(6)(0.04)+(7)(0.02)= 1.33/0.17]	7.82
LU/LC	[(0.20)(0.39)+(0.25)(0.21)+(0.33)(0.17)+ (1)(0.10)+(3)(0.07)+(4)(0.04)+(6)(0.02)= 0.78/0.10]	7.80
Roads	[(0.17)(0.39)+(0.25)(0.21)+(0.25)(0.17)+ (0.33)(0.10)+(1)(0.07)+(3)(0.04)+(4)(0.02)= 0.46/0.07]	6.57
Elevation	[(0.14)(0.39)+(0.20)(0.21)+(0.20)(0.17)+ (0.25)(0.10)+(0.33)(0.07)+(1)(0.04)+(3)(0.02)= 0.28/0.04]	7.00
Slope	[(0.13)(0.39)+(0.17)(0.21)+(0.14)(0.17)+ (0.17)(0.10)+(0.25)(0.07)+(0.33)(0.04)+(1)(0.02)= 0.18/0.02]	9.00

Table 1.3: Consistency ratio analysis

V. Site Selection for Urban Development

The following are the useful criteria (factors) that were employed to determine appropriate locations based on each one's significance:

1) Land use Land Cover :

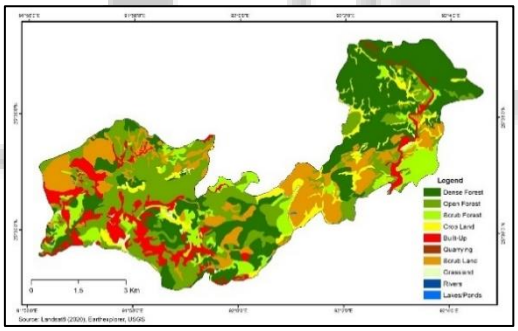


Fig. 1: Researcher construct.

The Research Area's land use/cover map as shown in fig 1 has been divided into sections for built-up areas, rivers, lakes/ponds, grasslands, forests, and agriculture. River beds are also unsuitable for development into built areas. Thus, it is believed that agricultural and barren land is the most suitable for development.

2) Slope:

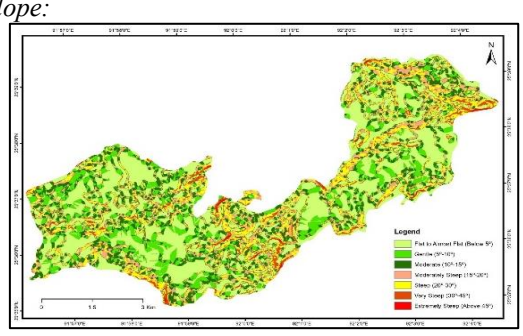


Fig. 2: Researcher construct.

When determining appropriate locations for built-up areas in hilly terrain, this is a crucial criterion. Because they raise the expense of construction, steep slopes (fig 2) are undesirable for building purposes.

3) Roads Network:

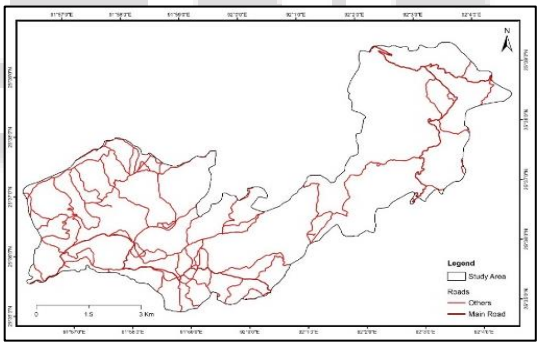


Fig. 3: Researcher construct.

Road accessibility (fig 3) facilitates mobility and transportation everywhere. However, building new roads is costly, particularly in steep areas. Thus, the site is located as close to roadways as possible.

4) Digital Elevation Model:

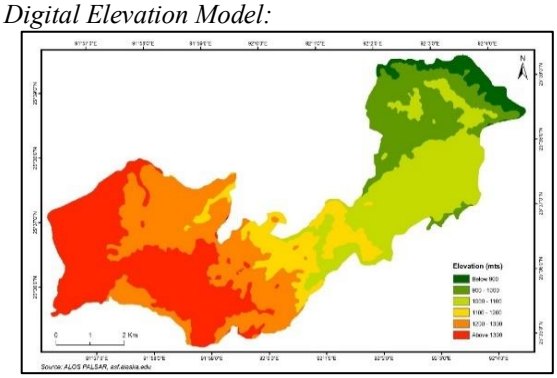


Fig. 4: Researcher construct

DEM: This criterion (fig 4) plays a significant function in understanding the elevation of an area, especially in hilly terrain, to be able to propose developments.

5) Aspect:

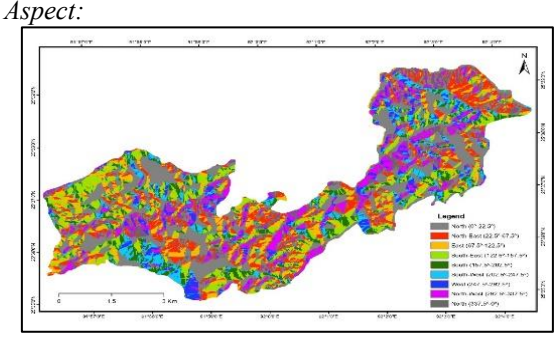


Fig. 5: Researcher construct

Aspect: This criterion (fig 5) helps to identify the orientation of the site for the greater good of any sort of development and functionality.

6) Land cost /Land Values

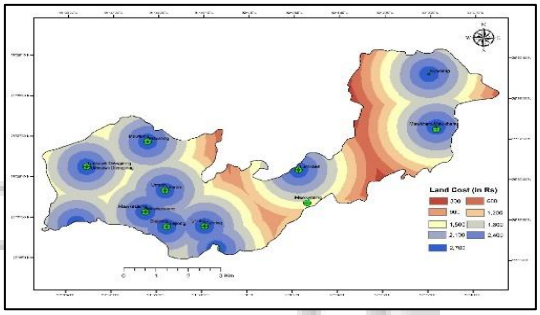


Fig: 6: Researcher construct

Land value is the cost of a property on the basis of its location at a specific moment in time. The value of land changes with location as indicated in Fig 6. In a city, land prices are highest in the center and lowest on the outskirts. Accessibility affects the value of land within a community; higher prices are found for land closer to a road.

7) Built Up:

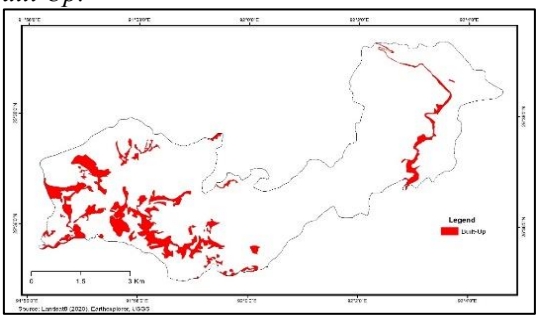


Fig. 7: Researcher construct.

The Built-up (fig 7) is the land describing the existing development in the study area which also plays an important part in site suitability examination. As a result, the area's built-up area provides insight into the land's suitability as well as its form and connectivity in areas where development has already occurred. Satellite imagery was used to create the map.

VI. Results and Discussion

Utilizing GIS software, all the theme layers were combined to identify appropriate locations within the study area. From there, a final suitability table, a map, and charts were produced.

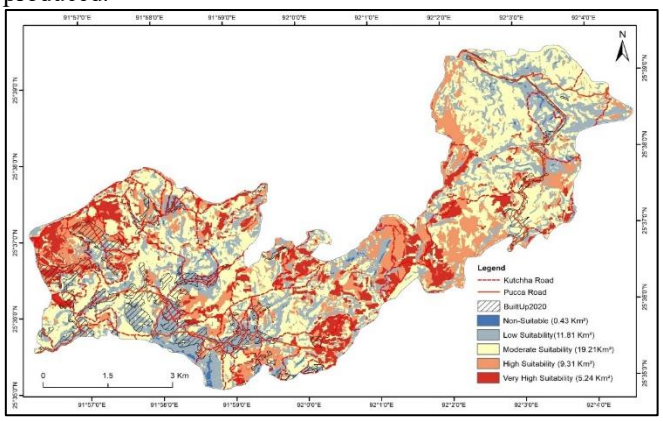


Fig. 8: Researcher construct

Land Suitability Study Area	Areas	%
Non-suitable	0.43	0.93
Low suitable	11.81	25.67
Moderate suitable	19.21	41.76
High suitable	9.31	20.24
Very high suitable	5.24	11.39
	46	100.00

Source: Primary data 2021-22

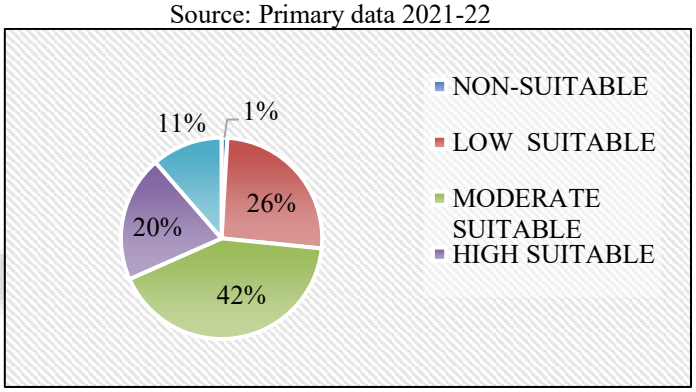


Fig. 6.1: Chart of Land Distribution for Site Suitability of Study Area Source: Researcher Primary data 2021-22

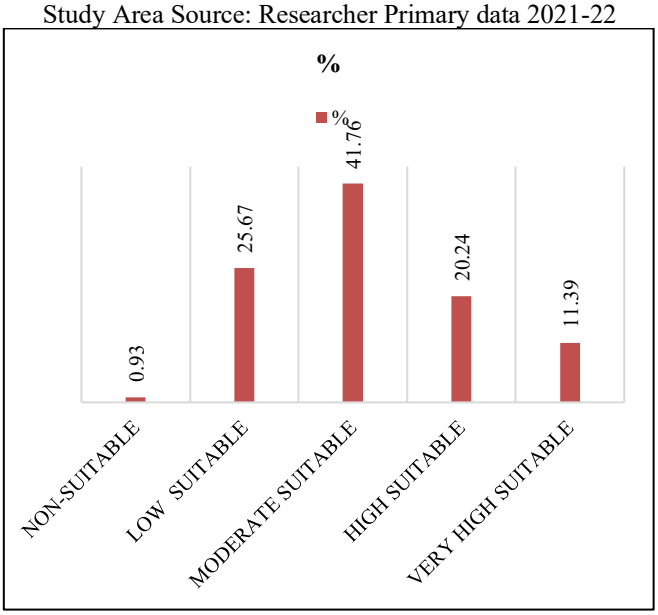


Fig. 6.2: Land Distribution for Site Suitability Source: Researcher Primary data 2021-22

After calculating the final normal weights of each theme layer and associated features, all thematic layers were transformed into raster format and added to each other using a GIS raster calculator to find suitable research locations. About 11.39% of the total area is made up of an extremely suitable area. The next zone, which made up about 20.24% of the area, was highly suitable. 41.76 percent of the total area is in the moderate zone. Low-suitability areas make up 25.67% of the entire area. The study area's 0.93% non-suitable portion is mostly made up of rivers.

VII. Conclusion

In hill towns and terrain areas, the GIS-based multi-criteria decision-making technique is straightforward and adaptable for evaluating final findings. It helps to resolve any given issue by offering a satisfactory and thorough database of possible urban development locations. This study is very promising and can be applied to any project or purpose in general. It can also help authorities and planners create and carry out master plans that are suitable for urban growth.

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