KATHMANDU UNIVERSITY

SCHOOL OF ENGINEERING

DEPARTMENT OF GEOMATICS ENGINEERING

FINAL REPORT
ON GIS BASED MULTI-CRITERIA DECISION MAKING
FOR THE SELECTION OF LANDFILL SITE
IN DANG DISTRICT

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ABSTRACT

In the face of rising population and urbanization, several countries are striving to build proper waste management systems. Although some attempts are being made to reduce and recover garbage, landfill dumping remains the most popular method of waste disposal. An unsuitable landfill location could have serious environmental, economic, and ecological consequences. As a result, it should be carefully chosen, taking into account both regulations and constraints on other sources. Using the integration of Geographic Information Systems and Multi criteria Decision Analysis, suitable sites for an adequate landfill region in the Dang District is determined in this study where five criteria namely Road, River, Settlement, Land use and DEM data are considered for the analysis. Suitability criteria are rated from 1 to 5 where 1 represents unsuitable area and 5 represents highly suitable areas. The main aim of this study is to filter out best suitable and unsuitable sites for the waste disposal site in Dang District. Weighted overlay approach is applied to identify the suitable areas.

Analytical Hierarchy Process (AHP) pair-wise comparison model was used to accomplish weights of factor parameters. Processing of data are done by using model builder technique in Arc GIS. Suitability map was prepared by overlay analysis and assigned as highly suitable, suitable, moderately suitable, less suitable and unsuitable. Result shows that 1.4% of the study area is highly suitable, 21.932 % is suitable, 56.949 % is less suitable and 19.718% is unsuitable for the landfill sites. To reduce environmental danger and human health issues, certain sites are considered ideal for Landfill.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

AHP	Analytical Hierarchy Process
DEM	Digital Elevation Model
GIS	Geographic Information System
ICIMOD	International Centre for Integrated Mountain Development
Km	Kilometer
MCDA	Multi Criteria Decision Analysis
MCDM	Multi Criteria Decision Matrix
MCE	Multi Criteria Evaluation
VDC	Village Development Committee
WLC	Weight Linear Combination

1. INTRODUCTION

1.1 Background

Any item emitted from human operation that has a negative influence on human health or the environment is referred to as waste. Solid waste has emerged as a global environmental and health issue in today's globe, affecting both developing and developed countries. Many African, Asian, American, and European countries have switched from landfilling to incineration as a waste management method in recent decades. As a result, it's critical to figure out how to manage and dispose of garbage properly (Mussa & Suryabhagavan, 2019a). Landfill is the most extensively used means for municipal solid waste management in urban areas. Numerous considerations, such as land use, environmental, hydrological, and socioeconomic factors, had to be considered in the decision-making process to locate a landfill area (Basnet, 2015). Mismanagement of municipal waste directly effects on the environment and human beings. Most of the initiatives are taken for the reduction of waste at source and source segregation, but still, the problem is in handling and safe disposal up to the landfill site. The hierarchy of solid waste management includes prevention, minimization, reuse, recycling, energy recovery & disposal(Ahire et al., 2021).

GIS technology has been effectively used for optimizing trash management in coastal areas, calculating solid waste generation using local demographic and socioeconomic data, and forecasting waste generation at the local level(Yadav, 2013). Statistical models, heuristic algorithms, and Multi Criteria Decision Analysis (MCDA) procedures are only some of the techniques used to choose a landfill location. When both of the aforementioned provisions and laws are taken into account, MCDA can be a useful technique for locating prospective dump sites(Paul & Ghosh, 2022a). Almost all municipalities currently practice open dumping and landfilling with no remediation. It shortens the landfill's life expectancy. To effectively manage garbage, towns must plan both short and long term (Pokhrel & Viraraghavan, 2005). The anticipated trash projection for 2017 was calculated using data from the Asian Development Bank's solid waste management in Nepal study from 2013. Garbage generation in Nepali municipalities is estimated to be over 3023 tons per day, with an average per capita waste generation of 0.223 kg per person per day. About 60% of waste is decomposable, and about 25% is recyclable (Development Bank, 2013). Most municipalities in Nepal have adopted similar waste management strategies. Collection, transportation, and landfill disposal are the three basic waste management operations (Maharjan & Lohani, 2020).

1.2 Problem statement

District Dang was taken as the study area for determining the suitable sites for waste disposal as a part of this project. After the division of Nepal into 7 federal provinces by the new constitution of Nepal in September 2015, Dang has become one of the socio-economic hub and fastest urbanizing areas of Lumbini province. Exponential increase in population in Dang and the resulting urbanization has brought the need to develop environmentally sustainable and efficient solid waste management systems. Change is dynamic, in near future, the existing dumping sites may not bear the load of wastes produced by the increasing population and industries. So, this study aims to find new suitable dumping sites to reduce environmental danger and human health issues by using GIS integrated MCDA technique.

1.3 Objectives

Primary objective

- To determine the best Waste disposal sites in Dang District.

Secondary objectives

- To explore the Multi Criteria Decision Analysis (MCDA) as an analysis technique To help the local authorities in planning and selecting the new dumping sites.

1.4 Scope

This research is based on finding the best locations for waste management in the Dang district. As urbanization, industrialization and population are increasing rapidly in Dang district resulting in the excessive production of waste. Thus, produced wastes can be managed by selecting a suitable land fill site, enhancing sanitation and good hygiene within the district. Although the values assumed are based on general approximations and references from various sites, this research might be helpful in decision-making for the selection of suitable sites in order to manage waste.

2. LITERATURE REVIEW

(Pokhrel & Viraraghavan, 2005) shows the average per capita garbage generation in Nepali municipalities is 0.223 kg per day. On average, 60% of garbage is decomposable, and 25% is recyclable materials like plastics, papers, and metals. This research indicates that waste to bioenergy and fertilizer production are appropriate waste management solutions for Nepalese municipalities using the Multi-Criteria Decision Matrix (MCDM).

(Yadav, 2013) reported that Under Indian socio-economic and regulatory conditions, a GISbased environmental decision support system for solid waste management has been developed. The analytical hierarchy process (AHP) was used to assign weights to different variables for primary landfill site selection.

(Basnet, 2015) had suggested that the Sisdole dump facility in Nuwakot's Okharpauwa VDC is failing to keep up with the city's rubbish production. Daily, the valley alone generates 700 metric tons of rubbish, straining the area's carrying capacity. To resolve this problem she focused on using the Multi-Criteria Analysis in the GIS domain.

(Majid & Mir, 2021) focuses on using methodologies such as Multi Criteria Evaluation (MCE) and Analytic Hierarchy Process, prospective landfill sites in Srinagar were identified using a Geographic Information System (GIS) and Remote Sensing (AHP). They also suggested that the Selection of landfill sites by the integration of GIS and MCE can be an efficient technique that simultaneously pays attention to all restrictions.

(Ahire et al., 2021) used Geomorphology, hydrogeology, distance to road, drainage, lineament, slope, LULC, distance to water bodies, and population density into account when choosing a prospective landfill site for AHP-MCDA. They also used the wind rising diagram is employed, while for internal site appropriateness, the airport, water bodies, road, and habitation for restriction buffer analysis.

Multi-criteria decision analysis provides a set of strategies, procedures, and calculations for organizing choice issues, planning process, accessing and prioritizing from 4 the multiple set of alternatives. MCDA also has the power of decreasing the time and expenses by narrowing down the possibilities(Malczewski, 2004). He suggested boolean evaluation, Weight Linear Combination (WLC), and Weighted Overlay are the most commonly used MCDA procedures.

3. METHODOLOGY
3.1 Work Flow

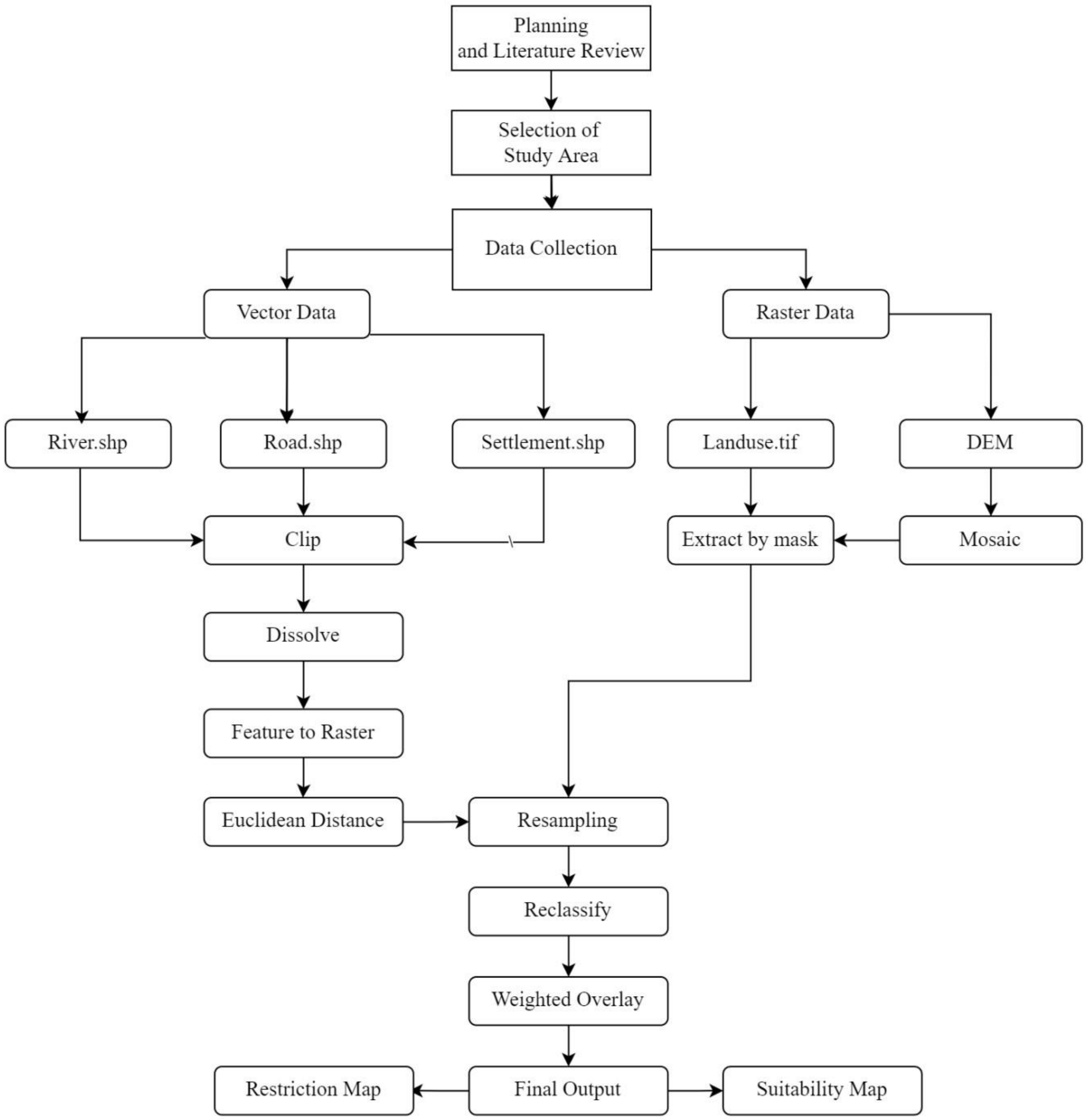

Figure 1 Work Flow

3.2 Planning

At first planning for the selection of study area, data do be used, source of data from where data to be extracted was done. Rough sketch for the framework of the entire process to be done in ArcGIS was prepared. To maintain the accuracy standardization for the parameters were researched and evaluated. Time schedule was prepared for the completion of the project in time. Various socio-economic, health and sanitation factors were analyzed.

3.3 Study Area

Home District Dang was taken as the study area for determining the suitable sites for waste disposal as a part of this project. It is located in inner Terai in the Lumbini Province. The district, with Ghorahi as its headquarters, and has a population of 548,141 according to the census of 2011. Dang is located at 28° 7' 0" north latitude and 82° 18' 0" east latitude in Nepal.

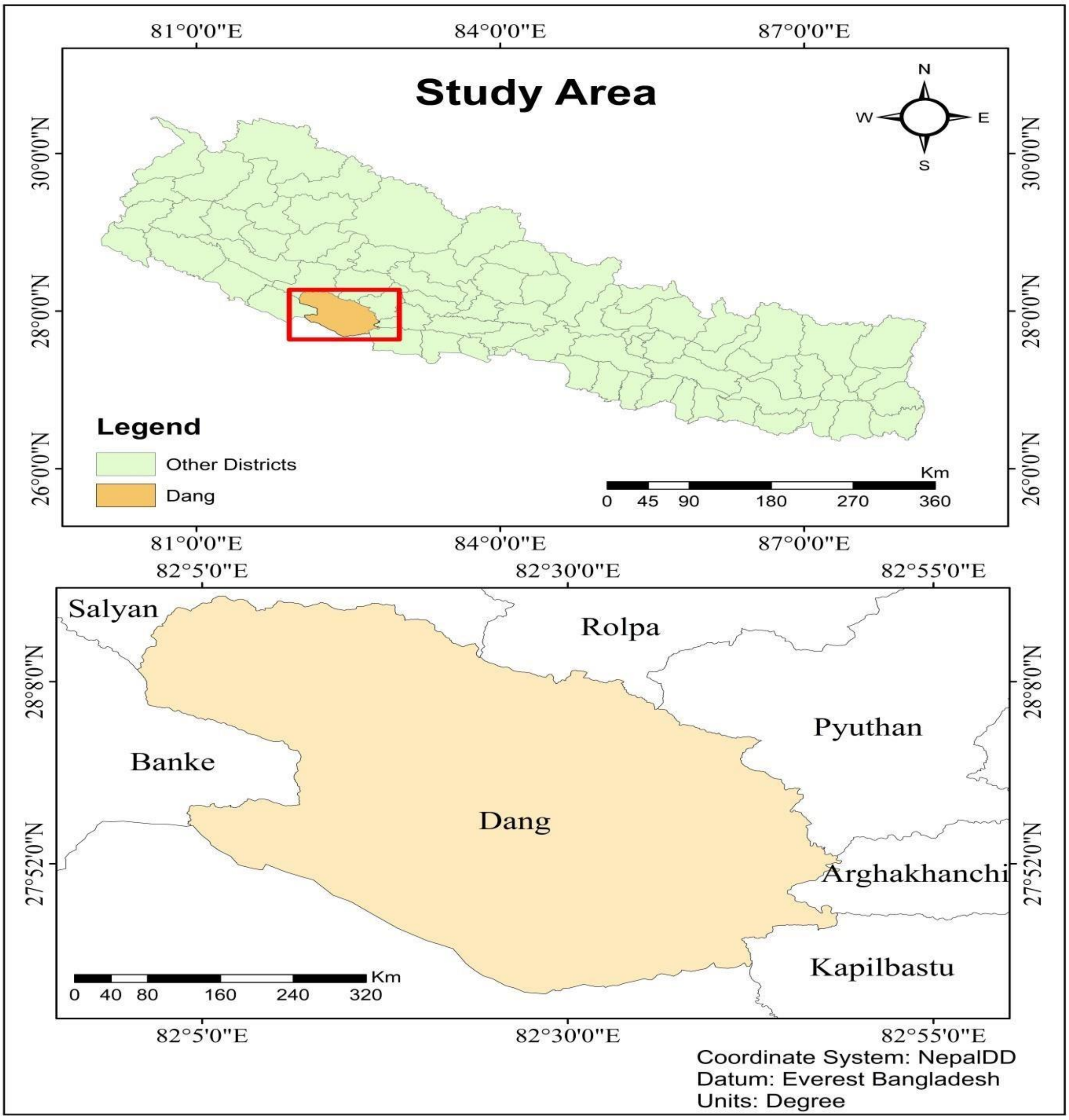

Figure 2 Study Area

3.4 Materials Used

3.4.1 Data used

Data used for this project are secondary data taken from different internet sources. Mainly six types of data were used throughout the project. All the data used were in Geographic Coordinate System so that while assigning the buffer, decimal degrees were assigned to the layers like road, river and settlement assuming that 1° = 100km = 1,00,000m.

Table 1 Data Type & Source

Data Type	Publisher and Source
DEM Data	U.S. Geological Survey
Road Network of Nepal	ICIMOD
River Network of Nepal	ICIMOD
Nepal settlement Data	Humanitarian Data Exchange
Land Use of Nepal	ICIMOD
Nepal Administrative Boundary	Hermes Download Center

3.4.2Software Used

ArcGIS 10.8 was used for performing the Multi-Criteria Decision Analysis

3.5 Data Preparation

The initial step in this process was to determine the criteria for selecting possible dump locations. As a result, criteria were derived from a review of existing studies on landfill selection criteria. For selecting the proper site, the criteria included slope, land use, water body, road, and settlement, as well as the data layers required for interpretation.

3.5.1 Data Selection Criteria

The following considerations were adopted for deriving the criteria for the selected 5 different layers for the suitability analysis.

- Slope: plays a vital role before the construction of any infrastructure, especially the landfill site. (Paul & Ghosh, 2022b) had assigned values from 1 to 5 to the slope based on worst to best construction i.e. 1 as the worst and 5 as the best. They also suggested, a slope up to 0- 8° is suitable and a slope greater than 25° can be rejected in case of a dumping site.
- Settlement area: The site was chosen to be away from residential areas to avoid public health issues caused by probable biohazards from the rubbish disposal facility. (Mussa

& Suryabhagavan, 2019b) had used a buffer of 700m and above for the suitable distance from the landfill to a residential area.

- Water Body: A buffering environment of 500m and above was created in a raster environment of ArcGIS 10.8 and reclassified providing rating 1 for unsuitable buffer and providing 5 to the most suitable buffer(Paul & Ghosh, 2022a).
- Road: is also considered an important factor for sitting the landfill for health and aesthetic purpose. It is considered the distance from the road to the dumping side area to be at least 700m and above. It is also assumed that a dumping site very far from the road is not suitable as it increases the transport cost. Besides this, sites very far from the major road may not have easy access to reach the dumping site.
- Land use: Grassland, forest, agricultural lands, etc fall under this category. The agriculture area was given a value of "1" by(Mornya et al., 2010), followed by "3" by forest and "5" by grassland area.

3.5.2 Suitability Rating

Altogether 5 classes were generated for each factor; 1 representing unsuitable zones and 5 representing most suitable zones for waste disposal. Most of the data used for rating the features are taken in reference to the article(Mussa & Suryabhagavan, 2019b). While some data were assumed by general approximation and community guidelines. Following guidelines were adopted for rating different factors.

Table 2 Ranking for the Suitability Class

Rank	Suitability Class
1	Unsuitable
2	Less Suitable
3	Moderate Suitable
4	Suitable
5	Highly Suitable

3.5.3 Suitability interval and Suitability Class

Based on the data and ranks obtained from the above-mentioned research papers, the following parameters (suitability interval) and rating are provided to the raster layers while reclassifying them. Each rank holds a unique suitability class ranging from 1=unsuitable to 5=highly suitable.

Table 3 Suitability interval and Suitability Class

Layers	Suitability Interval (m)	Rank	Suitability Class
Settlement	0-700	1	Unsuitable
	700-2000	2	Less Suitable
	2000-3500	3	Moderately Suitable
	3500-5000	4	Suitable
	>5000	5	Highly Suitable
River	0-500	1	Unsuitable
	500-1000	2	Less Suitable
	1000-1500	3	Moderately Suitable
	1500-2000	4	Suitable
	>2000	5	Highly Suitable
Road	0-700	1	Unsuitable
	700-2000	4	Suitable
	2000-3500	5	Highly Suitable
	3500-5000	3	Moderately Suitable
	>5000	2	Less Suitable
Land use	Crop	1	Unsuitable
	Water	1	Unsuitable
	Built-up Area	1	Unsuitable
	Bare Ground	2 (bare lands were seen only at the river bank areas)	Less Suitable
	Shrubs/Scrub	3	Moderately Suitable
	Grass	4	Suitable
	Trees	5	Highly Suitable
Slope	(0-8)%	5	Highly Suitable
	(8-15)%	4	Suitable
	(15-20)%	3	Moderately Suitable
	(20-25)%	2	Less Suitable
	>25%	1	Unsuitable

3.6 Data Analysis

Euclidean distance of raster layer of road, river and settlement was calculated whereas slope was created from DEM data. Thus, obtained results need to be reclassified based on suitability. The appropriate suitability interval and suitability rating were given to each layer on the basis of Table 3. Finally, Weighted Overlay was done by giving the appropriate weights to each layer.

3.6.1 Criteria Weight Analysis

In order to determine the weights for each criteria based on their importance, a pair-wise comparison technique was implemented. Pairwise comparison was done using an online AHP calculator. Comparison rating was given to AHP calculator from 1 to 9, where 1 refers to Equal Importance, 3- Moderate importance, 5- Strong importance, 7- Very strong importance, 9- Extreme importance (2,4,6,8 values in-between). The following priorities rating were given on the basis of their importance.

Table 4 Priorities Rating for Pair Wise Comparison

	A - wrt AHP priorities - or B?		Equal	How much more?
1	◉ Settlement	○ River	○ 1	◉ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9
2	◉ Settlement	○ Landuse	○ 1	○ 2 ○ 3 ◉ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9
3	◉ Settlement	○ Road	○ 1	○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ◉ 9
4	◉ Settlement	○ Slope	○ 1	○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ◉ 9
5	◉ River	○ Landuse	○ 1	◉ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9
6	◉ River	○ Road	○ 1	○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ◉ 7 ○ 8 ○ 9
7	◉ River	○ Slope	○ 1	○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ◉ 7 ○ 8 ○ 9
8	◉ Landuse	○ Road	○ 1	○ 2 ◉ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9
9	◉ Landuse	○ Slope	○ 1	○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ◉ 7 ○ 8 ○ 9
10	◉ Road	○ Slope	○ 1	◉ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9
CR = 2.9% OK				

After priority rank is provided to the AHP calculator, it generates following comparison matrix indicating the importance of criteria. The given below matrix shows how much a criteria is important than the other criteria. Values from 1 to 9 have their own meanings.

- 1 refers row and column factors are equally important
- 1/9 refers column factor is more important than row factor
- 9 refers that row factor is more important than the column factor

Table 5 Comparison Matrix from AHP calculator

Matrix	Settlement	River	Land use	Road	Slope
Settlement	1	2	4	9	9
River	1/2	1	2	7	7
Land use	1/4	1/2	1	3	7
Road	1/9	1/7	1/3	1	2
Slope	1/9	1/7	1/7	1/2	1

Finally, the suitable weights are derived on the basis of the principal eigenvector of the decision matrix. The below table shows the weights derived from the principal eigenvector of pairwise comparison matrix.

Table 6 Weights for each criteria derived from pairwise comparison matrix

Criteria	Eigenvector Weight	Priority(weight) %	Rank
Settlement	0.476	47.6	1
River	0.28	28.0	2
Land use	0.158	15.8	3
Road	0.052	5.2	4
Slope	0.034	3.4	5
	Total	100%	

3.6.2 Model Builder in GIS

Model Builder is a visual programming language that allows you to create geoprocessing workflows. Your geographical analysis and data management activities are automated and documented using geoprocessing models. Model Builder is used to construct and edit geoprocessing models. A model is a diagram that connects processes and geoprocessing tools by using the output of one process as the input to another (*What Is Model Builder?—ArcGIS Pro | Documentation*, n.d.).

Following geoprocessing model was developed in ArcGIS 10.8 for processing the data to get the final result.

- Calculating the Euclidean distance of Layers Road, river and settlement.
- Resampling all the layers using spatial resolution of slope.tif
- Reclassifying all the layers as per the parameters listed in Table 3.
- Using Weighted Overlay tool and assigning weights as per the parameters listed in Table 6.

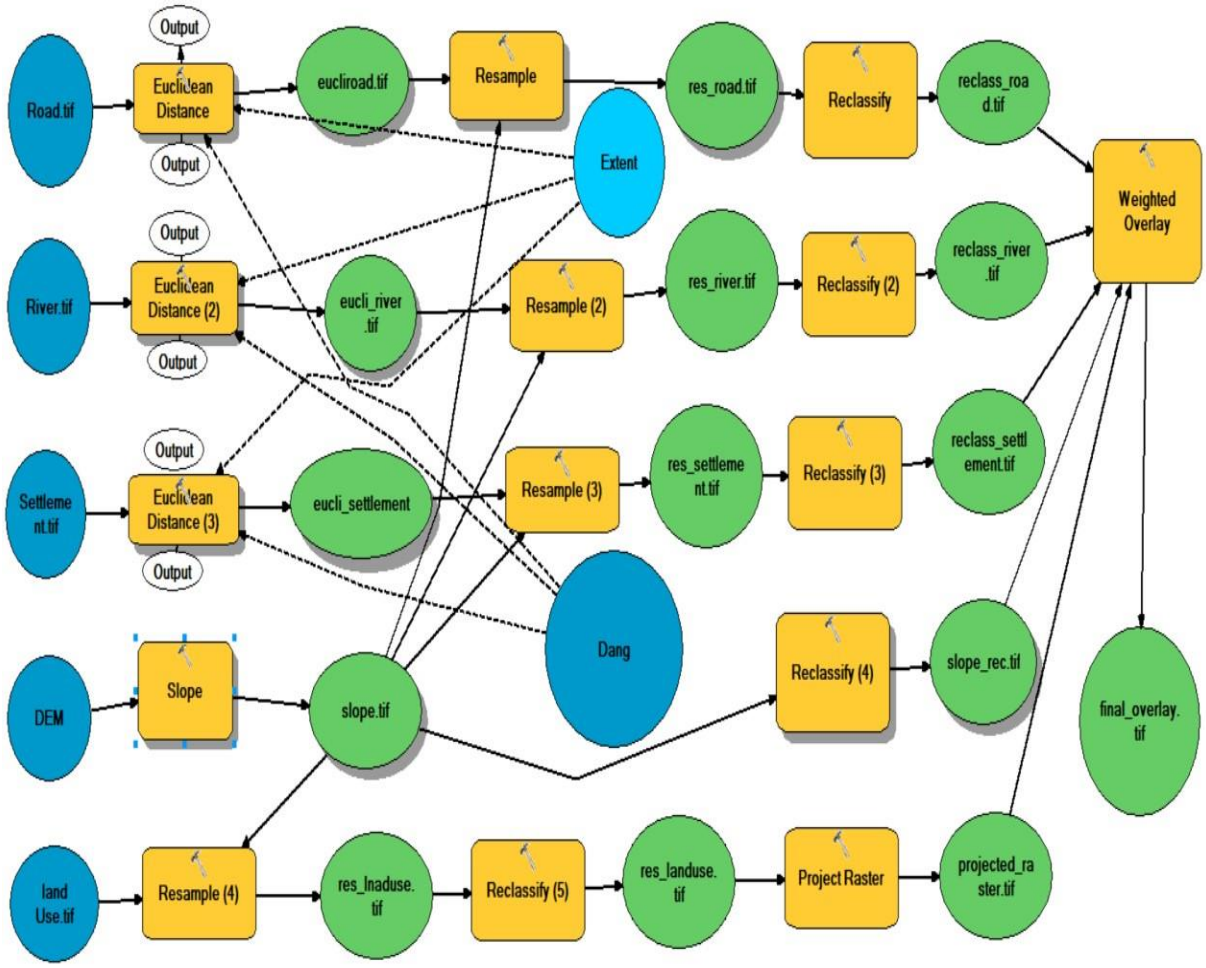

Figure 3 Model obtained in model builder after the analysis of database

4. RESULTS AND DISCUSSIONS

This report aims to fill a critical gap in the detection of dumpsites and improve the cost-effectiveness and performance of solid waste disposal activities. Multiple criteria were selected as per the requirement of selecting the dumping sites. Five criteria namely road, river, settlement, land use and DEM data were used for the analysis. Proximity analysis was done for each layer concerning the landfill site taking distance and slope in an account. Buffer of 500m and above for river, 700 meters and above for settlement were considered suitable. A slope of 8% and below was taken as acceptable as higher slope leads to the chance of draining of the wastes. In case of road a buffer of 700m and below was considered as unsuitable. Buffer of 500m and above for road was also considered as less suitable because it leads to the higher transportation cost, time-consuming as well as invites problems for waste management in time.

4.1 Reclassified Maps

Rating was done from 1 to 5 representing 1 as unsuitable area and 5 as highly suitable area Appropriate parameters and rating were as mentioned in Table 2 and Table 3 provided to the layers for reclassifying them and following suitability maps were obtained after the geoprocessing of data in Arc GIS.

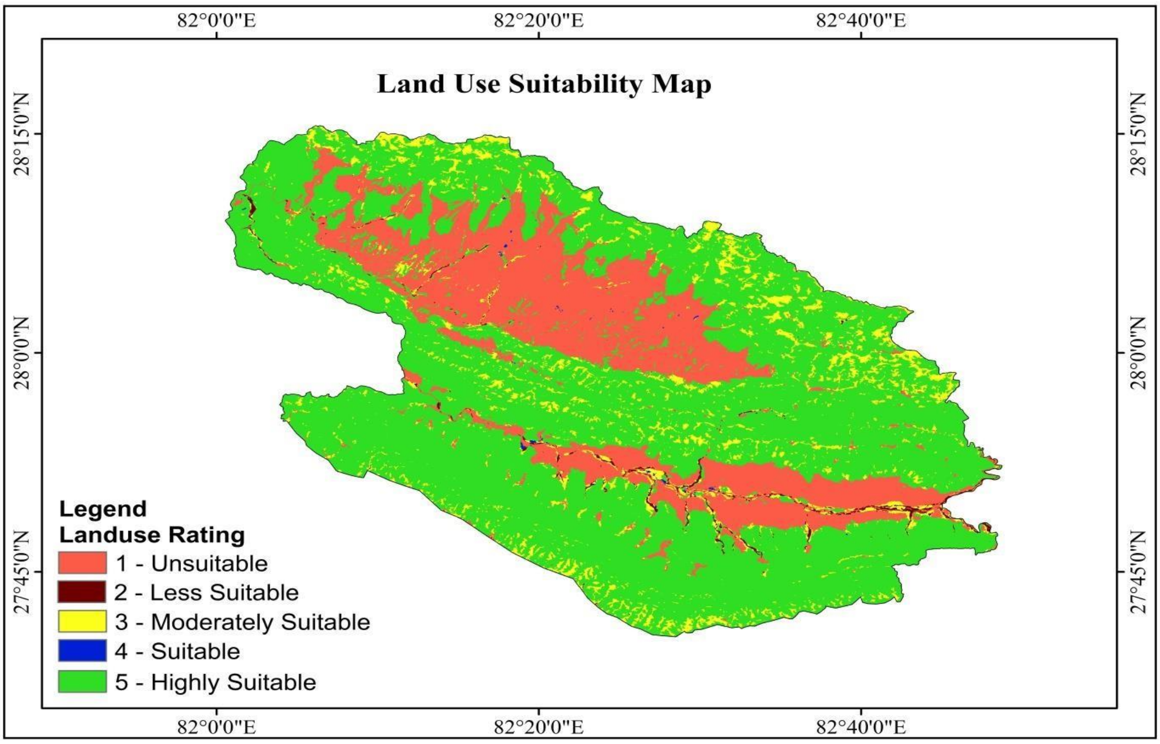

Figure 4 Land Use Suitability Map

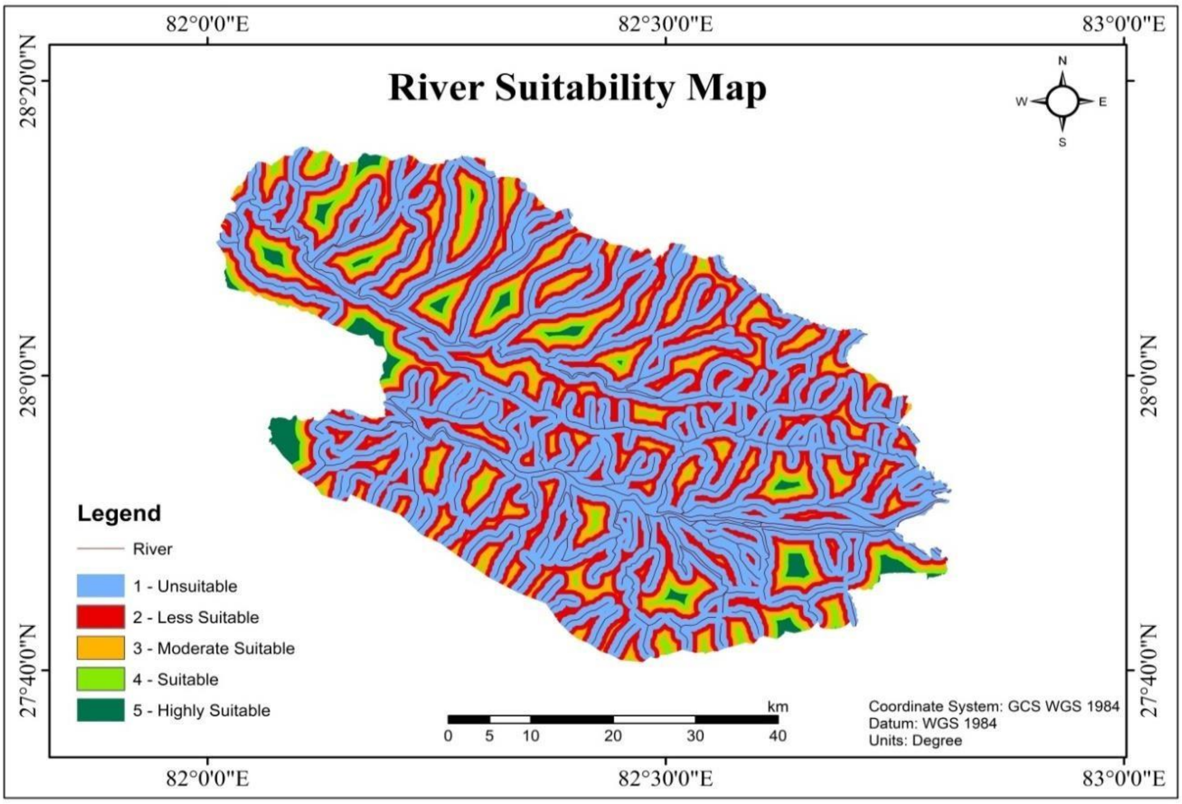

Figure 5 River Suitability Map

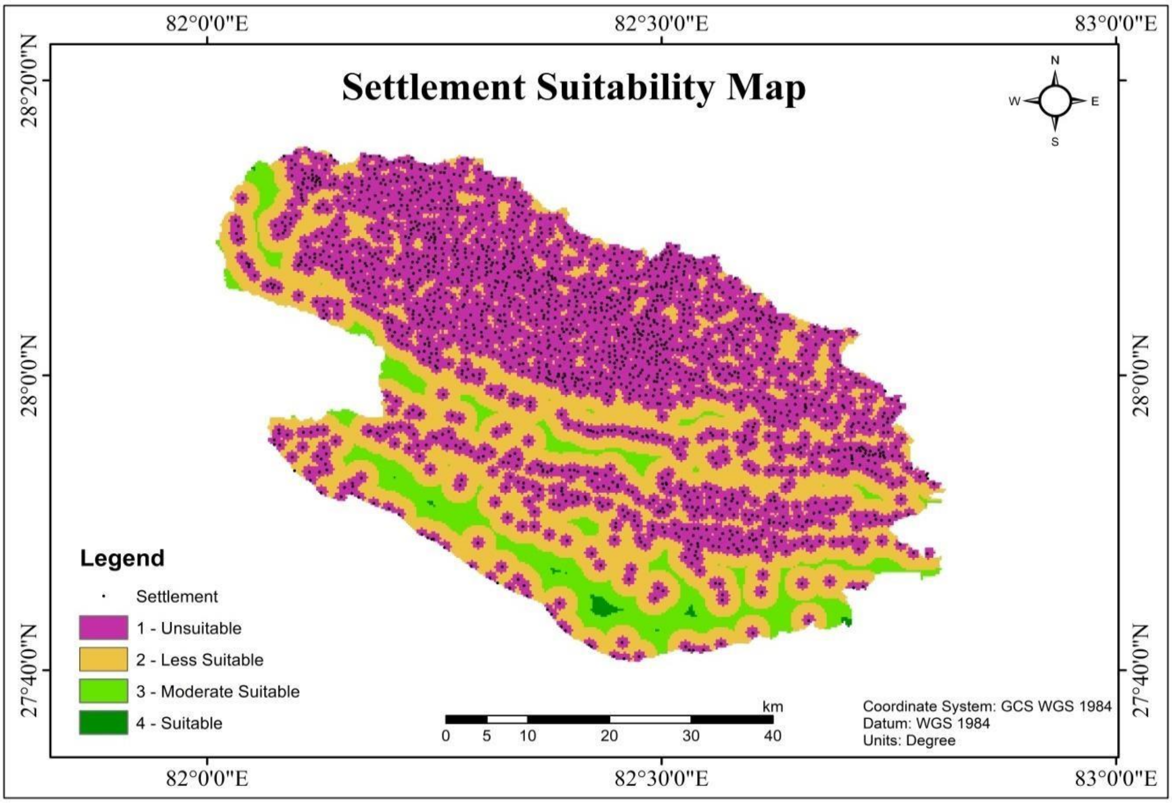

Figure 6 Settlement Suitability Map

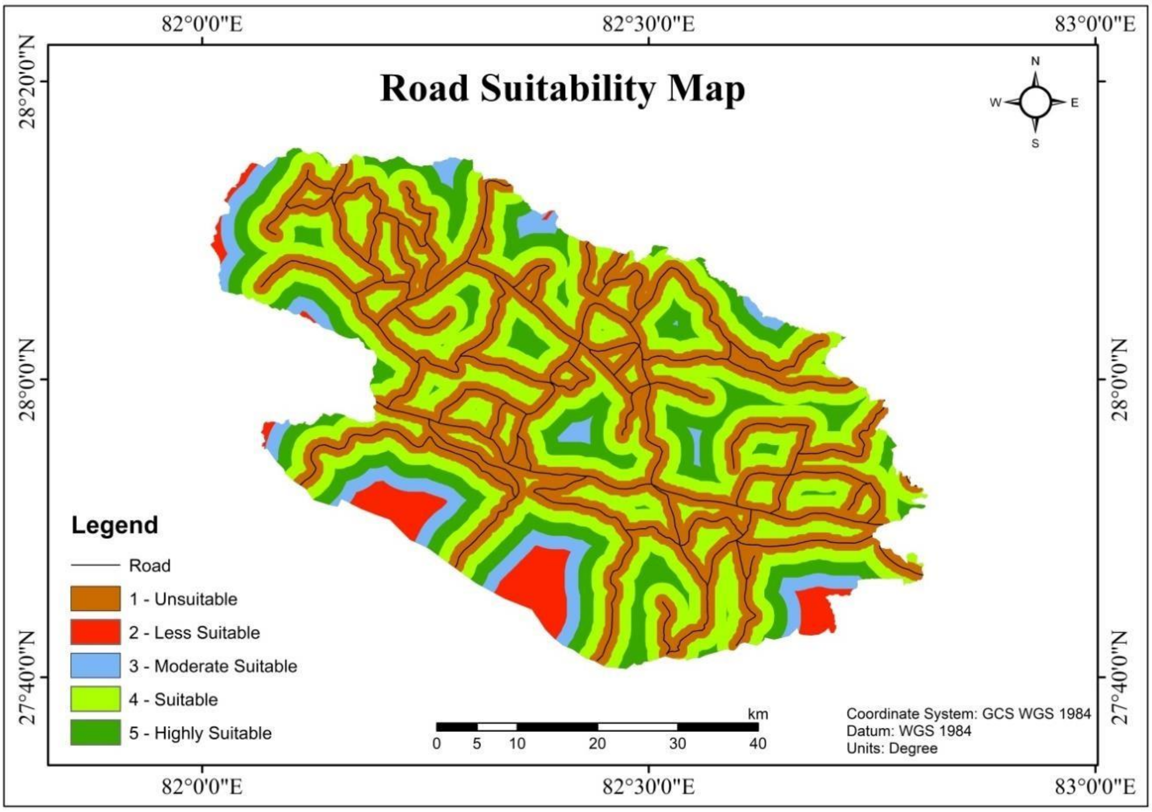

Figure 7 Road Suitability Map

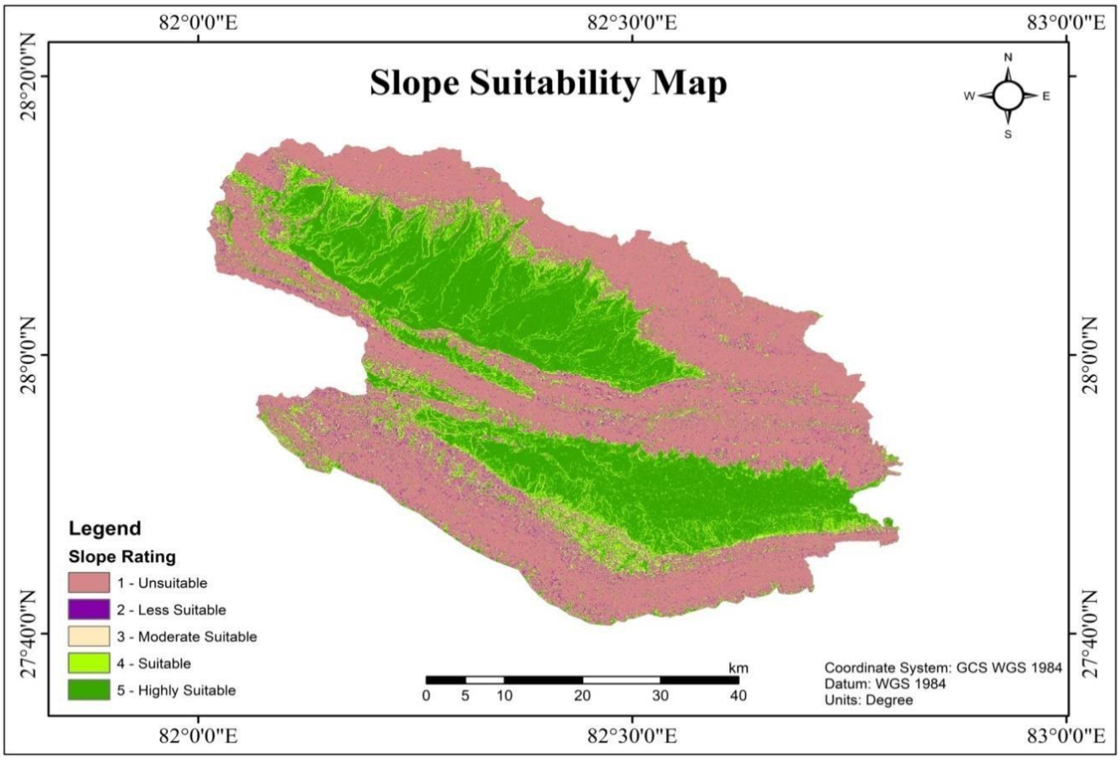

Figure 8 Slope Suitability Map

4.2 Final Suitability Map Obtained After Weighted Overlay

After reclassifying all the layers based on their suitability interval and rating, the obtained reclassified layers were then given the weight based on their relative importance as mentioned in Table 6. The Weighted Overlay tool was used in the model builder to overlay all the reclassified layers to find all the suitable areas for the selection of dumping site. The area covered by each suitability class was calculated based on cell count and cell size.

Following result was obtained.

Table 7 Area coverage of each suitability class

Suitability Class	Area Covered (km^2)	Percentage (%)
Highly Suitable Area	38.1938	1.4
Suitable Area	598.299	21.932
Less Suitable Area	1553.5143	56.949
Unsuitable Area	537.8872	19.718
Total Area=2727.923		

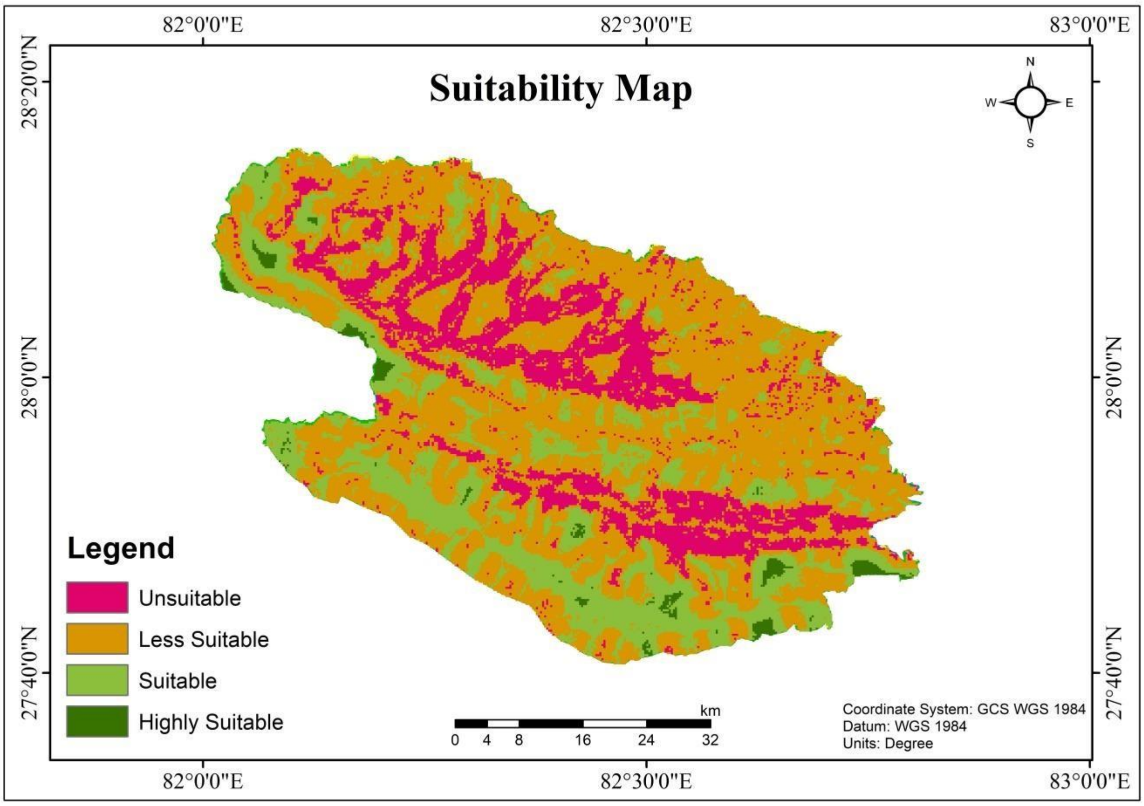

Figure 9 Final Suitability map

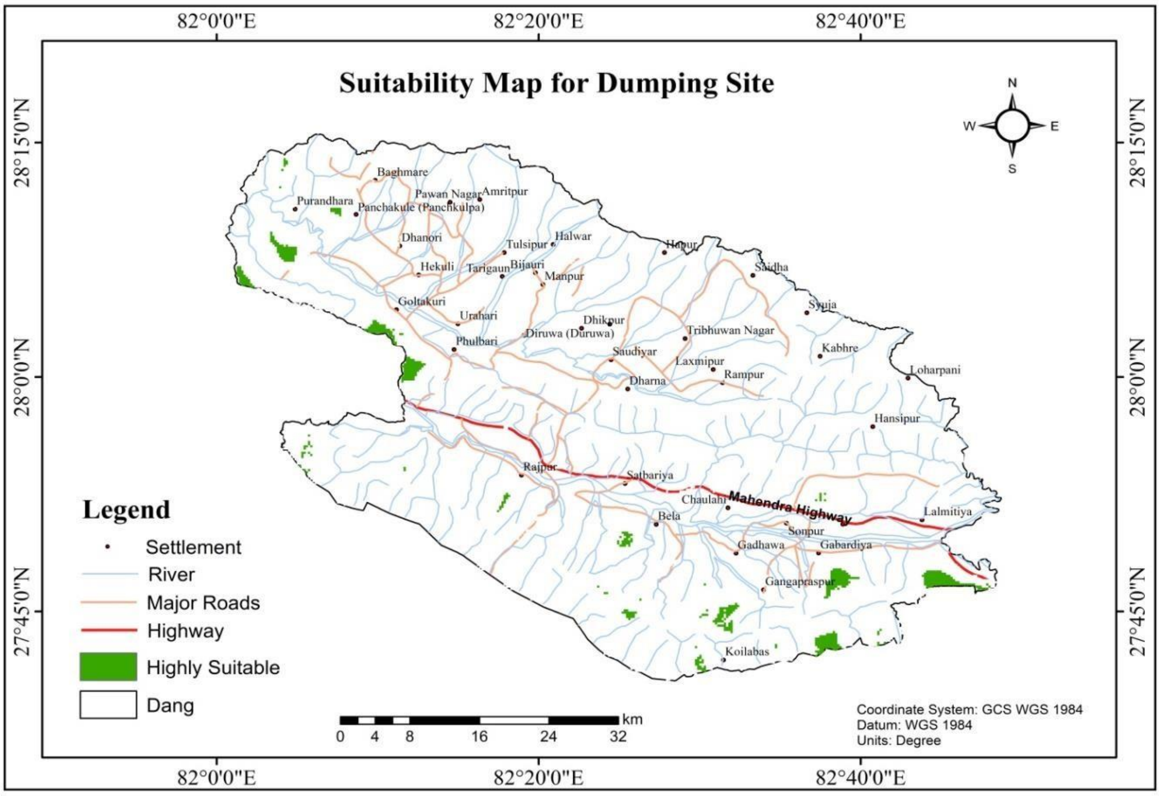

Figure 10 Location Map showing suitability for dumping site

4.3 Restriction Map

The given map shows the restricted areas which are not suitable for the selection of dumping sites. Restricted areas are mostly representing settlement areas, river sides and road periphery. The restricted area covers about 19% of the study area covering 537.8872 km^2.

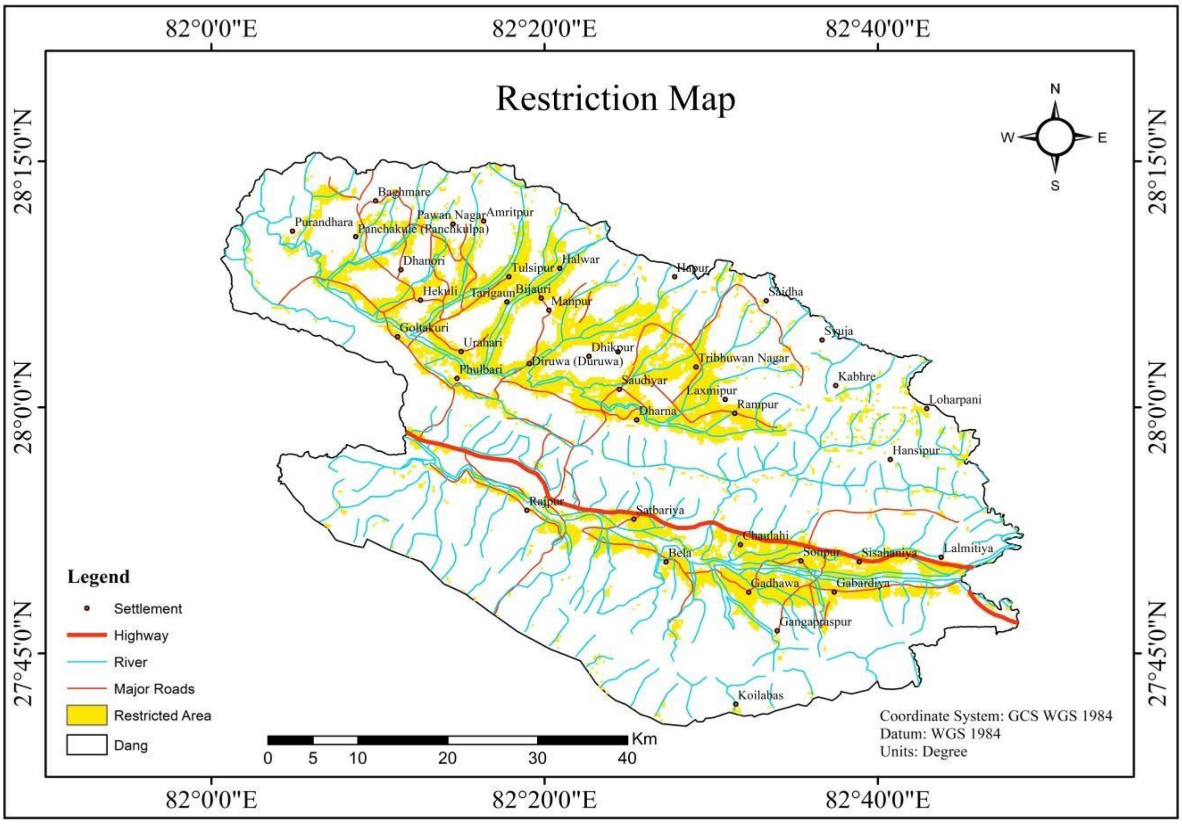

Figure 11 Location map showing restricted areas for dumping site

5. LIMITATIONS

- The result could have been better if more number of criteria were chosen but only five criteria were selected for the analysis in this study.
- The available data were not in same projection system and had different cell size in case of raster data.
- Cracked version of GIS was used for the processing of data which led many problems during the entire process.
- All the data used were secondary data obtained from internet source which may not be authentic and reliable.
- Due to lack of knowledge and guidance in the domain of GIS integrated MCDA technique, it was difficult in the initial state. Based on group discussion and literature review the entire project was done with limited understanding.

6. CONCLUSION AND FUTURE WORKS

6.1 Conclusion

Finally, this study meets the main objective of the project that is finding the best suitable sites for solid waste management in Dang district. GIS software was utilized in this study to create maps based on scientific criteria and standards to choose the optimum landfill site for Dang District. The ability to employ GIS integrated MCDA technique for the successful selection of suitable solid waste dumping sites will minimize environmental danger and human health problems. According to the study, multi-criteria analysis is a novel approach to locating a potential site as well as an effective tool for managing enormous volumes of data and narrowing down suitable dump sites.

6.2 Future Works

This was an attempt to determine the site appropriateness analysis for urban solid waste disposal with the time constraints and limited understanding of the data. Accuracy of result could be increased by using more number of criteria, data used should be in same coordinate system, data should be used from authentic sites and cell size must be equal for raster files which can be done by using the resampling tool. This study was done for the partial fulfillment of the requirements for the degree of Bachelor of Engineering in Geomatics Engineering within a limited time, so field visit was not done for the verification of suitable sites and restricted sites. I would recommend doing the field verification in future.

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8. ANNEX

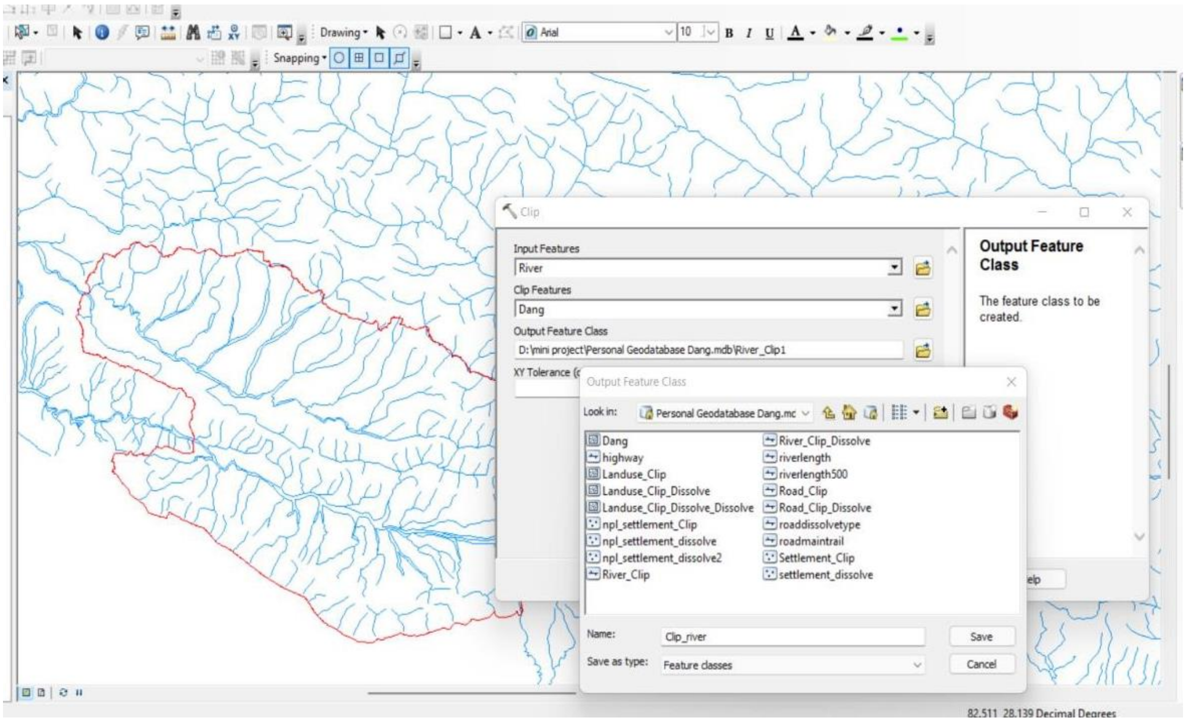

Figure 12 Clipping River for Dang

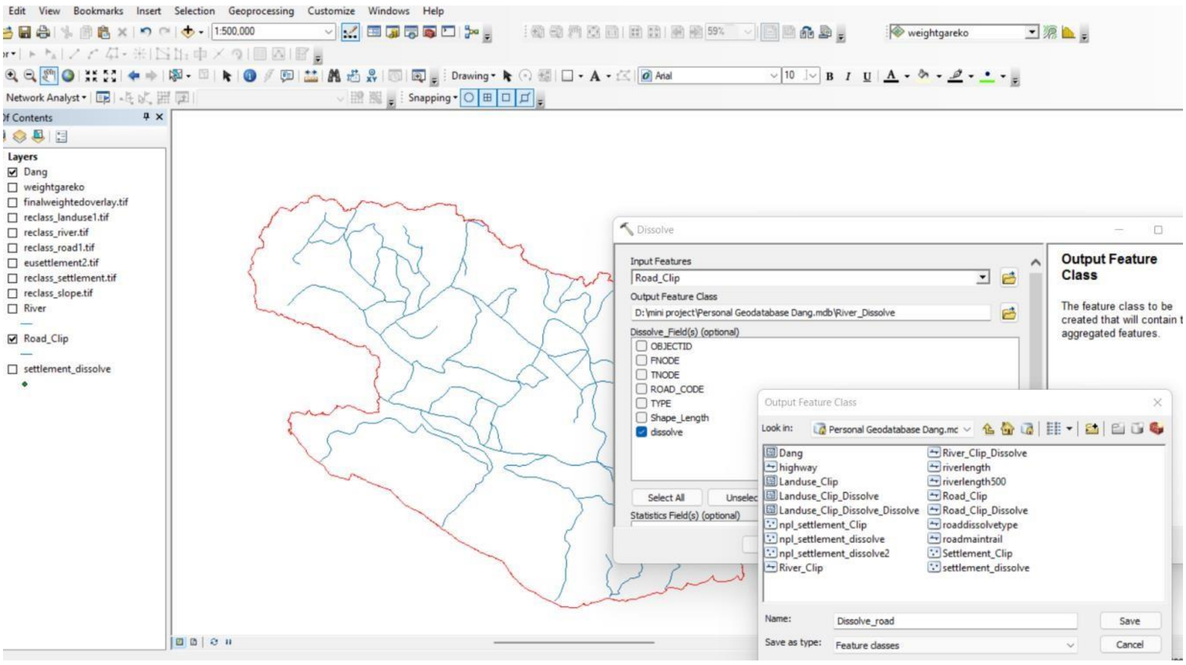

Figure 13 Dissolving Road

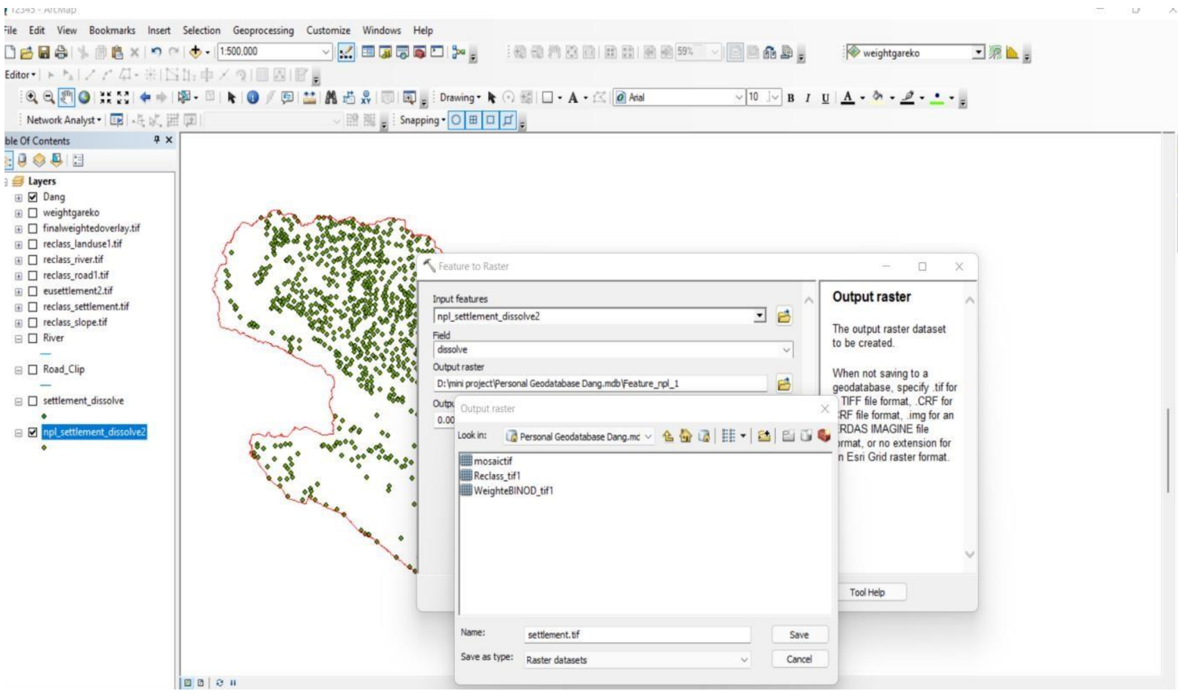

Figure 14 Converting vector data into raster using Feature to Raster tool

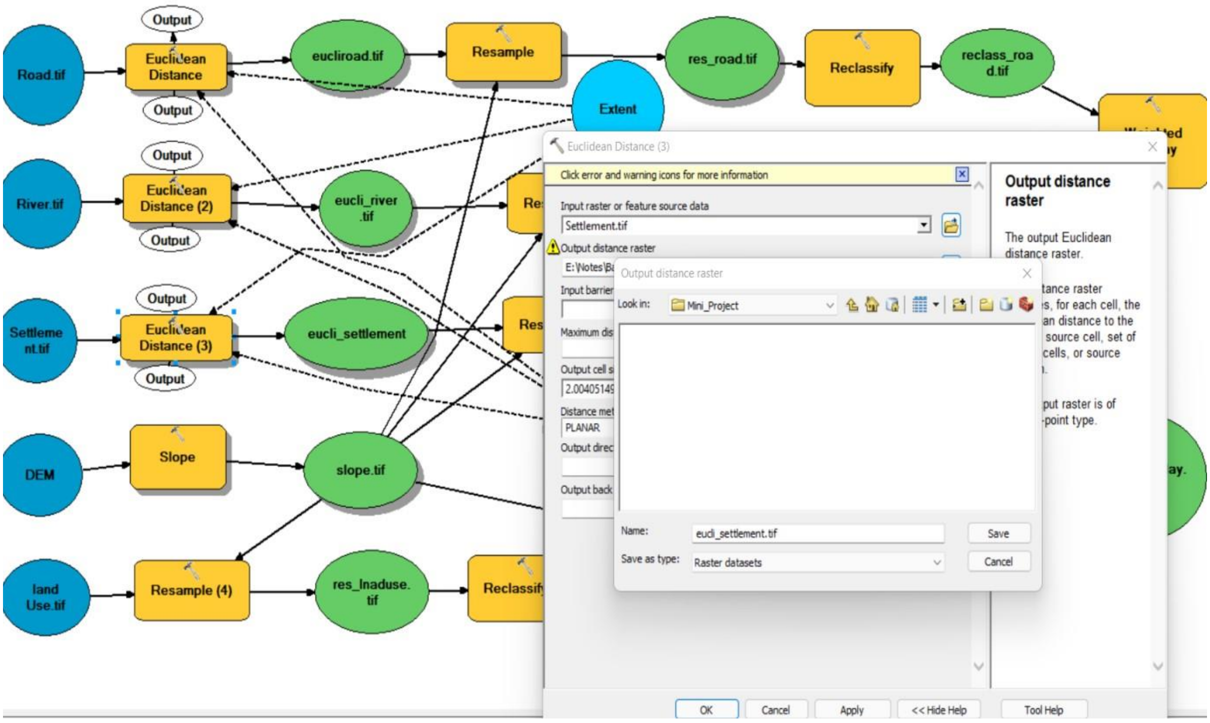

Figure 15 Calculating euclidean distance in model builder

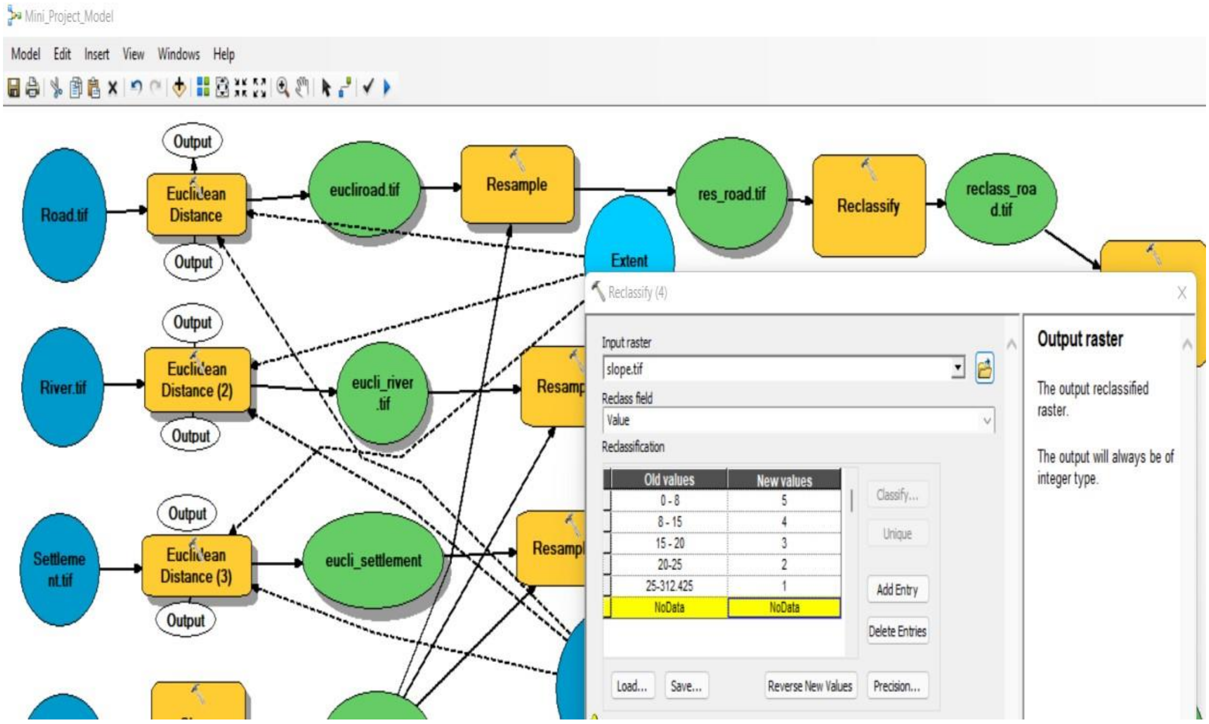

Figure 16 Reclassifying Slope using model builder

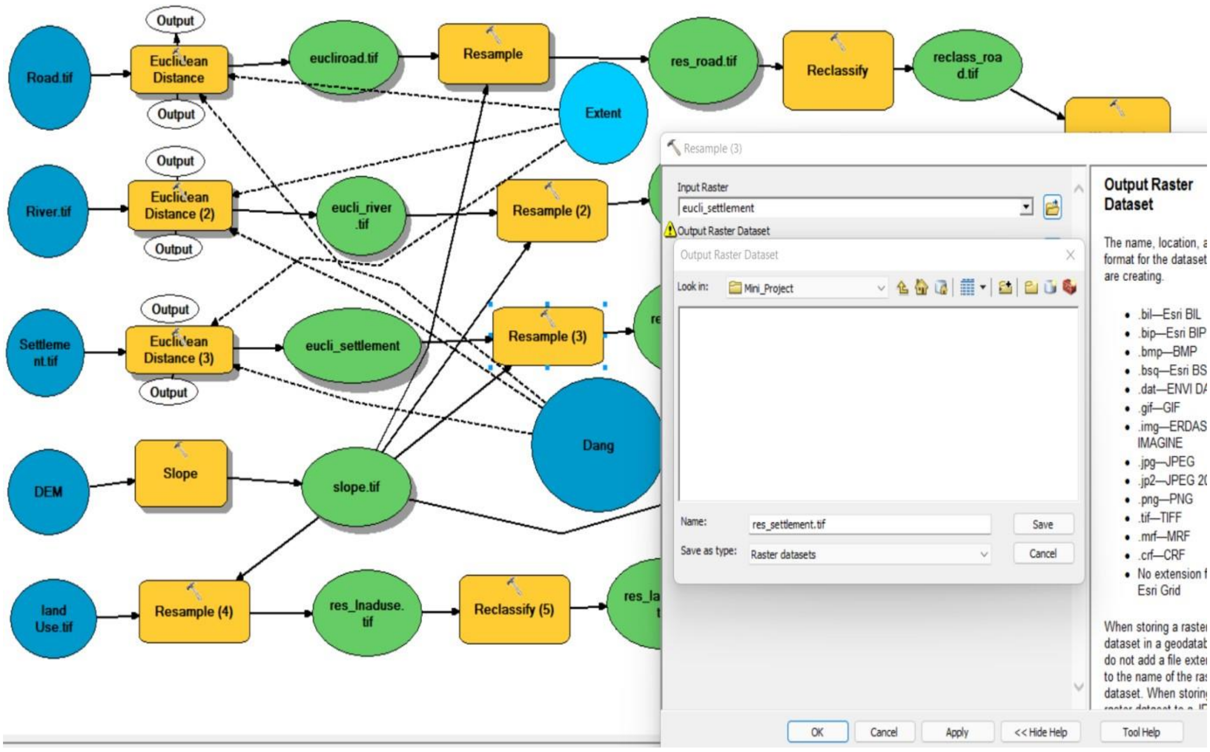

Figure 17 Resampling settlement.tif using spatial resolution of slope.tif

Figure 18 Using weighted overlay tool to provide weights to each criteria

Priorities

These are the resulting weights for the criteria based on your pairwise comparisons:

Cat		Priority	Rank	(+)	(-)
1	Settlement	47.6%	1	11.9%	11.9%
2	River	28.0%	2	5.2%	5.2%
3	Landuse	15.8%	3	4.5%	4.5%
4	Road	5.2%	4	1.0%	1.0%
5	Slope	3.4%	5	1.2%	1.2%

Number of comparisons = 10
Consistency Ratio CR = 2.9%

Decision Matrix

The resulting weights are based on the principal eigenvector of the decision matrix:

	1	2	3	4	5
1	1	2.00	4.00	9.00	9.00
2	0.50	1	2.00	7.00	7.00
3	0.25	0.50	1	3.00	7.00
4	0.11	0.14	0.33	1	2.00
5	0.11	0.14	0.14	0.50	1

Principal eigen value = 5.132
Eigenvector solution: 4 iterations, delta = 4.9E-8

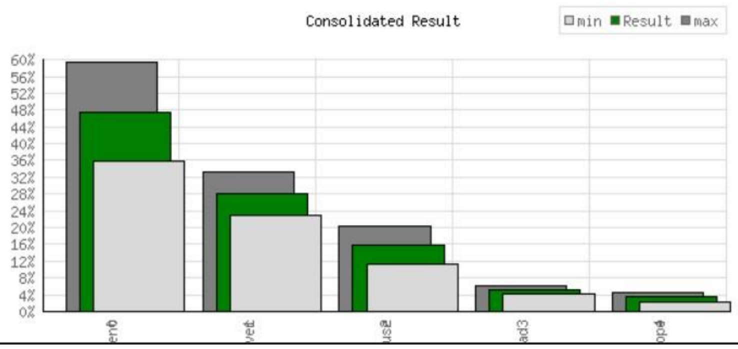

Figure 19 Result from AHP Calculator