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Solid Waste Disposal Site Selection and Suitable Management Strategy of Bardhaman Municipality, West Bengal, India

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ABSTRACT

Bardhaman Municipality is one of the fastest developing Municipalities in West Bengal with a population of 3,14,265 and population density of 11,949/sq km in 2011. The population growth rate of this Municipality is 10.04 % from 2001 to 2011. This Municipality has around 71,618 houses which generate 153.48 Metric Ton of solid waste per day. The study has been carried out to select solid waste disposal site and to find out the suitable management strategies of solid waste system by using Analytic Hierarchy Process and Geographical Information System techniques. Five criteria have been taken for disposal site selection namely land use land cover, distance from road and railway, surface water body, Normalised Difference Vegetation Index and household density. Thematic layers are prepared using Remote Sensing and GIS technique. 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 open dumping of solid waste without recycling, which resulted in environmental pollution for this Municipality. The study has been concluded with some fruitful management strategies which may be beneficial to the local people as well as municipal authority.

Introduction:

In recent years, the urban environment has become a major subject of concern. The major environmental problems faced by urban areas are air, water and soil pollution and growing volume of solid waste. Municipal solid waste management is one of the major problems facing by the city planners across the globe. The problem is more serious in developing nations than in developed nations, as their economic growth as well as urbanization is more rapid. Increased urbanization, poor planning, and lack of adequate resources worsen the problem in the municipal solid waste management in most of the developing countries (Davis and Cornwell, 1998; Obirih et al., 2002). The volume of garbage is increasing in Indian cities (Kumar & Gaikwad, 2004). In India, rapid population growth and economic development cause a significant rise in MSW generation during last few years (Kumar et al., 2009). Among the basic essential services, Solid waste management service is provided by local government to keep cities clean and hygienic. Municipal solid waste management (MSWM) is one of the major environmental problems of Bardhaman Municipality. In order to propose any suitable measures for the improvements of the city's solid waste management conditions and reduce the potential problems of the city, it is very important to make a situational analysis of the current conditions. The condition of disposal site of this municipality is not maintained scientifically and properly. Though the Municipality was established in 1865, the solid waste recycling processes have not started till date. Without segregation, solid waste is dumped on the dumping ground. Environmental degradation and pollution take

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place around the landfill site because there is no arrangement of a scientific landfill site in this Municipality.

New communication tools and technology options such as waste-to-energy (or energy from waste) offer possible strategies forward. Ultimately, waste management grants an opportunity, not only to avoid the detrimental impacts associated with waste but also to recuperate resources, realize environmental, economic and social benefits and to take a step on the road to a sustainable future (Guerrero et al., 2013).

Remote sensing and GIS techniques are useful for

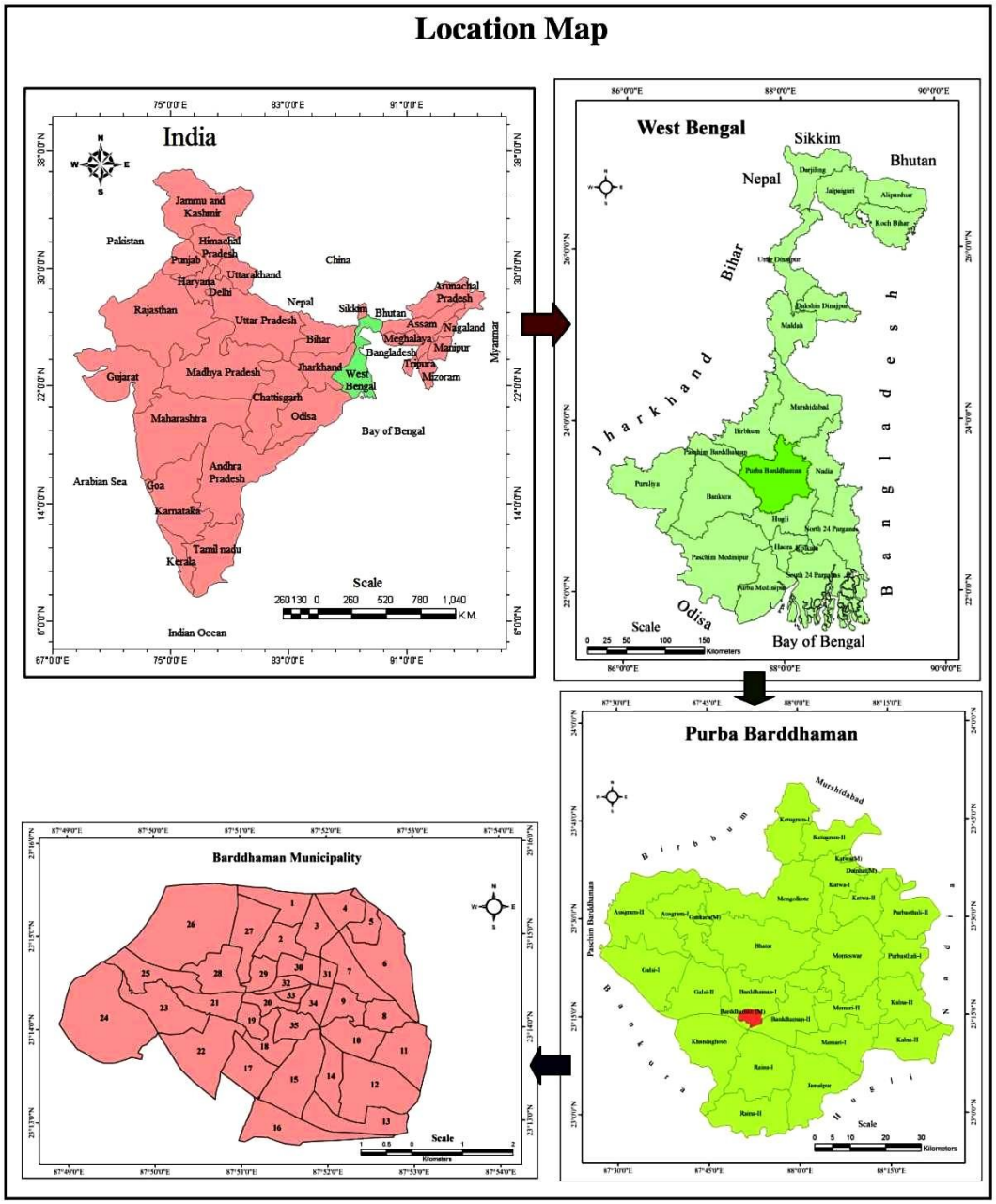

Fig. 1 : Location Map

suitability analysis, site selection problems etc. It has been successfully used to identify proper landfill sites in Mafraq city (Ansari et al., 2012), Khulna City Corporation (Rahaman et al. 2008), Nabadwip Municipality (Paul, 2012), Lucknow City, Uttar Pradesh (Kumar et al., 2014). The main objective of this present research work is to find out suitable solid waste disposal sites in Bardhaman Municipality area. Another objective is to propose recommendation for development of a sustainable solid waste management system for this Municipality.

2.0 Study Area

Bardhaman Municipality is located between 23°12'05" North to 23°16'13" North and 87°49'09" East to 87°53'33" East. The total area of this Municipality is 26.30 sq. km as per the census of 2011. It has an average elevation of 40 meters (131 ft). The main river is the Damodar. Bardhaman district recently divided into two districts such as Paschim Bardhaman and Purba Bardhaman. This Municipality is situated in the central part of Purba Bardhaman District. Bardhaman Municipality was established in the year 1865. In that time municipality covered 12.8 sq km area and the population was 39,818 only. According to the 2011census, area and total population of this municipality are 26.30 sq. km and 3,14,267 respectively. Now the Bardhaman Municipality consists of 35 wards, out of the 35 wards the largest and smallest ward according to the area are 26 no ward and 31no ward respectively.

3.0 Database and Methodology

A visit was paid to the open dumping site which is situated outside the municipality area beside the Bardhaman-Kalna road. Data regarding solid waste was collected from the municipal office, local residents and Municipal Solid Waste handling workers were also interviewed. The questions asked during the interviews were focused towards the satisfactory level of the residents with the municipal solid waste management practice. The continuous field visits helped to monitor the present management methods adopted by the Bardhaman Municipality. The waste bins provided for the secondary collection throughout the study area was inspected. The interviews with the concerned officers were made to assess their strengths and weaknesses in the management of solid waste.

Secondary data and its information have been obtained from a variety of sources, which is given in Table 1.

The analyses have been started after collection of the required datasets. A base map of the study area has been prepared by registering SOI topographical maps on 1:50000 scale into Universal Transverse Mercator projection northern zone 45 datum WGS 1984. Satellite image processing was done in the ERDAS 9.0 software. NDVI was calculated using the band 4 (RED) and band 5 (NIR) of Landsat 8 OLI satellite imagery of March 2017 in raster calculator extension of ArcGIS 10.3.1 Software. The Normalised Difference Vegetation Index (NDVI) is calculated as follows: (NIR – Red) / (NIR + Red). The land use and land covers were classified by the maximum likelihood classification method of supervised classification using the same satellite imagery and software. For assessing the ground validity and application of the study, the statistical analyses have been conducted using the

Table 1. Secondary Data

Secondary data	Source
I. Demographic details from Primary Census abstracts for 2001 and 2011.	Directorate of census operations, Census of India
II. All Secondary data related Solid Waste Management	Bardhaman Municipality
III. Ward maps and Administrative Boundary	Bardhaman Municipality
IV. Survey of India (SOI) topographical sheets	73M/16 scale-1:50000
V. Digital Data	LANDSAT Image (path/row: 139 / 44) OLI-TIRS dated 16th March 2017 Google Earth Image

MSO excel 2007. AHP method has been used in this study for suitable site selection. AHP is a useful tool for managing complex decision making by setting priorities to each factor, it helps to make the best decision by comparing the factors with each other. Thomas L. Saaty pioneered this technique in 1980. This technique reduces the chance of biasness in decision making by checking the consistency of the given priorities. Each factor gets weightage from the pair-wise comparison matrix, higher weight depicts more importance and consequent ranking is given to the factors. It is very simple and flexible tool because it is guided by decision maker's choice and the weightage and the rankings are given according to the pair-wise comparison matrix. All the thematic layers were integrated with their respective weightage to identify the sites for solid waste disposal.

4.0 Result and Discussion

4.1 Present Condition of Generated Waste

The waste generated from the town includes household waste, commercial waste, bio-medical waste and industrial waste. Total solid waste generated in Bardhaman Municipality is 153.48M.T. Per day (Municipality data)

4.2 Disposal of Municipal solid waste

One of the most critical steps in solid waste management system is to dispose the waste materials properly. Uncontrolled dumping is observed throughout the whole municipality which is a serious problem. Construction of a permanent dumping yard in the city is one of the long pending projects.

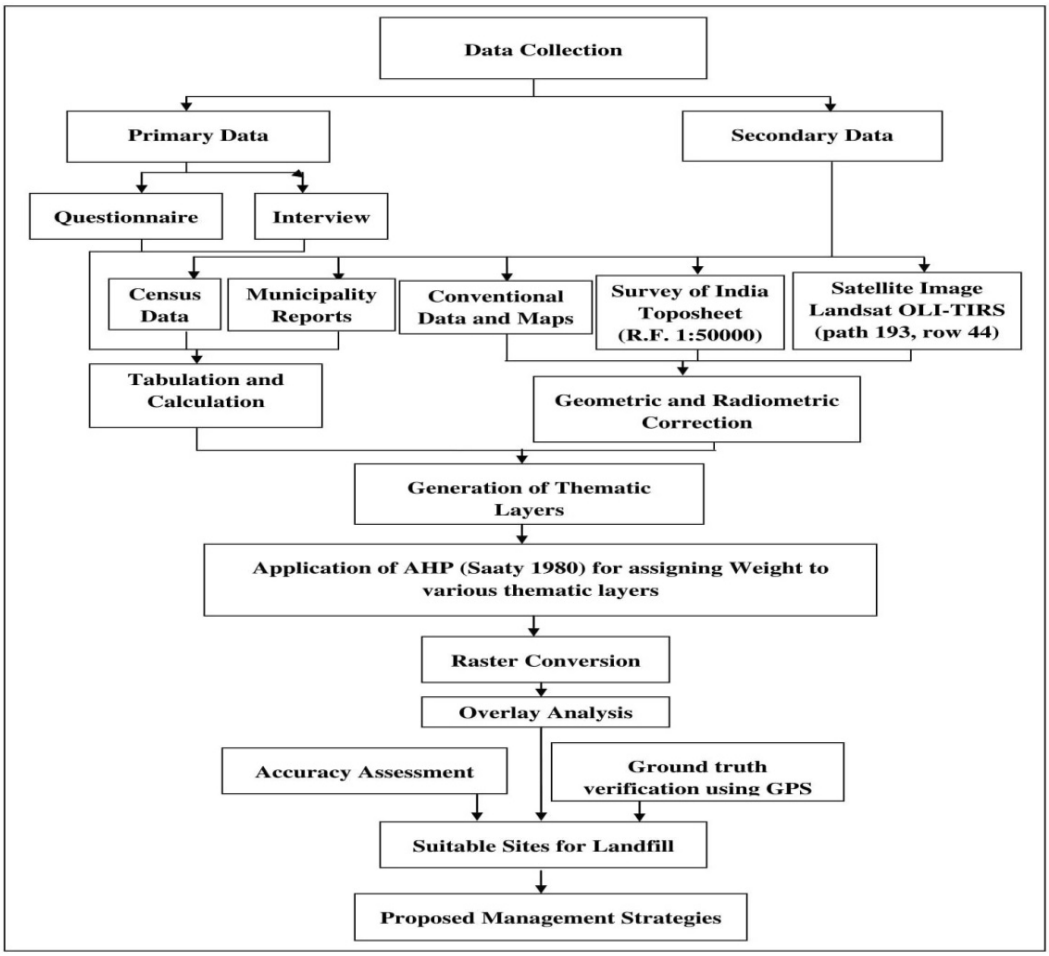

Fig. 2 : Flow Chart of Methodology

Table 2. Waste Generated by Different Categories of Source

Description	As per Municipality Record (in M.T)
Waste from Household	122.55
Waste from Market	15.3
Waste from Agriculture	2.5
Waste from Trade and commerce	9.21
Waste from Others Source	3.92

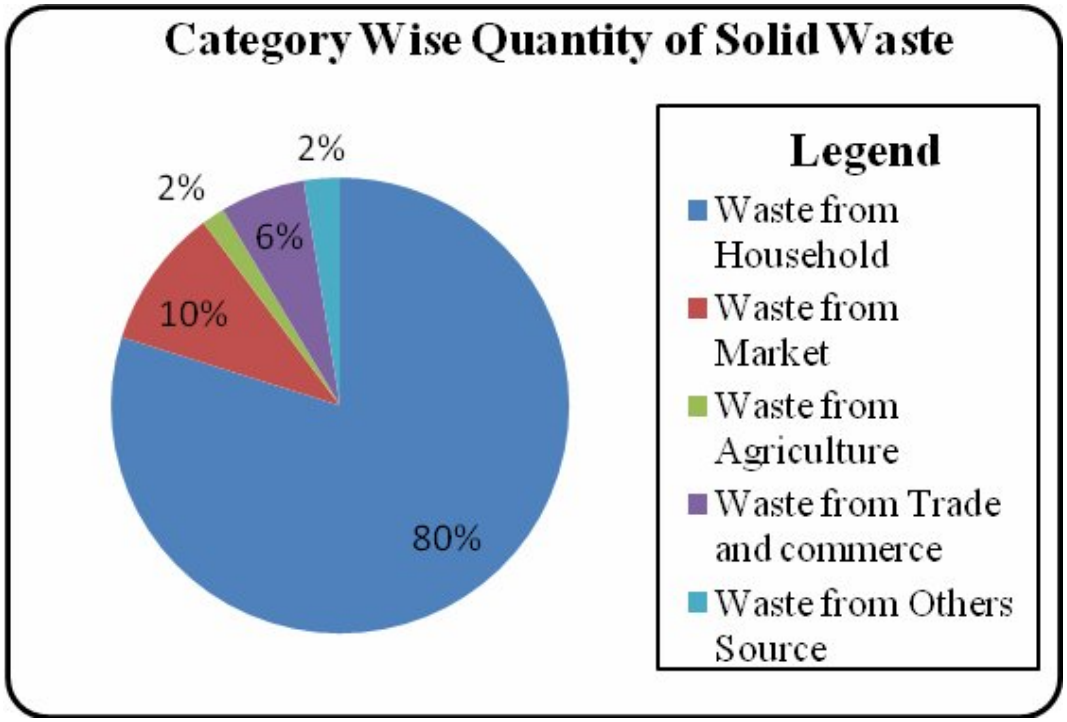

Fig. 3 : Category Wise Quantity of Solid Waste
Source: Municipality data, 2017

The condition of disposal site of this municipality is not maintained scientifically and properly. Without segregation, solid waste is dumped on the dumping ground. Environmental degradation and pollution take place around the landfill site because there is no arrangement of a scientific landfill site in this Municipality. There is currently no treatment plant for solid waste recycling. The dumping site of this municipality is situated beyond the municipality boundary. As dumping area is small, present site is unable to sustain the huge waste, other dumping sites needs to be searched out for effective functioning.

4.3 Disposal Site Selection Criteria

A landfill or disposal site selection depends on many criteria. According to the environment and circumstances of Bardhaman Municipality, five criteria have been considered for this purpose. Each criterion was weighted by the AHP technique. According to the AHP calculations, the weight of the LULC, distance from road and railway, surface water body, household density and Normalised Difference Vegetation Index criteria are 0.359, 0.115, 0.222, 0.216, and 0.084 respectively. The different types of parameters used for the present study are described as follows:

Table 3. AHP weightage value of criterion

class	Pair wise comparison matrices					AHP weightage values
	1	2	3	4	5	
Land use/land cover	1	3.0	2.0	2.0	3.0	0.359
Distance from road	0.33	1	0.33	0.50	2.0	0.115
Distance from water body	0.50	3.0	1	1.0	2.0	0.222
Household density	0.50	2.0	1.0	1	3.0	0.216
NDVI	0.33	0.50	0.50	0.33	1	0.084
Consistency ratio: 0.029						

Table 3. AHP weightage value of sub criterion

Class	Sub class	Pair wise comparison matrices					AHP weightage values
		1	2	3	4	5	
Land use/ land cover	Water body	1	0.50	0.50	0.33	1.0	0.112
	Settlement	2.0	1	0.50	0.33	1.0	0.149
	Agricultural field	2.0	2.0	1.0	0.50	1.0	0.210
	Vegetation	3.0	3.0	2.0	1.0	2.0	0.159
	Playground	1.0	1.0	1.0	0.50	1.0	0.370
Consistency ratio: 0.026							
Distance from road	200	1	1.0	0.50	0.33	0.25	0.088
	400	1.0	1	0.50	0.33	0.25	0.088
	600	2.0	2.0	1	0.50	0.33	0.153
	800	3.0	3.0	2.0	1	0.50	0.257
	1000	4.0	4.0	3.0	2.0	1	0.415
Consistency ratio: 0.008							
Distance from water body	300	1	0.50	0.33	0.25	0.20	0.062
	600	2.0	1	0.50	0.33	0.25	0.097
	900	3.0	2.0	1	0.50	0.33	0.160
	1200	4.0	3.0	2.0	1	0.50	0.263
	1500	5.0	4.0	3.0	2.0	1	0.419
Consistency ratio: 0.015							
Household density	<1500	1.0	3.0	3.0	4.0	5.0	0.451
	1500-3000	0.33	1.0	2.0	3.0	4.0	0.239
	3000-4500	0.33	0.50	1.0	2.0	3.0	0.155
	4500-6000	0.25	0.33	0.50	1.0	2.0	0.095
	>6000	0.20	0.25	0.33	0.50	1.0	0.060
Consistency ratio: 0.028							
NDVI	-0.04 – 0.01	1	0.50	1.0	2.0	2.0	0.207
	0.01 – 0.03	2.0	1	2.0	2.0	4.0	0.359
	0.03 – 0.10	1.0	0.50	1	2.0	2.0	0.207
	0.10 – 0.20	0.50	0.50	0.50	1	2.0	0.139
	0.20 – 0.40	0.50	0.25	0.50	0.50	1	0.090
Consistency ratio:0.022							

4.3.1 Land use and land cover

In the present study area, various categories with their aerial extent and spatial distribution are shown in the land use land cover map. Based on the satellite data of Landsat OLI-TIRS, various classes of land use land cover are interpreted. The different categories of land use land cover existed in the present study area are briefly described as follows:

1) Agriculture land - The land which is used primarily for farming and for the production of fiber, food, horticultural crops and commercial crops come under the category of farm land. It includes plantations, irrigated land and non-irrigated land. The agricultural land in the present study area is about 9.20 %. **2) Water bodies** -This category comprises areas with surface water in the form of ponds, lakes, tanks and reservoirs. There are few major water bodies present in the study area and is about 3.50 %. **3) Settlement** - Settlement means mainly built up area of human beings.The settlement area of this Municipality is 16.35Sq. Km. **4) Vegetation** - Those areas are covered by flora called vegetation zone. The area of vegetation is 5.47 Sq. Km. **5) Playground** - Playground means park, open recreational place, ground etc. The playground in the present study area is about 4.33 %.

Among five categories of LULC, water bodies, settlement and vegetation are avoided for landfill site selection.

4.3.2 Road network

The transportation network map has been prepared from the Survey of India (SOI) topographical map and Google earth image. Distances of different sites from existing transportation network have been measured for proximity of transport network with respect to each site.

Location of the landfill close to a road would help reduce costs related to transportation (Bhat., 1996). To accomplish this, the major road layer (fig.5) and a buffer zone around the major roads were created.

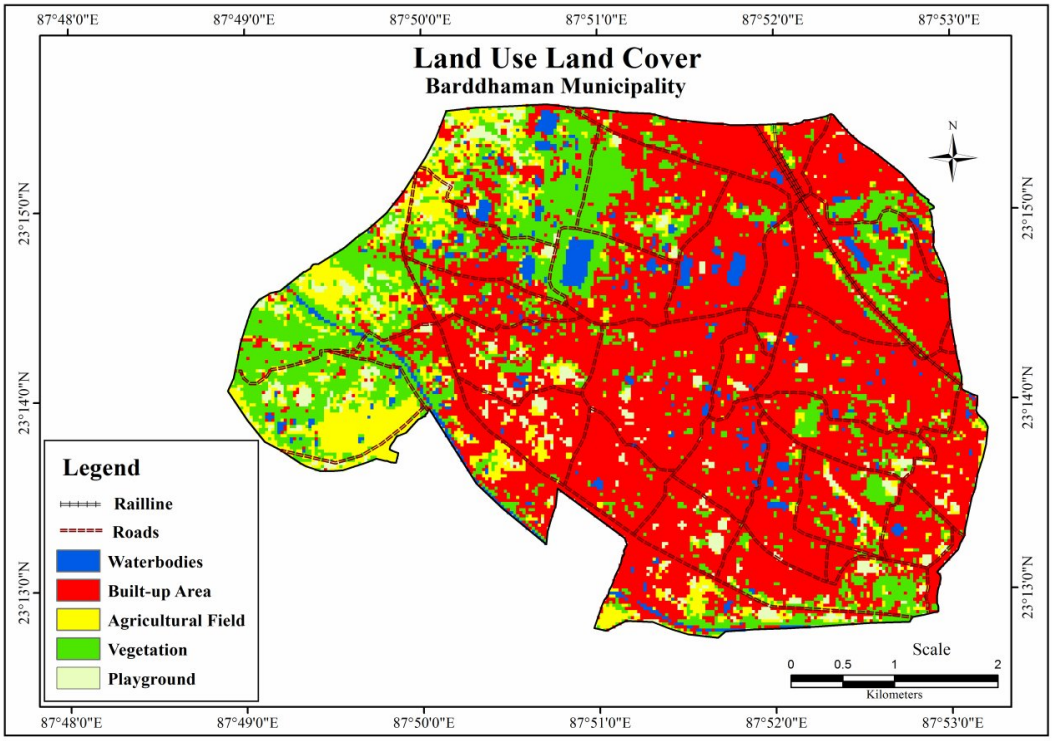

Fig. 4 : Land Use Land Cover
Source: Landsat OLI-TIRS, 2017 (path/row: 139 / 44, dated 16th March 2017)

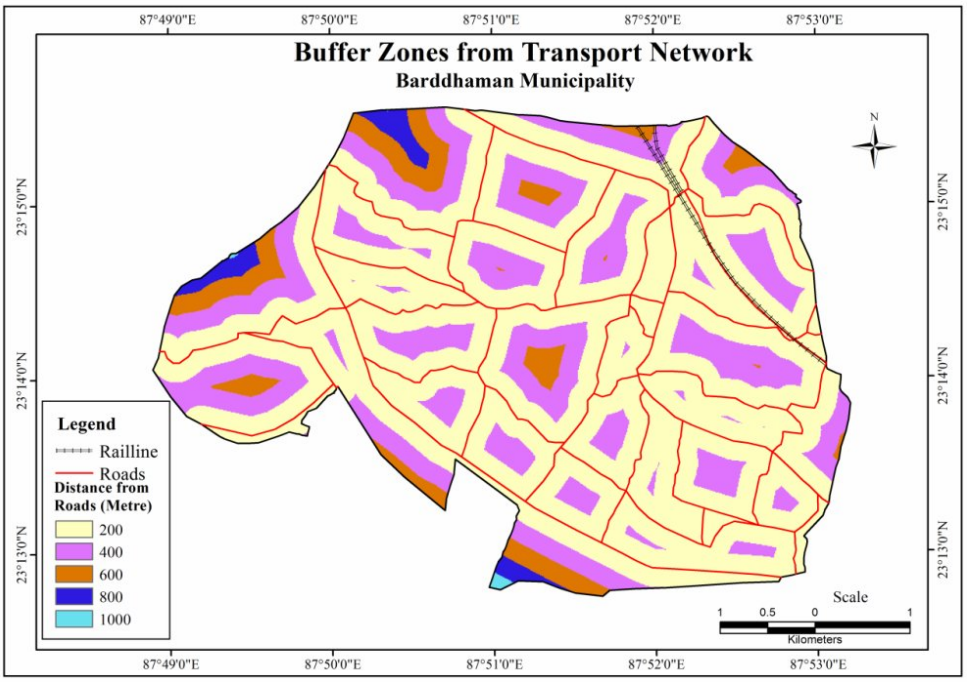

Fig. 5 : Buffer of Transport network
Source: Toposheet and Google earth

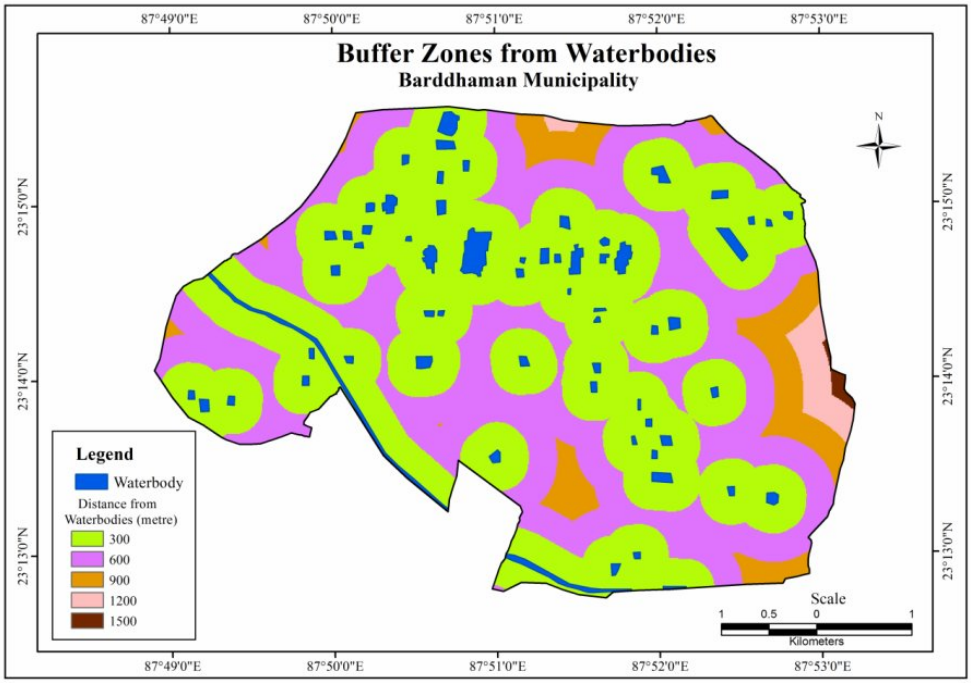

Fig. 6 : Buffer of water bodies
Source: Toposheet and Google earth

4.3.3 Surface water

Surface water contamination is a major concern for the setting of municipal landfill sites. It is always ideal to locate landfill far away from water bodies (lakes, ponds, rivers etc.) as far as possible (CPCB, 2000). A buffer map of the surface water is done for 300m, 600m, 900m, 1200m, and 1500m.

4.3.4 Household density

Household density is also an important criterion for disposal site selection. Mainly, it has been found that maximum vacant places are present in that area where the household density is low. Low household density is observed in the western parts where household density is below 1500.

4.3.5 NDVI

NDVI is selected as one of the criteria because of its capacity to identify dry bare soil, which represents fallow land or wasteland and they are most suitable for disposal sites. NDVI value 0.025 is best for dumping ground. The NDVI map is classified into five classes and NDVI value 0.025 belongs to 0.01 to 0.03 classes (figure no 8), so this is suitable for landfill.

From figure no.9 it is found that -0.04 to -0.01 class represent the water bodies of the study area which was given less weightage in AHP. Only 0.01 to 0.03 class areas are suitable for landfill site which was given a higher value.

4.3.6 Suitability Assessment

This approach consists of finding appropriate sites that may present favorable conditions for solid waste disposal. The various datasets were analyzed based on environmental and social criteria. Based on the available data, the site suitability map and suitable sites are presented (fig.9). The thematic maps are converted into raster form because the overlay analysis uses only raster files. The conversion tools are used to convert vector layer to raster layer. The raster layers itself generates its own numbering to different fields. All the converted rasters are reclassified, which is used to reclassify the fields into different groups and assigned new values to rasters according to the classification. The weights are given to each reclassified rasters according to their importance with respect to the site selection. Accumulation and the total percentage of influence

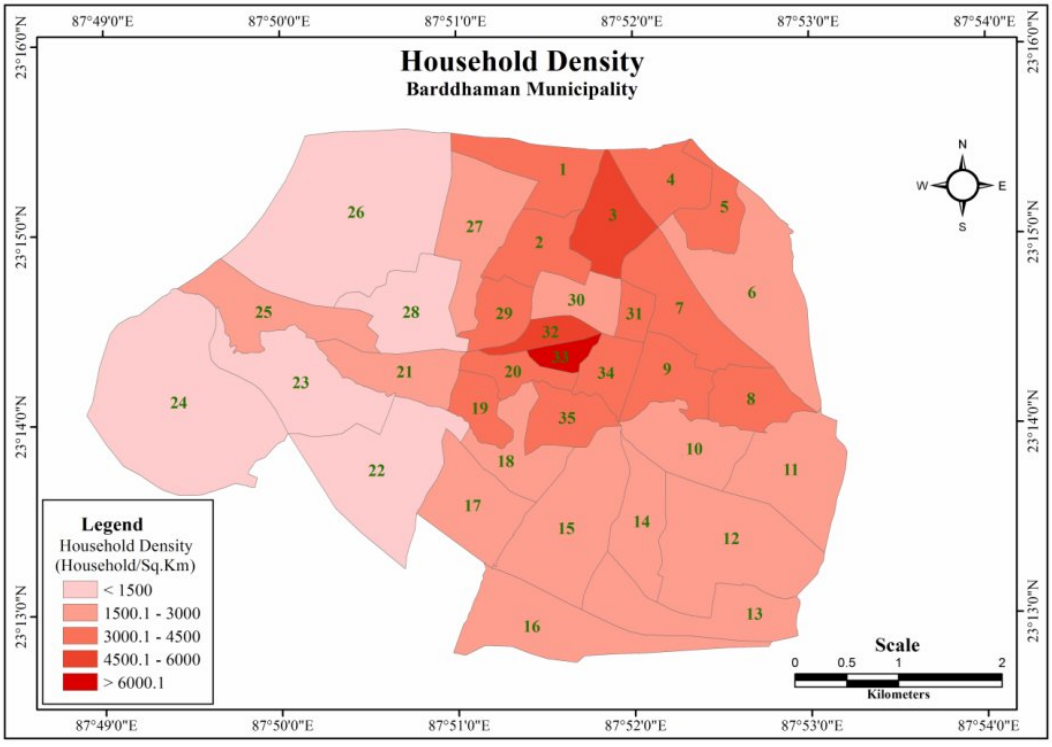

Fig. 7 : Household Density
Source: Census of India 2011

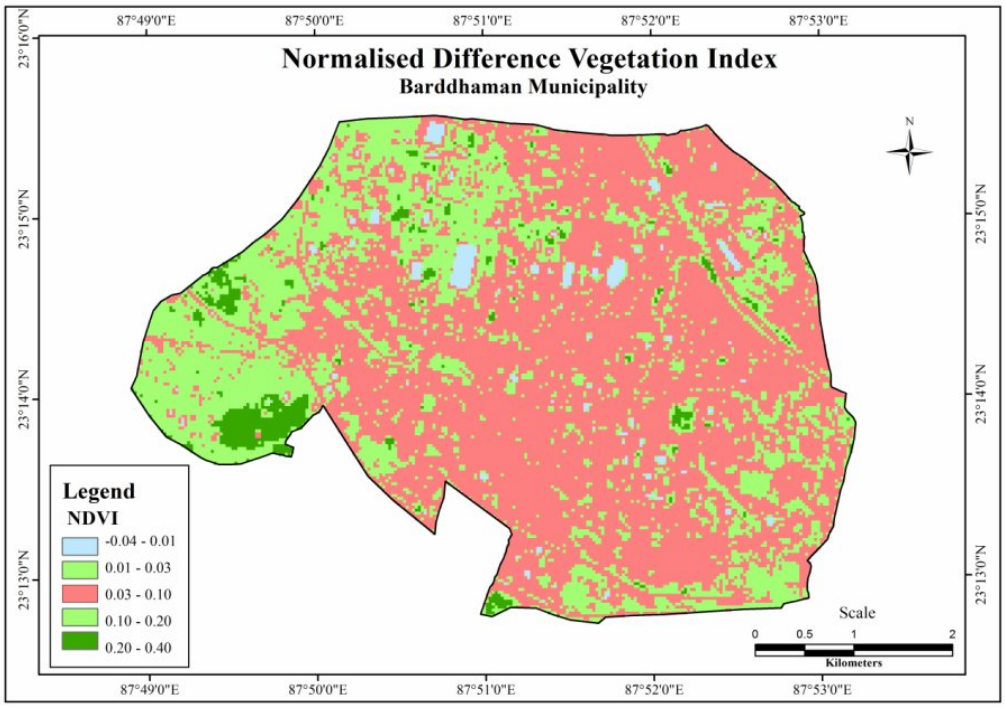

Fig. 8 : NDVI map

Source: Landsat OLI-TIRS, 2017(path/row: 139 / 44, dated 16th March 2017

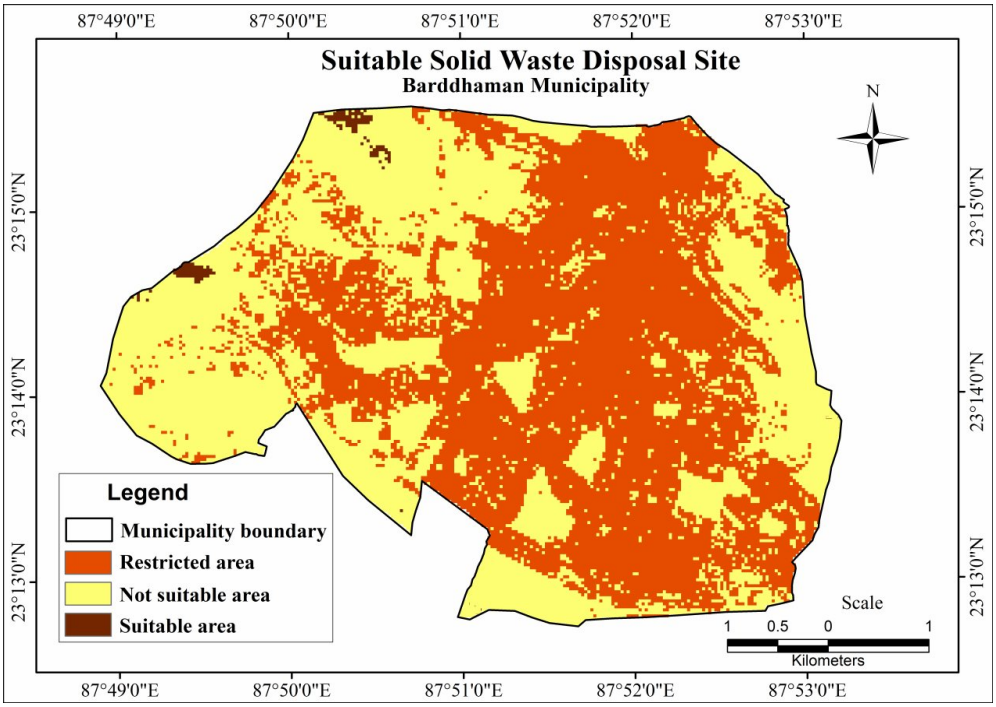

Fig. 8 : Suitable area for disposal site

are given as 100%. The final suitable map is evaluated using overlay method in Arc Gis.

The percentage of influence given to Land use land cover, Distance from the road, Distance from water bodies, Household density and NDVI are 35.9%, 11.5%, 22.3%, 21.6% and 8.7% respectively. The output raster is converted into vector form to obtain the areas of each zone in the prospect map.

The result indicates maximum parts of the study area have very low suitability for disposal site. Only two areas in this municipality have been proposed for disposal site, one is situated in ward no. 24 and another in ward no. 26.

Fig. 10 : Field photographs of possible land sites within Ward No. 24(A) and 26 (B).

The result of the AHP method is compatible with our field observations. Two sites are suggested for disposal site because these regions were determined to be high suitability regions by the AHP and GIS techniques (Figure 9). When the disposal sites are determined, the location of settlements, amount of solid wastes and transportation of waste are considered.

4.4 Suitable Management Strategies

Sustainable management involves scientific, hygienic, controlled and proper management of solid waste which reduce the environmental degradation and health risk. The following recommendations are proposed to minimize the drawbacks of solid waste management of Bardhaman Municipality.

Some recommendations are as follows regarding the collection of solid waste:

1. Number of community bin should be increased and properly placed.
2. Economically backward people may be employed for this work.
3. The workers should be trained and well equipped.
4. Care should be taken during transportation
5. Transport vehicles should be well covered.
6. Municipal authority needs to provide red and green bucket to every household for non-degradable and degradable waste respectively.
7. Municipal authority should recruit expert at every ward for better monitoring of solid waste management.

Some proposals for better transportation system of solid waste are as follows:

1. In this Municipality only 276 vat trolleys are available which is not sufficient for collection and transportation of solid waste. 352 more vat trolleys are required for this matter.
2. Truck and vat trolleys both should be covered to reduce environmental degradation.
3. Separate vat trolleys are needed for non-biodegradable wastes.
4. Trolleys are preferable in place of community bins.
5. The number of compactors should be increased.

The recommendations made in the proposal to make waste collection, temporary storage, transfer, processing and the disposal of waste are mandatory pre-condition in urban planning. This will help the municipality to design and plan the future

development of the city in such a manner that a mechanism for sustainable solid waste management will be automatically incorporated.

Public consultation should be made a prerequisite for any solid waste management system. By doing so, the Bardhaman Municipality stands to gain on many different fronts. Foremost, public involvement in decision making may help the Bardhaman Municipality to bring the issue at hand to the people. This may in turn help in informing the people and making them aware of the existing problems or solutions proposed. People may be able to share their ideas, thoughts and concerns regarding various aspects of solid waste management in Bardhaman Municipality. This may make the system transparent and efficient, as decisions once taken with general consensus will be easier to execute and people will be hopefully more willing to help to execute the plan by reducing their waste, segregating their waste and so on.

At the present situation, in Burdwan Municipality, construction of landfill is of prime importance, which is more hygienic than open dumping ground. This should be well equipped, well managed and lined properly with impermeable materials such as plastics as a protection against contamination of soil, surface water as well as groundwater. The basic principles of the measure are to deposit the garbage, compact it with bulldozer and cover the materials with at least 6 inches of dirt. There must be a provision to tap CO_2, methane gas and other greenhouse gases (GHGs) from landfill site during anaerobic decomposition of waste. Before disposing of waste materials to a landfill, the volume of waste can be reduced through thermal treatment. The excessive amount of heat produced during this treatment can be used as non-conventional energy.

One of the important methods of managing and treating organic wastes (plant materials, food scraps etc.) is composting. For the purpose, compost plants with windrows (8-10ft wide, 4-6ft high) are necessary, where under controlled condition of temperature (140°F), humidity and O_2, the organic materials are converted into compost that can be used as bio-fertilizer in surrounding agricultural field of the rice bowl of West Bengal.

Regular ward level meetings should be organized to keep the people involved and informed. Baseline data on the status of waste generated, collected, properly disposed, recycled, composted and thrown in the street etc - should be generated. For this, local bodies and institutions can play a substantial and an active role. Research and development should be promoted and encouraged.

5. Conclusion

The present work was taken up to study the problems of solid waste management and open dumping of MSW at Bardhaman Municipality. The study also suggests a sustainable solution for the solid waste problems. The result showed that the current solid waste management is unsustainable in the long run based on some key factors like waste generation, waste disposal practices, waste collection and transportation, changing nature of waste etc. The proposed system is an improvement on the existing system and has much strength, but it does not address the whole issue. Two disposal sites have been identified in this study as a sustainable landfill site. The process of solid waste management has been initiated by municipal government and has also taken some new ideas to improve.

Following the socio-cultural, and geo-political setting of the area, along with the understanding of the strengths, weaknesses and problems associated with current waste management system and practices, recommendations were made based on the present status. These recommendations have the potential to make the solid waste management system in Bardhaman Municipality more sustainable in the future.

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