Raster GIS Modelling when Selecting a Suitable Solid Waste Dumping Site

R.M.L.U. Rathnayaka and N.T.S. Wijesekera

ABSTRACT

Disposal of solid waste is a major problem which is rapidly increasing with the growth of population and development of industries. In a majority of places, open pits have become major disposal locations causing severe environmental and health issues. Since, solid waste disposing is an important part of a waste management system, locating proper sites for solid waste disposal is considering main issue for the management of solid waste. Site selection involves working with several map layers while requiring qualitative assessment for decision making. Multiple layer operations can be carried out by using Geographic Information system and is a suitable method for site selection. Vector and raster data models are the primary data models used in GIS. The present study is intended to demonstrate the capabilities of raster GIS formats in suitability analysis by finding out a suitable site for the disposal of urban solid waste generated from Rathnapura municipality.

Concept and the objective function were identified and the factors which are necessary to achieve the aims of study were determined by reviewing literature. AHP technique in combination with GIS overlaying was used to arrive at optimum weights for each parameter. In literature land use, water bodies, flood risk zones, streams, population density, protected area, major roads, landslide prone zones, water supply sources, ground water depth, proximity to roads, rainfall, build-up areas, slope and soil are described as factors affecting land selection. According to the results obtained, 0.59 km2 of area was suitable for solid dumping site. In Raster GIS multilayer operations can be perform and overlaying process is very fast, causing data analysis is quick and easy. GIS technique is a better tool for suitability analysis as it reduce time and cost of site selection..

KEYWORDS: GIS, Raster, Solid waste disposal, Land use

1. Introduction

1.1. General

Geographic Information System (GIS) allows users to view, understand, query, interpret and visualize spatial and non-spatial data in many ways that reveals relationships, patterns and trends in the form of maps, reports and charts (Lui and Mason, 2009; Bhatta, 2010). In Geographic Information System human and computer based resources are combined with spatially referenced data to achieve efficient management and planning of resources. GIS is capable to collect, store, retrieve, communicate and analysis spatially referenced data for product generation. Vector and raster data models are the primary data used in GIS.

Disposal of solid waste is a major problem which is rapidly increasing with the growth of population and development of industries. In a majority of places, open pits have become major disposal locations causing severe environmental and health issues. Since, solid waste disposing is an important part of a waste management system, locating proper sites for solid waste disposal is considering main issue for the management of solid waste. Site selection involves working with several map layers while requiring qualitative assessment for decision making. Multiple layer operations can be carried out by using Geographic Information system and is a suitable method for site selection. Vector and raster data models are the primary data models used in GIS. Present study is intended to demonstrate the capabilities of raster GIS formats in suitability analysis by finding out a suitable site for the disposal of urban solid waste generated from Rathnapura municipality. Rathnapura city generates 28-30 tons of waste per day and 80 % of them are collected by municipality. Dumping site is located at Kanadola near to Rathnapura town. Waste collection is primarily done by municipal council. Waste is not graded as bio-degradable, glasses, polybags, paper shreds or hazardous. There are pollution problems, because the dumping site is located on a hilly area and waste moved down the hill causing environmental pollution. As a result, most paddy lands in the hilly area remain abandoned. It is very difficult to find dumping site near Ratnapura town because of the frequent flooding. Locating suitable sites for solid waste dumping can be easily done with conceptual GIS models either using Raster or Vector formats. Vector GIS provides clear and easy to understand

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representations but has the difficulty when working with large projects and many overlays. Though raster GIS enables easy working with many overlays, they have the problems due to compromises made in spatial resolutions.

Raster data is made up from pixels or grid cells. These grids also vary with the data type and representations of either discreet or continuous data. Integer grids represent discrete data and floating point grids represent continuous data. A case study was conducted to demonstrate capabilities of Raster GIS, when selecting a solid dumping site.

1.2. Study Area

Study area is the Rathnapura municipality (104 km^2) which comes under administrative district Rathnapura in the Sabaragamuwa province, Sri Lanka.

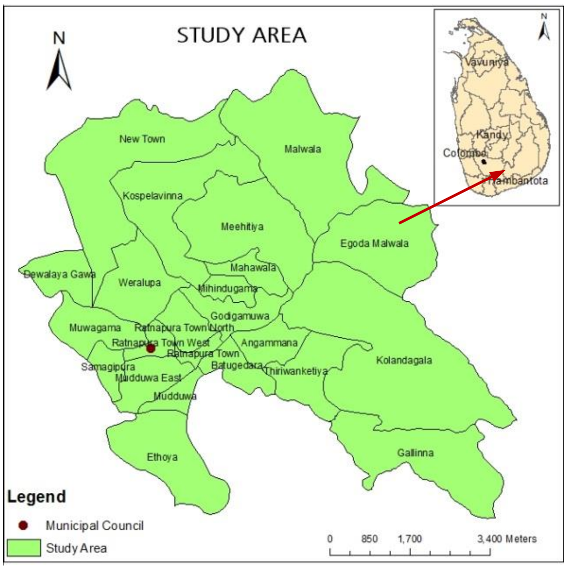

Figure 2 1 Study Area

1.3. Spatial data and data types

Digital data was obtained from different government authorities and used for the study are listed in Table 1.

Table 0 Spatial data and data type

No	Data Layer	Layer Type	Resolution
1	Study area	Polygon	1: 50,000
2	Soil	Polygon	1: 10,000
3	Land use	Polygon	1: 10,000
4	Contours	Polyline	1: 10,000
5	Roads	Polyline	1: 50,000
6	Streams	Polyline	1:10,000
7	Build up areas	Polygons	1:10,000
8	Protected areas	Points	1:10,000
9	Rainfall	points	

2. METHODOLOGY

ARC GIS 10.2 was used to create solid dumping site suitability model. Criteria for solid dumping site selection process were extracted from national regulations, international guidelines and from previous studies. . Prioritised weights were computed using an analytical hierarchy process (AHP) multi criteria model. Land use, water bodies, flood risk zones, streams, population density, protected area, major roads, landslide prone zones, water supply sources, ground water depth, proximity to roads, rainfall, build-up areas, slope, soil were identified as influencing the waste disposal site selection

Land use helps to identify availability of suitable land uses. Build-up areas, forest reserves, wetlands, potential agricultural lands are not considered for selection. Low population density areas are preferred because of the effects on health, nuisance, environmental pollution, property values, odour, aesthetic aspects etc. Urban towns, residential areas, protected areas, religious areas, parks, water bodies, major roads and streams are areas that need to be at a fair distance away from dumping site. Proximity to roads is a consideration due to concerns of transportation time and cost. Soil type indicates the possibility of pollutant leaching towards groundwater. High elevation and slopes facilitate the travel of polluting material towards lower elevations with the runoff. Locating dumping sites in flood prone areas lead to washing away of waste in to water bodies. Unstable slopes must be avoided and depth to groundwater must be evaluated prior to selecting a site.

Accordingly objective function for the site selection model is as below.

Suitable solid waste dumping site = *f* (Socio-Geological Suitability, Aesthetic suitability, Environmental Suitability, Natural Hazard Suitability)

Socio- Geological Suitability = *f* (Land use + Soil +Slope)

Aesthetic Suitability = *f* (Build-up areas + Sensitive Places + Major Roads)

Environmental Land Suitability = *f* (Stream, Rainfall, Ground water depth)

Natural Hazard Suitability = *f* (Flood risk, Land prone hazard)

Ground water depth = *f* (Land use, Stream, Water bodies)

Flood risk Zones = *f* (Land use, Slope, Soil, Elevation, Rainfall)

Land slide hazard prone Zones = *f* (Slope, Soil, Elevation, Rainfall)

2.1. Raster Analysis

Classified layers were re-classified with the use of raster calculator and added together after multiplying each criterion from their weightages. Cell size of 10 is selected for spatial data operation due to easiness of calculations.

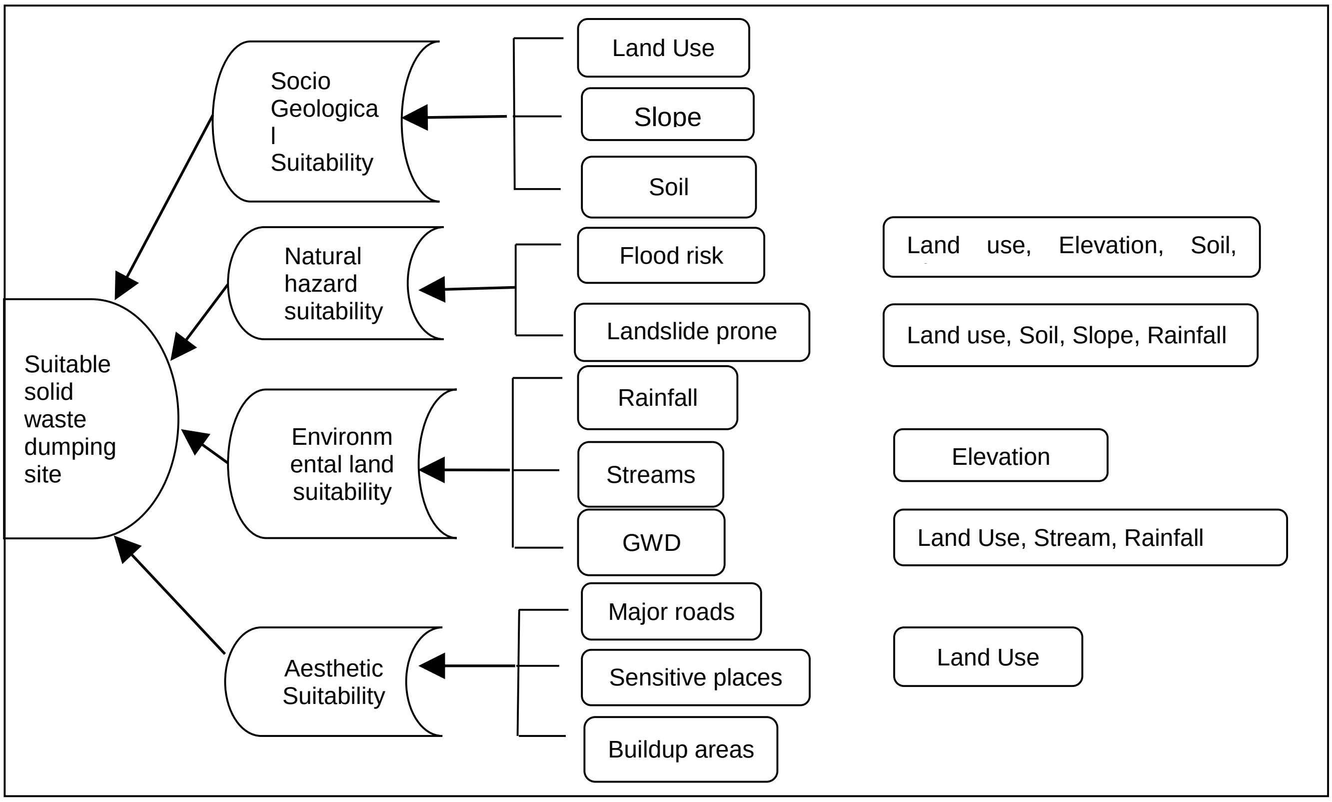

Figure 2 1 Methodology flow chart

2.1.1. Socio Geological suitability

Under socio geological suitability, land use, slope and soil were considered as criterion. Slope raster map was created using elevation (1:50000) digital map and after convert it in to TIN and DEM.Layer classifications and the sequence of combining multiple layers at a time are shown in the table 2.1-1 and Figure 2.1-2.

Table 2.1 1 Parameter classification

Criteria	Classification	Suitability
Land use	Bare and grass land area Scrub, bush land Build-up, Agriculture Forest, water bodies	High Moderate Low Un-Suitable
Slope	< 10 (Degrees) 15 - 20 >20	High Moderate Low Un Suitable
Soil	Low Permeable Moderate Permeable High Permeable	Suitable Moderate Un-Suitable

Classified layers were reclassified to achieve common scale ranked from 0 to 9 indicating unsuitable to high suitable in the order of decision maker's preference. Weightages were given to each criterion according to their relative importance. Weights were assigned for each reclassified layers by using AHP.

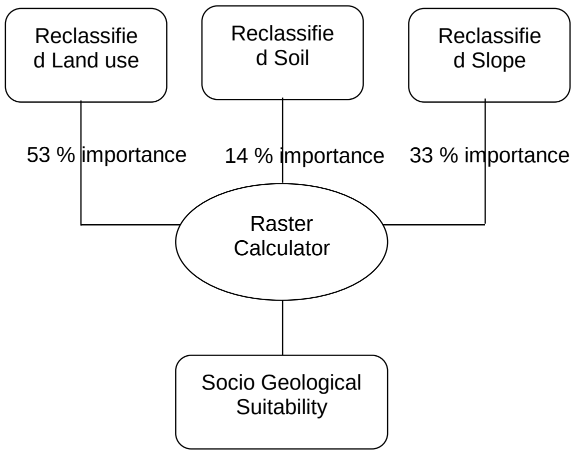

Figure 2 2 Raster Analysis -Socio Geological Suitability

2.1.2. Aesthetic Suitability

Buffer zones of protected areas, build-up areas, and major roads were considered to find out aesthetic suitability. Protected area, major roads and build up areas were converted to raster and buffered by using Euclidean Distance tool. Layer classifications and the sequence of combining multiple layers at a time are shown in the table 2.1-2 and Figure 2.1-3. According to British Columbia criteria and EPA guideline, Jayawicrama, N.T. & Weerasinghe, V.P, the landfill footprint must not be located within 300 m of an existing or planned sensitive land use. Major roads should be greater than 250 m (Sener *et* *al.*, 2010). According to Rajan S.S., Yeshodah L., Babu S.S., (2014) build-up areas should be not be within 300 m.

Table 2.1 2 Parameter classification

Criteria	Classification	Suitability
Protected areas	0-300 300-500 500-800 (m) 800-1500 >1500	Un Suitable Low Suitable Moderate Suitable High Suitable Extremely HS
Major Roads	0-250 250-500 500-750 (m) >750	Un Suitable Low Suitable Moderate Suitable High Suitable
Build up areas	0-300 300-500 500-800 (m) 800-1100 >1100	Un Suitable Low Suitable Moderate Suitable High Suitable Extremely HS

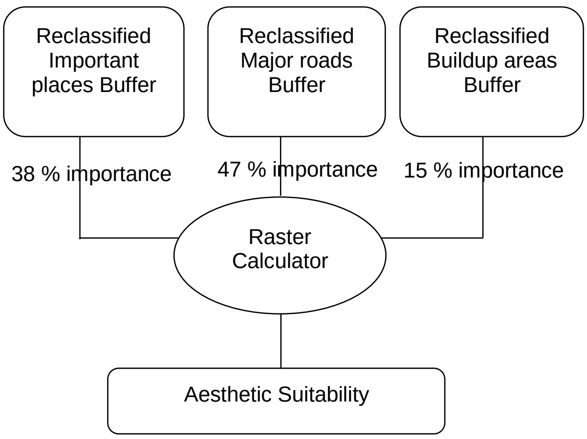

Figure 2 3 Raster Analysis -Aesthetic Suitability

2.1.3. Environmental Suitability

Under environmental suitability rainfall, ground water depth and distance from stream were considered. Layer classifications and the sequence of combining multiple layers at a time are shown in the table 2.1-3 and Figure 2.1-4.
Stream network was created by using digital elevation map (1: 50000) with 20 m contour intervals and created streams were compared with physical streams to identify similarity. There is no ground water map for study area. Hence, conceptual model was developed to prepare a ground water map using land use, streams and rainfall base data. Very close to the paddy and streams are considered as high potential to ground water depth.

Table 2.1 3 Parameter classification

Criteria	Classification	Suitability
Land use	Bare and grass land area Scrub, bush land Build-up, Agriculture Forest, water bodies	High Suitable Moderate Suitable Low Suitable Un Suitable
Slope	< 10 15 - 20 (Degrees) >20	High Suitable Moderate Suitable Low Suitable Un Suitable
Soil	Low Permeable Moderate Permeable High Permeable	Suitable Moderate Suitable Un Suitable

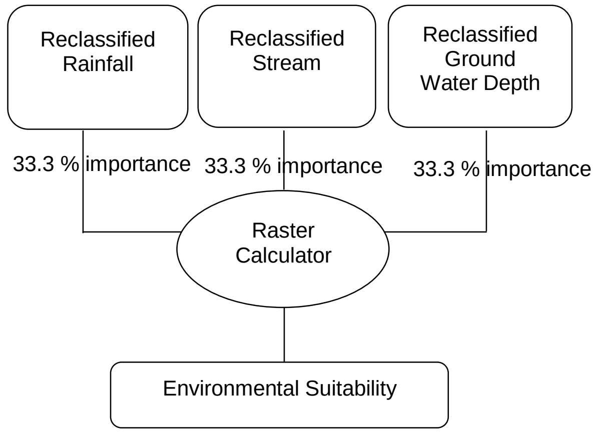

Figure 2 4 Raster Analysis –Environmental Suitability

2.1.4. Natural Hazard Suitability

Natural hazard suitability map was created by overlaying flood hazard areas layer with land slide prone areas layer. Flooding causative factors such as rainfall distribution, slope, soil type, land use, flow accumulation and elevation were integrated for flood vulnerability mapping in the study area.
Layer classifications and multiple layer operation for reclassified layers are shown in table 2.1-4 & Figure 2.1-5. The results were validated with flood vulnerability map created by NBRO, Sri Lanka.
Land slide was the most common natural hazard in hilly terrains. Soil, slope, rainfall and land use were identified as causative factors in the study area. Raster parameter layers were classified according to the classification system as illustrated in table 2.4. Classified layers were reclassified to achieve common scale by ranking from 0 to 9, indicating unsuitable to high suitable. This ranking system was carried out according to the decision maker's preference. Weights were assigned for each reclassified layers by using AHP model which analysis was carried out accordance with relative importance of each criteria. Classified soil, slope, rainfall and land use layers are added by raster calculator after multiply by weightages to obtain land slide prone map. Flood zonation layer and landslide prone area layer were added by using raster calculator to obtain natural hazard suitability map.

Table 2.1 4 Flood Hazard - Parameter classification

Criteria	Classification	Suitability

Land use	Building, Roads, slum area Shrub, bush, range land Crop land, pasture Other agricultural land Mixed forest lands	Very High High Moderate Low Low risk
Flow accumulation	0-241 241-523 523-922 (m) 922-1471 1471-2120	Very High High Moderate Low No risk
Slope	0 – 11.4 11.4 – 23.2 23.2 – 36.3 (Degrees) 36.3 – 51.9 51.9 – 88.3	Very High High Moderate Low No risk
Soil	Low Infiltration capacity Moderate High Infiltration capacity	High Moderate Low

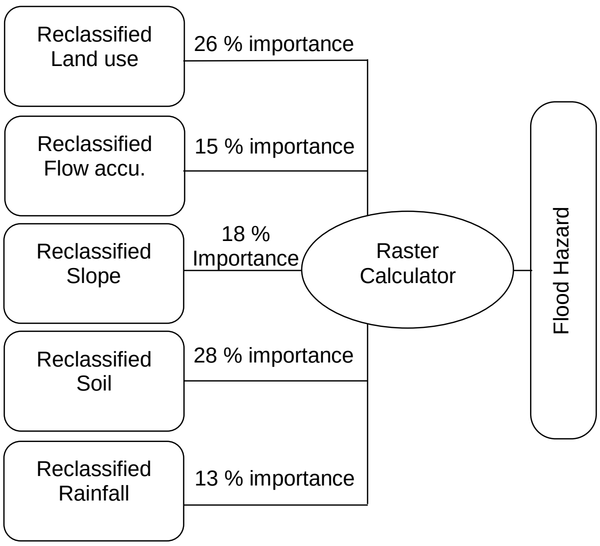

Figure 2 5 Raster Analysis –Flood Hazard

2.1.5. High reliable solid dumping site

Socio geological suitability, environmental land suitability, aesthetical land suitability and natural hazard suitability maps were added by using raster calculator to create high reliable solid dumping site.

3. Results

According to the AHP method, It was found that build-up areas (21.9 %), land use (18.6 %), slope (16.8 %), soil (14.3%) and flood hazard zones (11.4%) are the high priority factors that should be considered for the study area. In raster model, total study area covers 104.23 Km^2. The final suitability map indicates that 0.76 km^2 area is suitable for dumping site. To identify suitable dumping sites within the municipal council area, MC area was extracted from the study area. According to the results obtained, 0.59 km^2 of area was suitable for solid dumping site. Suitable areas within the municipal council of Rathnapura were verified with field data. Table 3-1 shows the percentage values of study area according to suitability conditions.

Table 3.1 Area according to suitability level

No	Suitability level	Area (Km2)	Percentage %
1	High Suitable	0.76	0.73
2	Moderate Suitable	9.55	9.16
3	Low Suitable	93.77	89.96
4	Un Suitable	0.14	9.8

Final suitability map of the study are shown on figure 3.2.

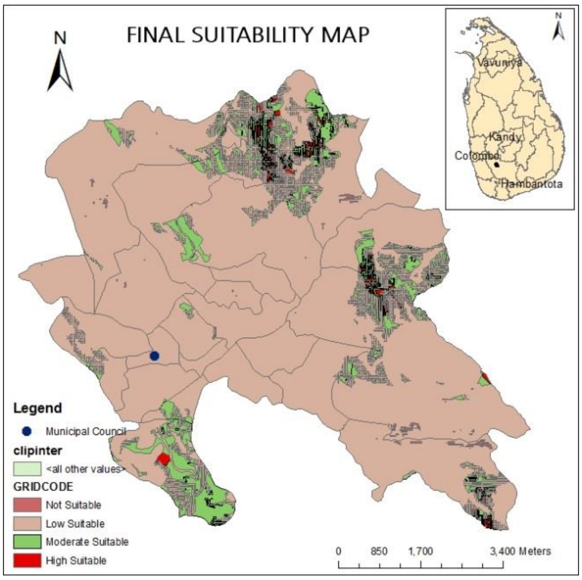

Figure 3.2 Solid Dumping Sites suitability map

4. Conclusion

According to literature review it was found out that many parameters are affected to solid waste disposal site selection. If we can increase the number of parameters considered, we can get optimum solutions, minimizing environmental and health hazard. In this study many parameters were handled and analysis without confusion. In Raster GIS multilayer operations can be perform and overlaying process is very fast, causing data analysis is quick and easy. Hence, GIS technique is a better tool for suitability analysis as it reduces time and cost of site selection.

Raster models have capabilities to assign weights to criteria to get optimum solution and also layers can be reclassified to a common scale by using user preference ranking system. Suitability analysis models are frequently cooperated with continuous features (elevation) and have to analysis surface data. Raster GIS facilitate surface analysis for continuous data and is a highly suitable for suitability site selection.GIS tool also provides a digital data bank for future monitoring programme of the site.

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