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Suitable Site Selection for Solid Waste Dumping Zone Management: A Case Study of Medinipur Municipality

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Abstract : *Medinipur Municipality is one of the fastest developing Municipalities in West Bengal. Using methodologies from the Geographic Information System and the Analytic Hierarchy Process, the study was conducted to determine the best management strategies for the solid waste system and to choose a location for its disposal. Six criteria have been taken for disposal site selection namely land use land cover, distance from road and railway, slope, population density, geomorphology and dumping side. Using GIS and Remote Sensing techniques, thematic layers are created. Weights were assigned to all the themes and their classes through AHP and finally overlay analysis technique was applied in Arc GIS Software to identify the disposal sites. The main problem is the open dumping of solid waste without recycling, which resulted in conservation pollution for this Municipality. The study has been concluded with some fruitful management plans that may be beneficial to the local people as well as municipal authority.*

Key words: *Municipal solid waste (MSW), Environmental Pollution, Solid Waste Dumping Site, Solid Waste Gathering, Geographic Information System.*

1. Introduction

One of the most significant issues facing developing nations is the handling of solid waste. The sources of Solid waste materials in a municipality are natural outcomes like human activities, plastic, medical waste, end automobiles, food, fruits, polythene, paper, construction materials etc.(Al-Salem et al., 2009**).** The important reason for solid waste is the growth of population and urbanization decreases. Disease transmission, fire dangers, odour annoyance, air and water pollution, visual nuisance, and financial losses are the most frequent issues linked to inappropriate solid waste management (Sahoo et al., 2022). The majority of India's municipal solid garbage is now disposed of improperly. As the solid waste breaks down, methane (CH4), carbon dioxide (CO2), and other trace gases are released (Ghosh & Pal, 2018). Unscientific landfills can lower drinking water quality and create illnesses like asthma, nausea, and jaundice. The present study intends to find a suitable site for the disposal of urban solid waste generated from Medinipur municipality with the help of Remote Sensing and GIS techniques (Devichi Wibowo et al., 2020).

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Solid waste Management is a very important problem in the Medinipur town area and finding a suitable waste dumping area is a serious problem faced by the Medinipur Municipality (Mahata & Mondal, 2022).

1.1 Statement of the problem:

One of the biggest factors endangering the health of the environment worldwide is the generation of municipal solid waste. Therefore, to achieve sustainable development, integrated waste management systems must be taken into consideration. The functional components of waste reduction, reuse, recycling, and ultimately disposing of the leftover material in landfills are typically the focus of such a system (Mahata, 2021). Given that sanitary landfilling is an unavoidable component of the Municipal Solid Waste (MSW) management system, choosing the right disposal site may be crucial to lowering environmental pollution (Mahata, 2023). The municipality of Medinipur's solid waste management system is ineffective, nevertheless, as rubbish is frequently discarded on private property, along roadways, and next to sensitive locations. To prevent environmental deterioration, it is crucial that collected solid waste be appropriately disposed of at specified locations inside the city (Jaybhaye et al., 2014).

1.2 Application of Remote sensing and GIS in solid waste dumping management:

Due to its unique ability to provide a synoptic view of a broad region of the earth's surfaces and its capacity for repetitive coverage, remote sensing is one of the best tools for inventory and analysis of the environment and its resources. While its recurrent coverage offers information on the dynamic changes occurring over the earth's surface and the natural environment, its multispectral capacity allows for adequate contrast between a variety of natural characteristics. Since many facets of solid waste management's operations and planning heavily rely on spatial data, GIS plays a significant role in the field. Generally speaking, GIS is essential to keeping track of account data to streamline collection processes (Saaty, 1999) (Saaty, 2008). Customer service, determining the best places for transfer stations, organizing the routes for vehicles carrying waste from residential, commercial, and industrial clients to transfer stations and from transfer stations to landfills, identifying new landfills, and landfill monitoring are all crucial in this way. GIS is a tool that not only reduces the time and cost of site selection but also provides a digital data bank for future monitoring programs at the site(B. K. Mondal et al., 2024).

2. Objectives of the study area:

- Analyze the health hazards associated with the existing location patterns of dump sites.
- Make recommendations for the best locations for municipal solid waste sorting facilities and disposal sites.
- Suggest a framework for sustainable solid waste management.

Aim of the study:

- Identification of a suitable site of solid waste dumping zone in the Medinipur Municipality area.

3. Literature review

A useful tool for locating appropriate trash disposal locations is the GIS. The main advantage of a GIS is that it can be expanded into a comprehensive waste disposal management GIS solution once a GIS database is established. The process of determining a site's suitability for solid waste management involves several social and physical factors (Mahata & Khalua, 2022). In the area of site suitability, the use of GIS and remote sensing techniques yields significant results. The disposal of solid trash is more problematic since it pollutes the air when burned, the land when it is disposed of sincerely and the water when it is disposed of in low-lying areas. Because most solid waste is not disposed of in the proper locations, solid waste dumping is a major issue in urban areas (Sahoo & Mahata, 2021). Therefore, the first concern for solid waste management is finding suitable locations for the disposal of solid waste and choosing a landfill site that is remote from residential areas, natural resources, and settlements. Images from satellite remote sensing can offer details on the wasteland and other related characteristics, which aid in site selection. When combined with GIS, it can offer a chance to combine population and other pertinent data with field metrics (Sahoo et al., 2022). Geographic Information Systems (GIS) have emerged as a cutting-edge tool in the landfill process because of advancements in computer science technology. GIS integrates existing quantitative, qualitative, and descriptive information databases with spatial data (maps, satellite pictures, and aerial photos). Due to its unique ability to provide a synoptic view of a broad region of the earth's surfaces and its capacity for repetitive coverage, remote sensing is one of the best tools for inventory and analysis of the environment and its resources (M. Mondal et al., 2020). While its recurrent coverage offers information on the dynamic changes occurring over the earth's surface and the natural environment, its multispectral capacity allows for adequate contrast between a variety of natural characteristics (Amasuomo & Baird, 2016). A great framework for data collection, synthesis, storage, measurement, and analysis is created when remotely sensed data is integrated with other landscape variables and arranged inside a GIS system. (Gour et al., 2014) Several political and environmental considerations as well as laws should be taken into account when evaluating a site as a potential location for the disposal of solid waste.

4. Location

Medinipur city is situated in the Medinipur block of West Medinipur district in the state of West Bengal. Medinipur is the district headquarters of Paschim Medinipur district of the state of West Bengal. It is situated on the banks of the Kangsabati River (variously known as Kasai). Medinipur town is located at 22.25°N. latitude, 87.65°E. longitude and 23 metres above sea level. Medinipur Municipality covers an area of 13.6 sq. km with twenty-five Wards.

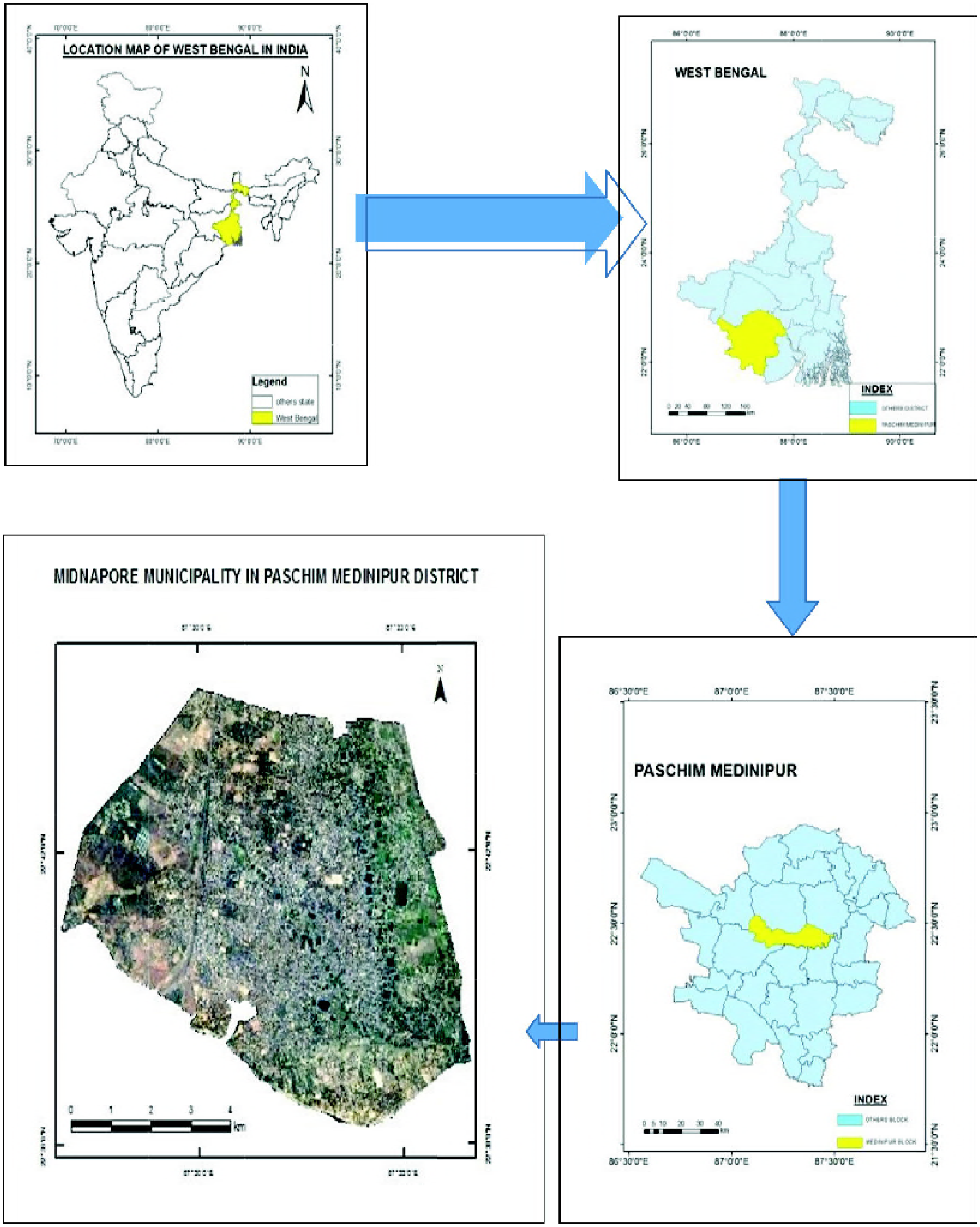

Fig. 1: Location map of Medinipur Municipality

4.1 Population:

As per the 2011 Census Report Medinipur Municipality has a population of 168496 Out of which 85313 are Male and 83183 are Female. The 0-6 years population is 14365~ Effective literacy rate for the 7+ population is 90.01%. As of the 2001 India census, Medinipur had a population of 153349; Medinipur had an average literacy rate of 75%, higher than the national average of 59.05%, male literacy was 80%; and female literacy was 71% in Medinipur , 10% of the population was 6 years of age (Tiwari et al., 2014). This makes it the second largest town in Paschim Medinipur district after Kharagpur, the town is almost equally divided in terms of population between Hindus and Muslims (Mahata & Mondal, 2022). There are Twenty-five wards; ward-wise population density has been shown in Figure No. 2.; the Figure indicates that Wards 11,13,14,15,21,22 have a high population density of greater than 15,000 per sq.km and the lowest is Wards 3,18,25 with

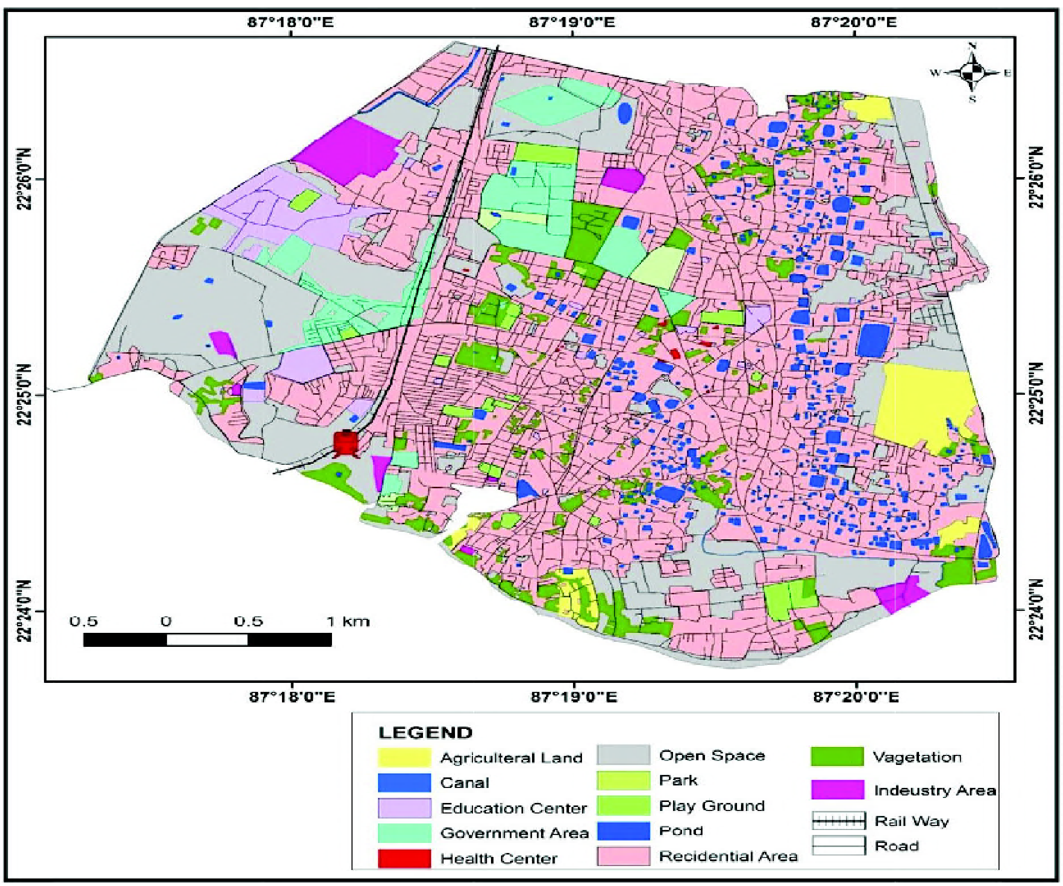

Fig. 2: Land use/land cover map of Medinipur Municipality

a density of less than 6000 per sq.km/ Land use land cover map of the study area create object base classification. The map shows that there are concentrations and a mix of many land use zones.

Table. 1. Area of Land use Land cover

LULC Classes	Area in sq, km	Area in (%)
Play Ground	0.265118	1.33763
Education Centre	0.581546	2.93414
Industry Area	0.366039	1.84681
Settlement	10.607723	53.5203
Canal	0.035591	0.179571
Government Area	0.963677	4.86214
Vegetation	1.106265	5.58156
Park	0.132767	0.669862
Health Centre	0.009449	0.047673
Agricultural Land	0.512104	2.58377
Vacant land	4.50792	22.7443
Pond	0.755357	3.81108

Source:

5.1 Methods used for the study:

Since many facets of solid waste management's planning and operations heavily rely on spatial data, Geographic Information Systems (GIS) plays a significant role in the field. In addition to saving time and money during the site selection process, GIS offers a digital data bank for the site's ongoing monitoring program. To analyze the suitability of landfill sites, the approach uses GIS to assess the entire region according to certain evaluation criteria. The criteria were chosen based on the local features of the study locations. Road, slope, water body, population, land use land cover (LULC), dumping site, and geomorphology are the main sub-criteria employed in spatial analysis. Table 1 displays the criteria and sub-criteria that were used in the creation of the GIS database.

Table:2 Criteria used in the development

Sl. No.	Criteria
1	Road
2	Slope
3	Land use Land cover
4	Population
5	Geomorphology
6	Dumping site

Proposed model for municipal solid waste management:

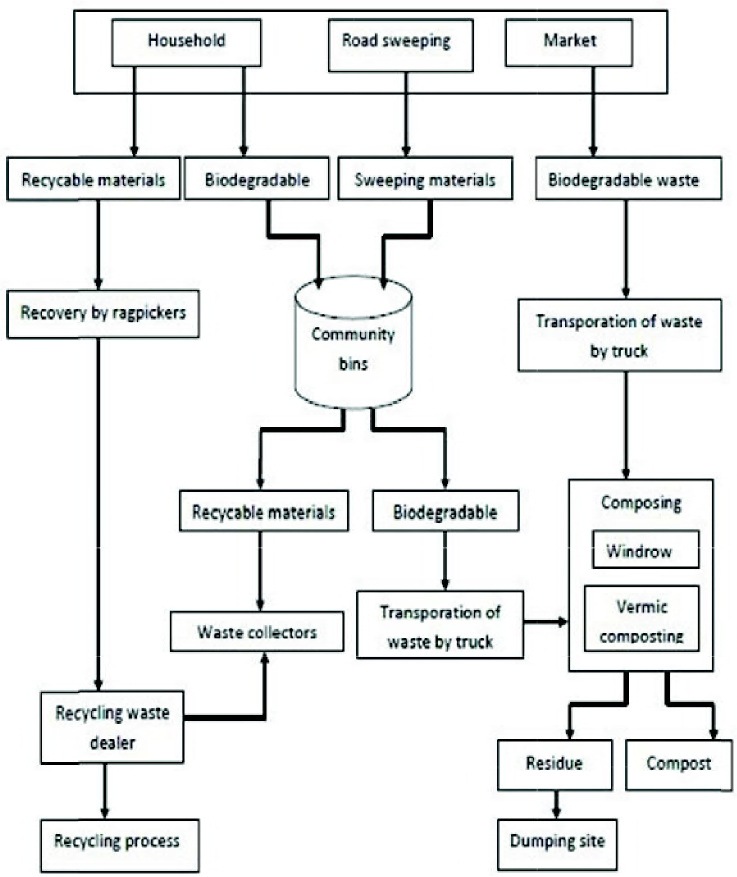

Fig. 3: Proposed Model

Table: -3 Weightage Table

Definition	Index	Definition	Index
Equally important	1	Equally important	1/1
Equally or slightly more important	2	Equally or slightly less important	1/2
Slightly more important	3	Slightly less important	1/3
Slightly to much more important	4	Slightly to weigh less important	1/4
Much more important	5	Weigh less important	1/5
Much too far more important	6	Weigh to far less important	1/6
Far more important	7	Far less important	1/7
Far more important to extremely moreimportant	8	Far less important to extremely lessimportant	1/8
Extremely more important	9	Extremely less important	1/9

5.2 Overly Analysis:

A collection of techniques known as overlay analysis is used in suitability modelling and optimal site selection. It is a method for producing an integrated analysis by applying a common scale of values to many distinct inputs.

5.3 Weighted Sum:

The general procedures of the overlay analysis mentioned above are followed in the weighted sum overlay analysis. An additive overlay analysis can be carried out by utilizing the Weighted Sum tool in conjunction with additional Spatial Analyst capabilities. Before utilizing the Weighted Sum tool, the input layer values must be classed. The weights applied to the input rasters can have any value and are not required to add up to a certain sum, in contrast to the weights in the Weighted Overlay tool. The Weighted Sum tool's output values are directly derived from the addition of the weights multiplied by each value when the input rasters are added. It preserves the attribute resolution of the values entered in the model since, in contrast to Weighted Overlay, the values are not rescaled back to a predetermined scale. Weighted Sum identifies these locations as the best since it thinks that more favourable factors lead to higher values in the final output raster.

6. Result and Discussion:

6.1 Suitability analysis of solid waste dumping site in Medinipur Municipality area:

As the general concept, the Dumping Zone shall not be located within 100 m of any major highways, city streets or other transportation routes. Solid waste dumping sites must be located at a suitable distance from the road network. The study preferred a buffer of 1000 m distance from main roads by referring to different sources. It was reclassified as an unsuitable road within 150 mt very low suitable, the distance between 150 to 300 representing low suitable, the distance between 300 to 450 meters representing the moderately suitable zone, and highly suitable zone representing 450 to 700 meters and finally 700 to 1000 meter represents very high suitable zone of solid waste.

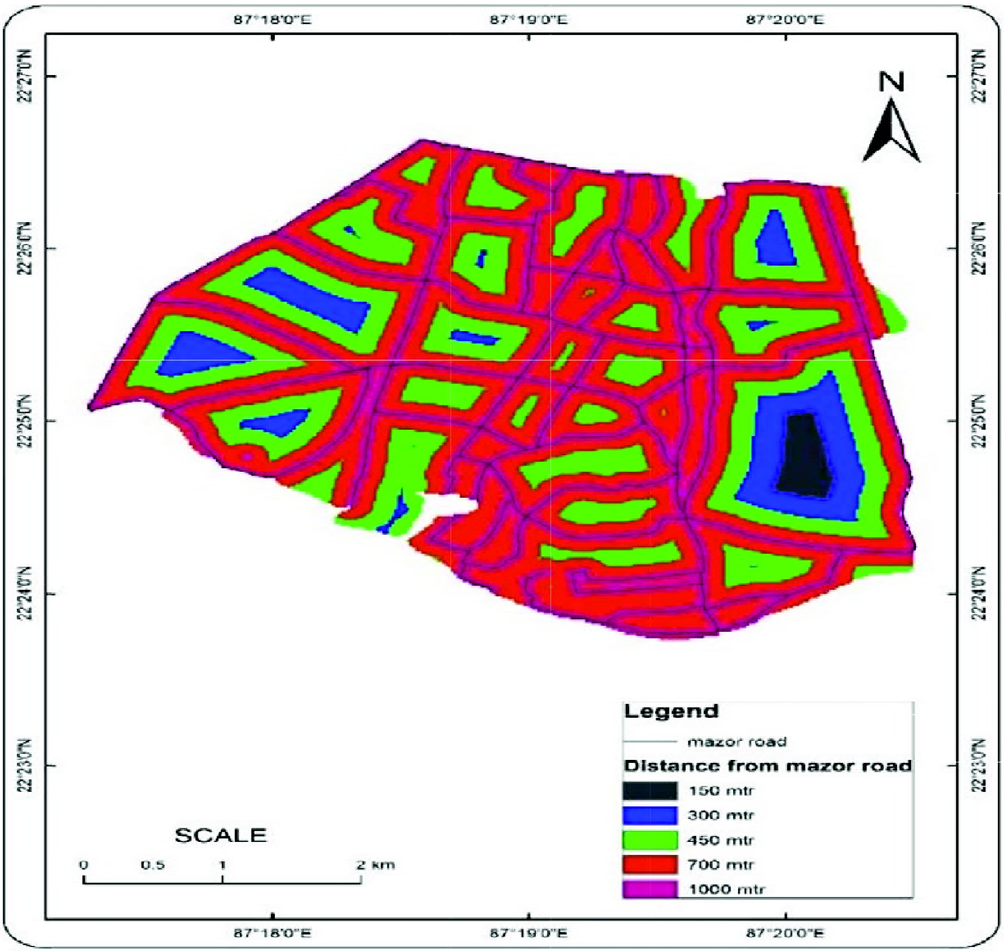

Fig. 4: Reclassified from the main road of Medinipur Municipality

6.2 Suitability of slope area for selecting Dumping zone:

This study considered the very low slope area and more highly slope area as not suitable for solid waste dumping zones. Very high slope areas will have a high risk of population and the potentially not a good site for Dumping. On the other way, a very low-slope area is not a suitable zone for waste dumping, because these areas are covered with water in the monsoon season of maximum time. For this reason, these sites are also not suitable areas for waste dumping. So, a moderate slope area is more suitable for waste dumping than a very high and low slope area.

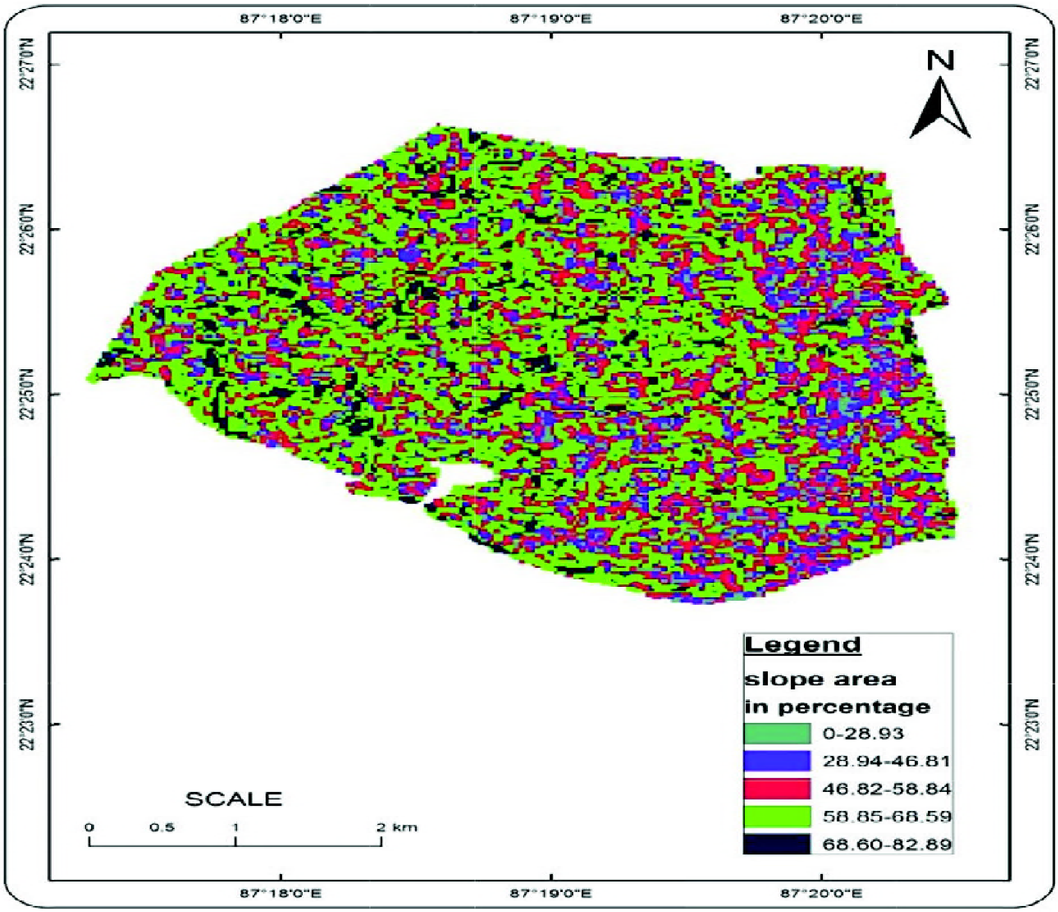

Fig. 5: Reclassified Slope Map of Medinipur Municipality area.

6.3 Suitability of land use/land cover zone for selecting solid waste dumping zone:

The land use/ land use cover is the important criterion for selecting a solid waste dumping management zone of an area. Vegetation and vacant land are the two main classes of land use/ land cover that provide to selecting suitable solid waste dumping management in the study area. The grass and bare lands by referring only to the land use criteria indicated by the yellow colour were the most suitable areas for solid waste dumping sites. Vacant land (22.74%) and Vegetation (5.58%) Are the two classes that are most used for Solid waste dumping management. Which is 28.32% area in the total area.

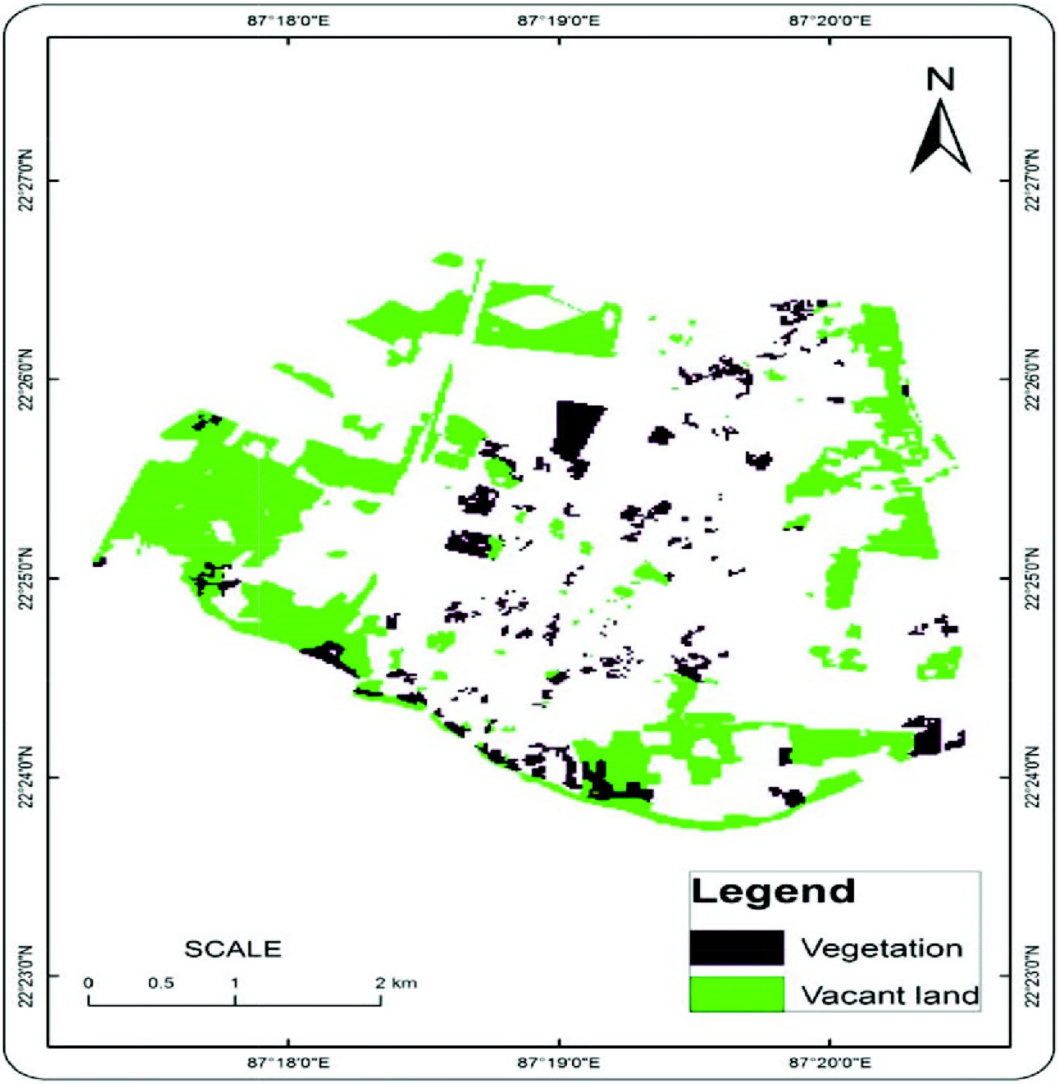

Fig. 6: Reclassified Vegetation Map of Medinipur Municipality area.

6.4 Suitable distance from the dumping site to the solid waste dumping site:

In this study area, 25 dumping zones exist in the total ward that is covered around 750 meters distance from the centre point to collect solid waste in the Medinipur Municipality area. Out of this range from a dumping point, we can select a zone for solid waste management.

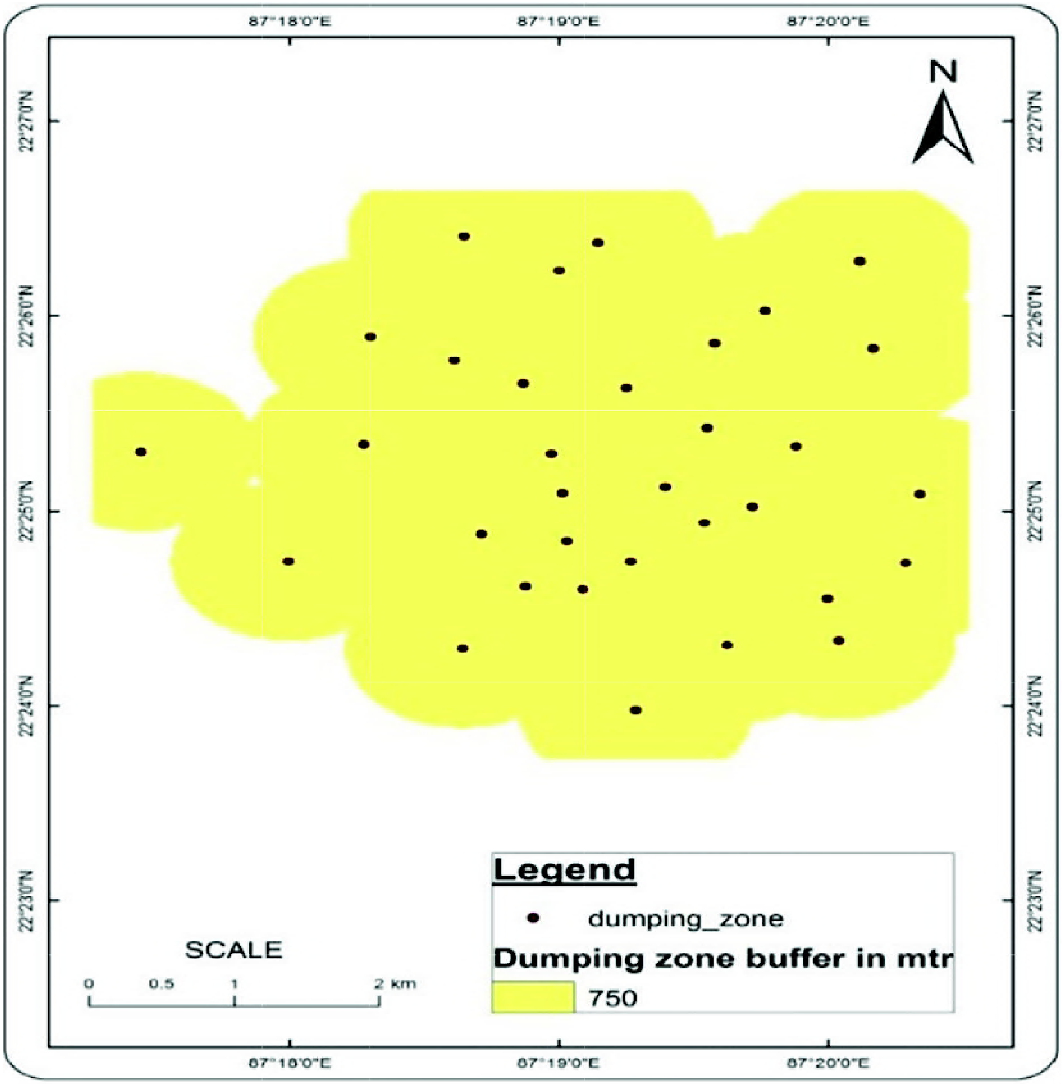

Fig. 7: Dumping Zone with a 750-meter buffer zone

6.5 Suitability analysis with Geomorphology for solid waste dumping management:

Geomorphology is one of the important criteria for selecting a suitable solid waste dumping management zone.

Table 4 Suitability scores given for Geomorphology.

Sl. No.	Types of geomorphology	Suitability score
1	Deeply wetlands plains/duricrusts	3
2	Badlands	4
3	Uplands plains	5

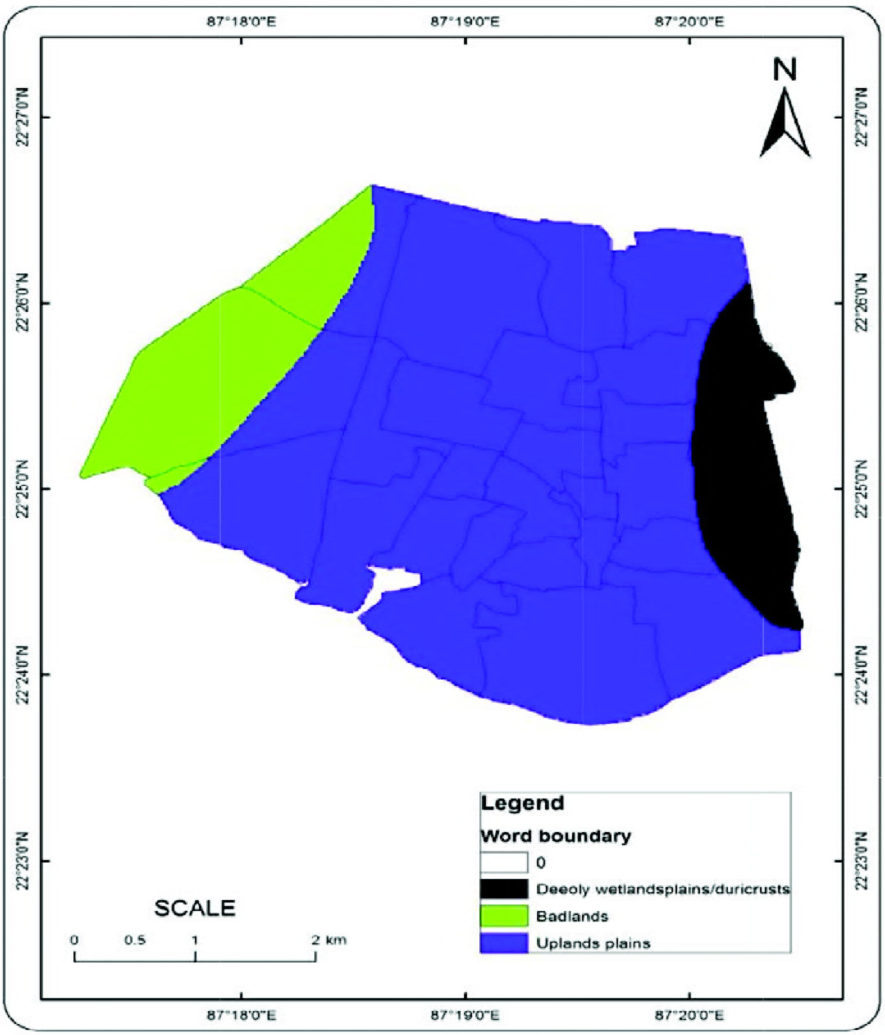

Fig. 8: Reclassified Map of Geomorphology of Medinipur Municipality

Pair-wise comparison ratio:

Criteria	Road	Slope		Geomorphology	Population Density	
Road	1	2	3	4	5	6
Slope	0.5	1	6	2	4	5
LULC	0.3333333	0.16666667	1	2	4	3
Geomorphology	0.25	0.5	0.5	1	2	3
Population Density	0.2	0.25	0.25	0.5	1	3
Dumping Site	0.1666667571	0.2	0.33333	0.333333	0.3333333	1
Total	2.5928	4.61666667	11.1667	10.16667	16.666667	21.5

Aggregating criterion weights and standardized criterion maps [Suitability Map]

Criteria	Road	Slope	LULC	Geomor-phology	Population Density	Dumping Site	Weightage
Road	0.3856749	0.433213	0.262774	0.393443	0.3	0.27906977	0.341072482
Slope	0.1928375	0.2166065	0.525547	0.196721	0.24	0.23255814	0.242786994
LULC	0.1285583	0.03610108	0.087591	0.196721	0.24	0.13953488	0.138766282
Geomorphology	0.0964187	0.10830325	0.043796	0.098361	0.12	0.13953488	0.107038612
Population Density	0.077135	0.05415162	0.021898	0.04918	0.06	0.13953488	0.077822396
Dumping Site	0.0642792	0.0433213	0.029197	0.032787	0.02	0.04651163	0.047333449
Total	0.9449036	0.89169675	0.970803	0.967213	0.98	0.97674419	0.954820215

Source:

Table 5

CRITERIA	WEIGHTEDSUM VECTOR	CONSISTENCY VECTOR
ROAD	2.3442124	6.87306237
SLOPE	2.007955	8.27043884
LULC	0.9602888	6.92018805
GEOMORPHOLOGY	0.6807285	6.35965375
POPULATION DENSITY	0.4369449	5.6146416
DUMPING SITE	0.260612	5.50587439

Lambda = (6.87306237+8.27043884+6.92018805+6.35965375+5.6146416+5.50587439)/6

= 6.59064

Consistency index (CI):

= (ë-n / n-1)

= (6.59064-6)/ (6-1)

= 0.11812

Consistency ratio (CR):

= CI / RI

= 0.11812/1.24

= 0.0952

Consistency is acceptable, as CR< 0.10

Table: 6 Pair-wise matrix

CRITERIA	WEIGHTAGE
ROAD	0.341072482
SLOPE	0.242786994
LULC	0.138766282
GEOMORPHOLOGY	0.107038612
POPULATIONDENSITY	0.077822396
DUMPING SITE	0.047333449

7. Result and Conclusion:

7.1 Result:

This section discusses the results produced by the GIS analysis. The total area in our project including the buffer zone covers 5.15 Sq.km. The results show that 0.809 Sq.km area is very highly suitable, 1.583 Sq.km area is highly suitable, 1.605 Sq.km area is moderately suitable and 0.898 km 2 area is low suitable and 0.256 km 2 area is very low suitable for dumping waste. The suitable area obtained in the analysis is shown in the following table 4.3 and the suitability map is shown in figure 4.6. Maximum high and very high suitable categories are found outside of Medinipur town and almost all low and very low suitable zones are found inside of the town. The placement of the landfilling is the primary environmental factor that should be taken into account while disposing of hazardous solid waste. The suggested approach could be applied to site selection procedures in different settings and circumstances where there are differences in the intensity of the introduced characteristics.

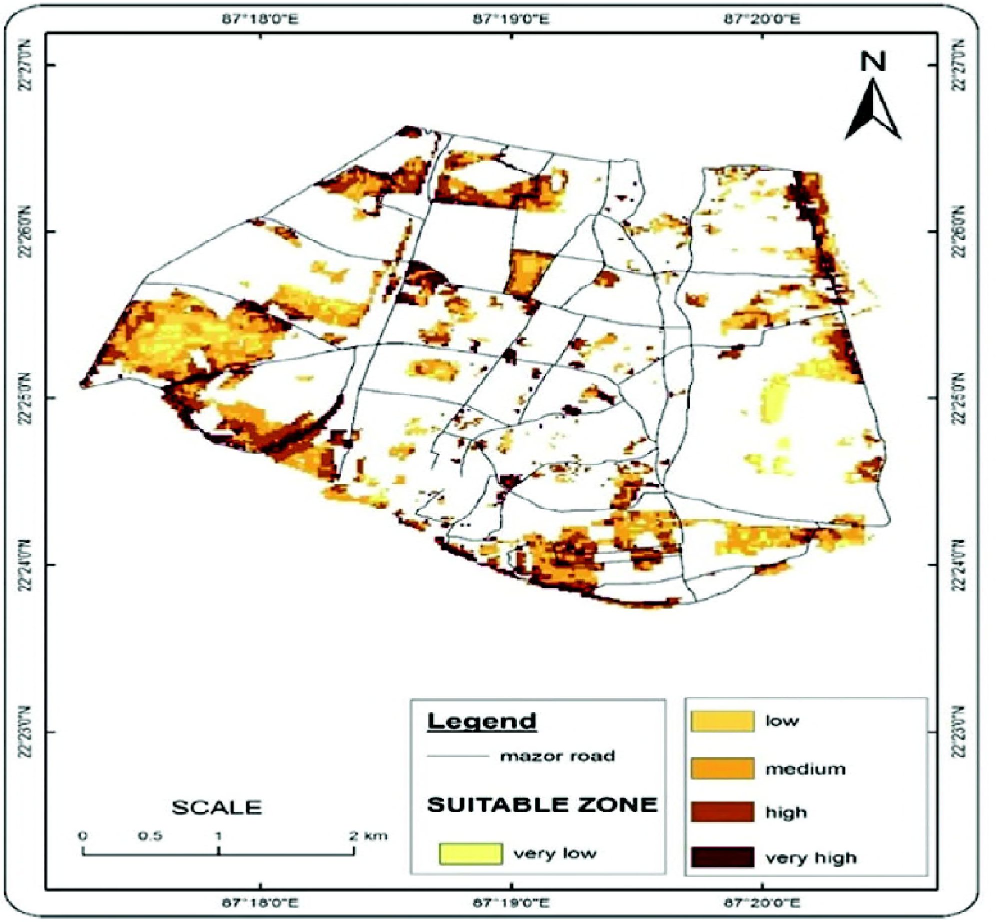

Fig. 9: Suitability map of Waste Dumping Zone in Medinipur Municipality area

Table: 7 Area of final suitable zone

ZONE	AREA INSQ.KM	AREA IN (%)
VERY HIGH	0.809377	15.71606
HIGH	1.58309	30.73961
MODERATE	1.6054	31.17282
LOW	0.898334	17.44338
VERY LOW	0.256399	4.978621
TOTAL	**5.1526**	**100**

8. Conclusion:

The suitability of the garbage disposal locations chosen in the Medinipur Municipality region was evaluated in this study using GIS. The current study considers several important environmental and economic aspects. The study demonstrates how crucial GIS technology is to today's urban problems. It would have been challenging to obtain current land use data using traditional methods, but GIS has made it easier to integrate this data for the current study. A more advanced tool for decision-making is a geographic information system (GIS). The majority of Medinipur town has low to moderate suitability for the disposal of solid waste, according to the suitability map.

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