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IDENTIFICATION OF LANDFILL SITE BY USING GEOSPATIAL TECHNOLOGY AND MULTI CRITERIA METHOD- A CASE STUDY OF KATHMANDU, BHAKTAPUR AND LALITPUR DISTRICT OF NEPAL

Deepa Basnet
Livelihoods theme, ICIMOD, Nepal
Corresponding author: basnetdeepaji@gmail.com

Abstract

Landfill is a mode of municipal solid waste disposal. Thus, it is imperative to select relevant site for landfilling in order to curtail environmental damage and harmful impacts on wellbeing of public. Through the decades, rummage around various places for landfill site has been going on concerning its distance from artery road, resident area and water surface in order to prevent serious health and environmental hazards. In case of Nepal, Sisdole landfill site at Okharpauwa VDC in Nuwakot is struggling to manage garbage produced by the Kathmandu valley. The valley alone mounds to 700 metric tons of garbage on a daily basis that would loosened carrying capacity of the place really soon. With the intention of uncovering suitable site for alternative to present disposal site, the Multi criteria method has been applied in GIS domain. Here, data layers of land use pattern, residential areas, urban areas, roads and water bodies of the Kathmandu, Lalitpur and Bhaktapur district were mainly considered. The buffer zones were created to those 5 layers assigning various decisive factors to determine area around them within a certain distance. Then, weightings were assigned to each criterion as per their relative importance and ratings. Furthermore, weights were integrated in GIS environment to generate suitable site. Lastly, comparative study of data layers suggested that next site for dumping refuse could be the Bhaktapur district.

Keywords: Solidwaste, Landfill site, GIS & Multicriteria method

Introduction

Industrialization and Urbanization has led to numerous problems from over exploitation of natural resources to increment in the amount of waste production (Neupane & Neupane, 2013). Landfill is the most extensively used means for municipal solid waste management in urban areas (Assan, 2013). The selection of landfill site is a serious issue in urban planning process attributable to colossal impacts on the economy, ecology, environment and public health (Sener et al., 2006). Shafqat et al., (2014) informed that lack of adequate resources, poor planning and booming population in developing nations is leading to meager situation of municipal solid waste disposal. It is proportionately developing environmental and health hazards in those areas. As sanitary land filling is unavoidable part for municipal solid waste management system (Ekmekcioglu, 2010), suitable selection of landfill site is judicious. In order to lessen the environmental damage along with public health thereby developing overall sustainability allied to life cycle of landfill (Lou & Nair, 2009). It is apparent that in order to site landfill area, numerous factors had to be incorporated in the decision making process like: land use, environmental, hydrology and socio economy etc (Chiangmai University, 2003). For solving problem of landfill site selection process, combination of Geographic Information System (GIS) and Multi-Criteria Evaluation (MCE) is a powerful tool admired globally (Nas, 2010). Radiarta et al., (2008) agreed that GIS provides proficient manipulation and presentation of data. At the same time, MCE provides factors weights of the garbage dump according to the importance of criteria. Li et al., (2014) informed usefulness in managing large volumes of spatial data from a variety of sources. Gorsevski et al., (2012) highlighted the numerous attributes engaged in selection of landfill sites that has stimulated the prevalence of geographical approaches in the previous years. It permitted the amalgamation of multiple attributes by GIS. (Higgs, 2006) stated the possibility of integrating multi-criteria techniques with GIS in siting the garbage dump services and then documented through a review of the existing literature to emphasize on the prospect and challenges for the decision makers at various phase of the throw away management process. Another research used GIS digital map overlay methods for finding the suitable disposal site in Western Macedonia, Greece (Vatalis & Manoliadis, 2002) where conflicting siting restraints were considered as well as numerical and qualitative criteria were applied. Using MCE models, the resulting alternative sites were estimated. (Lin & Kao, 1998) developed a model which was relevant for vector-based data that was incorporated with GIS. The model developed was capable of processing digital spatial data to aid in landfill site study. Allen et al., (2003) acknowledged EU funded research project for locating landfill site using GIS model an Interreg IIC. It was carried out by a team of Irish and Portuguese engineering geologists, civil engineers, and GIS experts from universities and local government.

The main purpose of this study is to locate appropriate landfill site using geospatial technology and to prepare the Model for the process of analyzing and acquiring suitable site map.

Materials and methods

Study area

The study area (fig 1) known as Kathmandu valley is a bowl shaped intermontane basin. It is at an elevation of approximately 1,400 metres (4,600 ft) in central Nepal surrounded by four major mountains: Shivapuri, Phulchoki, Nagarjun, and Chandragiri. Geographically, the valley is situated between 27°31′55″ to 27°48′56″ North latitude and 85°11′11″ to 85°31′52″ East longitude. The valley is drained by the Bagmati river system (Thapa & Murayama, 2009). Kathmandu, Lalitpur and Bhaktapur district united to form the Kathmandu valley that has highest population density in the country. The city of Kathmandu covers area more than 300 km^2 and is home to about 58.65% of Nepal's population. The existing land uses are residential, forest, public amenity, catchment area, commercial area, fishery, agriculture, recreational area, water, industry, airport etc.

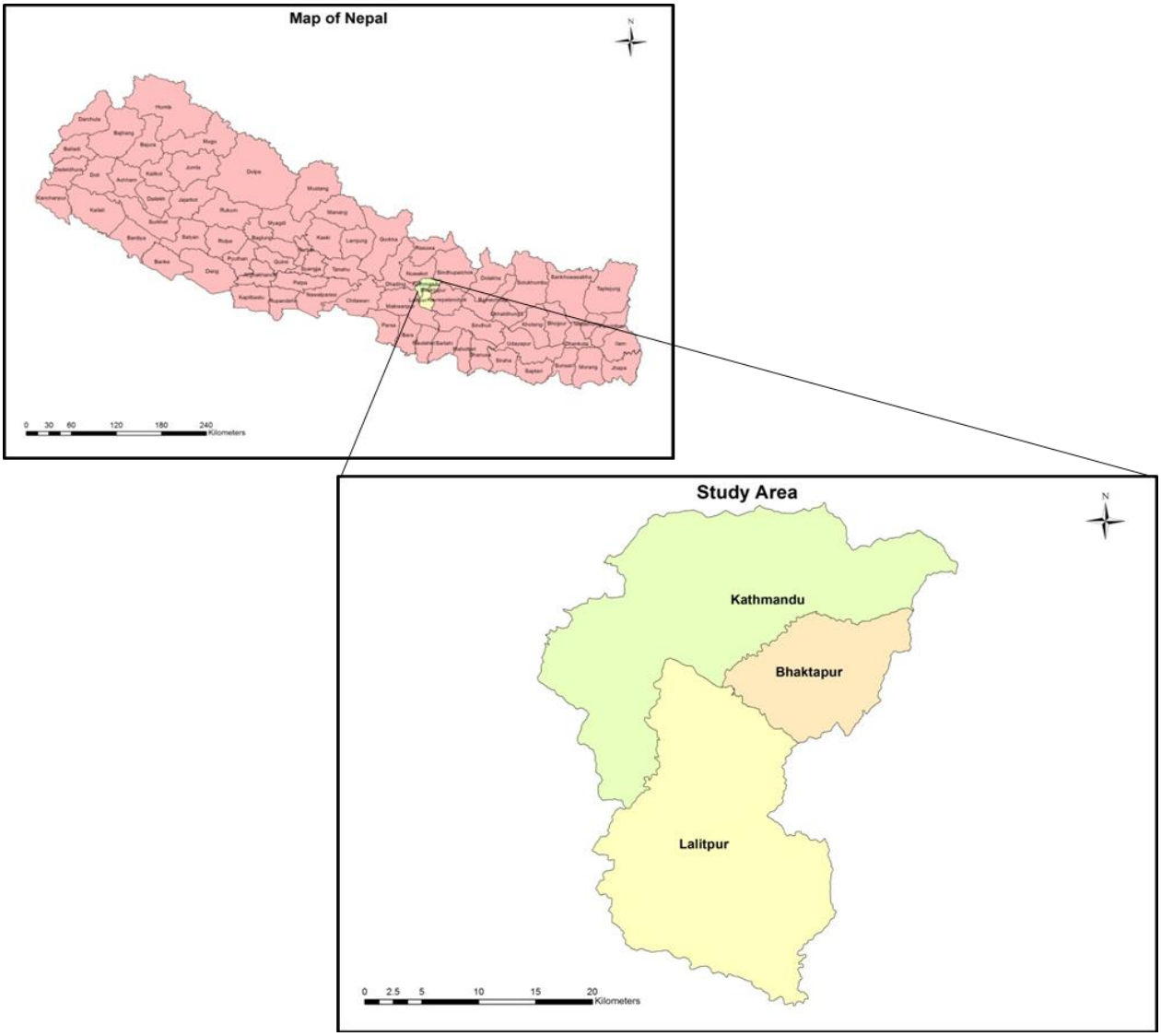

Fig 1. Study Area

Methods

The very first step in this methodology was to identify criteria for potential landfill sites selection. So, criteria were drawn from relative review of other researches on landfill selection criteria. The criteria included slope, land use, water body, road and residential for locating proper site taking an account of data layers used for interpretation. The study area had a relatively bowl shaped land which was a logic behind considering slope for the analysis. The data layers were bought together for proposed study site and were supported by Arc GIS 9.3 software. All of the map layers were converted into raster format as in figure 2.

Fig 2. Digital Elevation Model for 3 districts

Some data layers were extracted from land use and named as residential area and water body. The water body included peddles river, spring, and reservoir area. The process of deriving criteria for 5 data layers are shown below:

Slope: Since, slope from elevation is the most vital requirement before construction of any infrastructures especially the landfill site. Mornya et al., (2010) assigned value from 1 to 5 to the slope on the basis of worst to best for construction. i.e.: 1 as worst and 5 as the best. The slope criterion was incorporated into Arc GIS 9.3 and reclassified in raster format from 1 to 10.

Land use: It includes grassland, forest and agricultural areas. As literatures lay emphasis on siting of landfill not to be located in agricultural land, it was taken care of. Mornya et al., (2010) graded value "1" to agriculture, "3" to forest plus "5" to grassland area. The values

indicate that landfill suitability condition varies from not suitable 1 to suitable 5. The land use criterion was integrated into Arc GIS 9.3 and reclassified in raster format from 1 to 10.

Residential Area: In order to avoid public health nuisance because of potential biohazards from garbage disposal site, site was considered away from residential area. According to (Wang, 2009), 500m and above would be suitable distance from landfill to the residential area. Consequently, distance of 500 m and above was taken as a suitable landfill location. The study area was buffered in raster format and reclassified according to suitability of distant criteria. Value 1 was assigned to inappropriate one and to 5 to the most appropriate one for distant criteria.

Water body: The buffering in a raster environment of Arc GIS 9.3 was created in such a way that it would consider the distance of 1,000 m and above for siting (Sharifi et al., 2009). It was again reclassified allocating value 1 for inappropriate one and 5 to the most appropriate one. The target for this allocation was basically to prevent irreparable environmental and health impact as it would enter inside water body otherwise.

Road: Similarly, road was also considered for siting the landfill for health and aesthetic purpose. As per Mornya et al., (2010), study area was buffered in a raster environment which was then reclassified according to their suitability by categorizing them from 1 to 10. The distance of 1,000 m and above was believed to be the most suitable for landfill sites location.

Determination of weights of Criteria: The Analytic Network Process by means of pair wise comparison was employed. It helped to provide detail framework for including clusters of elements interlinked in any way to see if the process of deriving ratio scales priorities commencing distribution of influence.

Pair wise Comparison: The relative weight of each criterion was determined by using pair wise comparison method of ANP method. The method of comparing relative importance of two criteria or elements is known as pair wise comparison that includes creating a ratio matrix. Here, pair wise comparison was input and weight was output where a scale with values ranging from 1 to 10 was used. The criteria were compared using pair wise comparison method. From literature review, relative importance of each criterion to another was determined. In reference to (World Bank, 2010) for comparative assessment of landfill site selection facilities, analysis was carried out. It compared criteria by giving ranking. Like: water resources as 2, land use as 2 and road as 1. It aimed to specify that water and land use are two times more important than road. In view of ranking system from literature review, logical comparison was attained from study area criteria.

Weights or Priorities of Criteria: By raster calculator, selecting all the classified layer of criteria, weights were integrated into GIS environment. Then, suitable site was calculated to gain required areas for locating landfill site (fig 3 and fig 4). The required landfill site should not be less than 1, 00,000 km^2 considering the present status and area of landfill site around Kathmandu valley.

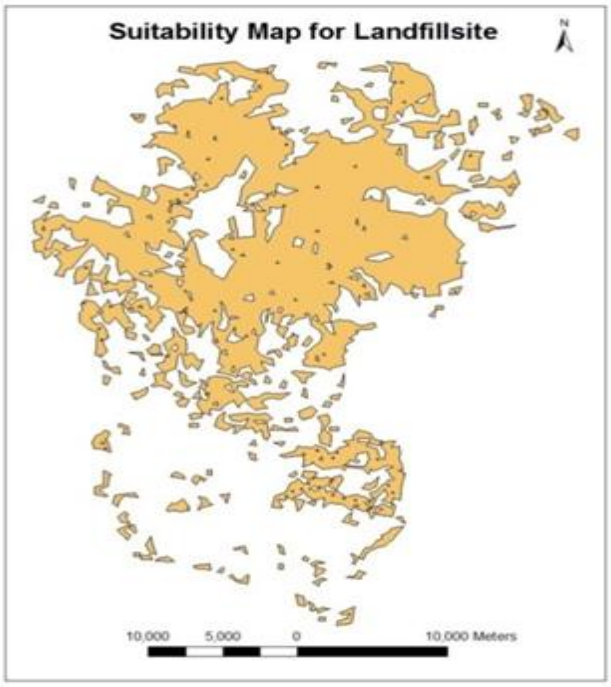

Fig 3. Euclidean distance map for 3 districts

Fig 4. Suitability Map for Landfill site for the Kathmandu valley

Model Building Process for suitable site selection: The process started from using the spatial analysis tool of Arc GIS 9.3 to build a new model as per the demand of study site getting inside Model builder. Now, environmental setting was specified for the process. Subsequently, data layers for the analysis were derived. For example: slope, distance from road site, distance from household area and distance from the river site followed by reclassification of all the data layers used. At the end, a Model was attained using the tools like: Weighted overlay, Con, Majority filter, Raster to polygon, Calculate areas and Area site.

Results

The multi criteria method was used as a tool which included 2 sequential processes. In this method, GIS helped in selection of suitable landfill site and final analysis was performed by using multi criteria method tool. So, landfill sites were determined through series of analysis of data layers. Some of the data were buffered to determine uncertain areas. Then, reclassified union were converted to raster and reclassified according to the order of importance of sub-criteria. The reclassification layers were overlaid to determine suitable sites where result revealed the Bhaktapur district as a potential landfill site. Likewise, using the data bases for Kathmandu, Bhaktapur and Lalitpur, a model was built for the site analysis with all parameters intruded inside it (Fig 5).

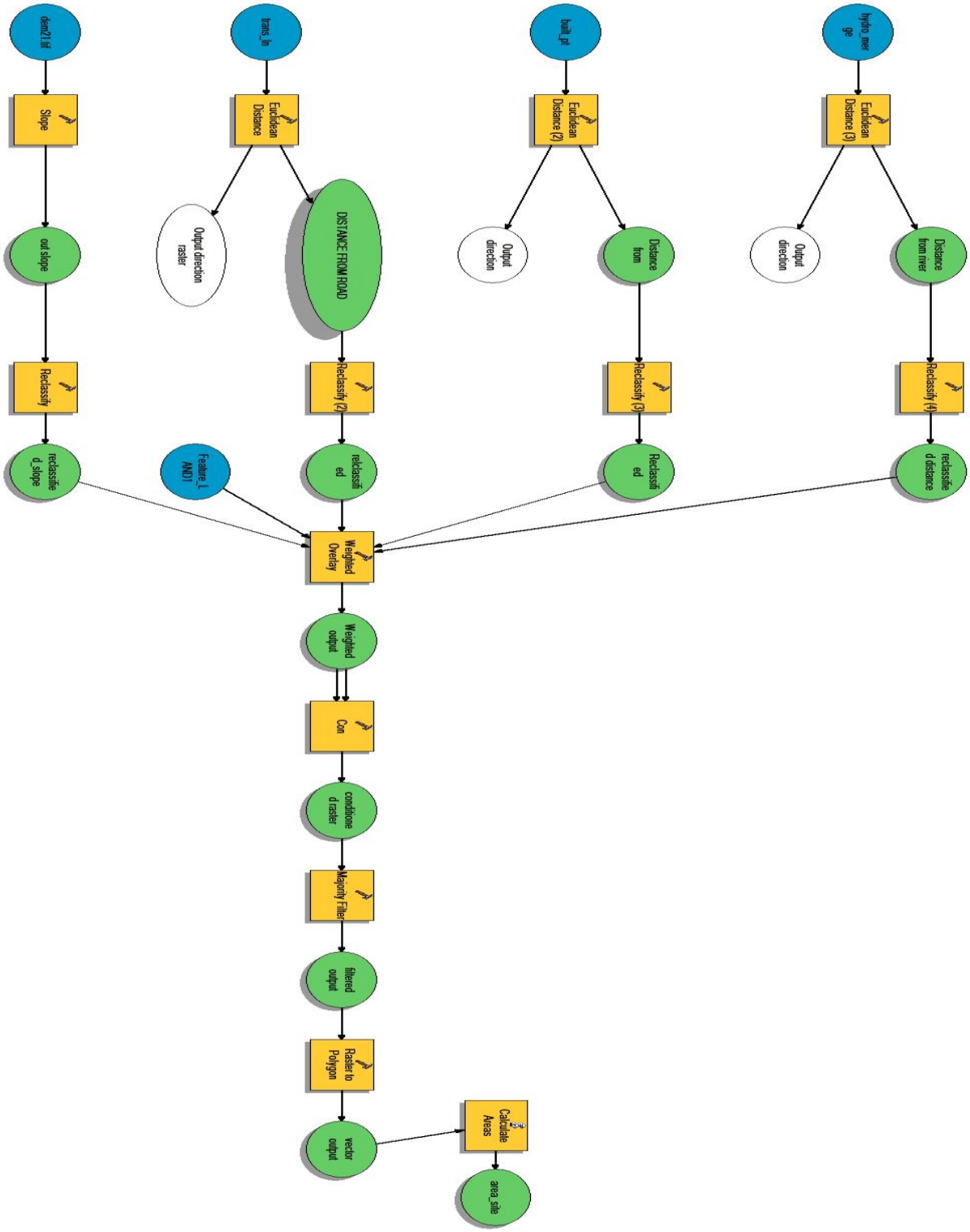

Fig 5. Model obtained after analysis of databases

Discussion

Landfill location sites were determined through series of analysis of data layers. Only five different thematic layers were considered. There are certainly other factors such as industrial areas, airports, flood plains, geographical and hydrological properties, wind direction and other social economic factors. There weren't some important factors such as industrial areas, airport, and sensitive ecosystems and recreations areas in the study area. Therefore, some siting factors were not used in this study. For example: slope, residential area (household), road and water body were buffered to determine the uncertain areas, and then reclassified based on order importance of their distant criteria. The reclassification layers were overlaid to determine suitable sites. 130 plots were found as an area that occupies more than 1, 00, 000 km^2 in Bhaktapur district. Having thousands of acres of suitable land in Bhaktapur district, would be the most appropriate site for bio hazard dumping.

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References

Allen, B. G., Caetano, P., Costa, C., Cummins, V., Donnelly, J., Koukoulas, S., & Vendas, D., 2003. A landfill site selection process incorporating GIS modeling. In *Proceedings of Sardinia*.

Assan, G. A., 2013. *GIS-Based approach for landfill site selection in Obuasi Municipality* (Doctoral dissertation, College of Science).

Chiangmai University, Faculty of Engineering, 2003. "Hand Book Practice to Bury the Waste", Chiangmai.

Ekmekcioglu, M., Kaya, T., & Kahraman, C., 2010. Fuzzy multicriteria disposal method and site selection for municipal solid waste. *Waste Management*, *30*(8), 1729-1736.

Gorsevski, P. V., Donevska, K. R., Mitrovski, C. D., & Frizado, J. P., 2012. Integrating multi-criteria evaluation techniques with geographic information systems for landfill site selection: a case study using ordered weighted average. *Waste management*, *32*(2), 287-296.

Higgs, G., 2006. Integrating multi-criteria techniques with geographical information systems in waste facility location to enhance public participation. *Waste management & research*, *24*(2), 105-117.

Kao, J. J., Lin, H. Y., & Chen, W. Y., 1997. Network geographic information system for landfill siting. *Waste management & research*, *15*(3), 239-253.

Li, D., Yao, Y., Shao, Z., & Wang, L., 2014. From digital earth to smart earth. *Chinese Science Bulletin*, *59*(8), 722-733.

Lin, H. Y., & Kao, J. J., 1998. A vector-based spatial model for landfill siting. *Journal of Hazardous Materials*, *58*(1), 3-14.

Lou, X. F., & Nair, J., 2009. The impact of landfilling and composting on greenhouse gas emissions–a review. *Bioresource Technology*, *100*(16), 3792-3798.

Mornya, A. A., Rafee. M & Yola, L., 2010. Identification of Landfill sites by using GIS and Multi Criteria Method in Batam, Indonesia. Universiti of Teknologi Malaysia, Johor Bahru, Malaysia.

Nas, B., Cay, T., Iscan, F., & Berktay, A., 2010. Selection of MSW landfill site for Konya, Turkey using GIS and multi-criteria evaluation. *Environmental monitoring and assessment*, *160*(1-4), 491-500.

Neupane, B & Neupane, S., 2013. Scenario of solid waste management in Hetauda Municipality, Nepal. *International Journal of Environment*, 2(1), 105-114.

Radiarta, I. N., Saitoh, S. I., & Miyazono, A., 2008. GIS-based multi-criteria evaluation models for identifying suitable sites for Japanese scallop aquaculture in Funka Bay, southwestern Hokkaido, Japan. *Aquaculture*, *284*(1), 127-135.

Şener, B., Süzen, M. L., & Doyuran, V., 2006. Landfill site selection by using geographic information systems. *Environmental geology*, *49*(3), 376-388.

Shafqat, A., Noor, S., & Fatima, M., 2014. Practices and Challenges of Municipal Solid Waste Management in Bahawalpur City, Pakistan. *Journal of Sustainability Science and Management*, *9*(1), 90-98.

Sharifi, M., Hadidi, M., Vessali, E., Mosstafakhani, P., Taheri, K., Shahoie, S., & Khodamoradpour, M., 2009. Integrating multi-criteria decision analysis for a GIS-based hazardous waste landfill sitting in Kurdistan Province, western Iran. *Waste management*, *29*(10), 2740-2758.

Thapa, R.B., Murayama, Y., 2009. Examining Spatiotemporal Urbanization Patterns in Kathmandu Valley, Nepal: Remote Sensing and Spatial Metrics Approaches. *Remote Sensing*, 1(3), 534-556.

Vatalis, K., & Manoliadis, O., 2002. A two-level multicriteria DSS for landfill site selection using GIS: case study in western Macedonia, Greece. *Journal of Geographic Information and Decision Analysis*, *6*(1), 49-56.

Wang, G., Qin, L., Li, G., & Chen, L., 2009. Landfill site selection using spatial information technologies and AHP: a case study in Beijing, China. *Journal of environmental management*, *90*(8), 2414-2421.

World Bank, 2010. "Comparative assessment of alternative waste disposal facilities".