Vector Based GIS Applications to Select Suitable Land for Landfill Sitting in Kandy, Sri Lanka

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Abstract: *The accumulation of solid wastes around urban centers has become a worldwide environmental problem. Therefore determining the location of landfill sites that are situated in urban areas is an urgent necessity. Aimed to select suitable, orpotential landfill areas from Kandy district, Sri Lanka, minimization of the hindrance to integration of socio-economic determinants using vector based geographical information systems (GIS) analysis was performed. Grama Niladari (GN) divisions having lowest geographic population in Kandy district were selected to acquire the highest spatial associations between land use and population density. Land use including home garden, buildup areas and paddy fields were evaluated as socio-economic factors for successful landfill sitting in the Kandy district. Vector based approach in GIS was used since it is able to perform spatial suitability analysis more precisely. Vector form of the data obtained from GIS analyses indicated that 53.40% of the total land area has a low population density (<400 persons per square kilometer). However 7.56% of this low population density area was excluded due to home gardens, buildup areas and paddy fields and 35.20% of was under both environmental and social influenced in order to minimize the human health and socio-economic conditions and risks associated with land filling. The rest of these lower population density areas (29.80%) were suggested to be more suitable for landfill sitting in the Kandy district. Future studies will be focused on the application of geospatial and hydrogeological factors in the above selected areas for sitting landfills.*

Keywords: *Landfill sitting, Spatial model, Vector-based data, GIS*

1. INTRODUCTION

Exponential population growth subjected to enhance the accumulation of human being around the built-up areas (Kontos et al., 2003). Due to inappropriate consumption pattern with high per capita ecological foot print in urbanized culture, the tremendous increase in waste generation has been reported (Marín et al., 2012). Therefore, municipal solid waste management (MSW) problems have been assumed a huge proportion in the less developed parts of the world (Rahman et al., 2008). In addition, solid waste management is a major global concern at present that is increasing day by day (Gorsevski et al., 2012).

The most common MSW management practice is open dumping. Most of the developing countries are still focusing on open dumping due to advantages of ability to manage a huge quantity of MSW generated per day (Paul & Krishnagar, 2012). However, open dumps are responsible several environmental problems including surface water and groundwater contamination and severe health issue due to air and water pollution (Ruben & Paralik S., 2006). Hence, it is really important to locate the landfill in an appropriate place which reduces the environmental pollution.

Evaluation of the most applicable location for a new landfill is a complex process that requires undertaken of various criteria (Chang et al., 2008, Gorsevski et al., 2012). Among those criteria economic, ecological and social effects are often considered for enhancing the planning process and for setting guidelines that minimizes environment and public health risks. Some of the locational standards are not compatible when evaluating the entire land mass of the regional selected area at a one time. These criteria are site specific and should be used when evaluating a single site or a limited number of potential sites (Reinmuth, 2004). Therefore siting process included in this plan is intended as preliminary step before going to wide scale site specific siting study. Central Environmental Authority (CEA) in Sri Lanka has established general guideline for the landfill site selection (CEA, 2005) provides. Nevertheless, lack of macro level spatial data influences for proper quality risk assessment in Sri Lanka.

To evaluate preliminary aspect of the landfill siting, assigning simple sum of weight method is considered as a very useful tool. In addition, it is one of common methodologies used for site selection in general, and for siting landfill in a selected region (Al-Hanbali et al., 2011). The socioeconomic concern, geodemogrophy provide more spatial data for landfill siting. However some of demographics characterize as follow, high, medium, and low minority, poverty and population density (Gragg III et al., 1996), among the parameters population density data are very useful attribute for spatial analysis (Weerakoon, 2013). The (Luo, 2005) reviled that, compatibility of the census data and the administrative units avoid spatial adjustments. In Sri Lankan census, it is geographically divided by 25 districts within 9 provinces. Each district is divided into DS (Divisional Secretariat) divisions and each DS division is sub divided into GN (Grama Niladari) divisions. The lower geographic area of census data is the GN division level. In population analysis, GN level is mostly suitable for representative macro level visualization.

For gaining high suitability of landfill siting, the sites has to also satisfy the land use criteria (Paul & Krishnagar, 2012), specifically home garden, paddy fields and water bodies to be assign.

Vector based data are comprised of points lines and polygons which express geo reference attributes of the real world more precisely than the low resolution raster data. (Lin & Kao, 1998, Gorsevski et al., 2012, Marín et al., 2012)Vector based GIS model is capable of processing digital spatial data efficiently and precisely to facilitate landfill siting analysis.

Therefore this study aimed to select preliminary suitable landfill site using the vector based Geographic Information System (GIS) and weighted sum analysis method in Kandy District.

2. MATERIALS AND METHODS

2.1. Study Area

The Kandy Municipal Council (KMC)is located in the central part of the country. The location of the study area is shown in Figure 1.

District upper and lower limit of the extent given below (upper left 80° 25' 21.32" E 7° 29' 32.318" N, upper right 81° 0' 48.282" E 7° 29' 33.549" N, lower right 81° 0' 48.204" E 6° 56' 29.356" N and lower left 80° 25' 23.662" E 6° 56' 28.09" N) which geography derive mean altitude of around 900 m above mean sea level in central of Sri Lanka.

The KMC covers an area of 1934.29 km^2 and consists of 20 Divisional Secretariat divisions also sub divided in to minor divisions as Grama niladari (GN) divisions representing residential population nearly 139,000 and floating population of over 50,000 visit Kandy daily, mainly due to tourism and temple of Lord Buddha's tooth relic located in the middle of the city (Wijesekara et al., 2014, Statistical report 2012). Generation of 130 tons/day of MSW including food waste and industrial waste mainly generated from Kandy (Balasooriya et al., 2013). The average annual precipitation varies around 3175 mm and it has an average temperature range from 21 to 26 ºC and in dry periods the temperature of the area rises up to 29-30 ^{o}C. The complex geomorphological terrain of different landscapes, soil types, geology and their respective land use patterns, paddy fields, home garden and several others can be observed.

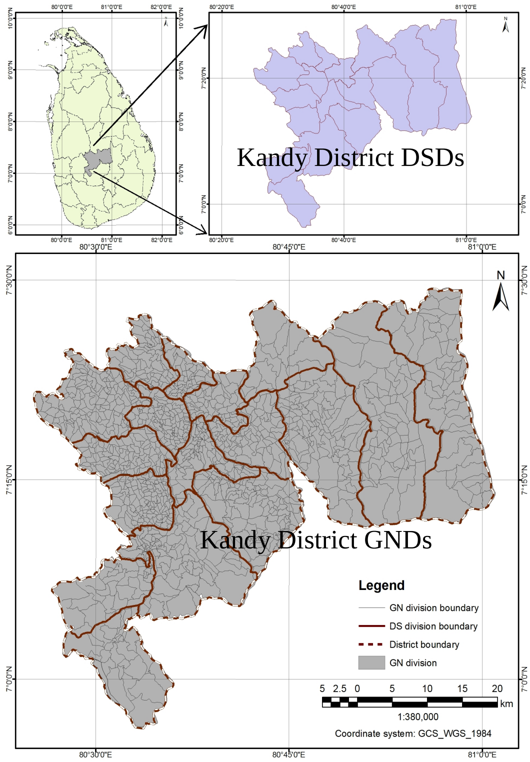

Figure 1 Location of the study area.

2.2. Methodology

In this study, two map layers such as 1:50,000 land use, GN level population density data was processed and digitized within the area of district. Suitable landfill site was analysed by using the GIS together with assigned simple sum of weight method (Al-Hanbali et al., 2011). Figure 2 shows the flow diagram of the method used for the study.

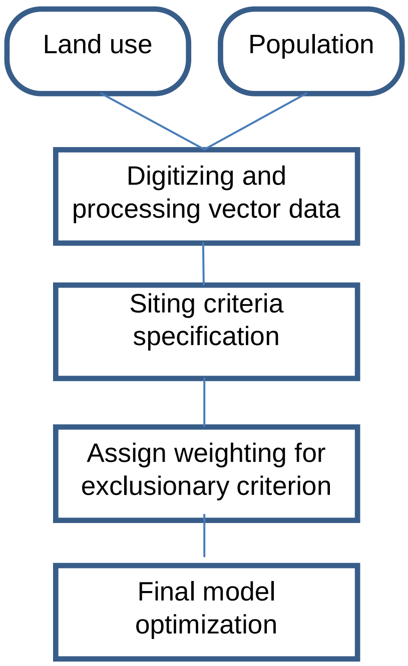

Figure 2 A flow chart illustrating the methodology used in landfill siting.

Table 1 Summarized assign Weights in attributes.

Attribute	**Hazard type**	**Criteria**	**Weight**
Population (W_1)			
Population Density (per km^2)	Social	<400	1
		400 - 800	2
		800 - 1600	3
		>1600	4
Land use (W_2)			
Home Gardens/ Built up Area	Social		4
River/ Water Bodies/ Tank (Working)/ Tank (Abandoned)/ Reservoirs	Environmental		4
Nature reserve/ Forests/ Marsh			3
Paddy	Social		3
Tea/ Other Plantation	-		2
Grassland/ Scrub barren/ Chena	-		1

The layers, the criteria used and there weights are summarized in Table 1 Population data in Kandy district was collected from census and statics department (Statistical report 2012) and population density was calculated foe each GN division. Density higher than 400 per sq km weighted as high risk (weight = 4) area and lower than that weighted as low risk areas (weight = 3, 2 and 1). Low risk areas were considered to be suitable for waste disposal. In the exclusionary criteria of land use map in the area was identified and home gardens, built up area, river, water bodies, tank (working), tank (abandoned), reservoirs were weighted (weight = 4) as high risk area for landfill site selection and other low risk area weighted according to Table 1 (CEA, 2005).

Weighted values were incorporate to each layer according to criteria and analysis was finally optimized by using ArcGIS 9.3 software.

3. RESULTS AND DISCUSSION

Taking into account of the mentioned considerations, the district was screened for preliminary potential landfill sites. Pattern of land use is considered as necessary criteria for the landfill site selection, accordingly the some unsuitable land uses were excluded for landfill site selection as follows; home gardens, built up area, river, water bodies, tank (working), tank (abandoned), reservoirs (CEA, 2005, Environmental Protection Agency, 2006.). Chena, grassland and scrub barren land were considered as very low risk areas for landfill site selection considered 1:50,000 land use map (Figure 3).

Population density of the area was considered as another criterion with representation of demographic attribute. Surround area of the Kandy Four Gravest, all GN divisions has highest density range 1600-4400 person per sq km, higher value compared to the other regions. Therefore, it is considered as high risk region and also the high amount of waste generated area (Figure 4).

Suitability of sites was classified into seven categories (Abessi & Saerdi, 2010, Vogt, 1999), high risk area (in dark red colour), low risk land use and socioeconomically affected area (gradiently red to green colour) and low land use and socioeconomic impacted area (in dark green colour). Potential landfill sites in terms of suitability within the province are illustrated in Figure 5.

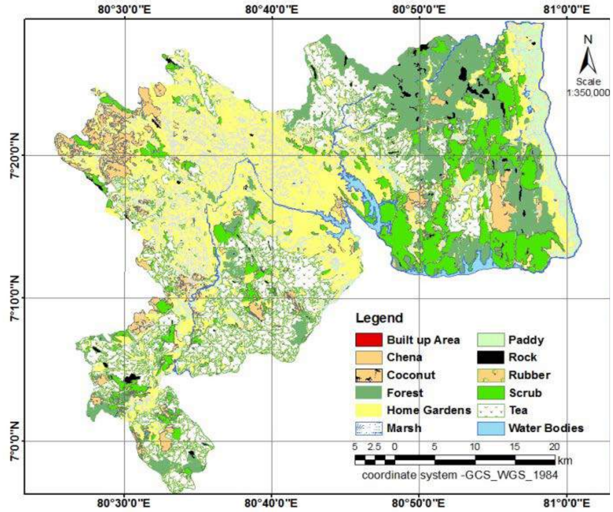

Figure 3 1:50,000 land use map in Kandy district.

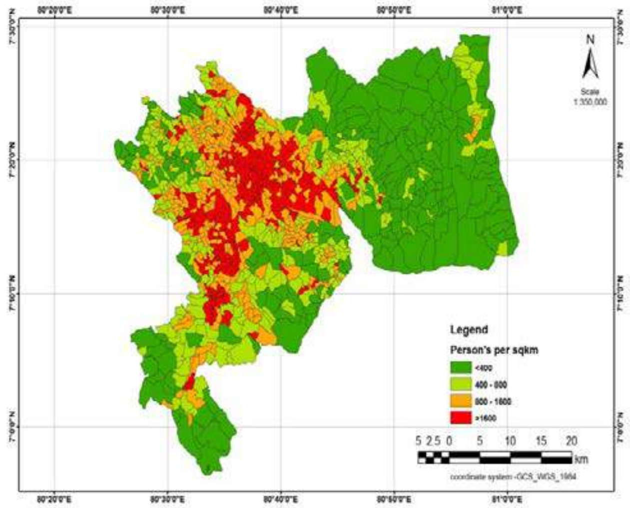

Figure 4 GND level Population density map in Kandy district.

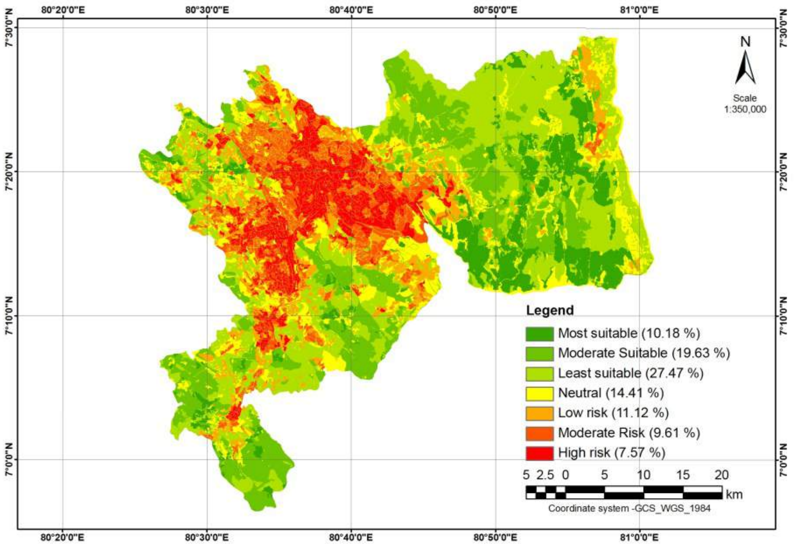

Figure 5 Risk categorization map of Kandy district.

That vector form of the data obtained from GIS analyses indicated that 53.40% of the total land area has a low population density. However 7.56% of this low population density area was excluded due to home gardens, river, water bodies, tank (working), tank (abandoned), reservoirs and 35.20% of was under both environmental and social influenced in order to minimize the human health and socio-economic conditions and risks associated with landfilling.

The rest of these lower population density and lower land use impacted areas (29.80%) were suggested to be suitable and under the above percent 10.18% was most suitable zone (dark green colour) for landfill sitting in the selected area.

4. CONCLUSIONS

According to preliminary consideration of above demographic and environmental attributes, potential amount of land (moderate and most suitable) area 29.80% can be further investigate for site specific landfill selection. The least criteria of selected attributes and without buffer zones also provide significant portion of surrounding under risk area category. Then the sensitivity of this area can be concluded as a quite high with respect to subjected socioeconomic attribute rather than environmental attributes. Further investigation on following areas (most suitable) including hydrogeological pedological and geotechnical investigation can be applicable and useful for prior engineering selection.

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