# RESIDENTIAL LAND SUITABILITY MODEL FOR RESETTLEMENT PLAN OF ENVIRONMENTAL IMPACT ASSESSMENT A CASE STUDY – KALU GANGA DEVELOPMENT PROJECT

**S.M.D. Samarakoon[1], Jagath Gunatilake[1,2] and K.K.S.A. Withanage[1]**

[1]Postgraduate Institute of Science, University of Peradeniya, Peradeniya, Sri Lanka
Email:**deepthisamarakoon@gmail.com**
Email:amindika.kks@gmail.com
[2]Department of Geology, University of Peradeniya, Peradeniya, Sri Lanka
Email:jagathpgis@gmail.com

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## ABSTRACT

Kalu Ganga Environmental Impact Assessment (EIA) project is a part of one of the major agricultural development projects started in 2006, which comes along with the Mahaweli Development Projects launched by Mahaweli Authority of Sri Lanka. Resettlement is a very complicated process due to real world complexities. Most of the resettlement sites choose according to the availability of lands. But according to legal acts and policies, the lives of affected people should be better off than they were before. So this contradictory situation has created long term effects on people as well as environment in the past. This study is an attempt to integrate Geographic Information Systems (GIS) and resettlement process under EIA to minimize the social and environmental impacts, to design a methodology of GIS-based residential land suitability assessment, to identify the most suitable residential areas and to integrate GIS and community participation in the resettlement process. The study area was in Laggala Pallegama Divisional Secretariat Division in Matale District. The tool spatial analyst used to perform a multi criteria analysis through model builder in Arc GIS 9.3. Fourteen parameters selected for the model as, slope, landslide susceptibility, water reservation, water availability, mineral resources, road reservation, road accessibility, soil type, hazard prone areas, forest reservation, service centers, land use, archaeological sites, and community participation. With the guidance of subject specialist and legal aspects different weights and influences were decided for each parameter of the model. Also, the Information Value Method (IVM) used to find landslide susceptibility. Most of the data layers were derived from 1: 10, 000 topographic maps. Accordingly, the study reveals that 2%, 14%, 65%, 17%, and 2% found as highly, moderately, low, very low and not suitable for residential lands respectively. Most suitable areas are laid in the South East area of the resettlement area. Thus, this integration of EIA and GIS gives a contribution in decision making, while minimizing social and environmental impacts.

## INTRODUCTION

Identifying suitable housing areas is being very important for future development in every aspect. According to World Bank (2013), population of Sri Lanka was 20.48 million with 0.8% growth rate. To support this population, there are many physical infrastructure development projects concerning the sea, air, road, power and telecommunication of a country. Thus, the demand for land is increasing daily. In this context, it is very important to find residential suitable areas to resettle the affected people from the development projects in Sri Lanka.

Land Evaluation has become more important as people strive to make better use of the limited land resources. It is the process of assessing land performance for specified purposes (Rossiter, 1996). Residential Land Suitability Model (RLS) are established to provide a standardized process for modeling residential lands. These models incorporate appropriate suitability factors. Usually, suitability analysis process integrates three factors of an area such as location, development activities, and environmental processes. Using this modeling approach, lands are assigned relative values depending on how well they provide the requisites. The present generation of GIS is used to support these strategic planning processes in different ways. It is designed for the acquisition, management, analysis and display of geo referenced data. Multi Criteria Decision Analysis (MCDA) provides procedures for structuring decision problems, and designing, evaluating and prioritizing alternative decisions. The incorporation of multi-criteria evaluation methods into GIS has emerged as a promising research area attracting many planners and managers (Svoray, 2005). In any

development project, there are some negative impacts too. For an example, under the Mahawali Development Project, which is the Sri Lanka's biggest agricultural development project, resettlement has been done at a larger scale, creating some major social and environmental problems, such as recording high rates of suicides due to lack of social cohesion and human elephant conflicts.

Environmental Impact Assessment (EIA) is an internationally accepted transparent process to predict and identify potentially significant environmental impacts of development proposals and to suggest mitigation measures to minimize the negative impacts and to maximize the positive impacts. Social Impact Assessment (SIA) is the assessment of the social impacts of a development project on society which consists of people and their economic, social, cultural, religious and political activities which comes along the EIA process. Development induced displacement and resettlement is a common phenomenon in any EIA and then SIA process.

With all these concerns, main objectives of this study are, to create a GIS based model through multi criteria analysis to select the most suitable residential land areas over a designed resettlement area and to integrate EIA, SIA and GIS while minimizing social and environmental negative impacts of the Kalu Ganga Agricultural Development project.

## METHODOLOGY

### Study Area - Kalu Ganga Agricultural Development Project, Matale District

This study aims to select the most suitable residential areas within the selected resettlement area declared by the EIA project and Mahawali Authority of Sri Lanka (MASL). The study area is laid in the downstream areas of Kalu Ganga reservoir in Laggala Pallegama DS division (Figure 1). Two resettlement areas have been proposed as left bank (9 $km^2$) and right bank (22 $km^2$) of the river in Laggala Pallegama DS Division. Based on these areas, the study area of this research is selected by overlying the 21 neighboring *Grama Niladari* (GN) Divisions. This whole area consists of 168 $km^2$ of land.

### Residential Land Suitability (RLS) Assessment Procedure

RLS analysis involves the application of various relevant criteria to assess where land is most and least suitable for residential areas. The following steps (Figure 2) have followed to perform the RLS model in this research.

**Table 1: Sources of maps used for the study**

| No | Map title | Source |
|---|---|---|
| 1 | 1:10000 topographic maps | The Department of survey, Sri Lanka |
| 2 | Landslide Hazard Prone Map | The *National Building Research Organization* (*NBRO*), Sri Lanka |
| 3 | Soil Map | The Department of Agriculture, Sri Lanka |
| 4 | Geology | The *Geological Survey and Mines Bureau* (*GSMB*), Sri Lanka |
| 5 | Mineral Resources | Kalu Ganga EIA Report, MASL, 2007 |
| 6 | New townships (Service Centers) | Kalu Ganga EIA Report, MASL, 2007 |
| 7 | Archaeological Sites | Kalu Ganga EIA Report, MASL, 2007 |

In this research, data analysis was done using Arc GIS 9.3 version. According to legal and institutional aspects, buffer areas are demarcated around certain natural areas. As mentioned below, buffer zones maps and Kernel Density maps were created.

- **Water reservation (Hydrology)**

According to the Land Reclamation Act (1968) and Mahawali Authority of Sri Lanka(MASL) legal documents (1979) the buffer zone distances have considered for the model.

- **Roads - Road reservation**

With reference to National Thoroughfares Act (2008) road buffer zone distances have considered.

- **Forest and Wildlife-- Forest reservation**

According to Flora and Fauna Protection Act (2009) and National Environmental Protection Act (1979) the buffer zone distances have considered for the model.

- **Archaeological sites**

As given by the Protection of Ancient Monuments other than those on Crown Land Act (1947) buffer zone distance away from archaeological sites was selected.

- **Mineral resources**

According to National Gem and Jewelry Authority (NGJA), gem mining is still considered as domestic economic activity. Therefore, there are no major restrictions, rules and regulations for residential areas. The distance of constructions is depending on the depth of the mining site. Therefore Geological Surveying and Mines Bureau (GSMB) concerns for sand mining have been considered in this aspect.

- **Soil**

Base map for Soil types has extracted from the Land Use Division, Irrigation Department (1988) Sri Lanka. According to Policy Planning and Resettlement Division of MASL, soil types for residential suitability have decided based on their drained abilities and these situations are considered for the model as Table 2.

**Table 2: Soil types suitability for residential areas**

| No | Soil Type | Suitability Class |
|---|---|---|
| 1 | Miscellaneous land units comprising of Rock knob Plains Erosional remnants with eroded and shallow * | Moderate |
| 2 | Reddish Brown Earths and Immature Brown Loans; rolling hills and steep terrain | High |
| 3 | Reddish Brown Earths and Low Humic Gley Soils; undulating terrain | Low |

- **Landslide prone areas**

Landslide prone areas have extracted from the landslide prone areas map of NBRO (Landslide studies and Service Division, 2000). The available hazard prone areas are assigned into suitability classes for residential areas as they are appeared according to the intensity of hazardous.

- **Land Use**

According to Policy Planning and Resettlement Division of MASL and their expertise knowledge, some special Land Use parcels have considered for the model.

- **Slope**

According to Policy Planning and Resettlement Division, the following slope angles and their suitability classes have decided for the model. Surface analysis in spatial analyst tool is performed to get the output slope raster layer, which can be calculated in two types of units, degrees or percent (called 'percent rise'). Slope percent is considered for this analysis. To calculate percent slope from contour layer, divide elevation change by the distance between two contour lines. Multiply the resulting number by 100 to get a percentage value equal to the percent slope of the hill. In this study area, contour lines are positioned from 100 m to 700 m by the distance of 10 m contour interval. Therefore, elevation change equals to 10 m and distance of the lines varies from place to place.

- **Density of water availability (Hydrology Density)**

Through Kernel Density analysis, density of water availability, hydrology density map has created. This map shows the water surface variations in densities of the respective areas. Accordingly, the output map is classified. If water density is too high= 1 (low suitability), water density is too low= 5 (very low suitability).

- **Road density**

Residential suitability of road density map was created using 6 classifications. Moderately accessible areas are considered as the most suitable areas for residential areas.

- **Service centers**

Service centers are mainly considered, on their accessibility in selection of residential suitability. Decisions taken from MASL, resettlement Division and EIA report are also taken into consideration in this attempt. Accordingly, after calculating the Kernel Density of service centers, the classified output layer is divided into following suitability classes.

- **Landslide susceptibility**

Final Land susceptibility map has obtained by using the statistic method called Information Value Method (IVM) analysis. The IVM model was used to determine the information value of each category of the factors and the total information value of each grid cell of the area. The more the total information value the more is the degree of landslide susceptibility. This method is used to analyze landslide susceptibility through GIS for the model. Landslide prone areas map with the six thematic data layers (Slope, Slope aspect, Soil, Hazard prone areas, Land use, Geology structure, Geology) were the input data layers for spatial analysis in GIS.

- **Community participation**

Accordingly, affected people's preference locations are taken to perform Kernal Density analysis to find the most liked places by the resettles. Social impact assessment is one of the major components in EIA process. Therefore, Kalu Ganga project has paid special attention for affected people's preferences in the selection of resettlement areas through the EIA study (2006) With reference to the primary data collection obtained from the questionnaire, interviews of the Kalu Ganga EIA report and affected people's preferences are considered for this data layer.

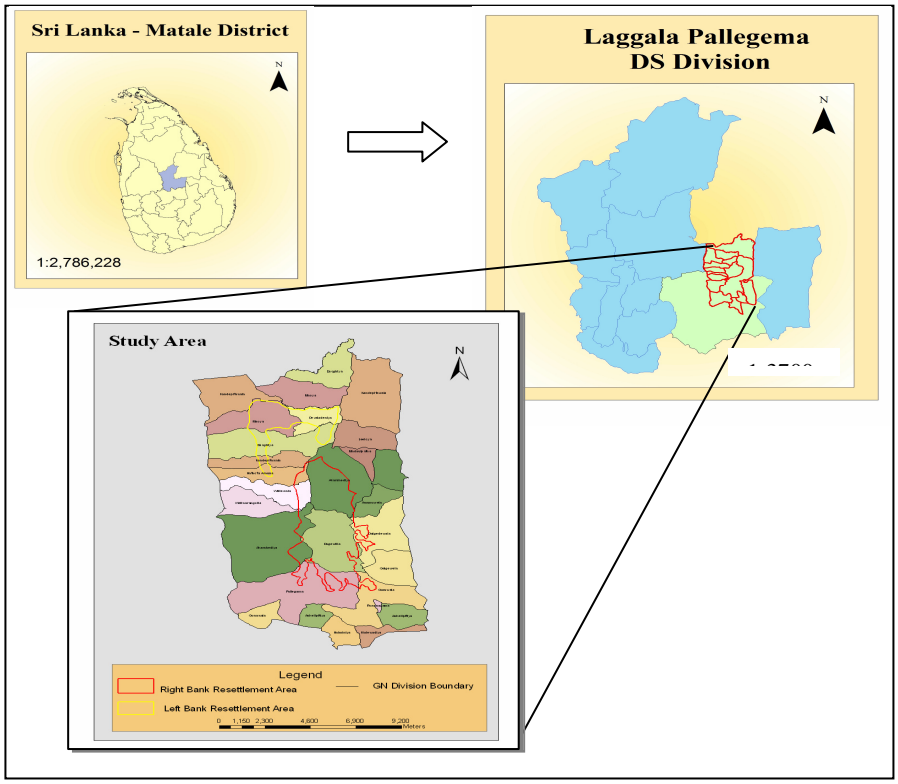


**Figure 1: Map of the Study Area and Resettlement areas in Kalu Ganga Agricultural Development Project**

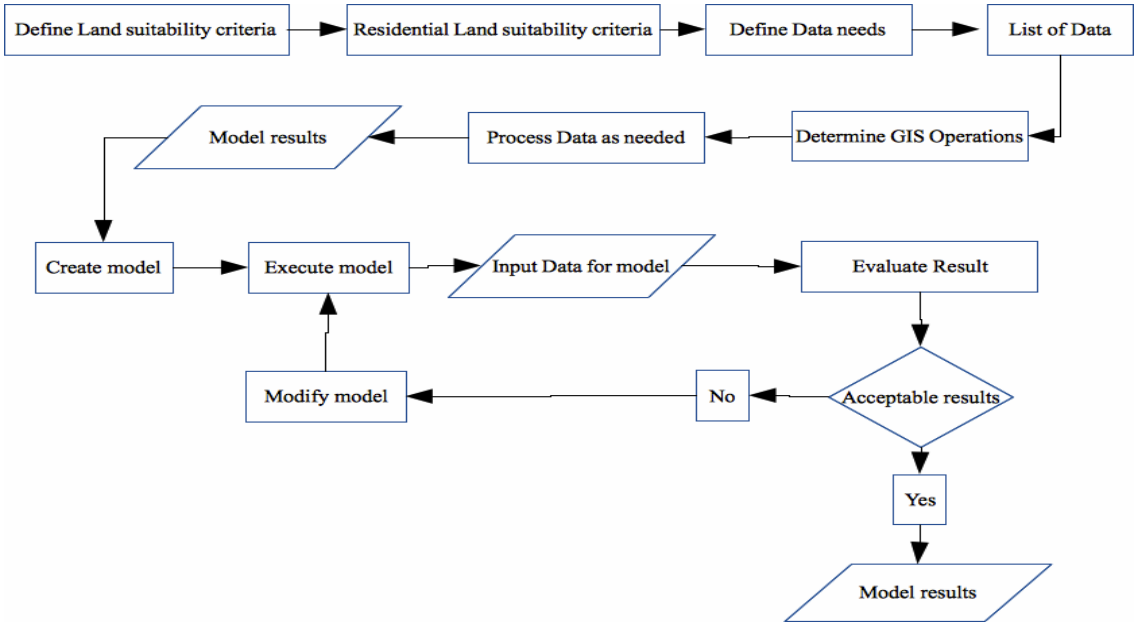


**Figure 2: Residential Land Suitability Analysis**

**Multi Criteria Analysis and Weighted Overlay**

Once the relevant criteria are decided as mentioned above, the weighted overlay and the influence for each type of criteria are performed according to their importance in selecting residential areas. All the fourteen input raster layers are reclassified into a common suitability scale from 1 to 5 as shown in Table 3.

**Table 3: Weight scale**

| Suitability class | Weight |
|---|---|
| High | 5 |
| Moderate | 4 |
| low | 3 |
| Very low | 2 |
| Not | 1 |

The determined criteria and weights that were used for the layers selected, of the GIS model are shown in Table 4. After assigning weights, influence percentage is set with an assumption of that all the criteria are equally important to select these residential lands. Then, the sum of weights is calculated to integrate all the criteria, and to get the final out put raster map. This raster layer is classified to show the most suitable residential land plots with reference to the given weight scale as in Table 3.

Through model builder tool in Arc GIS, multi criteria analysis has performed and run to get the final residential suitability map.

**Table 4: Criteria and Weights**

| Layer name | | Suitability | Weighting |
|---|---|---|---|
| • Slope | **Slope angle categories (%)** | | |
| | <8 | Very low | 2 |
| | 8-16 | High | 5 |
| | 16-30 | Moderate | 4 |
| | 30-60 | low | 3 |
| | >60 | Not | 1 |
| • Land Slide Susceptibility | **Classified classes** | | |

| | | | |
|---|---|---|---|
| Moderate<br>Low<br>Very low<br>least | 1 | Not | 1 |
| | 2 | Very low | 2 |
| | 3 | Low | 3 |
| | 4 | Moderate | 4 |
| | 5 | High | 5 |
| • Hydrology Buffer Zones | **Width of rivers and streams (m)** | | |
| | <3 or 3 | Not | 1 |
| | 15-23 | Not | 1 |
| | 23 | Not | 1 |
| | Reservoirs/lakes | Not | 1 |
| • Hydrology Density Layer | **Density classes** | | |
| | 1 | Low | 3 |
| | 2 | High | 5 |
| | 3 | High | 5 |
| | 4 | Moderate | 4 |
| | 5 | Very low | 2 |
| • Mineral Resources | **Multiple buffer** | | |
| • Brick | 1000 | Very low | 2 |
| | 2000 | Moderate | 4 |
| • Gem | 100 | Not | 1 |
| | 1000 | Low | 3 |
| | 2000 | Moderate | 4 |
| • Sand | 1000 | Not | 1 |
| | 2000 | Moderate | 4 |
| • Road Buffer Zones | **Buffer (m)** | | |
| B Secondary/ minor road | 12 | Not | 1 |
| C Jeep/cart track | 7.5 | Not | 1 |
| D Foot path | 7.5 | Not | 1 |
| B Proposed Road | 12 | Not | 1 |
| • Road Density Map | **Density classes** | | |
| | 1 | Very low | 2 |
| | 2 | Low | 3 |
| | 3 | Moderate | 4 |
| | 4 | High | 5 |
| | 5 | High | 5 |
| | 6 | Moderate | 4 |
| • Soil | **Soil type** | | |
| | 1 | Moderate | 4 |
| | 2 | High | 5 |
| | 3 | Low | 3 |
| • Hazard Prone Areas | **Hazard prone areas** | | |
| | Land slide prone | Not | 1 |
| | Likely to happen | Very low | 2 |
| | Safer areas | High | 5 |
| | Moderate | low | 3 |
| • Service Centers<br>Sub post office<br>Schools<br>Police stations<br>Main post office<br>Government buildings | **Density classes** | | |
| | 1 | Low | 3 |
| | 2 | Moderate | 4 |
| | 3 | High | 5 |
| | 4 | High | 5 |
| | 5 | High | 5 |

| | | | |
|---|---|---|---|
| • Land Use | **Land Use type** | | |
| | Cemetery | Not | 1 |
| | Chena cultivation | moderate | 4 |
| | Home gardens | High | 5 |
| | Paddy | Not | 1 |
| | Rock | Low | 3 |
| | Scrub land | High | 5 |
| • Archaeological Sites | **Sites (Buffer distance)** | | |
| | 1 | Not | 1 |
| | 2 | Not | 1 |
| | 3 | Not | 1 |
| | 4 | Not | 1 |
| | 5 | Not | 1 |
| | 6 | Not | 1 |
| | 7 | Not | 1 |
| | 8 | Not | 1 |
| | 9 | Not | 1 |
| • Community Participation | | | |
| | 1 | Low | 3 |
| | 2 | Low | 3 |
| Generally like | **3** | Moderate | 4 |
| Mostly like | **4** | Moderate | 4 |
| | 5 | High | 5 |
| | 6 | High | 5 |
| • Forest and Wildlife Reserves | **Buffer distances** | | |
| | Forest (one mile) | Not | 1 |
| | Wildlife (one mile) | Not | 1 |

**RESULTS AND DISCUSSION**

**GIS and Residential Land Suitability (RLS) Model**

After completion of the model, the final out put map (figure 3) displays the most suitable residential land areas in the selected resettlement site. Residential suitability by GN Division is presented in the map (Figure 4).Towards the South and South East are found as highly suitable for residential lands. As most suitable residential areas, Dagawilla, Galgedewala, East Pallegama, Ankelipitiya, Rawaanagama, west Galgewela and Guruwela can be introduced. Areas like, Ankelipitiya, Dasgiriya, Akarahadiya, Halminiya can be considered as moderately suitable for residential lands. Kandepitawala, Haththota Amuna, Wellewala, are not or least suitable for residential lands.

The study area, selected for this research is consisted of 167 $km^2$. Highly suitable for residential lands are 3 $km^2$ followed by are moderately good (23 $km^2$), low suitable (108 $km^2$), very low suitable (28 $km^2$) and not suitable areas (4 $km^2$). As in figure 5 the percentage of most suitable areas for residential lands represent only 2% of the total resettlement area. 65% lies with low suitability. It is followed by, moderate areas 14%, very low areas 17% and not suitable areas 2%.

To obtain a better terrain and proper drainage for residential areas, slope angles from 8% to 30% have taken from the slope map. This area is mostly laid towards the South East and Central parts. North Central part is mainly found with paddy lands, which is below 8% slope and not suitable for residential lands due to their poor drainage ability. Since this area is consisted of slope terrain landslide risk also can be an impact on residential areas. Therefore, apart from the hazard map, using IVM, susceptibility also has found to minimize the impact. According to these two output maps again South East side is more suitable for residential lands. To avoid those areas, given a lower weight because of the risk. As a result most of the areas around boundary are more susceptible and risky and considered as lower suitability. Environmentally protected areas like, water bodies, mineral resources, wildlife reserves, forest areas, and archaeological

sites, demarcated buffer zone areas have excluded from residential lands. Hence, all the parameters are given weights and influences to minimize social and environmental impacts, created in the resettlement area for affected people.

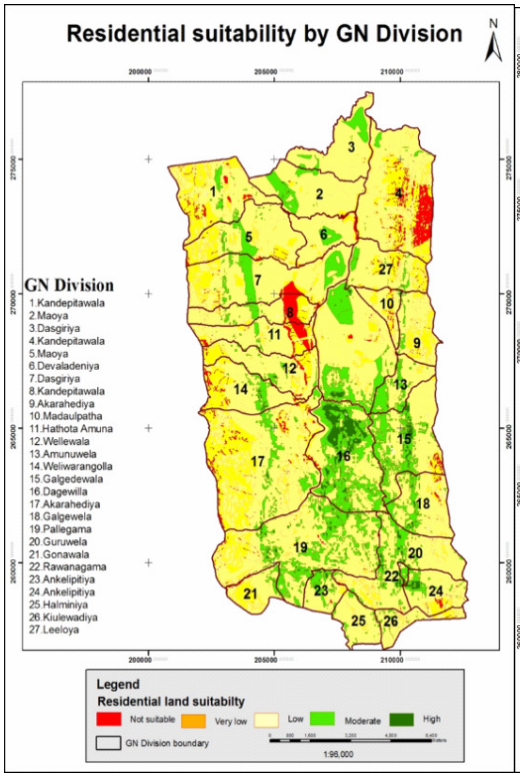


**Figure 3: Residential land suitability map**

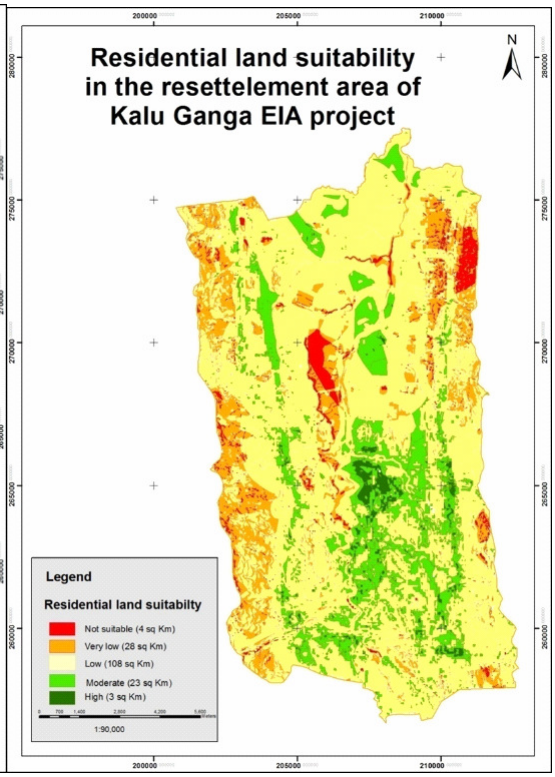


**Figure 4: Residential suitability by GN Division**

In validating the RLS model following comparison was done between the suitability map and slope angle maps (Figure 5). According to the comparison of slope angle and RLS, the slope angle map shows from high to lower slope angle. Out of which slope angles between these two extremes are the best areas for residential lands So that it shows most of the areas are distributed in the Central South with a moderate height and which are most suitable for residential lands. This distribution pattern clearly shows in the suitability map too. Most of the areas towards the Central South are found as the best areas proving the model reliability. As well as considering the , community participation of affected people the overlay of community preference location on to residential land suitability, the distributions of mostly liked places are mainly concentrated in the South East and the Central parts where most suitable areas are also located. About 50% of the generally liked places are also located towards the South East part of the area. At the same time some of the places labeled as Kalu Ganga, Kandagahakaday, and Kandepitawala are located on least or not suitable areas. Thought the community likes to be lived in these areas, if the areas are not suitable to live, these places can be avoided to settle people to make them better-off.

## CONCLUSION

The study area was in Laggala Pallegama Divisional Secretariat Division in Matale District. Based on fourteen parameters for the model as, slope, landslide susceptibility, water reservation, water availability, mineral resources, road reservation, road accessibility, soil type, hazard prone areas, forest reservation, service centers, land use, archaeological sites, and community participation, the RLS model was built for the study area. Accordingly, the study revealed as highly (2%), moderately (14%), low (65%), very low (17%) and not suitable (2%) for residential lands respectively. Most suitable areas are laid in the South East of the resettlement area. Thus, this integration of EIA and GIS gives a contribution in decision making, while minimizing social and environmental impacts.

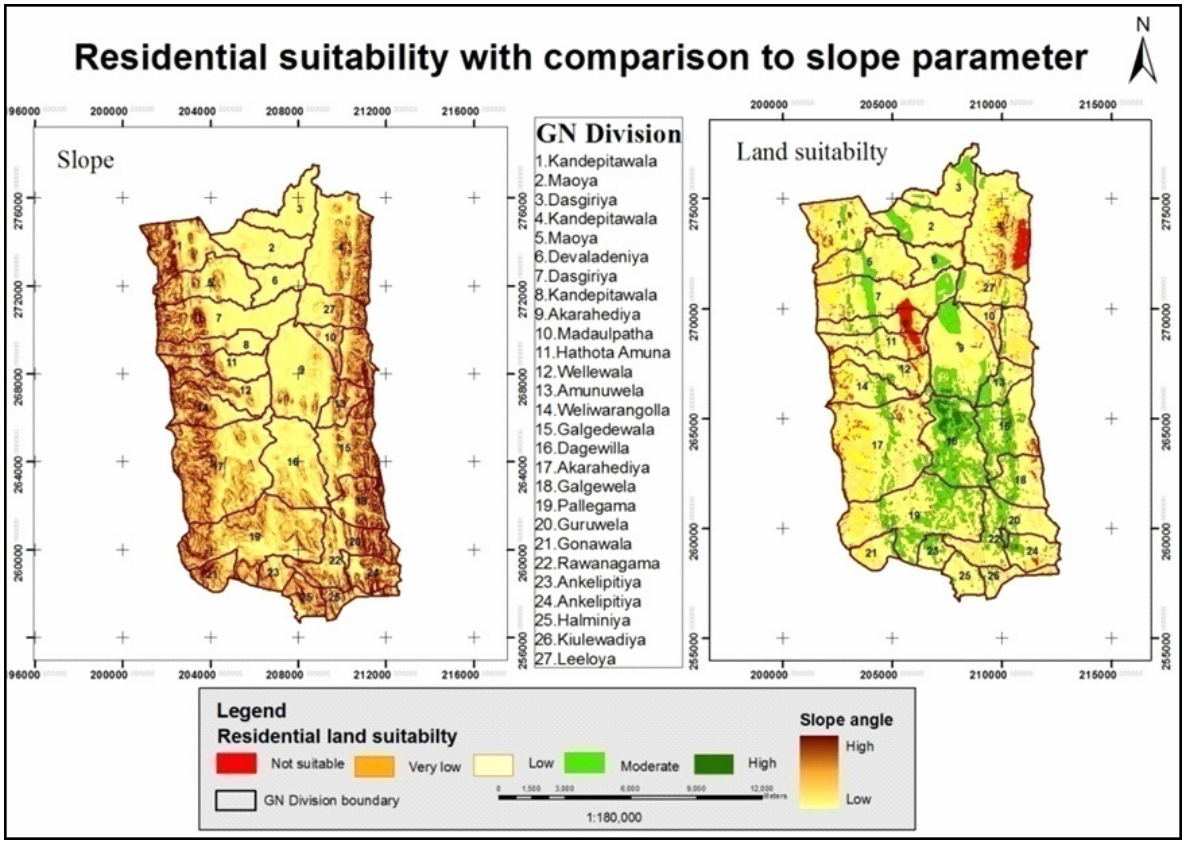


**Figure 5: Residential suitability with comparison to slope parameter**

## FUTURE DIRECTION

However, to get rid of such a complexity automation of Model Builder is possible by using programs run in Arc GIS like Python and VB.net scripts. GIS specialist can create and interface to automate this type of a model. Then that can be used by a layman easily on s user friendly environment. This may be helpful to use model builder widely in EIA projects specially for selecting suitability of a certain factor.

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