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Suitability Analysis for Waste Disposal Site Using GIS Based Multi-Criteria Decision Analysis: A Case Study of Jhapa District, Nepal

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Abstract
Environmental degradation resulting from rapid urbanization, industrialization, and overpopulation has become a critical global issue, primarily due to the generation of vast amounts of solid waste. Effective solid waste management and proper disposal arrangements are imperative to mitigate the adverse impacts on the environment. This research article focuses

on identifying an appropriate waste disposal site for efficient waste management and dumping. Jhapa district in Nepal is chosen as the study area due to its diverse settlement zones, including industrial and commercial regions. To achieve this goal, Geographic Information based Multi-Criteria Decision Analysis (MCDA) method is used. The outcome of this project is a suitability model that categorizes different areas as least suitable, suitable, more suitable, and most suitable for establishing a waste disposal site. By considering multiple criteria, including environmental, health, residential and political factors, and the model provides a comprehensive assessment of potential sites. This research contributes to the field of waste management and environmental sustainability by offering a practical approach to decision-making in waste disposal site selection, promoting a healthier and cleaner environment for the residents of Jhapa district and beyond.

Keywords: GIS, MCDA, Spatial, Suitability, Waste

1. Introduction

1.1 Background

Wastes refers to materials that are no longer useful and are thrown away because they have become worthless or defective. In the context of Jhapa district of Nepal, the waste management problem have become the serious growing issue. So in the given article, we have tried to find the best and suitable site for waste management by the use of GIS based multi criteria decision analysis technique. The site should be selected by considering multiple criteria in such a way that it should be far away from Residential area, schools, Hospitals, water resources and agricultural land. The site should be selected nearer to the road networks so that the wastes can be safely disposed and the transportation costs can be minimized as well. Similarly, the site should be selected in the less sloppy area to avoid the hazardous waste water poisoning in nearby areas.

Suitability Analysis refers to the set of techniques and procedures used for structuring decision problems and designing, evaluating and prioritizing alternative decisions. It has an important role to play in analyzing decision problems. The potential sites used in suitability analysis includes the location of new hospital, school, store, tourism or dumping site, etc. Site selection analysis can utilize either vector or raster data, but among the two, the use of raster data is more prevalent and widely adopted. It is determined through systematic, multi-factor analysis of the different aspects of the terrain, physical, cultural and economic factors.

Multi-criteria decision making is an approach that helps decision-makers consider multiple criteria effectively. MCDA enables logical evaluation and comparison of these often conflicting criteria, leading to optimal decision-making. By breaking the decision into smaller, manageable parts, analyzing each part, and integrating them, MCDA produces a meaningful solution.

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1.2 Literature Review

The study in Anambra State, Nigeria, utilized GIS technology and multi-criteria decision analysis to identify suitable bioenergy plant locations, considering environmental, economic, and sustainable aspects. The research emphasizes informed decision-making in transitioning to renewable energy sources, providing valuable insights for energy planning(Chukwuma, Okey-Onyesolu, Ani, & Nwanna, 2021). This approach aligns with the objectives of a separate study focusing on GIS-based multi-criteria decision analysis for waste disposal site suitability in Jhapa district, Nepal.

The study conducted in Dar es Salaam, Tanzania, utilizes GIS and MCDA to determine optimal landfill sites, considering environmental and health-related impacts. The research identifies areas unsuitable for landfill siting and emphasizes the importance of environmentally friendly waste-to-resource strategies. The study highlights the need for comprehensive fieldwork to address various factors for site selection.(Kazuva et al., 2021)

The study in Alexandria, Egypt, presents a GIS-based model for siting a solid waste incineration power plant, aiming to address environmental challenges and enhance waste management in urban areas. By converting solid waste into electricity, the proposed incineration approach offers potential benefits, such as reduced waste disposal costs, pollution, and surplus energy generation. The methodology integrates various criteria to assess site suitability quantitatively, facilitating the identification of optimal locations for the power plant. The research highlights the significance of utilizing municipal solid waste for electricity generation, promoting sustainability and prolonging landfill lifespan. Further improvements are suggested, incorporating additional criteria for comprehensive site selection analysis.(Hassaan, 2015)

The study focuses on integrating multi-criteria decision analysis (MCDA) and GIS for hazardous waste landfill site selection in Kurdistan Province, Iran. The research aims to address the complexities of evaluating hazardous waste disposal sites in an underdeveloped region. By employing GIS for spatial analysis and MCDA for decision support, the study identifies the most suitable landfill sites based on expert input and criteria assessment. With increasing hazardous waste generation posing environmental and public health challenges, proper landfill siting becomes crucial. The research emphasizes the need for efficient waste management solutions, highlighting the importance of safe hazardous waste disposal in developing countries, including Iran(Sharifi et al., 2009).

The review explores GIS-based multi-criteria decision analysis (MCDA) methodologies for landfill site suitability analysis. It highlights the integration of geographical information systems (Demesouka, Vavatsikos, & Anagnostopoulos) and MCDA, enabling efficient and reliable landfill site selection by incorporating decision maker (Demesouka et al.) preferences and conflicting objectives. The review examines 36 articles, discussing the criteria and methods implemented in GIS-based landfill siting analyses, considering both exclusionary and non-exclusionary criteria. Notably, the progress in GIS-based MCDA studies concerning landfill siting over the last decade demonstrates its significance as a rapidly developing research topic. The use of modern GIS software packages has influenced decision analysis criteria, allowing

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for efficient handling of large raster datasets and enhancing the quality of decision-making (Demesouka, Vavatsikos, & Anagnostopoulos, 2014).

The study introduces Spatial UTA, a new approach for raster-based GIS multi-criteria suitability analysis in wastewater treatment site selection. By integrating decision makers' preferences, S-UTA enhances credibility and consistency(Demesouka et al., 2013).The insights from S-UTA could contribute to enhancing decision support for sustainable waste management in our paper focusing on waste disposal site suitability using GIS-based multi-criteria decision analysis in Nepal.

1.3 Research objective

The primary objective of this article is to produce the map showing the best and suitable site selection of the waste management of Jhapa district of Nepal.

The secondary objectives are enlisted below:

- To prepare the restriction map that contains the area of the land being restricted for the disposal of wastes by considering all the suitable criteria.
- To prepare the rating maps based on each of the respective criteria.
- To produce the suitability map showing the best site for waste disposal

2. Methodology

2.1 Planning

The suitable site is selected using certain criteria for the disposal of Waste. The criteria selected are enlisted below:

1. Residential Area- The suitable site must be 1500 away from the residential areas because the waste sites affect the human beings.so it must me far away
2. River-the suitable site must be 1000 away from river because the contaminated waste pollutes the water resources which hampers water creature and vegetation.
3. Road Networks-the suitable site is within 500m or more, so that the transportation the cost is minimized.
4. Health Sectors-suitable site is 1000m away from health sector because different disease may spread from waste which affects the health status of living creature.

2.2 Data collection

The data used in this project is secondary. These secondary data include base map of Nepal, Residential area, Road Networks, Health sectors and river are collected via internet from Open Street Map (OSM) and ICIMODRDS.

The secondary datasets were either in raster or vector format. The spatial format of vector data can be divided in three kinds: Point, Polyline and Polygon. The dataset attributes used in this project are shown in the table:

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Table 1: Data Type

Data layer	Type	Vector format
Resident	vector	polygon
river	vector	line
Road	vector	line
health	vector	polygon

2.3 GIS suitability Analysis

2.3.1 Defining a Projection

The projection system was defined in each layer and was projected into world coordinate (WGS_1984_UTM_Zone_44_N).

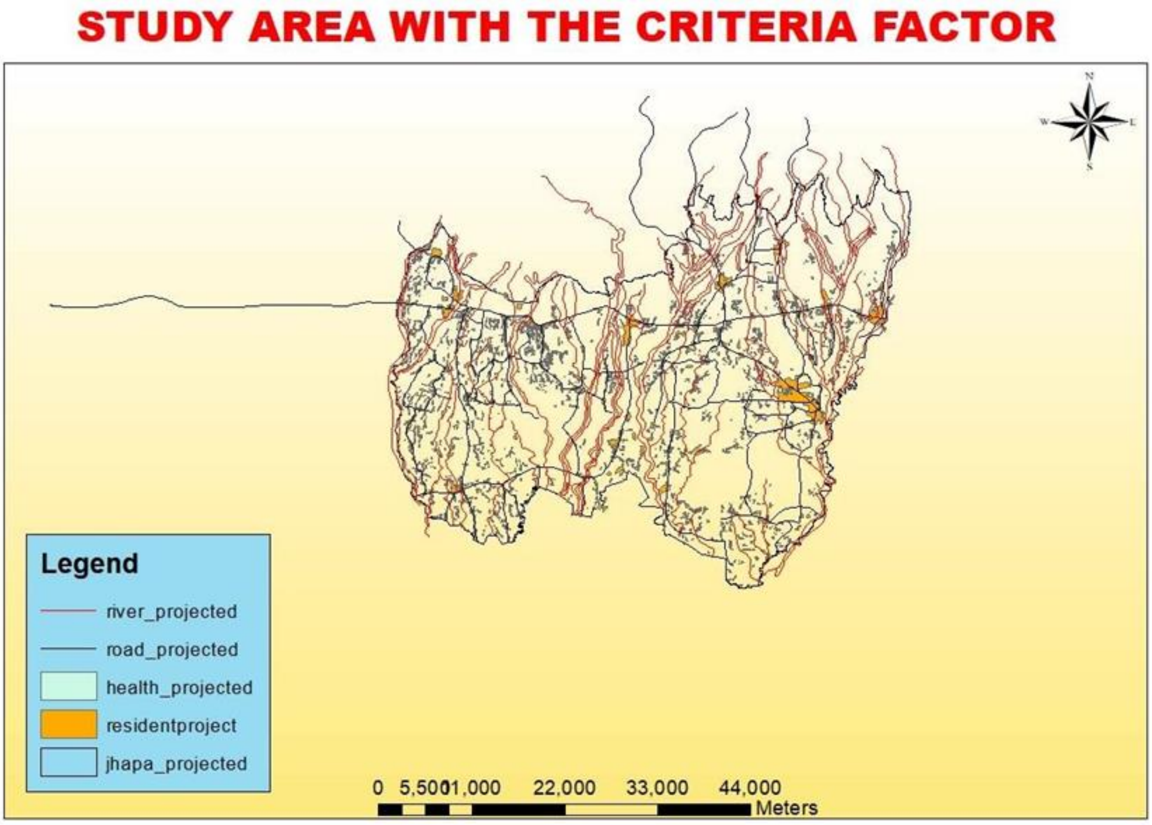

Figure 1: Each factor are projected to WGS_UTM_1984_Zonw_44_N

2.3.2 Suitability Model

Suitability model was developed by GIS operations. The different operations involved are:

Euclidean Distance: The Euclidean distance for the factors were set.

Reclassify: The Euclidean distance from aforementioned factors were subjected to reclassification. Slope data is in raster and is directly subjected to reclassification. The

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Euclidean distance of all criteria are calculated and reclassified and the suitable value are assigned to each features and the best Map with the class divided is achieved. The range of classification with importance (least, less, suitable, more, most) suitable.

Table 2: Reclassification of individual features

Data	Values	Range(m)		Suitability Criteria
Residential Area	1 2 3 4 5	0-1500 1500-2000 2000-2500 2500-3500 3500-5731.492		Least suitable Less suitable Suitable More suitable Most suitable
River	1 2 3 4 5	0-500 500-800 800-1500 1500-2000 2000-5731.492		Least suitable Less Suitable Suitable More suitable Most Suitable
Road Networks	1 2 3 4 5	3500-5731.492 2500-3500 1500-2500 500-1500 0-1500		Least Suitable Less suitable Suitable More suitable Most Suitable
Health Sectors	1 2 3 4 5	0-4000 4000-8000 8000-15000 15000-20000 20000027679.094		Least suitable Less suitable Suitable More Suitable Most suitable

Weighted Overlay: Weighted overlay was done on the classified layers. The euclidean distance of all the feature is calculated and the output is reclassified and weight overlay is done giving the score values and percentage as:

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Raster	% Influence	Field	Scale Value
		3	3
		4	4
		5	5
		NODATA	NODATA
reclass river	25	Value	
		1	1
		2	2
		3	3
		4	4
		5	5
		NODATA	NODATA
reclassify resident	25	Value	
		1	1
		2	2
		3	3
		4	4
		5	5
		NODATA	NODATA

Raster	% Influence	Field	Scale Value
reclassify road	35	Value	
		1	5
		2	4
		3	3
		4	2
		5	1
		NODATA	NODATA
reclassify_health	15	Value	
		1	1
		2	2
		3	3
		4	4
		5	5
		NODATA	NODATA

Figure 2: percentage weight given to each factor and score value to each classified field

The final suitability map is extracted using the conditional operator.
The step involved in assigning the weight to each factor 1) calculate the sum of the values in each column

2) divide each element in the matrix by its column sum;
3) Compute the average of the elements in each row of the normalized matrix, divide the sum by the number of factors. These averages provide an estimate of the relative weights of the factors

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1/4	1/3	1/2	1	2	3	4
very	strongly	moderate	equally	moderate	strongly	very

Normalization Table

Table 3: Weight assigned to each factor

	health	river	resident	road
health	**1**	**1/2**	**1/3**	**4**
river	**2**	**1**	**3**	**1/3**
resident	**3**	**1/4**	**1**	**1/4**
road	**4**	**5.75**	**3**	**1**
sum	**10**	**5.75**	**7.333**	**5.583**

Factors	Weight
health	**0.237**
river	**0.210**
resident	**0.1311**
road	**0.421**

3. Results

3.1 Restriction Map

The restriction model was used to generate a restriction map that included two zones. The lighted golden part represented the areas that were restricted for suitability of dumping sites while the blue zones were not restricted. Restriction map gives the area which is restricted and which is not restricted.

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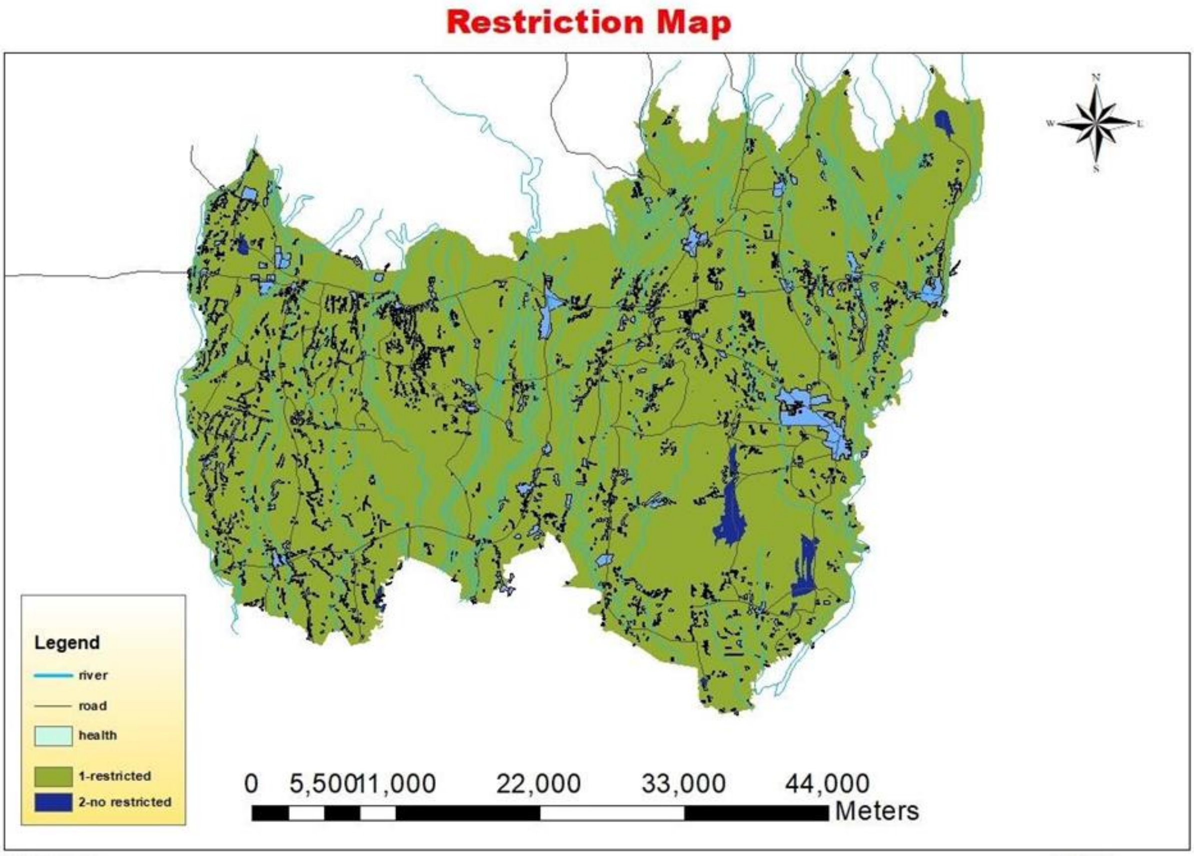

Figure 3: map showing restricted and non-restricted area for waste disposal

3.2 Rating Map

Rating Maps were generated which represent how each factor suits the selection of sites for establishing dumping sites. These rating maps scale the areas on the basis of each factor. The rating map according to each factor are as follows:

3.2.1 River

Most suitable site represented by brown color and green color represent the least suitable sites considering river only.

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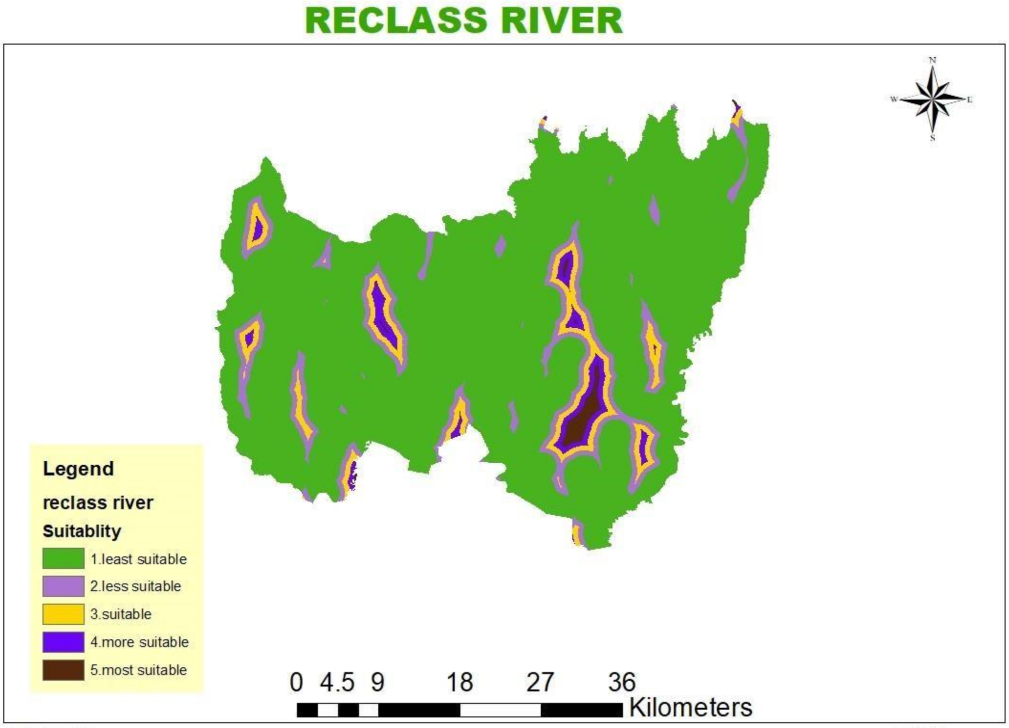

Figure 4: River Rating Map

3.2.2 Residential

Most suitable site represented by red color and green color represent the least suitable sites considering residential only.

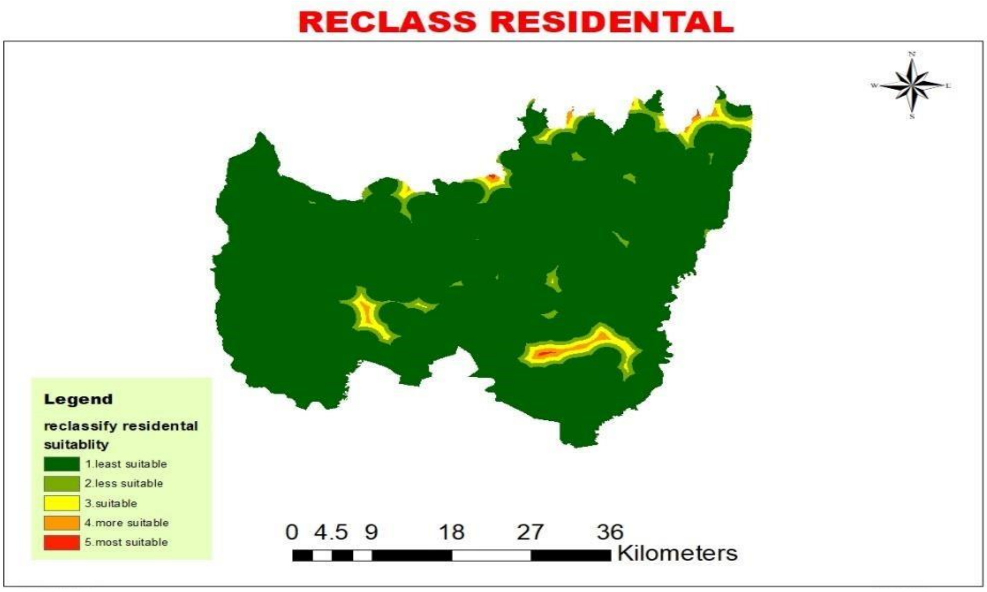

Figure 5: Residential Rating Map

3.2.3 Health

Most suitable site represented by Yellow color and silver color represent the least suitable sites considering health only.

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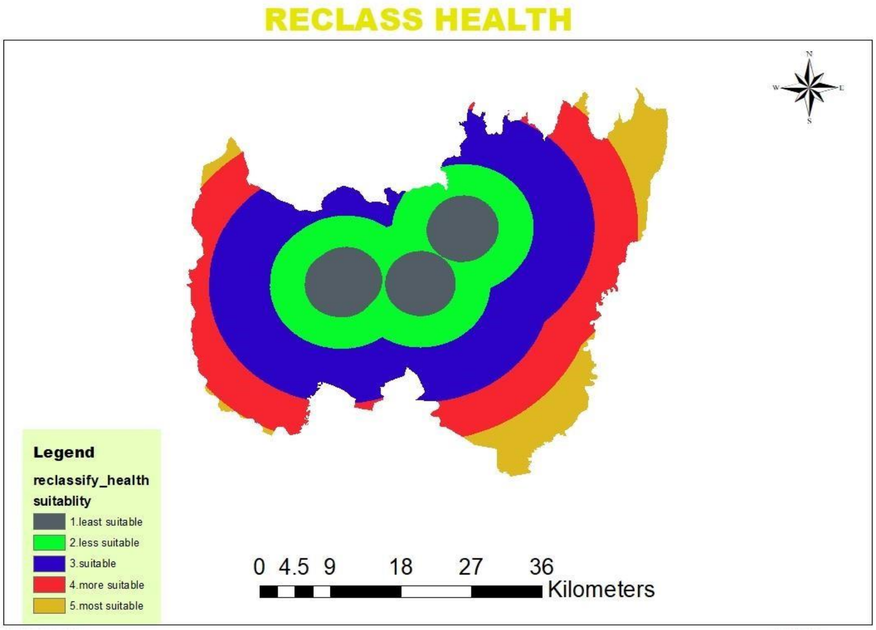

Figure 6: Health Rating Map

3.2.4 Road

Most suitable site represented by dark blue colour and weak blue colour represent the least suitable sites considering road only.

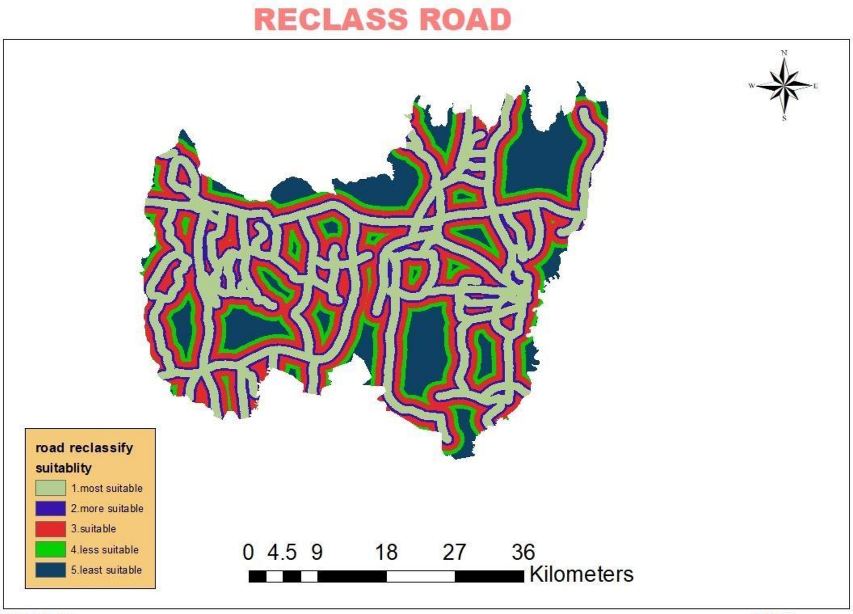

Figure 7: Road Rating Map

3.3 Suitability Map

The suitability model was used to generate a suitability map which shows the degree of suitability for selection of best site. The degree of suitability ranges from most suitable represented by blue through green, light blue, and least suitable represented by light orange..

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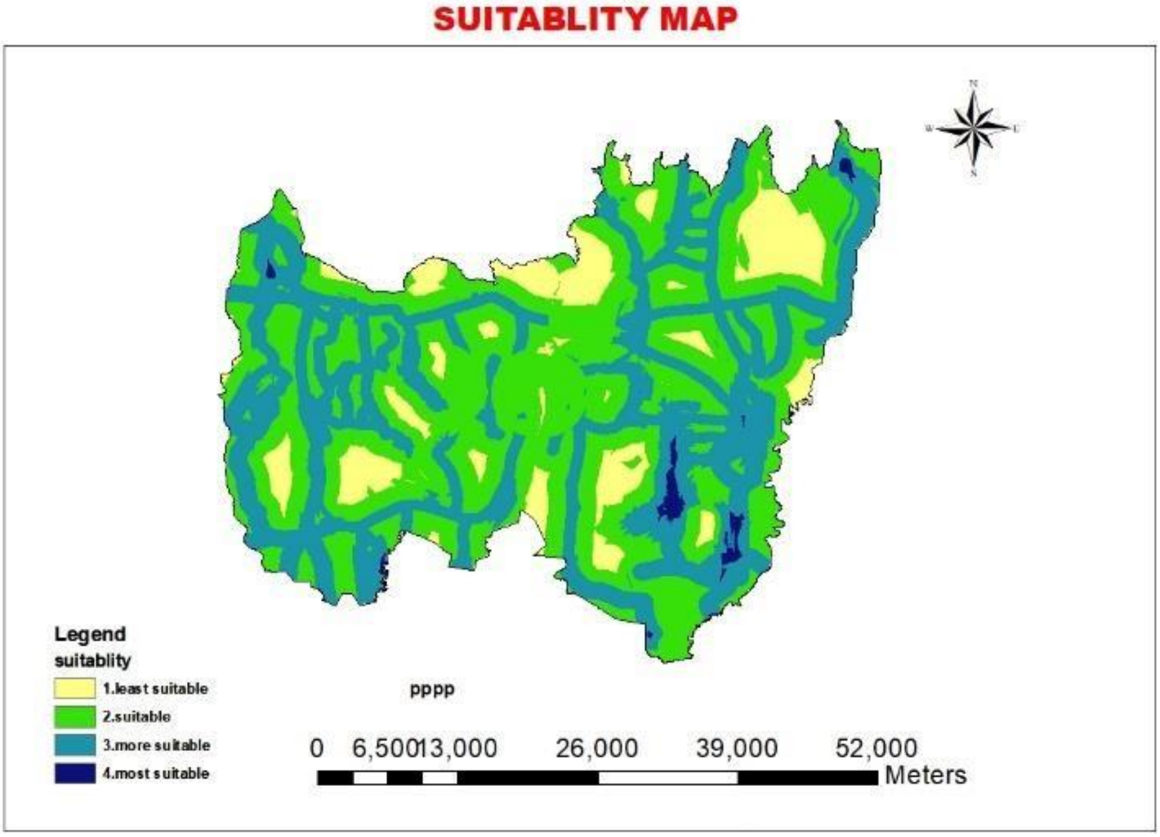

Figure 8: Suitability Map

3.4 Final map showing suitable sites for the waste disposal

Total of 14 zones were obtained as suitable areas for the dumping sites. All the zones were selected.

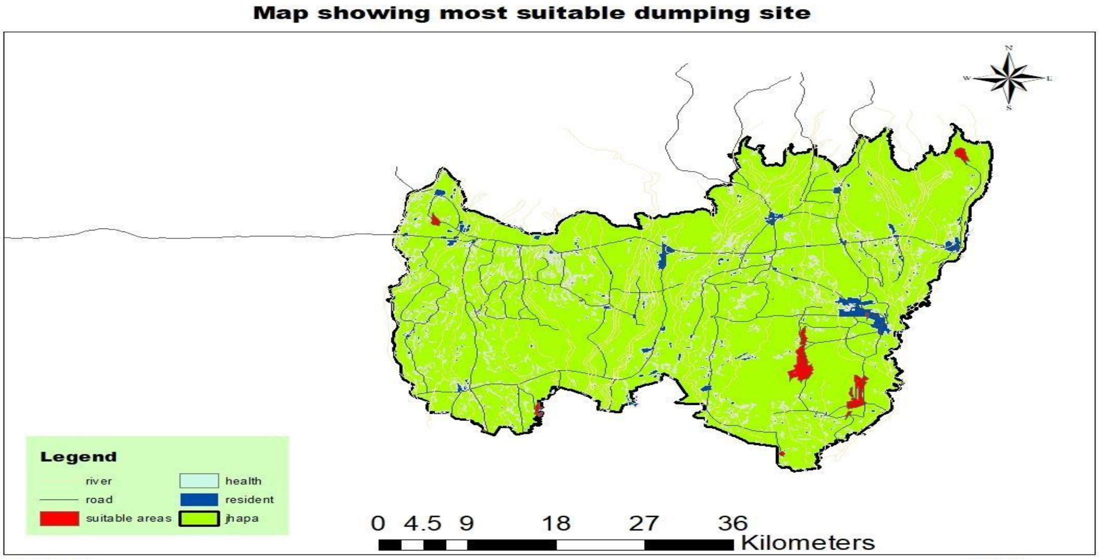

Figure 9: Map with suitable areas for waste disposal sites

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3.5 Final Verification

The verification sites was done by field visit and 4 zones were noted as the best suitability for waste disposal. The 10 zones are no suitable by field visit. The black portion represent the sites that are excluded from the field visit.

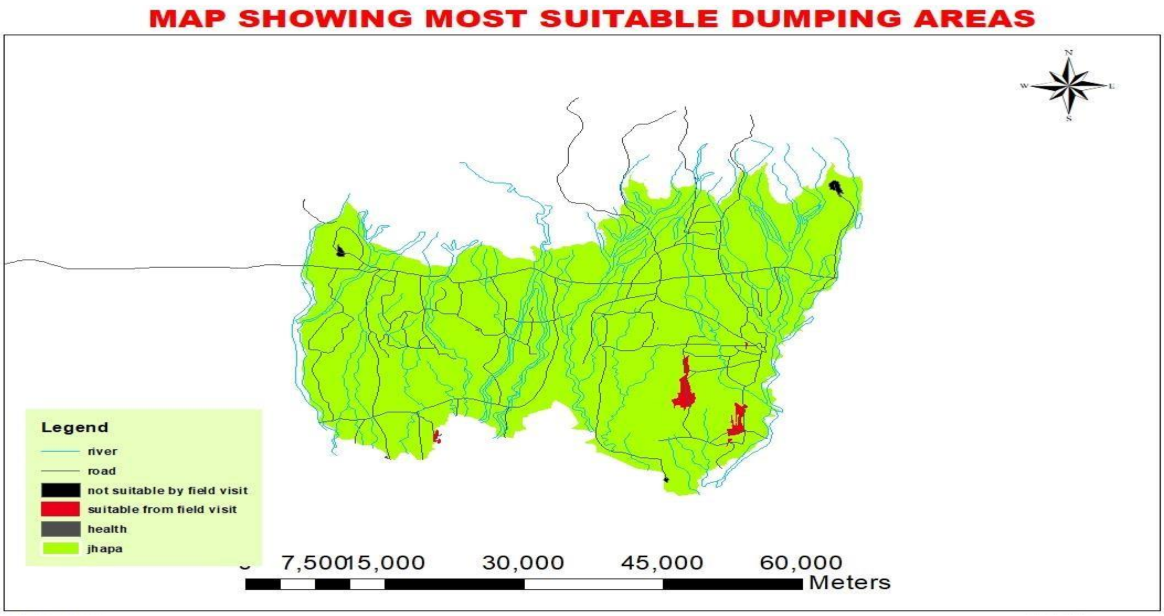

Figure 10: visited and verified sites

4. Conclusion

This research effectively addresses the global issue of environmental degradation resulting from rapid urbanization, industrialization, and overpopulation, leading to significant solid waste generation. The focus is on identifying an optimal waste disposal site in Jhapa district, Nepal, using Geographic Information System (GIS)-based Multi-Criteria Decision Analysis (MCDA).

Through MCDA, various criteria, including environmental, health, residential, and political factors, are logically evaluated to categorize areas as least suitable to most suitable for waste disposal. The resulting suitability model empowers decision-makers to make informed choices for efficient waste management and dumping.

This research contributes significantly to waste management and environmental sustainability, providing a practical decision-making framework for site selection. The verification of the model through field visits enhances its reliability, ensuring better waste disposal solutions in the region. The study concludes by fulfilling its objectives and offering valuable insights and recommendations for waste management practices in Jhapa district. The suitability map serves as a valuable resource for future projects, promoting a cleaner and healthier environment for residents.

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