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Research Article

Landfill site selection using GIS and Multicriteria Decision Analysis : A Case Study of Butwal Sub-Metropolitan City

Keshav Raj Bhusal,[1] Prabin Banstola,[2] Surya Adhikari[3]

[1,3] Research Scholar, Institute of Engineering, Paschimanchal Campus.
[2] Lecturer, School of Engineering, Pokhara University, Nepal.

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Corresponding Author:
Prabin Banstola, Lecturer, School of Engineering, Pokhara University, Nepal.
E-mail Id:
Pbanstola8@gmail.com
Orcid Id:
https://orcid.org/0000-0003-3968-1053

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A B S T R A C T

In developing country like Nepal there are not enough technology for scientific solid waste management and is dependent on traditional direct wastes disposal on specified area (landfill site). This study utilizes GIS and Multicriteria Decision Analysis for the selection of landfill sites in one of the growing city of Nepal, Butwal. Different factors like road, river, slope, land use land cover(LULC) and built-up were determined according to past literatures and existing data availability. The data used in this study are open data available through openstreetmap and QGIS software was used for data cleaning and analysis. The LULC data used was downloaded from Esri 10 m high resolution data 2022 from Esri living atlas. Each data were differentiated into five classes unsuitable, less suitable, moderately suitable, suitable and highly suitable on basis of proximity and their characteristics. Weightage was given to each criteria on basis of Analytical Hierarchy Process (AHP) through pairwise comparison matrix. Finally, overlay resulting a final landfill suitability was obtained. The result shows 0.01% highly suitable, 10.61% suitable, 53.12% moderately suitable, 34.96% less suitable and 1.29% unsuitable land availability for landfill site in Butwal. It is seen that there is very less highly suitable region for landfill site in Butwal and suitable region for landfill lies in southern part of Semlar and Motipur with neighbouring region of Sudhdhodhan Gaupalika, northern part of Belbas, eastern part close to Charange and few in Northern region. Thus, obtained result is supposed to help in the decision making for proper landfill site selection.

Keywords: Waste Management, GIS, Multi-Criteria Decision Analysis(MCDA)

Introduction

Waste is a substance which is released and abandoned from human activities which has harmful affect in the environment and human health.[1] The solid and liquid waste letting go from community and houses have serious health hazards and can rise to spread of infectious diseases.[2]

Butwal Sub-metropolitan city has been throwing its garbage near the bank of Tinau River and settlement area.[3] The landfill site surface runoff leads to river pollution and affects the river water quality.[4] This being mixed with water has contaminated the Tinau and agricultural lands where Tinau river is used for irrigation. Moreover, the life of people

living nearby such area has become hard due to the foul smell of waste.[5] Lack of effective municipal solid waste management system may result in serious negative impacts on environment like water and land pollution, infectious diseases, loss of biodiversity and obstruction of drains.[6]

The selection of suitable site of landfill would reduce the impacts on environment and also would form a basis for proper management.[7] The selection of suitable landfill sites can be done by the integration of GIS and Multi-criteria Decision Analysis(MCDA).[8] For this study five data criteria were chosen. Factors such as river, land use, road, built-up and slope were considered.

Since, solid waste disposal site should not be close to river distance less than 500 meter is taken as unsuitable and distance greater than 2000 as highly suitable.[9] Likewise, for built-up distance less than 300 meter is taken as unsuitable and distance greater than 1500m as highly suitable.[10] Similarly, distance less than 100 meter is taken as unsuitable and distance greater than 1500 as highly suitable for road.[10] For slope less than 5 degree is considered as highly suitable and greater than 20 is considered as unsuitable.[11] According to literatures for land use land cover water bodies is considered to be unsuitable and bare and shrub as highly suitable for landfill site.[1,9,10]

AHP is used to calculate the weightage of each criteria over other through pairwise comparison matrix.[13]

The main aim of this study is to obtain final suitable site of landfill by using AHP and GIS tool.

Study Area

The study area is located below the Siwalik Hills and at Northern edge of Terai plain of Rupandehi district, Nepal. Its precise location is 27 41' 10.9896'' N , 83 25' 56.7336'' E and has elevation of about 152 meter. Butwal has got area of just 101.6 km^2. River Tinau which flows through the heart of Butwal is its main river. It lies in the intersection of Mahendra and Siddhartha Highway and is the hub for education and other economy of this region.[12] Being rich in facilities and opportunities many people have migrated in this city for job, education and other services. With the increasing population and corresponding waste, management of waste has become a concern for this city.

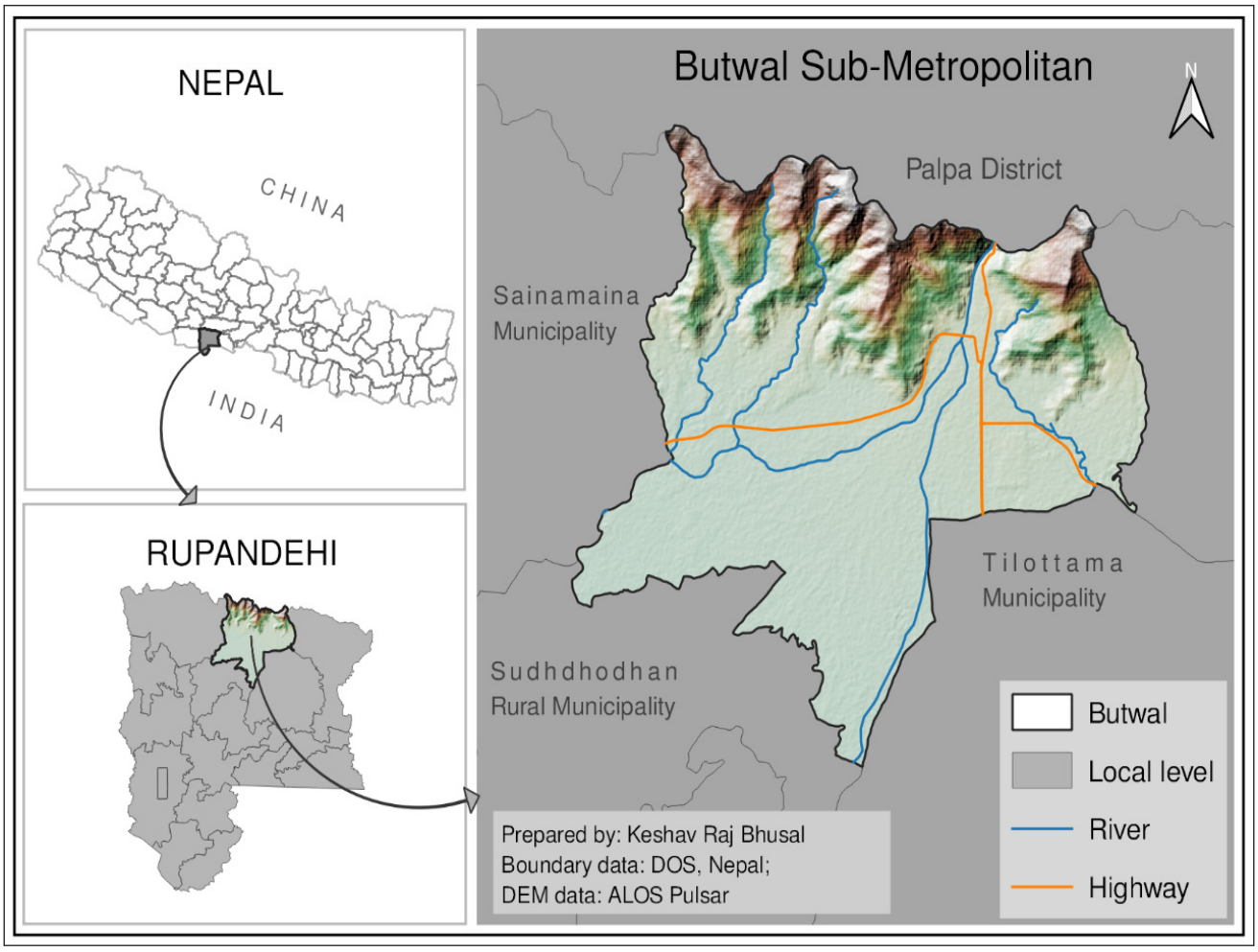

Figure 1.Showing study area map of Butwal

Data Sources and Software

Data depends upon the geography of study area. Normally slope, surface water (river, lakes, ponds, streams), built-up areas, LULC, road and soil data is taken. For this study data used are: slope, river, built-up, LULC and road.

The data like road, built-up and river of 2022 were downloaded from openstreetmap through quickOSM plugin in QGIS. The free 10m resolution Land use land cover data of 2022 was obtained from Esri website. Simiarly, high resolution terrain corrected ALOS Pulsar Digital Elevation Model (DEM) was used and downloaded from Alaska portal. All the GIS tasks like data cleaning and analysis were done in QGIS.

Methods

This study uses Multicriteria Decision Analysis(MCDA) for selection of suitable landfill site of Butwal. After downloading vector data like road, river and built-up they were first clipped with boundary shapefile of Butwal to get the features that are within Butwal only. After this, they were rasterized and projected into local projected coordinate system, WGS84 44N along with dem and LULC. Then, buffer calculation of those rasterized data were done. Data were then reclassified (standardized) using raster calculator tool multiplying each raster with 0, 1, 2, 3 and 4. Thus, the new obtained raster had the values ranging from 0 to 4. Finally, all rasters were given weightage according to pairwise matrix of AHP and were overlayed using raster calculator tool and final site suitable for dumping site was obtained.

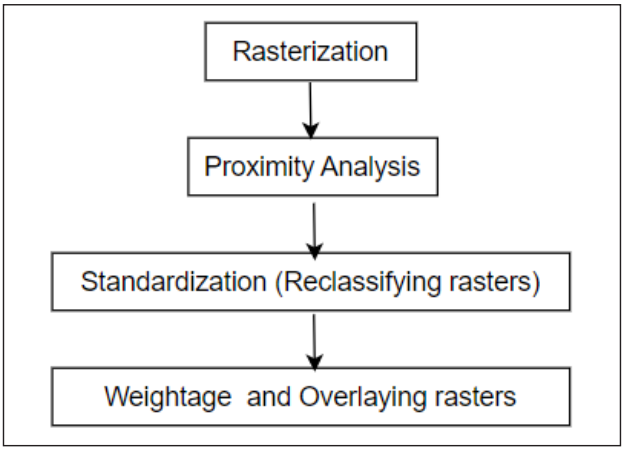

Figure 2.Showing main flowchart of methodology used

Results and Discussion

Present Solid Waste situation of the City

The local government till now has no standard site for processing the garbages. The wastes (both biodegradable and non-degradable) are dumped on the side of Tinau river.

Figure 3.showing existing landfill site of Butwal

Description of Criteria Used

Suitability of Slope

For this study areas with high slopes were considered less suitable while area with lesser slope were considered highly suitable. Slope was obtained from DEM in QGIS. Reclassification of slope was done and categorized into five classes with slope ranging from 0-5, 5-10, 10-15, 15-20 and 20> as highly suitable, suitable, moderately suitable, less suitable and unsuitable respectively. At last area and percentage occupied by each classes were calculated.

Road

For road main highway like Siddhartha and Mahendra were only taken. The secondary road and other streets data were not considered.

River

Tinau and Dano are the main rivers of Butwal. Similarly, smaller river like Sukhaura, Rajpur Khola and Suili Khola were considered. Water data was downloaded from QuickOSM plugin. Later on data was cleaned and only required river was kept.

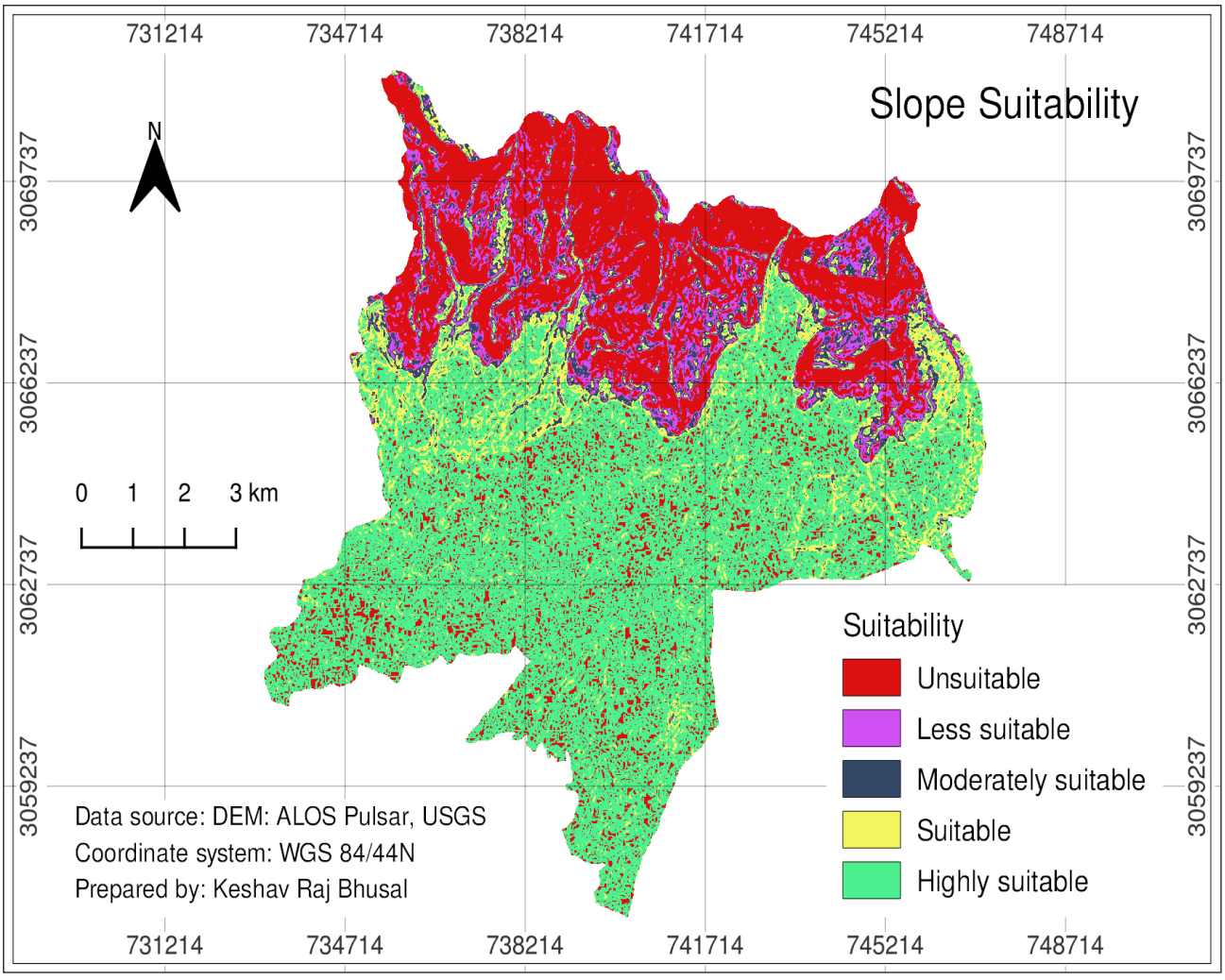

Figure 4.Showing suitable areas for landfill site according to slope criteria

Table l .Showing area and percentage of slope suitability

Slope (degree)	Suitability	Value	Area (in m²)	Area (in %)
0-5	Highly suitable	4	50533617.41	49.58
5-10	Suitable	3	9146878.76	8.97
10-15	Moderately suitable	2	5339439.63	5.24
15-20	Less suitable	1	7475122.30	7.33
20>	Unsuitable	0	29436627.719	28.88

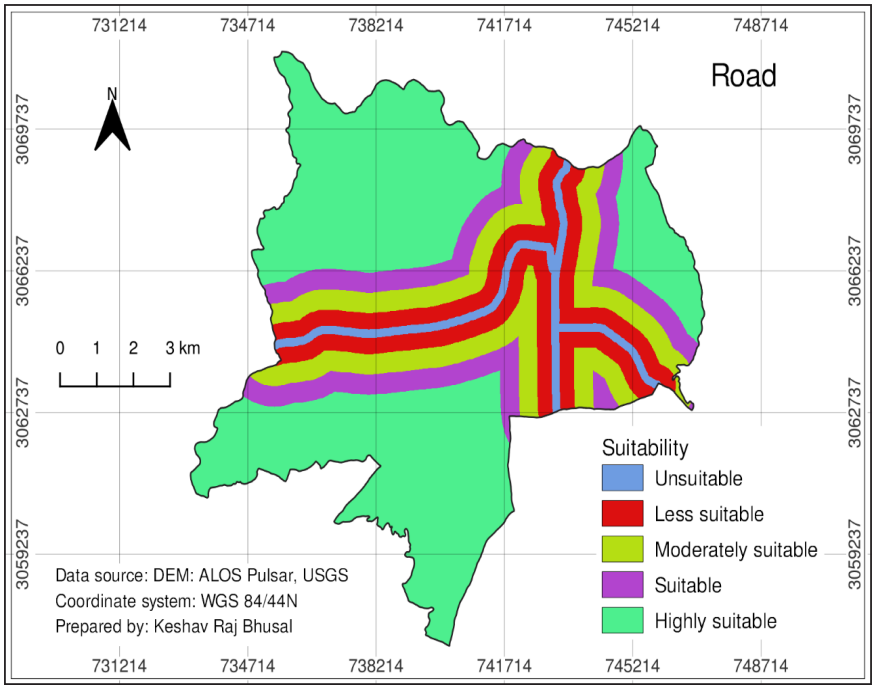

Figure 5.Showing suitable areas for landfill site according to Road criteria

Table 2.Showing area and percentage of road suitability

Road(meters)	Suitability	Value	Area(in m^2)	Area (in %)
>1500	Highly suitable	4	55434694.38	54.54
1000-1500	Suitable	3	12768332.34	12.56
500-1000	Moderately suitable	2	15485094.55	15.23
100-500	Less suitable	1	14024945.21	13.80
0-100	Unsuitable	0	3935578.97	3.87

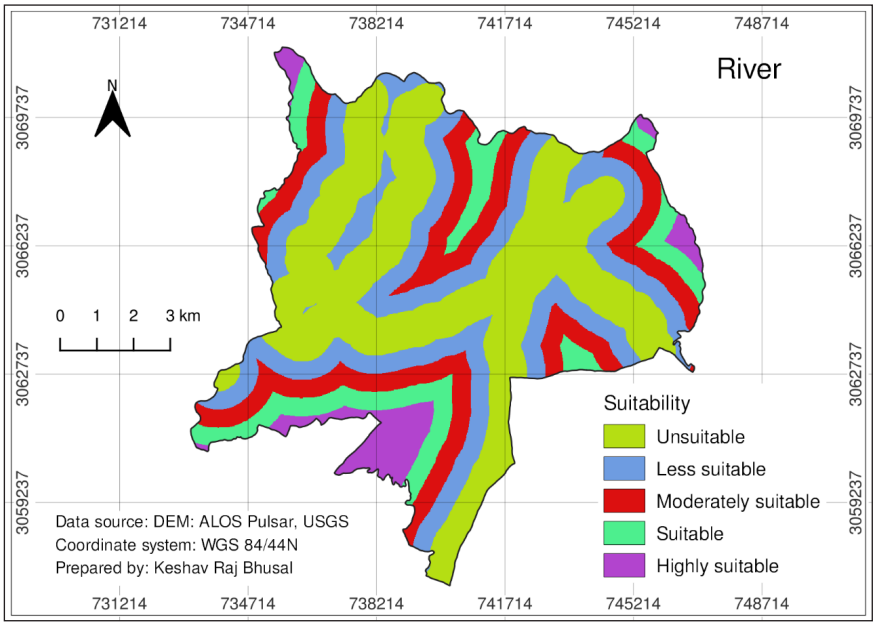

Figure 6.Showing suitable areas for landfill site according to river criteria

Table 3.Showing area and percentage of river suitability

River (meters)	Suitability	Value	Area(in m²)	Area (in %)
>2000	Highly suitable	4	5466794.87	5.38
1500-2000	Suitable	3	10710989.25	10.54
1000-1500	Moderately suitable	2	18966240.33	18.66
500-1000	Less suitable	1	26457204.07	26.03
0-500	Unsuitable	0	40050635.24	39.40

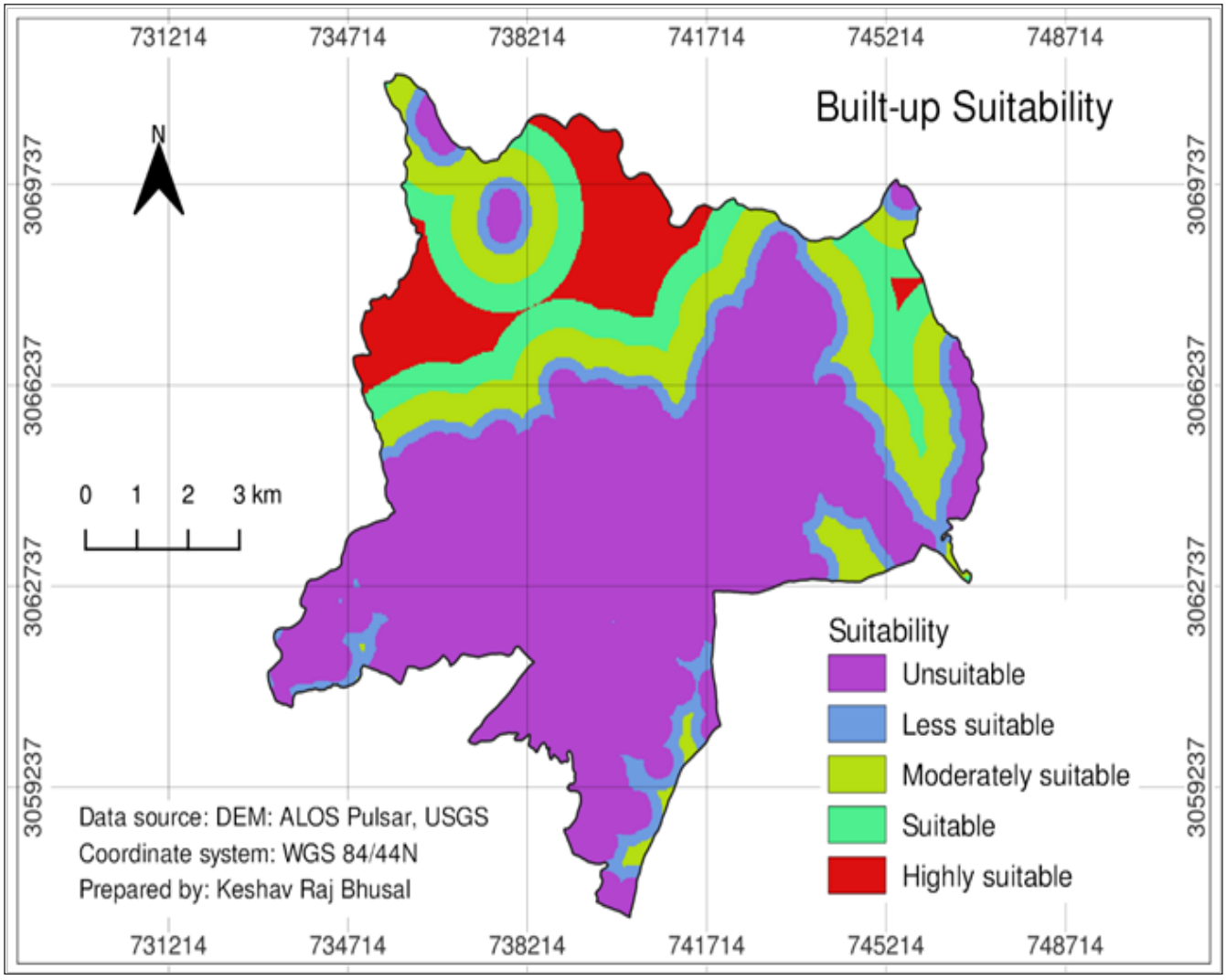

Figure 7.Showing suitable areas for landfill site according to built-up criteria.

Table 4.Showing area and percentage of built-up suitability

Builtup(meters)	Suitability	Value	Area(in m²)	Area (in %)
>1500	Highly suitable	4	9733545.84	10
1000-1500	Suitable	3	10888375.03	11
500-1000	Moderately suitable	2	14809475.21	15
300-500	Less suitable	1	8770356.34	9
0-300	Unsuitable	0	57444446.37	57

Built-up

For this criteria the buildings data were used. It was downloaded from openstreetmap through quickOSM plugin in QGIS.

Land Use Land Cover (LULC)

The LULC data used was Sentinel-2 10m high resolution Esri data 2022 downloaded from ArcGIS living atlas. The reason for using this data is the technique through which it was obtained (use of machine learning and AI) and is definitely more precise than the one we could have generated by oneself using image classification technique.

Overlay of all criteria

After the standardization of all the required criteria weightage was given to them. The weightage given was according to Analytical Hierarchy Process (AHP).

Weightage was given to each factor on basis of Analytical Hierarchy Process (AHP) through pairwise comparison matrix. For AHP and pairwise comparison an online AHP calculator tool was used. After giving the criteria and its importance relative to other the tool automatically gave the final weightage of each criteria along with pairwise matrix.

1/9, Extremely; 1/7, very strongly; 1/5, strongly; 1/3, moderately; 1, equally; 3, moderately; 5, strongly; 7, very strongly 9, extremely

Consistency ratio =0.029<0.1 (it is acceptable)

Final suitability result

After weightage and overlaying on standardized raster final overlay raster is obtained. This is the required final suitability map.

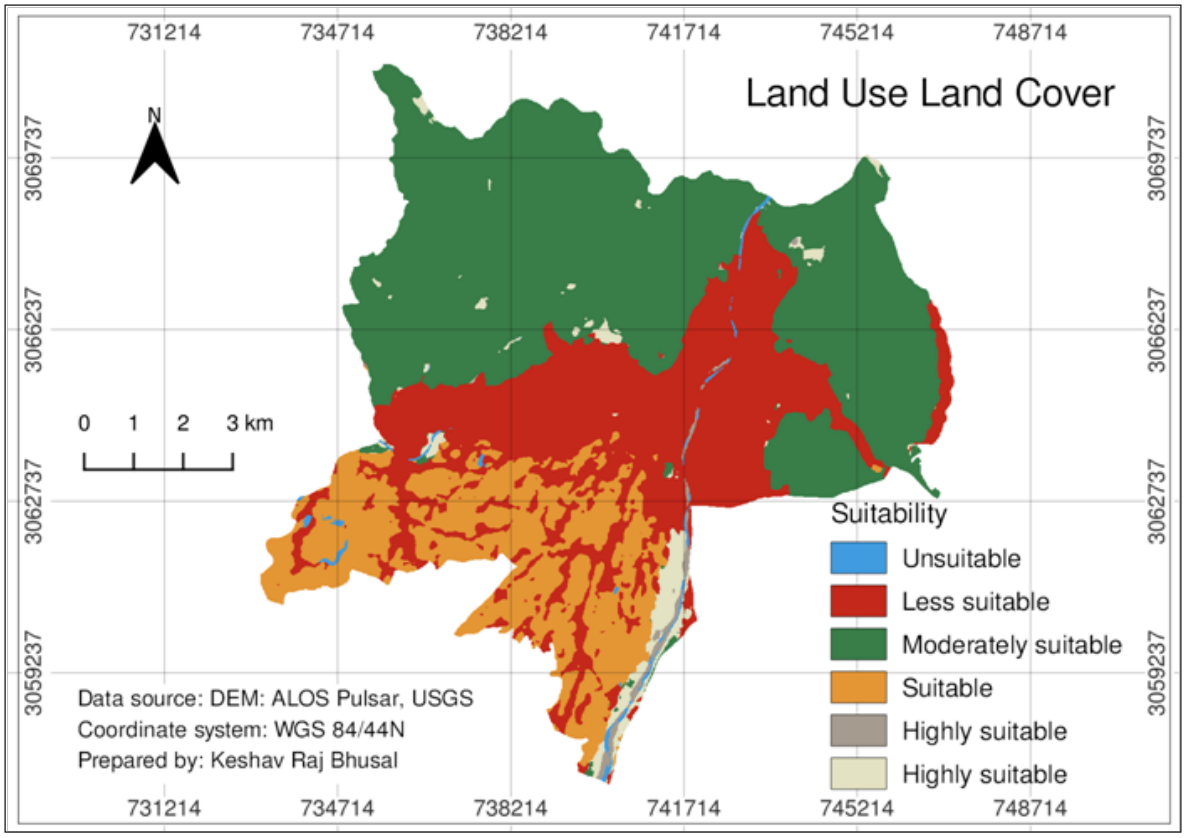

Figure 8.Showing suitable areas for landfill site according to LULC criteria.

Table 5.Showing area and percentage of LULC suitability

LULC class	Suitability	Value	Area(in m^2)	Area (in %)
Bare & Shrub	Highly suitable	4	3011398.83	2.96
Agriculture	Suitable	3	18132158.12	17.84
Forest	Moderately suitable	2	49350173.11	48.55
Urban	Less suitable	1	30548788.55	30.05
Waterbodies	Unsuitable	0	607526.52	0.6

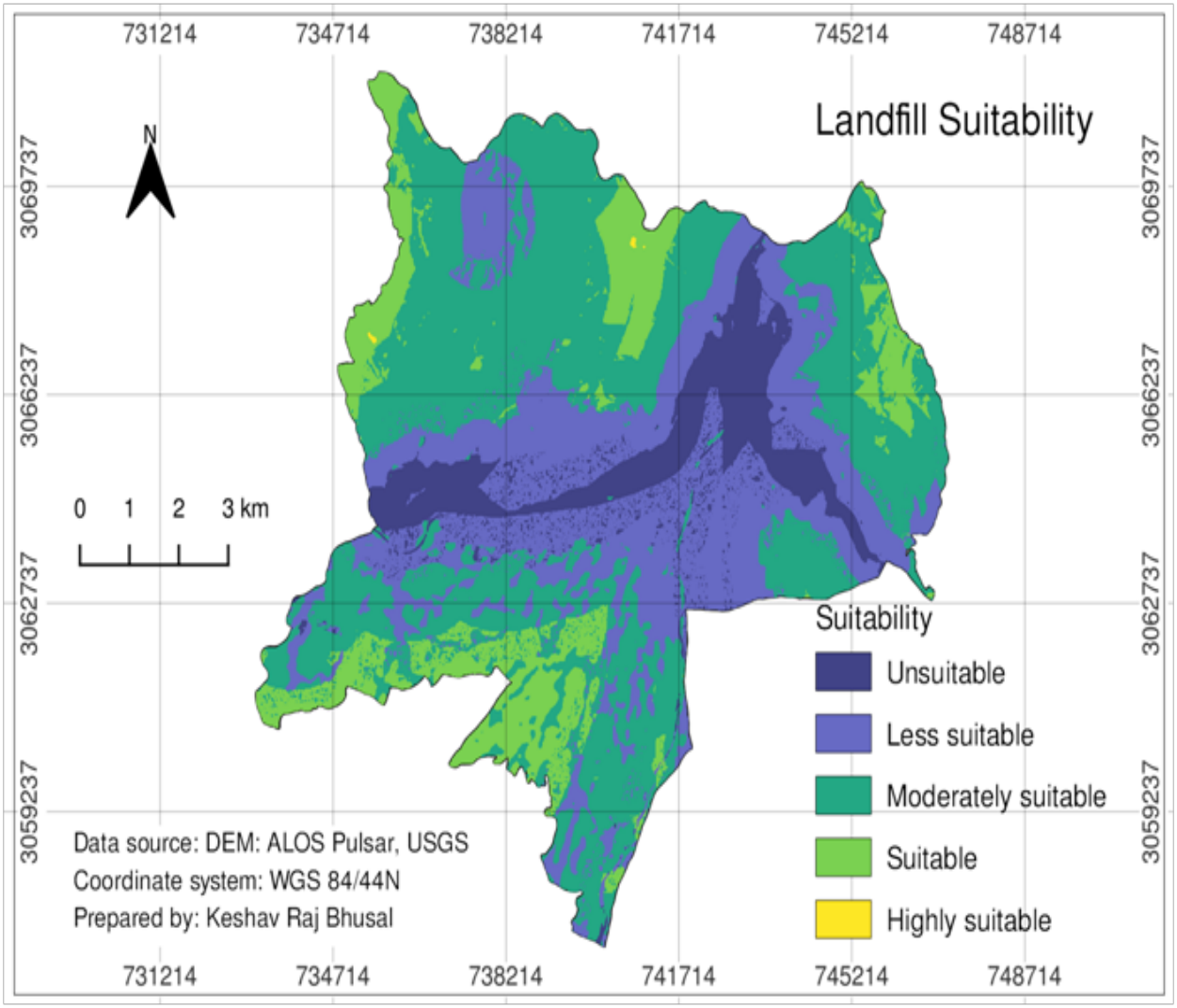

Figure 9.Showing final landfill suitability areas of Butwal

Table 6.Showing weightage for each factor criteria.

Criteria	LULC	River	Built-up	Road	Slope	Weight(%)
LULC	1	2	2	3	5	37.5%
River	1/2	1	2	2	4	25.5%
Built-up	1/2	½	1	3	3	20%
Road	1/3	½	1/3	1	2	10.8%
Slope	1/5	¼	1/3	1/2	1	6.3%
Total						

Table 7.Showing final area and percentage of landfill suitability

Suitability	Value	Area(in m^2)	Area (in %)
Highly suitable	4	7195.46	0.01
Suitable	3	10763273.69	10.61
Moderately suitable	2	53875915.44	53.12
Less suitable	1	35461041.139	34.96
Unsuitable	0	1313365.94	1.29

It is seen that 0.01 % of the total area of Butwal Sub-metropolitan is highly suitable, 10.61% is suitable, 53.12 % is moderately suitable, 34.96 % is less suitable and 1.29 % of total land is unsuitable for landfill. The northern hilly region and southern border of Butwal seems to be suitable for landfill sites.

Conclusion and Recommendation

Hence, GIS and Remote sensing can be used for determination of suitable landfill sites for waste disposal. The freely available datasets make it much easier for data collection and preparation. The final output of this research can help for effective planning and management of wastes in Butwal Sub-metropolitan.

As the road data taken for this research was of main highway i.e Mahendra and Siddhartha Highway only, road data of minor and secondary roads also could have been taken and the results could have been different. It is also recommended to use latest high resolution satellite imagery and LULC classification.

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