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GIS Based Land Suitability Analysis for Expansion of Adigrat Town, Ethiopia

Ayele Behaylu[1] and Dr. Zubairul Islam[2]

[1]*Lecturer, Department of Geography and Env. Studies, Adigrat University. Ethiopia.*
Email ayeleby@gmail.com

[2]*Associate Professor, Department of Geography and Env. Studies, Adigrat University. Ethiopia.*
Email: zubairul@gmail.com

Abstract

The objective of this study was to spatially evaluate land suitability for urban expansion in Adigrat town, Ethiopia. Geographical Information System (GIS) was used to create land suitability map. In this paper, Euclidian distance was calculated from roads and underground water sources. Aster data was used to classify elevation and slope. Land use map was prepared using Landsat 8 data. The influence of different factors was given as Land use 30%, Elevation 25%, Slope 25% Underground Water Sources 10%, and Roads 10%. Scale values for criteria were given 1 to 9. Closed distances from underground water sources and Roads were given higher values. Elevation more than 2646 meter, Slope more than 28 degree and Buildup areas were restricted. As a result 6.9498 sq. km of area was found as most suitable area for urban expansion.

Key words: *GIS, Land Suitability, Remote Sensing, Suitable Areas*

1. Introduction

Today urban growth all over the world is one of the most significant phenomenon. This is particularly true for developing countries like Ethiopia where number of urban centers are increasing with the passage of time (Anwar and Bhalli, 2012). The urban areas in Ethiopia have witnessed tremendous changes in terms of population growth and urban expansion. In the absence of proper urban management practice, uncontrolled and rapid increase in population pose enormous challenges to governments in providing adequate shelter to people in urban areas. This has also posed great concern among urban planners. Urban growth due immigration has led to increase in population density. This uncontrolled population growth resulting in serious problems with regards to informal settlements, environmental pollutions, destruction of ecological structure and so on (Maktav and Erbek 2005). The population settlements in the fast-growing urban world need to be monitored in order to design a sustainable urban habitat. In light of rapid global urbanization, monitoring and mapping of urban and population growth is of great importance. Land suitability mapping and analysis is a prerequisite to achieving optimum utilization of the available land resources (Gizachew and Yihenew, 2015). Land use suitability analysis for urban development is necessary to overcome the problem with limited land availability against drastic growth of urbanization.

The Geographic Information System has proven practical throughout the world and effective when used for determining suitable lands for a built environment (Baban, *et al*, 2007). It is considered as an effective monitoring and decision-support tool in urban planning. Geographic Information System help users to view, understand, question, interpret and visualize spatial and non-spatial data in many ways that reveals relationships, patterns and trends in the form of maps reports and charts (Babu and Sivasankar, 2015).

The future success of economic growth policies depends a lot on the infrastructure development. It is universally established that remote sensing and GIS tools play a major role in various infrastructure development. Several decisions taken by different planning agencies require spatial analysis of maps involving many parameters (Shan, 1999, Liu, 1998).

The GIS based maps provide the most important sources for spatial analysis. Remote sensing data provide latest and accurate maps, when used in the GIS environment, they become integrated. Also, the non-spatial data attached to it provide great help to the urban planners and decision makers (Hauser *et al*, 1982). GIS-based land suitability analysis using the multi-criteria evaluation (MCE) approach is therefore the most suitable method for solving complex problems related to land-use planning and development (Malczewski, 2004). To this end the present paper is aimed at identification of suitable areas using multi-criteria evaluation for urban expansion of Adigrat Town in Ethiopia.

2. Objective of the Study

The study aimed at attempting the future plan for urban expansion in Adigrat Town and suggesting the possible site for sites for future settlement using GIS and Remote sensing techniques. Hence, the objective of this study is to select the suitable site for future expansion plan using weighted overlay analysis through the application of GIS and remote sensing techniques.

3. Materials and Methods

3.1. Description of Study Area

Adigrat town is located at 14^0 15′0″ N to 14^0 18′30″ N latitude and $39^0$26′30"E to $39^0$29′30″E longitudes at a distance of about 898 kilometers North of Addis Ababa, the capital city of Ethiopia and 125 kilometers North of Mekele, the capital of Tigray state. The town is the administrative capital of Eastern Tigray Zone. The population of Adigrat town is about 57,588 (CSA, 2007). An area of including one kilometer buffer out of the municipal boundary has been taken for the present study.

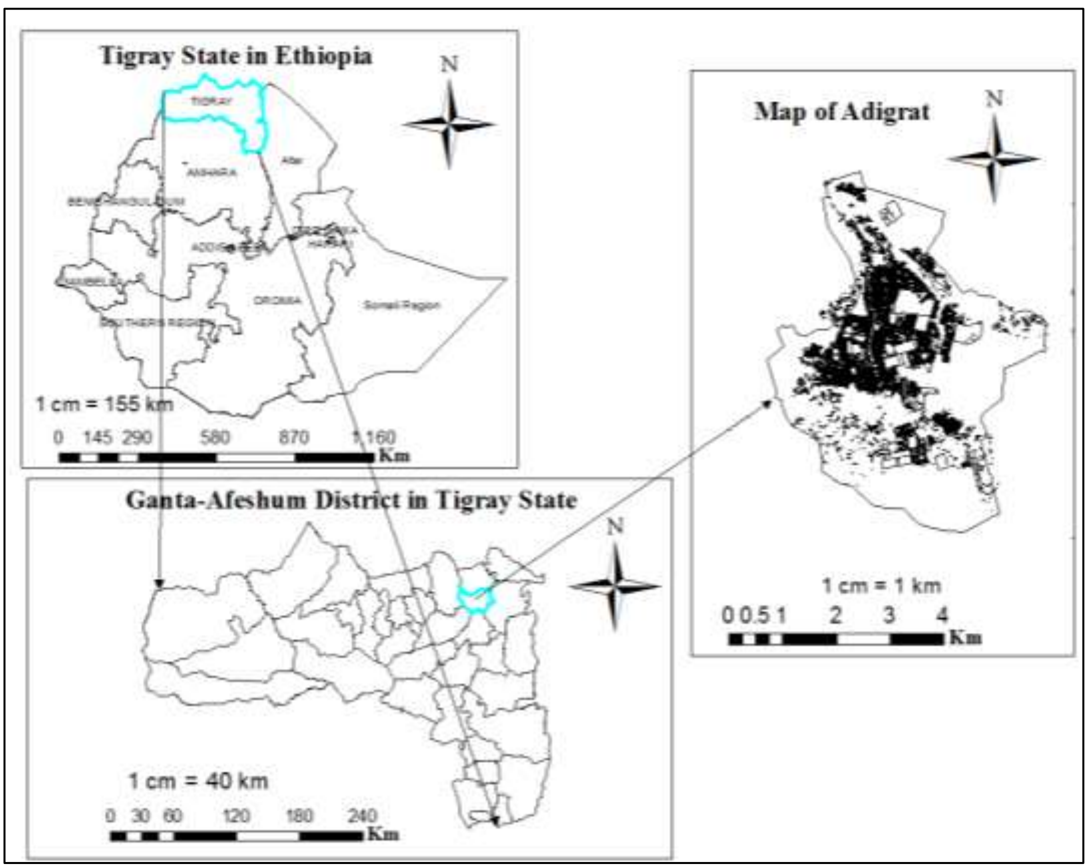

Figure 1: Location Map of Study Area

3.2. Data used

For present study data like land use data; Digital Elevation Model (DEM) for elevation and slope; hydrologic data; and road data has been used. The following are the key thematic layers created for the selection of suitable sites for urban expansion: -

a. Land Use
b. Elevation (Boundary 1 km buffer)
c. Slope generated from DEM
d. Road Network
e. Underground Water Source Data

These thematic layers are then added with a weightage and a corresponding rating value in order to assess their importance to be considered for potential suitable sites for urban expansion.

3.3. Weighted Overlay Suitability Model

Weighted overlay Suitability Model was used with GIS techniques for locations suitable for urban expansion Each individual raster cell was reclassified into units of suitability and multiplied by a weight to assign relative importance to each and finally add them together for the final weight to obtain a suitability value for every location on the map; this can be interpreted by the following equation (*Eastman, 2001*)

$$\mathbf{S = \Sigma\, w_i\, x_i}$$

Where w_i is the weight of i^{th} factor map;

x_i is the criteria score of class of factor I;

S is the suitability index for each pixel in the map

All the thematic layers were integrated in ArcGIS 10.2.1 platform in order to prepare a map depicting suitable areas for artificial groundwater recharge. The total weights of each pixel of the final integrated layer were derived from the following equation;

$$S= (SL_f\, SL_c + LE_f\, LE_c + LU_f\, LU_c + DR_f\, DR_c + DG_f\, DG_c$$

Where, SL is Land slope; LE is land elevation; LU is land uses; DR is the distance to Road; DG is the distance to ground water potential areas. The subscript letter ‘f’ represents the weight of each factor, while ‘c’ represents the weight of each class of the individual factor.

Suitable sites for expansion of Adigrat town was estimated using the above equation for each pixel in the final integration layer and was regrouped into different classes with equal class interval to divide the entire study area into different suitable zones.

4 Results and Discussion

4.1 Land Use Classes

The land use of the area was divided into five classes: buildup land, open land, agriculture land, mangrove and woodland. The area of each class is shown in table 1. The scale value to each classes was given as shown in Table 2

Table 1: Land Use Classes

SN	**Land Use Type**	**Area (sq. km)**
1	Agriculture Land	18.22
2	Open Area	17.93
3	Mixed Grove	0.70
4	Woodland	6.0
5	Built-Up	6.48

Table 2 Land use classes and assigned values

Parameter	**Influence (Weight) %**	**Classes (5)**	**Scale Value**
Land Use	30	Open land	9
		Woodland	8
		Mangrove	7
		Agriculture	5
		Buildup	Restricted

Areas found within a buildup land are restricted for expansion, as it is not possible further construction there. On the other hand, open areas are rated with a high value which is 9, because these areas are readily available for expansion of the town.

4.2. The Land Slope

Slope of the town is ranging from 0 to 54 degrees; however 0 degree was given class value 9 as the best land slope in that it is most suitable for urban settlement. Steep slope areas are not advisable for urban expansion, and hence, slope greater than 28 degree is restricted in the evaluation. The class of slope parameter is given in the following table.

Table 3: Slope Classes and scale values

Parameter	**Weight**	**Classes (9)**	**Scale value**
Slope	25	0 - 4.05	9
		4.05 - 7.25	8
		7.25 - 10.66	7
		10.66 - 14.50	6
		14.50 - 18.77	5

		18.77 - 23.47	4
		23.47 - 28.80	3
		28.80 - 35.84	Restricted
		35.84 – 54.19	Restricted

4.3 The Land Elevation

Land elevation of the study areas ranges from 2328 to 2819 m.a.s.l. Very high elevated areas (greater than 2646 m.a.s.l.) were restricted because such areas are not considered for urban expansion for so many reasons like water availability problems and other infrastructure developments. On the other hand low to moderate areas were given high values.

Table 4: Elevation classes and scale values

Parameter	Weight	Classes (9)	Scale Value
Elevation	25	2328 - 2424	9
		2424 - 2456	8
		2456 - 2484	7
		2484 - 2516	6
		2516 - 2553	5
		2553 - 2596	4
		2596 - 2646	3
		2646 - 2708	Restricted
		2708 - 2819	Restricted

4.4 Distances to Roads

The proximity of roads to expansion areas is considered as an advantage because such roads will be used as a source for transportation. Areas lying close to the roads are considered the best and are assigned a class value of 9.

Table 5: Distance to Road and scale values

Parameters	Weight	Classes (9)	Scale Value
Distance from the Road	10	0 - 346.50	9
		346.50 - 735.68	8
		735.68 - 1131	7
		1131 - 1534.35	6
		1534.35 - 1965.08	5
		1965.08 - 2445.08	4
		2445.08 - 2998.99	3
		2998.99 - 3731.99	Restricted
		3731.99 - 4994.62	Restricted

4.5 Nearness to Groundwater Sources

The proximity of wells to expansion areas is considered as an advantage because wells will be used as a source for water. Areas lying close to the wells are considered the best and are assigned a class value of 9.

Table 6 Proximity from the wells & Scale Values

Parameter	Weight	Classes (9)	Scale value
Distance from Underground Water Source		0 - 459.89	9
		459.89 - 809.21	8
		809.21 - 1131	7
		1131 - 1444.75	6
		1444.75 - 1775.45	5
		1775.45 - 2150.88	4
		2150.88 - 2571.02	3
		2571.02 - 3021.08	Restricted
	10	3021.08 - 3769.05	Restricted

4.6. Suitable locations for urban expansion

One integrated layer from excellent to not suitable land was generated based on the weights assigned to each criterion. Finally suitability was rated for suitable sites were extracted from integrated layer as shown in the following figure. Figure 2 shows all the sites from not suitable to most suitable for expansion. Most suitable sites comprise an area of 6.9498 square kilometer Figure 2.

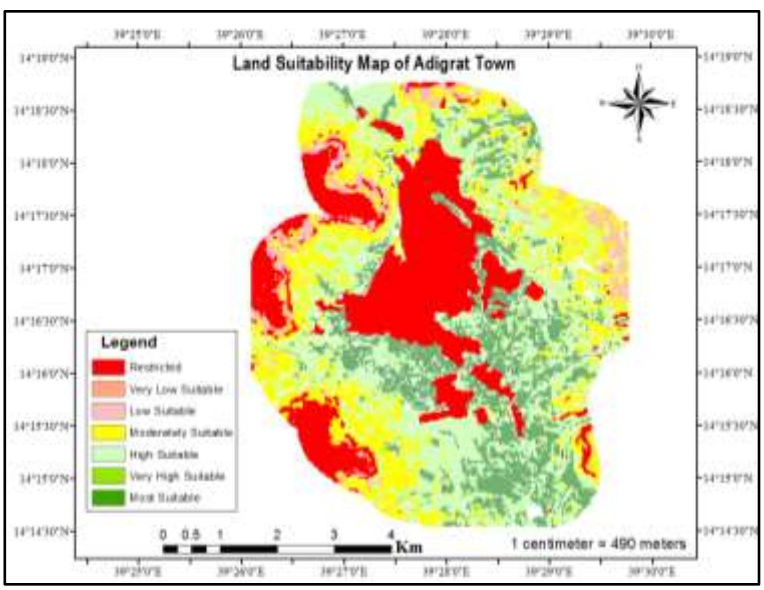

Figure 2 – Land suitability map of Adigrat Town

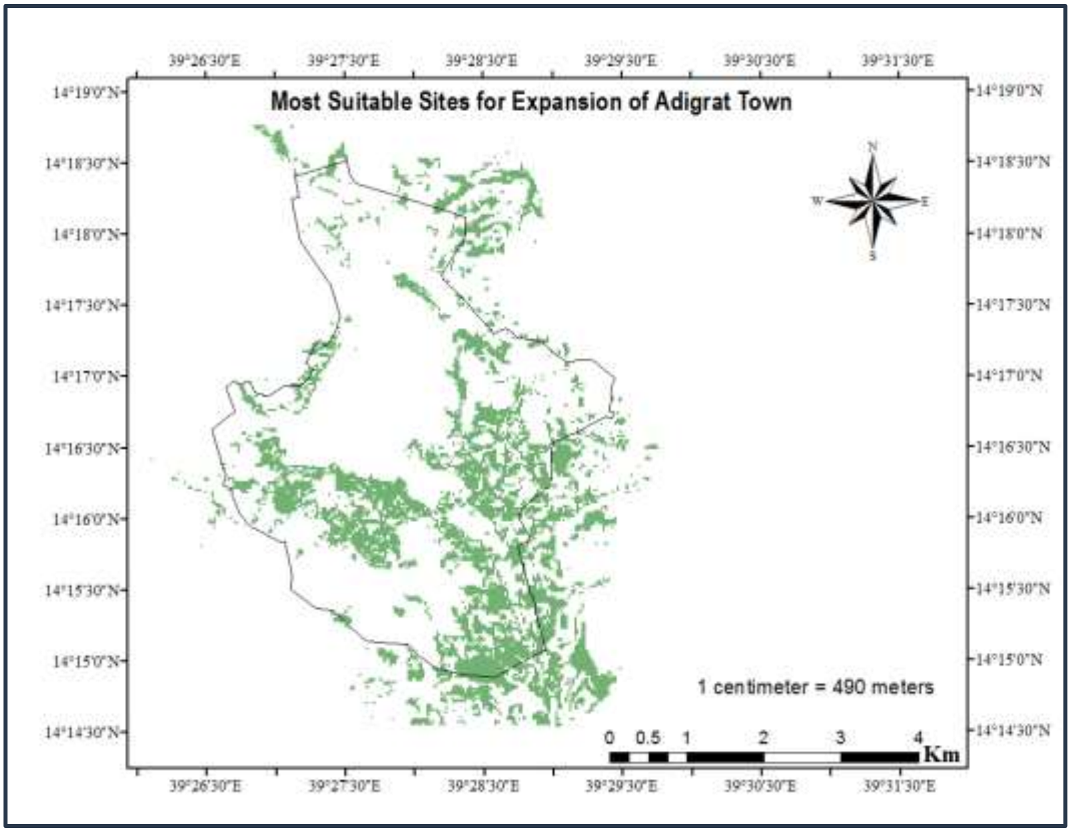

Figure 3 Most Suitable Sites for Expansion of Adigrat Town

Conclusion

In the present study as result of the multi criteria overlay analysis the following suitable sites for urban expansion in Adigrat Town. Each parameter was viewed from different viewpoints. Expansion is impossible to west side of the town due to topographic influence.

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