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Site Suitability for Urban Solid Waste Disposal Using Geoinformatics: A Case Study of Pune Municipal Corporation, Maharashtra, India

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Abstract Urban solid waste disposal is a major problem, faced by majority of cities or towns in the world. Rapidly increasing population growth, urbanization, industrialization and rural to urban migration created acute problem of solid waste management. Solid waste per capita generation rate in India has increased from 0.44 kg per day in 2001 to 0.5 kg per day in 2011. These increasing rates of waste generation stress on all infrastructural, natural and budgetary resources with adverse impacts on human health and environment due to the improper and unscientific solid waste dumping. Pune is one of the fastest growing city, it generates total quantity of waste is about 1300 to 1400 metric tons per day. So, there is need suitable solid waste disposal sites for prevention of environment. The present research work to find out the suitable solid waste dumping sites using Geoinformatics approach for Pune Municipal Corporation (PMC). For this purpose topographical maps and medium resolution satellite data were used to generate various thematic layers. Site suitability analysis for urban solid waste disposal consider the nine parameters such as, road network, rivers, lakes, canals, geology, population density, slope, airport and land use/land cover. The generated thematic maps of these criteria were standardized using multi-criteria analysis method. A weight for each criterion was generated by comparing them with each other according to their importance. With the help of these weights and criteria final site suitability map was prepared. This site suitability map presented in four suitability level such as highly suitable, moderate suitable, less suitable and unsuitable. The result shows that around 1.70 % area is under high suitable for solid waste disposal site, 7.86 % is moderate suitable, 80.92 % of study area is less and 9.52 % area is unsuitable for dumping site. There are ten potential site have been determine based on sitting criteria and all sites are identify surrounding part of city area within newly added 34 villages. The suggested potential sites are economically and environmentally suitable for solid waste dumping.

Keywords *Geographic Information System (GIS); Multi-Criteria Analysis; Remote Sensing (RS); Urban Solid Waste*

1. Introduction

Solid waste comprises unwanted and discarded materials from houses, street sweeping, commercial and industrial operations. Uncontrolled momentum of urbanization, industrialization and modernization lead to the generation of solid waste (Basagaoglu et al., 1997). There has been a significant increase in solid waste generation in India over the years from 100 gm per person per day in small towns to 500 grams per persons per day in large towns. These increasing rates of waste generation stress on all infrastructural, natural and budgetary resources with adverse impacts on human health and environment due to the improper and unscientific solid waste dumping. The unscientific landfill site may reduce the ground water quality, drinking water purity and causes the disease like nausea, jaundice, asthma etc (Bean et al., 1995).

Pune is the second largest fast developing urban agglomerations in Maharashtra and ranks eight at national level. In Pune Municipal Corporation (PMC) primary sources of waste are local households, commercial establishments, vegetable markets, hotels, restaurants and hospitals. Pune Municipal Corporation generates huge amount of solid waste. The quantity of waste generated per day is about 1400 to 1500 metric tons (approximate generation per capita per day is 500 grams). This large amount of waste poorly disposed and untreated. Pune city does not have a scientific landfill site and the capacity of Uruli Devachi dump site cannot provide the future demand of the waste generated (Mundhe et al., 2014).

It is very critical issue to identify the suitable location for disposal of solid waste. Since the land is limited resource, there is a shortage of land as the land prices are raising. Moreover the sight of garbage is not pleasing hence there is a lot of opposition from the masses and a Hercules task for the municipality to decide a place for dumping the garbage. If the land is selected on a scientific basis, there is less likely to have an opposition to the place of dumping.

The present research work focused on to find out suitable dumping sites for urban solid waste generated from Pune Municipal Corporation using Geoinformatics techniques like Geographical Information System (GIS), Remote Sensing (RS) and Global Positioning System (GPS) with the help of multi-criteria analysis to minimize adverse effects on environment, social and economic of solid waste management.

2. Study Area

Pune Municipal Corporation lies between latitudes 18°25'N and 18°37'N and longitudes between 73° 44'E and 73°57'E and the geographical area is over 243.84 Sq. Km with a population of 3.1 million (according to Census of India, 2011). Now there are 34 villages added in Pune Municipal Corporation therefore after State Government notification area of Pune Municipal Corporation over 500 Sq. Km. Pune has had traditional old-economy industries, which continue to grow. Pune is the cultural capital of Maharashtra since the after independence. The city is now also known for information technology and educational hub that attract migrants and students from other places.

Pune city situated at an altitude of 560 meters above mean sea level (MSL) on the western margin of the Deccan plateau. The city is bounded by Thane district to the north-west, Raigad district to the west, Satara district to the south, Solapur district to the south-east and Ahmednagar district to the north and north-east (Figure 1).

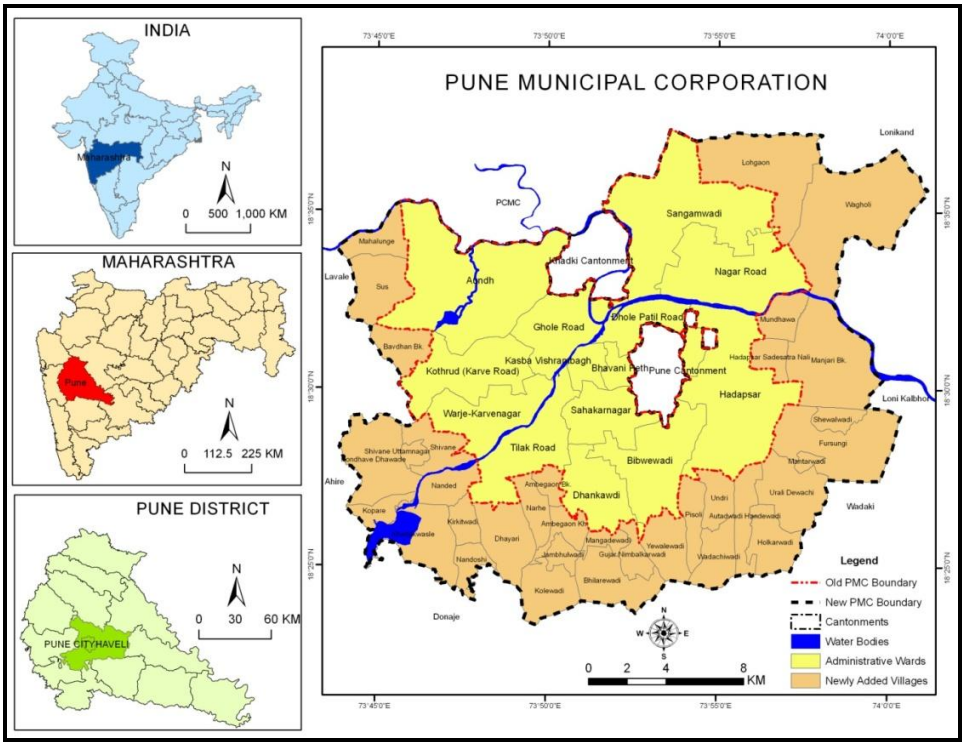

Figure 1: *Location Map of Study Area*

3. Objective

The main objective of this present research work is to find out suitable dumping sites for urban solid waste using Geoinformatics technique with the help of multi-criteria analysis.

4. Materials and Methods

In the present study primary and secondary data were used. The primary data were collected from field surveys using GPS instrument to measure the coordinates of some location in the study area. Whereas, the secondary data for the study was acquired from governmental institutions, reports, books, journals and internet. The main data used for this study were Landsat 8 OLI/TIRS image with spatial resolution of 30m and topographical maps like 47F/10; 47F/11; 47F/14; 47F/15; 47J/2 and 47J/3 were used. Aster data also used to create the slope map of study area. Geological maps were used to create geology layer of the study area and which is obtained from Geological Survey of India, Pune. Demographic data obtained from Census of India, which is useful for the creation of population density map. Ward maps and administrative boundaries of the study area were collected from Pune Municipal Corporation (PMC). Hence, in the present study various thematic maps are prepared by visual interpretation of the satellite imagery and SOI toposheets.

Pre-processing operations involved scanning, geo-referencing and digitization of Survey of India (SOI) topographical maps, satellite image and other solid waste related base maps. Firstly, Survey of India (SOI) toposheets has been geo-referenced using WGS 1984, Universal Transverse Mercator (UTM) projection system. After geo-referencing the SOI toposheets and other maps are digitized in different features like point, line and polygon such as ward boundaries, road network, contour, drainage network, river and lakes etc.

Landsat 8 image obtained from USGS website, this image already geo-rectified. Initially, standard image processing techniques have been applied for the analysis of satellite image such as

enhancement, band extraction, restoration and classification (Congalton et al., 1999). The hybrid image classification technique was employed with for the image classification using ERDAS software. The classification of land use/land cover was categorized into seven major classes such as agriculture land, vegetation, built-up (residential & commercial), scrub land, fallow land, river and lakes and canal. About seven training sites for each class were used in hybrid image classification approach (Lillesand et al., 1993).

The present research work used multi-criteria analysis technique to identify the most suitable solid waste dumping site (Bilgehan et al., 2010). Multi-criteria approaches have the potential to reduce the costs and time (Kontos et al., 2005). The solid waste disposal site selection mapping was done using multi-criteria analysis and creating layers to yield a single output map or index of evaluation (Wiley and Sons, 2009). The procedure by which the weights were produced follows the logic developed by Saaty (1977) under the analytical hierarchy process (AHP) which is utilized to determine the relative importance of the criteria in a specified decision-making problem.

Classifications were done on various layers and the values were assigned ranging from unsuitable to high suitable. Whereas, reclassification of layers were classified into the 1's, 2's, 3's and 4's ranking system, where first, represented unsuitable, second, less suitable, third, moderate suitable and fourth, highly suitable after distance calculation was done, respectively. These criteria were developed by referring to different sources like Central Pollution Control Board (CPCB), Municipal Solid Waste (Management and Handling rules) 2000 and CPHEEO manual have been used as a guide to determine the best site location. These criteria were then analyzed using multi-criteria analysis to evaluate and to seek potential locations of sanitary landfills. When potential sites were found in several locations, appropriate ranking techniques were applied to decide the best choices produce by Geoinformatics approach (Figure 2). The analysis has been used to find out potential sites for PMC region.

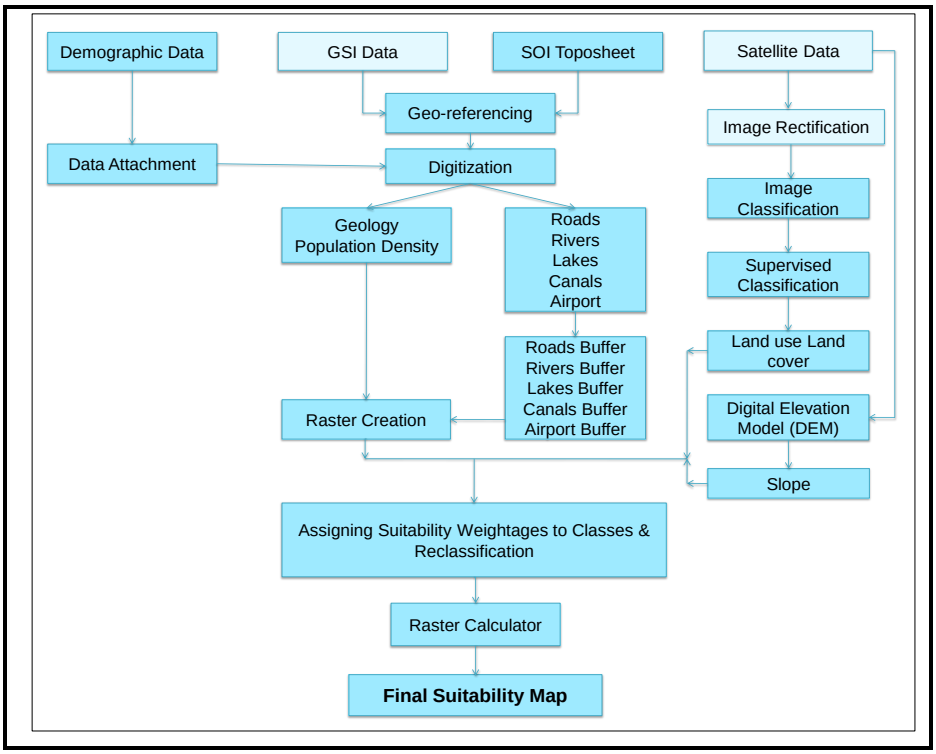

Figure 2: *Flow Chart of Methodology*

5. Decision Rules/ Criteria for Selection of Potential Dumping Site

Present study evaluation criteria were determined depend on Central Pollution Control Board (CPCB), Municipal Solid Waste (Management and Handling rules) 2000 and CPHEEO manual. There are nine criteria that were considered when selecting a landfill site in the Pune Municipal Corporation. These are slope, geology, population density, land use/land cover, distance from road network, distance from rivers, distance from lakes, distance from canals and distance from airport. Each criterion was explained below in detailed.

5.1. Slope

The slope map was generated from the ASTER DEM data. Slope refers to the measures of the rate of change of elevation of surface location (Chang, 2010). In the study area North, East and middle part of the city mostly flat and southern and western part is covered by hilly area. The lower degree of slope is highly suitable than the higher degree of slope. Different research states that area with high slope will have high risk of pollution, lichet and potentially not good site for dumping (Ebistu et al., 2013). Slope is indicates in degree and divide into four categories with assigning values are given below Figure 3. In the results, most of the study area falls under slope category less than 10^0 which covered 84% of the total study area. This is highly suitable, slope from 10^0 to 15^0 is moderately suitable and slope 15^0 to 20^0 and more than 20^0 are less suitable and unsuitable respectively for solid waste dumping site selection.

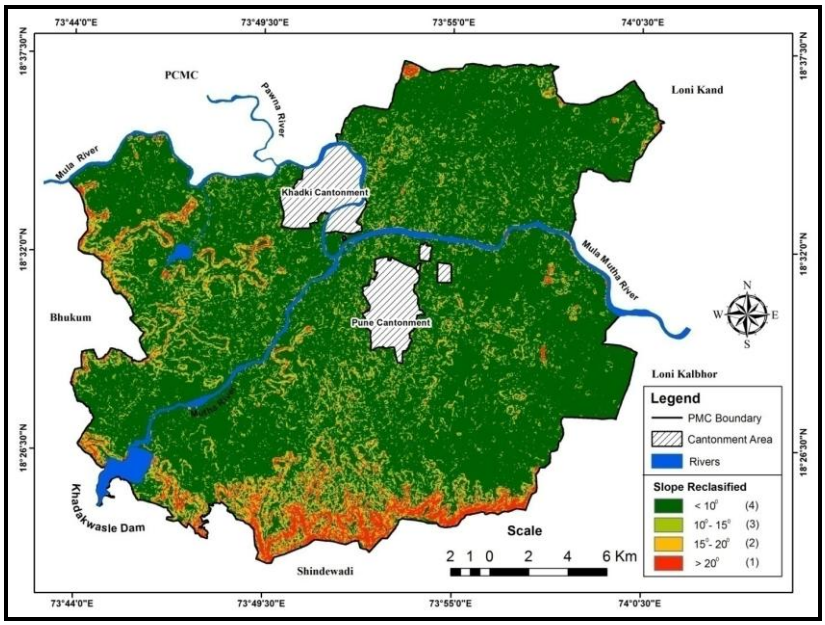

Figure 3: *Reclassified Slope Map*

5.2. Geology

Geological layer created from the Geological Survey of India maps. There are five Geological formation type found in study area. Geological formation thickness is considered to analyze suitability. The Purandargarh and Diveghat formation is highly suitable for solid waste dumping site due to their 50m to 350m high thickness and Upper Ratangarh Formation thickness is 50m to 100m so this formation is unsuitable due to the low thickness. Purandargarh and Diveghat formation assigned the value 4s, Indrayani formation 3s, Karla formation 2s and Upper Ratangarh formation assigned 1s based on their thickness for suitability criteria (Figure 4).

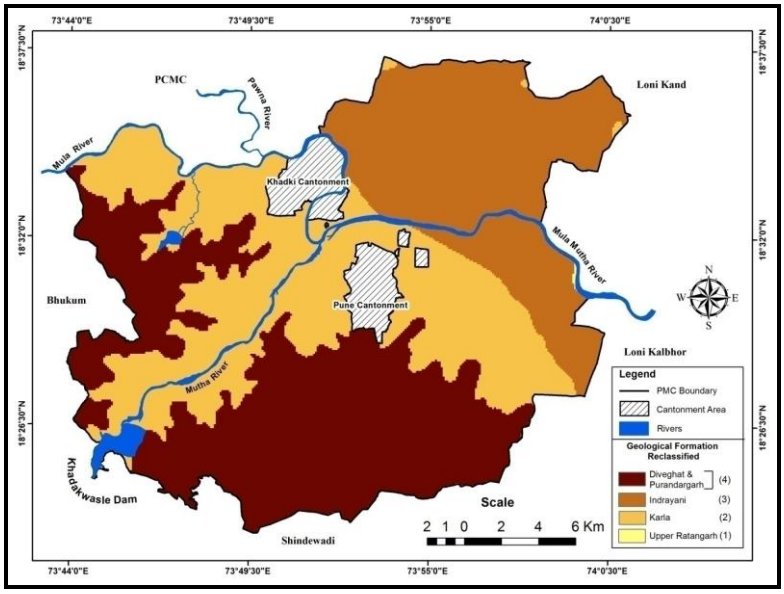

Figure 4: *Reclassified Geology Map*

5.3. Population Density

Population density is also important suitability parameter. The population of PMC as per Census of India, 2011 is more than 31 lakhs. Population density of Pune city is 12,777 persons per sq. km in 2011. There are 34 newly added villages in Pune Municipal Corporation in June 2014. Highest population density found in Bhavani Peth and Kasba Vishrambaghwada that is 661 and 445 persons per hectare respectively in city and lowest density recorded in newly added village Kolewadi is 1P/Ha, Wadachiwadi and Nandoshi both are 2P/Ha. Population less than 200 P/Ha persons per hectare is found in all newly added villages highly suitable, population within 200 P/Ha to 400 P/Ha is recorded in Sahakarnagar and Dhankavdi wards moderately suitable, population between 400 P/Ha to 600 P/Ha is found in Kasba Vishrambagh less suitable and more than 600 persons per hectare in Bhavani Peth is unsuitable for waste dumping site (Figure 5).

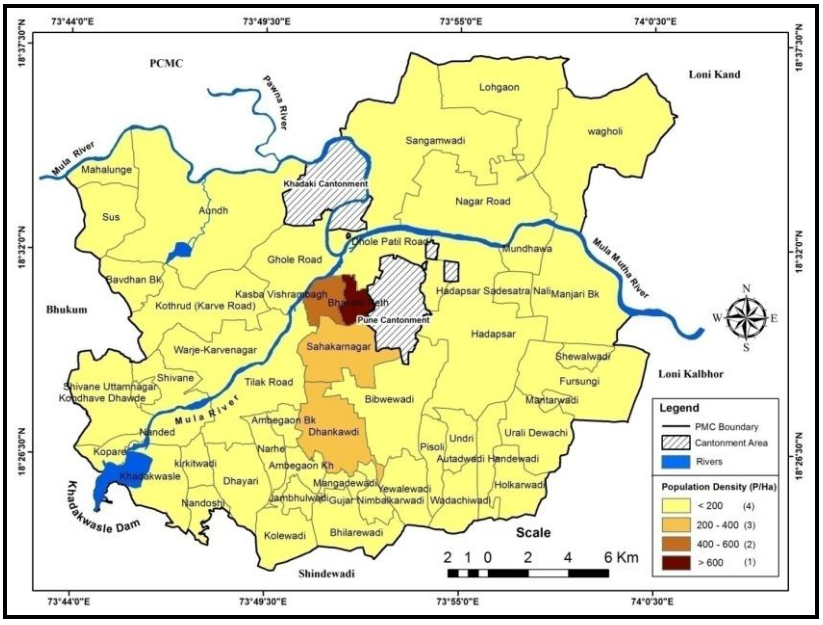

Figure 5: *Reclassified Population Density Map*

5.4. Suitability of Land Use/Land Cover

The land use/land cover of the present study area was analyzed from Landsat 8 data for the solid waste dumping site selection. The dumping site should not be selected close to settlement to avoid adversely affecting land value and future development and to protect human being from environmental hazards created from dumping sites (Clark et al., 1974). It should be selected at a suitable distance from the residential area. Scrub land and fallow land both are most suitable for dumping site. Rivers and lakes, canals, built-up, vegetation, agricultural land, scrub land and fallow land are major land use/land cover classes in the present study. Ranking were assigned of each class of land use and land cover. Hence, small value give for unsuitable and highest value give for highly suitable to solid waste disposal site location. Fallow land and scrub land classes covered near about 33% from the total study area which is most suitable for dumping site (Figure 6).

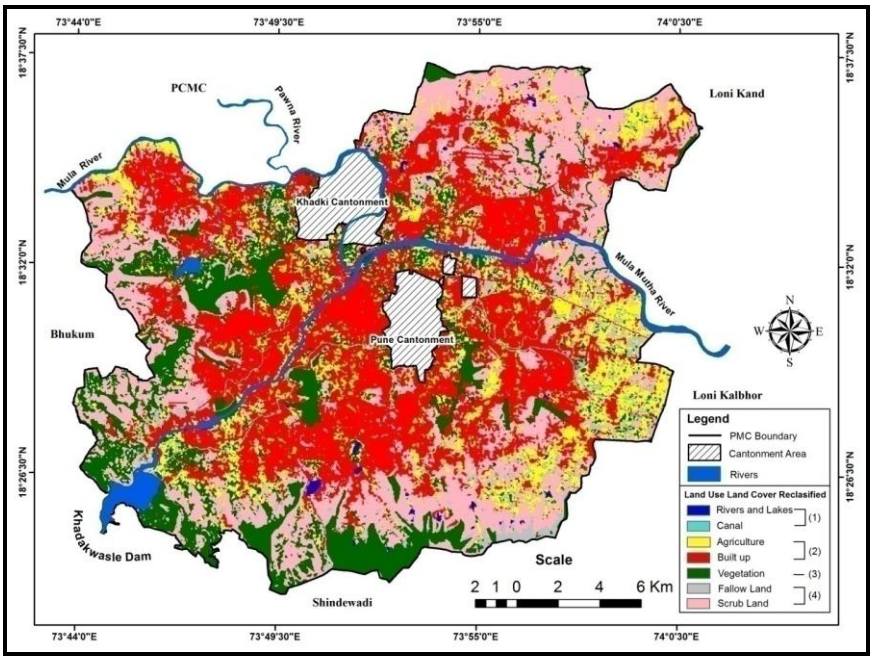

Figure 6: *Reclassified Land Use Land Cover Map*

5.5. Distances from Road Network

The waste disposal site should not be located within 250m distance from transportation network (Bhambulkar, 2011). Solid waste landfill site must be located at suitable distance from road network to decrease the cost of transportation. Distance of 250m, 500m, 750m and more than 750m, multiple ring buffer were created around the road network and ranked were assigned of each buffer zone based on siting criteria are shown in (Table 1). Distance less than 250m from road is unsuitable for dumping site, distance from 250m to 500m is less suitable, distance from 500m to 750m is moderately suitable and distance more than 750m is highly suitable for urban solid waste landfill site (Figure 7).

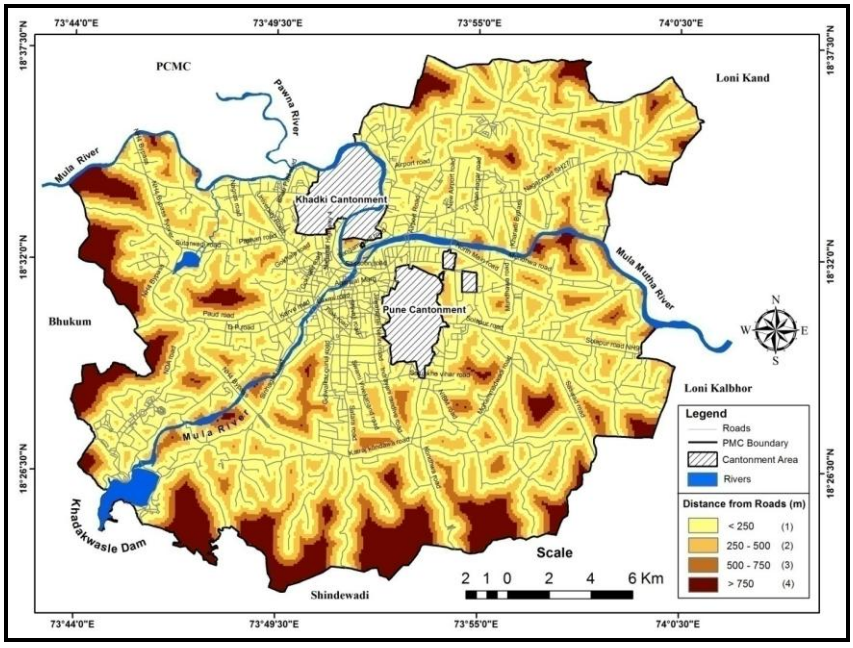

Figure 7: *Reclassified Road Network Map*

5.6. Distances from Rivers

As per Central Pollution Control Board, it is clearly states that dumping of solid waste on any water surface be it river or lake is prohibited. Solid waste disposal site must not be located near river, stream and surface water (Paul, 2012). In the study area Mula - Mutha are two main rivers in PMC. Using Arc GIS tool, multiple ring buffer are created for distance of 250m, 500m, 750m and more than 750m from rivers and 1, 2, 3 and 4 ranked were assigned each buffer ring respectively. Distance less than 250m from rivers is unsuitable, distance from 250m to 500m and distance from 500m to 750m are less suitable and moderately suitable respectively and distance more than 750m is highly suitable for disposal site (Figure 8).

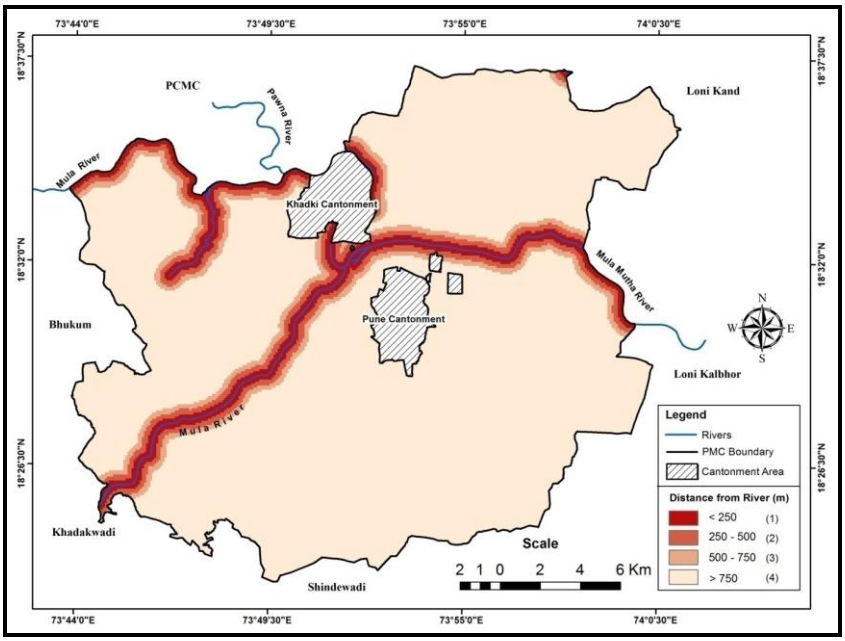

Figure 8: *Reclassified River Map*

5.7. Distances from Lakes

Khadakwasla reservoir is main source of water supply to Pune city and cantonment areas, which is constructed on Mutha River approximately 10 km from the city in south western direction and Pashan Lake, Katraj Lake, Lohegaon Lake, Vishrantwadi Lake, Jambhulwadi Lake; these lakes are also within different part of the city. Dumping site near the lakes and rivers also prohibited. Criteria of lakes for dumping site same as rivers and canal layer. Distance from lakes less than 250m is unsuitable and distance more than 750m is highly suitable for solid waste dumping site (Figure 9).

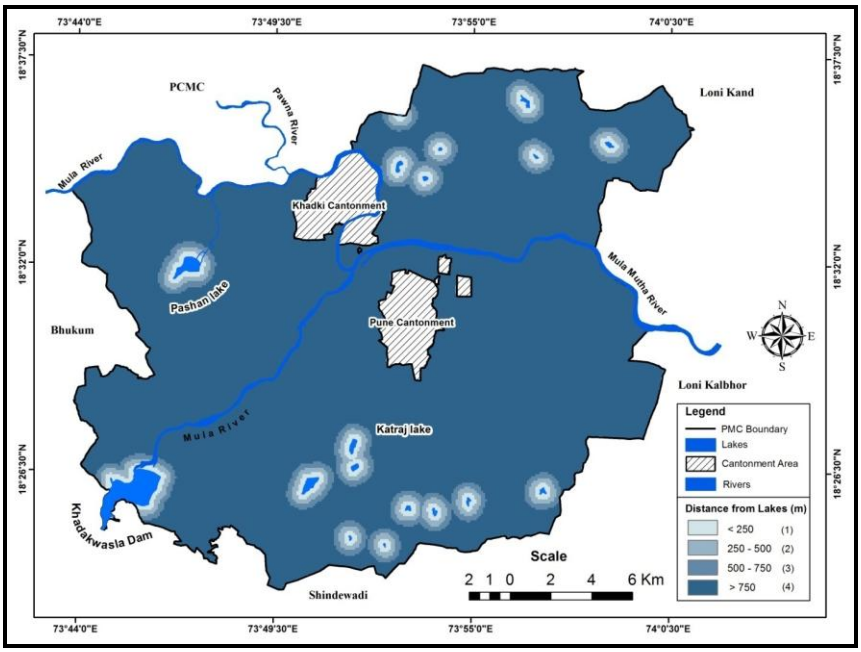

Figure 9: *Reclassified Lakes Map*

5.8. Distances from Canals

Canal layer digitized from the Survey of India, topographical maps. Mutha left bank canal and Mutha right bank canal constructed within core part of the study area. Dumping site not located near the canal is environmentally hazardous. It is located suitable distance from canal. Multiple ring buffers were created around the canal. Distance less than 250m is unsuitable and distance more than 750m from canal is highly suitable for urban solid waste dumping site (Figure 10).

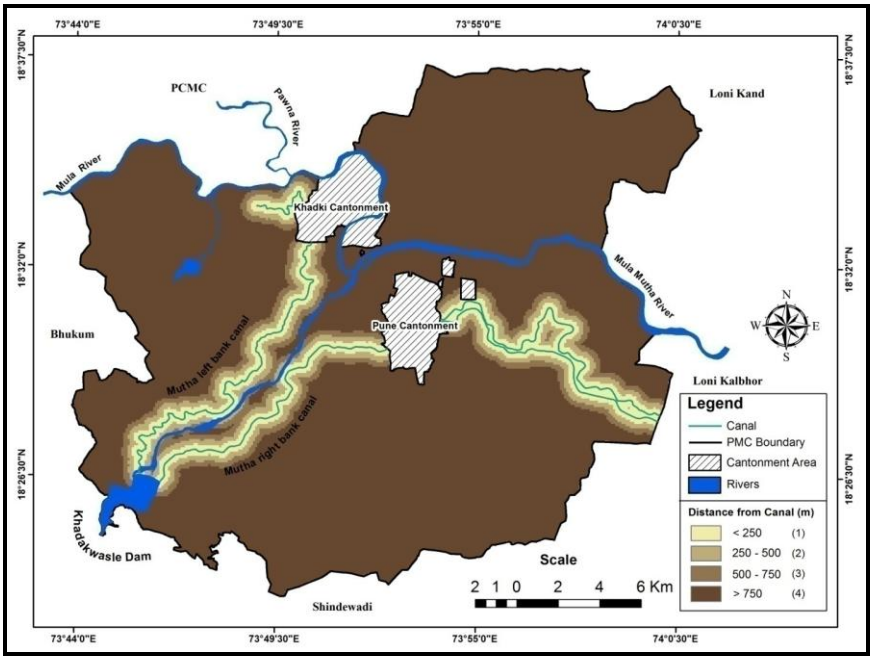

Figure 10: *Reclassified Canals Map*

5.9. Distances from Airport

Airport parameter also considers finding the suitable dumping site. International Airport in Pune at Lohegaon. It shared its runways with Indian Air force. Based on siting criteria distance less than 500m, 1000m, 1500m and more than 1500m multiple ring buffer zones was created around the both airport location and ranked were assigned each buffer zone on the base of suitability criteria. Distance less than 500m from airport and ranked assigned value 1s which is unsuitable and distance more than 1500m ranked assigned value 4s, which is highly suitable for dumping site (Figure 11).

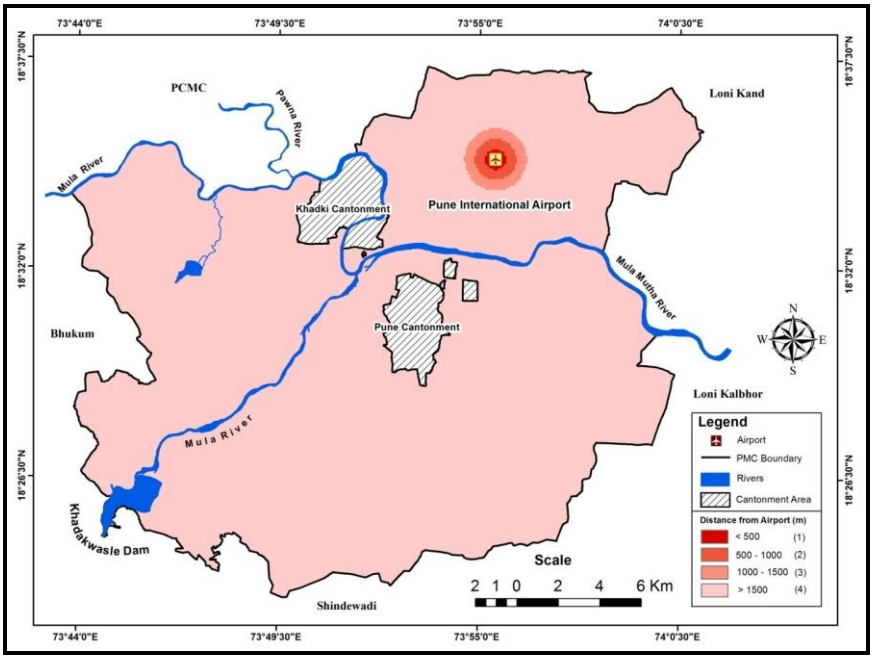

Figure 11: *Reclassified Airport Map*

Table 1: *Summary of Rankings and Suitability Level used in Selection of Dumping Site*

Criteria	Sub Criteria	Ranking	Level of Suitability
Slope	$>20^0$	1	Unsuitable
	15^0 - 20^0	2	Less suitable
	10^0 - 15^0	3	Moderate suitable
	$< 10^0$	4	Highly suitable
Geology	Upper Ratanghar	1	Unsuitable
	Karla formation	2	Less suitable
	Indrayani formation	3	Moderate suitable
	Diveghat/ Purandarghar	4	Highly suitable
Population Density	> 600ha	1	Unsuitable
	400ha - 600ha	2	Less suitable
	200ha - 400ha	3	Moderate suitable
	< 200ha	4	Highly suitable
Land Use/Land Cover	Rivers, Lakes and Canals	1	Unsuitable
	Built up and Agriculture	2	Less suitable
	Vegetation	3	Moderate suitable
	Scrub and Fallow Land	4	Highly suitable
Distances From Roads	< 250m	1	Unsuitable
	250m -500m	2	Less suitable
	500m- 750m	3	Moderate suitable
	> 750m	4	Highly suitable
Distances From Rivers	0m - 250m	1	Unsuitable
	250m - 500m	2	Less suitable
	500m - 750m	3	Moderate suitable
	750m - 1000m	4	Highly suitable
Distances From Lakes	< 250m	1	Unsuitable
	250m -500m	2	Less suitable
	500m- 750m	3	Moderate suitable
	> 750m	4	Highly suitable
Distances From Canals	0m - 250m	1	Unsuitable
	250m - 500m	2	Less suitable
	500m - 750m	3	Moderate suitable
	750m - 1000m	4	Highly suitable
Distances From Airport	< 500m	1	Unsuitable
	500m - 1000m	2	Less suitable
	1000m - 1500m	3	Moderate suitable
	> 1500m	4	Highly suitable

6. Results and Discussion

To identify the urban solid waste disposal site there are nine parameter, different siting criteria, various referenced materials and sources are used. The overlay analysis of the given factors using raster calculator in Arc GIS software produced the suitable solid waste dumping site (Figure 12). The final solid waste dumping site suitability map was divided into four categories: unsuitable, less suitable, moderate suitable, highly suitable. The result indicate that 9.52 % of the study area is unsuitable, 80.92 % area is less suitable, 7.86 % area is moderate suitable and 1.70 % study area is highly suitable for dumping site (Table 2). Out of total study area 1.70% means 8.52 km^2 (2105.04 acres) area is highly suitable for dumping. There are 10 potential site are identify in study area, out of them

Uruli Devachi is the existing waste dumping site. Now Uruli Devachi dumping site is not sufficient to dumped waste. Remaining nine sites are suggested to solid waste dumping (Table 3).

Table 2: *Level of Suitability and Percent Total Area Coverage*

Sr. No.	Suitability Classes	Area (km^2)	Area (acres)	Area (%)
1	Unsuitable	47.84	11,822.61	9.52
2	Less Suitable	406.54	1,00,458.47	80.92
3	Moderate Suitable	39.48	9,756.31	7.86
4	Highly Suitable	8.52	2,105.04	1.70
	Total	**502.39**	**1,24,142.43**	**100**

Table 3: *Potential Sites of PMC*

Sr. No.	Potential Disposal Sites	Area (Km^2)	Area (acres)
1	Near Mahalunge	0.65	159.807
2	Near Kirkatwadi	0.7	172.91
3	Near Yeolewadi	0.32	78.79
4	Near Pinjanwasti	0.58	142.48
5	Near Authadewadi	0.75	185.25
6	Near Wagholi	0.74	184.06
7	Near Shindewasti, Lohgaon	0.68	167.8
8	Near Dighi	1.41	347.21
9	Near NDA, Khadakwasale	0.6	147.92

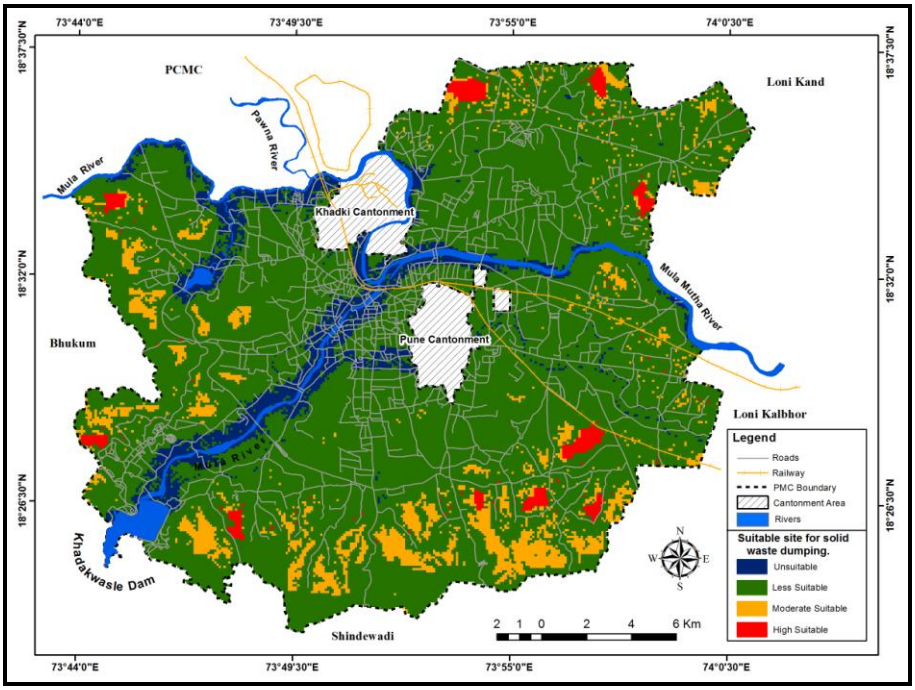

Figure 12: *Final Suitability Map of Solid Waste Dumping Site*

By using the stated criteria, the suitable areas for solid waste dumping site fall on the northwestern, northeastern and southern direction from the city (Figure 12). The areas were highly suitable for solid waste dumping site suggested that selecting the optimum site for solid waste dumping may facilitate transportation and reduce the cost of transport. Moreover, suitability, for slope analyses had shown that slope less than 10 % are more suitable in order to minimize environmental impacts.

The total area of the nine most appropriate sites is 1586.23 acres out of a total area of 502.39 Sq. Km. for the study area. The areas of the potential sites are given as 347.21 acres for Near Dighi being the largest site; 185.25 acres, 184.06 acres and 172.91 acres for Near Authadewadi, Near Wagholi and Near Kirkatwadi respectively.

Near Authadewadi site with an area of 185.25 acres and an indigenous residential area located far away from any resource of economical/ecological value can be described as one of the most appropriate site. Near Kirkatwadi has an area of 172.91 acres and is described as an undeveloped land.

7. Conclusion

The analysis has taken land use/land cover, slope, geology, population density, water sources, and settlement and transport facilities as determining factor in order to find appropriate site for solid waste dumping site. The results have shown that nine sites were selected as the highly suitable. The sites are easy to access; manage for disposal of solid wastes. These places are far-away from any water sources and other variables put into analysis.

The study demonstrated the capacity to use GIS and remote sensing technology for the effective identification of suitable solid waste dumping sites will minimize the environmental risk and human health problems. The study is useful in planning for the city in future. It emphasizes on the importance of the requirement of solid waste management system. The use of multi criteria analysis is a new attempt to get the potential site. There is no limit to the scope of the innovations and technology use. With the given time and the limited knowledge with the data constraint this was an attempt to derive the site suitability analysis for urban solid waste disposal.

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