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IT Based Land Suitability Modeling for Urban Development Using GIS: A Case Study of Kabul City, Afghanistan

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Abstract: ***This paper was directed by using Land Suitability Analysis (LSA) to decide the best areas for urban development in Kabul city utilizing an incorporated GIS-AHP model. The outcomes of this paper showed that GIS-AHP is a helpful strategy for ecological administration and for planning urban areas. With the produced criteria, maps were standardized by utilizing the pairwise comparison matrix technique. Weights for every model were produced by contrasting each other based on their significance. Criteria weights and maps were joined utilizing Weight Age Average (OWA) and Weighted Linear Combination (WLC). For determining the suitability of land for Urban Development Six thematic layers namely (Slope, Road, Land use, River, Settlement and Elevation) were utilized to distinguish the appropriate land for urban Development. Their weighted scores were obtained by AHP as per the pairwise comparison. For multiplying the weight and score of each factor Linear combination method was used and then its result was multiplied for making the urban development suitable. The highly suitable land was 45.3 sq. km, moderately suitable land was 191.77 sq. km, marginally suitable land 72.14 sq. km and 0.79 sq. km area was not suitable.***

Keywords: ICT, Urban Development, Suitable area, GIS, Analytical Hierarchy Process

1. Introduction

Kabul city have extended quickly since the last ten years, without proper spatial plans and lack of limitations in order to access formal lands and lodgings. This resulted in the irregular outcomes, lack of infrastructure considerations, increase in socio-spatial dissimilarities and lower dense sprawl. In order to deal with such issues, Organizers are trying different disciplines to get knowledge about appropriate locations for Urbanization.

The main target of land appropriateness modeling is to lead us in deciding the land cover and management for a specific area for urban sprawl. Preliminary methods such as the delineation of land units (LUs) are used for assessing the appropriateness of land for urbanization such as topographic maps and aerial photography in which the physical features are kept consistent to a range of high possibility (Baja et al., 2006).

Urbanization is a vital component for the economy of Afghanistan. The quick growing cities of Afghanistan host the quarter of the total population which is a source of creating challenges for development. Lack of urban planning along with feeble municipal control has failed to achieve the delivery of equality in services as well as the active management of the unavoidable urban evolution fronting the country. This progressive growth of the expected urbanization in the coming decades has both the opportunity and criticality to enhance the development that is justifiable, unbiased as well as it should serve as a catalyst for economic development. Therefore, the cities of Afghanistan has high capability in progressing socially and economically under the condition if accurately managed and governed (Asia, 2017).

During urban extension planning, to determine the suitable location for urban in the marginal area is one of the critical issues. Aim of this research is to use Geographic Information System (GIS) and Analytical Hierarchy Process (AHP) to select the appropriate location for urban development in Kabul city in Afghanistan. Different factors and parameters were used for the production of final suitable map including Slope, Road, Land use, River, Settlement and Elevation (Aburas et al., 2017).

One important and effective technique for urban extension is the suitability modeling to determine the appropriate location for urban growth. This technique works on various types of weights and criteria. Modeling for appropriate land includes to select the best location for urban growth through mapping of a specific area. GIS techniques has an important tool for monitoring and controlling changes in urban growth and their effect on ecosystems.

Here in such way, Suitability modeling for site decision ends up being outstandingly basic and accept an imperative part to anticipate suitable land for urban growth. It is found that GIS is a viable tool to play out the examination on spatial data. That is the reason this investigation will be planned to attempt on sensibility exhibiting through GIS using topography for effective and better land use organizing later on.

2. Literature survey

2.1 General

In the rapid urbanization process, the optimized and planned use of land is very much lacking. In developing countries like Afghanistan, this unplanned growth has widely affected the development of urban cities. The importance of land

utilization in an organized way is realized throughout the world and recorded in many forum and occasions. Importance of land utilization is expressed by Nagarajan and Poongothai (2011), as land is one of the most important resources which play a key role in determining the economic, social and cultural progress of human beings. Lands are used for cultivation, development of forests, pasture, mining, transportation, gardening and recreation, industrial, commercial and residential purposes.

GIS and satellite remote sensing technologies are the potential tools in exploring changes in land cover. In a study conducted by Sinha, Dudhani and Vihar (2004), it was felt that the knowledge of both land use and land cover is important for the socio-economic planning of a region. They have clearly distinguished that, while land use relates to residential, institutional, commercial and recreational activities, land cover relates to various types of features present on the surface of the earth. For proper planning exercise, information on both the above aspects should be available separately (Sinha et al., 2004).

2.2 GIS based Multi Criteria Spatial Decision Support System Concept

The integration of MCDM techniques with GIS has considerably advanced the conventional map overlay approaches to the land-use suitability analysis (Malczewski, 1999). GIS-based MCDA can be thought of as a process that combines and transforms spatial data into a resultant decision (output). The MCDM procedures (or decision rules) define a relationship between the input maps and the output map. The procedures involve the utilization of geographical data, the decision maker's preferences and the manipulation of the data and preferences according to specified decision rules.

Consequently, there are two importance considerations for spatial MCDA: (1) the capabilities of GIS for data acquisition, retrieval, storage, manipulation and analysis, and (2) the capabilities of MCDM to combine geographic data and the preference of decision makers into multidimensional values. For tackling the land use suitability problems in GIS environment, there are some numbers of multi criteria decision rules which have been implemented.

3. Materials and method

3.1 Study Area

Kabul (34° 35' N 69° 12' E) is the capital of Afghanistan which located in the eastern section of the country as well as its largest city. According to estimation in 2019, the population of Kabul city is almost 4.9 million and its total area is 1029 sq. km. Fast urbanization had made Kabul 64th largest city around the world. The city is located high up in a narrow valley between the Hindu Kush mountains. Kabul became the capital of Afghanistan during the reign of Timur Shah Durrani (reigned 1772–1793), the son of Ahmad Shah Durrani.

Kabul city has 68% informal settlement and its population density is almost 980 people per square km. More than 2.5 million Kabul city's population are living in unplanned area without having access to public services like safe drinking water, paved access roads, drainage systems, sanitation, solid waste management and canalization system. Figure 1 shows the map of the study area.

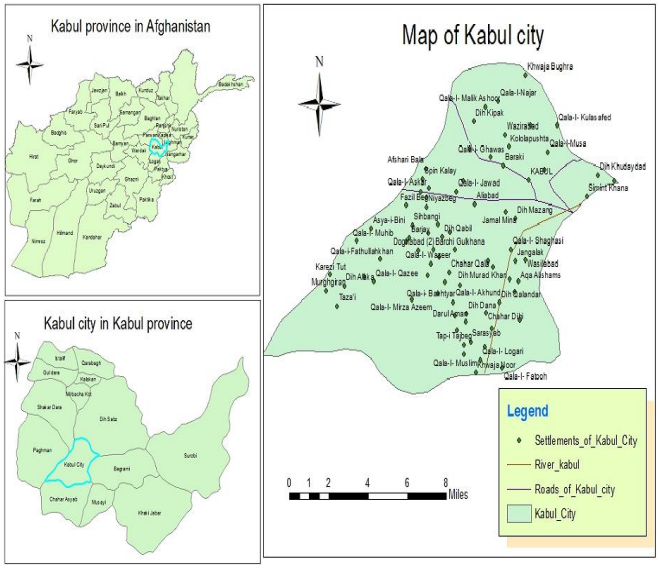

Figure 1: The Location Map of the study area

3.2 Statement of the Problems

Cities provide high capability to improve livelihoods, enhance economic growth, serve safe environment and reasonable lodging services. The ongoing urbanization in Kabul city in the next few decades, serves a high possibility to support urban development which would be justifiable, unbiased and a catalyst for economic growth. In order to compute the weight factors as well as criteria used tools of GIS must be combined with other conventional methods to achieve higher results value of land suitability for analysis.

Kabul City population has increased from some 1,200,000 people estimated in 2001 to 2,800,000 in December 2005. And increased from 3,200,000 in 2010 to 4,900,000 in 2019. Considering the profile of Kabul city afterwards a conceive destructive war and nonexistence of an adequate economy to undertake the overall problems, there is not exists a well-known map that quantitatively describe land suitability for urban development.

3.3 Objectives

The main objective of the paper is to form a methodology for finding most suitable areas for urban development through integrated tools of Geographic Information System (GIS). To achieve the overall objective, the specific objectives of this paper are listed below:

- To produce Land Suitability Index (LSI) map
- To produce a methodology for finding and selecting suitable areas of urban development
- To identify suitability maps for locally adaptable urban development.

3.4 Methodology

The first section of this paper is mapping current Land Use (LU)/Land Cover (LC) classification by Landsat-8 of the satellite image. The map projection is WGS 84, zone 42s. The second section is Land suitability analysis for the urban development of Kabul city using Multi-Criteria Spatial Decision Support System (MC-SDSD) coupled with AHP. Linear combination method was employed by multiplying score and weight of each factor. Six factors were considered in each analysis. The Urban land was extracted from LULC map and later it was multiplied with the result derived from linear combination method in raster calculator. Finally, Land Suitability maps were achieved for urban development in Kabul city. Figure 2 illustrates the overall process for doing this research.

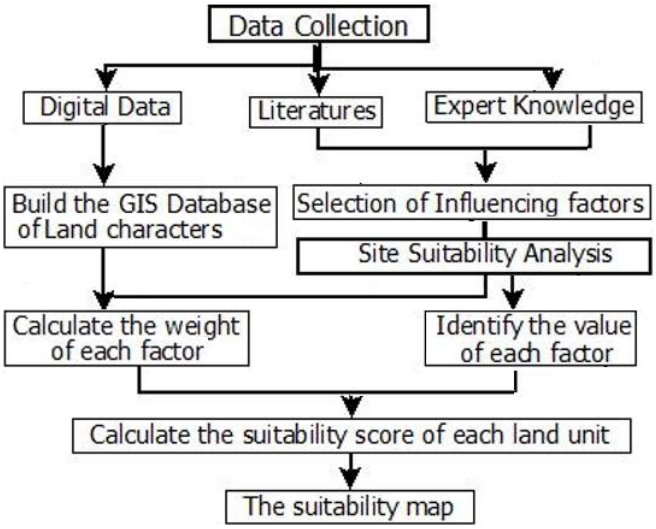

Figure 2: The process of suitability assessment

4. Result and discussion

4.1 Selection of factors of land suitability for urban development

Acquiring new area for urban development or improvement is becoming increasingly challenging, particularly in a growing real estate market and with stringent environmental standards or regulations. The selection of suitable area is based upon a specific set of local criteria. To assess the overall suitability a scoring and weighting system is applied to the various aspects of suitability (Town & Pradesh, 2014).

Site suitability is the process of understanding existing site qualities and factors, which will determine the location of a particular activity (Hofstee & Brussel, n.d.). Land suitability assessment is a multiple criterion evaluation processes. Suitable locations are found out by adding all layers which are affecting site suitability. The slope is one of the major factors taken into consideration in any land suitability analysis. On the whole, the following parameters have been considered for the suitability analysis in the present case:

- Slope
- Road
- Land use
- River
- Settlement
- Elevation

Figure 3 illustrates the map of every influenced factors which used in GIS-AHP analysis.

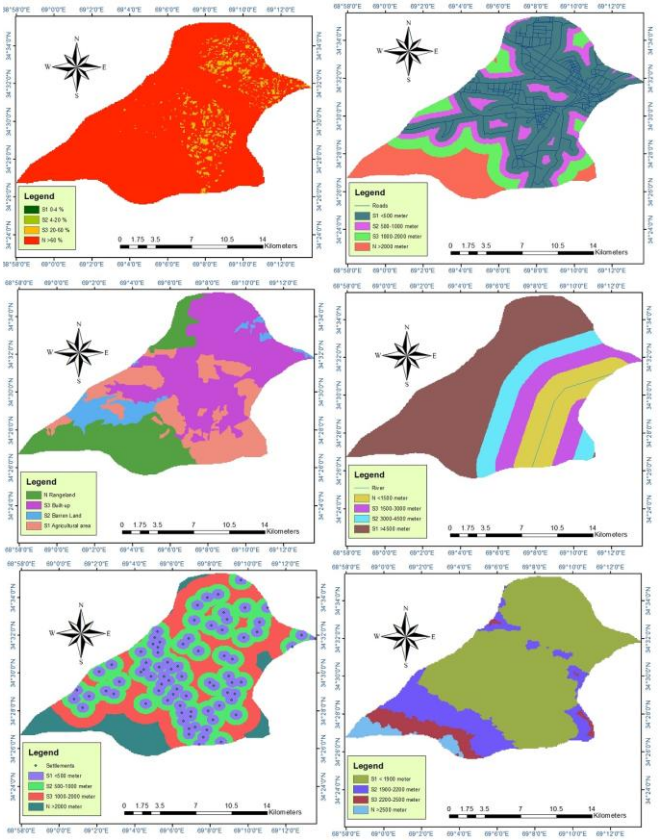

Figure 3: Factors used in GIS-AHP analysis (Slope, Road, Land use, River, Settlement and Elevation)

4.2 Weighting Analysis AHP (Analytical Hierarchy Process

Analytic Hierarchy Process (AHP) analysis involves factors of varying importance to decision making. The Analytic Hierarchy Process (AHP), one of the more widely used multi criteria methods and one of Multi Attribute Decision Making (MADM) decision rules. The AHP developed by Saaty (1980) is a technique for analyzing and supporting decisions in which multiple and competing objectives are involved and multiple alternatives are available.

Computation of the criteria weights involves the following options: (1) Sum the values in each column of the pair-wise comparison matrix, (2) Divide each element in the matrix by its column total, and (3) Compute the average of elements in each row of the normalized matrix. Estimation of the consistency ratio involves the following operations: (1) Determine the weighted sum vector by multiplying the criterion weights with the values of the original pairwise comparison matrix and finally sum these values over rows, and (2) Determine the consistency vector by dividing the weighted sum vector by the criterion weights. After calculation of consistency ratio the result is less than 10%, which is acceptable (4.6%). Table 1 demonstrates the

weights of every factor and the score of every class of factor for the final land suitability map.

Table 1: Weights and scores of factors and classes

N	Factor	Suitability Classification	Factor Weighting	Class Scoring	Remarks
1	Slope	0-4% 4-20% 20-60% >60%	0.38	8 6 4 1	S1 S2 S3 N
2	Road	<500m 500-1000m 1000-2000m >2000m	0.25	8 6 4 1	S1 S2 S3 N
3	Land Use	Agricultural Land Barren Land Built-up Mountains	0.16	8 6 4 1	S1 S2 S3 N
4	River	<1500m 1500-3000m 3000-4500m >4500m	0.10	8 6 4 1	S1 S2 S3 N
5	Elevation	<1900m 1900-2200m 2200-2500m >2500m	0.07	8 6 4 1	S1 S2 S3 N
6	Settlement	<500m 500-1000m 1000-2000m >2000 m	0.04	8 6 4 1	S1 S2 S3 N

4.3 Assigned weights of selected factors for Kabul city

Table 2 shows the weights of every factor for the final suitability map.

Table 2: Weights for the final suitability map

Factor	Criterion weight
Slope	0.38
Road	0.25
LU	0.16
River	0.10
Elevation	0.07
Settlement	0.04

For adding the weights in raster calculator:
MKabulcity = ([Reclass of Slope] * 0.34) + ([Reclass of Road] * 0.19) + ([Reclass of LU] * 0.15) + ([Reclass of River] * 0.12) + ([Reclass of Settlement] * 0.11) + ([Reclass of Elevation] * 0.09)

4.4 Land Suitability final map for urban Development of Kabul city

The weighted overlay technique has been used to extract a land suitability map for urban development. As mentioned above, the application of GIS and AHP in the analysis of land suitability is an effective way to assess the suitability of urban land. The assessment is based on a literature review that creates indicators of land use suitability influencing factors. Coverage mapping is a basic method of application in GIS and helps planners to obtain the final suitability map. On the other hand, in the weight value calculation process the attribute scores along with the weights combined by the AHP methods can be used. In this regard we can totally avoid such ideas that affects the consequences and combine both qualitative and quantitative methods.

The final output has been shown in land suitability map. In figure 3, as could be seen the study area was divided into four different suitable categories such as:

- High suitable
- Moderate suitable,
- Marginally suitable
- Not suitable

After suitability analysis it was found that from the available area 0.79 sq. km falls under not suitable, 72.14 sq. km under marginally suitable, 191.77 sq. km under moderately suitable and 45.3 sq. km under high suitable. The result shows that highly suitable areas for urban development is either agricultural or barren type. Figure 3 shows Final Land suitability map for Urban development of Kabul city.

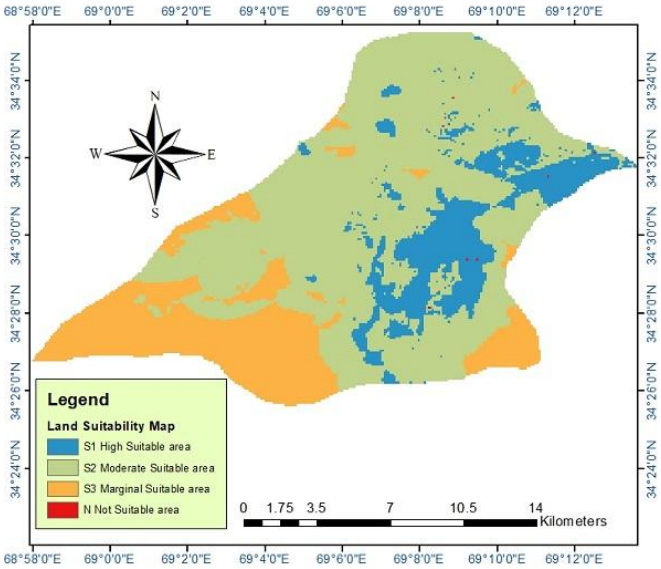

Figure 3: Final land suitability map for urban development of Kabul city

From Figure 3, we can observe the land suitability map of the study area. As the above map is generated based on the weights specified in the six factors. Considering the previous maps, this area which is in blue is only not suitable in the river map while it shows a level of high and low suitability in the other maps. As the weight given to river is low, hence the final map generated this area as suitable. The second class shows the area in gray which is moderately suitable and it covers most of the parts of the city. According to the previous maps, this class is higher suitable in the road network and elevation map but it is less or not suitable in the land use map. Therefore, this area is marked as moderate suitable in the final map. The third category which is light brown is marginally suitable. It is considered as non-suitable in most of the maps but we can observe that considering the river map it is highly suitable so it is categorized in the marginally suitable areas for urbanization. Finally, the fourth class in red color shows the areas not suitable for urbanization. We can observe these areas as just visible as small points. this means that this area is less than one percent which is considered not suitable in Kabul city for

urbanization. The main reason why this is a limited area in this map because it is considered as suitable in some maps while not suitable in other maps. These areas which are less than one percent are those areas which are not suitable according to the six factors. Absolute values and percentage share of these categories are shown in Table 3.

Table 3: Land suitability for urban development of Kabul city

Suitability Classes for final map	Area (Km2)	Percentage	Remarks
S1	56.16	18.12	Highly Suitable
S2	25.39	8.19	Moderately Suitable
S3	155.55	50.17	Marginally Suitable
N	72.9	23.52	Not Suitable

4.5 Suitability classes distribution

Figure 4 shows the percentage of suitability classes for urban development of Kabul city.

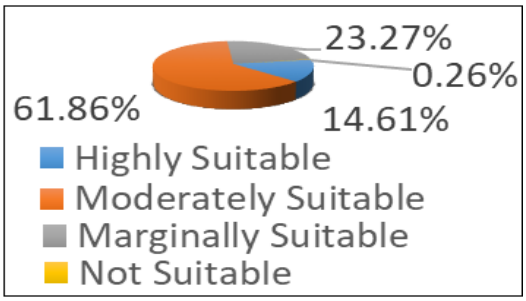

Figure 4: The percentage of land suitability classes for urban development of Kabul city

Total study area is 310 km² which categorized into four classes. Figure 5 illustrates the area of every class of land suitability for urban development of Kabul city.

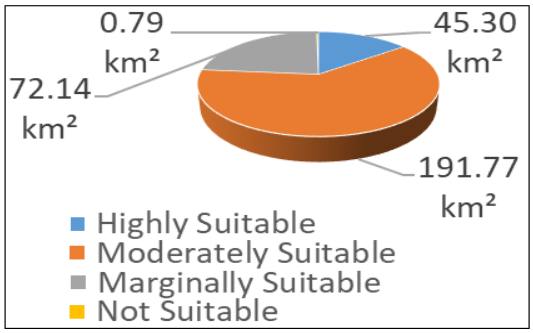

Figure 5: The area of Land suitability classes for urban development of Kabul city

5. Conclusions and Recommendations

5.1 Conclusion

The paper distributes the finding of suitable areas for urban development by using Geographical Information System (GIS). Land Use (LU)/Land Cover (LC) classification was derived from the Landsat-8 image. Spatial data (Landsat-8) and six thematic information layers were analyzed using ArcGIS 9.3 software to identify suitable areas for urban development in Kabul city. It focuses on GIS-based Overlay Weight Age Average (OWA) sum and Weighted Linear Combination (WLC). Six thematic layers (Slope, Road, Land use, River, Settlement and Elevation) was used to identify the suitable land for urban development. Weights/ scores were derived from AHP according to the pairwise comparison. Linear combination method was used in multiplying score and weight of each factor and the result was multiplied as only urban development will be considered as suitable.

Six thematic layers were considered to put as factors by AHP method. AHP is analysis hierarchy process to analyze weighting of each factor. The respective land suitability maps were generated using these models, including the suitability map of each model and Land Use Land cover map. Finally, final land suitability map for urban development of Kabul city was obtained by integrating land suitability maps of each model with current potential land use map derived from the Landsat 8 satellite image.

Pairwise comparison matrix indicates weights for Slope (0.34), Road (0.19), Land use (0.15), River (0.12), Settlement (0.11) and Elevation (0.09). Consistency ratio, (CR = 0.046) <0.10 indicated a reasonable level of consistency in the pairwise comparisons.

5.2 Recommendations

For future research, it is necessary to explore new direction and need to do field survey. In this paper, land use types related to the use of Landsat 8 satellite imagery were classified with remote sensing for a modern land use map and GIS techniques to update the database for the appropriate area of urban development. Long-term sustainable development plans in particular for urban development should be a useful way to analyze urban development suitability. So that for the purpose of urban development, it will be quite effective and beneficial for all cities of Afghanistan. The recommendation for a land use map to improve is to use a 15 x 15m pixel Landsat 8 image, which will use detailed land use data and optimize the appropriate areas for urban development.

This paper presented in integrating between multiple factors such as" Topography (Slope), Road, Land use, River, Settlement and Topography (Elevation) and factor as the baseline information to extract the suitability classes for the suitable area of urban development. However, this research still has many limitations to be covered whole study area. Therefore, it is recommended that the future research should include a detailed field survey.

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