APPLICATION OF GIS BASED MODEL IN LANDFILL SITE SELECTION: A CASE STUDY OF LAHORE, PAKISTAN

S. Rathore, S.R. Ahmad and S.A. Shirazi*

Institute of Geology, University of the Punjab, Lahore, Pakistan
*Department of Geography, University of the Punjab, Lahore, Pakistan
Corresponding Author E-mail: sana47rathore@gmail.com

ABSTRACT: Open dumping sites for solid wastes in Asian developing countries, including Pakistan, have recently received particular attention in terms of environmental pollution problems. In the Lahore District, Mehmood Booti is the only authorized open dumping site developed by city district government which is now unable to fulfill district's requirement. Therefore the data was collected to propose a new landfill site in Lahore district, Pakistan. These data sets involved the processing of spatial information that was utilized in GIS environment using Boolean Operation as a tool for land suitability analysis. In order to achieve desired results, five input raster layers; including water bodies, roads, important places, existing dumping site and tube well were prepared. After omission of unsuitable areas, the suitability analysis of the residue areas was accomplished.

Key words: Landfill, Geo spatial, Boolean, Site Selection, Lahore

(Received 12-08-2015 accepted 09-12-2015).

INTRODUCTION

Lahore is amongst the most urbanized districts in the South Asian region with a population density of seven thousand people for every square kilometer. The waste generation is an identified problem with urban advancement, where population increases, more waste is produced. There is only one authorized dumping site possessed by the City District Government Lahore (CDGL) at Mehmood Booti spread on 79 acres of land, which was built in 1996 and around 6 million tons of waste was dumped there till 2010. The dumping site contaminates underground water tables. The main issue in Lahore is the non-accessibility of the final disposal site. Landfill site choice is a troublesome and complex procedure, which helps assessment of a wide range of criteria for bringing sustainability in any area (Chang *et al*., 2008). Sustainable practices, which include the demand of three basic criteria, i.e. environment, economy, and society which must be considered while choosing the site of landfill.

GIS is a useful tool which decreases the time and expense of the site selection. It provides a wide range of techniques to store information for long term planning and better management (Sener *et al*., 2006). It has also been associated in the past for site selection studies (Curtis and Perry, 2000; Thomas, 2002; Shah and Wani, 2014; and Kamran. 2008). Thus the aim of this study was to find a best suitable landfill site in Lahore District using geospatial techniques.

MATERIALS AND METHODS

Study area: Lahore is the capital territory of the province of Punjab, as shown in Figure 1. It is located at 31° 25' 0" N Latitude and 74°19' 60" E Longitude. It is the second largest metropolitan city in Pakistan and a critical recorded focus in South Asia. The range of people count in Lahore has been multiplied many folds in the last 12 to 14 years.

Strong waste management has now turned into an imperative issue in this area. Therefore excessive urban planning was indebted for the stakeholders to play their positive role in the study area-the Lahore.

Criteria for Landfill Siting: In this study, there were five constrains for landfill site selection by considering hydrological, economic and environmental conditions for bringing sustainability to the society. In order to do so various secondary vector data i.e. distance to road, existing dumping site, surface water, tube wells and important places of the study area, were found to be useful. Accessibility of roads to the proposed landfill site was very important in order to minimize transportation cost. The sites with more than three hundred meters distance were not considered suitable. All the hospitals, school, colleges, universities, parks and historical places were also considered unsuitable as these could not be rebuilt easily again. The existing open dumping site at Mehmood Booti was projected to reach capacity in the coming years. Therefore, this site would not be able to help in this concern. Hydrological network could be obtained by using Arc hydro tools. The ground and surface water resources should be at a reasonable distance

from the proposed landfill site so that there may be less chances of contamination from the landfill pollutants. All the maps were geographic data layers stored in the GIS raster-based data bank.

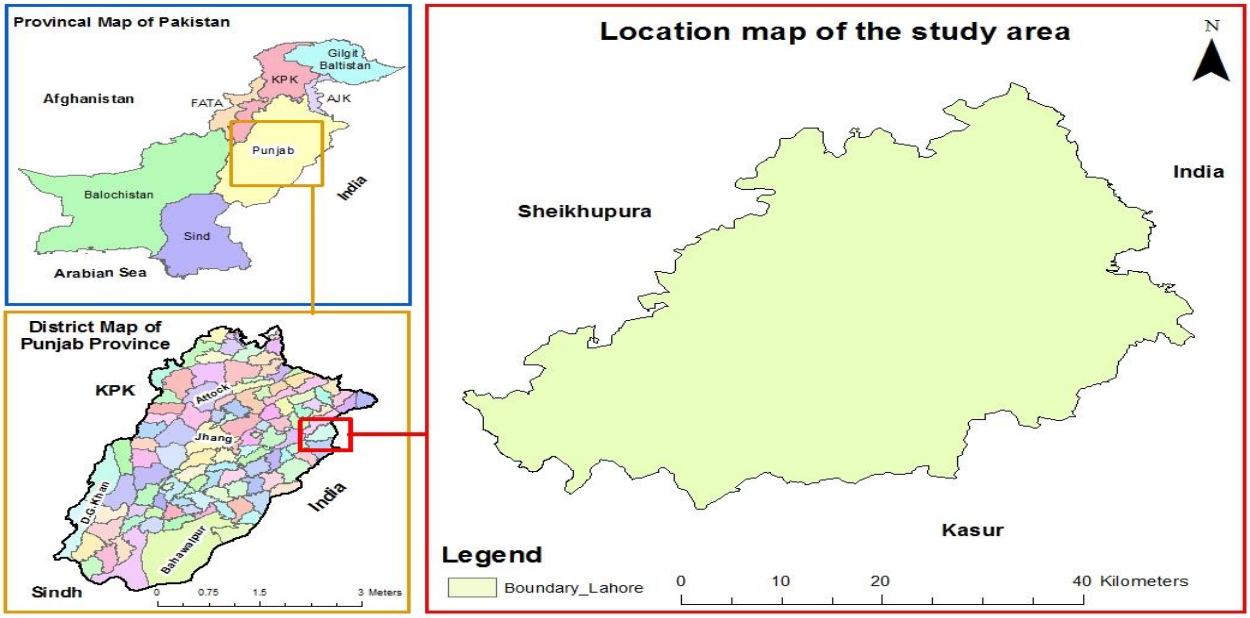

Figure 1. The location of the study area in Punjab province, Pakistan

Table 1. Desired limits of criteria considering for landfill site selection

Criteria	Buffer Boundary (meters)
Important Places	1000
Existing Dumping Site	500
Roads	300
Surface Water	200
Tube wells	300

Boolean Restriction Model: To locate a suitable site, Boolean method was used within a GIS environment. It screened the areas by restricting all those criteria which were not suitable for a landfill site. All the materials that were considered in this study, were in the raster layer because Boolean operation worked on raster only, in the form of raster value of 1 and 0, where 1 was for suitable area and zero for unsuitable (Mahini and Gholamalifard, 2006). The mathematical formula used for this purposed model expressed by (Gemitzi *et al.*, 2007):

$$S= \prod_{j=1}^{m} r_j$$

Where: S= suitability value (0 or 1); r_j = suitability index value for each constraint criterion (0 or 1) and m= total number of constraint criteria. Thus, this formula multiplied all the above described criteria to propose a landfill site by excluding all those areas which were unsuitable for landfill site (Shamshiry, *et al.*, 2011).

RESULTS AND DISCUSSION

Five restrictions were used to propose the suitable sites for landfill in study area of Lahore. The results in figure (2.A) are showing the buffer distance of three hundred meters around the tube wells. Figure (2.B) shows the buffer distance of five hundred meters around the existing dumping site, while figure (2.C) shows the roads of Lahore district and three hundred meters buffer around them. The figures 2.D and 2.E show the buffers around the water bodies and important places/landmarks of the Lahore District respectively. The buffer distance was used for the exclusion of selected factors through defined buffer distances to ensure their safety from degradation through landfill pollutants (Balasooriya, *et al.*, 2014).

The Boolean model worked only with raster datasets. It transformed all the related information of chosen criteria into binary form (True or False). Thus all vector data sets were converted into the raster datasets by using the conversion tool (feature to raster) in Arc Map

10.1. These raster layers were classified as suitable or unsuitable site for the landfilling by assigning values 1 and 0, respectively. Therefore, for Boolean operation model, all the criteria were converted into 0 and 1 (Shahabi, *et al.*, 2013) by using spatial analyst tools. Figure (3.A) shows restriction for all the important places (landmarks) in the study area. The Red polygon in figure (3.B) indicated the restriction for the existing dumping site at Mehmood Booti Lahore whereas figure 3 (C, D and E) depicted the restriction maps for the roads, water bodies and tube wells, respectively. The resultant restriction map was prepared by using overlay analysis of ArcGIS Spatial Analyst reported by (Alfy, *et al.*, 2010). All the restrictions were multiplied by using the raster calculator and obtained the final restriction as is shown in figure 4. This figure 4 shows the area was either suitable for landfilling or not in the form of Boolean values (1 and 0). Pixels of purple color were considered as restricted cells as they have value of 0. These restricted cells covered 68% of the area. Thus, these pixels were excluded from the candidate sites for suggesting landfilling. All other remaining 32% cells had the values of 1 so they were considered as the suitable areas for proposing a landfill site in the study area. By using the stated criteria, the suitable areas for landfill site fell on the southern west direction of the district. The selected site areas were significantly at the optimum distance from water resources, major roads and other mentioned criteria (Siddiqui, *et al.*, 1996). Most of the suitable area was found to be situated in the Iqbal town and Nishtar Town as is shown in the figure 5.

Due to fast urbanization open areas and villages of these towns have been converted into new societies. Since, as the population increased, the demands for food and other essentials also increased and there has been a rise in the amount of waste being generated daily by each household. According to the Lahore Waste Management Company's report (2013), due to lack of resources, all of the waste could not get collected and transported to the final dump sites.

If at this stage the management and disposal were improperly done, it could cause serious impacts on health and surrounding environments. Thus, for betterment of the society, there is a need of strong waste management (Khan and Samadder, 2014). This integrated waste management system will introduce job opportunities for the villagers living nearby it, which could bring prosperity in the society.

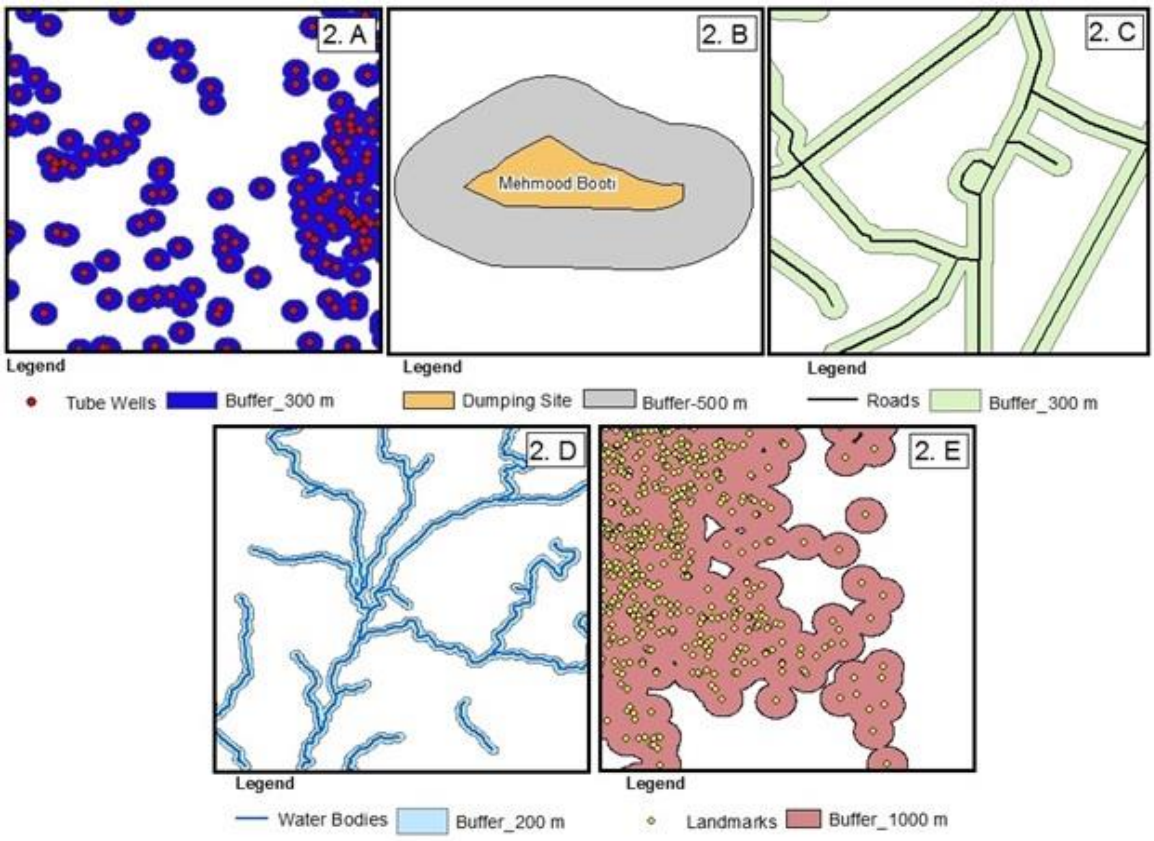

Figure 2. (A) Buffer Distance for Tube wells (B)Buffer Distance for existing dumping site (C) Buffer distance for the roads (D) Buffer Distance for water bodies (E) Buffer Distance for important places (landmarks)

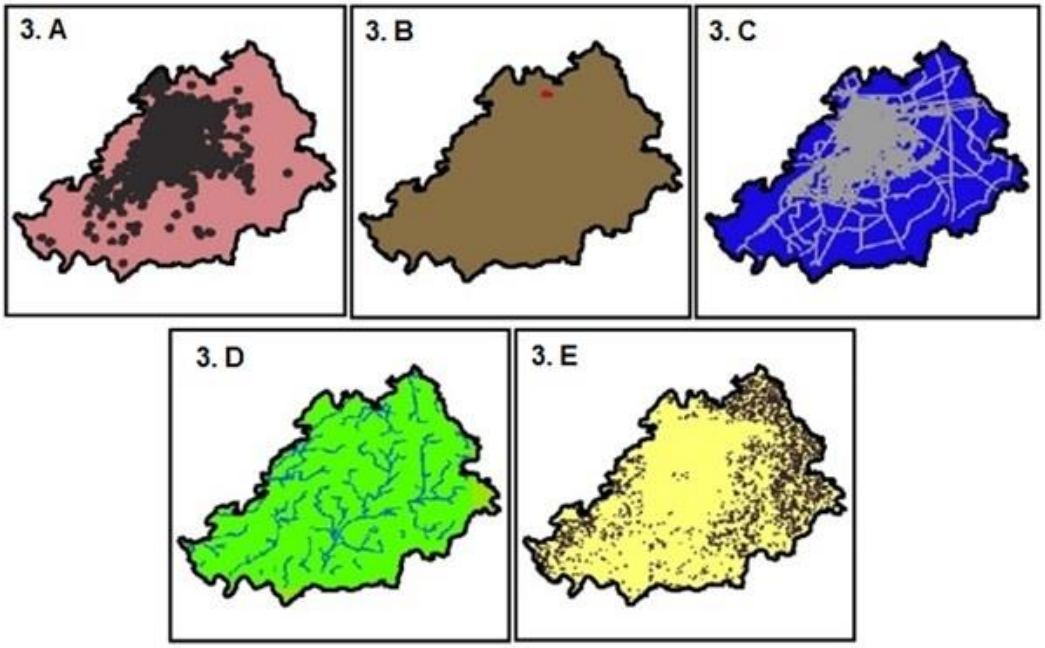

Figure 3. (A) Restriction map shows all the tube wells in Lahore District (B) Restriction map of existing dumping site in Lahore District (C) Restriction map shows the roads of Lahore District (D) Restriction map of surface water in Lahore District (E) Restriction map of important places in Lahore District.

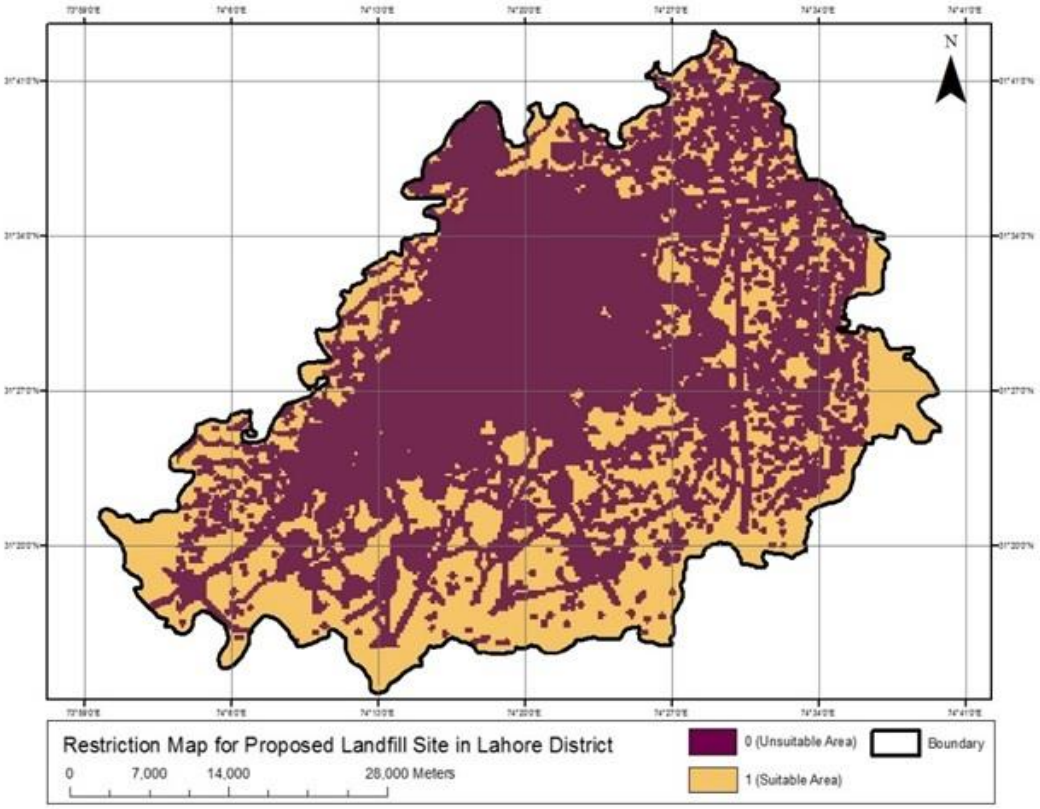

Figure 4. Final Restriction Map to Select Suitable Site for Land Fill

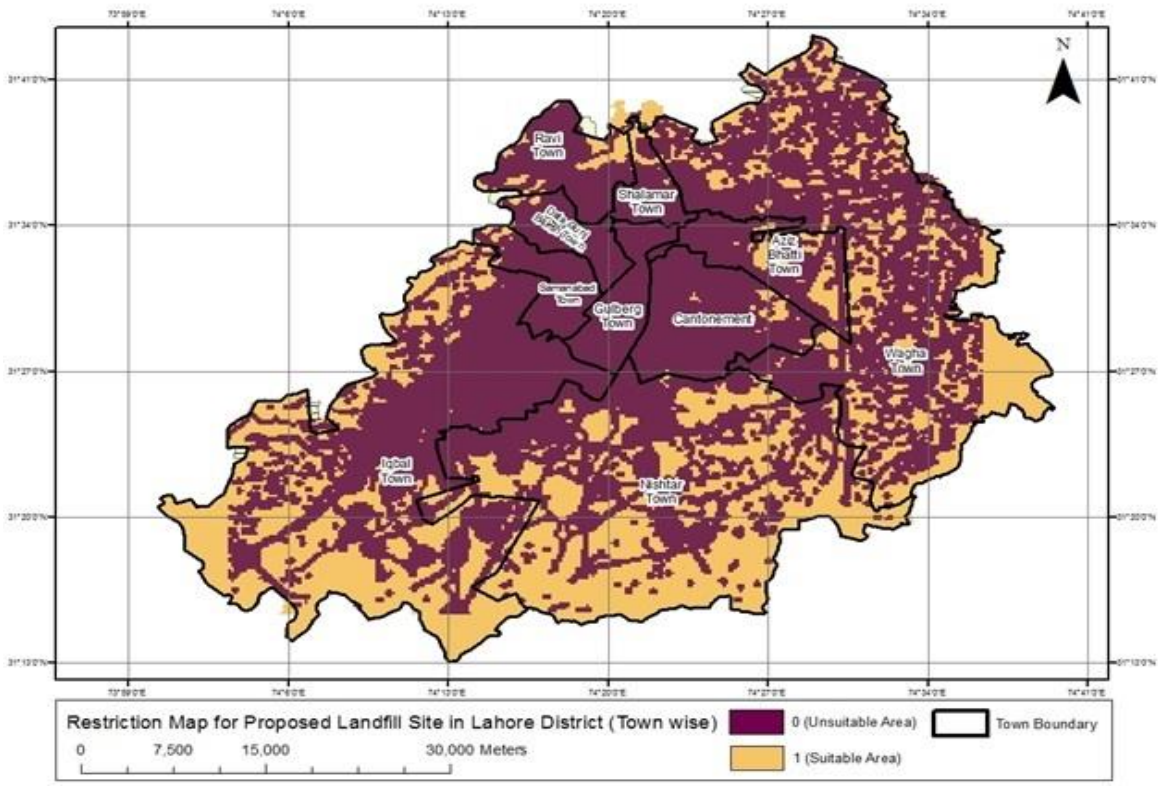

Figure *5*. Final Restriction Map to Select Suitable Site for Land Fill in Towns of Lahore District

Conclusion: Site selection for landfill is a complicated process which after utilizing GIS is an economical and reliable method. This strengthens the concept that a coupled GIS Boolean Operation technique is extremely useful and acceptable providing the screening approach for suggesting landfill sites in the Lahore district. Different criteria are being defined to select a suitable site for a landfill and utilize as input map layers.

All the criteria which have been considered in this study were based on the availability of suitable data. For landfill siting studies special purpose hydrogeological maps are required. For future studies, it is recommended to include sensitivity analysis to detect the effect of buffer distance impact on the total remaining area and estimation of possible effects on the human health and natural resources.

Acknowledgement: The author is very thankful to the Lahore Development Authority, City District Government, Lahore Waste management Company and The Urban Unit for their cooperation in providing the required data.

REFERENCES

Alfy, Z. E., R. Elhadary and A. Elashry (2010). Integrating GIS and MCDM to deal with landfill site selection. Intl. J. Engineering & Technology, 10(6): 33-40.

Asian Consulting Engineers (2013). Union councils profiles. Retrived from Lahore waste management comapy: http://www.lwmc.com.pk/uploads/UC%20Profiles.pdf

Balasooriya, B. M., M. Vithanage, N. J. Nawarathn, K. Kawamoto, M. Zhang, G. B. Herathand and M. I. Mowjood (2014). Solid waste disposal site selection for Kandy District, Sri Lanka Integrating GIS and Risk Assessment. Intl. J. Scientific and Research Publications, 4(10): 11-20.

Chang, N. B., G. Parvathinathanb and J. B. Bre (2008). Combining GIS with fuzzy multicriteria decision making for landfill siting in a fast-growing urban region. J. Environ. Management, 87(1): 139-153.

Curtis, N. T., and H. Perry, (2000). Remote sensing/GIS integration to identify potential low-income housing sites. Cities, 17(2): 97-109.

Gemitzi, A., V. A. Tsihrintzis, E. Voudrias, C. Petalas and G. Stravodimos (2007). Combining geographic information system, multicriteria evaluation techniques and fuzzy logic in siting MSW landfills. Environ. Geology, 51(5): 797-811.

Kamran, K. V. (2008). Comparison of Boolean, Overlay Index and Fuzzy Logic Methods for Hazardous Material Disposal Center Site Selection. J. Applied Physics, 1(6): 1-7.

Khan, D., and S. R. Samadder (2014). Application of GIS in landfill siting for municipal solid waste. International Journal of Environmental Research and Development, 4(1): 37-40.

Mahini, A. S., and M. Gholamalifard (2006). Siting MSW landfills with a weighted linear combination methodology in a GIS environment. International Journal of Enviomental Science & Technology, 3(4): 435-445.

Sener, B., M. L. Süzen and V. Doyuran (2006). Landfill site selection by using geographic information systems. Environmental Geology, 49: 376-388.

Shah, S. A. and M. A. Wani (2014). Geospatial Based Approach for Enhancing Environment Sustainability of Srinagar city - A study on solid waste disposal. International Journal of u- and e-Service, Science and Technology, 7(3): 28 9-302.

Shahabi, H., S. Keihanfard, B. B. Ahmad, and J. T. Amiri (2013). Evaluating Boolean, AHP and WLC methods for the selection of waste landfill sites using GIS and satellite images. Environmental Earth Sciences, 71(9): 4221-4233.

Shamshiry, E., B. Nadi, M. B. Mokhtar, I. Komoo and H. S. Hashim (2011). Urban solid waste management based on geoinformatics technology. J. Public Health and Epidemiology, 3(2): 54-60.

Siddiqui, M. Z., J. W. Everett and B. E. Vieux (1996). Landfill siting using geographic information systems: A demonstration. Journal of Environmental Engineering, 122(6): 515-523.