

## GIS application for finding the best residential lands in Ratnapura municipal council area of Sri Lanka

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### Abstract

*One of the most important and urgent problem in Ratnapura Municipal Council (RMC) is the level of higher vulnerability to natural hazards and calamities. This area has already been proved as vulnerable to floods, landslides, river bank failures, environmental and health hazards; hence hardly developed for residential purposes. The aim of this study is to develop a Geographic Information System (GIS) based model to assess suitable sites for residential developments. This case study incorporates three major steps for suitability analysis which includes, identifying the factors that are essential for residential site selection, weighting suitability factors and developing a suitability map and a model spatial analysis tool in GIS. Selecting suitability factors is mainly based on views of key informants, who are the experts of land use planning. Slopes, land use, distance to roads, distance to natural hazardous areas and distance to environmental sensitive areas were the selected factors in the analysis. Before determining potential suitable sites, the Analytic Hierarchy Process (AHP) was applied to quantify the relative significance of each factor. Finally suitability map was created and it was found that 41.96 % (8.9 KM<sup>2</sup>) of the area is most suitable for residential development. Meanwhile this integration of GIS and AHP can be served as a decision support analysis for residential site selection for other local authorities also.*

**Keywords:** Suitability analysis, Residential site, Land use Planning, AHP Model.

### Introduction

A “residential area” is a land use in which the predominant use is housing settlement. Under the land use sector, residential sector is the largest one of the urban space; it may include 30-50% of developed land in urban areas<sup>1</sup>. Residential areas include mini-communities within a large urban community. The increase of population in the world, suitable land requirements for residential development and recreational activities have become a major factor for planning. Therefore, the role of the planner is not just allocating houses but Social, physical, economic, environmental and institutional planning aspects are also to be considered. Suitable site selection for residential development has become a growing concern of most of Town Planners, Architects and Decision-makers in city planning.

Land suitability analysis has ability to support and manage the land database to defined existing land area for housing. The process of land suitability analysis is determining a land that is suitable for development with other amenities<sup>2</sup>. Land suitability analysis needs timely and accurate information on the different land use systems, their suitability, sustainability, potentials and the consequences of their implications.

When considering the present context in Sri Lanka, Urban Development Authority (UDA), National Housing Development

Authority (NHDA) and National Physical Planning Department (NPPD) are the major institutions that are highly involved in residential site selection. Town Planners, Architects and Decision makers apply very conventional methods in planning and this method would not be efficient in terms of the accuracy and time. However the use of new technology to achieve the reliable, accurate and fast analyzing and mapping for residential site selection is not really applied.

In the field of suitability analysis for Urban Development, Geographic Information System (GIS), Remote Sensing and Spatial modeling have been proved to be efficient tools by existing literature. GIS have been applied in many studies to land suitability solution for managing spatial data and presenting visual results than other techniques. With the development of science and technology, the integration of GIS and Analytic Hierarchy Process (AHP) has been utilized for selecting the best and most suitable location for residential sites.

The aim of this study is to develop a GIS based model to identify suitable sites for residential developments, to determine the factors which are important in evaluation of the land for residential development and to identify suitable areas as residential areas while determining the suitability level. The research outcomes can be applicable to other cities in Sri Lanka as well as to other countries that have similar conditions with different parameters.

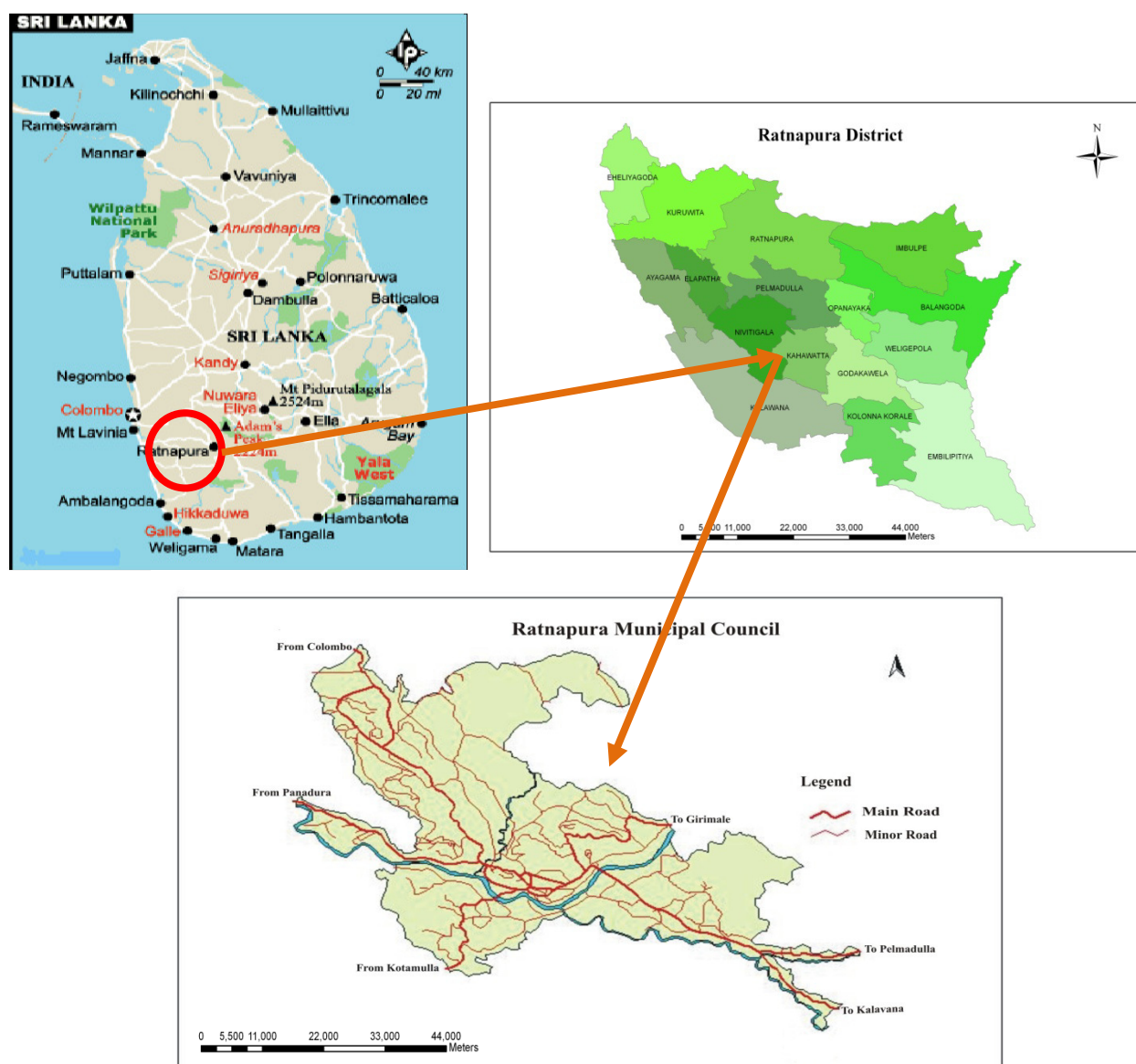
**Study area:** Ratnapura is located within the South-western part of Sri Lanka and is in-between the Northern latitudes 6°41' to 6°42' and Eastern longitudes 80°23' to 80°24'. Ratnapura district is one of the two administrative districts of the Sabaragamuwa Province in Sri Lanka and is the capital city of the province. Ratnapura Municipal Council area (Figure-1) is 22.2 square kilometers in extent.

In this paper, Ratnapura Municipal Council (MC) area was selected as the study area; since Ratnapura is a highly vulnerable area to the natural hazards and calamities than any other areas in Sri Lanka. The proportion of residential use within the MC area is only 37.1%. However, more than 50% of this area has already been proved as vulnerable to floods, landslides, bank failures, environmental and health hazards due

to results of gem mining; hence this are cannot be developed for residential purposes. Furthermore, the city has a high potential for development. Therefore, the Ratnapura MC has been selected as the most suitable location for this study.

## Methodology

This study involved three steps as shown in Figure-2. The first step was involved to determine the suitable factors for residential development. The second step was the weighting for defined factors by using AHP technique. Both experts' opinion and literature were required in these steps. The last step was developed a GIS model and suitability map for residential developments.



Source: Survey Department, 2000.

**Figure-1:** Location of the Study Area.

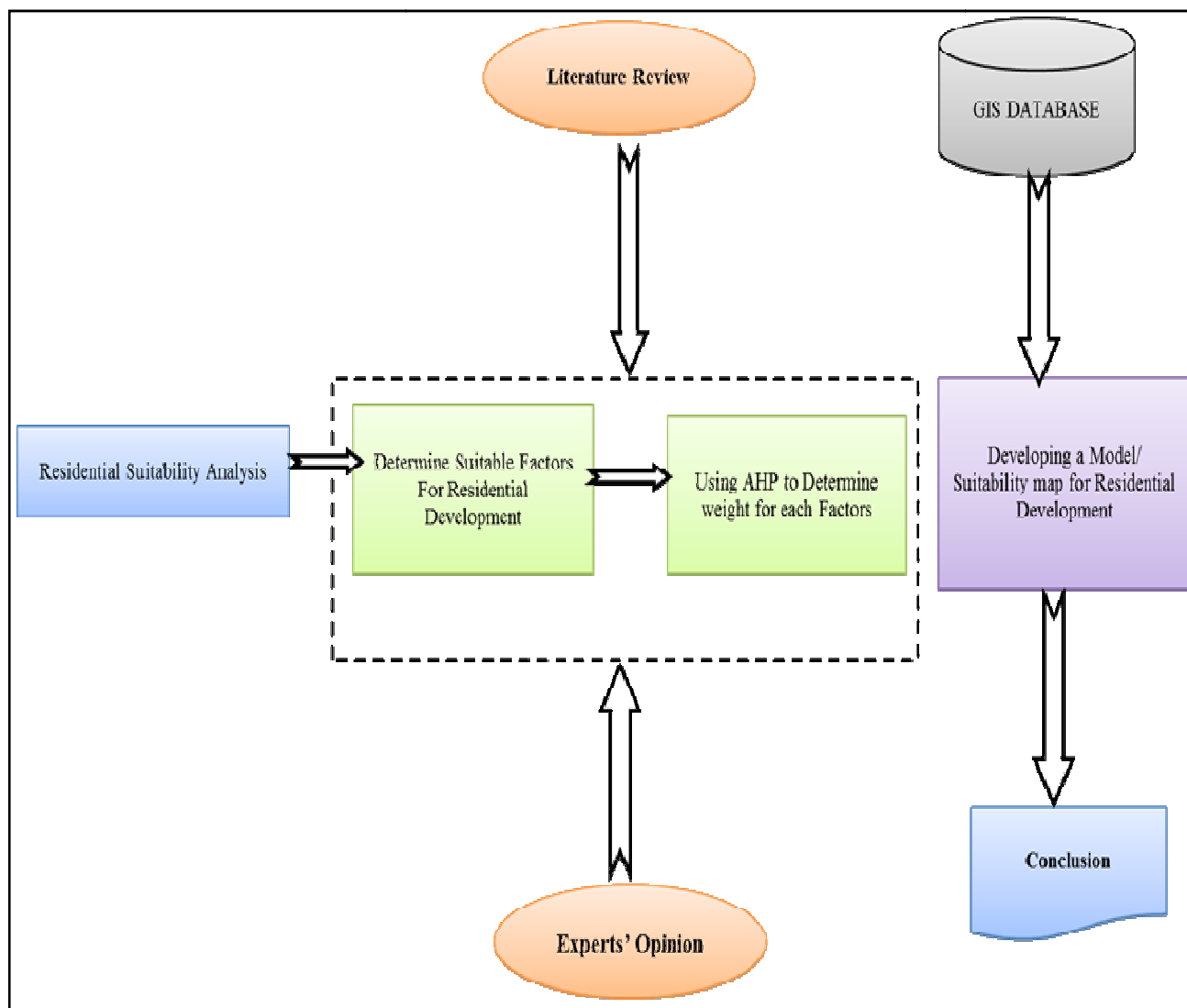


Figure-2: Residential Analysis Process.

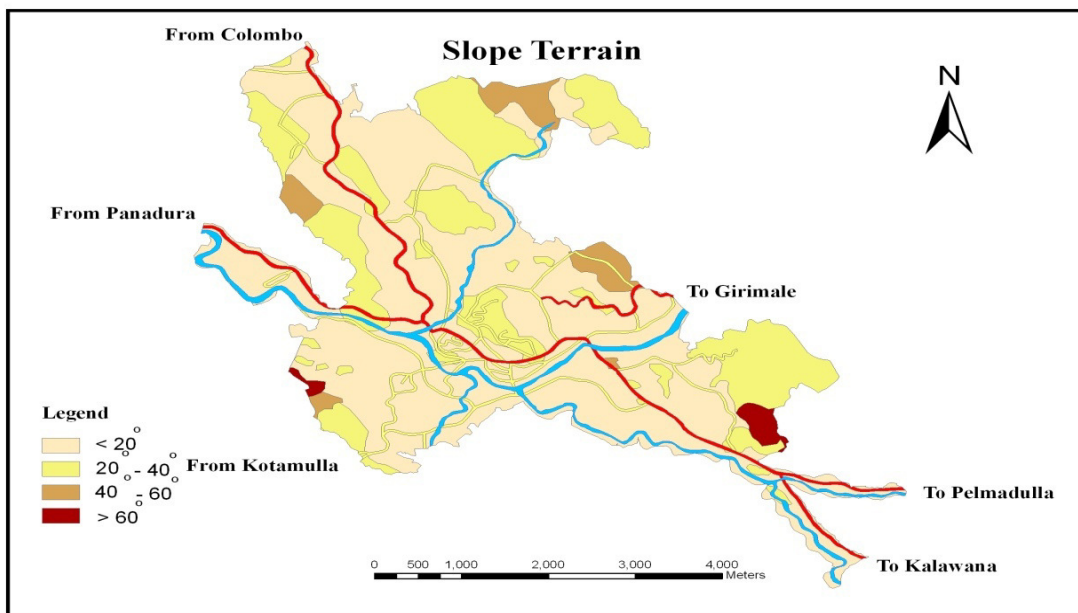
**Selection of Suitability Factors:** The Selecting of suitability factors was mainly based on the views of key informants, who are the experts of land use planning and published literatures. Slopes, land use, distance to roads, distance to natural hazardous areas and distance to environmental sensitive areas were the selected factors for the residential development in Ratnapura MC area. These factors were considered as highly specific for the study area. The said factors were selected to evaluate potentiality of residential development and to support decisions concerning the location of residential areas<sup>3</sup>. These factors include:

**Slope:** According to the topographic features, the MC area contains mountains with steep slopes, rivers, river valleys, low lying lands and plains. It is situated at a range of 18 to 305 meters above MSL. The Kalu Ganga and the We Ganga confluence the Ratnapura town in a way that about 13% of the urban area low lying land (Paddy lands is under and marshy

lands) which plays an important role in retaining excess water during floods. Malwala, Muwagama, Samagipura, Hidellana and Angamma, are located in very steep slope areas as shown in Figure-3. Chapin, F.S, *et al*, suggested that areas exceeding 20% slopes are usually not suitable for residential development. The ideal areas for residential function are areas with 2-6 % slopes<sup>1</sup>.

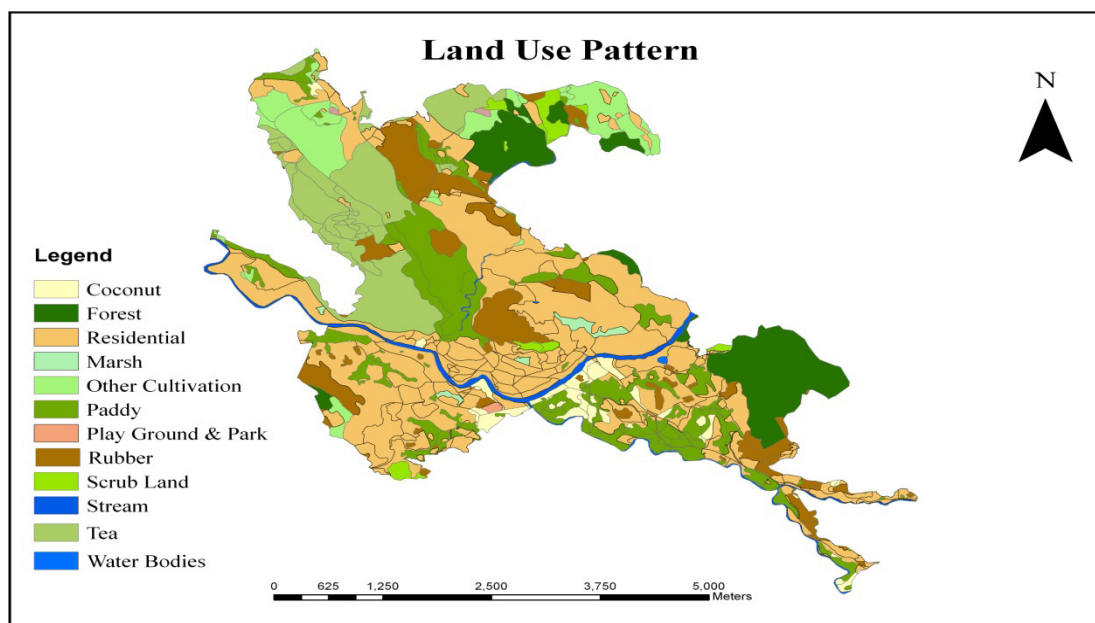
However, the zoning plan of Ratnapura MC area suggests that the slopes exceeding 20% is not suitable for residential development.

**Land Use:** The developed land area consists of 61.3% of the total area of Ratnapura MC. Undeveloped area is 38.7%, of which 21.1% can be used for urban development activities. The balance 17.7% cannot be developed and they are comprised of paddy lands, marshy lands and watercourses<sup>4</sup>. These are environmentally important lands because during the annual floods they become retention areas for excess water.



Source: Urban Development Authority, 2004.

**Figure-3: Slope Map.**



Source: Urban Development Authority, 2004 and Survey Department, 2000.

**Figure-4: Land Use Map.**

**Distance to Road:** The details about the present Road Network System of Ratnapura MC Area is shown in Table-1 and Figure-5. G-O yeh A. stated that the locations must be adjacent to residential areas, in the low-density population areas, within 1-5 km from the main and minor roads<sup>5</sup>.

**Distance to Natural Hazard Areas:** Most areas in Ratnapura MC are vulnerable for natural disasters such as landslides and floods; they have a tendency to get natural hazards.

**Table-1: Length of the Road.**

Road Category	Length (Km)
Tarred	85.3
Graveled	3.5
Others	2.3

Source: Ratnapura Peoples Transport Service and Sabaragamuwa Road Transport Authority, 2004.

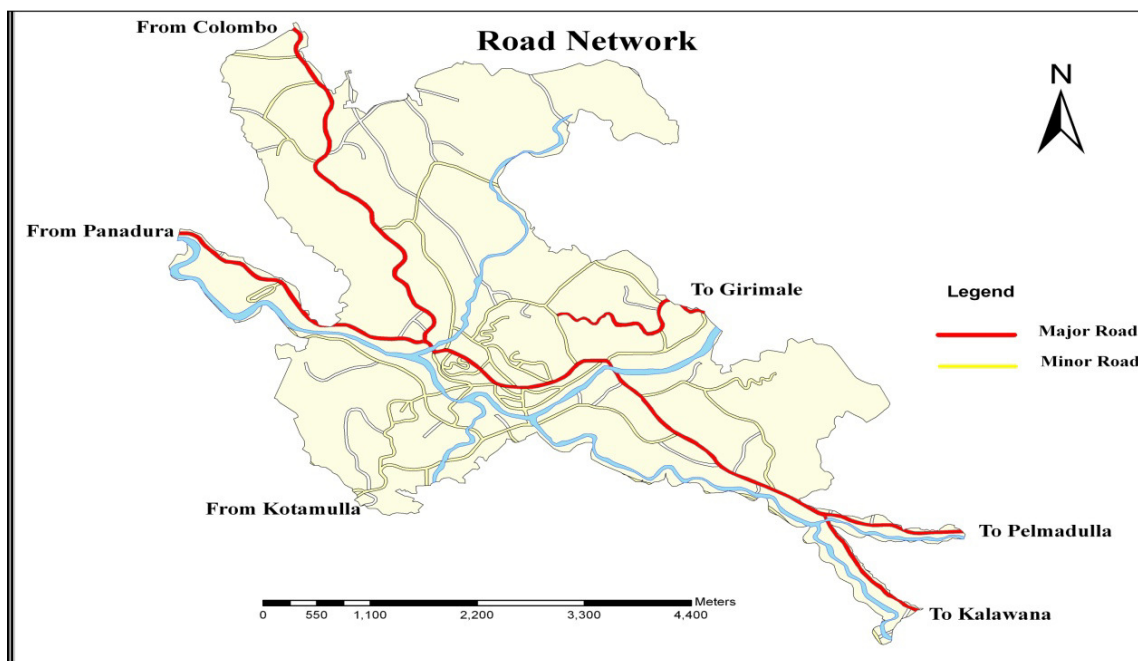


**Landslides:** Most of hilly areas get affected by landslides due to unauthorized constructions. Therefore National Building Research Organization (NBRO) has introduced guide lines for development activities within landslide areas<sup>6</sup>.

Flat land: slope < 8% (about 5°): These slopes are gentle with no environmental hazards being caused.

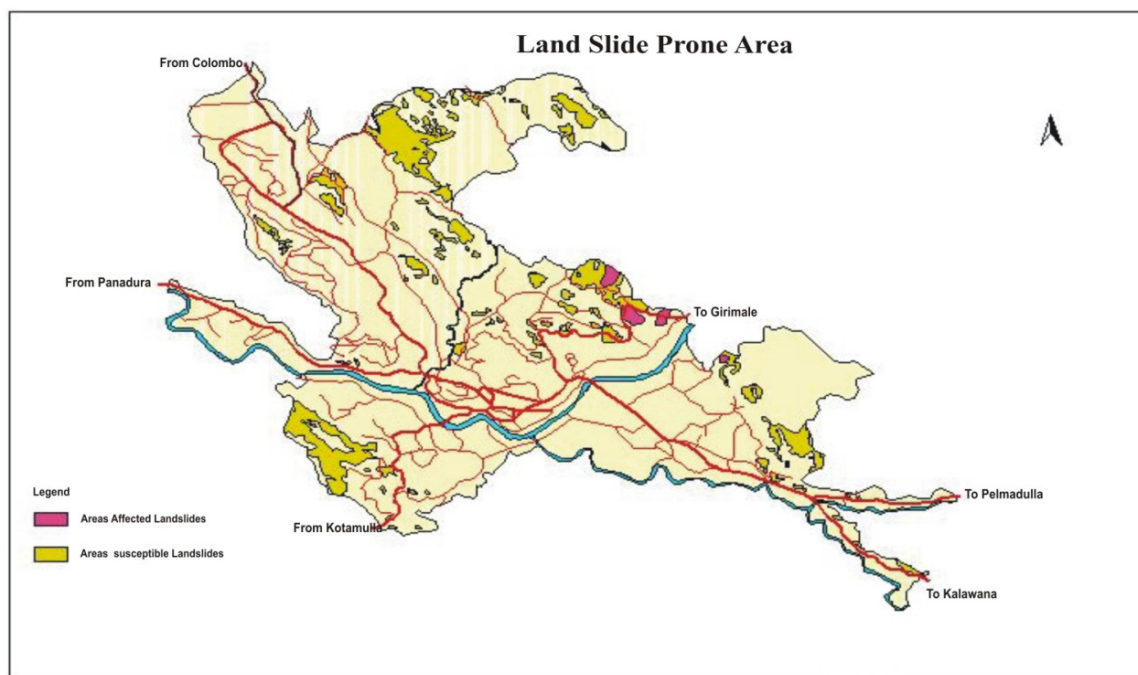
Moderate land: slope 8-60% (about 5° - 30°): Constructions are allowed with very strict guidelines.

Steep slope: slope > 60% (about 30°): These slopes are not recommended for any construction.



Source: Urban Development Authority, 2004 and Survey Department, 2000.

**Figure-5: Road Map.**

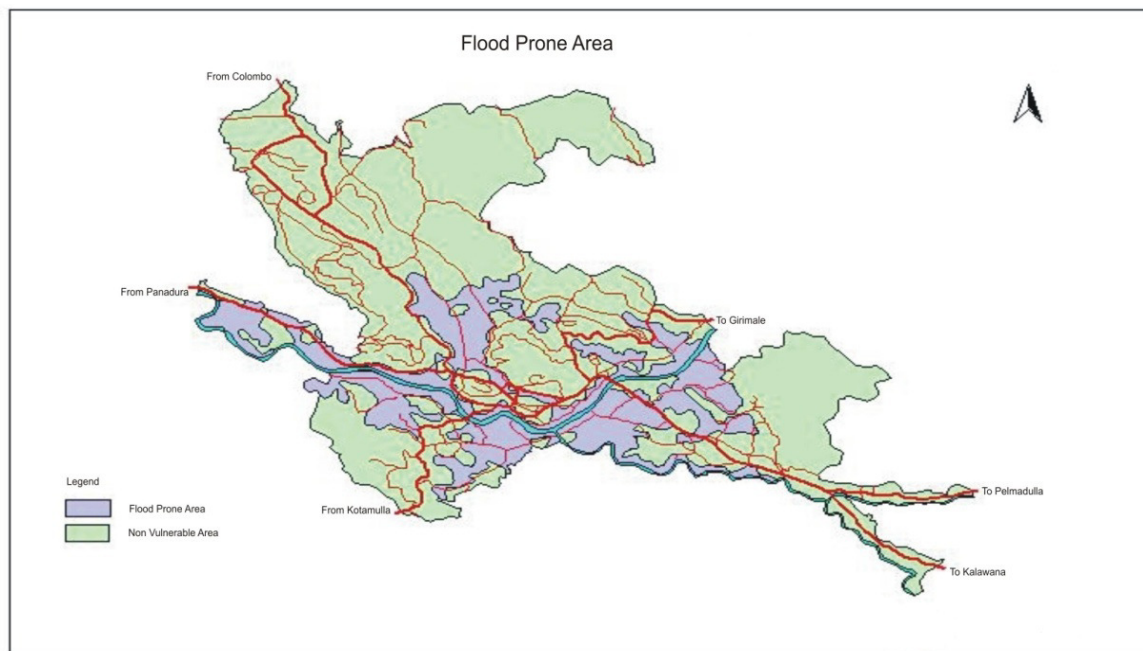


Source: Urban Development Authority, 2004.

**Figure-6: Landslides Map.**

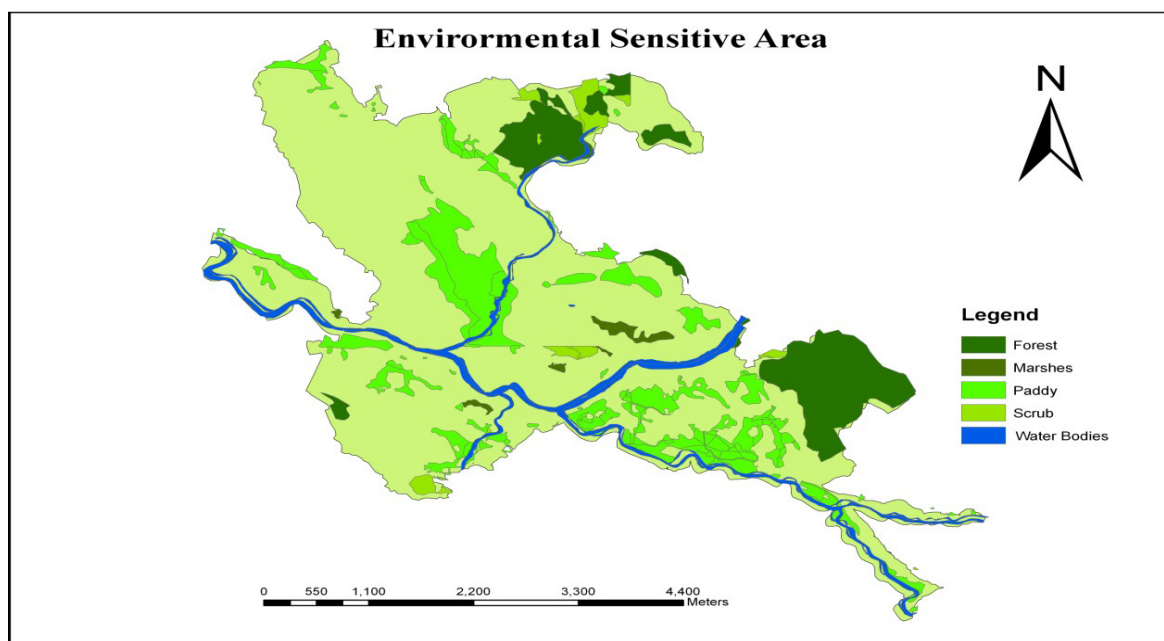
**Flood:** Guidelines for the settlement planning in flood-prone areas can be given as follows<sup>6</sup>: i. Settlement should be strictly avoided in the prohibited zone. ii. Settlement should not be promoted and encouraged in the restricted zone, iii. Construction of river banks or raising the levels of existing riverbanks should be done to prevent flood of dense settlements in urban areas after assessing their vulnerability.

**Distance to Environmental Sensitive Areas:** According to the **National Environmental Act No 47 of 1980**, environmental sensitive areas such as Marshes, mangroves, water bodies, forest patches, paddy land, and coastal belt must be protected, managed and enhanced<sup>7</sup>.



Source: Urban Development Authority, 2004.

**Figure-7: Flood Map.**



Source: Urban Development Authority, 2004 & Survey Department, 2000.

**Figure-8: Environmental Sensitive Map.**

**Weighting Factor Using AHP Technique:** AHP is a decision making technique developed by Thomas L. Satty in 1980 and based on a “pair-wise comparison” matrices which compare all the factors to one another. It is a measurement model theory that ranks the hierarchy and consistency of judgmental data provided by a group of multiple experts and decision makers. AHP can be

used to systemize complicated problems and dissolve these factors into different levels from various directions<sup>8</sup>.

The AHP has three basic steps for decision making as following.

#### Arrange factors in a structural hierarchy

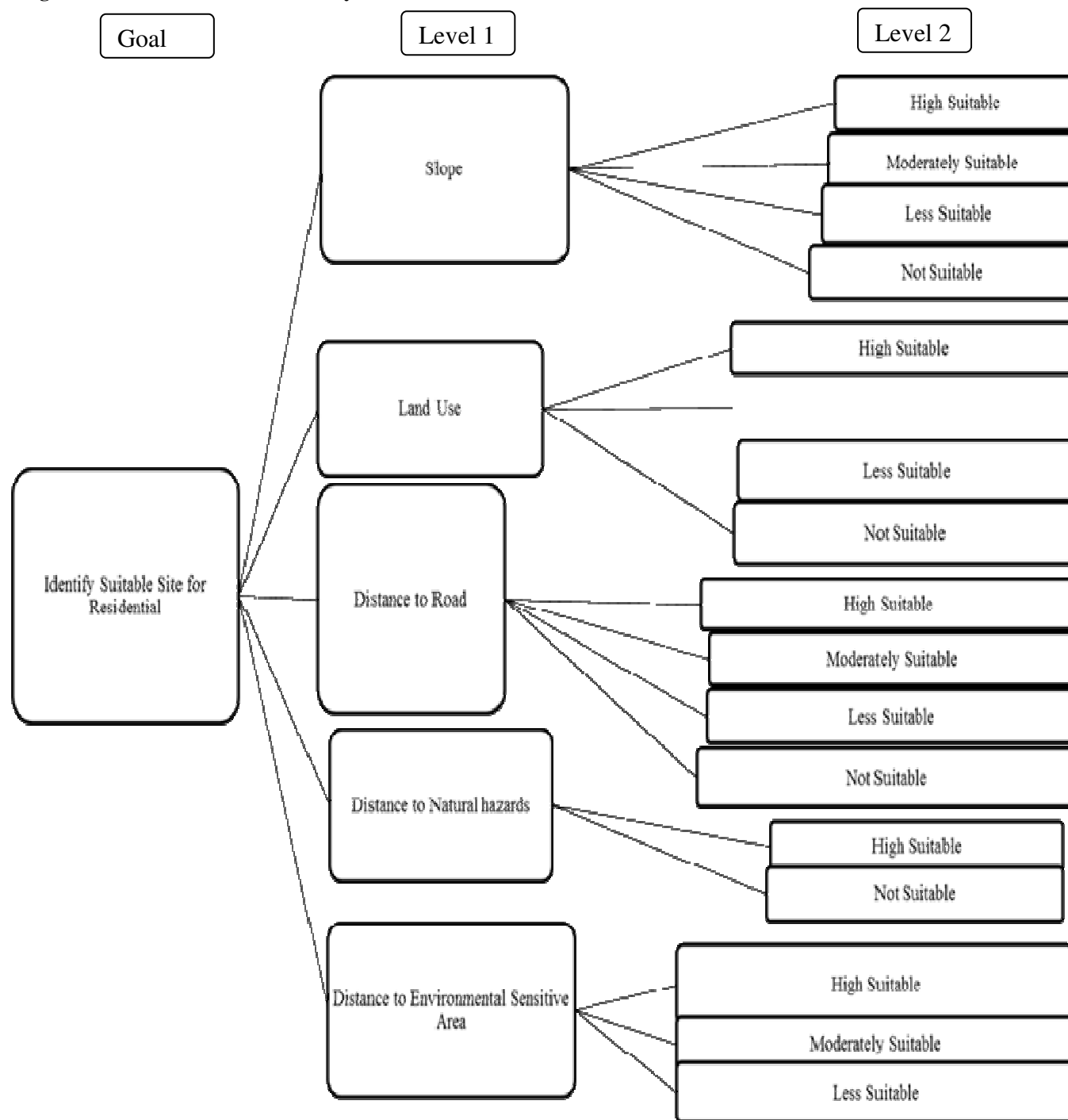


Figure-9: Structural Hierarchy.

The selected factors were arranged in a multilevel hierarchical decision structure as shown in Figure-9. This structure represents the ultimate objective of the decision making process. The major selected factors were placed in the first level of the hierarchy structure.

**Establishment of comparison judgments:** AHP was used to determine weights of each factor. AHP works by developing priorities, which are derived for the factors in terms of their importance to achieve the goal. The priorities, are derived based on pair wise assessments<sup>9</sup>. The pair wise ratings were determined on a nine (9) degree which is illustrated in Table-2.

**Table-2:** Scale of Importance between Two Criteria.

Degree	Description of pair wise comparison judgment
1	Criterion i is equally important as Criterion j
3	Criterion i is moderately more important as Criterion j
5	Criterion i is strongly more important as Criterion j
7	Criterion i is very strongly more important as Criterion j
9	Criterion i is extremely more important as Criterion j
2,4,6,8	The important is between the two degrees

Source: Saaty T.L., 1980.

The relative importances of the selected parameters were achieved by consulting and surveying the opinions of 20 experts who are having the special experiences in residential development in the Ratnapura MC area. A semi structured questionnaire was designed to guide the experts to offer their opinions according to the hierarchical model constructed. MATLAB7.0 (Mathematical software) was used to calculate the weight of factors. The results of this procedure are indicated in Table-3.

**Table-3:** Weight Calculated by AHP.

Factors	Weight
Slope	0.2883
Land Use	0.0545
Distance to Road	0.1546
Distance to Natural Hazards	0.3038
Distance to Environmental Sensitive Areas	0.1989

The next stage of AHP analysis, the consistency must be tested to verify the reliability of the judgment of the experts. The

calculated Consistency Ratio is 0.06, if  $CR \leq 0.10$  the ratio indicates a reasonable level of consistency in the pair-wise comparisons.

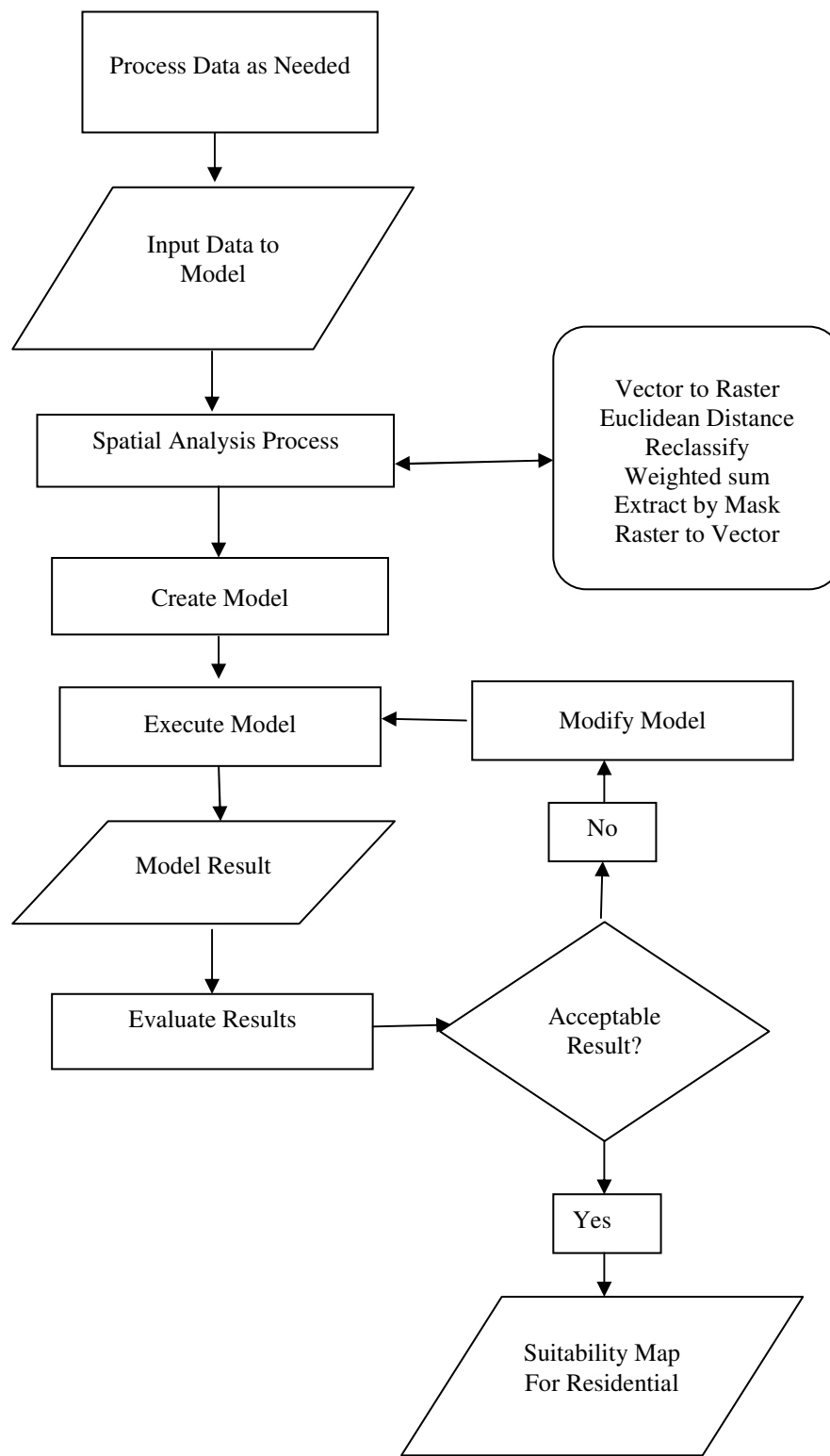
**Standardize the values of the parameters:** Before applying weights to factors, suitability levels are calculated and these level scores are standardized to 0 (Not Suitable) 1 (Less Suitable), 3 (Moderately Suitable) and 5(High Suitable). Scores for the attribute values of taking are also decided by the summarization of expert opinion as seen in Table-4.

**Table-4:** Score Attribute.

Factor	Attribute value of Factor	Suitability
Slope	< 20°	5
	20° - 40°	3
	40°-60°	1
	>60°	0
Land Use	Coconut	1
	Forest	0
	Residential	3
	Marsh Land	0
	Other Cultivation	5
	Paddy	0
	Play ground& Parks	0
	Rubber	1
	Scrub Land	0
	Stream	0
	Tea	1
	Water Bodies	0
Distance to Road	0-500m	5
	500-1000m	3
	>1000m	1
Distance to Natural hazardous Area	Highly risk	0
	Moderately	3
	No risk	5
Distance to Environmental Sensitive Area	0-100m	1
	100-200m	3
	>200m	5



**Developing GIS Model and Suitability Map:** In this paper spatial analysis tool was used using in (Arc GIS 9.3) Model Builder in Figures-10. In model builder processes, following steps were included:



**Figure-10:** GIS Analysis Process.

Then the overlay process in GIS was used to combine the factors and constraints in the form of a Weighting Overlay process. The results were then summed up producing a suitability map as shown by the formula<sup>10</sup>;

$$\text{Suitability Map} = \sum [\text{factor} (C_n) * \text{weight} (W_n) * \text{constraint} (b_0/1)]$$

Where:  $C_n$  = standardised raster cell,  $W_n$  = weight derived from AHP,  $b_0/1$  = Boolean map with values 0 or 1.

Figure-11 represents the suitability analysis model in ArcGIS 9.2. The model can be modified in to two ways: i. Adding data

layers and the defining suitability factors for the analysis, ii. Changing weight in the model for better land use planning priorities and perspectives in a particular jurisdiction.

## Results and discussion

The result of this study showed that out of the total area of 22.2 km<sup>2</sup>, 41.96% (8.9km<sup>2</sup>) of the area is most suitable for residential development, 15.03% (4.28km<sup>2</sup>) is moderately suitable for residential development and 43.02 % (9.11km<sup>2</sup>) of the area is unsuitable for residential development (Table-5).

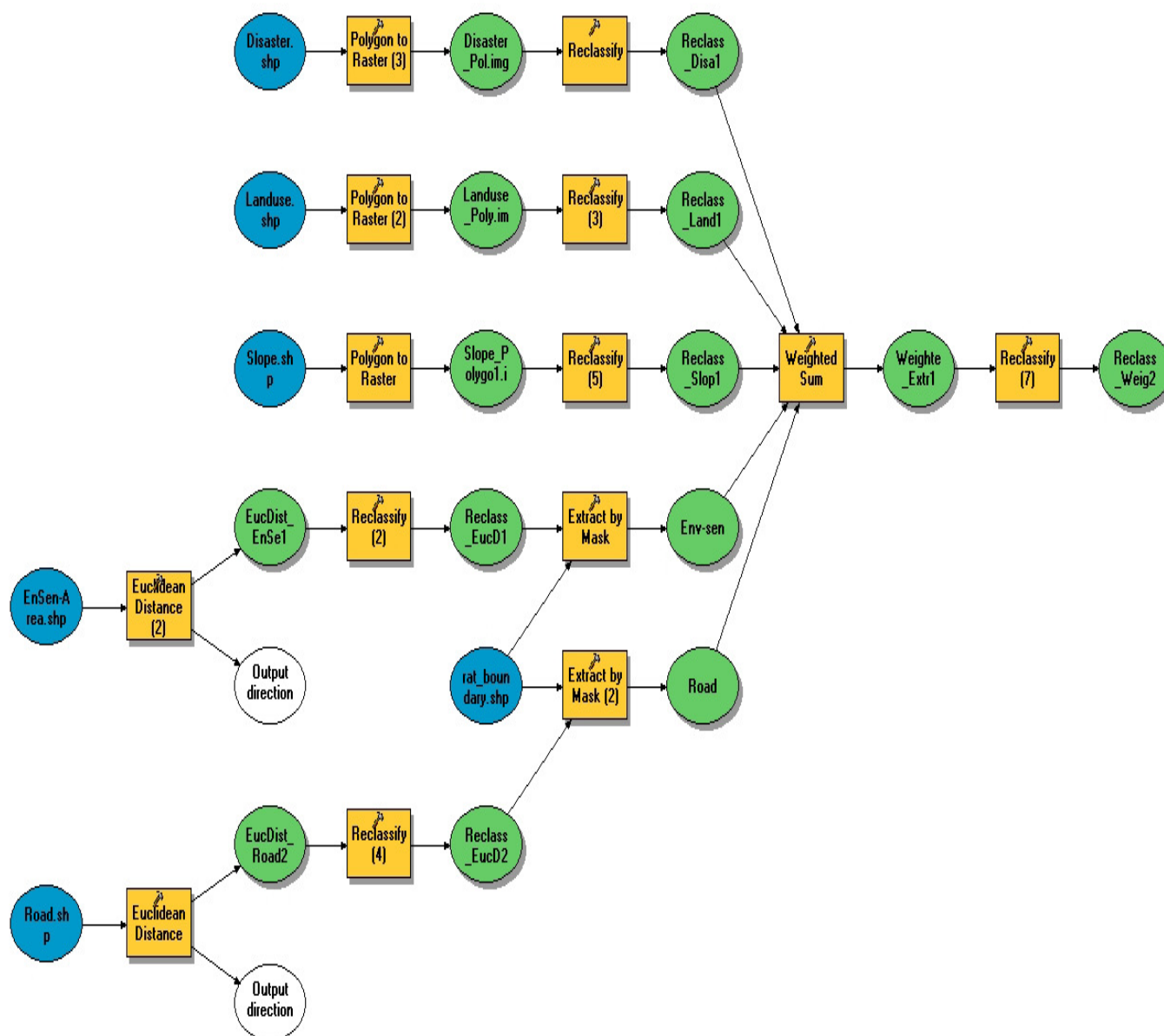
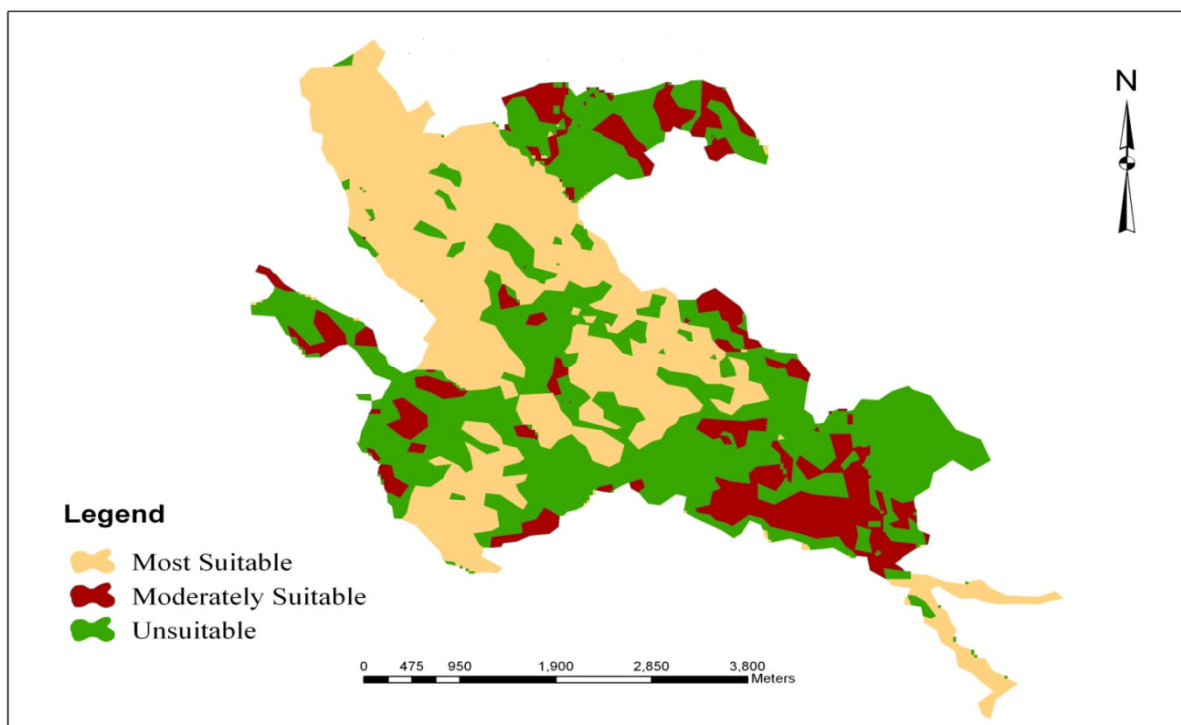


Figure-11: Flow Chart of GIS Model running in ArcGIS.



**Figure-12:** Suitability Map.

**Table-5:** Residential Suitability Area.

Suitability	Area	Percentage
Most Suitable	8.9Km <sup>2</sup>	42%
Moderately Suitable	4.28Km <sup>2</sup>	15%
Unsuitable	9.11Km <sup>2</sup>	43%

of comparing the existing land use with the suitability map, 26% of optimum area for residential development covers Vacant Lands, Abundant Paddy, Cultivation, Commercial and Government institute and Residential (Table-6). Hence these areas can be used for residential development activities. Forest, paddy and marsh land classes excluded from the proposed area of residential development.

## Conclusion

Residential site selection is one of the major tasks of urban planners as this is very important for residential development. Although, Town Planners of Rathnapura have conducted similar exercises in the past decades using manual methods, the GIS can perform these complicated tasks much faster and reliable way. The combination of AHP method with GIS is very sophisticated in urban planning. The outcome of this study also showed that integrated evaluation of urban development could be conducted in an efficient way using, GIS spatial analysis technique and AHP method.

In this study, a GIS model was developed to evaluate the suitable sites for residential purposes in the Rathnapura MC Area. As main finding of the this study is that only 42 % land areas are suitable for residential occupation meanwhile 43% is not suitable for development of residential activities, researchers can be overlooked the how hazard will be occurred in the unsuitable spatial location in each year in Rathnapura MC. This model is suitable not only for the study area; it is also supportive for Town Planners of every city planning projects all over in Sri

**Table-6:** Field Verification.

Existing Situation	Percentage
Residential	16%
Vacant Land, Abundant Paddy, Cultivation,	9%
Government institute & Residential	12%
Commercial	5%
Total	42%

Finally, the results were verified with the existing field reality. An evaluation of existing residential areas in Rathnapura Municipality is 37.1% out of the total area. Most of these lands are slope, vulnerable to floods and landslides. An overlaying this suitability map and the existing residential zone show that around 16% of area is located on most suitable areas. As a result

Lanka. Integrating GIS and AHP served as a decision support system for residential site selection. This system will assist Town Planners and Decision Makers for taking actions on various decisions at different levels. The future urban planning would be better guided to sustainable and safer residential locations.

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