GIS based Landfill Site selection for Faisalabad City

Sajid Rashid Ahmad, Khalid Mahmood

Abstract— Shortage of land for waste disposal and inappropriate landfill site is one of the biggest problems in urban areas. This problem could be solved by applying new technologies like Geographic Information Systems. Most of the landfill sites in Pakistan are selected randomly, and waste is burned in air which has impacts on nature and human lives. The main aim of this research is to determine a suitable landfill site with less impact on environment. In this research, a potential site for an appropriate landfill area for Faisalabad city was determined by using Geographic Information System (GIS) as a tool to aid the decision making process. To achieve this purpose, thematic layers, and different tabular data such as topography, land use, roads network, ground, and surface water, infrastructure, and urban areas were collected. Thematic maps were used to create the vulnerability map for the area and the results were compiled to the buffer zones around sensitive areas. Multi-criteria analysis (MDA) was used to measure the relative importance weighting for each criterion. Each map layers were formed with the aid of GIS and final suitability map was created by overlay analyses of each criterion map. According to obtained results, high and low suitable areas were determined in the study area.

Index Terms— Faisalabad City, Geographic Information System, Landfill Site Selection, Multi-criteria Decision Analysis, Overlay Analysis, Urban Areas, Waste Disposal

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1 Introduction

A landfill site is a place for the discarding of waste things by interment and is the ancient form of waste action. At present, solid wastes are serious problems having the first priority of the environmental problems. There are many techniques used for waste management such as land filling, thermal treatment, biological treatment, recycling etc. (Kantos et al., 2005). All important aspects of waste management for public health, aesthetic, and environmental reasons are the collection, processing, transport and disposal of solid waste (Al-Khatib et al., 2007). Without creating a hazard to public health, it is essential to dispose the solid waste to a landfill (Yilmaz, and Atmaca, 2006). Hence, suitable site choice for waste dumping is one of the key complications in waste controlling.

The disposal site must not damage to the ecology of the surrounding area and the biophysical environment (Siddiqui et al., 1996; Erkut and Moran, 1991; Lober 1995). Economic factors and geomorphologic features must be considered during selection for the solid trashes (Yesilnacar and Cetin, 2007). Several practices can be found for site choice of solid waste disposal in literature (Kontos et al., 2005; Kontos et al., 2003; Sener et al., 2006; Simsek et al., 2006; Banar et al., 2006; Gemitzi et al., 2006; Mutluturk, and Karaguzel 2007; Nas et al., 2008). Many criteria should be considered, to determine the most proper landfill site for a region. The Multi-criteria Decision Analysis (MDA) is widely used method for site selection process.

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Really, it is a discipline aimed at supporting decision makers who are faced with making numerous and conflicting evaluations. Measurements in MDA are derived or interpreted subjectively as indicators of the strength of various preferences, unlike methods that assume the availability of measurements (Saaty, and Thomas 2005). In order to find the best choice, the main objective of MDA is the design of mathematical tools to support the subjective evaluation of a finite number of decision alternatives under a finite number of criteria (Pournamdarian, 2010).

Geographic Information System combines spatial data (maps, aerial photographs, satellite images) with quantitative, qualitative and descriptive information databases (Kontos et al., 2005). The overall process for GIS supported landfill site selection contains has two primary screening steps:

i. GIS/Pre-Screening Step: exclusion of areas unsuitable for landfill, and

ii. Decision Analyses Step: weighting (ranking) of remaining areas (Siddiqui et al., 1996; Allen et al., 2003; Muttiah et al., 1996; Lin, and Kao 1998; and Ozdemir et al., 2007).

To solve the landfill site selection problem, the integration of GIS and MDA is a powerful tool because GIS delivers effective handling and appearance of the data and MDA provides reliable position of the latent landfill areas founded on a diversity of criteria (Sener et al., 2006). To control the most suitable landfill place/site for the Faisalabad City catchment area by integrating the GIS with the Multicriteria Decision Analysis (MDA) is the main objective of this paper. Eight criteria were considered, In order to determine suitable landfill site, such as distance from surface water, distance from buildings, distance from prohibited areas (ecologic, technical or significant), geol-

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ogy or hydrogeology, land- use, distance from infrastructures, hill and feature.

2 The Method and Material

Faisalabad district formerly consisted six sub-divisions:

- Faisalabad City, Faisalabad Sadar, Chak Jhumra, Samundri, Jaranwala, and Tandlianwala.

In 2005, Faisalabad was reorganized as a City District composed of eight autonomous towns:

1. Lyallpur Town
2. Madina Town
3. Jinnah Town
4. Iqbal Town
5. Chak Jhumra Town
6. Jaranwala Town
7. Samundri Town
8. Tandlianwala Town

Faisalabad district has made quick steps in the arena of industry after freedom. It is currently named as "Manchester of Asia" for its wide growth of textile production. The city is at a road and railway junction, which has played an influential role in the development of trade and economy.

In order to decide landfill site, numerous standards were inspected such as:

- distance from surface waters,
- distance from settlements,
- distance from roads, slope, aspect and
- distance from protected areas (ecologic, technical or significant), geology or hydrogeology and land-use.

The Multi-criteria Decision Analysis (MDA) was in practice to amount the comparative status allowance for each standard. All map layers were designed with the assistance of GIS and absolute appropriateness map was produced by overlay investigates of each standard map. High and low appropriate areas were founded in the study area, according to obtained results.

In this study/paper, the methodology which is integration of GIS and MDA was used and applied to the Faisalabad City catchment area. Eight criteria were considered such as:

- distance from surface waters,
- distance from settlements,
- distance from protected areas (ecologic, technical or significant), geology or hydrogeology, land-use,
- distance from roads, hill and feature.

These basic criteria and sub-criteria were selected by taking relevant international literature and Turkish regulations (Ministry, 1991) into consideration.

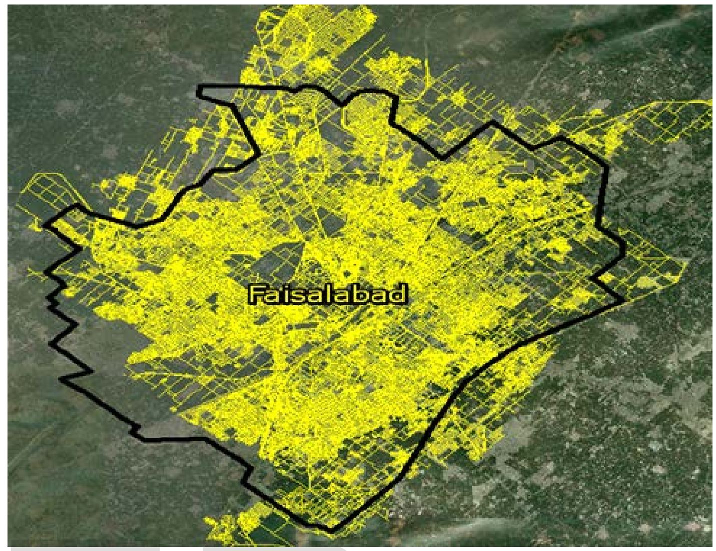

Figure 1: The location map of the study area (Faisalabad City)

For imaging and analysis of spatial data, ArcView 9.0 software was used. Plus, several GIS analyses such as buffer zoning, adjacent calculation, cost calculator and overlay investigation were used. MDA was in use to amount the relative status weighting for assessment criteria, In order to evaluate site selection criterion. Because, MDA is to split the decision difficulties into minor parts, examine each part distinctly, and then incorporate the portions in a logical way (Malczewski, 1997).

To determine Landfill Suitability Index (LSI), the ranking and weight values were assigned to each criterion. It (LSI) was calculated by means of growth of each standard weight with separately sub-criteria weight.

LSI =(Acwi x Ascwi)+(Rcwi x Rscwi)+(Scwi x Sscwi)+(LANcwi x LANscwi)+(GHcwi xGHscwi)+(SETcwi x SETscwi)+(PAcwi x PAscwi)+(SWcwi x SWscwi)

Where:

LSI:	Landfill suitability index
Acwi:	Weight index of aspect criteria
Ascwi:	Weight index of aspect sub-criteria
Rcwi:	Weight index of roads criteria
Rscwi:	Weight index of roads sub-criteria
Scwi:	Weight index of slope criteria
Sscwi:	Weight index of slope sub-criteria
LANcwi:	Weight index of landuse criteria

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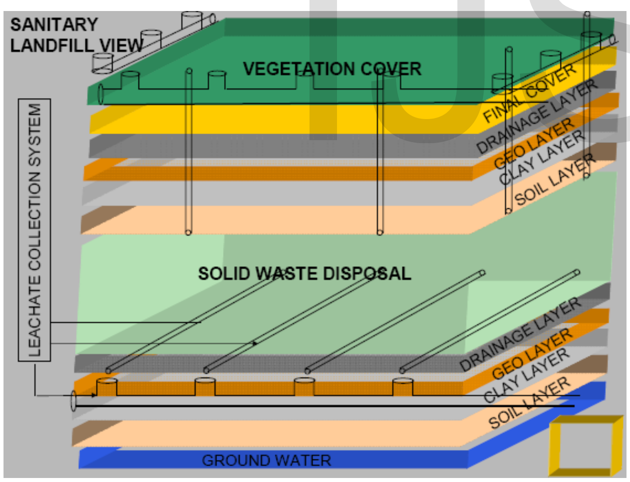
LANscwi:	Weight index of landuse sub-criteria
GHcwi:	Weight index of geology-hydrogeology criteria
GHscwi:	Weight index of geology-hydrogeology Sub-criteria
SETcwi:	Weight index of settlement criteria
SETscwi:	Weight index of settlement sub-criteria
PAcwi:	Weight index of protected area criteria
PAscwi:	Weight index of protected area sub-criteria
SWcwi:	Weight index of surface water criteria
SWscwi:	Weight index of surface water sub-criteria

Here, rankings varies between 0 (no constraint) and 10 (total constraint). Generally, weights are assigned according to the relative importance of each criterion. The assigned weights can be changed according to properties of the study area. Hence, there is not any standard for this topic. The weights were assessed by taking into account the possibility of modifying the natural conditions of the sites and suggested for only this study area. The map layers were formed in the GIS environment and last appropriateness map was shaped by overlay examines of each standard map. Map weights had to add up to 100% and the attribute scores had to be chosen using a scheme that was the same for each map, in order for the output map to be meaningful and consistent (Nas et al., 2008).



Guidelines for Identification and Establishment

Figure 2: Guidelines for the identification and establishment of a landfill site

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Guidelines for the Selection of a Landfill Site:

The following criteria for site selection are delivered as direction. A projected landfill site can be nominated although it does not run into each of the following criteria. Manufacturing design can ease insufficient site conditions however at a cost. Further literature for the selection of landfill site has also considered before declaring a landfill site.

- Landfill shall be designed at least for 10-30 years therefore adequate land area and volume shall be provided for sanitary landfill capability to run into projected requirements for at least ten years, so as to the cost in access roads, drainage, fencing, building work if constructed at the landfill site and weighing bridge stations are justifiable
- A landfill site must be within distance of 25 Kilometer from the center of a town, if the average round-trip haul (travel) distance is more than 50 Km then garbage transfer stations will be constructed.

Garbage Transfer Station (GTS) (Garbage transfer station GTS means where the garbage is primarily stored and then transported to landfill/dumping site). Transfer stations are centralized facilities where the waste is unloaded and collected, from scattered collection vehicles and reloaded in to longer vehicles for transport to a final disposal point or processing sites. Waste Transfer Stations are frequently accompanied with sorting units for separation of recyclable material. Compacting units for Solid Waste compaction further transported to final Disposal Point are also installed at transfer stations. If the hauling distance exceeds to 160 Km than rail hauling will be adopted.

The site is not inside 1 Km of socio governmentally thoughtful sites where public getting might be unlikely (e.g., Mosques, Churches, graveyards, schools, hospitals, historical places, play grounds etc).

Population shall be more than 200 meter away from the boundary of a landfill site.

Landfill site shall not be sited near any existing or planned drinking water protection and catchments-areas.

Landfill site shall not be located at an un-favorable local hydro-geological situation, e.g. springs or drinking water wells within very close distance to the chosen area.

Landfill site shall not be advised where the access roads are of very poor quality and the garbage collection vehicles has to pass through densely populated areas.

There should be no reserved or community drinking, irrigation or livestock water supply wells down-gradient of the landfill boundaries if at risk from contamination, unless other water supply bases are willingly and carefully available.

No significant protected forests are within 0.5 Km of the landfill cell (in landfills, a portion of refuse that has been compacted and then surrounded with cover material. Daily cover is placed over the land filled materials at the end of each day to complete the cell) development area. No main lines of electrical broadcast or gas, water, sewerage and lines are crossing the landfill plot expansion area, unless the landfill procedure would obviously cause no fear or redirecting is economically practicable.

There is no underlying limestone, carbonate, or other porous rock formations that would be ineffective as barricades to Leachate and gas relocation, where the growths are more than 1.4 meter (m) in thickness and present as the uppermost geological unit.

Landfill site shall not be developed in the following areas:

a) The site shall not be 3-5 Kilometer nearer to the airport area
b) The landfill site shall not be located at the areas which are susceptible of flood plains, wetlands, fault zones, seismic zones, and unstable areas.
c) The site should not be near water catchments area, surface water and other sources of fresh water
d) The landfill site shall not be constructed in low permeable soil areas which allows a fast penetration and permeation of water or possible Leachate to the next aquifer (ground water pollution)
e) Areas with unstable ground like swamps, moors, swallow holes, collapse sites, deep digging
f) Areas nearer than 200 meter to populated areas
g) National parks, natural protection areas and nature monuments, historical, religious or other important cultural sites or heritage
h) Near very intense agricultural use, mainly small scale farming
i) Extremely bad access, i.e. no existing access roads to the selected area which may involve long hauling distances (5 km) from main roads to the surroundings of the site and to the site itself
j) Access roads of a very poor quality or passing through densely populated areas
k) Too little available volume

Site appropriate for Landfill:

a) The site must be accessible from major roadways
b) The site should be large enough to accommodate the TMA wastes for a reasonable time of 10 to 30 years
c) The ground water table should be at least 1 m below the foundation of landfill
d) The site should be found in a zone where the landfill's process will not adversely affect environmentally sensitive resources
e) The site should have an adequate amount of earth shield material that is handled and compacted
f) The site should have enough space to accommodate workshop area, office building, mini lab, weigh bridge, recycling activities etc
g) Area for the intermediate storage of hazardous waste, e.g. industrial waste and medical waste which must not be mixed with household waste and which will have to be taken away to a special landfill for hazardous waste
h) Fence around the site; instead of a wire fence a living fence, i.e. a row of bamboo or cactus
i) Construction and equipment to collect (and treat) the biogas produced in the landfill during the process of decomposition of the refuse

3 Results and Discussion

In this study, evaluation criteria were determined depend on relevant Turkish Solid Waste Control Regulations (1991) and international literature. There are eight criteria that were well-thought-out when choosing a landfill place in the Lake Beysehir catchment area. These are distance from buildings, distance from apparent waters, distance from secure areas (ecologic, technical or significant), geology or hydrogeology, land-use, distance from highways, hill and feature. Every criterion was explained below in detailed.

Distance from settlements:

According to Turkish regulations (Ministry, 1991) landfill cannot be sited inside 1000 m of settlement areas. Therefore, an area with a 1000 m buffer zone was scored as 1 and buffer zones greater than 4 km were scored as 9.

Distance from surface waters:

According to Turkish regulations (Ministry, 2004) and worldwide literature (Kontos et al., 2005; Nas et al., 2008; Dorhofer and Siebert, 1998) landfill site must not be located near some surface water. In the study area such a zone has been created around lakes, springs and rivers of a 500 m buffer zone was scored as 1 and buffer zones greater than 2 km were scored as 7.

Distance from protected areas:

According to Turkish regulations (Ministry, 2000), protected areas such as national parks, archeological areas etc. are not suitable for landfill siting and landfill site should not be placed within these areas. Hence, a weighting of 9 is applied if >1000 m away and 1 for <250 m away.

Geology or Hydrogeology:

Basin's geological map was designed to profit from field previous investigations (Elitok, 2000; Demirkol et al., 1977; Ozturk et al., 1987). The six lithologic units such as alluvium, limestone, volcanic, flysch, ophiolite and metamorphic were grouped and mapped. According to aquifer properties of the lithologic units, the buffer zones were created. Alluvium and limestone have large water potential and are not suitable for landfill siting. Hence, the lowest ranks were assigned to these units such as 1 and 2 respectively. Also, metamorphics are impermeable unit so this unit was scored as 8.

Landuse:

To evaluate landuse properties of the study area, the 1:100 000 scale landuse map was taken from Management of Agriculture and Village Works. According to landuse of the region, Forest and rocky areas were scored as 1, dry agricultural areas was scored as 5.

Distance from highways:

The landfill place must not be located excessively far away from existed road networks (Nas et al., 2008). Similarly, it can be extended by other roads beneath all weather conditions. Hence, a weighting of 6 is applied if >1000 m away and 1 for <250 m away.

Slope:

Land slope is basic parameters for the construction of a landfill site (Kontos et al., 2005). The suitable slope for building a landfill is about 8–12% (Allen et al., 2003). Therefore, the vertical areas (> 20) were assigned a grade of 01 and the marginally sloping areas (0-10) with a grade of 5.

Aspect:

Settlements must not be affected from the odor which is originated from the wastes. Therefore, wind direction of the basin was taken into consideration. The wind frequency percentages data were gotten from the National Climatological Agency. In the basin, SW and NE winds are the dominant winds. So, these directions lowest weight values.

In present study, the high weights were given to the criteria of distance from settlements and distance from surface waters. But, aspect and slope criteria were assigned with low weights. Eight map layer s were prepared by GIS. The final suitability map was derived by overlay analyses of ArcGIS Spatial Analyst.

Initially forbidden areas were extracted by masking and then the land appropriateness of the study zone was considered by the LSI. Considered LSI differs between 1,45 and 13,6. The exact high and exact low appropriate areas were found. Pixels with 1,45 (colored yellow) are considered as very low suitable and are excluded from the alternative candidate's sites to be inspected as dumping areas. Conversely pixels with numbering around 13, 6 proposed sites that are possible to be further suitable and are colored red.

4 Conclusion

In the present study the landfill site selection for municipal solid waste was performed using GIS and MDA methods. For this aim, eight evaluation criteria were determined and their ranking and weights were assigned. The criteria maps were prepared in GIS environment using obtained numerical values. The ultimate suitability map was designed by overlay analysis and high – low suitable regions of the study area were determined. This study shows that suitable areas are quite limited for landfill siting in Beysehir Lake catchment area. In general, the regions where around the lake is unsuitable for landfill siting. Also, near the surface waters were determined as unsuitable areas.

The north and east of the lake were determined as high suitable areas in the region. These places are dry agricultural areas and have 0-10o slope. The flysh and metamorphic units are overlay in there. Furthermore, these places are away from surface waters and protected areas. The transportation is quite suitable for waste transport. However, detailed field studies should be performed for the final site selection.

The presented study is very helpful tool to aid decision makers. But, detailed field studies should be performed for the final site selection. Also, urgent preventions should be taken for every kind of activity within the area to protect the lake.

should be saved and submitted as a black and white file (grayscale or bitmap.) If a graphic is to appear in color, it should be submitted as an RGB color file.

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