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A CASE STUDY

Solid waste disposal site selection using multi-criteria evaluation in the GIS interface: A case study of Neyyattinkara Municipality, Kerala, India

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ABSTRACT : Selection of sites for solid waste disposal is one of the biggest hitches in semi urban and urban areas because of the harmful impacts of wastes on public health. The present paper focuses on the identification of suitable site for solid waste disposal using multi-criteria decision analysis (MCDA) in the geospatial environment of Neyyattinkara Municipality, located 20km south of Thiruvananthapuram in Kerala. Eight thematic layers such as land use, geomorphology, slope, population density, distance from streams, distance from roads, drainage (stream) density and road density have been considered in the analysis. The resultant thematic maps have been allocated weightages and suitability scores. The final potential site map for solid waste disposal is developed by applying weighted overlay method by integrating the factors in the GIS software. The study revealed that a total area of 0.13 sq.km (31.76 acres) in the Neyyattinkara municipality is suitable for solid waste disposal. This very high potential area is spatially distributed in 13 out of 44 wards of the municipality. Of all, ward number 19, Thavaravila has the highest potential area of 9.52 acres for solid waste disposal. The potential site suitability map for solid waste disposal will serve as base information for locating the solid waste disposal areas in Neyattinkkara municipality. Further, this methodology can be applied to other municipalities and townships in Kerala which have similar terrain characteristics.

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Site selection for waste disposal is meant for a long period of time and should be done scientifically without disturbing the environmental factors (Asha and Vinod, 2016). In developing countries, the ever rising human population and the associated anthropogenic interventions have hastened the process of urbanization. In India, the rate of increase of urban population shot from 25,851,873 in 1901 to 286,119,689 in 2001. The census of 2001 indicates the fact that presently 25.73 per cent of the total population resides in the urban centers. The fast development rates of the cities, pooled with their huge population base, has left many Indian cities missing in basic infrastructure services like water supply, sanitation and sewerage, and solid waste management (Sumathi *et al.*, 2008). Poor waste management systems together with hot climatic circumstances have always resulted in serious environmental issues. The need of the hour is to develop a proficient solid waste management method in which decision-makers and waste management planners could reach a consensus in dealing with the complication, ambiguity and subjectivity allied with this problem. Because of the ever-increasing strain towards the cut back of solid waste at the source, as well as recovery and recycling of the solid waste, disposal of solid waste by land filling remains as the most commonly followed method. But in the domain of the science of solid waste management, identification of potential sites for solid waste disposal remains a grave management subject wherein the selection should be based on a number of considerations without affecting humans and his environment (Dipanjan *et al.,* 1997 and CPCB, 1999). A number of studies have been carried out by researchers in identifying the potential solid waste disposal site by using GIS and remote sensing techniques (Sumathi *et al.,* 2008; Nishanth *et al.,* 2010; Ebistu and Minale, 2013; Alanbari *et al.*, 2014; Karthiheyan and Yesodha, 2016; Sunder Rajan *et al.,* 2014 and Asha and Vinod, 2016).

Study area and background information of the study:

The study area is Neyyattinkara Municipality in Kerala. It lies between North latitudes 8° 22' 23.16" and 8°27'9.24" and East longitudes 77°3'29.48" and 77°7'19.90" (Fig. A). Neyattinkkara has an average elevation of 26 metres (85 feet). The town is situated on the Neyyar river side, one of the principal rivers in Thiruvananthapuarm district of Kerala. The river flows to the south part of the town. Water Supply for the town and the adjacent places is dependent on this river. Topography of the town is rather uneven, with higher areas in the downtown. Nearby the town is the hillock Aruvippuram. The Western Ghats form a scenic backdrop to the town. The town is sandwiched between the Western Ghats and the Arabian Sea. The geology is said to be typical of the Kerala soil - the Laterite and Red soil. The town has a good green cover in residential and non-residential areas. Neyyattinkara has heavy rains during June–August due to the southwest monsoon. Annual average rainfall is 3,100 mm. Winter starts from December and continues till February. Population of Neyyattinkara Town (Municipal Area) as on 1991 was 30,419. The population rose to 69,467 as per Census 2001, which grades it under Class-II town. Most of the urban population lies within the 44 wards of municipality.

In Neyyatinkara, the sources of waste generation are households, vegetable, fruit and meat markets, shops and establishments, hotels, hospitals and construction-demolition sites. From the study conducted by Soya and Prakasam (2016), it is inferred that no primary collection is practiced in the municipality; segregation of waste at source is lacking ; no community bins are placed anywhere in the municipality; no waste storage facility is provided in market places or nearby slaughter houses and no disposal sites identified. All these result in littering of wastes on streets, sides of the roads and along the banks of Neyyar River. Random disposal without proper treatment creates environmental pollution and human health issues. From the analysis of the composition of wastes generated in the municipality, Soya and Prakasam (2016) found that the organic waste fraction makes a relatively large contribution to the total waste. Fig. B and C describe the source of waste generation in Neyyattinkara and the composition of the waste generated, respectively. They also reported that in the municipality the prevalent approaches for final disposal

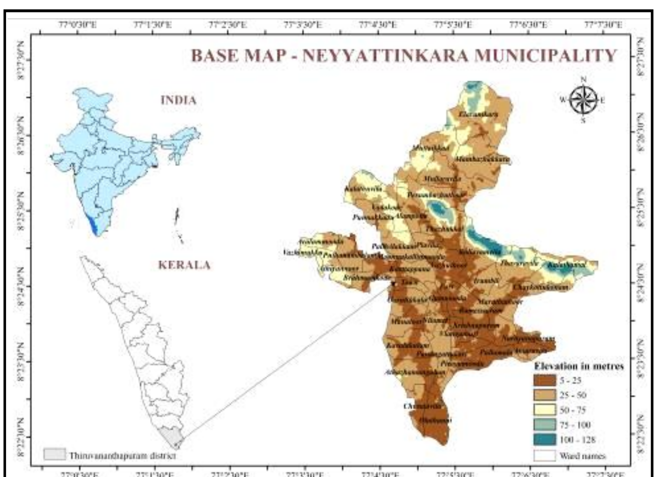

Fig. A : Base map

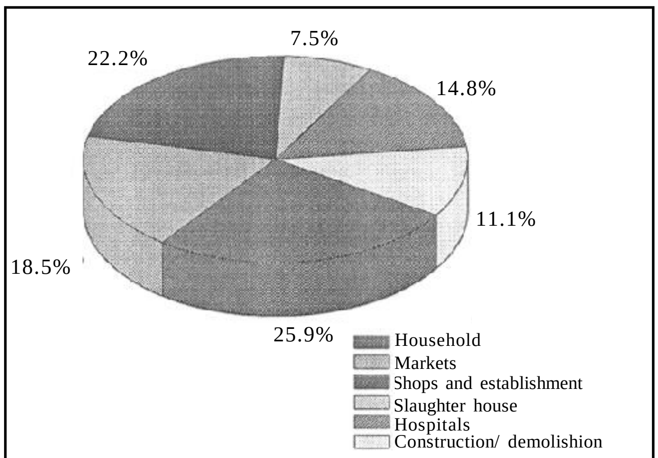

Fig. B : Sources of waste generated

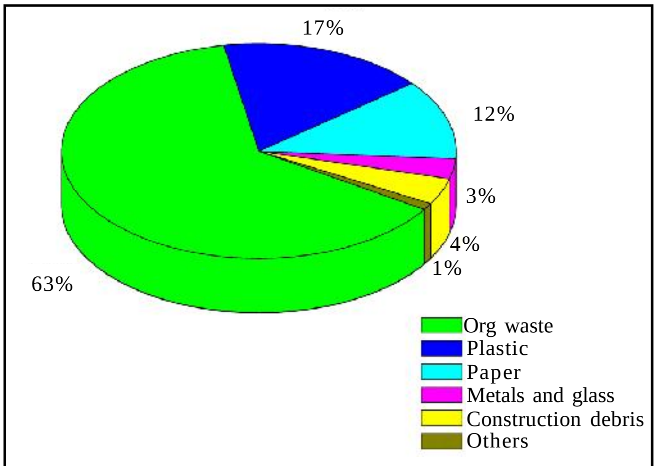

Fig. C : Components of waste generated

are open dumping and burning, and based on this further suggested that a sustainable solid waste management (SWM) can be achieved if the biodegradable wastes are subjected to vermin- composting process along with reduction, recycle and reuse of plastic and paper fractions. But no matter how much control, decomposition and recycling a society realizes, there will remain some type of waste which can be only land filled. The aim of the present study is to make an optimized land use site suitability selection for solid waste disposal based on multi-criteria decision analysis and GIS overlay analysis in Neyattinkkara municipality, a typical fast growing urbanizing township of Thiruvananthapuarm district, Kerala, India. It is anticipated that the suitable site section for waste disposal will produce little impact to the environment and the population.

EXPERIMENTAL METHODOLOGY

The methodology adopted for the present study is shown as flow chart (Fig. D). The major data sources for the study included the Survey of India (SOI) toposheets at a scale 1:50,000 of Neyyattinkara municipality, which are used to prepare the base map for the study. The ward map of the municipality (Fig. E) is prepared in the geographic extent by taking the base map of Delimitation commission, Local self government, Kerala. The land use map is generated through the image interpretation and classification of the Indian Remote Sensing satellite, LISS III imagery of the study area of 22.8 m resolution. Geomorphologic map is prepared from LISS III image. Stream network map is developed based

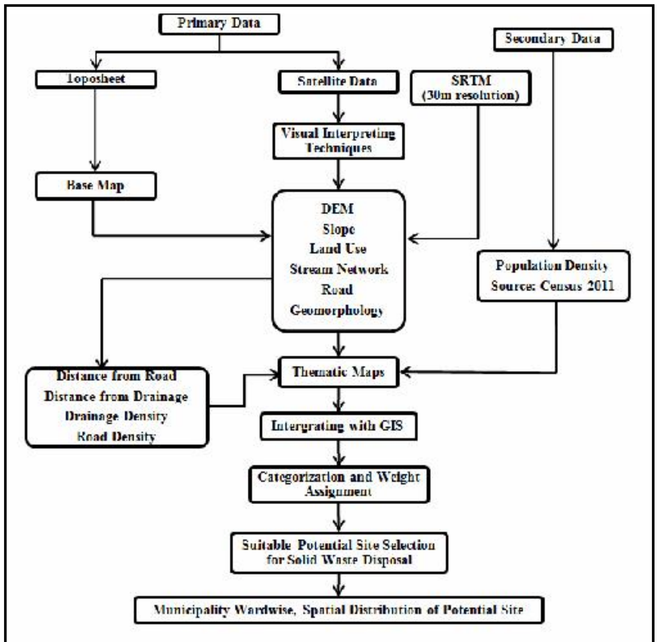

Fig. D : Methodology flowchart for identification of potential site for solid waste disposal

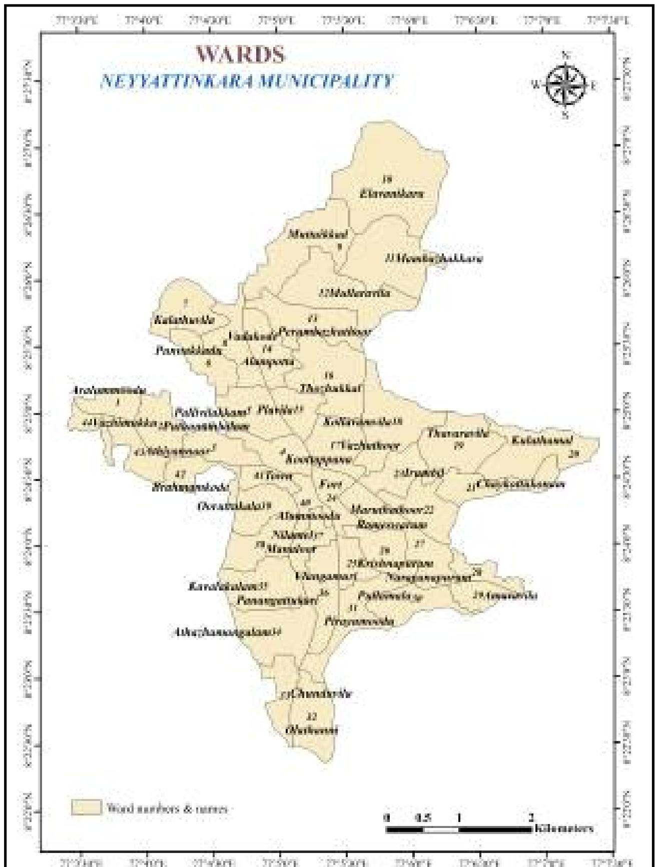

Fig. E : Ward map of Neyattinkkara municipality

on the Survey of India map by digitization.

Roads of the study area are prepared from open street maps. Shuttle Radar Topographic Mission (SRTM) derived Digital Elevation Model with 30m resolution which is used for preparing Slope map. The digitization and analysis of the thematic maps are performed within the framework of the desktop GIS - Arc GIS Desktop 9.3 version. ERDAS 9.2 imagery software is used for digital image interpretation of LISS III imagery. Line density model of spatial analysis is used for deriving the road density and stream density. Distance from roads and distance from streams are developed using the Euclidean distance toolset of spatial analysis in GIS environment. The entire study area is evaluated based on certain evaluation criteria for analysing solid waste disposal site suitability (Ozeair and Mohesn, 2009) and these criteria are classified into two categories .The first category is a physical criterion which includes slope, drainage, water bodies and residential buildings. The second one is the social economic criterion which includes population density, distance from streams, distance from roads, distance from water bodies and distance from residential areas. All the thematic maps are prepared using the GIS software by assigning weights for each class. The rank of each factor was given on the basis of its significance in solid waste disposal site suitability. The data layers have been integrated in GIS environment by Weighted Overlay Analysis in GIS software in order to find out the best suitable site.

EXPERIMENTAL FINDINGS AND DISCUSSION

The findings of the present study as well as relevant discussion have been presented under following heads :

Geomorphology :

Geomorphology plays significant role in the land and water management related planning processes. Geomorphology of the surface is given importance during site selection particularly for solid waste disposal. Significance of geomorphology in provincial and confined decision making has to be given value. Similarly topography is an important factor in site selection of a landfill site because it has important implications on landfill capacity, drainage, ultimate land use, surface and groundwater pollution control, site access and related operations. Deciding the type of landfill design (area, trench, and depression-type landfills) is also directly related to topography of a site. Flat and gently rolling hills that are not subjected to flooding are the best sites for area and trench type landfills.

The geomorphology map of Neyyattinkara municipality is shown as Fig. 1. The geomorphologic classes are flood plain, river channel, valleys and lower plateau (lateritic). The major part of the study area has lower plateau landform.

Land use :

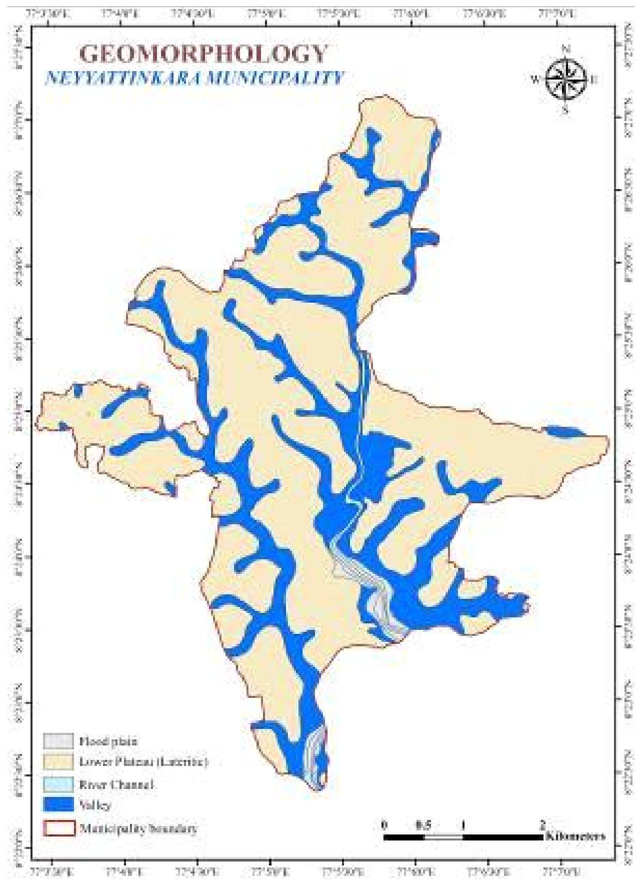

Fig. 1 : Geomorphologic units of the study area

The land use / land cover pattern of a region is an outcome of both natural and socio-economic factors and their utilization by man in time and space (Karthiheyan and Yesodha, 2016).The land use map (Fig. 2) displays the land utilized by the human and the natural cover in the study area. Land use map is developed by image interpretation and classification of the IRS satellite imagery. It indicates the areas of settlements (built ups), barren land, mixed vegetation, thick vegetation, plantation, sandy area and water bodies. It also showed that the

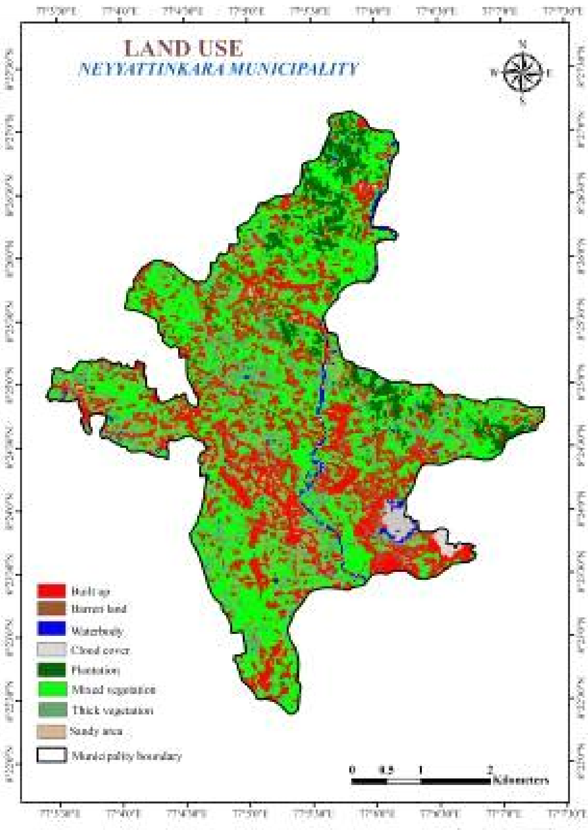

Fig. 2 : Land use classes of the study area

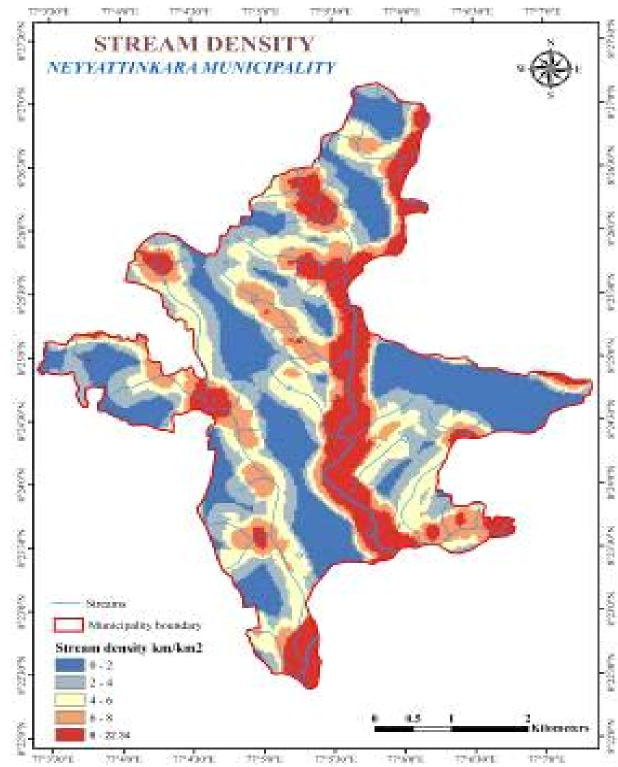

Fig. 3 : Stream (drainage) density of the study area

greater part of the regions is occupied by built ups and mixed vegetations.

Stream density :

Stream (Drainage) density map is most likely to be a useful aid for finding areas with relatively high concentrations of drain. The stream density map is shown in Fig. 3. The areas marked in red shows a higher stream density. The stream density of the study area ranges from 0 to 22.34 km/km^2

Road density :

It is a visual aid for finding areas with relatively high concentrations of roads. Road density (Fig. 4) is most useful in a context that high concentration of roads is a problem for solid waste disposal. The road density of the study area ranges from 0 to 16.80 km/km^2.

Distance from streams :

It has been reported that a solid waste disposal site must not be located near drainage channels, wells,

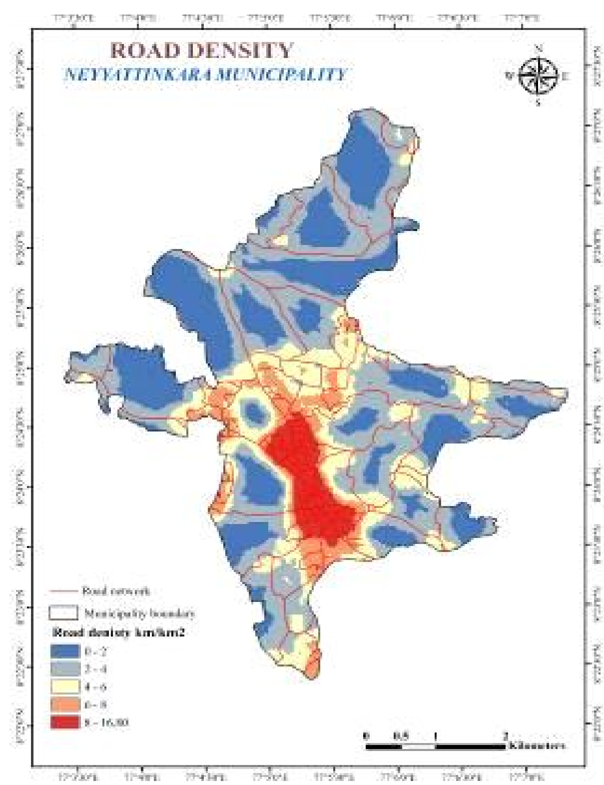

Fig. 4 : Road density of the study area

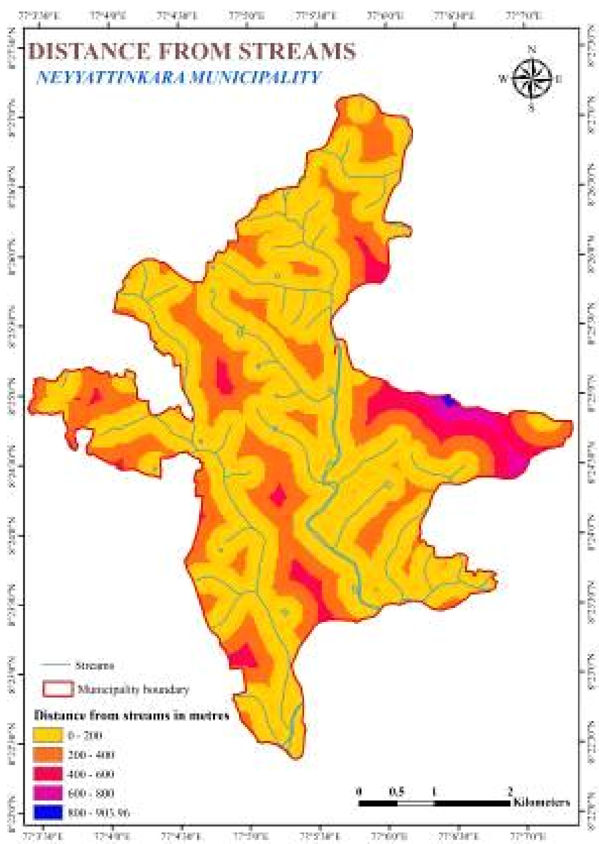

Fig. 5 : Map showing distance from streams

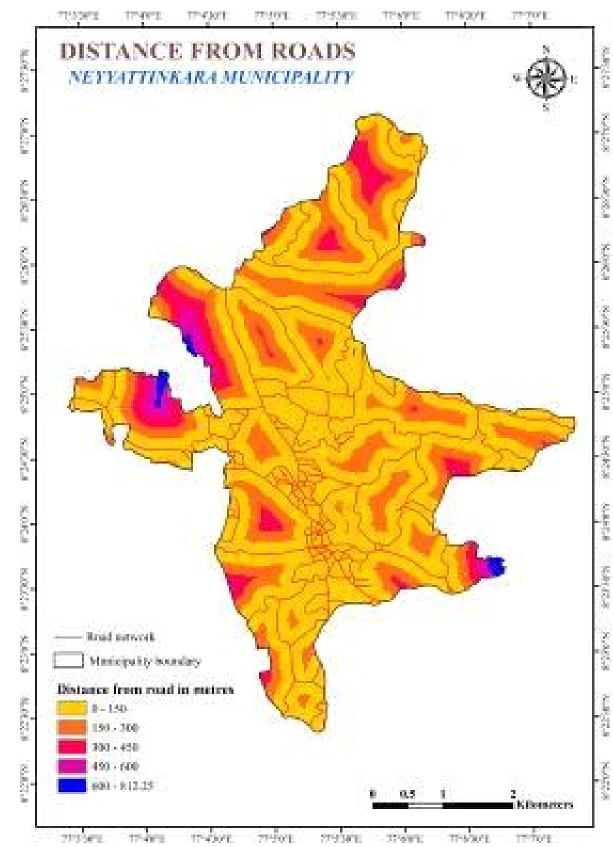

Fig. 6 : Map showing distance from roads

wetlands or coastlines; not within 100 feet (30.48 m) of any non-meandering stream or river, and at least 300 feet (91.44 m) from any meandering stream or river (Despotakis and Economopoulos, 2007 and Lunkapis, 2010). Large bodies of water (greater than 20 acres (80937.45 m^2) of surface area) should be at least 100 feet (30.48 m) from any landfill site. Since major rivers have a higher discharge and greater downstream influence, no landfill should be sited within the floodplains of major rivers (Bagchi, 1994). Central Pollution Control Board, India imposes prohibition of dumping of solid waste on any water surface be it river or lake, and that solid waste disposal site must not be located near river, stream and surface water (Paul, 2012). The map on distance from stream is shown in Fig. 5. The distance varies from 0– 903.96 meters.

Distance from roads :

Road density is a straight forward pointer of the concentration of roads in an area. The road density can be determined for road fragments that have distinctiveness attributed. As the general concept, the solid waste disposal site shall not be located within 100 m of any major highways, city streets or other transportation routes. The waste disposal site should not be located within 250m distance from transportation network (Bhambulkar, 2011). Solid waste dumping site must be located at suitable distance from roads network in order to facilitate transportation and consequently reduce relative costs. The distance from road map of the study area is shown in Fig. 6.

Slope :

Elevation is an important parameter in the identification of landfill site. In the method used here, the land morphology was evaluated using the grading of the slope and specified in degrees format. Slope refers to the measure of the rate of change of elevation of surface location (Chang, 2010).The slope map (Fig. 7) was generated from the digital elevation model (SRTM)

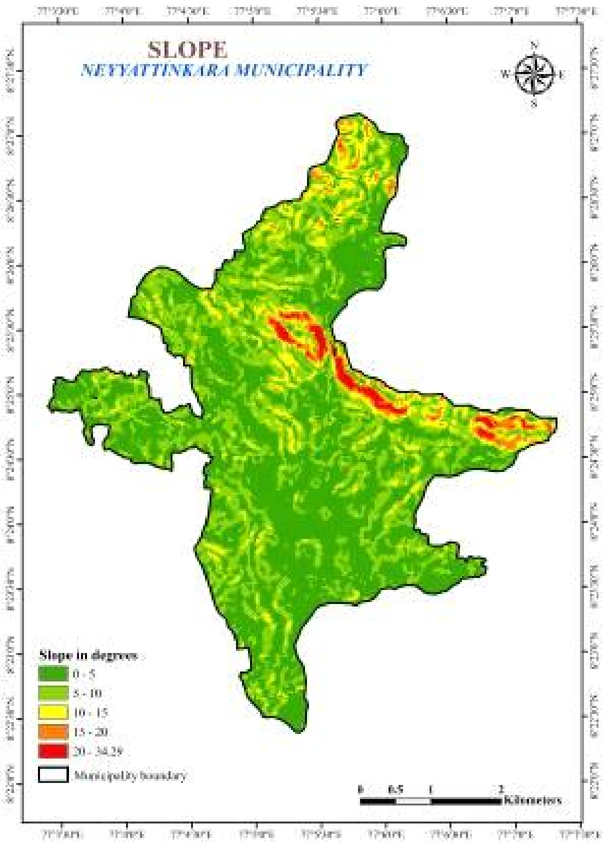

Fig. 7 : Slope of the study area

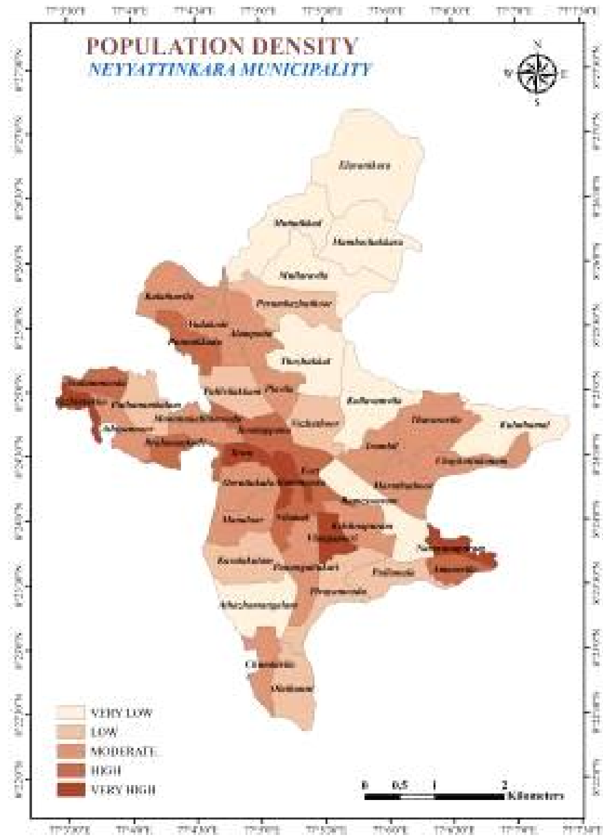

Fig. 8 : Population density map of the study area

that was obtained from the USGS portal. The slope of the study area ranges from 0^0 to 34.29^0. According to Leao *et al.* (2001) and Sener *et al.* (2011) the land with a slope less than 10 per cent is highly suitable for solid waste disposal.

Population density :

Population density is also an important suitability parameter normally considered. By taking into account the Census 2011 data of the study area and ward map the population density map has been prepared. Logically the population density has been classified into 5, namely: very low, low, moderate, high and very high. Very low and low population density areas are suitable for solid waste sites. The population density map of the study area is shown in Fig. 8.

Weightage given to the thematic layers :

Weightages are given to individual classes of each thematic layers based on their possible influence on the solid waste disposal site. Neither the areas with high slopes nor flat areas are ideal for solid waste disposal. This study considered the lower slope (slope less than 10^0) more highly suitable than the land with higher slope. Different researches show that areas with high slopes will have high risk of pollution and potentially not a good site for dumping (Ebistu and Minale, 2013). The weighted slope map of the study area is shown as Fig. 9. The weightage scores given to various parameters such as slope, stream (Drainage) density, distance from streams, distance from roads and road density is shown in Table 1.

The regions having high drainage density is not suitable for considering them for solid waste disposal as it spoils the surface and ground water through leaching. Hence a region with low drainage density is preferable. The weighted drainage density is shown in Fig. 10.

Taking into consideration the distance from streams, distance less than 200m and 400m from streams is unsuitable, distance from 400 to 600m is moderately

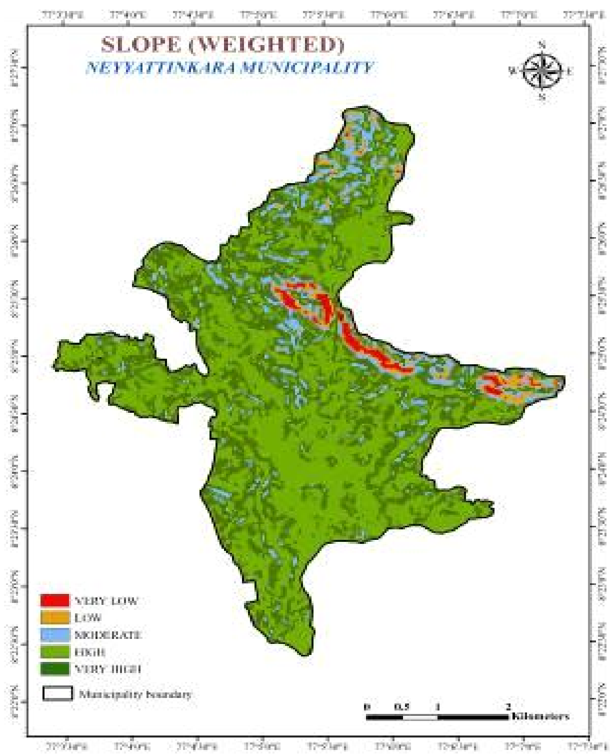

Fig. 9 : Weighted slope map of the study area

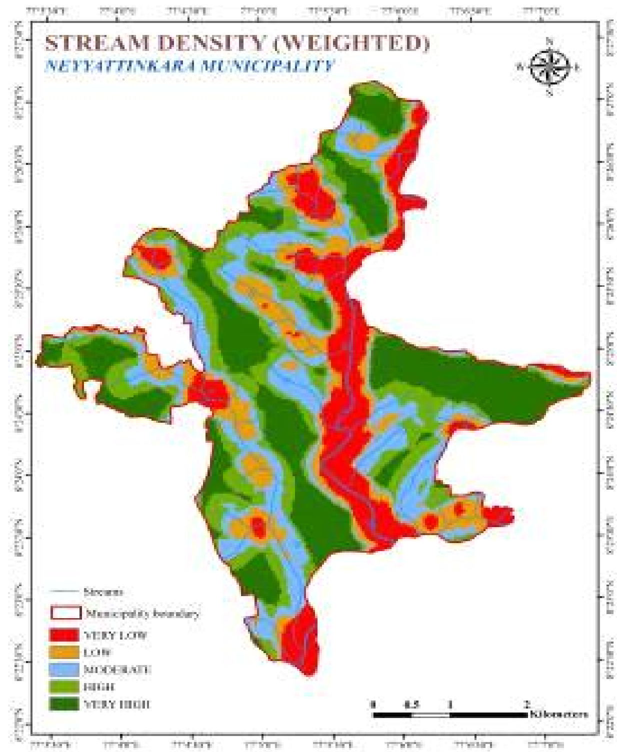

Fig. 11: Map showing weighted distance from streams of the study area

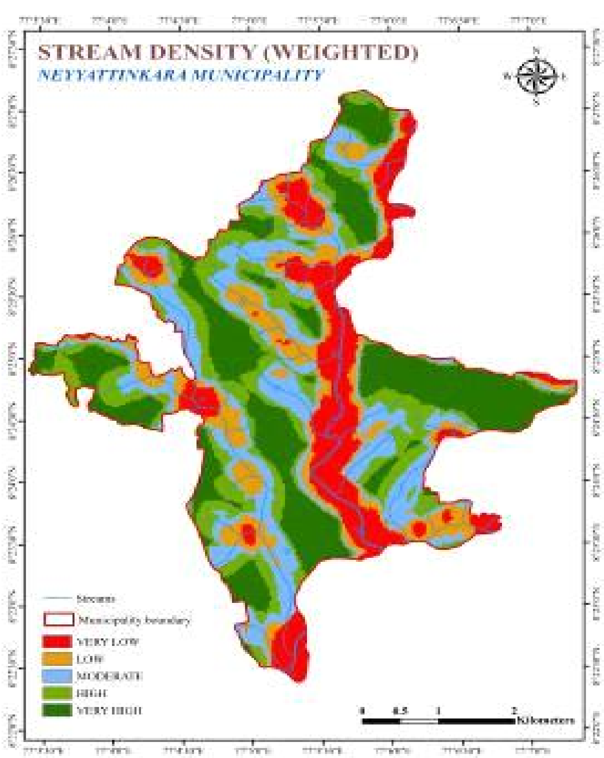

Fig. 10 : Weighted drainage density of the study area

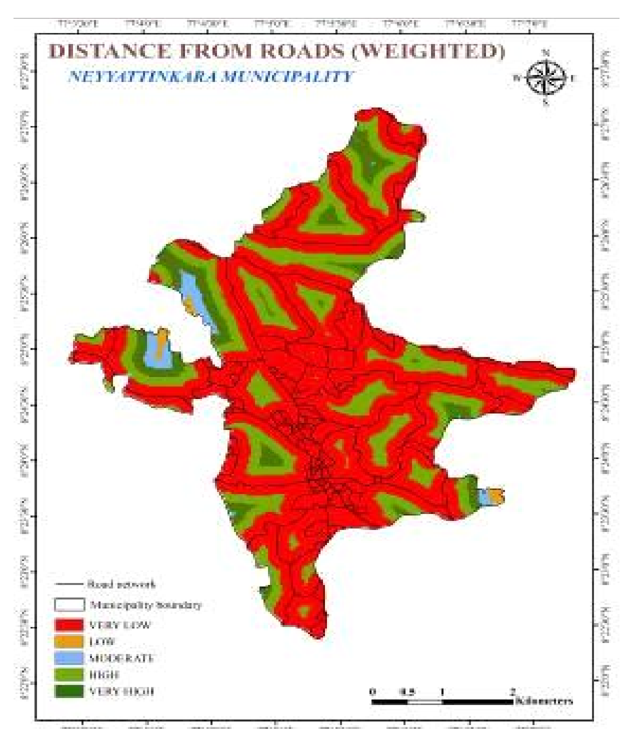

Fig. 12 : Map showing weighted distance from roads of the study area

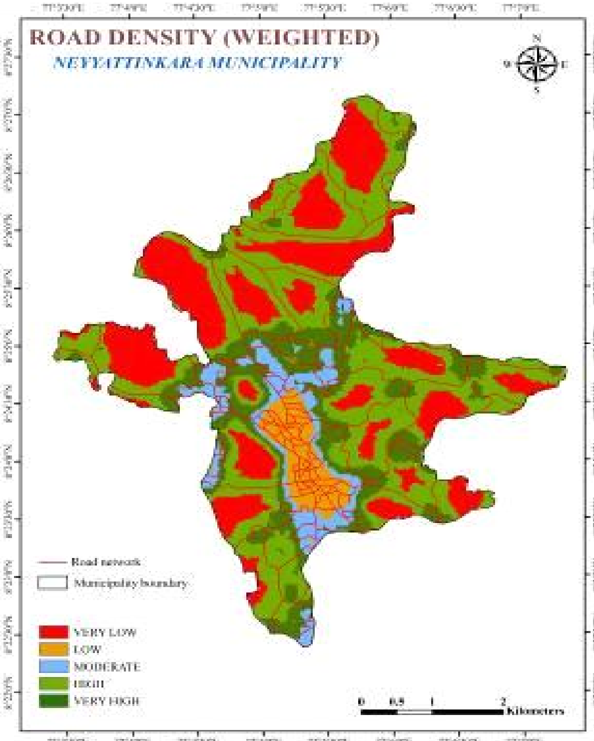

Fig. 13: Map showing weighted road density of the study area

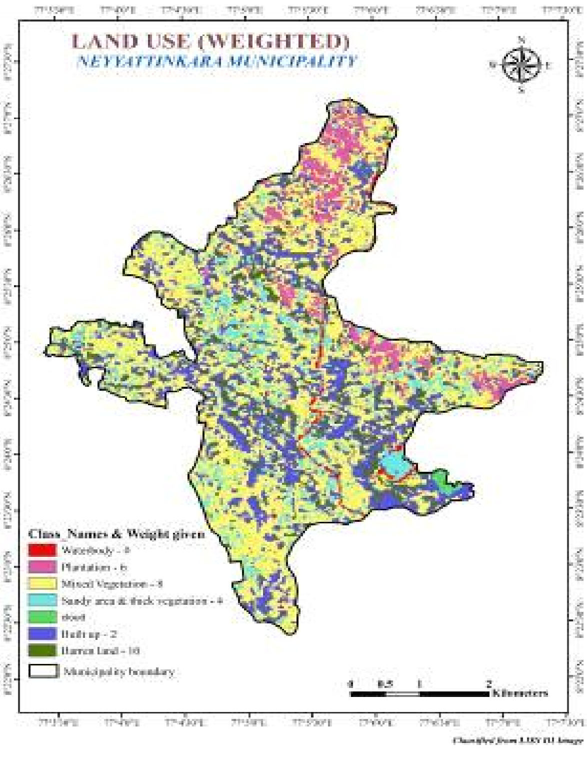

Fig. 15: Map showing weighted land use classes

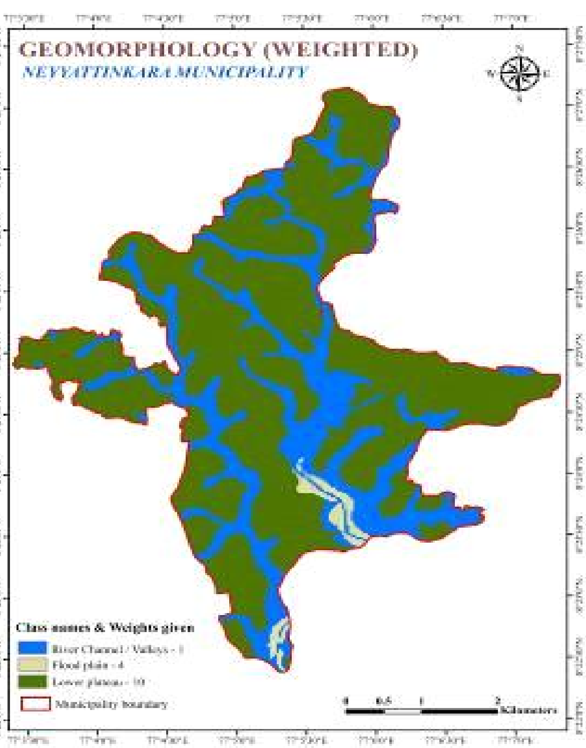

Fig. 14 : Map showing weighted geomorphic units

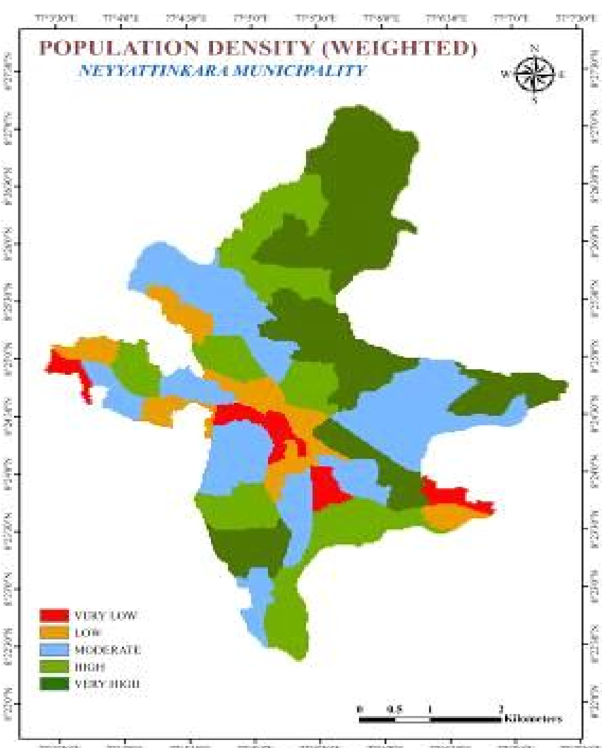

Fig. 16 : Weighted population density

suitable and distance from 600 to 800m is highly suitable and distance more than 800 m is very highly suitable for disposal site and accordingly suitability scores are given. Fig. 11 depicts the weighted distance from streams of the study area.

Road is an important factor when we consider the human settlement and transportation of the waste. The site should not be too near to the road or too far from the road. Then only the conveyance of waste should be smooth and more economical. The weightage is given accordingly along with suitable scores (Asha and Vinod, 2016). Similar methodology is applied in giving the weightage to road density also. Fig. 12 and 13 show the weighted maps of distance from roads and road density, respectively.

The major geomorphologic features, land use classes, population density classes and their suitability scores are given in Table 2. The plateau region is given high suitability

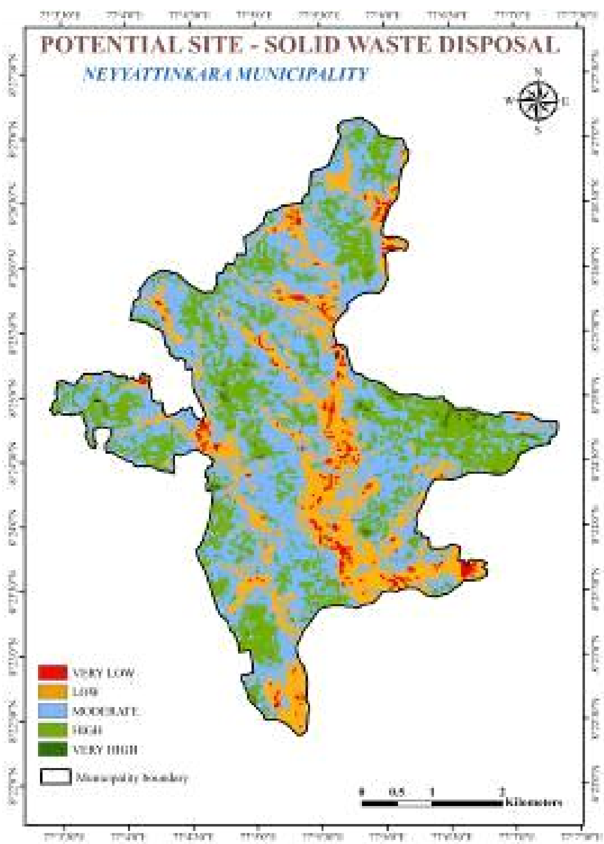

Fig. 17 : Potential zones for solid waste disposal in study area

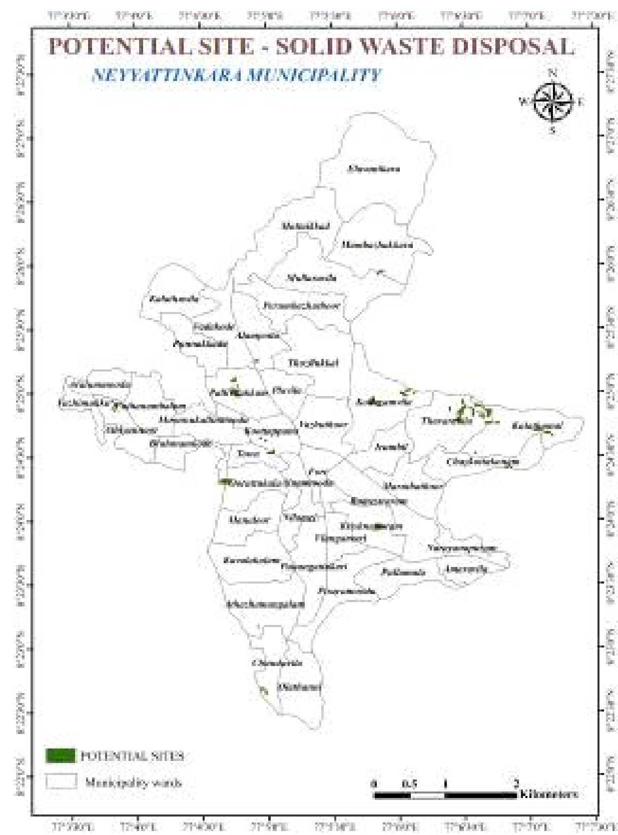

Fig. 18: Map showing the best suitable sites for solid waste disposal in Neyattinkkara municipality

Table 1 : Weightage given to various parameters *viz.*, slope, stream (drainage) density, distance from streams, distance from roads and road density

Weightage parameter									
Slope		Stream density (Drainage density)		Distance from streams		Distance from roads		Road density	
Slope in degrees	Suitability score	Density (km/km^2)	Suitability score	Distance (m)	Suitability score	Distance (m)	Suitability score	Density (km/km^2)	Suitability score
0-5	8	0-2	10	0-200	2	0-150	2	0-2	2
5-10	10	2-4	8	200-400	4	150-300	8	2-4	8
10-15	6	4-6	6	400-600	6	300-450	10	4-6	10
15-20	4	6-8	4	600-800	8	450-600	6	6-8	6
20-34.29	2	8-22.34	2	800-903.96	10	600-812.25	4	8-16.80	4

Table 2 : Weightage given to various parameters *viz.*, geomorphology, land use and population density

Weightage parameter					
Geomorphology		Land use		Population density	
Classes	Suitability score	Classes	Suitability score	Classes	Suitability score
Lower plateau (Lateritic)	10	Barren land	10	Very low	10
Flood plain	4	Mixed vegetation	8	Low	8
Valleys / River channels	1	Plantation	6	Moderate	6
		Thick vegetation	4	High	4
		Sandy area	4	Very high	2
		Built up	2		
		Water body	0		

Table 3 : Potential area for solid waste disposal site in acres distributed in 13 wards of Neyattinkkara municipality

Sr. No.	Ward number	Ward name	Potential area for solid waste disposal site in acress
1.	19	Thavaravila	9.52
2.	20	Kulathamal	6.35
3.	18	Kollavamvila	4.76
4.	15	Pallivilakam	4.13
5.	43	Athiyannoor	1.59
6.	39	Ooruttukala	1.27
7.	33	Chundavila	1.27
8.	4	Kootappana	0.95
9.	42	Brahmamkode	0.64
10.	41	Town	0.64
11.	12	Mullaravila	0.32
12.	16	Thozhukkal	0.32
	Total area		31.76

score. The dumping site should not be selected close to the built up area in order to avoid adverse effects on land value and to human beings (Clark and Gillean, 1974). The weighted geomorphic unit is illustrated in Fig. 14 and the weighted land use classes are given in Fig. 15. In addition Fig. 16 shows the weighted population density map.

Potential solid waste site suitability regions :

To delineate the different potential zones for site suitability, all the thematic layers are integrated with one another according to their importance through GIS platform. The resultant potential zone map (Fig. 17) is categorized into five classes based on suitability-very low, low, moderate, high and very high zones .It indicated that very high zone is the best disposal site for solid waste disposal. Accordingly the best potential sites (very high) in the Neyattinkkara municipality are calculated as 0.13 sq.km (31.76 acres) spread over 13 wards (Fig. 18). A detailed ward wise distribution of these high potential zones is given in Table 3. It can be seen that Ward number19, Thavaravila of the municipality has a potential area of 9.52 acres for solid waste disposal followed by Kulathamal (Ward number 20) with 6.35 acres and Kollavamvila (Ward number 18) with 4.76 acres. The potential area in Thavaravila was physically verified and found perfectly suitable for land filling.

Conclusion :

This paper attempts to identify the potential sites for disposal of solid waste in Neyyattinkara municipality of Kerala. A multi-criteria approach was employed in conjunction with GIS-based overlay analysis to identify the most suitable sites for solid waste discharges. The study showed that out of 44 wards, 31 wards do not have suitable locations for solid waste disposal. However, very high potential areas of 31.76 acres spread over another 13 wards are found suitable for the purpose. This study result can be used as first hand information for effective management of the solid wastes in the municipality. This model based on GIS can also be applied to other municipalities of Kerala with similar terrain.

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