GIS BASED SUITABILITY ANALYSIS FOR RESIDENTIAL LOCATIONS IN HORANA URBAN COUNCIL AREA

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KEYWORDS: Analytic Hierarchy Process (AHP), GIS Model Builder, Residential Development, Suitability Analysis

ABSTRACT: Urbanization is rapidly increasing especially in developing countries like Sri Lanka. Urbanization is highly significant in small-town areas. Notably, higher congestion can be observed in urban areas compared to semi-urban and rural areas. One of the main reasons for higher congestion is the movement of residents to metropolitan areas. Consequently, choosing a potential location for residence is one of the critical factors in spatial decision making in Sri Lanka. In the Sri Lankan context, there are several cities with various spatial issues when locating the residents. Horana city can be identified as a highly populated metropolitan area in Sri Lanka with increasing residential characteristics. The main objective of this research was to evaluate the availability of suitable residential areas in the Horana urban council area. This research also identified criteria for residency and the extent to which its impact has influenced the creation of relevant residential areas. Furthermore, the geographical information system (GIS) based analytic hierarchy process (AHP) is vital for identifying the potential areas. Accordingly, this research also recognized GIS-AHP models as a cost-effective and time-efficient approach to spatial decision making. This research evaluated AHP analytical methods by specifying the criteria in terms of elevation, slope, land use, and proximity to utilities and infrastructure. It could be concluded that 24.18% (1.04 Km^2) of the total area of consideration (4.33 Km^2) as a high potential area for residential development, 60.53% (2.62 Km^2) of the total area of consideration as a moderately potential area for residential development, and 13.97% (0.6 Km^2) of the total area of consideration as a fairly potential area for residential development in the Horana urban council. Moreover, 1.3% (0.056 Km^2) of the total area of consideration could be observed as the least potential area for residential development. Finally, it could be concluded that 84% (3.66 Km^2) of the total land area in the Horana urban council is appropriate for residential development under different levels.

1. INTRODUCTION

There are several land-use patterns including industrial areas, environmentally sensitive areas, agricultural areas, and residential areas. Residential land use is one of the significant land use patterns among them. At present, a rapid expansion of residential activities could be observed with the social and economical development of the communities. Thus, the rapid increase in the population in a limited area has caused various shortcomings resulting in serious issues among the land users. Most of such issues are originated due to the drawbacks in the planning phase. Therefore, planners need to be cautious with the social, economical, and environmental factors during the planning phase. Appropriate decisions should be made at the planning phase to overcome such issues which are influenced by the growth of the population.

With urbanization, the demand for land use in residential, commercial, and industrial areas are rapidly increasing. People have established these land-use patterns to satisfy their aspects of

residential needs, education, cultivation, manufacturing, finance, transportation, public services, and entertainment. In the Sri Lankan context, there is no proper development planning mechanism for land use. Consequently, this situation has a profound impact on the environment as well (Weerakoon, 2013). As the population grows, rising expectations from residents are creating new challenges for housing planning and provision. Among them, accessibility considerations rank high on the list (Zhu, Liu, & Yeow, 2005).

Land evaluation is the process of assessing land performance for specific purposes. Therefore, land use planning and land evaluation have become more important with the increasing demand for land, as people strive to make better use of limited land resources (Rossiter, 1996). The urban community of developing countries, in contrast to the rural community, has a much higher quality of life in the urban environment. That is accessibility, education, and employment. This situation is favoured by both urban and rural communities. As a result, the community is constantly living in urban centres to satisfy their needs. Due to the high demand for land in the major urban centres, the average rural community cannot afford to buy the adjoining land. That is, when land demand increases, so do the price of land. Subsequently, the suburbs around the major cities are being developed. Due to such as urban congestion and land price, the outsourced community builds up its residences in major metropolitan areas. Horana is one of such congested metropolitan areas in Kalutara district. Since the major cities surrounding the Horana metropolitan area (Panadura, Kalutara, Colombo, Piliyandala and Ratnapura) can not assure the residential needs, Horana town is chosen by the majority for residential purposes. As a result, Horana has grown to a highly-populated area at present (Ekanayake, 2011). Accordingly, as a developing country identification of potential sites for residential development especially in congested urban areas is one of the critical issues of planning and spatial decision making in Sri Lanka (Sandamali,Lakshmi & Sivanantharajah,2018).

1.2 Problem Statement

This research was aimed to evaluate the urban development plan of the Horana urban council area. Six land use zones could be identified in Horana urban council area namely residential zone, commercial zone, mixed development zone, education zone, environmental sensitive zone, and environmental conservation zone. Usually, the people living in residential areas have a comparatively high living standard compared to the people living in non-residential areas such as commercial and industrial areas. This research focused on addressing the land use requirements faced by people living in non-residential areas since the city itself has a physical barrier to residential development in the urban area. Therefore, assessing the potential of expanding residential areas in Horana urban council is crucial.

1.3 Research Objectives

The main objective of the research can be summarized as follows.

I. To find suitable residential areas using the geographical information system (GIS) model based on three major criteria (Physical Characteristics, Physical and Built Environment Facilities, Social Infrastructure) in Horana Urban Council area.
II. To identify criteria for locational suitability for residential development in Horana urban council area.
III. To identify challenges in a suitable residential zone and other zones.

1.4 Limitations

This research was conducted only for the Horana urban council area to assess the residential standard aspects of the development plan. Considering the time constraints, it was hard to conduct research covering all the residential areas in the country. Therefore, Horana urban council area was chosen as a sample for the study of residential suitability. Since the parameters assessed are not only applicable to the Horana urban council area, outcomes from this research may be applicable to other urban council areas with the same residential characteristics.

2. METHODOLOGY

In the first phase of the study, an extensive literature survey was conducted to identify the factors affecting the decision of choosing suitable residential areas using the geographical information system (GIS) model. Furthermore, Information required to identify criteria for locational suitability for residential development was also considered in the literature survey.

In the second phase, considering the availability of data and easy access to them, Horana Urban Council area was chosen to conduct the research. Horana is located in Kalutara district and it is situated 12 Km from Kalutara and 35 Km from Colombo. Horana urban council area extends from 6^0 $41^/$ to 6^0 $44^/$ North latitude and East longitude from 80^0 $2^/$ to 80^0 $3^/$. Additionally, Horana is situated close to Panadura town in the west, Kalutara in the south, Madurawala and Beruwala in the east and south respectively. The town is also located in between the Ratnapura-Panadura main road. The Horana urban council area covers an area of 4.53 Km^2 and consists of 07 Grama Niladhari Divisions. Moreover, this area is located off the coast of the country, accessed by A-grade main roads. It is also situated at an altitude of 5- 30 m above sea level. This area of the wet zone is ideal for living as there are minimal natural disasters. After determining the study area, the factors required for the residential activities in Horana urban council area were noted. The nature of residential areas, especially in and around the city centre were also observed. This observation helped to understand the common features of the area, especially for residential purposes.

Figure 1: Study Area Map
Source: Created by Author

In the third phase, data collection was conducted in the Horana urban council area. In this context, special attention was paid to identify residential characteristics and the problems that arise in it. Then, interviews were conducted to gather information from residents.

Discussions were conducted among several groups. Initially, corporate personnel were chosen including officials from Urban Council, Urban Development Authority (UDA) in Kalutara, Divisional Secretariat in Horana, Grama Niladhari Office in Halkotiyawatta and Wawala West. Hence, these discussions with the UDA officers, in particular, revealed the need and importance of a development plan for Horana urban council area. Accordingly, residential activities in Horana residential areas could be clearly understood through these informative interviews.

Additionally, interviews were conducted using a semi-structured method of selecting random samples. Two main groups were considered for this purpose. The groups were the people who came to the city centre for everyday needs and the people who were engaged in land trading. Information obtained from these people was important to establish the criteria for the research. Based on the information gathered from the land traders, market values of the various localities could be learnt. Relevant records and reports were also gathered from authorities to get an idea about residential development in Horana urban council area.

Table 1: Secondary Data Used for the Analysis

Criteria	Map scale	Base map	Source
Population Density	1:17000	GN Division map	UDA
Proximity to schools	1:17000	Schools map	UDA
Land Use	1:17000	Land Use map	UDA
Land Values / Prices	1:17000	_	Field survey details and UDA
Social infrastructure	1:17000	Infrastructure map	UDA

Finally**,** base maps of the selected criteria were also considered. Using these base maps, spatial analysis of the selected criterion was carried out utilizing the technique of GIS.

2.1 Data Analysis

2.1.1 Developing Criterions

Residential suitability analysis requires integration of several data sets to model land use requirements and the characteristics of the residential for the alternatives (Jankowski & Richard 1994). The current spatial decision making could benefit from more systematic methods for handling multicriteria problems while considering the physical suitability conditions. Traditional decision support techniques lack the ability to simultaneously take into account these aspects. The process of housing site selection begins with the recognition of an existing or projected need (Al-Shalabi, Mansor, Ahmed & Shiriff,2006). Accordingly, various factors such as physical, social and economic determinants were considered when establishing a location of residence. Furthermore, physical determinants consisted of the slope, elevation, soil condition, natural hazards, and land cover. Social factors consisted of land use, distance to shops, access to roads, hospitals, schools and religious places. Additionally, economic factors consisted of job placements, land price, and taxation. Accordingly, considering the information gathered through literature survey, interviews, discussions, observations and reports, major and minor criteria were identified and they are presented in Table 2.

2.1.2 Creating Base Maps Using the GIS Techniques

Base maps were developed for the suitability criteria. Using these base maps, spatial analysis of the selected criterion was carried out utilizing the technique of GIS.

Spatial data analysis is the process of extraction of useful information distributed over space. Spatial data analysis focuses on patterns and accommodates maps that help to characterize, understand and predict spatial phenomena. It is important to understand the suitability and rationality of modern GIS analytical methods in spatial decision making, such as residency. GIS analytical methodology is important for identifying the spatial decision-making suitability of analytical methods compared to traditional methods, by focusing on residential conditions compared to an urban plan. Summary of the development of base maps is presented in Table 2.

Table 2: Major and Minor Criteria and GIS Operation for Criterion Maps of the Study.

Major Criteria	Minor Criteria	GIS techniques and tools
Physical Characteristics	Slope	Surface Slope 3D Analyst Tool
	Elevation	TIN
Physical and Built Environment Facilities	Land Price	IDW
	Town Centres	Multiple Ring Buffer
	Roads	Multiple Ring Buffer
	Land Use	Quarry
Social Infrastructure	Hospitals and Medical Centres	Multiple Ring Buffer
	Primary and Secondary Schools	Multiple Ring Buffer

2.1.3 Weight the Criteria by Using AHP

Spatial data analysis is the process of extraction of useful information distributed over the space (Carver,1991). The Analytic Hierarchical Process (AHP) is one of the methodological approaches that may be applied to resolve highly complex decision-making problems involving multiple situations, criteria and factors (Saaty,1970). Among GIS analytics, AHP methodology can perform suitability analysis systematically. Criteria for different disciplines were developed and then weights were assigned to those criteria. This weighting process identified the suitability of the respective area. In AHP, all identified factors were compared with each other in a pairwise comparison matrix which is a measure of relative preference among the factors. Therefore, numerical values expressing the relative preference of a factor against another. Table 3 shows a scale suggested by Saaty in 1970 ranging from 1 to 9 which describes the intensity of importance.

Table 3: The AHP Scales for Paired Comparison

Intensity of Importance	Definition
1	Equal importance
2	Equal to Moderate importance
3	Moderate importance
4	Moderate to strong importance.
5	Strong importance
6	Strong to very strong importance.
7	Very strong importance.
8	Very to Extremely strong importance
9	Extreme importance

Source: Saaty,1970.

2.1.4 Development of a Model/ Suitability Map for Residential Development

A model was developed using the base maps. Each of these criteria given in Table 2 was incorporated into the developed model and weighted as shown in Table 3. The model can be presented as in Figure 2.

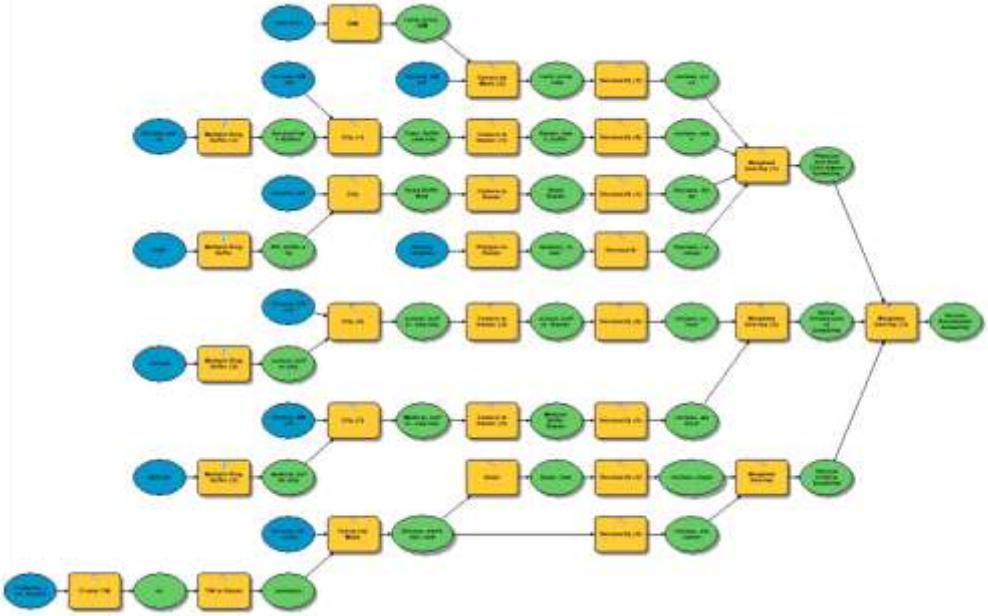

Figure 2: Flow Chart of GIS Model Running in ArcGIS for Residential Suitability.

3. ANALYSIS

3.1 Suitability Analysis Using Model Builder Tool

The model builder tool in ArcGIS 10.1 software was used to obtain the final results. This tool is capable of building existing data in multiple layers into one layer. It could also create a single layer by combining different criteria for a residential place. Accordingly, the result could create a single layer with high reliability. Process of the model building is presented in Figure 3.

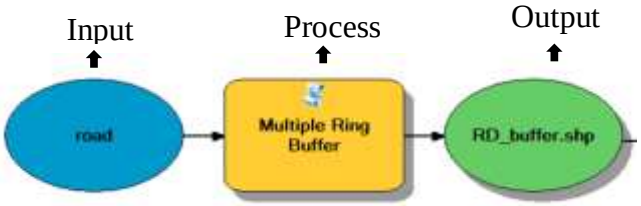

Figure:3 Process of the Model Builder

3.2 Determine the Suitability Levels of the Sub Criteria.

Before applying weights to factors, suitability levels were calculated and level scores were standardized to 0 (Not Suitable) 1 (Less Suitable), 3 (Moderately Suitable), 5 (High Suitable) and 8 (Very High Suitable). Scores for the attribute values of taking were also decided by the summarization of expert opinion as presented in Table 4. The reclassification tool (spatial analyst) of the ArcGIS 10.1 software was used to determine the level of suitability in this manner.

Table 4: Summary of Reclassified the Criteria.

Minor Criteria	Attribute Value of Factor	Suitability
Slope	$<10^0$	8
	10^0 -15^0	5
	15^0 - 20^0	3
	$>20^0$	1
Elevation	<20m	9
	20m -40m	7
	40m -60m	5
	>60m	3
Land Price	Rs. <500000	9
	Rs. 500000-1000000	7
	Rs. 1000000-1500000	5
	Rs. 1500000-2000000	3
	Rs. >2000000	1
Access to Town Centres	<500m	9
	500m-700m	7
	700m-1000m	4
	1000m	2
Access to Road	<500m	9
	500m-700m	7
	700m-1000m	4
	>1000m	2
Land Use	Rubber	8
	Residence and built area	7
	Tea	5
	Chena	3
	Water area	2
	Paddy	1
Hospitals and Medical Centres	<400m	9
	400m-700m	7
	700m-1000m	4
	>1000m	1
Primary and Secondary Schools	<300m	9
	300m-500m	7
	500m-700m	5
	>700m	3

3.3 Weight Criteria for Residential Suitability.

After determining suitability levels for the sub-criteria, weighting for the main criteria could be found as follows. Relevant criteria have been weighed for suitable residential activities accordingly.

Table 5: Weights Calculated by AHP

Major Criteria	AHP Weight (%)	Minor Criteria	Weight
Physical Characteristics	25	Slope	60
		Elevation	40
Physical and Built Environment Facilities	60	Land Price	40
		Town Centres	30
		Roads	15
		Land Use	15
Social Infrastructure	15	Hospitals and Medical Centres	55
		Primary and Secondary Schools	45
Total	100		

3.4 Main Suitability Criteria and Criterion Maps.

3.4.1 Physical Characteristics Suitability

Based on slope and elevation, the residential suitability for physical criteria map was developed. Figure 4 illustrates the suitability of the physical criteria. It was divided into five suitability levels. Results depict that a large area of the Horana UC area is suitable for residential activities. The impact of the physical characteristics for maintaining suitable residences could not be observed in this region, as there is no disparity in this area.

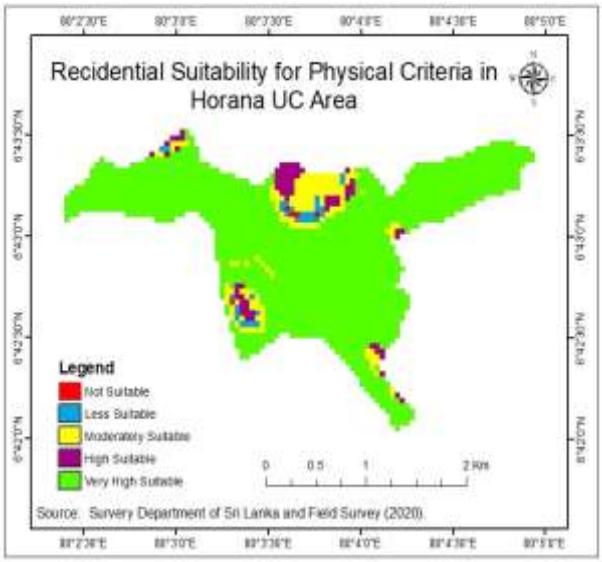

Figure 4: Residential Suitability for Physical Criteria
Source: Prepared by Author.

3.4.2 Physical Infrastructure and Built Environment Characteristics Suitability

This criterion is the most important factor in determining residential suitability in this area. The area is an urban area and the community is most concerned with physical infrastructure and built environment factors. Therefore, based on land price, proximity to the town centre, proximity to the roads and land use pattern, the residential suitability of physical infrastructure and built environment criteria map was created and it is shown in Figure 5.

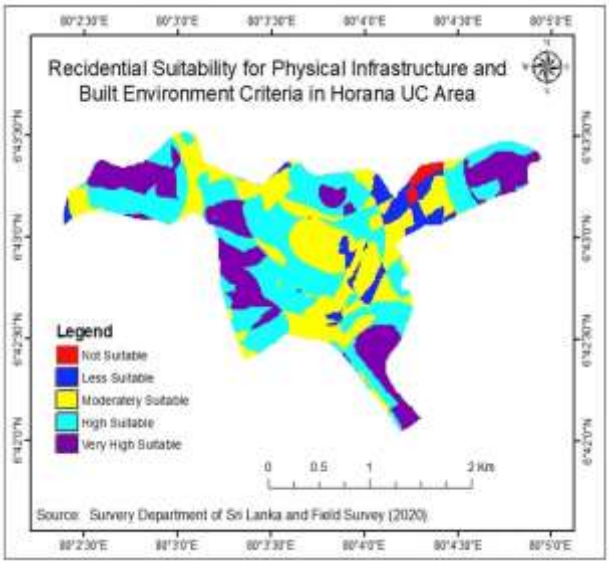

Figure 5: Residential Suitability for Physical Infrastructure and Built Environment Criteria
Source: Prepared by Author.

3.4.3 Social Infrastructure Suitability

The social infrastructure suitability map was created based on the criteria of proximity to hospitals and medical centres and primary and secondary schools as shown in Figure 6. Subsequently, there is a developed social infrastructure in the majority of the total area. It is a special characteristic that such an area is located outside the city. Also, most of the social infrastructure is located in the urban centre.

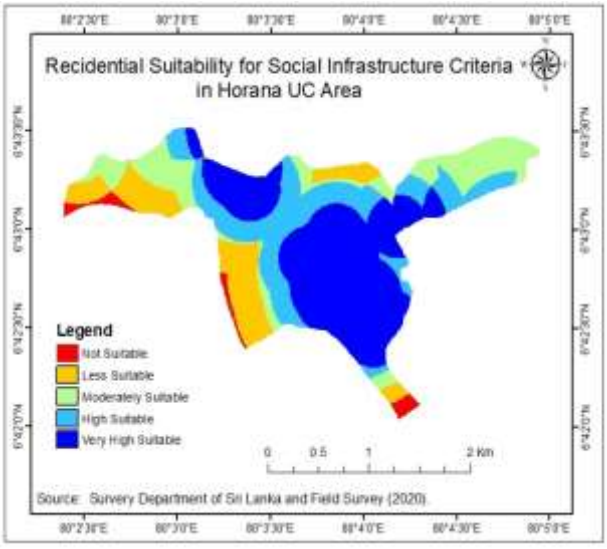

Figure 6: Residential suitability for Social Infrastructure Criteria
Source: Prepared by Author.

3.5 Calculating Residential Suitability in Horana UC Area

In assessing the suitability of the residential area in Horana, a weighted overlay tool in ArcGIS 10.1 software was used. It is illustrated in Figure 7. According to the map, it is clear that most of the area is highly suitable for residential activities. After creating the Horana residential suitability map, it was converted to vector format using the raster to polygon conversion tool and it is illustrated in Figure 8. Figure 9 shows the flow chart of the process. The suitability areas were then calculated through field and geometry calculation options.

In consequence, each of the suitability levels could be identified as shown in Table 6. After overlaying each criterion and maps, obtained model results sorted the total area under five classes of land suitability; least suitable, fairly suitable, moderately suitable and highly. The outcome of the model is summarized in Table 6.

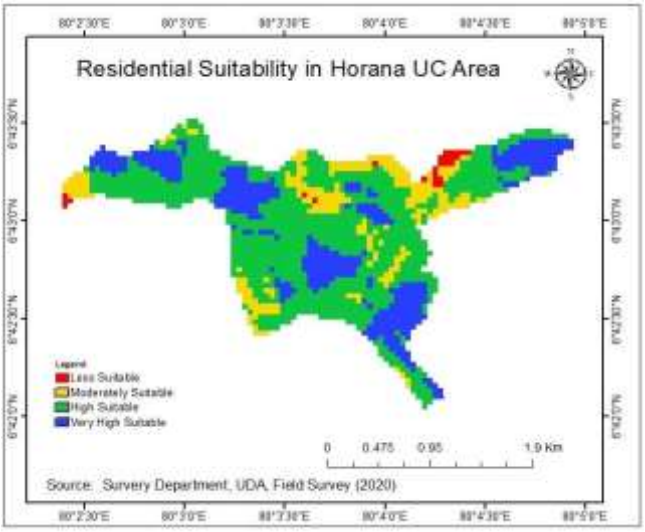

Figure 7: Residential Suitability in Horana Urban Council Area. Source: Prepared by Author.

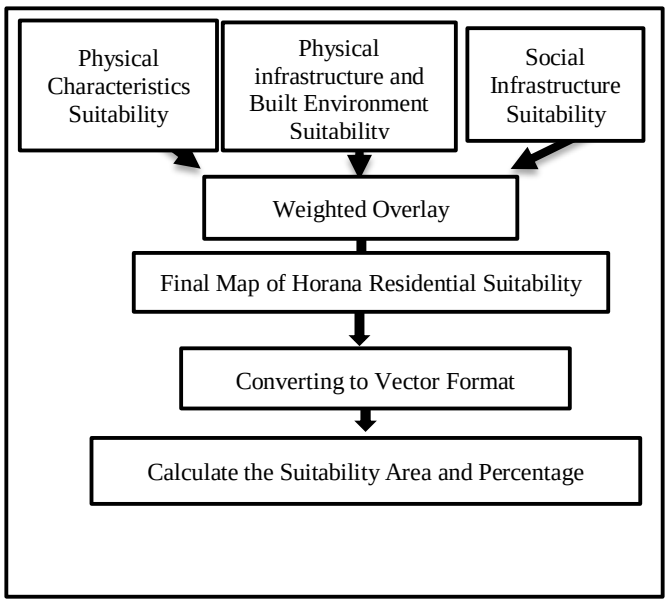

Figure 8: The Procedure for Finding the Suitability and Calculating Suitability Area.

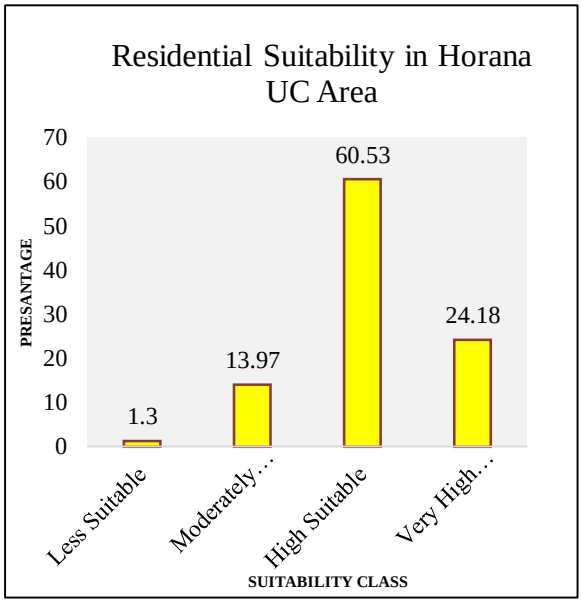

Figure 9: Suitability Levels in Horana UC Area.

Table 6: Calculating Suitability Levels in Horana UC Area

Suitability Class	Area (Km^2)	Percentage (%)
Least Suitable	0.0563	1.300
Fairly Suitable	0.605	13.978
Moderately Suitable	2.623	60.533
Highly Suitable	1.048	24.187
Total	4.333	100.000

Model results emphasized that out of the total area under consideration (4.33 Km^2), 24.18% (1.04 Km^2) as a highly suitable area for residential development, 60.53% (2.62 Km^2) as a moderately suitable area for residential development, 13.97% (0.6 Km^2) as a fairly suitable area for residential development in Horana UC area. Out of the total area, 1.3% (0.056 Km^2) was the least suitable area for residential development. Final model results also emphasized that the majority of the zones (84% of the total area) considered in this research were suitable for residential development in the Horana UC area. Therefore, it can be concluded that 84% of the land area of the Horana UC area is well equipped for residential activities and the majority of the land area is potential and feasible for residential development.

4. CONCLUSION

In the Sri Lankan context, there are several cities with various spatial issues when locating the residents. Horana city can be identified as a highly populated metropolitan area in Sri Lanka with increasing residential characteristics. The main objective of this research was to evaluate the availability of suitable residential areas in the Horana urban council area. This research also identified criteria for residency and the extent to which its impact has influenced the creation of relevant residential areas. As a result of analysis revealed that 24.18% (1.04 Km^2) of the total area of consideration (4.33 Km^2) as a high potential area for residential development, 60.53% (2.62 Km^2) of the total area of consideration as a moderately potential area for residential development, and 13.97% (0.6 Km^2) of the total area of consideration as a fairly potential area for residential development in the Horana urban council. Moreover, 1.3% (0.056 Km^2) of the total area of consideration could be observed as the least potential area for residential development. Finally, it could be concluded that 84% (3.66 Km^2) of the total land area in the Horana urban council is appropriate for residential development under different levels. The main finding of this study is that 84% of the land is highly suitable for residential development. It was also found that 1.3% of the area has a minimum of suitability. Most of the land can be identified as residential areas with high suitability such as proximity to the road, schools, hospitals, town centres and suitable and suitable land use, minimum land prices.

This model can help to prepare the strategic urban land development framework and the short-term land-use policies can be formulated. Furthermore, the use of GIS-based methods is best suited for the problem of selecting suitable residences in the growing urban areas. Thus, GIS analysis methods can be used with confidence to identify suitable residential areas that are a major problem in urban areas of Sri Lanka.

Furthermore, the findings of this research can be useful for many parties, particularly for personnel engaged in real estate development. People can also get an idea about the land and housing prices in a certain area and they can identify areas appropriate for community-based projects. Besides, it is important to identify on-site issues that may address residential problems and urban planners

and property developers can also make use of this knowledge to decide the locational issues affecting residential development. It is also beneficial to understand strategies to resolve the issues confronted with their investments and to predetermine other key factors related to investments such as the construction cost, deciding prices, potential areas to invest and to identify the behaviour of the residential property market depending on the feasibility of the area for residential development. Additionally, it is also important to recognize the diversity of residential activities in these different regions.

5. RECOMMENDATIONS

GIS Analysis method is a systematic way to make spatial decisions such as residential suitability. Since the residential activities are continuing to expand in Horana urban council area and due to the vertical expansion in the residential areas, it has affected several agricultural lands including rubber cultivation. The reason for this condition is the increasing land use for residential activities and the use of rubber cultivation lands for residential purposes. Therefore, it is advised to develop residential activities horizontally, not vertically. Although many of the residential facilities could be found in Horana urban council area, the lack of a wastewater drainage system and solid waste disposal has caused severe problems that have affected the residential activities. Therefore, it is beneficial to establish a waste disposal centre and a garbage segregation centre as well. Furthermore, allocation of space for a bus stop especially for long-distance buses at Horana main bus stand should also be considered to reduce the heavy congestion around the Horana bus stand. Establishing a new bus stop would be highly convenient to the community living in Horana urban council area. Hence, more emphasis should be given to the proper planning of transport facilities when developing suitable residences.

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