American Journal of Environmental Science and Engineering
2025, Vol. 9, No. 1, pp. 1-6
https://doi.org/10.11648/j.ajese.20250901.11

Research Article

GIS Based MCDA Selection of Waste Management Site in Kanchanpur District, Nepal

Sushil Subedi[1, *], Ashok Thakulla[1], Yogesh Joshi[2]

[1]Department of Geomatics Engineering, Kathmandu University, Dhulikhel, Nepal

[2]Department of Civil, Construction, and Environmental Engineering, University of Delaware, Newark, USA

Abstract

Selecting an appropriate site for municipal solid waste (MSW) disposal is a significant challenge in solid waste management (SWM) for local authorities, engineers, and urban planners. Rapid population growth, industrialization, diverse community characteristics, and limited land availability exacerbate this issue. Landfill site selection requires evaluating numerous factors, including environmental, social, and economic considerations, as well as adhering to various rules and spatial data. This paper presents an integrated approach using Geographic Information Systems (GIS) and the Analytical Hierarchy Process (AHP), based on Multi-Criteria Decision Analysis (MCDA), to select the most sustainable MSW disposal site in Kanchanpur district, Nepal. Criteria for site selection were derived from existing literature, including residential proximity, roads, water bodies, slopes, elevation, and national parks. GIS was used to develop criteria maps, and AHP was employed for pairwise comparison and normalization to assign weights to the criteria. The weighted overlay tool in ArcGIS was then used to evaluate the weighted criteria maps, categorizing the site suitability into five classes: “extremely suitable”, “considerably suitable”, “moderately suitable”, “slightly suitable”, and “restricted”. The suitability map identified the most suitable areas for waste disposal, with "extremely suitable" areas being ideal for immediate use, and "considerably suitable" areas offering potential for future development. This method demonstrates the effectiveness of integrating GIS and AHP for sustainable solid waste management site selection in challenging environments like Kanchanpur district.

Keywords

Analytical Hierarchy Process (AHP), Bhimdatta Municipality, Geographic Information Systems (GIS), Kanchanpur, Multi Criteria Decision Analysis, Landfill Site

1. Introduction

The most common and oldest methods of solid waste disposal is landfilling for many countries and in Nepal too. RCRA states that "solid waste" means any garbage or refuse, sludge from a wastewater treatment plant, water supply treatment plant, or air pollution control facility and other discarded material, resulting from industrial, commercial, mining, and agricultural operations, and from community activities. Solid waste management is major problem in Kanchanpur district. We can simply say that solid waste is by product of human activities which inclines to increase from ever growing populations, rapid urbanization etc [1, 2].

In many cities of developing countries, the increasing trend

*Corresponding author: subedisushant2057@gmail.com (Sushil Subedi)

Received: 27 August 2024; **Accepted:** 18 September 2024; **Published:** 14 January 2025

of solid waste management (SWM) has become an alarming challenge for land degradation, biodiversity loss, air pollution, sanitation and transmission of infectious diseases during recent decades globally. productions of solid waste surges due to rapid population growth and activities for economic development and lack of SWM practices. MSW produce from Daily activities, it causes the environmental pollution and endangers the human health, wealth and other living and non-living components of the ecosystem [3, 4].

Central Bureau Statistics survey found that in urban areas of Nepal, majority residents consider SWM as the serious environmental problem where wastes in piles are commonly found in public and open areas. The modern solid waste management techniques yet not introduced in many urban areas of our country. Suitability Analysis allows us to qualify, compare, and rank candidate sites based on how closely they adhere to criteria that we select and define. Multi- criteria decision making is one approach used to facilitate the consideration of multiple criteria by decision makers. MCDA is used to logically evaluate and compare multiple criteria that are often conflicting to make the best possible decision [2, 5, 6].

In most of the Municipality of Kanchanpur, SWM is also a serious problem. The door-to- door waste collect is limited only in main market area. Collected wastes are traditionally disposed and dumped haphazardly in the open areas. Bhimdatta Municipality facing WSM problem since last two decades. Around 12 tonne of garbage is generated within the municipality on the daily basis. This study aims to find out the place for SWM on the basis of 5 criteria.

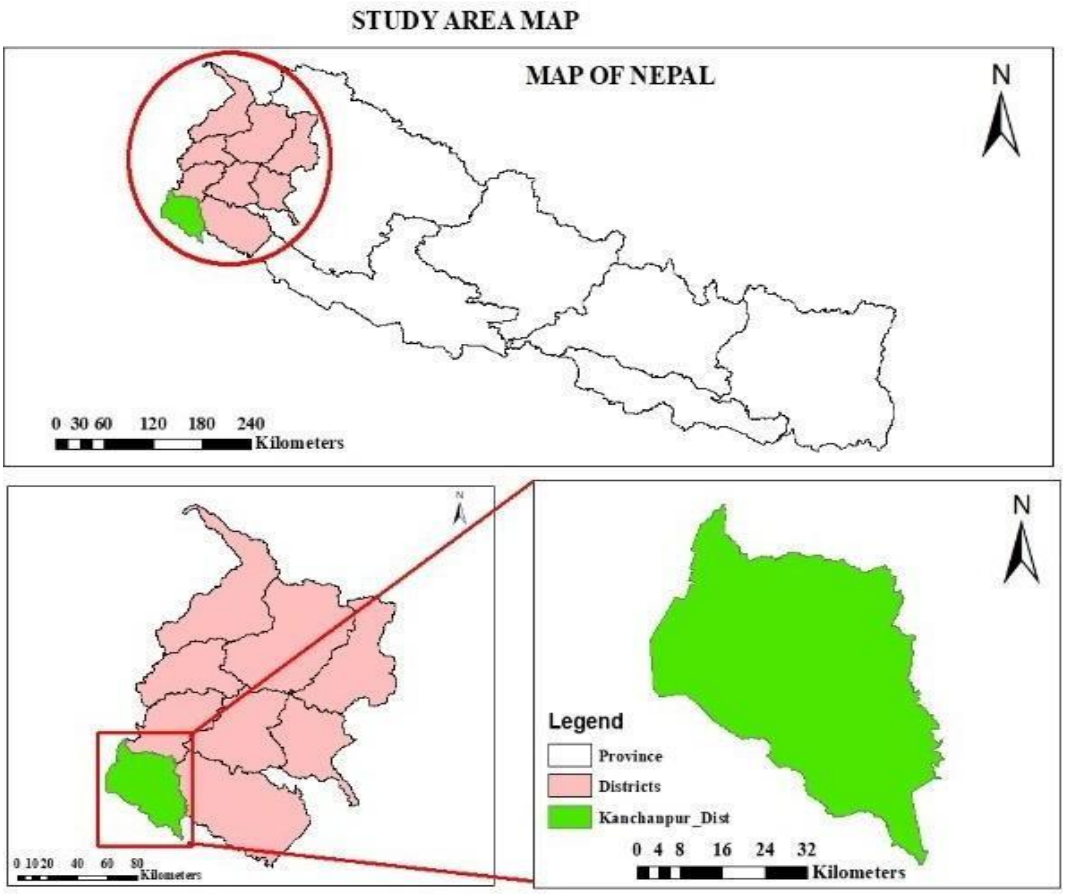

Figure 1. *Study Area.*

2. Methodology

2.1. Study Area

The Kanchanpur district is located in south far-western region of Nepal. It lies within latitude 28 °50' 13.9200" N and longitude 80 °19' 16.7232" E.

2.2. Materials and Methods

The landfill siting criteria was firstly identified based on the literature review. The criteria used for this study are Settlement Area (house), Rivers, Slope, Roads and National Park. GIS, APH and remote sensing techniques were used for sustainable landfill site selection. Slope and elevation were prepared from Satellite images and remote sensing methods.

Settle Areas (house) data were taken From Open Street Map. Inclusive literature obtained about secured and reliable distance to waste management site is employed to allocate the buffer zones for each layer. Each criterion was classified as class and class was given suitability score within 0 to 4 where 0 means Unsuitable and 4 means very Suitable [7, 8].

All the Maps layers were created and these map layers preparation was done using GIS techniques such as buffering, Distance map generation, overlay analysis and spatial analysis. Moreover, APH techniques were used to determine the weights to each criterion. The map layers were entered in the Map Algebra tool in ArcGIS software through the summation of the products of multiplying the weight of each criterion which was calculated using AHP method based on the rated value of each sub-criteria of each criterion.

2.3. Analytic Hierarchy Process (APH)

The most commonly used MCDA method is Analytical Hierarchy Process (APH) which was introduced and established R. W. Saaty. It is decision making tool used in solving multi-criteria problems and it determined the relative weight of multiple criteria which are expressed in numerical order of 1 to 9 [9, 10]. Pair wise comparison method is carried out among the criteria through the score and weight assigned to each criterion.

Table 1. *Pairwise comparison scale.*

Intensity of importance	Remarks
0	Restricted
1	Slightly suitable
2	Moderately suitable
3	Considerably Suitable
4	Extremely Suitable

This study compares each criterion in APH excel template, and relative importance of each criterion to another was determined. After the completion of comparison, the weight of each criterion was produced.

Table 2. *Criteria weights and rankings.*

Criteria	weights	Buffer zones	Ranking
Houses	0.405	<1500 m	0
		1500-2000	1
		2000-2500	2
		2500-3000	3
		>3500	4
Roads	0.314	>2500 m	0
		0-500	1
		500-1000	2
		1000-1500	3
		1500-2500	4
Rivers	0.136	<1000 m	0
		1000-1500	1
		1500-2000	2
		2000-2500	3
		>2500	4
National Park	0.101	<1000 m	0
		1000-1500	1
		1500-2000	2
		2000-2500	3
		>2500	4
Slope	0.44	>25 °	0
		20-25 °	1
		15-20 °	2
		10-15 °	3
		<10 °	4

3. Results and Discussion

An optimized Waste management Siting process must undergo a rigorous process of criteria evaluation in order to prevent long term negative impact such as ground water contamination, air pollution. And also, far from settlement areas for prevention of public health. Should be accessible from main road due to economic factor, this is to reduce the cost of transportation and collection. The study based only on 5 criteria, for more accurate we need to takes more criteria [11-13].

3.1. Waste Management Siting Criteria

3.1.1. Residential Areas

This criterion doesn't permit waste management siting in the area. The presence of any waste disposal site near or within urban residential area may cause health and environmental problems. The desirable distance from site to the residential should be 2km and above. Whereas 1km or above was taken in consideration as suitable landfill location.

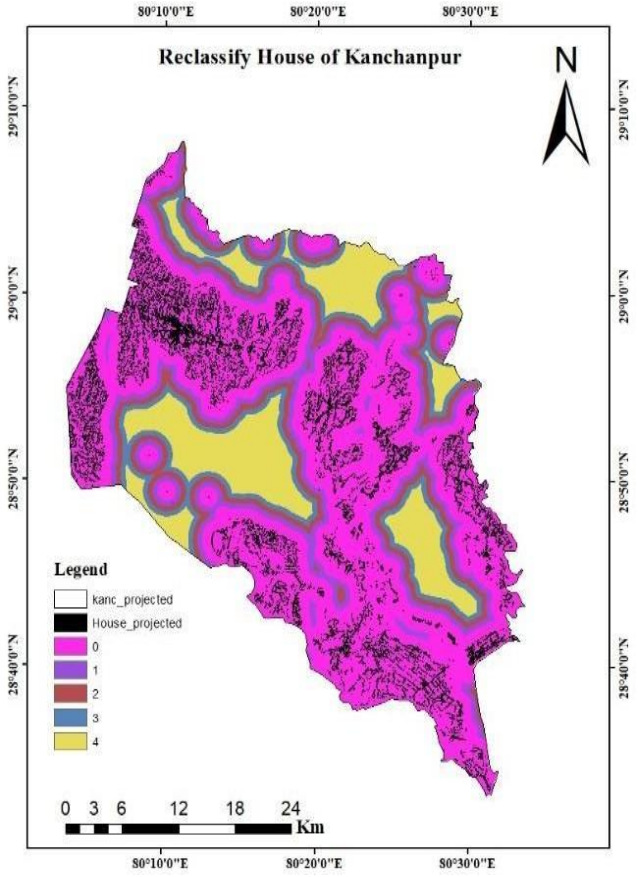

Figure 2. *Reclassify Residential area.*

3.1.2. Distance from Roads

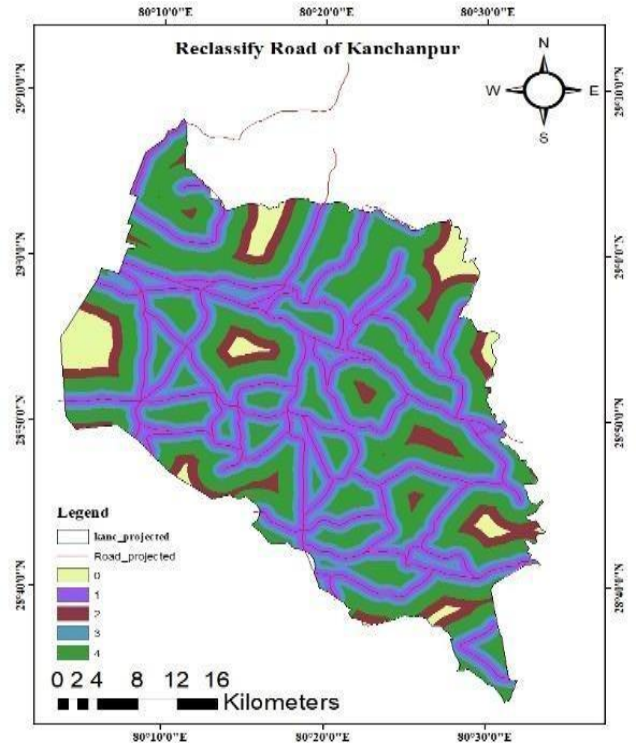

Figure 3. *Reclassified Distance of Roads.*

The roads networks were download from Open source i.e., OpenStreetMap. The roads data contains the information of highways, major and minor roads and its connections to residential roads etc. due to economic factors the accessibility of the site must be considered especially for the vehicles used for collection and disposal of waste to landfill. The more score given to landfill site near to roads.

3.1.3. Rivers

The waste management site cannot be constructed adjacent to water bodies likes Rivers, stream and ponds. This due adverse effect environment effects from Disposal site which can occur and contaminates the water bodies [14]. Therefore, a 1000m buffer zone was created for each of the rivers in the study area. The rivers are shown in blue line, while the red zones represent areas closest to the rivers, which are highly restricted for the development due to potential environmental risks. These buffer zones are color coded, others colors like green and purple representing progressively larger distances. This visualizations aids in planning decisions related to waste management, emphasizing the importance of maintain ng a safe from rivers to prevent water pollution.

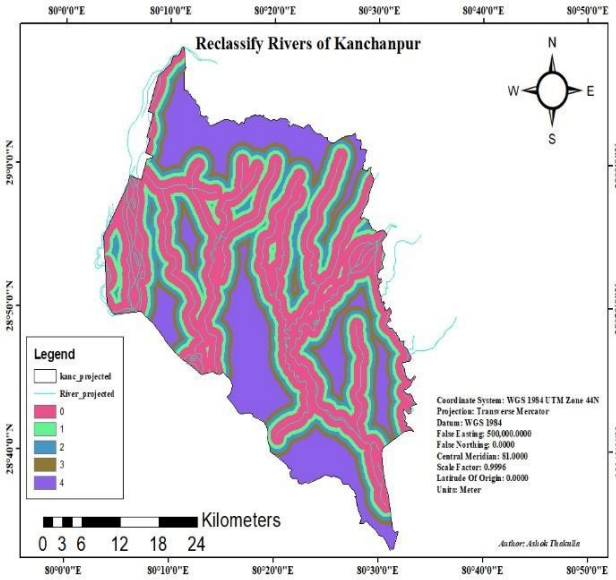

Figure 4. *Reclassified rivers.*

3.1.4. National Park

Kanchanpur district have one National Park which support the environmental. We cannot build Waste management site inside or near the national parks. Thus, 1km buffer zone created around the national park and above.

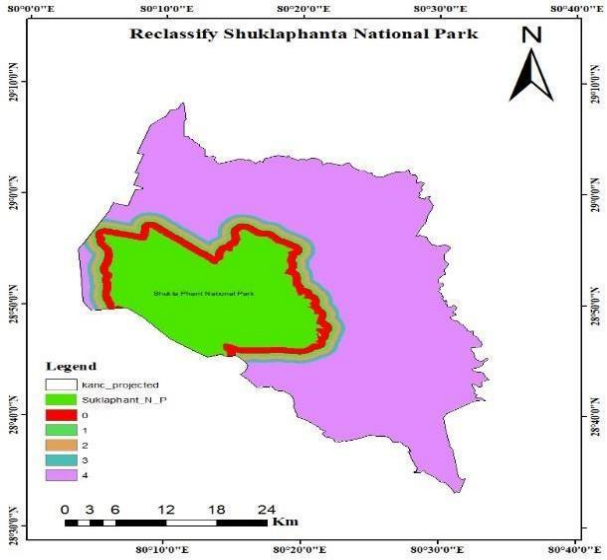

Figure 5. Reclassified National Park.

3.1.5. Slope

Slope is an important criterion when siting a sanitary landfill site. From economic perspective, cost of construction in areas with steep and high slope will be more expensive than in areas of medium slope. The slope layer for this study was generated from the digital elevation model (DEM). Which was taken from Humanitarian Data Exchange (HDX). The areas with slopes greater than 25 ° are considered unsuitable for waste management site [15].

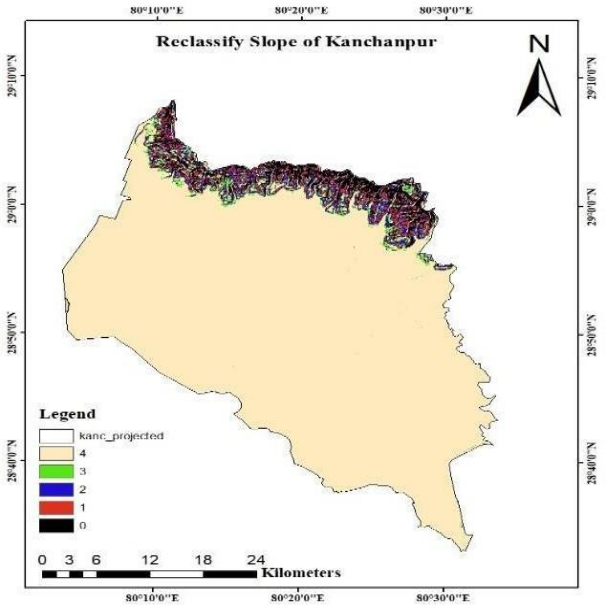

Figure 6. Reclassified Slope.

3.2. Analysis

Final suitability map was obtained after assigning weight to each criterion through the AHP method, the ArcGIS was used to reclassify each criteria map which was converted from vector to raster format using conversion tool. Map algebra tool was further used to execute the analysis by multiplying each criterion with its weight plus another criterion for the suitable landfill sites.

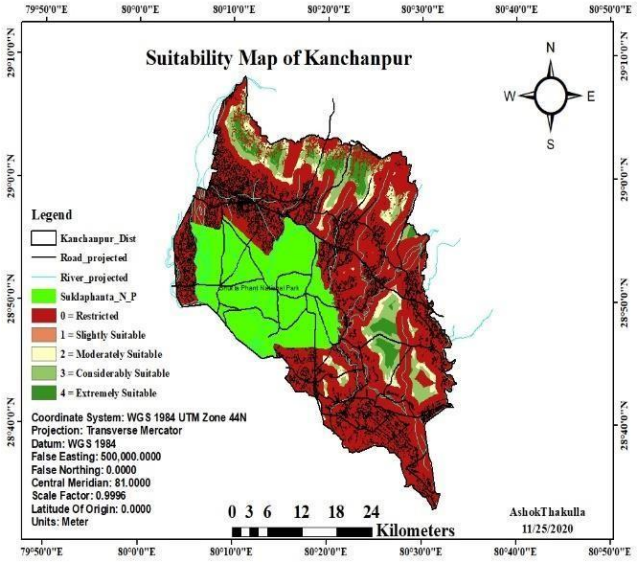

Figure 7. WMS Suitability Map.

After the suability map, the final suitability map created which shows only extremely suitable areas for the waste management site. Using CON tool and using conversion tool the obtained map in raster form change to vector. The suitable areas are in polygons form, at last area of landfill greater than 60000m^2. we get 10 Suitable sites in Kanchanpur.

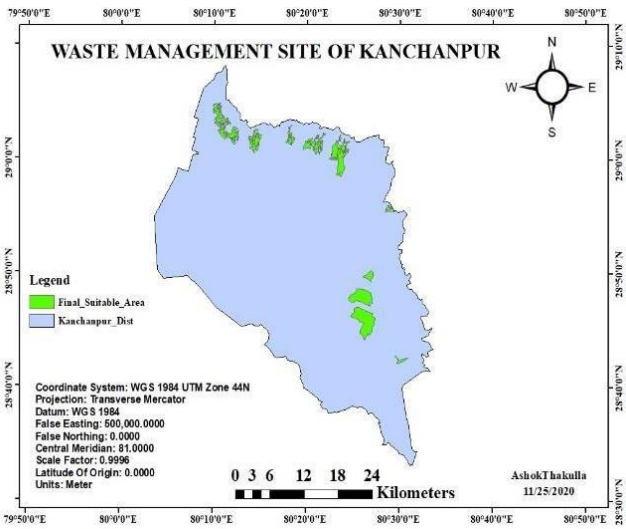

Figure 8. WMS of Kanchanpur.

4. Conclusion

The current study was able to analyze the convenient and suitable sanitary landfill sites for sustainable solid waste disposal in Kanchanpur district, Nepal. From, final Suitability map we get 10 locations. GIS- Based AHP method was selected as one of the most common techniques in MCDA, also because of its accuracy and efficiency in landfill site selection studies. Using only five criteria gives a scenario of suitable disposal site. The site is on plain terrain, far from settlement, rivers, national park and access to roads. If we need more accurate and precise Waste management site for disposal of solid waste we can consider more Criteria like Soils, Geology etc.

Abbreviations

MSW	Municipal Solid Waste
SWM	Solid Waste Management
GIS	Geographic Information Systems
AHP	Analytical Hierarchy Process
MCDA	Multi-Criteria Decision Analysis
RCRA	Resource Conservation and Recovery Act
CBS	Central Bureau of Statistics
DEM	Digital Elevation Model
HDX	Humanitarian Data Exchange
WMS	Waste Management Site

Author Contributions

Sushil Subedi: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing

Ashok Thakulla: Data curation, Formal Analysis, Investigation, Methodology, Visualization, Writing – original draft, Writing – review & editing

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] Olexa MT, Leviten A, Samek K. Florida Solid and Hazardous Waste Regulation Handbook: Solid and Hazardous Waste Disposal: FE457/FE457, 12/2003. EDIS 2004; 2004. https://doi.org/10.32473/edis-fe457-2003

[2] Joshi RP, Joshi YP. A Study on Solid Waste Composition in Kanchanpur District, Nepal. Health Prospect 2018; 17: 5–8. https://doi.org/10.3126/hprospect.v17i1.21201

[3] Guerrero LA, Maas G, Hogland W. Solid waste management challenges for cities in developing countries. Waste Management 2013; 33: 220–32. https://doi.org/10.1016/j.wasman.2012.09.008

[4] Sharholy M, Ahmad K, Mahmood G, Trivedi R. Municipal solid waste management in Indian cities – A review. Waste Management (New York, NY) 2008; 28: 459–67. https://doi.org/10.1016/j.wasman.2007.02.008

[5] Bhowmick P, Das S, Das N. Identification of suitable sites for municipal waste dumping and disposal using multi-criteria decision-making technique and spatial technology: A case of Bolpur municipality, Birbhum district, West Bengal. Waste Management Bulletin 2024; 2: 250–65. https://doi.org/10.1016/j.wmb.2024.02.001

[6] Greene R, Devillers R, Luther JE, Eddy BG. GIS-Based Multiple-Criteria Decision Analysis. Geography Compass 2011; 5: 412–32. https://doi.org/10.1111/j.1749-8198.2011.00431.x

[7] Dolui S, Sarkar S. Identifying potential landfill sites using multicriteria evaluation modeling and GIS techniques for Kharagpur city of West Bengal, India. Environmental Challenges 2021; 5: 100243. https://doi.org/10.1016/j.envc.2021.100243

[8] Makonyo M, Msabi MM. Potential landfill sites selection using GIS-based multi-criteria decision analysis in Dodoma capital city, central Tanzania. GeoJournal 2022; 87: 2903–33. https://doi.org/10.1007/s10708-021-10414-5

[9] Saaty RW. The analytic hierarchy process—what it is and how it is used. Mathematical Modelling 2021; 9: 161–76. https://doi.org/10.1016/0270-0255(87)90473-8

[10] Siekelova A, Podhorska I, Imppola JJ. Analytic Hierarchy Process in Multiple–Criteria Decision–Making: A Model Example. SHS Web of Conf 2021; 90: 01019. https://doi.org/10.1051/shsconf/20219001019

[11] Pokhrel D, Viraraghavan T. Municipal solid waste management in Nepal: practices and challenges. Waste Management 2005; 25: 555–62. https://doi.org/10.1016/j.wasman.2005.01.020

[12] Ferronato N, Torretta V. Waste Mismanagement in Developing Countries: A Review of Global Issues. International Journal of Environmental Research and Public Health 2019; 16: 1060. https://doi.org/10.3390/ijerph16061060

[13] Chandel AS, Weto AE, Bekele D. Geospatial technology for selecting suitable sites for solid waste disposal: a case study of Shone town, central Ethiopia. Urban, Planning and Transport Research 2024; 12: 2302531. https://doi.org/10.1080/21650020.2024.2302531

[14] Dangi MB, Malla OB, Cohen RRH, Khatiwada NR, Budhathoki S. Life cycle assessment of municipal solid waste management in Kathmandu city, Nepal – An impact of an incomplete data set. Habitat International 2023; 139: 102895. https://doi.org/10.1016/j.habitatint.2023.102895

[15] Sk MM, Ali SA, Ahmad A. Optimal Sanitary Landfill Site Selection for Solid Waste Disposal in Durgapur City Using Geographic Information System and Multi-criteria Evaluation Technique. KN J Cartogr Geogr Inf 2020; 70: 163–80. https://doi.org/10.1007/s42489-020-00052-1