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Assessment of Design Strategies and Economic Viability for Sanitary Landfill Planning Using GIS and AHP: A Case Study of Shuklagandaki Municipality, Nepal

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Abstract

The planning of sanitary landfills in emerging municipalities repeatedly hurts from a disjointed approach, where site suitability analysis is dissociate from comprehensive context-specific design strategies and economic viability assessment, leading to plans that are technically infeasible or economically unviable owing to limited integration between spatial appropriateness, engineering design, and lifecycle cost assessment . This research targets to bridge this gap by evolving an integrated framework for sanitary landfill planning, employed to Shuklagandaki Municipality, Nepal. The methodology integrates Geographic Information Systems (GIS) and the Analytical Hierarchy Process (AHP) for multi-criteria site selection, along with waste generation projections, engineering design calculations, and a lifecycle cost analysis. The most noteworthy results show that only 0.89% (1.489 km^2) of the municipal area is highly appropriate for landfill planning with land use, residential proximity, and water body protection being the most weighted criteria. The design for a 15-year facility approves a mineral liner system and estimates a peak leachate generation of 0.125 m^3/day, while the economic assessment reveals a serious dependency on establishing a dedicated waste management fee to bear substantial annual operation and closure costs. The major conclusion is that while suitable sites and feasible designs exist, sustainable implementation is reliant upon integrating spatial planning with pragmatic engineering and securing institutional commitment to long-standing financial mechanisms, providing a replicable model for evidence-based landfill planning in analogous constrained environments.

Keywords*—Sanitary Landfill, Site Selection, Geographic Information Systems (GIS), Analytic Hierarchy Process (AHP), Economic Viability, Solid Waste Management (SWM)*

1. INTRODUCTION

Fast urban growth in developing countries has intensified the load on municipal solid waste management systems, particularly concerning environmentally safe disposal and scarcity of suitable land. Regardless of advances in waste reduction and resource recovery, landfilling remains an indispensable component of integrated solid waste management systems Fard et al., 2022 [13]. Engineered sanitary landfills integrate liner systems, leachate and landfill gas management, and environmental monitoring to reduce opposing impacts Alkaradaghi et al., 2022 [2]. However, their sustained performance depends on systematic site selection, technically thorough design, and long-term financial feasibility. In several municipalities, landfill planning leftovers fragmented, where site appropriateness is conducted independently from engineering design and economic evaluation. This breakdown often fallouts in technically infeasible designs or economically unviable systems that cannot be sustained on the course of time.

Landfill siting is essentially a multi-criteria decision-making problem demanding balanced consideration of environmental safeguards, land use compatibility, transportation distance, public health risk, and lifecycle cost Alkaradaghi et al., 2022 [2]; Wang et al., 2018 [30]. The incorporation of Geographic Information Systems and multi-criteria decision analysis has become the leading methodological approach for suitability assessment Sumathi et al., 2008 [27]; Chang et al., 2008 [9]; Şener et al., 2010 [23]; Basnet, 2015 [6]. Analytical Hierarchy Process and its fuzzy or hybrid extensions are broadly adopted to weight criteria and rank substitutes Vasiljević et al., 2012 [28]; Mallick, 2021 [20]; Zarin et al., 2021 [32]; Kara and Doratli, 2012 [18]; Khan and Samadder, 2015 [19]. Current studies further combine remote sensing data, group decision frameworks, and sustainability indicators to improve sturdiness and transparency Elkhrachy et al., 2023 [11]; Arshad et al., 2023 [3]; Soyaslan, 2025 [25]; Sisay et al., 2025 [24]; Belete et al., 2024 [7].

Although significant progress has been achieved in spatial modelling, many researches point out environmental suitability while giving limited focus to economic appraisal, engineering conformation, and operational sustainability Asif et al., 2020 [5]; Etraj and Jayaprakash, 2018 [12]. The split-up of spatial analysis from design detailing and financial assessment limits real-world implementation, mainly in municipalities with constrained institutional capacity.

In Nepal, growing waste generation and changing in consumption behaviours have deepened disposal challenges Kandel et al., 2023 [17]. Numerous municipal assessments describe dependence on open or semi-controlled dumping because of technical and financial limitations Pandey et al., 2023 [21]. Although design guidelines for sanitary landfills exist Arthika et al., 2018 [4], extensive strategic planning leftovers limited. National assessments spotlight gaps in long-term financial sustainability, cost recovery mechanisms, and system integration World Bank, 2020 [31]. Although existing geospatial studies in Nepal exhibit the applicability of GIS based MCDA approaches for landfill siting (Chauhan and Ghimire, 2023 [10]; Bhusal et al., 2023 [8]; Subedi et al., 2025 [26]), these studies primarily focus on spatial suitability while providing limited responsiveness to the integration of engineering design strategies and economic viability assessment. As a result, the connection between site selection, design considerations, and cost implications leftovers inadequately addressed in practice. As a response, this study covers the identified gap by systematically assessing and incorporating prevailing engineering design strategies with spatial suitability and economic evaluation within a combined planning framework for sanitary landfill development in Suklagandaki Municipality, rather than suggesting entirely new design strategies.

The objectives are to assess landfill site suitability and related design strategies using GIS-based AHP, evaluate the economic viability of sanitary landfill development under local municipal settings. This study intended a structured and decision-oriented integrated framework for landfill planning in resource constrained environments.

2. LITERATURE REVIEW

Municipal solid waste management in Nepal is a foremost challenge caused by speedy urbanization, increasing waste generation, and limited engineered landfill infrastructure. Studies in Kathmandu Valley and neighbouring districts demonstrates rising household waste volumes and inadequate segregation, collection, and disposal systems Basnet, 2015 [6]; Kandel et al., 2023 [17]. National assessments spotlights institutional, technical, and financial constraints upsetting municipal solid waste services World Bank, 2020 [31]; Ghanbari et al., 2012 [14]. District-level GIS-based studies verify the applicability of spatial decision-support tools for landfill site identification, integrating environmental and social criteria Chauhan and Ghimire, 2023 [10]; Bhusal et al., 2023 [8]; Subedi et al., 2025 [26]. However, most research concentrates on environmental suitability, with partial integration of economic feasibility or comprehensive design planning Pandey et al., 2023 [21].

The combination of Geographic Information Systems (GIS) with Multi-Criteria Decision Analysis (MCDA) has become the leading framework for landfill site selection. Conventional AHP models evaluate slope, hydrology, land use, and proximity to settlements to generate consistent suitability maps Şener et al., 2010 [23]; Chang et al., 2008 [9]; Vasiljević et al., 2012 [28]. Hybrid methods, containing fuzzy-AHP, Best Worst Method, SAW, and DEMATEL, enrich weighting consistency and decrease subjectivity Fard et al., 2022 [13]; Alkaradaghi et al., 2022 [2]; Zarin et al., 2021 [32], Etraj and Jayaprakash, 2018 [12]. Current studies exhibit the continued perfecting of these approaches together with group decision models for sustainable location in Saudi Arabia Arshad et al., 2023 [3], GIS–AHP amalgamation in Ethiopia and Nepal Subedi et al., 2025 [26]; Sisay et al., 2025 [24], and basin-scale suitability analysis in Turkey Soyaslan, 2025 [25]. These modern applications underscore the ability of hybrid MCDA methods to simultaneously incorporate environmental, social, and economic criteria Elkhrachy et al., 2023 [11]; Mallick, 2021 [20], Santisteban et al., 2026 [22], Wang et al., 2009 [29].

Environmental safety and sustainability consideration is vital to landfill planning. GIS-based suitability models progressively include groundwater vulnerability, ecological sensitivity, and health risk indicators to decrease contamination and public health effects Ghanbari et al., 2012 [14], Wang et al., 2018 [30], Hazarika and Saikia 2020 [15]. Sustainability prone studies further incorporate social acceptance and lifecycle assessment benchmarks to maintain long-term operational and regulatory compliance Aidoo et al., 2024 [1]; Mallick, 2021 [20]; Asif et al., 2020 [5].

Landfill engineering design involves liner systems, leachate management, phased cell construction, and ability predicting Arthika et al., 2018 [4], Chang et al., 2008 [9], Sumathi et al., 2008 [27]. GIS data management delivers the spatial accuracy required for trustworthy parameter assessment and decision aid Huisman and de By, 2009 [16]. Despite methodological progresses, Nepalese studies seldom combine GIS–AHP site suitability with organised economic assessment. Uniting spatial optimization, design strategy, and financial assessment is consequently essential for evidence-based sanitary landfill planning in evolving municipalities like Shuklagandaki Basnet, 2015 [6]; Chauhan and Ghimire, 2023 [10]; Bhusal et al., 2023 [8]; Subedi et al., 2025 [26].

3. METHODOLOGY

A. Integrated Framework and Methodology Flow Chart

A conceptual integrated framework was developed connecting GIS-based site selection, engineering design assessment, and economic evaluation.

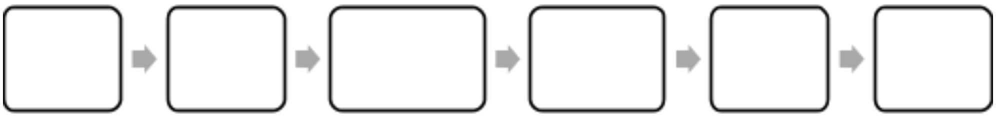

Figure 1: Integrated Framework for Sanitary Landfill Planning

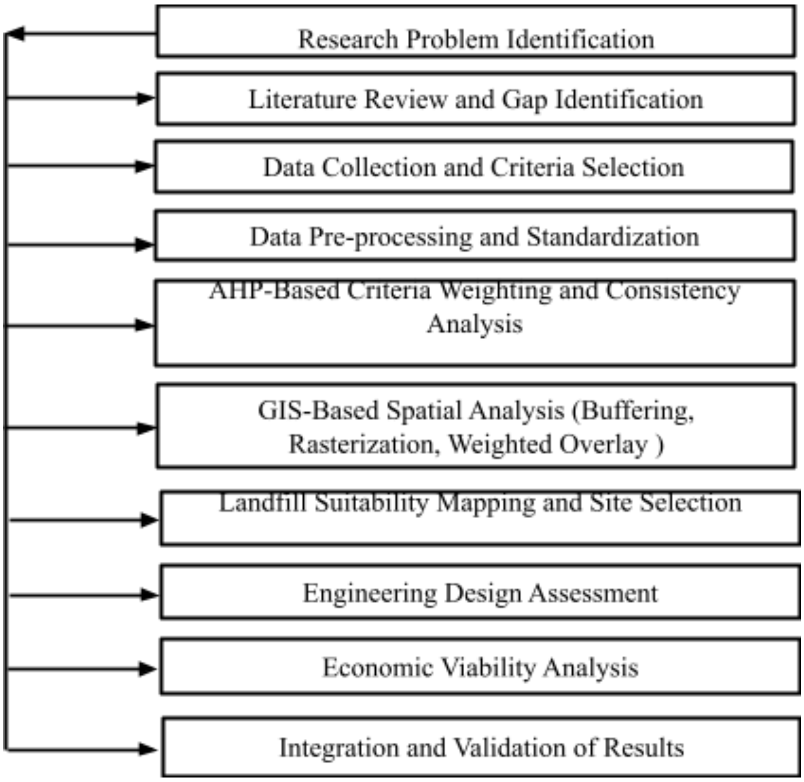

Figure 2: Flow Chart of Methodology

The methodology incorporates GIS-based spatial analysis, AHP-based decision-making, engineering design assessment, and economic evaluation in a consecutive framework. This organised integration ensures that spatial suitability, engineering design strategies, and economic viability are jointly evaluated thus directly fulfilling the identified research gap.

B. Study Area

The study was carried out in Suklagandaki Municipality, Gandaki Province, Nepal (Figure 2), situated at 28.043° N and 84.0696° E with an average elevation of 609 m above mean sea level. The municipality has an area of 164.8 km² and a population of 56,620 in reference of the National Population Census of Nepal, 2021. Mixed land use, growing waste generation, and spatial constraints validated its selection for integrated landfill planning assessment.

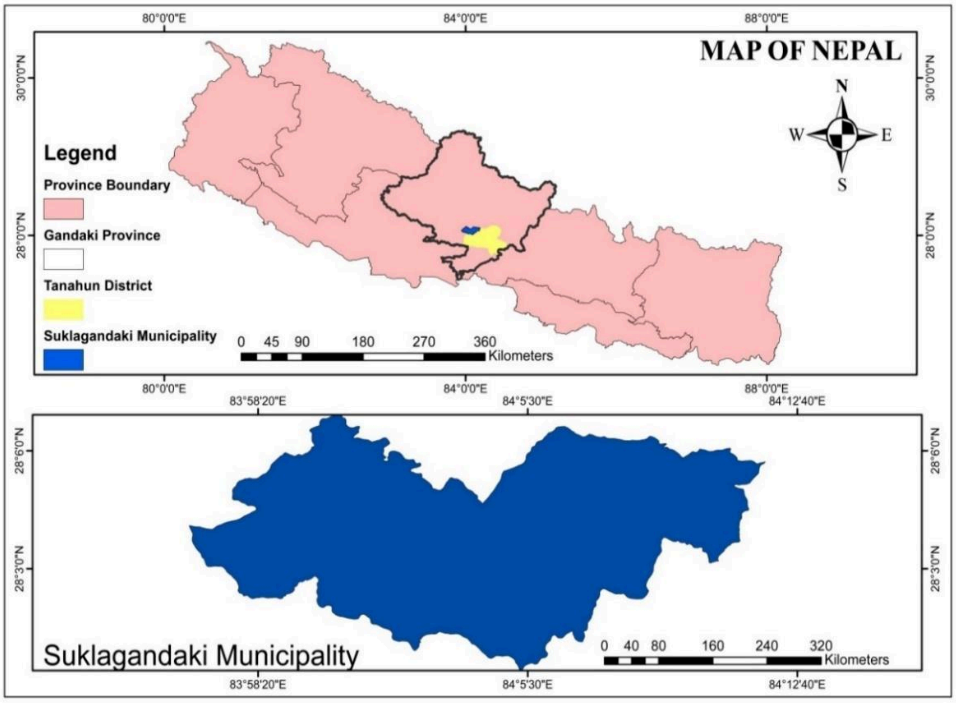

Figure 3: Study Area Map

C. Data Sources and Materials

Primary and secondary data were applied. Spatial datasets encompassed land use, hydrology, roads, settlements, soil, slope, elevation, land cost, and wind direction obtained from government agencies, municipal records, and open geospatial databases. Missing layers were digitized. Waste production and demographic data were attained from municipal records. Expert judgment for weighting was gathered through organised questionnaires. Spatial analysis was executed in ArcGIS 10.8.

D. Assessment of Current Design Practices

Current waste disposal practices in the study area mainly involve open dumping with least engineering controls. This study evaluates design strategies such as liner systems, leachate management, and phased cell development based on suitability outputs derived from GIS–AHP analysis.

E. Landfill Site Selection Standards

Ranking intervals were expressed in reference of national landfill guidelines, available literature, and environmental protection norms and standards. Buffer distances and suitability scores indicate regulatory thresholds and professional consultation. Detailed classifications and ranking scales are presented in Table 1.

Table 1: Suitability Classifications

Decision Standards	**Entries**	**Interval (m)**	**Rank**
Land Use	Agricultural		1
	Forest		3
	Public zone		5
Water body		0-500	1
		500-1000	2
		1000-1500	3
		1500-2000	5
		2000-2500	8
		2500-3000	9
Road way	Highway and	0-500	1
	Feeder, district road	500-1000	2
		1000-1500	3
		1500-2000	5
		2000-2500	8
		2500-3000	9
	Other road	0-500	7
Residential Area	Settlement	0-500	1
		500-5000	5
Slope		0-3	9
		3-15	5
		15-60	1
Cultural Area	Temples and police Station	0-1000	1
		1000-2000	5

Elevation		0-500	5
		500-1500	1
Land Cost	According to study Area		
Soil Type	Sandy/Gravel		1
	Silt		5
	Clay		7
Wind	According to study area /Direction	NW (North west)	1
		NS (North south)	3
		EW (East west)	5

The methodology incorporates GIS-based spatial analysis, AHP-based decision-making, engineering design assessment, and economic evaluation in a consecutive framework. This organised integration ensures that spatial suitability, engineering design strategies, and economic viability are jointly evaluated thus directly fulfilling the identified research gap.

F. Analytical Framework

A united framework joined GIS based multi criteria decision analysis, landfill engineering design, and economic assessment. Site suitability was assessed employing Analytical Hierarchy Process weighting and weighted overlay analysis. AHP was selected because of its competency to structure complex multi-criteria problems, include expert judgment, and guarantee consistency in decision-making. It is extensively applied in landfill siting studies due to its transparency and sturdiness. Pairwise comparisons obeyed the nine point Saaty's scale. Consistency was confirmed using:

$$CI = \frac{(\lambda_{max} - 1)}{(n - 1)}$$

Where λ_{max} the principal eigenvalue and n is the order of the matrix. The Consistency Ratio was obtained by comparing CI with the Random Index RI. Consistency Ratio $\leq$ 0.1 established acceptable judgment reliability. Raster layers were ordered to a 1 to 9 suitability scale and integrated to produce composite suitability maps.

a. Waste Projection and Landfill Design

Table 2: Summary of Suklagandaki Municipality

Description	**Quantity**
Total population	55,620
Total number of households	12,185
Total area (km^2)	165

Number of wards	12
Average household size	4
Average household waste (kg/day)	0.51
Average per capita municipal solid waste (MSW) (g/capita/day)	185.31
Average per capita household waste (g/capita/day)	127.74
Total household waste (ton/day)	6.19
Total institution waste (ton/day)	0.38
Total commercial waste (ton/day)	2.40
Total municipal solid waste (MSW) generation (ton/day)	8.98

At present, waste generation was 8.98 t/day. Population projection for a 15 year design period used:

$$P = P_0 + (1 + R)^N$$

Where, P is the projected population, P_0 is the current population, R is the annual population growth rate, and N is the design period.

Required landfill volume was calculated as:

$$V_L = \frac{(P \times C \times E)}{\rho}$$

Where,

V_L is landfill volume,

C is waste generation per capita disposed to landfill,

E is waste to cover ratio and

ρ is waste density.

Leachate generation was estimated by:

$$Q_L = [\frac{(1}{1000)\times} I_J\left(C_1 A_1 + C_2 A_2\right) \qquad \text{(Evliya, 2001)}$$

Where,

Q_L is leachate generation,

I_J is daily rainfall,

C_1 and C_2 are leachate generation coefficients, and

A_1 and A_2 represent contributing areas.

Design components involved cell configuration, mineral liner system, leachate collection, and final cover, reliable with standard sanitary landfill practice.

G. Economic Assessment

Lifecycle cost assessment deliberated capital, operation, maintenance, closure, and post closure costs using municipal financial data. Major assumptions comprised steady waste generation rates, linear population growth, and nearby available construction materials. Cross confirmation of spatial outputs and design parameters guaranteed internal consistency and decision trustworthiness.

4. RESULTS AND DISCUSSION

A. Site Suitability and Design Strategy Assessment

a. Data Acquirement and Pre-processing

Spatial data for Suklagandaki Municipality, containing land use, water bodies, roads, settlements, cultural sites, slope, elevation, soil, land cost, and wind, were attained from ICIMOD and municipal records. Data were confirmed and pre-processed for consistency. Vector datasets were projected to WGS1984 Transverse Mercator, aligned with 30 m × 30 m land use raster, and re-categorised as per suitability norms.

1. Land Use, Slope and Elevation: Land use analysis showed agriculture leads, followed by forests, urban area, and public zones. Agricultural lands were judged unsuitable, while public and thinly populated areas were prioritized for landfill placement. Urban zones were weighed to reduce impacts. GIS processing, including clipping and raster conversion, aided precise land use delineation within the municipality.

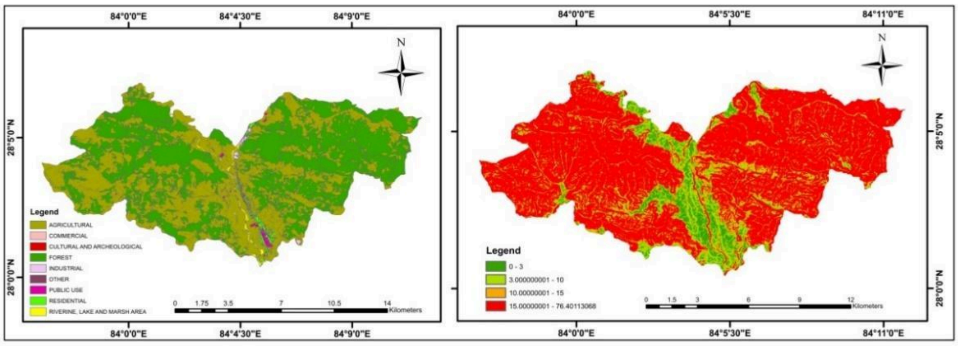

Figure 4: Land Use Map and Slope Map

2. Water Bodies: Water body analysis was concentrated on the Seti River. Buffers assured landfills were sited away from delicate zones, minimizing contamination risk. Reclassified data directed the suitability overlay.

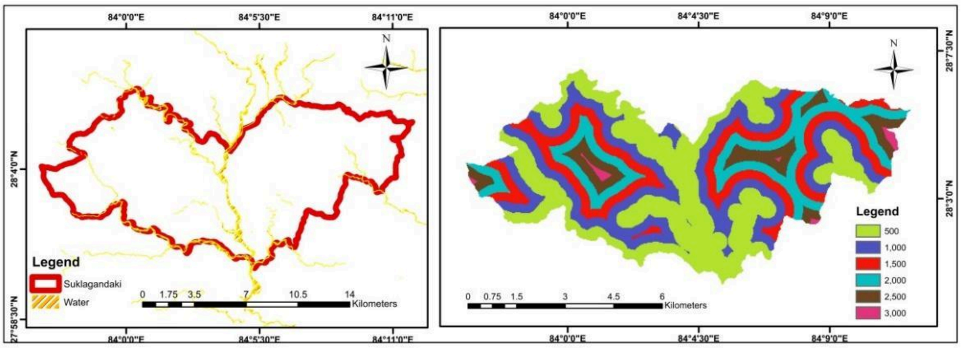

Figure 5: Water Bodies Map

3. Road Network: Road analysis differentiated major roads from local roads. Major roads received greater suitability for landfill access, whereas local roads were given average weights to ensure feasible waste collection routes.

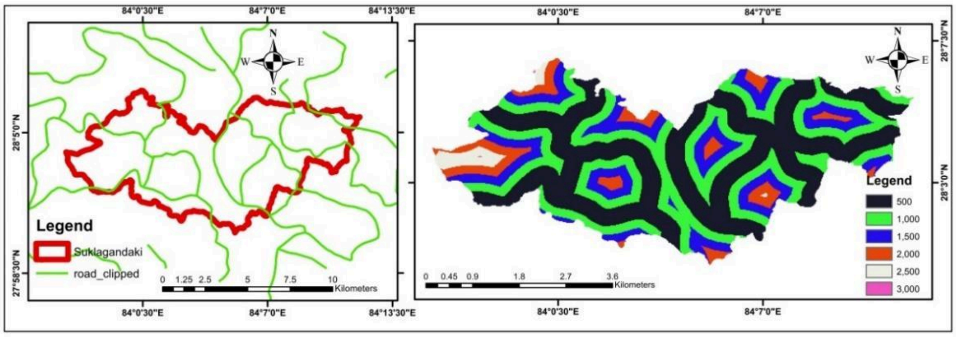

Figure 6: Road Network Map

4. Residential and Cultural Areas: Residential zones were categorised by density with landfills selected in low-density zones to minimise exposure. Cultural and archaeological sites were buffered and excepted. GIS raster analysis linked these constraints to define prohibiting zones as shown in Figure 7.

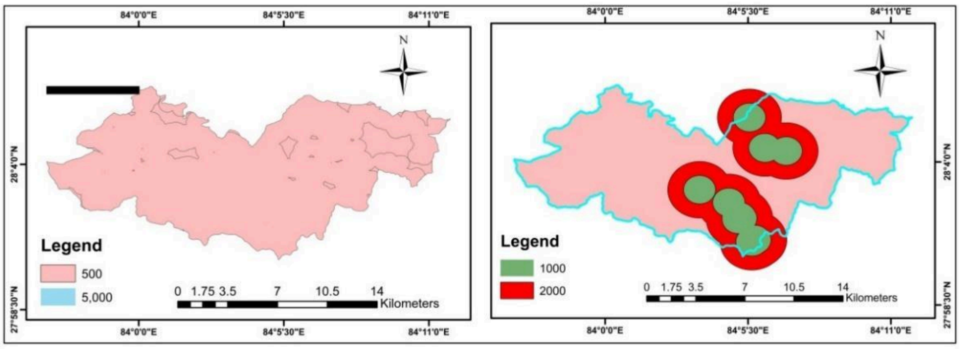

Figure 7: Residential and Cultural Areas Map

5. Slope, Elevation, Soil, and Land Cost: Slope and elevation were measured for drainage, stability, and feasibility. Suitable low-permeability soils were recognised to limit leachate migration, and land cost steered economic site selection. All layers were reclassified on a 1 to 9 suitability scale.

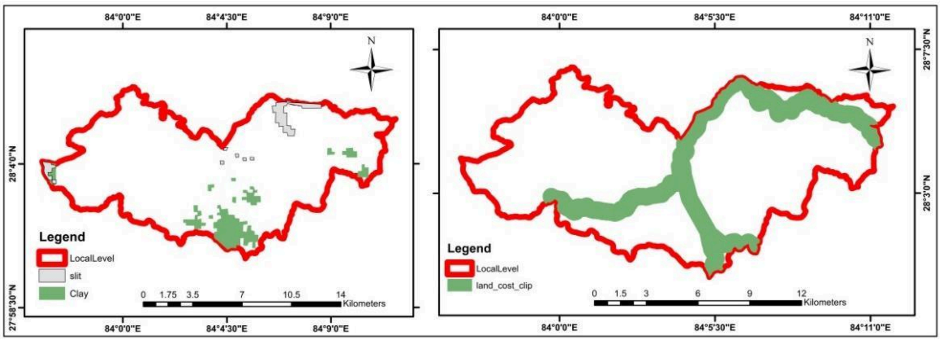

Figure 8: Soil Type and Land cost Map

b. AHP-Based Weighting and Criteria Consistency

An AHP survey with 10 stake-holders quantified landfill siting benchmarks with importance. Five datasets fulfilled consistency (CR < 0.10), and their mean was used to develop final criteria weights as displayed in Table 3. These weights feature the relative implication of environmental, social, and economic factors, with land use and residential proximity being the main considerations in landfill siting.

Table 3: Final AHP Weightage

Criteria	Criteria Weights
Land Use	0.16
Water Body	0.14
Road Way	0.12
Residential Area	0.15
Slope	0.05
Cultural Area	0.09
Elevation	0.05
Land cost	0.09
Soil Type	0.11
Wind	0.04

Table 4: Cost Estimation

Particulars	Estimated cost (NPR)
Location selection and characterization expenses	400,000.00
Detailed engineering design expenses	300,000.00
Yearly construction expenses	2,000,000.00
Yearly operation expenses	2,000,000.00
Yearly closure expenses	1,550,000.00
Yearly post closure expenses	490,000.00
Total	6,740,000.00

c. Landfill Suitability Analysis

Weighted overlay of all raster layers formed a suitability index map ranging from 1 (least suitable) to 9 (most suitable). The areas with suitability scores below 7 were excluded. The resulting suitable regions covered 1.489 km², indicating 0.89% of Suklagandaki Municipality's total area as shown in Table 5, Figure 9, 10, 11. These zones are primarily located in sparsely populated public lands, outer to critical water and cultural areas, and reachable by major roads. The overlay shows the effectiveness of combining GIS spatial analysis with stakeholder-informed AHP weighting to recognise environmentally and socially satisfactory landfill sites.

Table 5: Landfill Suitability Summary for Suklagandaki Municipality

Suitability Class	Area (km²)	% of Municipality	Land Use Type	Proximity to Water	Access	Remarks
7–9 (Suitable)	1.489	0.89	Public / Sparse	>1000 m	Near major roads	Environmentally and socially suitable
<7 (Excluded)	164.8 – 1.489 = 163.311	99.11	Mixed	<1000 m / critical areas	Limited / urban	Not recommended for landfill

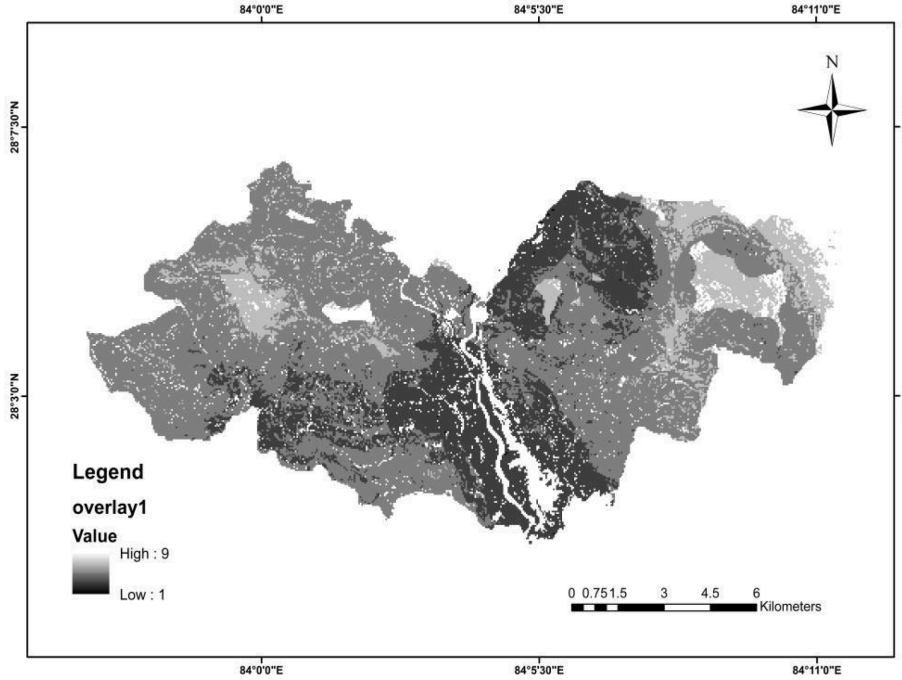

Figure 9: Favourable and Unfavourable Areas Map

d. Landfill Design Parameters

Population projection for a 15-year design period estimated a population of 67,725 persons, applying an annual growth rate of 1.1% from a baseline of 55,620. Waste generation was anticipated at 0.2–0.3 kg/capita/day, resulting in approximate 73 kg/year per person. Considering the commercial and institutional offerings as 8% and assuming 80% of waste is heading to the landfill, the total waste to be managed is 945.6 kg per capita over the design period.

The planned landfill design adopts a five-cell, four-lift system with a total height of 20 m., every day and intermediary cover thicknesses are respectively 0.15 m and 0.30 m, with a waste-to-cover ratio of 1.219. Requisite landfill volume was calculated as 156,131.37 m³, occupying an area coverage of 7,806.56 m² (length × breadth: 88.35 m × 88.35 m).

1. Liner and Capping Systems: A mineral liner system with a thickness of 0.30 m, a geological barrier of sand/gravel (0.30 m), and a subsoil layer (0.30 m) was accepted to decrease leachate migration. The capping system includes topsoil (0.50 m), coarse material (0.20 m), mineral sealing (0.30 m), and foundation soil (0.40 m). The volumes of materials were calculated as daily cover 18,735.74 m³, intermediate cover 9,367.87 m³, sand/gravel 2,341.96 m³, mineral liner 4,683.92 m³, subsoil 2,341.96 m³, topsoil 3,903.28 m³, coarse material 1,561.31 m³, mineral sealing 4,683.92 m³, and foundation layer 3,122.62 m³.
2. Leachate Management: Leachate generation was estimated by means of the formula $Q_L = [\frac{(1}{1000)\times} I_J \left(C_1 A_1 + C_2 A_2\right)$ (Evliya, 2001), producing 0.125 m³/day. A leachate collection tank of dimensions 2 m × 2 m × 2.3 m was designed, and a 200 mm diameter collection pipe network with 1 m spacing and 1% gradient was proposed, needing 89 pipes. The leachate management design confirms hydraulic efficiency and compliance with environmental safety criteria.

B. Economic Viability Assessment

The estimated cost for the sanitary landfill project totals NPR 6,740,000, covering site selection of NPR 400,000, detailed engineering design of NPR 300,000, annual construction and operation of NPR 2,000,000 each, closure of NPR 1,550,000, and post-closure maintenance of NPR 490,000. Construction and operation constitute the major regular expenses, whereas design and site selection are minor one-time costs as shown in Table 4.

The investigation confirmed that a transfer station is needless, as the farthest collection point lies within 15 km of the planned site. Employing a reasonable municipal solid waste management fee is recommended to safeguard sustainable operation. Sensitivity analysis demonstrates that cost variations are mostly influenced by land acquisition, construction, and cover material necessities, reinforcing the importance of site selection in lessening operational costs.

C. Discussion of Site Selection and Design Implications

The incorporation of GIS and AHP for landfill site selection offers a structured method to maintain equilibrium of environmental, social, and economic goals. Selected sites obey global sanitary landfill guiding principle, reducing proximity to residential areas and water bodies but maintaining road approachability. Overlay analysis points out less than 1% of the municipal area suitable as a result of topography, hydrology, and land use. Land use, residential proximity, and water bodies govern the weighting, reflecting local governance and safety priorities. Conversely the slope, elevation, and wind speed, though lower-weighted, affect operational proficiency and leachate dispersion. GIS-based reclassification efficiently excludes inappropriate areas, confirming compliance and community reception.

Design strategies consisting lift-based construction, mineral liners, and capping associate with Nepalese best practices. A 20 m multi-cell formation balances capacity and feasibility. Daily and intermediate cover layers mitigate odour, pests, and leachate hazards. Leachate collection infrastructure is compatible with operational requirements perceived in other Nepalese landfills. Moreover, MCDA outcomes steer design strategy selection by ascertaining environmentally suitable zones, which directly effect liner type, leachate control provisions, and operational feasibility.

Economic analysis reveals the landfill design is viable for anticipated population and waste generation. Total investment is moderate relating to municipal revenue, and avoiding a transfer station cuts the costs. Allocation for cover materials, liners, and leachate systems emphasizes the prominence of engineering design in lifecycle cost reduction. These findings aids informed decision-making for municipal solid waste management.

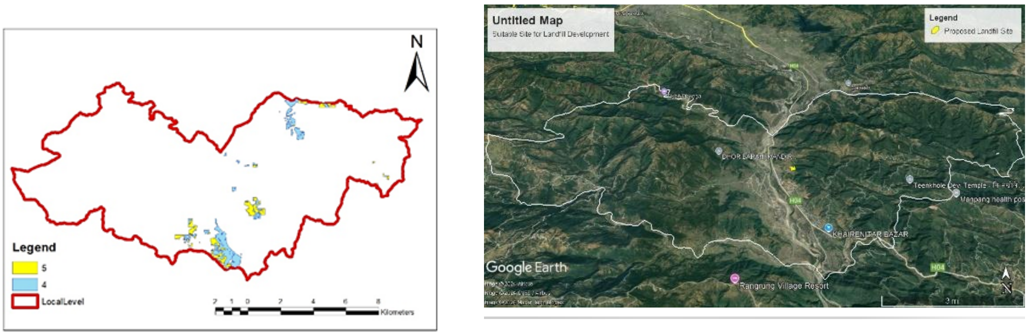

Figure 10: Favourable Sites for Sanitary Landfill Design (Source: GIS Map)

D. Comparison with Earlier Studies

The suitability analysis coincides with other GIS-AHP studies in South Asia, presenting less than 2% of municipal areas suitable caused by environmental and social constraints. While contrasting studies underscore slope and soil, this analysis ranks higher to land use and residential proximity, signifying local urbanization. The AHP weighting ensures stakeholder engagement and minimises subjective partiality compared with only expert relying approaches. Integrating economic analysis within GIS-AHP offers an applied tool for municipalities to maintain equilibrium between environmental safety and fiscal sustainability. The proposed site needs less land and produces lesser leachate than other Himalayan municipalities, validating efficient design and careful site assessment.

E. Limitations and Uncertainties

Despite detailed spatial analysis, uncertainties continue from population growth, waste generation, and land prices. Soil permeability and hydrology were derived from existing data, and field verification could advance liner and leachate design. AHP weighting depends on stakeholder input, which may change with future demographics or policies. Sensitivity analysis shows the nominated sites and design remain fit under plausible variations.

F. Contribution to Sustainable Landfill Planning

This study presents a replicable technique to landfill planning incorporating GIS, AHP, and economic assessment. Outcomes deliver decision-makers with direction on site selection, design, materials, and lifecycle costs. By balancing environmental safety, operational feasibility, and economic sustainability, the strategy assists sustainable solid waste management in emerging Nepalese municipalities. The methodology is transferrable to areas with similar topography and socio-economic conditions, encouraging evidence-based infrastructure planning.

5. CONCLUSIONS

This study employed an integrated GIS-based spatial analysis and Analytic Hierarchy Process to facilitate sanitary landfill planning in Shuklagandaki Municipality, Nepal. The approach exhibits that a scientifically justifiable and locally suitable strategy for sustainable waste disposal is attainable, despite limited suitable land and remarkable financial requirements. Spatial assessment categorised potential sites using ten environmental, social, and economic measures, with land use, proximity to settlements, and protection of water bodies receiving the highest weight. Results shows that only 1.489 km^2 (0.89% of the municipal area) is highly suitable, underlining serious spatial constraints while affording an objective basis for site selection that reduces environmental and social risks.

The study achieved its first objective by identifying suitable landfill sites and evaluating corresponding design strategies by means of an integrated GIS-AHP approach. The results confirmed that only a limited proportion of the municipal area is suitable for landfill development, emphasising significant spatial constraints while safeguarding environmental and social appropriateness.

The second objective was satisfied through lifecycle cost analysis, which revealed the economic viability of the proposed sanitary landfill under specified local conditions. The analysis further emphasized the inevitability of a sustainable financial mechanism to upkeep long-term operation and maintenance.

Grounded on site characteristics and projected local settings, a feasible engineering design was produced. For a 15-year perspective and a population of 67,725, the proposed cell-based landfill needs 7,807 m^2 of land which applies a mineral liner system, and comprises a leachate collection system designed for 0.125 m^3/day. The arrangement balances technical norms and standards with local material availability, construction routine procedures, and operational capacity.

Economic assessment demonstrates that operation and closure would each annually demand about NPR 2 million. A direct haul system is chosen over a transfer station, but long-term viability relies on a stable revenue mechanism, such as an organised waste management fee.

Finally, the study endorses that integrating spatial analysis, engineering design, and financial assessment can cater the absence of systematic landfill planning. Technically feasible options exist regardless of limited land. The effective implementation will require institutional assurance, regulatory enforcement, and sustainable financial management. The findings offer a widespread foundation for informed decision-making and practical implementation of municipal solid waste management.

6. SUGGESTIONS AND RECOMMENDATIONS

Only 0.89 percent (1.489 km^2) of the municipality was identified as highly suitable for landfill development, showing acute land scarcity. For future research, detailed geotechnical and hydrogeological examinations are required to verify soil permeability of $\leq 1\times10^{-7}$ cm/s and groundwater conditions at nominated sites. A phased implementation inaugurating with a pilot cell within the planned four lift, 20 m infrastructure setup is recommended to reinforce operational capacity and minimise risk.

The estimated capital cost of NPR 6.74 million and annual operating cost of NPR 2 million over a 15 year design period should be assessed through scenario based financial modelling. Sensitivity analysis including 2 to 5 percent annual waste growth and inflation is indispensable. Implementation of an organised municipal SWM service fee is necessary to ensure financial sustainability.

Active assessment of the leachate system designed for 0.125 m³/day under climatic changeability is advised. Integration of a material recovery facility, regular waste projection updates, GIS based observation and monitoring, and social surveys within the 500 m buffer zones are recommended to confirm long term technical and social viability.

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