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GIS AND MULTI-CRITERIA BASED ANALYSIS FOR BEST SOLID WASTE DISPOSAL SITE SELECTION INSHASHAMENE TOWN, ETHIOPIA

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Abstract

For this work first best experiences of solid waste management and site selection planning of Grahams town , South Africa and Kampala city of Uganda countries, suitable sites were studied. Multi criteria GIS based technique was used to identify suitable sites for waste disposal. The data used for applying multi criteria GIS based site selection are city base map, topography, settlements (urban center distance), roads network map, proposed railways route, slope, land use map, abattoir site, streams, important buildings, prevailing wind directions, residence land use, social service distribution map, greenery and sensitive area, floodplains, high tension line, cemetery area, utility map of the city, potential expansion area and master plan document and photo were used. In addition structural plan and city greenery and beautification reports (2013), city capital investment plan report (2012/13), city observation and manuals on Ethiopian urban planning and implementation and environmental protection authority guidelines (2002, 2003, and 2007) and individual knowledge on the site were used *to set selection criteria. The results obtained provide most suitable areas for landfill sites in the study area.*

Key terms: solid waste, Multi-criteria Analysis, disposal site selection, and urban planning.

1. Introduction and Background

Solid waste management may be defined as the discipline associated with the control of generation, storage, collection, transfer and transport, processing and disposal of solid wastes. Integrated solid waste management includes the selection and application of suitable techniques, technologies and management programs to achieve specific waste management objectives and goals (Tchobanoglous and Kreith, 2002). Landfill is the most cost-effective system of solid waste disposal for most urban areas in developing countries (Seneret al. 2006). Recently, due to the growing urgency of urban environmental problems, solid waste management and planning in lower income countries has attracted much attention, and there is now a movement toward landfills designed to increase environmental protection. One of the major problems in waste management is concerned with the selection of the appropriate site for waste disposal.

The use of GIS in urban planning involves many functions, scales, sectors, and stages. For instance GIS is used in planning for mapping or spatial analysis purposes, in suitable site identification for settlement, in land use planning, in transport planning, in environmental planning, in urban infrastructure planning, in the identification and location of utilities and services in urban areas. It also used in disaster management planning, in urban area change detection, in the detection of urban pollution and selection of optimum urban solid waste sites selection (planning) usi**ng** multi criteria analysis (Seneret al. 2006).

Therefore, urban area solid waste Site selection procedures can benefit from the appropriate use of GIS. Common benefits of GIS include its ability to: (a) capture, store, and manage spatially referenced data; (b) provide massive amounts of spatially referenced input data and perform analysis of the data; (c) perform sensitivity and optimization analysis easily; and (d) communicate model results with the difficulties that decision makers encounter in handling large amounts of complex information.

2. Methodology

2.1 Site

Shashamene city Administration is located in the southern part of the country at a distance of about 250 km from Addis Ababa. The geographical coordinate of the town lies roughly 7^0 08’ 51’’N to 7^0 18’ 19’’N latitude and 38 ^{0} 32’ 43’’E_ 38^0 41’ 07’’E longitude. Besides, the town is surrounded by lands in all direction and covering a total surface area of about 12,994.61ha. The distance from North to South extreme points of the town is about 22km. Likewise the East to West ground distance of the town is about 8km (OUPI 2010)

2.2 Method of Data Collection

Primary and secondary data was collected to identify potential site for solid waste. The primary data was collected through personal observation and expert interview. The secondary data was collected from the following data inputs: base map of the city 2012/13, contour, river, road, important buildings, residential and social service infrastructure, future expansion site of the city and prevailing wind direction. In addition Urban Planning and Implementation Manual, Integrated urban infrastructure and services planning manual.(September,2006), Environmental pollution control proclamation(300/2002), city investment capital report, OUPI report and city drainage master plan project report 2013,and municipality sanitation and greenery expert report of 2012/13 were used. The study also employed Auto CAD drawing format is transferred to GIS 9.31 data using Arc catalog and Arc Map and projected to UTM, Adindain zone 37.

2.3 Method of Data analysis

The input data was analyzed using the analyst tools and the weighted overlay process to produce suitable site by considering environmental criteria, health, compatibility of different urban infrastructure, location, standards clearance of different land uses, financial, economical, hydrologic, topographical criteria, geological criteria, and availability of construction material and other criteria.

Hence, each location was evaluated according to weighted criteria, resulting in a ranking on a suitability scale, rather than simply presence/absence. In order to select best site, the available information for the study area was digitized and stored in the information system.

2.4 Criteria Determination

For this paper the following criteria was developed depending on the existing urban planning and implementation police of Ethiopia (2006,) NUPI practice, Integrated urban infrastructure and service planning manual, solid waste management planning (2002,2003,2007) and planning principles in site selection and site analysis more over from review of best practice and on the limited availability of data. The criterion developed is given in the table 1.

Table 1.Creiteria for suitable solid waste disposal site selection for Shashamene city

No	Spatial Data	Layer name	Attribute	Criteria

1	Residential land use	Residence	Land use	250-500m away from residence
2	Administrative areas	Administration	Land Use	250m away from Administration
3	Commercial areas	Commerce	Land Use	250m away from Commerce
4	Recreational areas	Recreation	Land Use	300m away from Recreation
5	Abattoir areas	Abattoir	Land use	>=500m away from abattoir
6	Social service areas	services	Land use	>=3000m
7.	Schools	School	Land Use	3000m away from School
8	Health Service	Health	Land Use	300m away from Health
9	Worship place	Worship	Land Use	300 m away from Worship
10	Industrial area	Industry	Land Use	300m away from Industry
11	Conservation areas	Conservation	Land Use	10m away from conservation
12	Cemeteries	Cemetery	Land Use	100m away from cemetery
13	Rivers and Streams	River/Stream	water	100m away from River/Stream
14	High Tension Line	High/Tension Line	infra	500m away from High/Tension
15	Agricultural Land	Agriculture	Land use	Select Vacant/ Agriculture
16	Slope	Slope	Slope	Between 5-12 per cent slope
17	Road network	Road	Land use2	Not less than 1km
18	Wind direction	Wind	N/A	buffer zone (150 to 200m)
19	Future Land use	Future Land use	Land use	Prioritize/if expansion>500m
20	Site capacity	Site Capacity	Area (hec.)	< or = to 5 hectare
21	Boundary/Town	Area Boundary	boundary	Within municipal bounder
22	Rail way	Road	transport	>500M away
23	Wet land area	Wet land	Land use	500m buffer

Source: Study.

2.5 Factors criteria

This criterion was developed as the literature, urban planning guideline of Ethiopia, integrated infrastructure manual (2006) structural plan of Shashamene city (2001 and 2010) and in other cities. The ranking was also based on the objectives to minimize impact of solid waste on the surrounding environment, from Minimizing impact of nearby activities on the solid waste, existing land use, topographical slope, from optimum social service proximity, from the goal of environmental and health aspects and from minimizing of the cost of development reducing mobility.

Table 2 Matrix and weights of importance factors criteria

Factor	Unsuitable	Less suitable	Medium suitable	High suitable	Unsuitable
Slope	$<2^0$	2^0-4^0	4^0-7^0	7^0-12^0	$>12^0$

River/stream	0-100m	100-200m	200-500m	>500m	
Town center/settlement	0-1km	1-4km	4-8km	9-10km	>10km
Major road	0-1km	1-2km	2-3km	3-6km	>6km
Inner streets	0-30m	30-50m	30-100m	100-2000m	>2000m
Residential area	0-250m	250-300m	300-500m	>500m	
School service	0-500m	500-1000m	1000-3000m	>3000m	
Health service	0-300m	300-400m	400-500m	>500m	
Recreations and green area	0-300m	300-400m	400-500m	>500m	
Potential expansion areas	0-500m	500-800m	800-3000m	>3000m	
Industrial area	0-300m	300-400m	400-500m	>500m	
Abattoir	0-500m	500-600m	600-700m	>700M	
Tension line	0-100m	100-200m	200-500m	>500m	
Conservation area	0-10m	10-50m	50-100m	100-3000m	

Source : Study

To analysis the set criteria the following values were assigned

Table3 Values for assigned factor criteria

Importance	Not suitable	Less suitable	Medium suitable	High suitable	Not suitable
Values	1	2	3	4	5

2.6 Determining the influence to select suitable site

The total influences need to be weighted and the influence was assigned percentage based on the objectives to minimize environmental, health, social wellbeing risks, optimum services proximity, existing land use, topography and the cost of reducing development and mobility. The following suitability analysis GIS model shows the overall process in the determining the influence criteria for suitable solid waste site and applied an overlay weighted spatial analysis to come up with suitable site. By using aggregate the criteria weighted liner combination.

$S=\sum W/\sum n$

$S=\sum Wixi\times\pi cf$

$S=(F1*0.1)+(F2*0.31)+(F3*0.019)+(F4*0.019)+(F5*0.019)+(F6*0.0.15)+(F7*0.076)+(F8*0.019)+(F9*0.1)+(F10*0.13)$

Where s=composite suitability; F =each factor's; n=total number of factors; π=products of 1-

2.7 Site selection Phases and process

Phase 1: involves the use of Arc GIS spatial analyst Geo-processing tools to create Euclidian distance based on set distance criteria, using the spatial analyst reclassify the distances as unsuitable, less, medium and high suitability and using the overlay analysis and select sites that satisfy the landfill site selection criteria. For example, distance from water bodies, town center, major roads, greenery and sensitive area among others.

Phase 2: involves further analysis and evaluation of the potential sites obtained in the phase 1.with the prevailing wind direction ,the sites as much possible need to be within city boundary and out of existing developed settlements.

Phase 3: Designating highly suitable sites by combining the results of (1) & (2)

That is:

- Combining suitable sites map derived in (1) with the factor maps derived in (2)
- Considering future land use and the influence of wind to yield highly suitable sites.

3. Results

The final suitability map indicates that a suitable area was selected in the south west side from the city center at a distance of 9 to 10km from the center which is at highest suitability criteria set within the city boundary (GIS output) . The map also shows if the city administration in the future plan and discusses with the surrounding rural kebele and work on the mutual benefits of both there is an opportunity to have site outside the boundary.

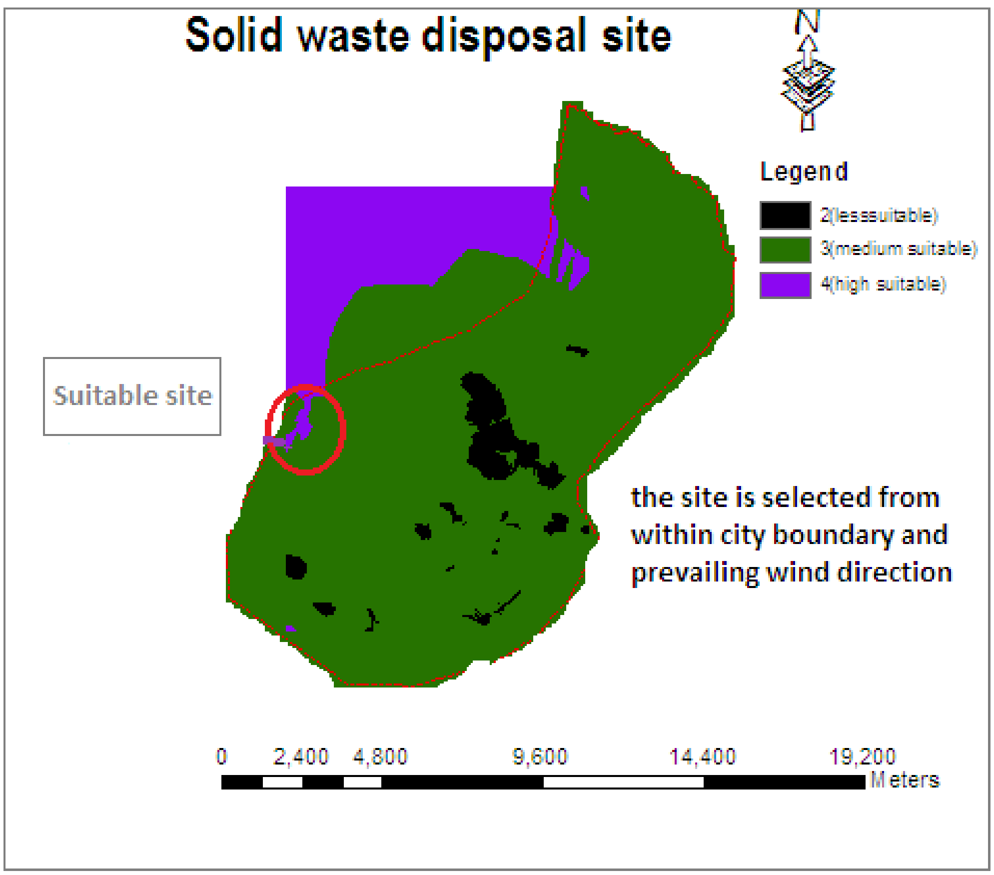

Figure 1

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