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Suitability Analysis to purpose the appropriate Dumpsite on Dadeldhura using MCDA (Multi Criteria Decision Analysis)

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Abstract

Solid waste management is a pressing environmental issue in many developing countries, including Nepal. The rapid urbanization and economic growth in these regions have led to an increased generation of municipal solid waste and hazardous waste. Improper disposal of medical waste from healthcare facilities further contributes to pollution and public health risks. In Nepal, solid waste management has become a major concern for municipalities. This research aims to address the problem of solid waste management by identifying suitable landfill sites in Dadeldhura district using Geographic Information System (GIS) and Multi-Criteria Decision Analysis (MCDA) techniques.

The study highlights the importance of proper waste collection and management to ensure the sustainable development of cities. It emphasizes the need for long-term planning, spanning 25-50 years, for solid waste disposal management. Currently, the existing landfill site in Dadeldhura lacks proper engineering measures, such as liners and perforated pipes. This results in various negative impacts, including accidents, infrastructure damage, environmental pollution, methane emissions, disease transmission, wildlife injuries, and nuisance problems.

To address these issues, the research utilizes GIS and MCDA to identify potential landfill sites. Previous studies have demonstrated the effectiveness of using remote sensing and GIS-based MCDA for waste disposal site selection. The research focuses on determining the most suitable landfill site in Dadeldhura district, considering factors such as proximity to water bodies, settlements, land use types, rivers, and road networks.

The objectives of the study include gaining knowledge about GIS-based raster data analysis and applying the concept of MCDA. The findings of this research will assist in selecting appropriate solid waste management sites within Dadeldhura district. The study's outcomes can contribute to various development projects, including urban planning, transportation, and the development of smart villages and cities.

The research paper follows a structured outline, starting with an introduction that highlights the need for a suitable dumpsite in Dadeldhura District. It includes a literature review discussing the significance of solid waste management and the roles of different levels of government in Nepal. The methodology section explains the data collection and processing steps, including proximity analysis, reclassification, and weighted overlay using QGIS 3.30.2 software. The results and discussion section presents the map showing the suitable landfill site in Dadeldhura district, along with other thematic maps generated during the study. The limitations of the research are also acknowledged. Finally, the paper concludes by summarizing the findings and emphasizing the importance of GIS and MCDA in determining suitable landfill sites for solid waste management.

KEYWORDS: Solid waste management, landfill site selection, Geographic Information System (GIS), Multi-Criteria Decision Analysis (MCDA)

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1 INTRODUCTION

Solid waste management is one of the major environmental issues in cities of many developing countries, including Nepal. Urban population growth and economic development lead to increasing generation of municipal solid waste. The use of products that generate hazardous waste is another concern. Unmanaged disposal of medical wastes from hospitals and clinics also contribute to pollution and public health hazards in the localities. Therefore, SWM has become a major concern for the municipalities of Nepal (ADB, 2013). Industrialization and Urbanization has led to numerous problems from over exploitation of natural resources to increment in the amount of waste production (Bigyan Neupane, 2013). The land use planning leads to the well managed and sustainable management of land resources. In the countries like Nepal with rapid urbanization, it is very vital to be preparing for about 25-50 years of solid waste disposal management. Therefore the land use suitability analysis is done to analyze and determine the suitable land fill site.

The landfill site shall not be considered a sanitary landfill site as the landfill site is not engineered, though there is the provision of waste segregation house, composting unit and collection house of plastic and paper. No liners and perforated pipes are used at the landfill site. The various impacts caused due to improper waste management at landfill site includes: fatal accidents, infrastructure damage pollution of the local environment, off-gassing of methane generated by decaying organic wastes, spreading of disease vectors such as rats and flies, particularly from improperly operated landfills, which are common in Third-world countries, injuries to wildlife, and simple nuisance problems. (Thapa & Kumar, 2011)

It is very important to collect the wastage from every household and every waste producing organizations in a well-managed manner. To collect the waste in two ways: organic and inorganic waste, for proper disposing is a finest and best way for segregating and producing sub products like fertilizers from organic and asphalt like materials from inorganic wastes. Therefore it is very important to select a proper dumpsite in a region. It also defines the proper management of well-organized cities.

Applications of GIS to identify potential waste disposal sites have been analyzed in different locations. During the previous couple of decades, researchers have extensively used remote sensing and GIS-based Multi-Criteria Decision Analysis (MCDA) revealed that sanitary landfilling is the most appropriate waste disposal method. These techniques provide important support to solve the problem of locating waste bins effectively. This study aimed to determine the most appropriate suitable solid waste disposal site for Dadeldhura district in Nepal.

1.1 Problem statement:

Since the population of Dadeldhura district is increasing day by day and the wastage from every household is increasing, it is much necessary to find an appropriate dumpsite within the district to collect and manage the wastage. This study will solve a problem of selecting suitable dumpsite within the district. It defines most of the important criteria like proximity from water body, settlement, landuse type, river and road networks existing there.

1.2 Objective

The main objective of this study is to determine the solid waste management sites within the Dadeldhura district.

1.3 Scope

With this study, the suitable dumpsite locations are determined in Dadeldhura district. This study can be further conceptualized under various development projects like urban planning, transport, developing smart villages and cities.

2 LITERATURE REVIEW:

Solid Waste Management (SWM) is a crosscutting issue that impacts various areas of sustainable development. The SWM strategies and approaches affect ecological, economic and societal sustainability domains of each country (RodicLjiljana & Wilson, 2017). In Nepal, the local governments are facing serious challenges to manage solid waste generated in the cities, and keep cities clean. Among the 753 local governments, 293 are urban that include metropolitan and sub-metropolitan cities, and municipalities, and rest 460 are rural municipalities. Among other, the SWM is one of the most prioritized responsibilities of the local governments.

The assessment of solid waste management sector is carried out at two levels—federal and local—as these are the two active tiers of government with regards to this service. The roles of the federal agencies include formulating policies and enacting the relevant legislations, providing financing support, and developing investment frameworks including private sector engagement, and protecting the environment from harmful effects of various services and operations including SWM. The local level governments are responsible for providing SWM services for areas under their jurisdictions. As per the Constitution, SWM is a concurrent subject with both the federal and provincial level governments; but the provincial governments are passive as yet and have not been playing substantial roles in SWM. The assessment at the federal level involves mapping the institutions engaged in the SWM sector and their roles and responsibilities. The legal and regulatory framework for SWM services is reviewed and the gaps are identified. Further, fiscal transfer mechanisms adopted by the federal government for providing financial support to local level governments and enabling framework for public-private partnerships in the SWM sector and environment monitoring mechanisms are assessed. (WorldBankGroup & GPRBA, 2020).

In recent practice, Kathmandu's landfill site Sisdole is one of the largest landfill sites in Nepal. However the many problems like capacity of the site reaching maximum, mansoon rain affecting the destruction of road and causing landslide are existing (Machamasi, 2021). Newly constructed Banchare Landfill Site can be a proper destination of the waste disposing of Kathmandu valley.

3 METHODOLOGY

3.1 Data used and experimental design:

3.1.1 Software:

For data analysis and processing QGIS 3.30.2 version software was used

3.1.2 Data used:

For the selection of suitable dumpsite within the district, several research literatures were studied and following datasets were collected:

Table 1: Datasets used in the study

Datasets	Data source
Road Network	ICIMOD
Land use	ICIMOD
DEM	Humanitarian Data Exchange
River Network	ICIMOD
Nepal Data	Survey Department of Nepal

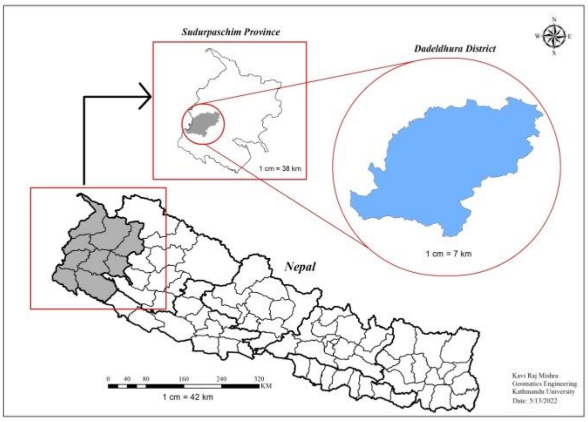
3.2 Study Area

Dadeldhura is one of the rapidly urbanizing district of Nepal located in Sudurpaschim Province consisting seven local administrations. According to the census bureau of statistics 2021 Dadeldhura has the population of 139,420. It is the center for all hilly districts of Sudurpaschim province as it is connected with all 6 districts through road networks.

This district has some spatial variations of topographic features. It ranges from some high elevation mountains to flat plains. Elevation of the area is from 300 – 2700 m. The district covers the area of 1,538 km^2. It has an average temperature of 27°C, May and June are the hottest months of the year, when it reaches around 33°C. The lowest average temperature occurs in December and January.

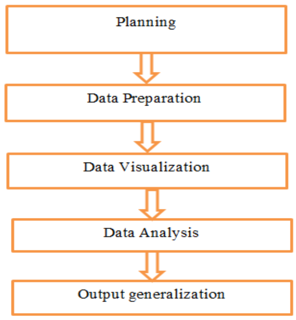
The migration of people from neighboring districts: Doti, Bajhang, Bajura, Darchula, Baitadi, Achham and others is one of the important factors for increased economic activities, traffic, waste and pollution.

Figure 1: Study area map- Dadeldhura district



3.3 Methodological Diagram:

Figure 2: Flow chart of data analysis



3.3.1 Planning:

A task was decided to select suitable dumpsite in home districts of each student in order to implement previously studied proximity analysis, reclassification of raster and weighted site selection in GIS. For this, we collected data from above mentioned (Table 1) data sources.

3.3.2 Data preparation:

We collected data of road, river network, boundary of district & settlement in vector format and DEM & Land cover data in raster format. It gives us the data of whole Nepal. Then we extract the data of only our district by clipping vector data and masking raster data. Finally we got all the data of only Dadeldhura district.

Being the large study area, raster format data are more effective for data analysis, fast in processing and simple to run and we therefore used raster datasets. So we converted the vector datasets into Raster using ***Feature to Raster*** tool in QGIS 3.30.2.

3.4 Data processing:

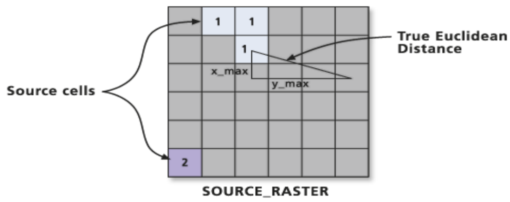
The collected data were analyzed and processed in QGIS 3.30.2 software. Proximity analysis is the key for calculating the physical distances between elements of raster data. Similarly, reclassification of the data layers according to the different criteria is another important step in data analysis and processing. Then Multi criteria decision analysis gives the ultimate decision for selecting the landfill site based on the different weightage for different data layers.

Euclidean distance*:*

The Euclidean distance output raster contains the measured distance from every cell to the nearest source. The distances are measured as the crow flies (Euclidean distance) in the projection units of the raster, such as feet or meters, and are computed from cell center to cell center.

Euclidean distance is calculated from the center of the source cell to the center of each of the surrounding cells. True Euclidean distance is calculated in each of the distance tools. Conceptually, the Euclidean algorithm works as follows: for each cell, the distance to each source cell is determined by calculating the hypotenuse with *x- max* and *y-max* as the other two legs of the triangle. This calculation derives the true Euclidean distance, rather than the cell distance. The shortest distance to a source is determined, and if it is less than the specified maximum distance, the value is assigned to the cell location on the output raster to a source is determined, and if it is less than the specified maximum distance, the value is assigned to the cell location on the output raster. (ArcGISPro, Tool Reference)

Figure 3: Determining true Euclidean distance



Resampling*:* Resampling method changes the spatial resolution of a raster dataset and sets rules for aggregating or interpolating values across the new pixel sizes. (ArcGISPro)

Some resampling methods are given below:

a) Nearest
b) Majority
c) Bilinear
d) Cubic

Reclassification: Reclassification is the process of reassigning one or more values in a raster dataset to new output values. The Reclassify tool is available in the Spatial Analyst extension in QGIS 3.30.2. (Lange, 2020) If a range of values is to be re-classed, the ranges should not overlap except at the boundary of two input ranges. Where overlapping occurs, the higher end of the lower input range is inclusive, and the lower end of the higher input range is exclusive.

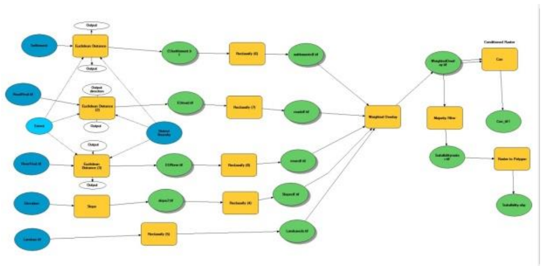
3.4.1 Data Visualization:

Data visualization of the datasets was done using model created in Arc Catalog. **Euclidean distance** tool was used for each dataset and output obtained was a raster dataset containing the distance of each data except DEM. For DEM, slope tool was used and slope was calculated keeping the same cell size of all the dataset to make the processing and analysis more smooth and easy.

After calculating Euclidean distance, reclassification of the datasets according to different criteria was done. For this I used **Reclassify** tool and again cell size of output kept the same.

Here is the model built in the analysis process:

Figure 4: Model Prepared in GIS Analysis



3.5 Data analysis:

The very first step in data analysis was to identify criteria for potential landfill sites selection. So, criteria were drawn from relative review of other researches on landfill selection criteria. The criteria included slope, land use, water body, road and residential for locating proper site taking an account of data layers used for interpretation. Here we considered following criteria during the analysis:

Table 2: Criteria used in the study

Rank	**Very High suitable**	**Highly suitable**	**Moderate suitable**	**Less suitable**	**Unsuitable**
Suitability grade	**5**	**4**	**3**	**2**	**1**
Slope	0-9%	9-16%	16-21%	21-30%	>30%
Land use	Grassland	Bare Land	Forest	Built up area	Cultivated
Distance from Residential area	1000-1500m	-	500-1000m	1500-2000m	0-500 & >2000m
Distance from Water Body	>2000m	1500-2000m	1000-1500m	500-1000m	0-500m
Distance from Road Network	1000-1500m	500-1000m	-	1500-2000m	0-500m & >2000m

The data layers were bought together for proposed study site and were supported by QGIS 3.30.2 software. All of the map layers were converted into raster format.

The process of deriving criteria for 5 data layers are shown below:

Slope: Since, slope from elevation data is the most vital requirement before construction of any infrastructures especially the landfill site, assigned value from 1 to 5 to the slope on the basis of worst to best for construction. i.e.: 1 as worst and 5 as the best.

Land use: It includes agricultural, commercial, cultural and archeological, forest, industrial zone, mine and minerals, public use, residential zone riverine and lake area and other areas. I assigned the values indicate the landfill suitability condition varies from not suitable-1 to suitable-5.

Residential Area: In order to avoid public health nuisance because of potential biohazards from garbage disposal site, site was considered away from residential area. A distance of 1000-1500m from the residential area was taken as a suitable landfill location. The study area was buffered in raster format and reclassified according to suitability of distant criteria. Value 1 was assigned to inappropriate one and to 5 to the most appropriate one for distant criteria.

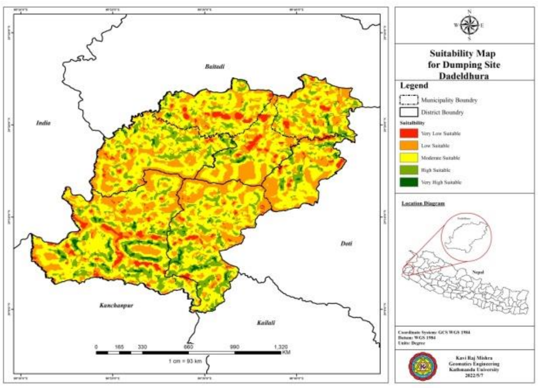
Water body: The buffering in a raster environment of QGIS 3.30.2 was created in such a way that it would be best to consider the distance of 1,000 and above as most appropriate location and below 1000m as moderate, low and inappropriate. It was again reclassified allocating value 1 for inappropriate one and 5 to the most appropriate one. The target for this allocation was basically to prevent irreparable environmental and health impact as it would enter inside water body otherwise. The water body included rivers, ponds, ground-water sources and reservoirs.

Road**:** Similarly, road was also considered for siting the landfill for health and aesthetic purpose. Study area was buffered in a raster environment which was then reclassified according to their suitability by categorizing them from 1 to 5. The distance of 1,000 m and above was believed to be the most suitable for landfill sites location.

Output generalization:

Using MCDA concepts in GIS and analyzing the data for desired task, a Map representing suitable landfill site in Dadeldhura was obtained as main output.

Figure 5: Suitability Map for Dumping site

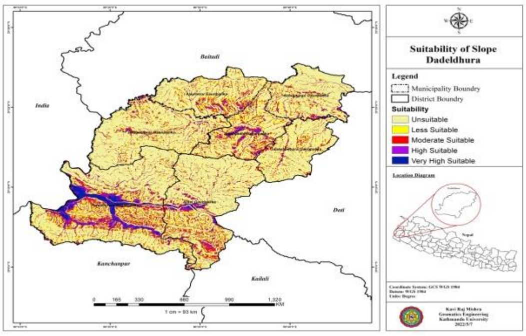


4 RESULT & DISCUSSION:

From the overall procedure some obtained supporting outputs are given below:

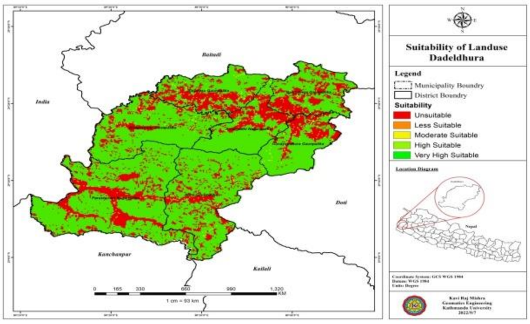
Suitability of Slope: This map shows the elevation difference and suitable areas for dumping site according to my criteria's.

Figure 6: Suitability of Slope



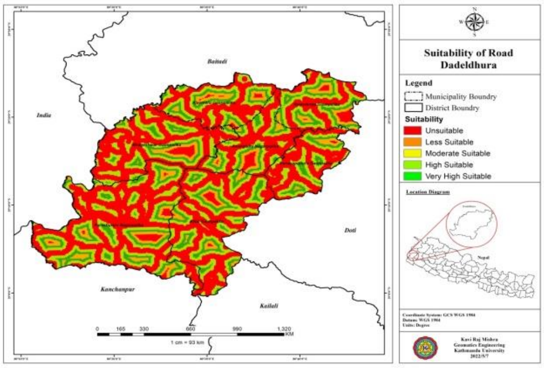
Suitability of Landuse: Different landuse types are represented in below data after defining my criteria to select or reject for selecting suitable dumpsite.

Figure 7: Suitability of Landuse



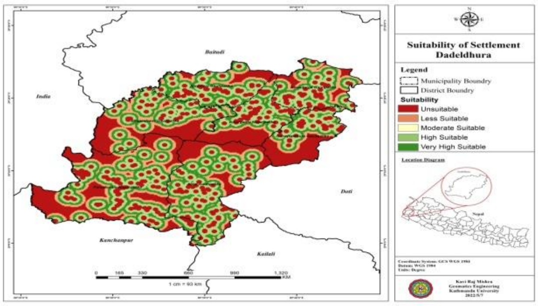
Suitability of Road: This map contains the areas that are far apart in defined criteria and represents the areas that are suitable of less suitable or other according to my criteria.

Figure 8: Suitability of Road



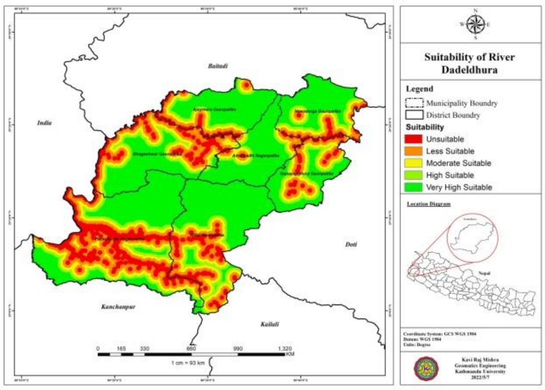
Suitability of Settlement: This map contains the areas that are in certain distance from settlement and represents the area for suitable landfill site according to defined criteria.

Figure 9: Slope Map



Suitability of River: This map represents the area near the water bodies (rivers) and also represents the different ranks for suitable areas as defined earlier.

Figure 10: Suitability of River



5 LIMITATIONS

Besides of all the procedures, factors and considerations that are adopted in this study, there are some limitations of this project that are given below:

i. Only few of the factors that affect the waste disposal site are taken into account.
ii. The distances assumed for the suitability are not based on community standards and guidelines or as defined in the law and constitution.
iii. The openly access data sets used for this project retrieved from the internet source may not be completely authentic and reliable.
iv. This is just a study project and the suitable site resulted from this study may not depict the suitable site for the waste disposal in reality.

6 CONCLUSION & FUTURE WORKS:

6.1 Conclusion:

This study has provided a systematic framework of choosing suitable site for waste disposal using GIS based MCDA procedures using six major parameters. Incorporating MCDA with GIS for a spatial decision-making process is complicated as it deals with the huge and conflicting criteria in waste disposal site selection. However, this procedure also helps in making right choice with logical reasoning. Waste disposal suitability maps were prepared in GIS. The result shows that 49 km^2 (3.22%) is highly suitable whereas 55.55 km^2 (3.61%) of the total study area is unsuitable for waste disposal.

The paper features the ecological issues brought about by inappropriate waste administration, including contamination, general wellbeing risks, and harm to framework. It stresses the requirement for very much oversaw and feasible strong garbage removal the board, especially in quickly urbanizing regions. The utilization of GIS and MCDA in distinguishing potential garbage removal destinations is talked about, with sterile landfilling recognized as the most proper technique.

The target of the review is to decide reasonable strong waste administration destinations in Dadeldhura locale. The examination cycle includes information assortment from different sources, information handling utilizing QGIS programming, and information investigation through closeness examination, renaming, and weighted overlay. The review recognizes measures, for example, slant, land use, distance from neighborhoods, water bodies, and street organizations to choose reasonable dumpsite areas.

The end features the meaning of the concentrate in advancing legitimate waste administration and empowering legislative and non-administrative organizations to foster reasonable dumpsites inside Dadeldhura area. The discoveries give a reasonableness map and topical guides, exhibiting the appropriate unloading site inside the region.

The exploration recognizes the restrictions of the review, for example, the set number of models considered and the scholarly idea of the examination. In any case, the review gives significant bits of knowledge into GIS-based strong waste administration and MCDA methods, which can be additionally applied in metropolitan preparation, transport, and the advancement of savvy towns and urban communities.

In rundown, the exploration paper adds to tending to the strong waste administration challenges looked by neighborhood legislatures in Nepal, especially in Dadeldhura locale. The utilization of GIS and MCDA strategies empowers the recognizable proof of appropriate dumpsite areas, advancing reasonable waste administration practices and supporting future improvement projects in the district.

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