Trans.Inst.Indian Geographers
ISSN 0970-9851

Identification of suitable landfill sites in Barddhaman development authority, West Bengal using AHP and GIS techniques

Chiranjit Ghosh, Burdwan, West Bengal

Abstract

Urbanization and industrialization lead to the generation of a huge amount of solid waste which is a major environmental problem in recent years. The importance of landfill sites for disposal of the wastes in such a situation is of paramount need not only in major metropolises but also in smaller order cities. Bardhaman municipality, a relatively small town in West Bengal is increasingly facing the burden of waste disposal which needs a proper disposal site. Disposal site selection is a complex process as it depends on social, environmental, political, and technical parameters. In this study, four criteria have been considered to identify suitable disposal sites namely land use land cover, distance from road and railway, surface water body, and distance from the settlement. Landfill sites have been identified based on remote sensing, GIS, and AHP. Based on overlay analysis mainly 3 classes are prepared such as most suitable, moderately suitable, and not suitable which occupies 0.26%, 10.55%, 89.19% of Barddhaman Development Authority respectively.

Keywords: *Municipal solid waste, landfill, analytical hierarchy process, GIS.*

Introduction

Effective Municipal solid waste management is essential to healthy urban living because of the high concentration of population that generates a large amount of garbage. Nowadays, Suitable land for disposal site is scarce due to the growing concern for public health, safety, and groundwater resources contamination. Proper selection of dumping sites for solid waste is one of the biggest challenges as it has a direct effect on its surrounding environment and community (Davis and Cornwell, 1998). Bardhaman municipality, a relatively small town in West Bengal faces serious problems related to waste management and landfill site selection. Selecting a suitable site for garbage disposal cannot be based on a single factor. Multi-dimensional independent criteria such as local geomorphology, geology, slope, land use land cover, surface water body, vegetation, groundwater, soil, transport network, settlement or built-up area, protected area need to be factored while selecting an appropriate site for disposal of solid waste. (Javaheri et al., 2006; Şchiopu et al., 2009; Nas et al., 2010; Şener et al., 2010; Jaybhaye et al., 2014; Paul et al., 2014; Foroughian et al., 2015). Given the inherent complexities of the site selection process, the present study carefully selects only four of the important

criteria namely land use land cover, distance from road and railway, surface water body, and distance from the settlement as these factors are found to be crucial in the town. Analytical Hierarchy Process (AHP) and Geographic Information System (GIS) techniques are used for identifying suitable landfill sites in Bardhaman development authority. These have been successfully used to find out the landfill in many towns such as Khulna in Bangladesh (Rahman et al., 2002), Nabadwip municipality in West Bengal (paul, 2012), Thiruvananthapuram corporation area of Kerala (Asha Poorna, and Vinod, 2016), Lucknow city in Uttar Pradesh (Kumar, Yadav and Rajamani, 2014), etc.

The Study Area

The Barddhaman development authority (BDA) is located between 87°47'59.09"E and 87°57'12.09"E longitude, and 23°10'56.44"N and 23°19'15.44"N latitude (Fig.1). The area is spread over 144 km^2. The study area includes within itself the Municipality and seven gram panchayats. There is not enough space to take the load of waste products in the Burdwan Municipality for a built-up landfill site, so Bardhaman Development Authority area has been considered for this purpose.

Materials and Methodology

Different kinds of data were used in this paper to acieve the objective of identifying a suitable landfill site. To meet the set objectives of the study, Survey of India topographical (SOI) Map sheet no. 73M/16 surveyed between 1973-76, on 1:50,000 scale and satellite image i.e. LANDSAT Image (path/row: 139 / 44) OLI-TIRS dated 16th March 2017, Google Earth Image downloaded from the internet has been used for the preparation of multi-criterion layers i.e. landuse/landcover, road/transport-network and the data related to solid waste generation in the city was collected from Bardhaman Municipality. The data procured/collected from various departments were digitized and converted into digital format in Arc GIS and ERDAS software for spatial analysis.

SOI topographical sheet 73M/16 on scale 1:50000 has been used as a base map. All the maps have been registered into Universal Transverse Mercator projection northern zone 45 datum WGS 1984 in ArcGIS software. Satellite image processing was done in the ERDAS 9.0 software. Land use and land covers were classified by the maximum likelihood classification method of supervised classification using the same satellite imagery and software. Then a suitable landfill site map was prepared with the help of all thematic layers using ArcGIS software.

Application of analytical hierarchical process

The study aims at identifying the suitable zone for disposal of wastes using the Analytical Hierarchical Process (AHP). AHP is a semi-quantitative approach where decisions are taken through hierarchical analysis of associated variables by assigning numerical scores through pair-wise comparison that represents the importance of every individual factor (Saaty, 1980, 1994). This approach includes the decomposition of the decision-making process into a hierarchy of criteria and alternatives. The preference values are assigned to each factor according to the importance scale of AHP to determine the relative importance in connection with the goal (Saaty, 1980).

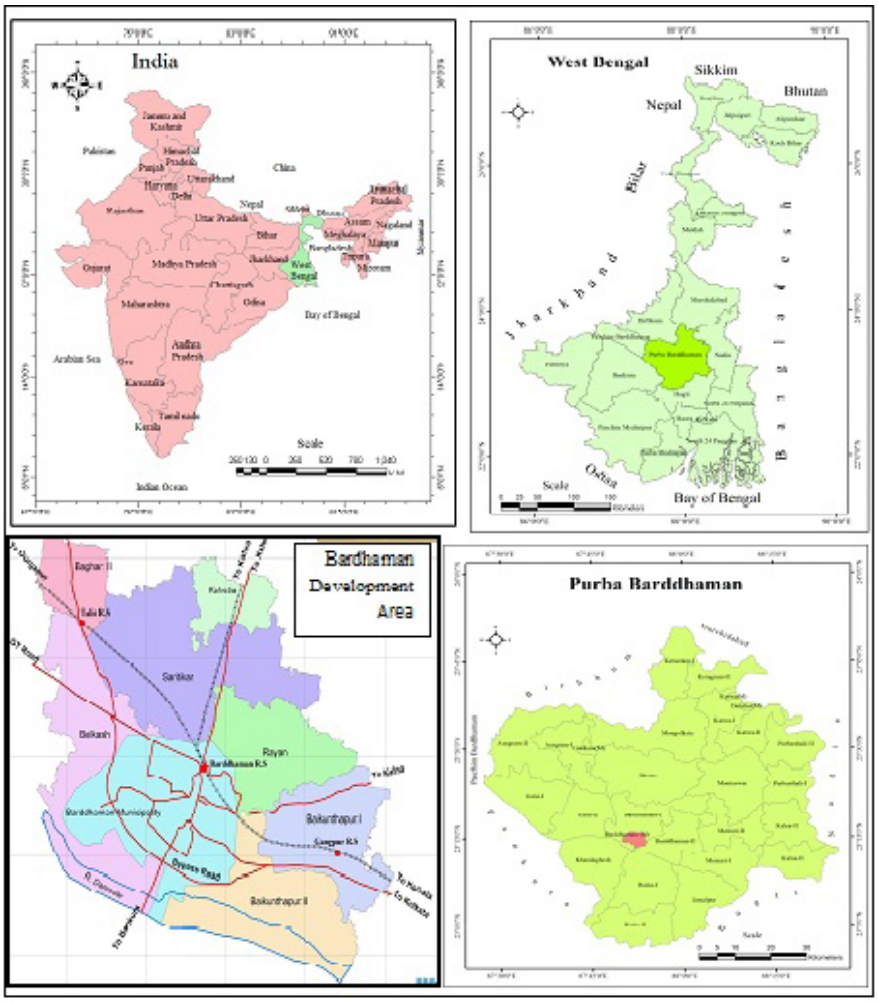

Fig 1: Study Area

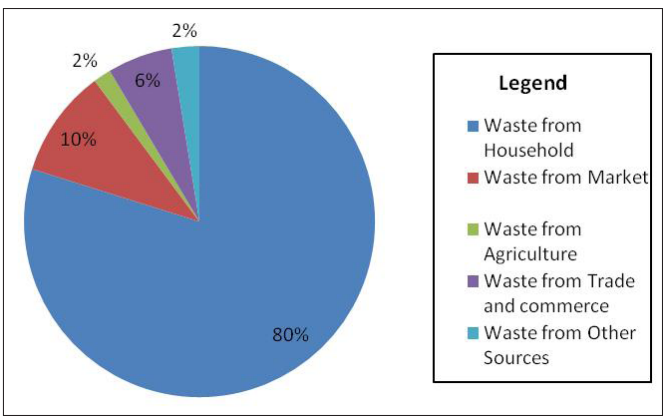

Fig 3: Category Wise Quantity of Solid Waste

Source: Municipality data, 2017

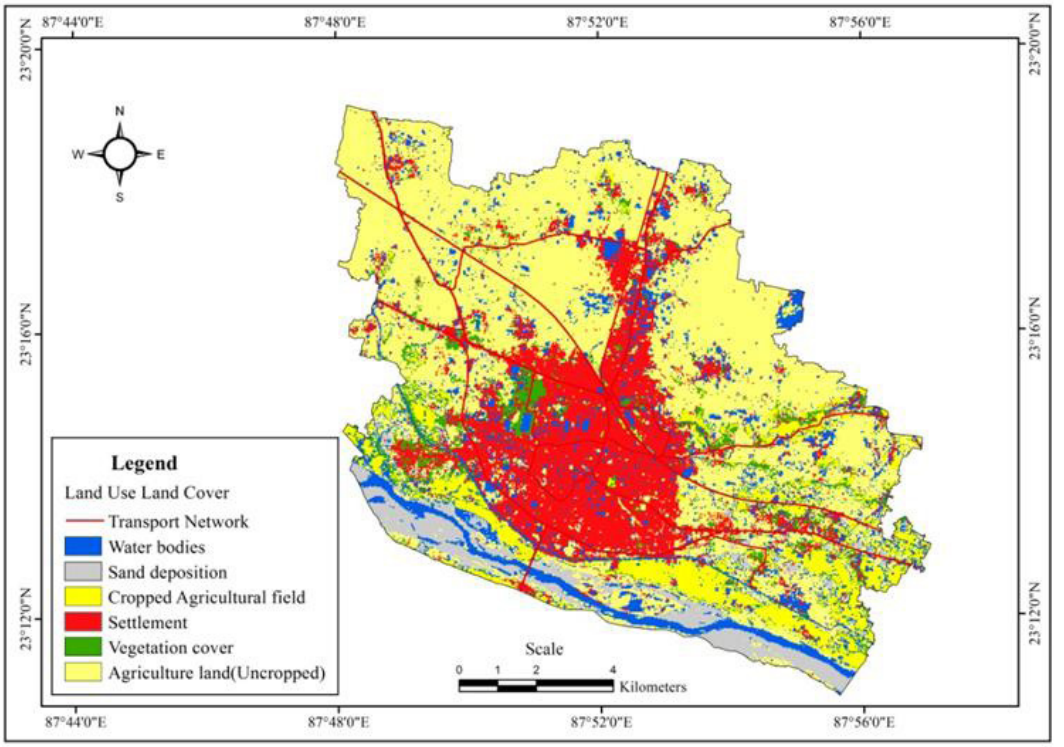

Fig 4: Land Use and Land Cover

Source: Landsat OLI-TIRS, 2017

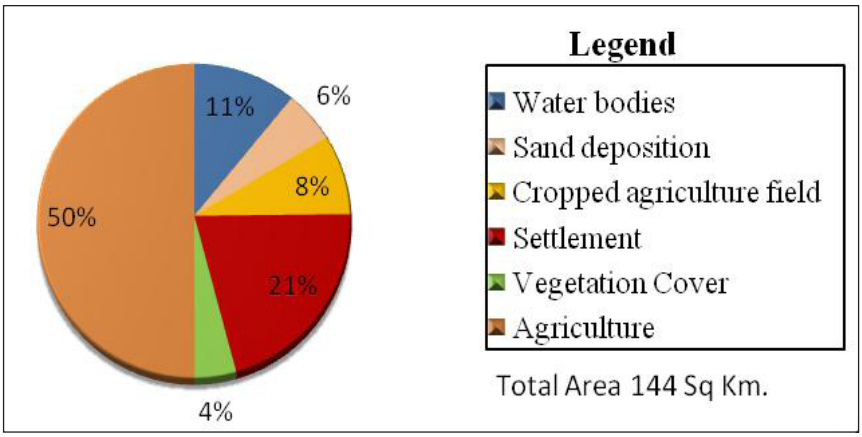

Fig 5: LULC Categories

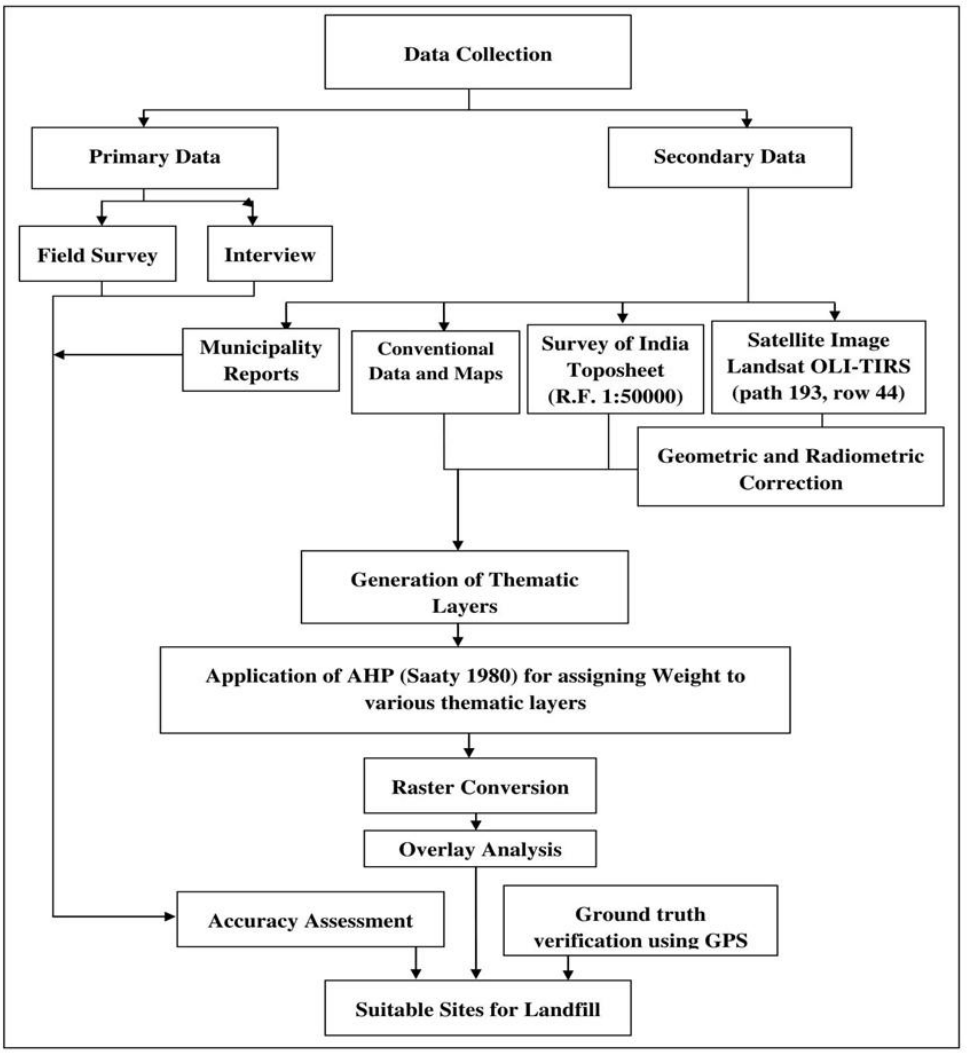

Fig 2**:** Methodology

Generation of suitable zones

Each criterion was weighted by AHP and mapped using GIS techniques. Thematic layers were prepared using Remote Sensing Data and GIS technique. For final output, all thematic layers were converted to the AHP weightage value using the Overlay analysis method in Arc GIS Software. Six sites for solid waste disposal could be identified within the Barddhaman Development Authority based on remote sensing, GIS, and AHP**.** Variable factor weights (w) and individual factor weights (wi) for each thematic layers were assigned to identify the disposal site. Spatial integration of all map layers was done using the raster calculator tool of ArcGIS 10.3.1 software version. For assigning weights, the spatial

occurrence of every parameter in the study area was observed carefully. Then a Linear Sum Combination method was adopted for identifying the Land Suitability Index (Şener et. al., 2010, Vasiljevic et.al., 2012) in RS-GIS environment and Land Suitability Index of the study area was determined by calculating:

$$\mathbf{LSI} = (LULC_w * LULC_{wi}) + (DfR_w * DfR_{wi}) + (DfW_w * DfW_{wi}) + (DfS_w * DfS_{wi})$$

Table 1**:** Scale of preference between two parameters in AHP (Saaty, 2000)

Scales	**Degree of preference**	**Explanation**
1	Equally	Two activities contribute equally to the objective
3	Moderately	Experience and judgment slightly to moderately favour one activity over another
5	Strongly	Experience and judgment strongly or essentially favour one activity over another
7	Very strongly	Activity is strongly favored over another and its dominance is shown in practice
9	Extremely	The evidence of favouring one activity over another is to the highest degree possible of an affirmation
2,4,6,8	Intermediate values	Is used to represent compromise between the preferences in weights 1, 3, 5, 7, and 9
Reciprocals	Opposites	Is used for inverse comparison

Where, LSI= Land Suitability Index, LULC = land use land cover, DfR = Distance from Road, DfW = Distance from Water bodies, DfS = Distance from the settlement, the subscripts w and wi refer to the normalized weight of a theme and normalized weight of individual features of a theme respectively.

Result and Discussion

Present Condition of Generated Waste

The town generates wastes from a variety of sources including households, commercial establishments, bio-medical use, and industries. According to the census undertaken in 2011, the total number of households in Barddhaman Municipality is about 71618 and the population is 314265. As per the records available with the Municipality, about 122.55 Metric Tons of domestic solid waste are generated every day. The total quantity of solid waste generated in Barddhaman Municipality is 153.48 Metric Tons per day. Most (80%) of the total wastes is thus generated by the households. Waste generated from other sources includes 2% by agriculture, 6% from commercial establishments, and 10% from markets, hotels, vegetable markets, and fruit shops (Fig.3).

Current Status of Solid Waste Disposal

At present, the disposal site is located outside of the Municipal boundary in the

eastern part of the municipality beside Barddhaman-Kalna road. Needless to mention, scientific processing for disposal of solid waste is not at all practiced while disposing of solid wastes. The disposal site lacks maintenance too. Construction of a permanent dumping yard in the city is one of the long-pending projects.

Though the Municipality was established in 1865, the solid waste recycling process has not started till date. The solid waste is dumped on the dumping ground without a segregated state leading to environmental degradation and pollution of the landfill site and beyond. There is no treatment plant for solid waste recycling either. The present dumping site is situated outside of the municipality boundary. The small size of the dumping site is unable to cater to the ever increasing solid waste, necessitating the search for more suitable sites for effective functioning. This present exercise is an effort to identify suitable landfill site for the Municipality.

Selecting Landfill site- the AHP Criteria

As stated earlier, selection of a landfill site depends on many criteria that vary from one region to another depending upon local conditions and circumstances. After a close scrutiny of the prevailing environment and circumstances of the Barddhaman Development Area, four major criteria were considered extremely vital. These are: land use/land cover, distance from the road, distance from water bodies, and distance from settlement patches. Each criterion was weighted by AHP and mapped using GIS techniques. The consistency ratio of land use land cover, Distance from Road, Distance from Water bodies, Distance from settlement, and all factors are below 10% or 0.10 which is acceptable as per AHP criteria. All of the considered criteria and their sub-criteria are summarized in table 2.

Land Use and Land Cover

Land use/land cover map has been prepared using Landsat OLI-TIRS data and six broad categories of land use have been identified and mapped namely cropped agriculture land, built-up/settlement, water bodies, uncropped agriculture land, sand deposit and vegetation cover (Fig.4 and 5). According to Thoso (2007) scrubland is moderately suitable for disposal sites. Sites nearby built-up areas, vacant plots, and other important recreational places are unsuitable for disposal.

Irrigated and non-irrigated arable lands, water bodies, built-up areas are generally considered unsuitable to landfill sites.

Settlements

Disposal sites near the settlement areas are to be avoided as they bring in various environmental problems. Landfill sites, therefore, need to be away from cities, towns, or villages due to odour and health issues. According to the Central Pollution Control Board Regulations (2000), landfills cannot be located within 1000 meters of settlement areas (Fig.6).

Transport network

Proximity to roads is an important consideration for landfill site selection. Landfill sites should not be too close or too far from the road because of both environmental and cost point of view.

Table 2**:** AHP weightage value for criteria

Factors	Sub-classes	Pairwise comparison matrices						AHP weight values
		1	2	3	4	5	6	
Land use/ land cover	Water bodies	1	1.0	1.0	1.0	1.0	1.0	0.164
	Sand deposit	1.0	1	0.50	1.0	1.0	0.50	0.129
	Agricultural field (cropped)	1.0	2.0	1	1.0	1.0	0.50	0.164
	Settlement	1.0	1.0	1.0	1	1.0	0.50	0.143
	Vegetation	1.0	1.0	1.0	1.0	1	0.50	0.143
	Agricultural field (uncropped)	1.0	2.0	2.0	2.0	2.0	1	0.258
Consistency ratio: 0.017								
Distance from road	<500	1	0.50	0.33	0.20	0.20	0.33	0.052
	500-1000	2.0	1	0.50	0.33	0.50	0.50	0.093
	1000-1500	3.0	2.0	1	1.0	2.0	3.0	0.261
	1500-2000	5.0	3.0	1.0	1	2.0	3.0	0.292
	2000-2500	5.0	2.0	0.50	0.50	1	2.0	0.184
	2500-3500	3.0	2.0	0.33	0.33	0.50	1	0.119
Consistency ratio:0.032								
Distance from water body	<400	1	0.50	0.33	0.25	0.20		0.062
	400-800	2.00	1	0.50	0.33	0.25		0.097
	800-1200	3.00	2.00	1	0.50	0.33		0.160
	1200-1600	4.00	3.00	2.00	1	0.50		0.263
	1600-2000	5.00	4.00	3.00	2.00	1		0.419
Consistency ratio:0.015								
Distance from settlement	<400	1	0.50	0.33	0.25	0.25	0.50	0.060
	400-800	2.00	1	0.33	0.33	0.50	0.50	0.089
	800-1200	3.00	3.00	1	0.50	1.00	1.00	0.185
	1200-1600	4.00	3.00	2.00	1	2.00	3.00	0.329
	1600-2000	4.00	2.00	1.00	0.50	1	2.00	0.202
	2000-2400	2.00	2.00	1.00	0.33	0.50	1	0.135
Consistency ratio:0.021								
All Factors	Land use/land cover	1	1.0	2.0	2.0			0.340
	Distance from water body	1.0	1	1.0	2.0			0.281
	Distance from settlement	0.50	1.0	1	2.0			0.239
	Distance from road	0.50	0.50	0.50	1			0.340
Consistency ratio:0.022								

Note: Consistency Ratio compares the Consistency Index and Random Consistency Index. If the value of Consistency Ratio is smaller or equal to 10%, the consistency is acceptable.

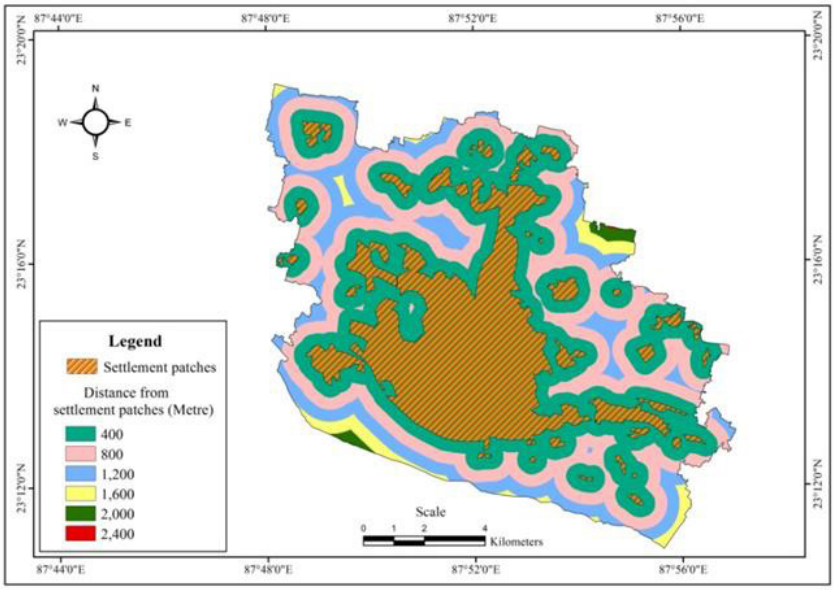

Fig 6: Buffer zone from settlement patches

Source: Landsat OLI-TRIS, 2017 and Google earth

Note: settlement buffers are created for 400m, 800m, 1200m, 1600m, 2000m and 2400m. Each buffer zone was weighted by AHP.

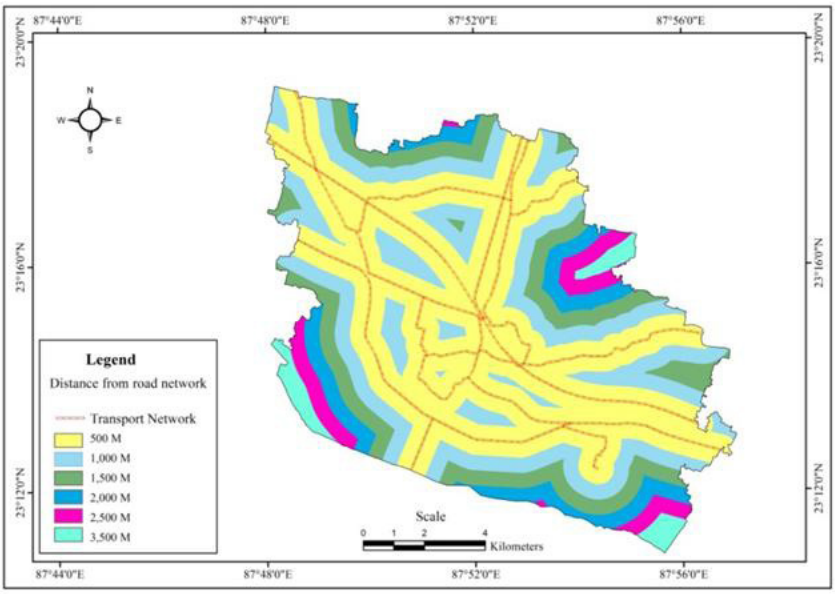

Fig 7: Buffer zone from transport network

Source: Toposheet and Google earth

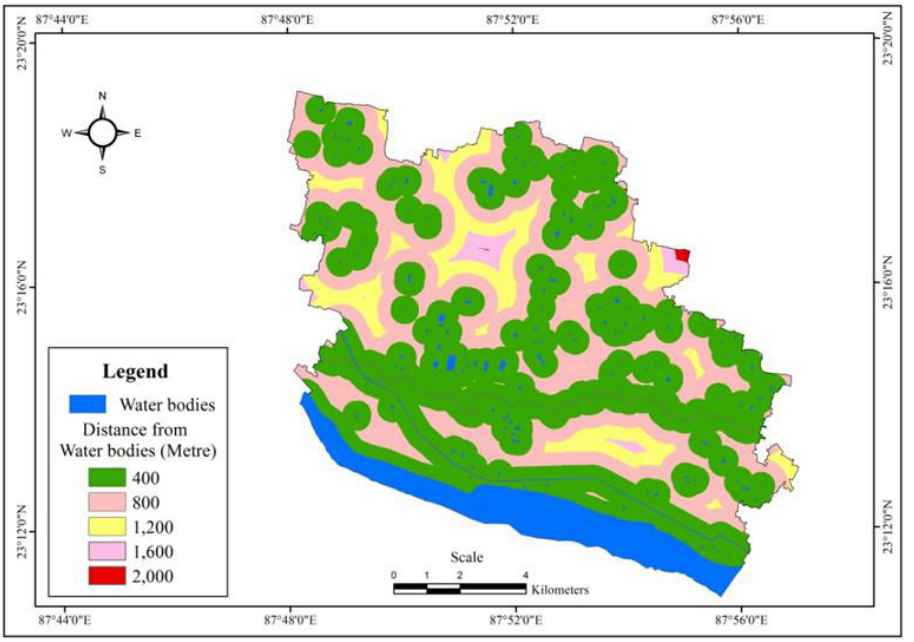

Fig 8: Buffer zone from water bodies

Source: Toposheet and Google earth

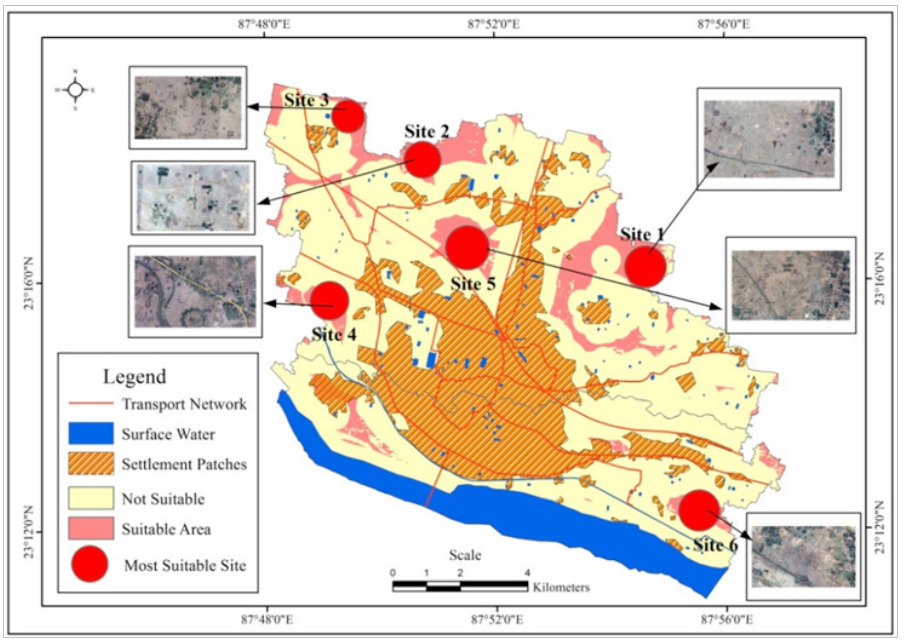

Fig 9: Suitable area for Landfill

Figure 7 shows that buffer from roads is 500m, 1000m, 1500m, 2000m, 2500m, 3000m, and 3500m respectively.

Surface Water

The water layer is constructed in order to generate a buffer zone around because it is unsuitable to place a landfill close to water bodies primarily due to environmental concerns. For this reason, a 400 metre buffer is used to generate the buffer around all the water bodies (fig 8). The location of a landfill site, if within 1000 m. from river and canal (Thoso, 2007); 500 m. from the drain and 200 m. from large water bodies are considered unsuitable for landfill (Rahman et al., 2007) (Fig. 8).

According to the Central Pollution Control Board (CPCB) Regulations, landfill sites should not be placed near any surface water like a lake, pond, river, and stream (Central Pollution Control Board, 2000). Therefore, 400 m buffer zones were drawn around all surface waters. Each buffer zone is weighted by AHP. The highest grade is assigned to a buffer of 1600m – 2000 m because CPCB indicated that landfill sites should be placed as far as 2000 m from surface waters in India. The lowest grade is assigned to buffer zones of <400 m (Table.2). The surface water map was obtained using the same process as for the distance from settlements.

Conclusion

Based on overlay analysis, 3 zones were identified such as most suitable, moderately suitable, and not suitable which occupy 0.26%, 10.55%, 89.19% of the area under Barddhaman Development Authority respectively. On the basis of AHP output six tentative sites have been identified (Fig. 9)

After field verification, it is found that sites no. 4 and 5 are situated near the settlement area and site no. 6 is situated near the river, rendering these sites not suitable for the purpose. Likewise, site no.3, situated far away from the municipality and facing some road network problems too is not suitable for landfills. But Site-1 and Site-2 are situated on fallow land and fulfill required criteria for landfill. These two sites are found to be the most suitable sites for the landfill in terms of criteria used in the analysis.

Reference

Central Pollution Control Board (2000). Status of Municipal Solid waste Generation, Collection, Treatment and Disposal in Class I Cities, Series: ADSORBS/31/1999– 2000.

Davis, M. L., & Cornwell, D. A. (1998). *Introduction to environmental engineering*. McGraw-Hill Education.

Foroughian, A., & Eslami, H. (2015). Application of AHP and GIS for landfill site selection (A case study: city of Susa). *Journal of Scientific Research and Development*. 2(5): 129-134.

Javaheri, H., Nasrabadi, T., Jafarian, M. H., Rowshan, G. R., & Khoshnam, H. (2006). Site selection of municipal solid waste landfills using analytical hierarchy process method in a geographical information technology environment in Giroft. *Journal of Environmental Health Science & Engineering,* 3(3): 177-184.

Jaybhaye, R., Mundhe, N., & Dorik, B. (2014). Site Suitability for Urban Solid Waste Disposal Using Geoinformatics: A Case Study of Pune Municipal Corporation,

Maharashtra, India. *International Journal of Advanced Remote Sensing and GIS*, 3(1): 769.

Kumar, V., Yadav, K., & Rajamani, V. (2014). Selection of Suitable Site for Solid Waste Management in Part of Lucknow City, Uttar Pradesh using Remote Sensing, GIS and AHP Method. *International Journal of Engineering*, 3(3): 1461-1472.

Nas, B., Cay, T., Iscan, F., & Berktay, A. (2010). Selection of MSW landfill site for Konya, Turkey using GIS and multi-criteria evaluation. *Environmental monitoring and assessment,* 160(1): 491-500, doi: 10.1007/s10661-008-0713-8.

Paul, K., Dutta, A., & Krishna, A. P. (2014). A comprehensive study on landfill site selection for Kolkata City, India. *Journal of the Air & Waste Management Association*, 64(7): 846-861.doi: 10.1080/10962247.2014.896834

Paul, S. (2012). Location allocation for urban waste disposal site using multi-criteria analysis: A study on Nabadwip Municipality, West Bengal, India. *International journal of geomatics and geosciences*, 3(1): 74.

Poorna, C. A., & Vinod, P. G. (2016). Solid waste disposal site selection by data analysis using GIS and Remote sensing tools: A case study in Thiruvananthapuram corporation area. *International Journal of Geomatics and geosciences*, *6*(4), 1734-1747.

Rahman, M. M., & Hoque, M. A. (2007). Site Suitability Analysis for Solid Waste Disposal Using GIS: A Case Study on KCC Area. *The Journal of Geo-Environment*, 6: 72-86.

Saaty, T. L. (1980). *The Analytic Hierarchy Process.* McGraw-Hill.

Saaty, T.L. (1994). Highlights and Critical Points in the Theory and Application of the Analytic Hierarchy Process. *European Journal of Operational Research*, 74: 426-447.

Saaty, T. L. (2000). *Fundamentals of decision making and priority theory with the analytic hierarchy process* (Vol. 6). RWS publications.

Şchiopu, A. M., Apostol, I., & Gavrilescu, M. (2009). Impact of landfill leachate on soil quality in Iasi County. *Environmental Engineering & Management Journal (EEMJ),* 8(5).

Şener, Ş., Şener, E., Nas, B., & Karagüzel, R. (2010). Combining AHP with GIS for landfill site selection: a case study in the Lake Beyşehir catchment area (Konya, Turkey). *Waste management*, 30(11), 2037-2046.

Thoso, M. (2007). *The Construction of a Geographic Information Systems (GIS) Model for Landfill Site Selection*, Thesis of M.Tech, Department of Geography, University of the Free State: Bloemfontein.

Vasiljević, T. Z., Srdjević, Z., Bajčetić, R., & Miloradov, M. V. (2012). GIS and the analytic hierarchy process for regional landfill site selection in transitional countries: a case study from Serbia. *Environmental Management*, 49(2), 445-458.

Chiranjit Ghosh
Research Scholar,
Department of Geography,
The University of Burdwan,
Golapbag, Rajbati, Burdwan,
Email-chiranjitghosh.64@gmail.com