Locational Suitability for Residential Development in Kandy District: GIS Based Multi-Criteria Evaluation

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Abstract

The research was carried out with the main objective of evaluating the locational suitability of the residential development in Kandy District using Geographic Information Systems (GIS) integrated Multi-Criteria Evaluation (MCE). Therefore, eight criteria, namely slope, landslide vulnerability, land use, population density, proximity to town centres, proximity to roads, proximity to schools, and proximity to hospitals were used to achieve this objective. Mainly secondary data were used for the study acquired from the Kandy District Secretariat, the National Building Research Organization (NBRO), the Provincial Department of Education Central Province, the Office of Regional Director of Health Services of Kandy and the Survey Department of Sri Lanka. The suitability maps were generated for individual criterion using Arc GIS 10.5 software. The weights for each map were assigned based on the Analytic Hierarchy Process (AHP) method considering the recommendations of four experts of relevant fields. Finally, all the map layers integrated using weighted overlay analysis method and the suitability map was generated. According to the results of the analysis, 512 km^2 of land extent is highly suitable while 666 km^2 of area is suitable for residential development. In addition, another 390 km^2 area could be identified as moderately suitable. On the other hand, 78 km^2 and 260 km^2 of areas are identified as unsuitable and extremely unsuitable for residential development respectively. Hence, the 82.2% of the total land area in Kandy District in suitable (26.8% highly, 34.9% generally and 20.5% moderately suitable) for residential development, and 17.8% of the area is not suitable (13.7% unsuitable and 4.1% extremely unsuitable). Therefore, it is important to consider the areas identified as highly suitable, suitable, moderately suitable, unsuitable and extremely unsuitable, through this study, when planning and developing the residential places for Kandy District to avoid and minimize the problems that occur through unplanned settlements.

***Keywords*:** Analytic Hierarchy Process, Geographic Information Systems, Locational suitability, Multi-Criteria Evaluation, Suitability map

1. Introduction

Locational suitability of residential development plays a vital role for procuring better living standards for all human beings living in each and every corner of the globe. Particularly, environmental and socio-economic factors of the residential area strongly influence to decide the quality of lives of the people.

However, at present, the situation has revolutionarily changed with high demand of land, occurring as a result of increasing of the population, induces people to settle down where they can find plots to build houses without considering its consequences. These unplanned residential developments reversibly influence to make environmental and socio-economic problems such as increasing deep-seated poverty, lack of education, health problems, and inadequacy of existing resources in the area for long term. As a result of that, identifying suitable land areas for residential developments is becoming an absolutely essential practice in the context of regional planning and development.

Therefore, this study was carried out with the purpose of identifying the suitable areas for residential development in Kandy District. Eight different criteria in terms of slope, landslide vulnerability, land use, population density, proximity to town centres, proximity to roads, proximity to schools and proximity to hospitals were selected to identify the suitable area. Secondary data sources were mainly used to acquire the data and a field survey was carried out to do the verifications. While weights were assigned for each criterion following Analytic Hierarchy Process (AHP) method which is on the pair wise comparison, weighted overlay method was used to integrate all the weighted layers and generate the final suitability map.

1.1. Research Objectives

The objective of the research is to identify the suitable and unsuitable areas for residential development in Kandy District using GIS integrated Multi Criteria Evaluation (MCE).

2. Research Methodology

2.1. Data Collecting Methods

The data collection was conducted using secondary data sources and the analysis was performed mainly according to the quantitative methods. The secondary data sources were mainly acquired from the Kandy District Secretariat, the National Building Research Organization (NBRO), the Provincial Department of Education Central Province, the Regional Director of Health Services of Kandy and the Survey Department of Sri Lanka. Population data in 2016 was taken from the Kandy District Secretariat. Base map on landslide prone areas of Kandy District was received from NBRO while land use, contours, town centres and roads of the district were extracted using the 1:50,000 topographic maps published by the Survey Department of Sri Lanka and updated using the Google images. The locational data related to the schools and the hospitals were taken from the Provincial Department of Education Central Province and the Regional Director of Health Services of Kandy respectively. Expert knowledge was used in order to assign the weights for generated maps using above base maps.

2.2. Software Selection

To calculate the weights for the individual classes of the maps and the map layers, and to do the quantitative analysis, Statistical Package for Social Sciences (SPSS) 20 software version was used whereas ArcGIS 10.5 version was used to conduct slope analysis, calculate density of population, calculate euclidean distance from town centres, roads, schools and hospitals, and finally to integrate all the map layers using the weighted overlay method assigning weights.

2.3. Data Processing and Analysing

After collecting the data using above methods and sources, data processing and analysing were conducted using GIS and AHP method.

Slope analysis was done using the contour layers whereas euclidean distances were calculated for road network, town centres, schools and hospitals. Based on the map taken from the NBRO, landslide prone area map was created. Population density was calculated based on the tabular population data which was taken from the Kandy District Secretariat. Land use map was created using topographic maps and Google Images. After that, class maps related to slopes, landslide vulnerability, road network, town centres, schools, hospitals, population and land use types were obtained using created map layers.

In order to assign the weights for the individual classes and map layers according to their relative importance, expert knowledge was used. According to that weights for eight main criteria and each sub criterion of main criterion were calculated based on AHP method which is a pair wise comparison matrix. This method was specifically used for this study because it has more theoretical basis than rating or ranking methods, and this method has widely been used for identifying locational suitability in previous studies. The Table 1 shows pair wise comparison matrix for eight main criterion and Table 2 to Table 9 show the pair-wise matrixes for individual main criteria and its sub criterions.

Table 1: Pair-Wise Comparison Matrix for Main Suitability Criteria

Criteria	Landslide vulnerability	slope	Land use	Proximity to the roads	Proximity to the hospitals	Proximity to town centers	Proximity to the schools	Population density	Weight
Landslide vulnerability	1	1	3	5	5	7	7	7	0.2893
Slope	1	1	3	5	5	7	7	7	0.2893
Land use	1/3	1/3	1	3	3	3	5	5	0.1407
Proximity to the roads	1/5	1/5	1/3	1	3	3	3	5	0.0953
Proximity to the hospitals	1/5	1/5	1/3	1/3	1	3	3	5	0.0758
Proximity to town centers	1/7	1/7	1/3	1/3	1/3	1	3	3	0.0496
Proximity to the schools	1/7	1/7	1/5	1/3	1/3	1/3	1	3	0.0357
Population density	1/7	1/7	1/5	1/5	1/5	1/3	1/3	1	0.0239

Table 2: Pair-Wise Comparison Matrix for Slope

Slope (%)	0-10	10-20	20-30	30-40	>40	Weight
0-10	1	1	1	5	7	0.2994
10-20	1	1	1	5	7	0.2994
20-30	1	1	1	3	7	0.2712
30-40	1/5	1/5	1/3	1	5	0.0942
>40	1/7	1/7	1/7	1/5	1	0.0355

Table 3: Pair-Wise Comparison Matrix for Landslide Vulnerability

Landslide Vulnerability Level	1	2	3	4	Weight
1	1	3	7	9	0.5490
2	1/3	1	5	9	0.2914
3	1/7	1/5	1	7	0.1202
4	1/9	1/9	1/7	1	0.0361

Table 4: Pair-Wise Comparison Matrix for Proximity to Roads

Proximity to Roads (km)	0-1	1-2	2-3	3-4	>4	Weight
0-1	1	3	5	7	9	0.4785
1-2	1/3	1	3	5	9	0.2538
2-3	1/5	1/3	1	5	7	0.1555
3-4	1/7	1/5	1/5	1	7	0.0822
>4	1/9	1/9	1/7	1/7	1	0.0278

Table 5: Pair-Wise Comparison Matrix for Proximity to Hospitals

Proximity to Hospitals (km)	0-2	2-4	4-6	6-8	>8	Weight
0-2	1	3	5	7	9	0.4483
2-4	1/3	1	5	7	9	0.2842
4-6	1/5	1/5	1	7	9	0.1623
6-8	1/7	1/7	1/7	1	9	0.0839
>8	1/9	1/9	1/9	1/9	1	0.0259

Table 6: Pair-Wise Comparison Matrix for Proximity to Town Centers

Proximity to Town Centers (km)	0-2	2-4	4-6	6-8	>8	Weight
0-2	1	3	5	7	9	0.4785
2-4	1/3	1	3	5	9	0.2538
4-6	1/5	1/3	1	5	7	0.1555
6-8	1/7	1/5	1/5	1	7	0.0822
>8	1/9	1/9	1/7	1/7	1	0.0278

Table 7: Pair-Wise Comparison Matrix for Proximity to Schools

Proximity to Schools (km)	0-1	1-2	2-3	3-4	>4	Weight
0-1	1	3	5	7	9	0.4785
1-2	1/3	1	3	5	9	0.2538
2-3	1/5	1/3	1	5	7	0.1555
3-4	1/7	1/5	1/5	1	7	0.0822
>4	1/9	1/9	1/7	1/7	1	0.0278

Table 8: Pair-Wise Comparison Matrix for Population Density

Population Density (km^2)	< 300	300-1000	1000-2000	2000-3000	>3000	Weight
< 300	1	5	7	9	9	0.4888
300-1000	1/5	1	7	9	9	0.2615
1000-2000	1/7	1/7	1	9	9	0.1485
2000-3000	1/9	1/9	1/9	1	9	0.0749
>3000	1/9	1/9	1/9	1/9	1	0.0253

Table 9: Pair-Wise Comparison Matrix for Land Use

Land use	Coconut	Chena	Forest	Home garden	Paddy	Tea	Rubber	Reservoir	Scrub	Stream	Tank	Rock	Other	Weight
Coconut	1	1/3	9	1/5	1	1	1	9	1/7	9	9	9	9	0.0875
Chena	3	1	9	1	3	5	5	9	1/3	9	9	9	9	0.1472
Forest	1/9	1/9	1	1/9	1/7	1/5	1/5	1	1/5	1	1	1	1	0.0166
Home garden	5	1	9	1	5	7	7	9	1/3	9	9	9	9	0.1753
Paddy	1	1/3	7	1/5	1	3	3	9	1/7	9	9	9	9	0.0966
Tea	1	1/5	5	1/7	1/3	1	1	9	1/7	9	9	9	9	0.0770
Rubber	1	1/5	5	1/7	1/3	1	1	9	1/7	9	9	9	9	0.0770
Reservoir	1/9	1/9	1	1/9	1/9	1/9	1/9	1	1/7	1	1	1	1	0.0145
Scrub	7	3	5	5	7	7	7	7	1	7	7	7	7	0.2505
Stream	1/9	1/9	1	1/9	1/9	1/9	1/9	1	1/7	1	1	1	1	0.0145
Tank	1/9	1/9	1	1/9	1/9	1/9	1/9	1	1/7	1	1	1	1	0.0145
Rock	1/9	1/9	1	1/9	1/9	1/9	1/9	1	1/7	1	1	1	1	0.0145
Other	1/9	1/9	1	1/9	1/9	1/9	1/9	1	1/7	1	1	1	1	0.0145

Consistency Ratio (CR) related to the suitability criteria and sub-criteria was calculated using the following equation.

$$CR = \text{Consistency Index (CI)} / \text{Random Consistency Index (RI)}$$

Saaty (1980) proved that for consistent reciprocal matrix, the largest Eigen value is equal to the number of comparisons, or $\lambda_{max} = n$ Then he gave a measure of consistency, called Consistency Index as deviation or degree of consistency using the following formula.

$$CI = (\lambda_{max} - n) / n - 1$$

λ_{max} is the Principal Eigen Value; n is the number of factors

$\lambda_{max} = \Sigma$of the products between each element of the priority vector

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

and column totals

Random Consistency Index (RI)

Source: Saaty (1980)

As shown in the Table 10, the CR values calculated related to the overall context and sub-criteria are less than 0.1. The fulfilling the condition of $CR<0.1$ proves that the assigned weights are within the acceptable range.

Finally, the weighted overlay method was used to integrate all layers into one and generate the suitability map for residential development in Kandy District. In this case, the calculated weights using AHP method were multiplied by 100 to convert the decimal values to integers. That is because the weighted overlay method only accepts integer values. The weights used for the study are shown in the Table 11.

Table 10: Consistency Ratio Related to Criteria and Sub-Criteria

Criteria	CR Value
Overall suitability criteria	0.095
Slope	0.053
Landslide Prone Areas	0.023
Proximity to Roads	0.019
Proximity to Hospitals	0.038
Proximity to Town Centers	0.019
Proximity to Schools	0.019
Population Density	0.060
Land Use	0.017

After the entire process, a model was created to identify suitable areas for residential development in Kandy District. The map indicates the highly suitable areas, suitable areas, moderately suitable areas, unsuitable areas and extremely unsuitable areas. Further, a comparison was conducted in terms of the DSDs (Figure 1).

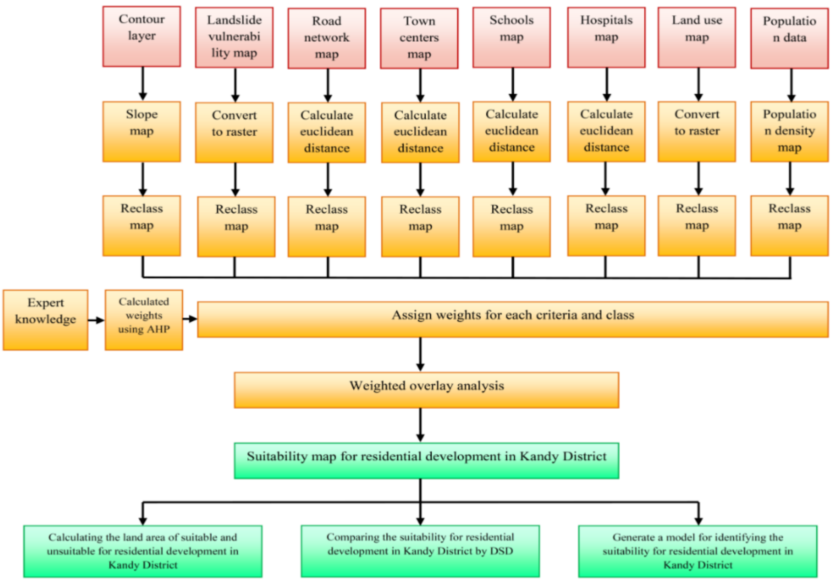

Figure 1: Data Processing and Analysing Method of the Study

Table 11: Weights for Each Criterion

No.	Criteria	Weight on each criteria	%	Sub Criteria	Weight	%
i	Landslide vulnerability	0.29	29%	1	0.55	55%
				2	0.29	29%
				3	0.12	12%
				4	0.04	4%
ii	Slope	0.29	29%	0-10 %	0.30	30%
				10-20 %	0.30	30%
				20-30 %	0.27	27%
				30-40 %	0.09	9%
				>40 %	0.04	4%
iii	Proximity to roads	0.10	10%	0-1 km	0.48	48%
				1-2 km	0.25	25%
				2-3 km	0.16	16%
				3-4 km	0.08	8%
				>4 km	0.03	3%
iv	Proximity to hospitals	0.08	8%	0-2 km	0.45	45%
				2-4 km	0.28	28%
				4-6 km	0.16	16%
				6-8 km	0.08	8%
				>8 km	0.03	3%
v	Proximity to town centers	0.05	5%	0-2 km	0.48	48%
				2-4 km	0.25	25%
				4-6 km	0.16	16%
				6-8 km	0.08	8%
				>8 km	0.03	3%
vi	Proximity to schools	0.04	4%	0-1 km	0.48	48%
				1-2 km	0.25	25%
				2-3 km	0.16	16%
				3-4 km	0.08	8%
				>4 km	0.03	3%
vii	Population density (population per km^2)	0.02	2%	< 300	0.49	49%
				300-1,000	0.26	26%
				1,000-2,000	0.15	15%
				2,000-3,000	0.07	7%
				>3,000	0.03	3%
viii	Land use	0.13	13%	Coconut	0.09	9%
				Chena	0.15	15%
				Forest	0.02	2%
				Home garden	0.18	18%

	Paddy	0.10	10%
	Tea	0.08	8%
	Rubber	0.08	8%
	Reservoir	0.01	0%
	Scrub	0.25	25%
	Stream	0.01	0%
	Tank	0.01	0%
	Rock	0.01	0%
	Other	0.01	0%

3. Results and Discussion

3.1. Suitability for Residential Development Based on Slope

According to the Digital Elevation Model (DEM) generated using contours, the elevation varies from 61 m to 1,859 m. The highest elevation records from the Knuckles mountain region lies in the Northern part of the Eastern half of the district. Despite this, the South Western part of the district shows comparatively ahigher elevation (Figure 2).

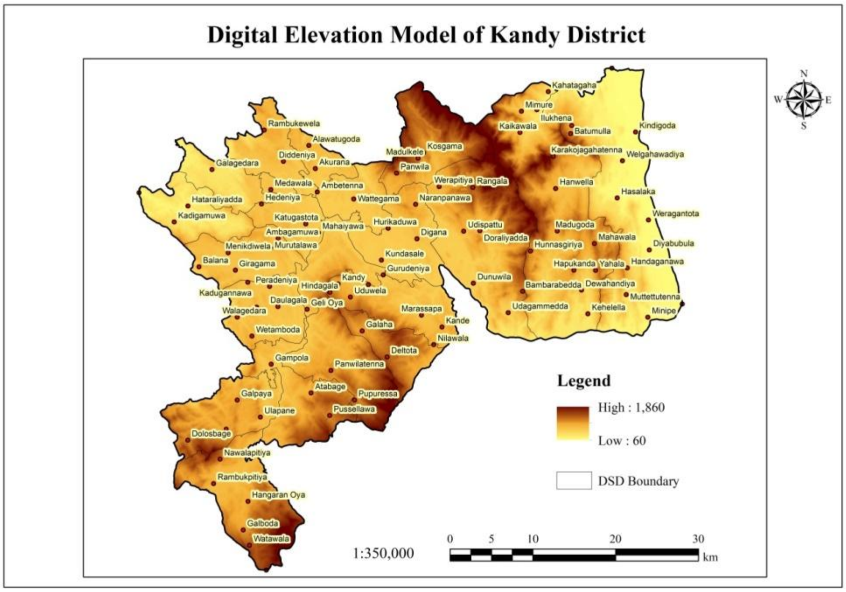

Figure 2: Digital Elevation Model of Kandy District

The slope calculated through the DEM varies from 4.78⁰ to 64.93⁰. As same as the elevation, the highest degree of the slope can be seen in the direction of Knuckles Mountain region. A slope less than 10⁰is distributed among 728 km^2 (38.20%) and a slope within 10⁰-20⁰is distributed among 684 km^2 (35.89%), while 19.41% of the district (370 km^2) is covered from the slope within 20⁰-30⁰. Only 101 km^2 (5.30%) are covered with the slopes within 30⁰-40⁰ and 1.20% (23 km^2) of the land area shows more than 40⁰ of slope distribution (Figure 3).

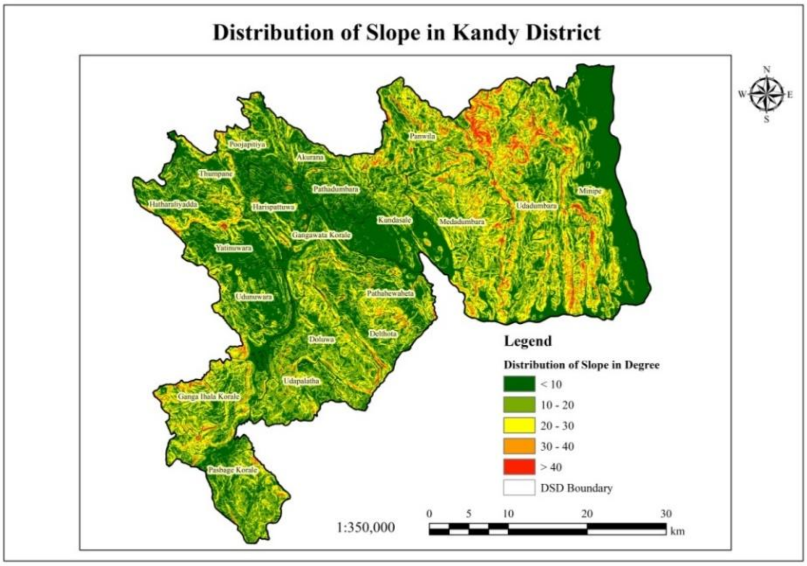

Figure 3: Distribution of Slope in Kandy District

According to DSDs, high slope areas belong to Ududumbara DSD and most of the low slope areas belong to Harispaththuwa, Kundasale, Yatinuwara, Poojapitiya and Udunuwara DSDs. In this context, the lowest slope areas are considered as the most suitable areas for the residential development and the high slope areas are consider as unsuitable for residential development.

3.2. Suitability for Residential Development Based on Landslide Prone Areas

As shown in Figure 4, edge line of the Eastern Kandy District and middle part of the district delineate the areas which have no vulnerability, while most of the areas in the Eastern part of the district and South Western region are fallen into the category of high and very high vulnerability. In addition, the most vulnerable areas belong to Udadumbara, Medadumbara, Panwila and Ganga Ihala Korale DSDs. On the other hand, the less vulnerable areas belong to Pathadumbara, Kundasale, Yatinuwara, Udunuwara and Pathahewaheta DSDs. Eastern part of the Minipe DSD shows no vulnerability, while Western part of the Minipe DSD shows high potential to occur landslides.

Furthermore, there is no vulnerability of occurring landslides for 561 km^2 (29.43%) of land extent of the district. However, only 185 km^2 (9.71%) of the area has very high vulnerability to occur landslides, while 320 km^2 (16.79%) of land area has high potential o occur landslides, and 840 km^2 (44.07%) of area has moderate vulnerability for the landslide occurrence. Therefore, the no vulnerable areas are the most suitable for residential development and high and very high vulnerable areas are not suitable for residential development.

3.3. Suitability for Residential Development Based on Proximity to Roads

For this study, roads are considered as main roads, minor roads and jeep tracks. Middle parts, Western and North Western part of the district consist of high dense road network although the density of road network gradually declines when the area becomes far away from the Kandy city area. Specially, the road network is comparatively poor in Eastern part of the district. However, most of the parts of the district consist of road accessibility and only a very few parts in Northern and South Eastern parts of the district are lacking the accessibility facilities (Figure5).

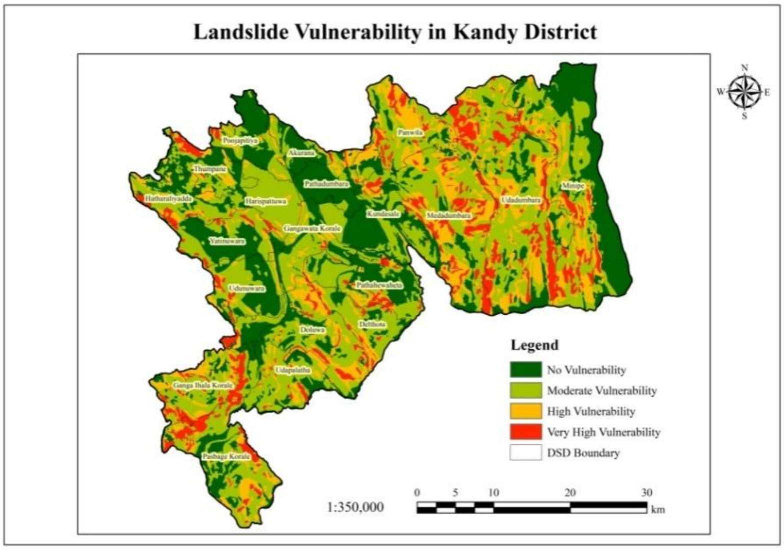

Figure4: Landslide Vulnerability in Kandy District

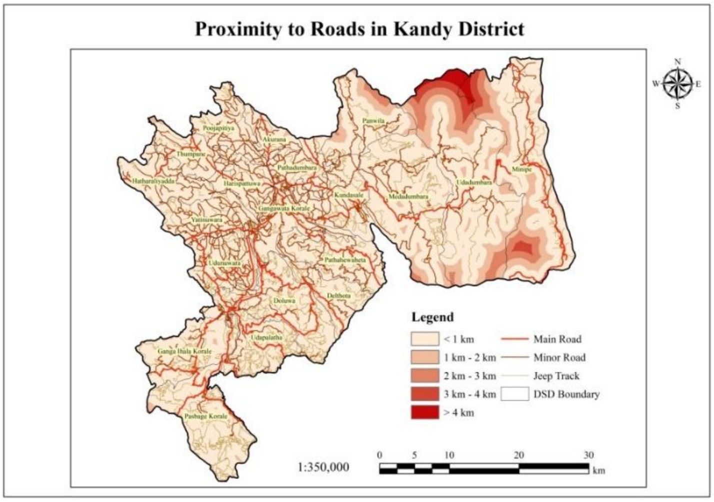

Figure 5:Proximity to Roads in Kandy District

The areas which have the road accessibility within one kilometre are considered as highly suitable areas for residential development and the areas which do not have the accessibility within more than 4 km are considered as not suitable for residential development.

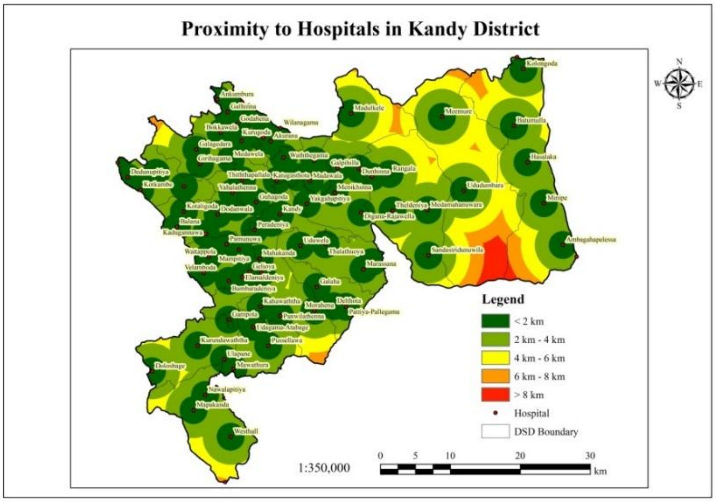

Figure 6: Proximity to Hospitals in Kandy District

3.4. Suitability for Residential Development based on Proximity to Hospitals

There are 85 government hospitals in Kandy District including teaching hospitals, district hospitals, base hospitals and central dispensaries. When we consider the distribution pattern of the hospitals, more hospitals have been located in central part and North Western part of the district in comparison to the other parts. As a result of that, almost all the people who live in the Western side of the district are able to find a hospital within 2 km diameter area. The people who live in 1,548 km² (81%) land extent of the district can access a hospital within 2 km. At the same time, 67 km² (3.52%) of area cannot find a hospital untilgoingon 6 km – 8 km distance, and 23 km² (1.2%) of area cannot access a hospital even after going 8 km of distance (Figure 6).

3.5. Suitability for Residential Development Based on Proximity to Schools

For this study, only the government schools were considered as schools when analysing proximity to schools. There are 666 government schools situated in Kandy District. Except Eastern areas of the district, schools have distributed densely in all other areas. Schools can be found within 1 km in 1,126 km² (58.93%) of area in the district, and schools lie within 1 km to 2 km distance range in 538 km² (28.15%) of land extent.

As same as the hospitals, a single school cannot be found within 4 km distance in South Western area and some parts of the Ududumbara, Minipe and Pasbage Korale DSDs face this problem (Figure 7)

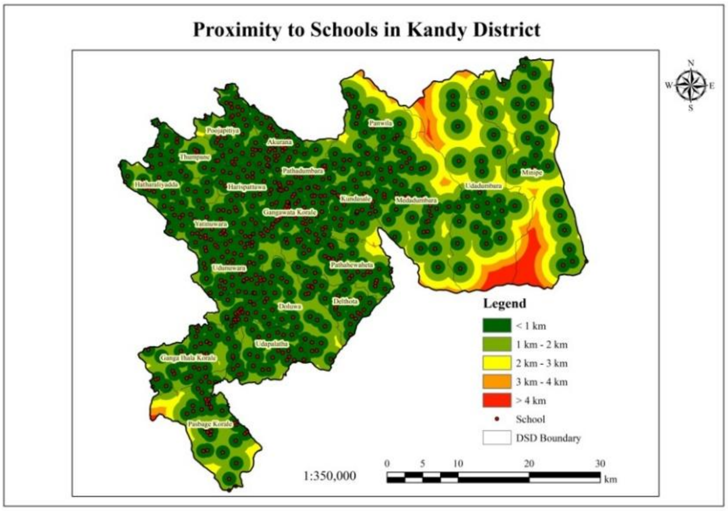

Figure 7: Proximity to Schools in Kandy District

3.6. Suitability for Residential Development Based on Proximity to Town Centres

There are 91 town centres considered in this study when calculating proximity. 906 km² (47.42%) of area is situated in less than 2 km diameter from the town centres, while 861 km² (45.04%) of area is situated within 2 km to 4 km distance. Yet, the people living in 20 km² (1.06%) of area have to go more than 6 km to find a town; mostly in Panwila, Medadumbara, Ududumbara and Minipe DSDs (Figure 8). Therefore, in this study, the areas located in a distance less than 2 km from town centres are considered as the most suitable for residential development, and the areas deviated from town centres from more than 8 km are considered the least suitable areas.

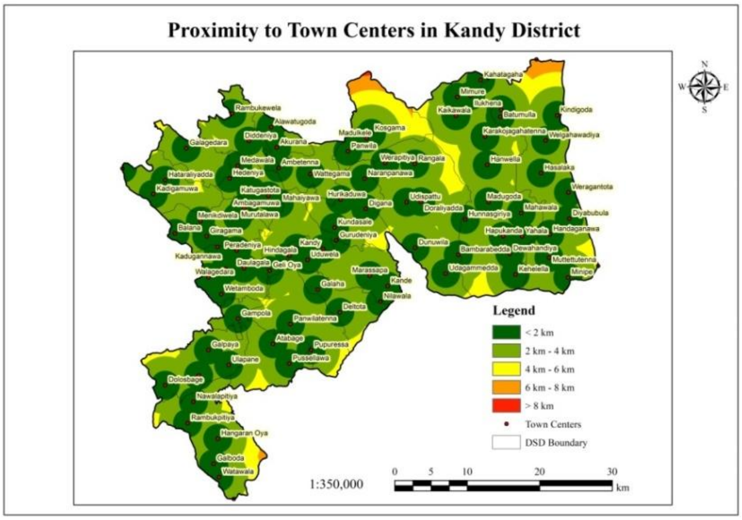

Figure 8: Proximity to Town Centers in Kandy District

3.7. Suitability for Residential Development Based on Land Use

In Kandy District, there are several land use patterns such as forest, scrubs, chena, coconut, tea, rubber, home garden, paddy, reservoir and tanks. As the major land use type, home garden covers 34.2% (655 km²) of area from the total land extent, and tea is cultivated in 22.6% (433 km²) while paddy covers 9.9% (189 km²) of land extent. Also, forest and scrubs covers 14.3% (273 km²) and 13.6% (261 km²) of the area respectively (Figure 9).

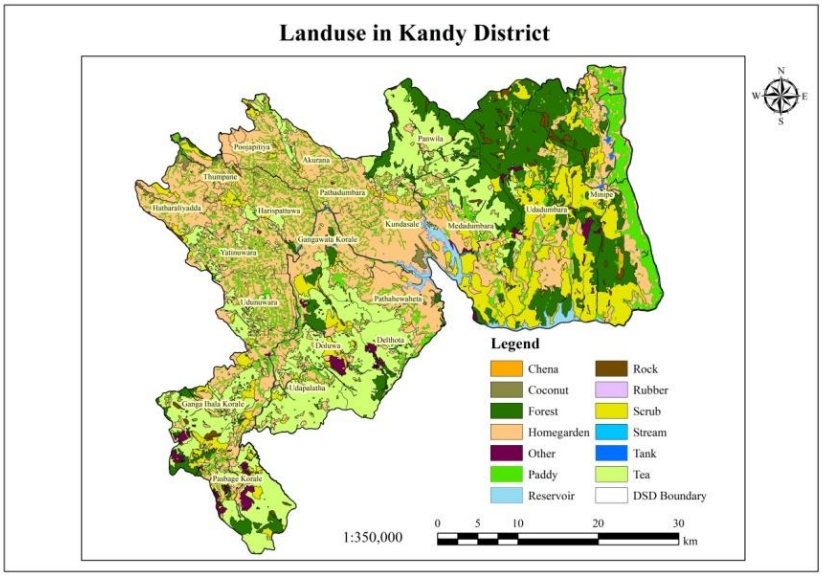

Figure 9: Land Use in Kandy District

3.8. Suitability for Residential Development Based on Population Density

There are 20 DSDs and 1,188 GNDs in Kandy District. According to the statistics in 2016, the total population of Kandy District was 1,347,612. Gangawata Korale is the most populated DSD in Kandy District. It records 148,343 populations and 11.01% from the population live in this DSD. As same as Kundasale, Udunuwara and Yatinuwara DSDs record 127,070 (9.43%), 110,905 (8.23%) and 99,088 (7.35%) of population respectively. On the other hand, Ududumbara, Panwila and Hatharaliyadda record the least number of population as 22,505 (1.67%), 26,294 (1.95%) and 29,520 (2.19%) respectively.

According to GNDs, Kundasale South is the most populated GND in Kundasale DSD in Kandy District recording 7,040 of population. The second and third highest populations are recorded from Thennekumbura GND in Gangawata Korale DSD, and Pussellawa GND in Udapalatha DSD. They record 6,195 and 5,878 of population respectively. Imbulpitiya GND that belongs to Pasbage Korale has the least number of population recording only 54 people. As same as the Imbulpitiya, Eriyagasthenna GND in Pathadumbara DSD has 60 of population and Karambaketiya that belongs to Udadumbara DSD has 76 of population.

In terms of the population density, Gangawata Korale DSD shows the highest population density as 4,541 people per 1 km^2. On the other hand, it is the biggest DSD in the district, but when we look at it in a more micro scale, according to GND, there is a huge variation between population densities. While Bowala GND records 92.49 people per 1 km^2 as the minimum population density in Gangawata Korale DSD, Poorna Watta West GND records 21,270 people per 1 km^2 as the maximum population density in Gangawata Korale DSD as well as in the entire district. The second and third highest population densities are recorded from Akurana and Udapalatha DSDs and they record 3,481 people per 1 km^2 and 2,660 people per 1 km^2.

The lowest population density records from Udadumbara DSD as 183 people per 1 km^2. The maximum population density within the DSD records from Bambarabedda East GND as 691 people per 1 $km^{2,}$ and the minimum population density within the DSD and within the entire district records from Karambaketiya GND as 6 people per 1 km^2. Minipe and Panwila DSDs also record second and third lowest density (Figure 10). For the purpose of identifying suitable areas for residential development, the densest GNDs are considered as least suitable and the low dense GNDs are considered as suitable areas.

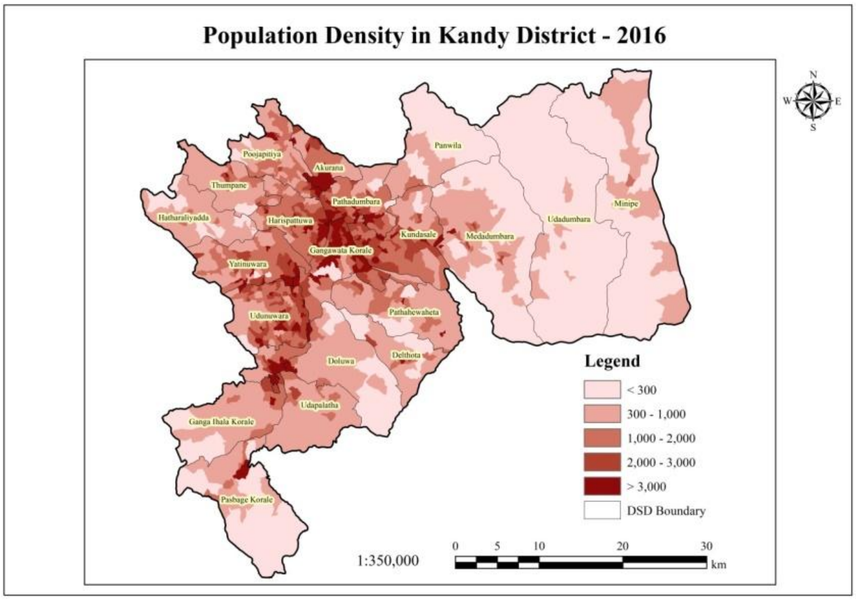

Figure 10: Population Density in Kandy District - 2016

3.9. Suitable Areas for Residential Development

Based on above eight criteria, the final suitability map was created for identifying the areas which are suitable for residential development in Kandy District. Results of the analysis indicate that 512 km^2 of land extent is highly suitable while 666 km^2 of area is suitable for residential development. Also, another 390 km^2 area could be identified as moderately suitable. On the other hand, 260 km² and 78 km² of areas are unsuitable and extremely unsuitable for residential development respectively.

According to the percentage from total land area of Kandy District, 26.8% of highly suitable areas and 34.9% of suitable areas for residential development are available in Kandy District. 20.5% of land area is moderately suitable for residential development. In contrast, 13.7% of land area is unsuitable and 4.1% of area is extremely unsuitable for the residential development. Therefore, there are 82.2% of liveable areas available although 17.8% of the areas are inappropriate to survive.

In addition, as the results indicate, the Western part of the district is more suitable for residential development than the Eastern part, and most of the unsuitable areas lie in North Eastern part of the district. Figure 11 illustrates the highly suitable, suitable, moderately suitable, unsuitable and extremely unsuitable areas for residential development. As the map indicates, most of the highly suitable areas belong to Minipe, Kundasale, Yatinuwara and Pathadumbara DSDs. In contrast, the highest amount of extremely unsuitable areas for residential development belongs to Udadumbara DSD. Although Minipe DSD records the highest amount of land extent for 'highly suitable', it records high amounts of 'extremely unsuitable' land extent as well.

According to the DSDs, Minipe DSD has the largest number of highly suitable areas of 95 km² while Kundasale, Yatinuwara and Pathadumbara have 40 km², 36 km² and 35 km² of highly suitable land areas respectively. Harispaththuwa and Panwila DSDs show very limited number of highly suitable land extent for residential development as 3 km² and 9 km² respectively. For the total of highly suitable areas, Minipe DSD contributes in 18.5% and Kundasale, Yatinuwara and Pathadumbara DSDs contribute in 7.8%, 7.1% and 6.8% respectively. On the other hand, Harispaththuwa DSD records 0.6% while Panwila and Delthota DSDs record 1.7% each.

According to the second category - the suitable areas for residential development-, Ududumbara and Medadumbara record the highest extent of land area as 75 km² and 61 km² respectively. Minipe DSD has 52 km² of suitable areas while Pasbage Korale DSD has 43 km² of suitable areas. Pathadumbara DSD has a very few land areas (8 km²) as suitable for residential development. Akurana DSD also has 9 km²of suitable land area. When we consider the total of suitable areas, Ududumbara DSD contributes in 11.3% while Medadumbara DSD contributes in 9.1%. In contrast, Pathadumbara DSD contributes only 1.1% to the total suitable areas.

Then, from 390 km² of moderately suitable areas, 83 km² (21.2%) belongs to Udadumbara DSD and 62 km² (15.9%) of land area records from Medadumbara DSD. Minipe has 42 km² (10.7%) of moderately suitable land area for the residential development while Doluwa has 28 km² (7.3%). Yet, Akurana, Pathadumbara and Harispaththuwa DSDs have the lowest land extent that belong to moderately suitable category and statistically they record 2 km² (0.5%), 4 km² (1.0%) and 4 km² (1.1%) land extents respectively.

In addition, the highest amount of unsuitable land area records from Udadumbara DSD as 66 km². It is one fourth from the total unsuitable areas. Minipe, Medadumbara, Panwila and Pasbage Korale DSDs also record high amounts of unsuitable conditions for the residential development and the land extents are 42 km², 39 km², 30 km² and 22 km² respectively. From the total unsuitable areas, they record 16.1%, 14.8%, 11.3% and 8.3% respectively. Akurana, Kundasale and Harispaththuwa DSDs have less than one square kilometre of unsuitable land areas.

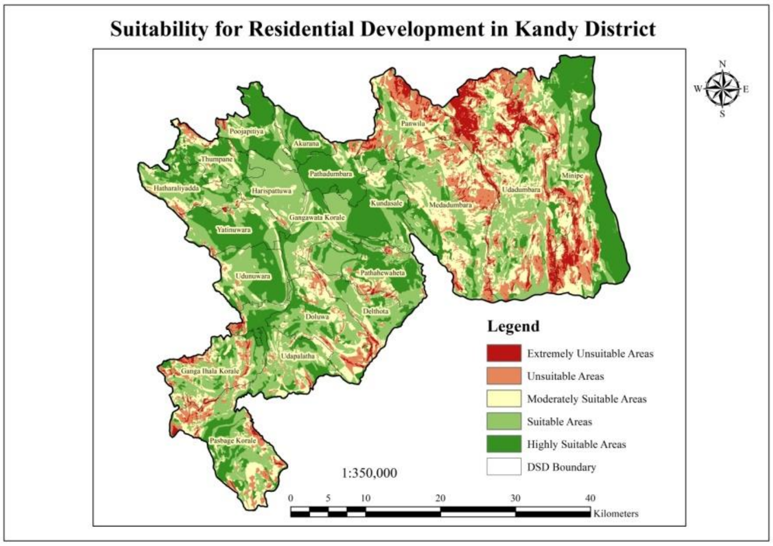

Figure 11: Suitable Area Extents for Residential Development in Kandy District

Furthermore, when considering extremely unsuitable land areas for residential development, Ududmbara records the highest extremely unsuitable land areaspread among 36 km². It is 45.7% from total extremely unsuitable lands. Also, Minipe DSD has 16 km² and Panwila DSD has 9 km² of extremely unsuitable land areas for residential development. Kundasale DSD does not have any land area that belongs to 'extremely unsuitable' while all other DSDs have less than 5 km² areas which can be considered as extremely unsuitable for residential development.

Pathadumbara DSD records the highest percentage (71.6%) of its total land area as highly suitable for residential development while Akurana, Poojapitiya and Yatinuwara DSDs record more than 50% of land as highly suitable. The statistics show 59.8%, 55.1% and 52.2% respectively from the total land area of the DSDs. On the other hand, Harispaththuwa and Udadumbara have less than 10% of land areas from their total land extent. Although Harispaththuwa has a very few highly suitable land areas, it has 83.8% of suitable land areas. When considering both highly suitable and suitable lands together, more than 90% of liveable areas are available in Harispaththuwa DSD. Delthota DSD also has 53.3% of suitable areas from its total land extent. Although Pathadumbara DSD shows the highest percentage of highly suitable land areas, it has only 15.4% of suitable land areas. Except Pathadumbara DSD, more than 20% of suitable land areas are available in all other DSDs in Kandy District.

Percentage of moderately suitable land areas from the total land area of each DSD vary from 6.6% to 32.7%. While 6.6% records from Akurana DSD, 32.7% records from Medadumbara DSD. Only 6 DSDs record less than 10% of moderately suitable land areas from their entire land and 7 DSDs record more than 20% of moderately suitable land areas from the total land of each DSD.

Moreover, when considering the unsuitable land areas as a percentage of the total land of each DSD, it varies from 0.8% to 32.3%. 0.8% records from Kundasale DSD and 32.3% records from Panwila DSD. 13 DSDs are available in less than 10% of unsuitable land areas while only 3 DSDs namely Panwila, Udadumbara and Medadumbara show the unsuitable areas in more than 20% of their total land extent.

Finally, only Panwila and Udadumbara DSDs record more than 10% of extremely unsuitable land for the residential development from its total land area and all other DSDs indicate less than 7% of extremely unsuitable land areas. Harispaththuwa, Kundasale, Udunuwara, Gangawata Korale, Akurana, Hatharaliyadda, Pathadumbara, Poojapitiya and Yatinuwara DSDs have less than 1% of extreme land areas from their total land.

4. Conclusion

Most of the highly suitable areas for residential development in Kandy District belong to Minipe, Kundasale, Yatinuwara and Pathadumbara DSDs. In contrast, the highest amount of extremely unsuitable areas for residential development belongs to Udadumbara DSD.

5. Recommendations

Firstly, it is important to consider the areas where highly suitable, suitable, moderately suitable, unsuitable and extremely unsuitable are identified through this study when planning and developing the residential places for Kandy District to avoid and minimize the problems occurring through unplanned settlements.

Secondly, especially the DSDs identified to behaving more unsuitable and extremely unsuitable areas for residential development in Kandy District, should be avoided from planning or developing any residential places in them without proper planning.

Thirdly, when conducting residential planning and development programmes in Sri Lanka, it will be more effective to minimize long term problems if a suitability study can be conducted based on relevant criteria and if the residences can be placed based on the results of the study.

Finally, to convert unsuitable areas to suitable areas for residential development, infrastructure facilities, accessibility to schools and hospitals have to be increased while following landslide prevention and mitigation measures especially focusing on most vulnerable areas.

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