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ssh.samodhana@gmail.com

Solid Waste Disposal Site Selection Using Geographic Information System: A Case study in Kandy Municipal Council

DMSLB Dissanayake[1] DML Dissanayake[2]

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දෛනිකව මහනුවර මහ නගර සභාව මෙ.ටො. 90ට ආසන්න ඝන අපද්‍රව්‍යය ප්‍රමාණයක් එකතු කරනු ලබන අතර ඉන් 90% ගොහාගොඩ පිහිටි විවෘත කසළ බැහැර කිරීමේ ස්ථානයට මුදාහරිනු ලබයි. මේ හේතුවෙන් සෞඛ්‍ය හා පාරිසරික ගැටළු රාශියක් උද්ගතව ඇති අතර ඇති අතර, වායු දූෂණය, ජල දූෂණය, භූමි හායනය හා ජෛව විවිධත්වයට සිදුවන හානිය මේ අතරින් බරපතල වේ. මේ නිසා, මෙම අධ්‍යනයේ පරමාර්ථය වන්නේ ඝන අපද්‍රව්‍යය බැහැර කිරීම සඳහා සුදුසු ස්ථානයක් (GIS) ඇසුරින් නිර්ණය කිරීමයි. බහුවිධ උපමාන නීර්ණ විශ්ලේෂණ (Multi Criteria Decision Analysis - MCDM) ක්‍රමවේදය ඇසුරින් අවකාශීය හා අවකාශීය නොවන දත්ත ප්‍රධාන උපමාණ තුනක් යටතේ (භෞතික, සමාජීය, ආර්ථික) විශ්ලේෂණය කල අතර සිව්රැස් දත්ත විශ්ලේෂණ (Raster Calculator) ක්‍රමවේදය භාවිත කරන ලදි. දත්ත විශ්ලේෂණයෙන් ලබා ගත් තොරතුරු අනුව, ඝන අපද්‍රව්‍යය බැහැර කිරීම සඳහා සුදුසු ස්ථාන තුනක් (i) දෙල්තොට (ii) යටිනුවර (iii) හාරිස්පත්තුව යන ප්‍රදේශ අසුරින හඳුනාගන්නා ලදි. පර්යේෂණයෙන් ලබාගත් තොරතුරු කසල කළමනාකරණය සඳහා මහනුවර මහ නගර සභාවට භාවිත කළ හැකි අතර වෙනත් පර්යේෂණ කටයුතු සඳහා මෙම තොරතුරු පිටුවහලක් වනු ඇත.

ප්‍රමුඛ පද ඃ කසල කළමනාකරණය, GIS, MCDA, පාරිසරික කළමනාකරණය

[1]*Department of Social Sciences, Rajarata University of Sri Lanka. Mihintale.*
dissanayakedmslb@yahoo.com
[2]*Department of Geography, University of Peradeniya*
lalitha_dissanayake@hotmail.com

01. Introduction

It is an obvious fact that mismanagement of solid waste and its improper disposal lead to health and environmental problems. Therefore solid waste management program is essential in order to address the environmental, social and economic problems associated with the present disposal practices (Central Environmental Authority, 1995).

Solid waste generated in the KMC area is collected by the KMC on daily basis. It is estimated that about 90000-100000 Kg/perday (KMC Project Report, 2007). Solid wastes collected by KMC and about 90% and directly disposed in the open dumping site in Gohagoda without any consideration of environmental issues such as air pollution, water pollution, lan d pollution, effects on biodiversity, effect on the scenic beauty, health issues and unpleasant environment. (GIS) is known as one of the decision making tools in any kind of projects based on spatial data. GIS is one applicable software that can be used to find out most suitable spatial area (Wang, Qin, Li, & Chen, 2009).

Accordingly, it becomes clear that there should be some kind of effective strategy to overcome the above issues pertaining to improper disposal of solid wastes in the study area. Therefore, in this study an attempt has been made to find out the most suitable site with Geographical Information System (GIS) (Srivastava, Ismail, Singh, & Singh, 2015) to establish a sanitary landfill in order to manage the solid waste in an environmentally sound and socially acceptable manner (Philip Rushbrook, 1999).

2. Objectives

2.1 General objective

To introduce the most suitable site to establish a sanitary landfill to the Kandy Municipal Council.

2.2. Specific Objectives

I To study the current waste management and its consequences

II To examine the applicable solution for overcoming the solid waste associated problem.

3. Methodology

3.1 Data Collection Methods

Primary data

1. Both formal and informal interview with households of Kandy municipal council area.
2. Informal interview with people of the KMCA
3. Field observation.

Secondary data

1. From Kandy Municipal Council
2. Rajarata University Library
3. Central Environmental Authority (CEA)
4. Related Books and Magazines
5. Digitize maps (1:50,000 map, sheet No 54 in Kandy map) and other digitize data sources.
6. Other GIS data sources Eg.- Google Earth

3.2 GIS and GPS data analysis

Once the needed data are collected, it converted into a raster format to produce various map layers that spatially represent various factors

contributing to the selection process. Numerous intermediate or analysis map layers was created using GIS map analysis approaches. It included buffer zones, neighboring computation, and geo-processing tools (overlay, intersection, union, clipping, etc.). Three types of criteria used to formulate best sanitary land fill area with environmental sound manner using the following 15 attributes as follows.

1. Physical criteria

1. Surface water
2. Ground water
3. Biodiversity
4. Flooding frequency
5. Soil permeability
6. Soil strength or stability
7. Slope stability

2. **Social cultural criteria**

1. Important public places
2. Tourist and scenic area
3. Security zones
4. Aesthetic appearance

3. Economic criteria

1. Industrial zones
2. Major crops
3. Important mineral resources
4. Congested roads and railways

4. Evaluation criteria

The evaluation criteria based on relative importance of each attributes are employed in the study of Kontos (2005).Result of the methodology is

the land evaluation based on the suitability indices. In this activity, three criteria namely physical, social-cultural, and economic were looked into and different attributes or sub criteria were examined under of each criterion. The following table 01illustrates grading system of the criteria. It has divided into three criteria such as zero, one and two. Two types of data layers (vector and raster) formulated in GIS based on the study of Kontos (2005) and local application by the Central Environmental Authority (2007).

Table 01 - Grading and each criterion

Grading	Colour	Criteria
0	Red	Total exclusion area within the selected area
1	Yellow	Restriction area. Before star built landfill should be apply remedial practices in this areas
2	Green	Accepted area for landfill site and suitable index

5. Selection Criteria

This part illustrates the suitable land selection criteria for sanitary landfill site with concerning three major group of criteria such as physical, cultural and economic. In addition, each criterion consists of sub attributes for illustrations with sub values spatial and non-spatial.

5.1 Physical Criteria

All physical components in the study considered under physical data and apply selection criteria and grading value to identify suitable landfill site within the Kandy District.

5.1.1 Distance from the surface water bodies

Table 02 shows the specific grading system given for the distance from surface water bodies to the potential landfill sites. This criterion classifies the whole area in terms of the occurrence of existing and

abandoned surface water bodies. In this context "water bodies" refers to rivers, waterfalls and tanks.

A buffer distance of 200m from surface water bodies is considered as an excluding area due to high biodiversity surrounding fresh water sources and prevention and contamination of water bodies. Therefore, in view of the above facts a grading of 0 is given to site at a distance less than 200 m.

Table 02 - Grading value for the distances from surface water bodies

Distance from surface water bodies	Grading value
<200 m	0
200-1000 m	1
>1000 m	2

Area under 200-1000m buffering considered as restricted area in research and grading 1 is given to a site at a distance between 200-1000 m. over 1000 m away from all surface water bodies is given a grading value of 2.

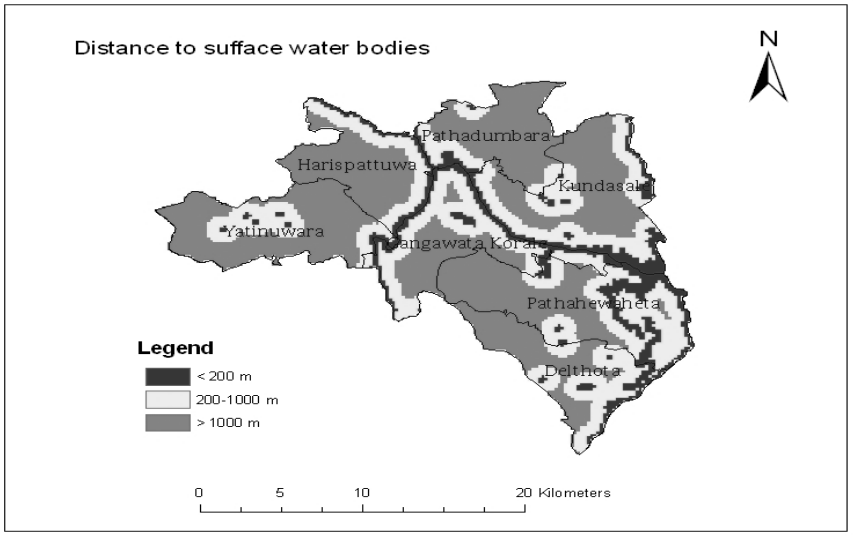

Figure 01 - Spatial pattern of distance of water bodies in Kandy district and Distance to surface water bodies

Figure01 illustrates the spatial representation of the surface water body criterion 11.3% of the site (1235 cells) was found to be unsuitable for sanitary land filling. In this respect some of the areas which were unsuitable for land filing include areas near the Mahaweli river and some tanks Eg: - Bogambara tank in Gagawata Korale DS division 33.1 % of the site (3627 cells) was identified as restriced area and out of the total area 57.7% (6105 cells) were identified as an acceptable area.

5.2 Social and cultural criteria

This section illustrates social and cultural data in the selected area of Kandy district. Further these data can be divided into sub attributes based on their values.

5.2.1 Important public places

Under this attribute, places of worship (temple, churches, mosques and Koviles) and the places of education, hospitals, libraries, recreation places, parks, cemeteries….etc. are considered. The following table 03 illustrates the grading system assigned for landfill sites in relation to important public places.

Table 03 - Grading value important public places

Distance from important public places	Grading value
<250 m from important public places	0
250-500 m from important public places	1
> 500 from important public places	2

Landfill should not be located proximity to in important public places or close to important public places because social issues and be anticipated. Contamination of drinking water, odor problem, aesthetic problems and health problems as well as garbage carrying vehicular movement and landfill equipment (caterpillar and other compacting equipment) can be affect such important public places. Therefore, areas at a distance less than 250 m from important public places are given grading of 0.

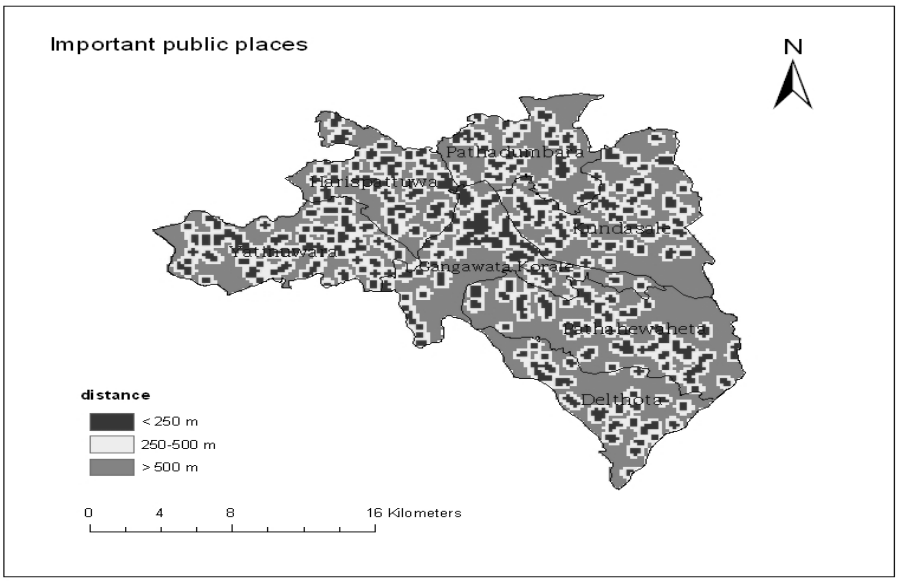

Figure 02- Important public places

The area which extends 250-500 m from important public places is suitable but with restrictions and the grading value is 1 for this area. Acceptable area is beyond (>500 m) from important public places and the grading is given as 2. The figure 02 shows the spatial representation of important public places in the selected area of Kandy district. It was revealed that 11.3 % of the land (1235 cells) are unacceptable for sanitary land filling because a number of important public places specially places of worship within Gagnawata Korale DS division such as the temple of the tooth, Paththeni Dewalaya, Vishnu Dewalaya…..etc. In addition, several churches, mosques and Kovils as well as important Dewalaya called "Kali" in Harispattuwa DS division are located here.

The area which is within 250-500 m is suitable for land filling but with restrictions and the area that is shown in green colour (>500 m) is acceptable and the most suitable for landfill site.

5.3 Economic Criteria

All critical primary, secondary and tertiary economic activity with regard to agricultural and industrial sectors has been considered under these criteria. Further the criteria can be divided and attributed as follows.

5.3.1 Industrial Zone

There are many industries in the study area in Kandy and increasing industrial activity surrounding Kandy city. This is because Kandy is the second largest city in Sri Lanka, Table 04 illustrates the grading system assigned in relation to industrial zones and major industries. This criterion classifies the whole area in terms of industrial zones, major industries, area proposed for industries and industrial parks.

Table 04 - Grading value of industrial none

Industrial Zone	Grading value
<500 m from Industrial zone	0
500-1000 m from Industrial zone	1
> 1000 from Industrial zone	2

Landfill activity is not normally allowed near or surrounding the industrial zones due to reasons such as possible fire and explosion hazards (due to significant CH_4 emission) with subsequent threat to work and even possibilities of fatal accidents. Investors do not like to start their industries near landfill sites due to unpleasant work environment and possible fire and explosion, especially international investors. Considering in all above reasons is given the grading value 0. The area from 500-1000 m is considered as suitable but with restrictions and the area which is beyond 1000 m, is moderated suitable for sanitary land filling.

Figure 03 shows spatial representation of Industrial zone criterion in selected area in the Kandy District. Unsuitable area was for very small and it include 1.1% of the sites (126 cells) from total area. Areas which extend 500-100 m through the buffer are considered as suitable but restricted. Areas that are beyond 1000 m are selected as most suitable for sanitary land fill sites.

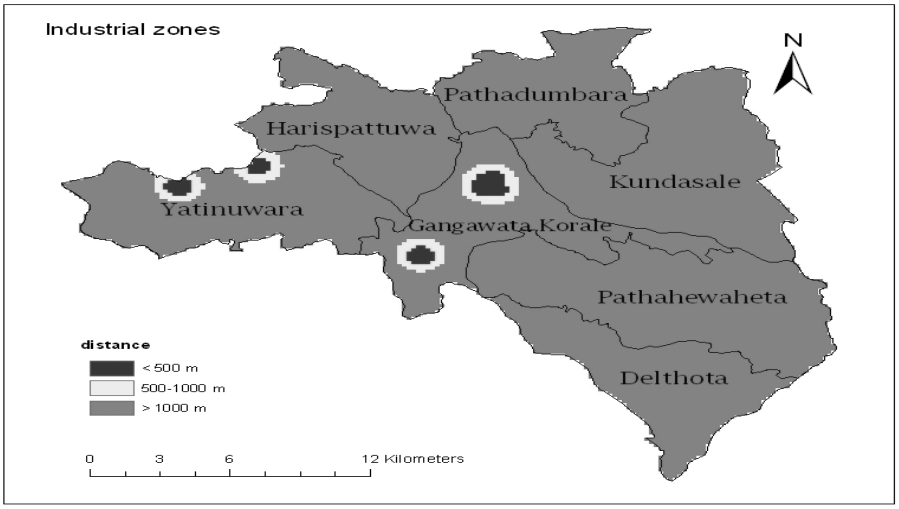

Figure 03 - Industrial zone

6. Data Analysis and Computations

This consists of spatial data analysis described under the methodology. The data are evaluated as multiple criteria and Weight class methodologies.

6.1 Multiple criteria

Multiple criteria methodology used to analysis spatial and non-spatial data in this study. In this method, it is the multiply of each attribute which coverts to the raster format. The equation as follows,

$$S_i = D_{L1} * D_{L2} \ldots\ldots\ldots\ldots D_{Ln}$$

Where - S_i = suitable index

$D_{L1, DL2}$ = selected raster data layer

D_{Ln} = All selected raster data layers

15 attributes (data layer) of this study under the three criteria have been used.

6.2 Weight Class Methodology

The simple additive weighting (SAW) method (Mahajan, 1991) used to calculate the suitability index for each cell or area based on different criteria.

$$S_{i = Dl} * W$$

Where - S_i =suitable index for area

D_l = selected data layer

W =important weight class

In this context region was subdivided into 4 hectare (200m x 200m) cells and in total 10967 cells and total area is hectare 43868. (10967 x 4 = 43868) was completed.

Physical criteria - Surface water, Ground water, Biodiversity, Flooding frequency, Soil permeability, Soil strength or stability, Slope stability)

Social cultural criteria - Important public places, Tourist and scenic area, Security zones, Aesthetic appearance

Economic criteria - Industrial zones, Major crops, important mineral resources, Congested roads and railways

7. Results & Discussion

7.1 Overall summary of selected site characteristics

The above table 05 illustrates characteristic of the selected sites. All this data collected through field surveys and some data taken from KMC. Financial aspect is the most important factor of any development project. Therefore, cost and benefit of the project should be evaluated before staring it. However, a cost and benefit analysis was not included in this study. The above summary characteristics considered only economic factors that integrated with landfill site. As an example, if there is not adequate daily covering material in vicinity area, it has to be collect from another area. It increases transport cost of the project.

According to the above table 05, there are no economically very unsuitable aspects in the investigation area (0 = 0). Two aspects are economically unsuitable (1 - 2) in the selected area such as transport

distance and population density. Five aspects found as economically most suitable (2 - 5) in the investigation area. They are the availability of daily cover material, close proximity to infrastructure, Demand for the rehabilitated land after closure, Availability of the Crown Land for planning of landfill from the vicinity.

Site	Availability of daily cover material	Close proximity to infrastructure	Lesser transportation distances	Close proximity to higher population density	Demand for the rehabilitated land after closure	Availability of the crown land	On-going planning of landfill in the vicinity	Overall rank
Site one	1	0	2	0	2	0	2	0 = 3 1 = 1 2 = 3
Site two	0	1	1	1	0	0	2	0 = 3 1 = 3 2 = 1
Site three	2	2	1	1	2	2	2	0 = 0 1 = 2 2 = 5

Table 05 - Overall ranking of the selec

8. Conclusions

Fifteen attributes of three criteria have evaluated. The selected attributes have been applied to two spatial data evaluation equations namely weight class methodology and multiple criteria methodologies. Evaluation of three selected suitable site and field observation data illustrated in the table 05 in the each site. Finally, Galaha Plantation area has selected as the most suitable place for landfill site.

Physical, social and economic criteria were considered in finding the suitability for sanitary land fill sites. Table 05 also summaries the field survey data. According to all the evaluated data Galaha Plantation that situated in the Perawatta West GN Dividion of Delthota DS Division selected as suitable landfill site.This area can be used as a final disposal site of KMC. The person in charge of this plantation have been willing to hand over this land to any kind of activity because is an abandoned plantation area,Subject to the following.

I. Relevant authorities should acquire the selected land as a landfill site

II. Waste transport vehicles with road capacity should be determined

III. The nearest road network to the selected site is Kandy to Delthota road but it is runs through the Peradiniya University. Therefore Authorized agent should transport waste in fully covered vehicles to prevent visual pollution and dour issues.

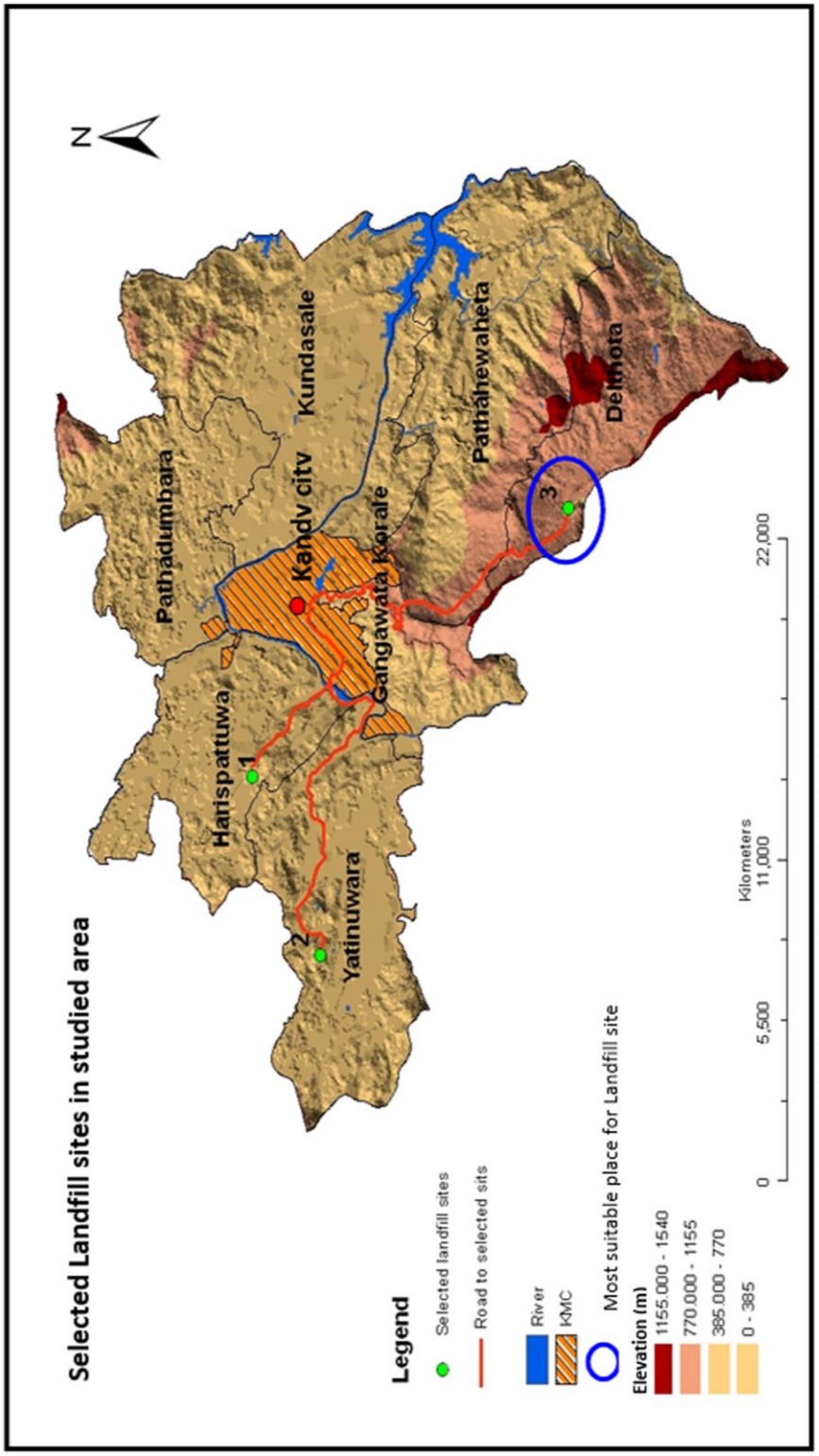

Figure04 -3D views of the most suitable land sites in selected area of Kandy

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