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Site Suitability for Solid Waste Disposal in Mumbai, India

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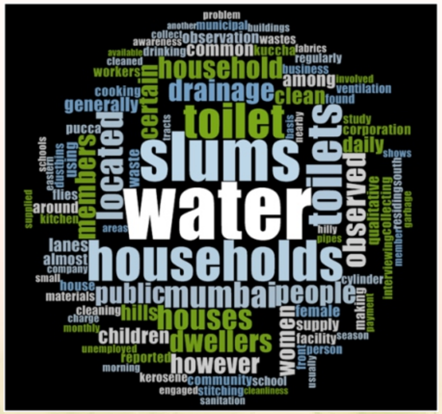

Forthcoming
Report
on
Housing, Water and Sanitation (HWS) Survey of Slums in Mumbai

ISSN NO 0975 7287

SITE SUITABILITY FOR SOLID WASTE DISPOSAL IN MUMBAI, INDIA

Sudha.G and Aparajita Chattopadhyay***

Introduction

Solid waste comprises of wastes resulting from anthropogenic and natural activities which are discarded as useless or unwanted. Solid waste is considered as a global environmental problem in today's world, both in developing and developed countries. Increasing population, rapid economic growth and rise in the community living standards speed up solid waste generation. Waste disposal is one of the serious threats faced in recent decades. Management of this enormous waste in terms of collection, handling and disposal with conventional methods has become increasingly difficult. However, selecting and managing a suitable site for waste disposal is a challenging problem. Increasing environmental awareness, increasing cost, community and political opposition and public health concerns have made choosing suitable land for landfills quite difficult (Dina; 2008). Advancement in recent technology has made the application of environmental criteria in national planning and waste management achievable. The methodology utilizes GIS to estimate the probable waste disposal site in the entire region based on certain estimation criteria specified by Abessi et al; (2009). Environmental factors are very important to be considered in such work to the fact that landfill might affect the biophysical environment and the ecology of the surrounding area (Siddique et al;1996). GIS is a dominant tool that can integrate spatial data and perform a variety of analysis. The potential advantage of a GIS-based approach for siting arises from the fact that it not only reduces time and cost of site selection, but also provides a digital data bank for long-term monitoring of the site (Miles et al; 1999).

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. Presently most of the municipal solid waste in India is being disposed of unscientifically (Akolkar; 2005). Mumbai, one of the largest cities in India, is a major business centre and the commercial and financial capital of the country (Municipal Corporation of Greater Mumbai, 2007). With one of the highest population densities in the world, service providers find it difficult to supply basic amenities like health, water and sanitation. Water supply, sewerage and solid waste disposal systems need augmentation. Initiatives are being taken by Municipal Corporation of Greater Mumbai to supplement water supply, adopt technology and mechanisms that ensure substantial reduction in quantity of solid waste. An average of about 9400 metric tonnes per day (MTPD) of solid waste is estimated to be generated in Mumbai. Of this, approximately 45 percent is biodegradable waste, 20 percent recyclable materials, 12 percent inert matter and 23.5 percent construction waste and silt (www.mcgm.gov.in). According to the Municipal Corporation of Greater Mumbai the total solid waste generation in Mumbai is expected to reach about 10,000 MTPD by 2025. Of the 1,27,486 tonnes of waste generated daily in India in 2011-12, Mumbai alone accounted for 6.11 percent. It is estimated that every resident in the metropolis now generates about 630 grams of waste daily, a figure that is expected to touch 1 kg in the coming years. Solid wastes are mainly disposed of to landfill, as it is a simple, cheap and most cost effective method for disposing of waste (Barrett and Lawler,1995). Landfill is therefore likely to remain a pertinent source of groundwater contamination for the near future (Allen, 2001). All the dumping grounds in Mumbai are located for decades nearby built-up area which creates environmental hazards. In an attempt to achieve zero garbage status, the Corporation has initiated segregating, recycling and composting of non-biodegradable and biodegradable waste. Vermiculture within residential complexes is being encouraged, vegetable market waste is being diverted to gardens for vermiculture (currently 43 metric tons per day of market waste is being disposed at 24 sites) and rag pickers are being employed for house to house collection. The collection of waste includes the segregation of dry and wet waste for which Municipal Corporation of Greater Mumbai has provided separate bins; bio-degradable bags and separate ward wise vehicles for dry waste collection. The gardens department of Brihanmumbai Municipal Corporation (BMC) has taken up an initiative to install mini composting in select gardens occupying an area of 300 to 400 sqft which process the wastes from the parks and wastes generated from the surrounding areas (Mid-Day, January 2015).

An inefficient waste management system may create serious negative environmental issues like infectious diseases, water pollution, ground water contamination and also loss of biodiversity. Wastes that end up in water bodies, change the chemical composition of the water leading to water pollution. Chemicals resulting out due to waste dumping contaminate the soil and if plants and animals consume the contaminated soils, there can be negative impact on human health. Improper waste management practices lead to land and air pollution and can cause serious health issues. Hence, the present study intends to find the suitable and potential area for the disposal of solid waste with the help of geoinformatic technique with an objective to identifying site for waste disposal.

Database used for the present study:

Mumbai is located on the western coast of India (Fig.1). The spatial extent lies

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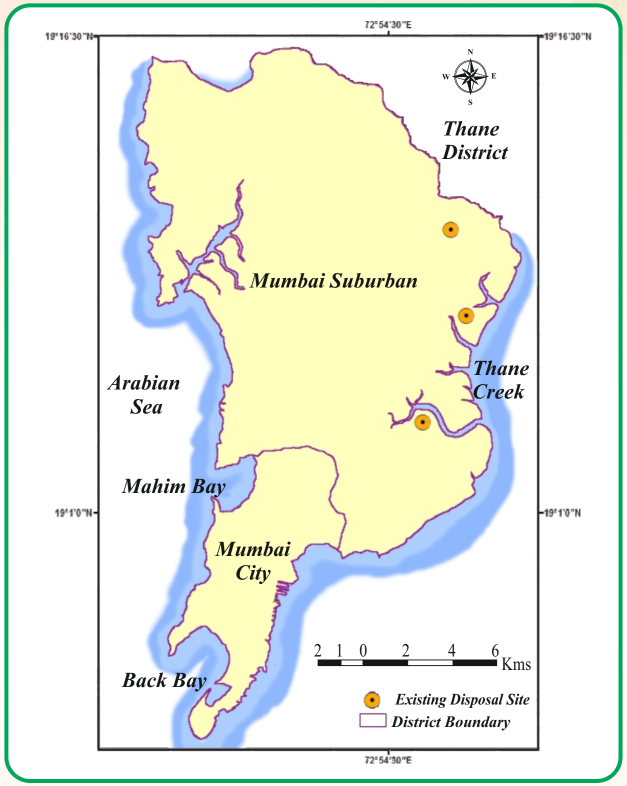
between 18°50' and 19° 18' north latitudes and 72° 45' and 73° 03' east longitudes.

Fig.1 Location Map of Mumbai



Dataset used for the analysis are:

- Toposheet : E43A16, E43G13, E43A15 & A11 Scale : 1:50,000 (Source: Survey of India)
- Bhuvan Portal (Source: http://bhuvan.nrsc.gov.in/)
- Google Earth Image (Source: Flashearth.com)
- LANDSAT and Advanced Spaceborne Thermal Emission and Reflection Radiometer Digital Elevation Model (ASTER DEM) Satellite Imagery (Source: Global Land Cover Facility (GLCF) http://glcfapp.umiacs.umd.edu)
- Census Report 2011
- Data from Ground Water Board, Nagpur
- Software ArcGIS version 10.0.

Methodology:

The focal theme of the study is to find places which are not suitable for habitation, agricultural uses and other allied human activities but are favourable for solid waste disposal. Actually, those land parcels not apt for any human activities were generally known as waste land and they are considered as appropriate land for solid waste disposal. The process of identification includes various thematic layers viz., land use / land cover classes, geological features, geomorphological features, hydrological parameters, lineaments /fracture zones, slope, soil texture and road accessibility etc. While any land cannot be declared as waste or non useable considering any one of the above mentioned parameters. Hence, the present study also considers five valid parameters discussed above to identify suitable land for solid waste disposal. The methodology adopted for obtaining the potential site for solid waste is as follows:

Toposheets are georeferenced using UTM WGS 84, zone 44 projection systems and mosaiced. Subsequently, the study area boundary is demarcated using toposheets and its corresponding geographical area is also calculated in GIS software and cross verified with government records. After finalizing the aerial extent of the study area, various thematic layers viz., land use / land cover, geology, geomorphology, slope, lineament and drainage were also digitized using visual interpretation technique.

National Land Use/ Land Cover classification system has been primarily developed with remotely sensed data in order to meet the required basic information needed on land use for Agro-climatic zone planning (NRSA, 1989). Initially a nine-fold land use classification was used extensively. The types are: 1) Forest, 2) Barren and Uncultivable land, 3) Land put to non agricultural uses, 4) Cultivable Waste, 5) Permanent Pastures and other Grazing land, 6) Miscellaneous tree crops and groves not included in the net area sown, 7) Current Fallow, 8) Other Fallow lands and 9) Net area sown. However, keeping in line with other countries, a detailed scheme of land use classification was developed by National Remote Sensing Agency (NRSA, 1989). In NRSA classification, 6 major categories are identified under Level–I, each of which was further subdivided in Level–II. For the present investigation, level I classification is adopted and it includes built-up land, agricultural land, forest, waste lands, water bodies and others. The land use / land cover map was prepared from LANDSAT 7 ETM+ satellite imagery using visual image interpretation technique.

Similarly, the geomorphology map is prepared by onscreen digitization of maps obtained from the Department of Geology, Government of India and Bhuvan web portal. The morphological classes considered for the analysis includes three major classes namely denudation landforms, coastal and fluvial landforms. The three classes are further subdivided into cuesta, linear ridge, residual hill, mud flats, rocky beach, salt pan, sandy beach, delta, plains and water bodies respectively.

While the geology map is prepared in the same manner and classes considered for the analysis are hard rock (basalt), soft rock (sandy & mud flats) and hilly area.

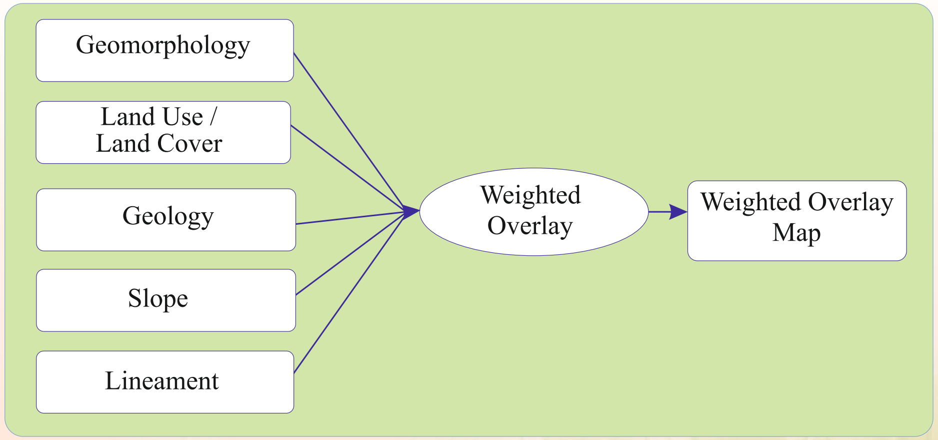
The lineament map is generated from the data obtained from Bhuvan web portal and it is also digitized using visual interpretation technique. For the purpose of overlay analysis, a 500 meter buffer zone has been created to identify lineament.

The drainage features were captured from the Survey of India toposheets with scale of 1:50,000 (1980). So, to verify the existence of water body in 2015, the digitized layer is overlaid with Google satellite imagery to enhance the level of accuracy and also to substantiate its existence within the study area.

Finally, the slope map is prepared from the data obtained from ASTER DEM and is classified as low, moderate and steep slope.

The above discussed thematic maps are overlaid using weighted overlay technique to find out the suitable site. The weighted overlay is a technique which applies a common scale of values to diverse and dissimilar input to create an integrated analysis. Geographic problems often require the analysis of many different factors. Weighted overlay analysis is a simple and straight forward method for a combined analysis of multi-class maps.

Fig. 2 Flow Chart Representing Overlay Analysis



A weight represents the relative importance of a parameter and the overlay method takes into consideration the relative importance of the parameters and the classes belonging to each parameter. There is no standard scale for a simple weighted overlay method. For this purpose, criteria for the analysis are defined and each parameter is assigned importance (Fig 2). Total rank is divided into 3 categories such as suitable, less suitable and not suitable.

Weighted overlay is a technique for applying a common scale of values to diverse and dissimilar input to create an integrated analysis. Geographic problems often require the analysis of many different factors. Weighted overlay analysis is a simple and straight forward method for a combined analysis of multi-class maps. The efficacy of this method depends upon human judgment and can be incorporated in the analysis. A weight represents the relative importance of a parameter. Weighted index overlay method takes into consideration the relative importance of the parameters and the classes belonging to each parameter. There is no standard scale for a simple weighted overlay method. For this purpose, criteria for the analysis should be defined and each parameter should be assigned importance. (Sashikumar and Lalwin, 2013).

Results and Discussion

Solid waste eliminates adverse impacts on environment and human health. A number of processes are involved in effectively managing waste for a municipality. These include monitoring, collection, transport, processing, recycling and disposal. While the final stage of management i.e., disposal plays a vital role since it has to be done in a right place, so the process of management gets fulfilled. Identifying sites for waste disposal with five important thematic layers viz., land use / land cover, geology, geomorphology, lineament and slope could be of help for policy measures.

Land Use / Land Cover:

The classes namely built-up area, agriculture land, water bodies / wetland, barren land, forests and hills are observed in the study area (Fig.3). The major portion of the study area is covered with built–up area that includes residential, commercial, recreational and industrial area. Agriculture land includes crop land, fallow land and plantation which are present in the north western part of the study area. Barren land includes open scrub, ravine land and salt affected land which can be seen in the south eastern, north western and northern part of the study area. Forests are present in the northern part of the study area. Water bodies include wetland, river, stream and lake. Wetlands are observed in the eastern, north western, western and south eastern part. The area has three lakes, Powai lake (artificial lake), Tulsi lake and Vihar lake which can be found in the northern part of the study area. Table 1 shows the estimated areal extent of the land use / land cover of the study area.

Table 1 Estimated Areal Extent of Land Use / Land Cover

S No.	Land use / Land cover Classes	Area (Km²)
1	Built-up Land	337.26
2	Agriculture Land	39.81
3	Wet Land	68.78
4	Forest Land	135.31
5	Barren or Waste Land	21.84
Total Area		**603.00**

Geomorphology:

The study area has been divided into fluvial, denudational and coastal landforms (Fig.4).

Fluvial landforms are developed due to the deposition of sediments carried by streams. Alluvial plains and deltaic plains are the different fluvial landforms seen in the study area. Alluvial plains are stream deposited features and are relatively flat areas composed of alluvium. Extensive alluvial plains are confined to the area between the sea coast and hilly regions of Borivli National Park.

Table 2 Estimated Areal Extent of the Geomorphology

Sr.no.	Geomorphological Classification	Area (Km²)
1	Linear Ridge	16.47
2	Cuesta	108.06
3	Residual Hills	7.23
4	Mud Flats	119.7
5	Rocky Beach	18.21
6	Salt Pans	8.44
7	Delta	6.26
8	Plains	284.7
9	Water Body	33.93
Total Area		**603.00**

Denudational landforms are formed as a result of active processes of weathering, mass wasting and erosion i.e., action of exogenic agents upon the exposed rocks. Cuesta, a landform with gentle dip slope on one side and an escarpment on the other is found mainly in the northern and southern part of Mumbai. Linear ridge is found in the south eastern part of Mumbai. Residual hill can be found in the northern and south eastern part of Mumbai.

Coastal landforms are produced by the action of waves and tides. Mud flats, rocky beach, salt pans and sandy beach are the common coastal landforms found in the study area. Mud flats are covered by the salt water and are found in the low land area and has a rich flora and fauna especially mangroves. Mud flats are found in Thane creek in the east, Malad creek, Manori creek in the north and Mahul creek in the south. Within these mudflats, salt marshes can be found in the eastern and northern part of the study area. Sandy and rocky beaches can be found in the western part. Table 2 shows the estimated areal extent of the geomorphology of the study area.

Geology:

The study area is covered mostly of soft rocks comprising of sand and mudflats (Fig.5). Hard rock comprising of basaltic rocks is found in the southern, northern, south western and north eastern part of the study area. The estimated area under different types of geology of the study area is shown in Table 3.

Table 3 Estimated Areal Extent of Geological Classification

S No.	Geological Classification	Area (Km²)
1	Hard Rock (Basalt)	158.48
2	Soft Rock (Sand and Mud flats)	331.29
3	Hills	79.30
4	Water body	33.93
Total Area		**603.00**

Lineament:

Lineaments are linear features caused by the linear alignment of regional morphological features such as streams, escarpments, and mountain ranges, and tonal features that in many areas are the surface expressions of fractures or fault zones (Lillesand and Kiefer, 1994). Lineaments are seen in the patches of the northern and eastern part of the study area (Fig.6).

Slope:

Slope is one of the important terrain characteristic which controls the infiltration rate. When the slope increases, the runoff also increases. Erkut & Moran (1991) state that if the slope is too steep, it is difficult and costly to construct the landfill. According to Sener et al. (2011) and Leao et al. (2004), the land with a slope less than 10 degree is highly suitable for solid waste dumping. In this context, the study area slope map is prepared and it ranges from less than 10 degree to more than 30 degree. The area is covered mostly of low slope. However, steep slope can be found in the south eastern and northern part of the study area (Fig.7).

Drainage and Water body:

The natural / artificial water body should not be disturbed and destroyed due to human activities as water is the major source for our day to day needs. Mumbai has rivers such as Dahisar, Poisar and Oshiwara that originates within the Borivli National Park. The Mithi river originates from Tulsi lake. Lakes such as Powai lake, Tulsi lake and Vihar lake can be found in the northern part of Mumbai (Fig.8).

Each thematic map is categorized into three classes based on their effect in selection of suitable site for waste disposal. Table 4 shows the parameters classified into three categories with reference to the suitable site for waste disposal. The rank assigned for different criteria to select the suitable site for waste disposal has been shown in Table5 (Jaybhaye et.al, (2014), Sashikumar and Lalwin, (2013)). Rank has been assigned as 1, 2 and 3 which represents not suitable, less suitable and suitable respectively. That means, higher value represents suitable and lower value represents not suitable land for waste disposal.

Table 4 Suitability Parameter for Identifying Site

Parameter	Category		
	Not Suitable	**Less Suitable**	**Suitable**
Land Use / Land Cover	Cultivable land, built-up area, water body, wet land	Forests / hills	Open scrub/ barren/ waste land
Geology	Soft rock (sand and mud flats)	Hard rock (Basalt)	-
Geomorphology	Mud flats, rocky beach, sandy beach, salt pans, delta	Cuesta, linear ridge, residual hill	Plains
Slope	Steep slope	Moderate slope	Low slope
Lineament	Present	-	Absent

Land use should be considered as an important criterion for any planning activities. Barren / waste land is the land which cannot be used for anything. Hence, for the present study higher value (rank 3) has been given for barren / waste land which is considered ideal for solid waste disposal.

Central Pollution Control Board, clearly stated 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). Hence, for the present study water bodies such as rivers, lakes and tanks have been assigned lower weightage.

Irhoumah et. al. stated that Geological structures have great importance in ground investigation (2014). Clay regions, silt, sand and rock shows degree of weathering and fracture, as well as to locate groundwater. Slope is also an important factor while siting a landfill. Higher slopes would increase runoff of pollutants from the landfill, and thereby contaminate areas further away from the landfill site (Lin & Kao, 1999).

For the present study, a 500m buffer zone for lineament has been created which represents whether lineament is present or absent. The zone of 500 m is not suitable for waste dumping and absence of lineament is considered as suitable for waste disposal.

Table 5 Rank and Level of Suitability Assigned for Each Criteria to Select Suitable Site

Sr no.	Criteria	Classes	Rank	Suitability
1	Land use / Land Cover	Cropland	1	Not Suitable
		Water bodies	1	Not Suitable
		Open scrub/barren land	3	Suitable
		Built-up land	1	Not Suitable
		Forest	1	Not Suitable
		Hill	1	Not Suitable
		Wet land	2	Less Suitable
2	Geomorphology	Residual hill	2	Less Suitable
		Cuesta	2	Less Suitable
		Linear ridge	2	Less Suitable
		Mud flats	1	Not Suitable
		Rocky beach	1	Not Suitable
		Salt pans	1	Not Suitable
		Sandy beach	1	Not Suitable
		Delta	1	Not Suitable
		Plains	3	Suitable

3	Lineament	Present	1	Not Suitable
		Absent	3	Suitable
4	Geology	Hard rock	2	Less Suitable
		Soft rock	1	Not Suitable
5	Slope	Low	3	Suitable
		Moderate	2	Less Suitable
		Steep	1	Not Suitable

According to notification S.O.908 (E), 2000 made by the Ministry of Environment and Forest, the final disposal of municipal solid waste should be done in specified measures in order to prevent contamination of ground water, surface water and ambient air quality. Land fill site shall be large enough to last for 20-25 years. One of the biggest dumping grounds in the city since 1927 is Deonar that takes more than 80% of the total waste. Mulund dumping ground is already being over-used and has reached the saturation point. The disposal site in Deonar has already taken a shape of a mountain, which has been staring at closure since 2011, receives 3,500 tonnes and Mulund dumping ground receives 2,200 tonnes of wastes. Neither of these dumping grounds (Deonar and Mulund) currently in use has a waste processing unit, and mostly unsegregated and untreated garbage is simply dumped there, and the garbage catching fire due to the gases are common. The recently-opened Kanjurmarg dumping ground now processes 3,000 tonnes of waste, where the garbage is processed and methane gas is generated (Indian Express, August 2015). The Brihanmumbai Municipal Corporation (BMC) is in a quandary as to where to find new open spaces. The situation is equally grim when it comes to hazardous wastes generated by industries. (Daily News Analysis , September 2013).

Table 6 Suggestive Suitable Site for Waste Disposal

Sr no.	Suitable site	Area
1	Site 1 (northern Mumbai)	Near village Vatarna
2	Site 2 (south east Mumbai)	Near , NPCIL and Paylipada, Trombay

Thus, in the present study, the suitable sites were identified based on geoinformatic technique. After assigning the ranks to all the five thematic data (geomorphology, land use, drainage, geology, slope and lineament) and superimposing each other, three zones are identified and demarcated such as Suitable, Less suitable and Not Suitable. Eventually, there are two suitable sites identified for waste disposal. It can be observed in the northern part and south eastern part of the study area (Fig.9 and Table 6). Site 1 is located in the northern part of Gorai village which satisfies the minimum requirements for new site. Site 2 is located in the industrial area close to BARC, Trombay, NPCIL and Wadala. Both the sites are waste land observed to be close to the wet lands and hence if selected, should be given due importance to protect the wet land environment. However, potential site should be identified through field survey also. The selection of site finally requires further studies on soil testing, ground water level and depth to water table. Thus, proper selection of waste disposal site helps in developing a safe and healthy environment. As the use of remote sensing and GIS technologies have given a considerable output in identifying suitable site it will help minimizing the environmental risk and human health issues.

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MAPS

Fig 3

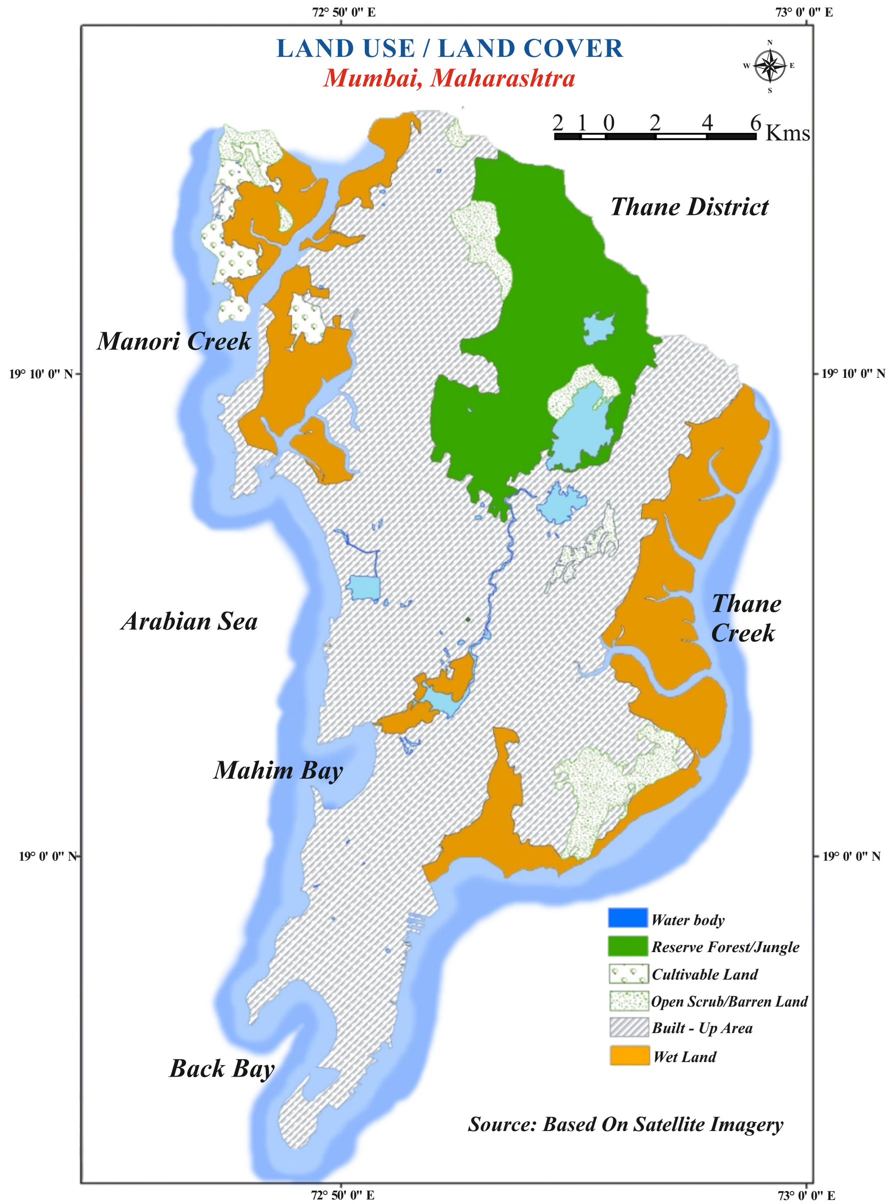
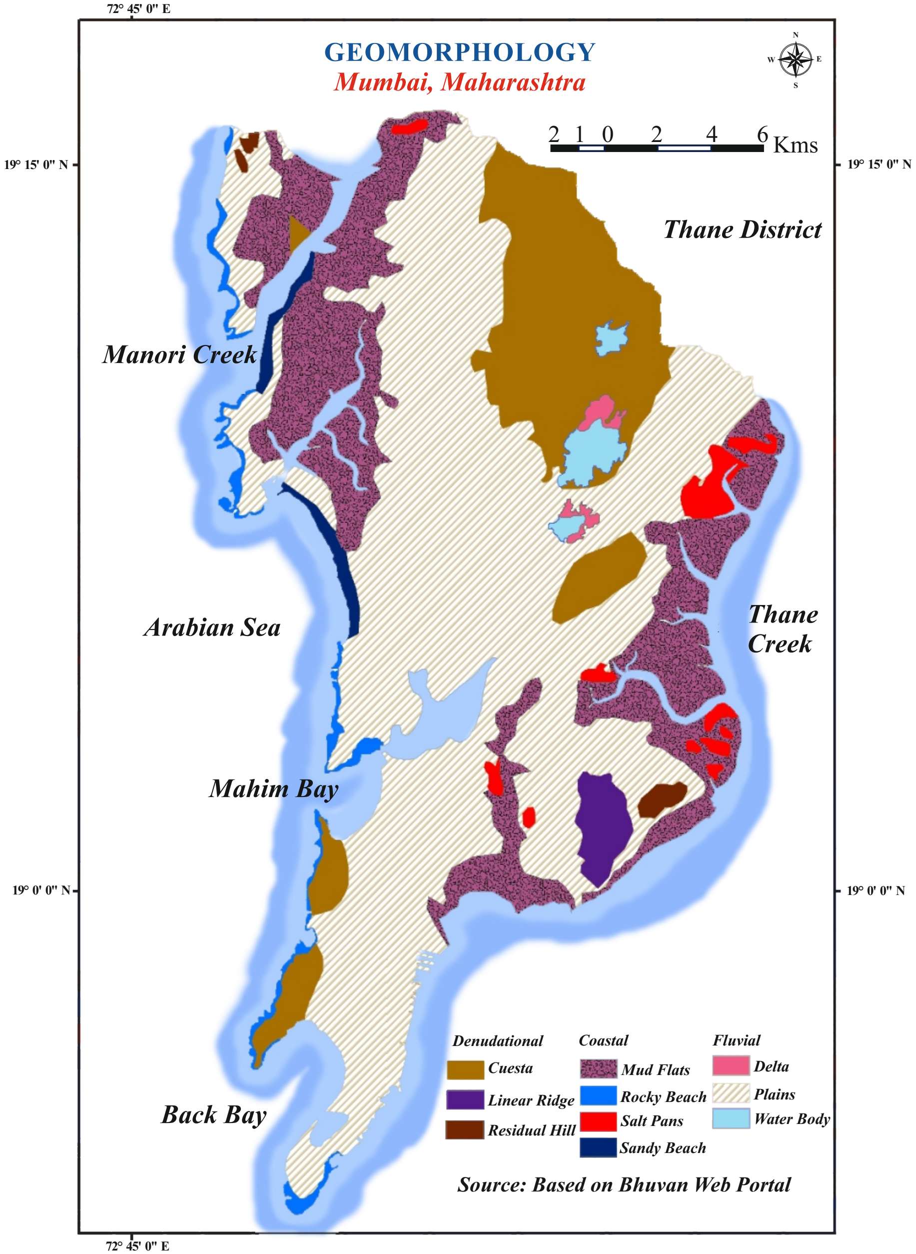


Fig 4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Linear Ridge
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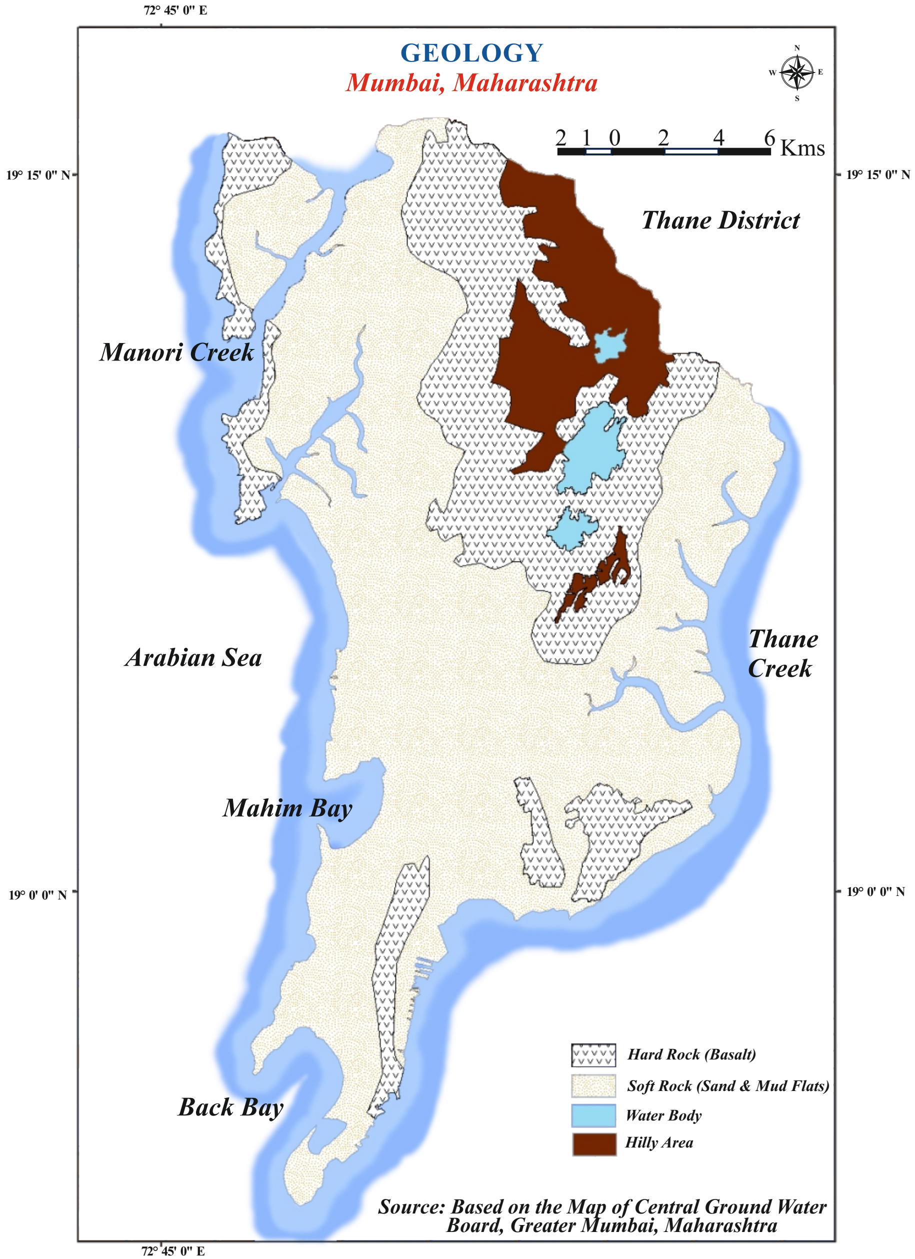
Coastal
Mud Flats
Rocky Beach
Salt Pans
Sandy Beach
Fluvial
Delta
Plains
Water Body
Source: Based on Bhuvan Web Portal

Fig 5


GEOLOGY
Mumbai, Maharashtra
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19° 0' 0" N
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Thane District
Manori Creek
Arabian Sea
Thane Creek
Mahim Bay
Back Bay
Hard Rock (Basalt)
Soft Rock (Sand & Mud Flats)
Water Body
Hilly Area
Source: Based on the Map of Central Ground Water Board, Greater Mumbai, Maharashtra

Fig 6

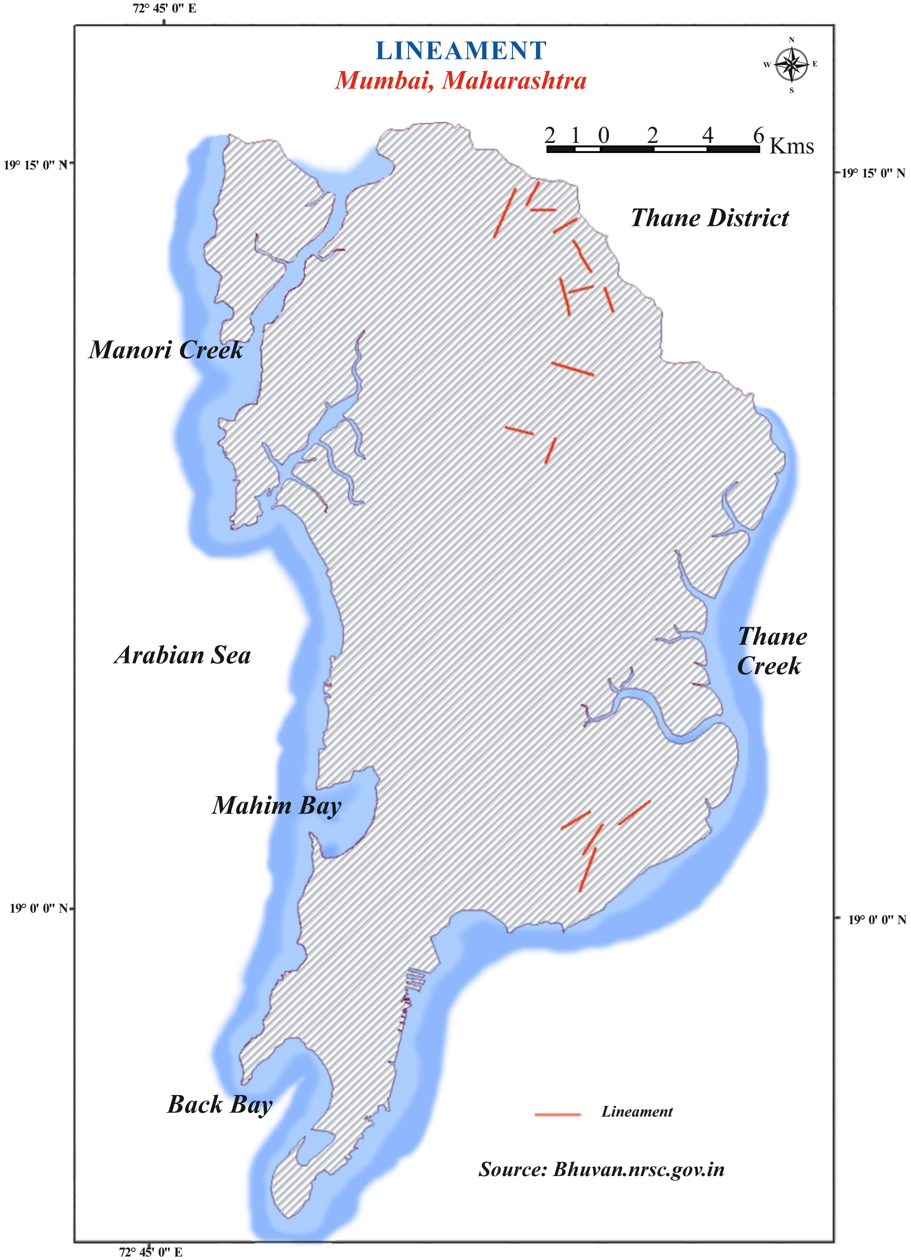
LINEAMENT
Mumbai, Maharashtra
72° 45' 0" E
19° 15' 0" N
19° 0' 0" N
2 1 0 2 4 6 Kms
Thane District
Manori Creek
Arabian Sea
Thane Creek
Mahim Bay
Back Bay
Lineament
Source: Bhuvan.nrsc.gov.in

Fig 7

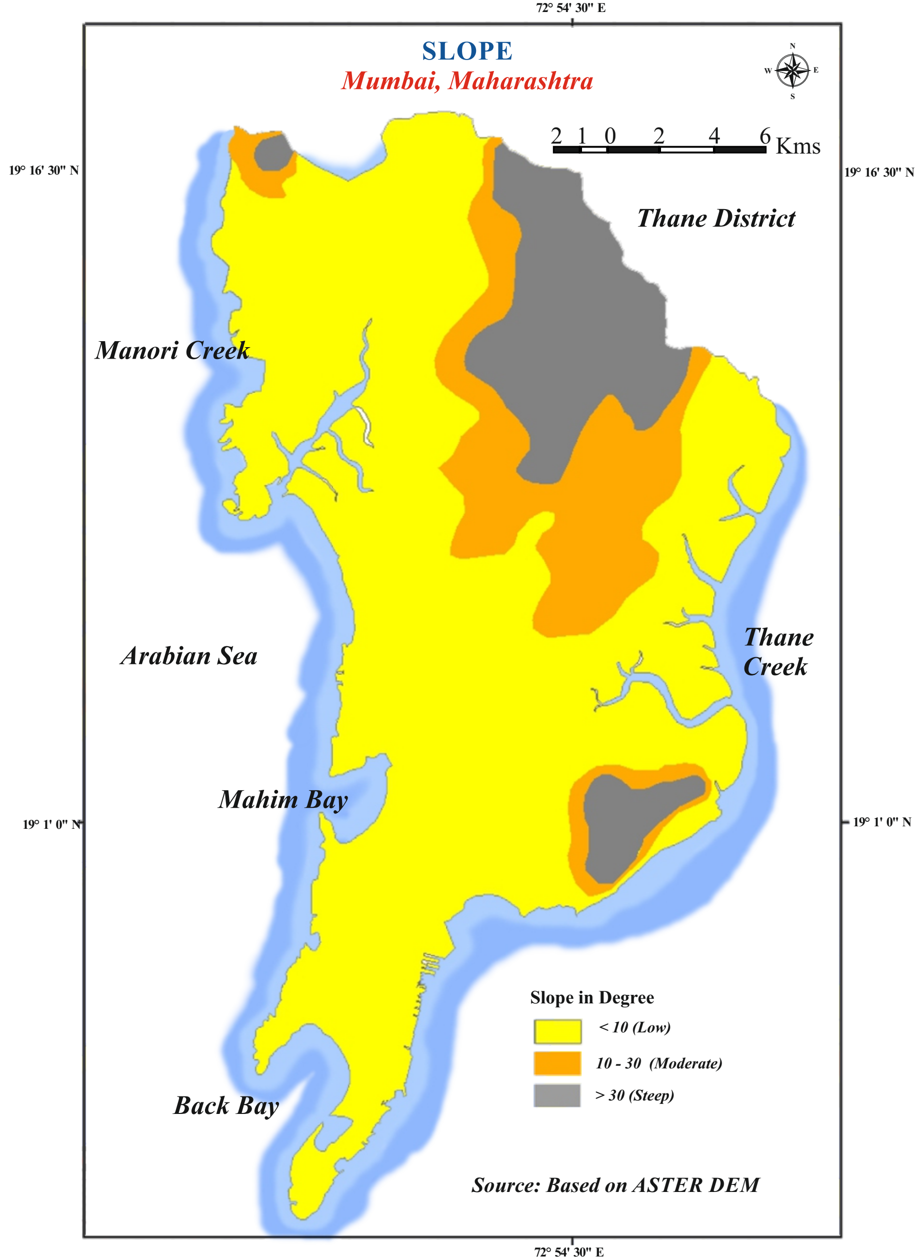
SLOPE
Mumbai, Maharashtra
72° 54' 30" E
19° 16' 30" N
19° 1' 0" N
2 1 0 2 4 6 Kms
Thane District
Manori Creek
Arabian Sea
Thane Creek
Mahim Bay
Back Bay
Slope in Degree
< 10 (Low)
10 - 30 (Moderate)
> 30 (Steep)
Source: Based on ASTER DEM

Fig 8

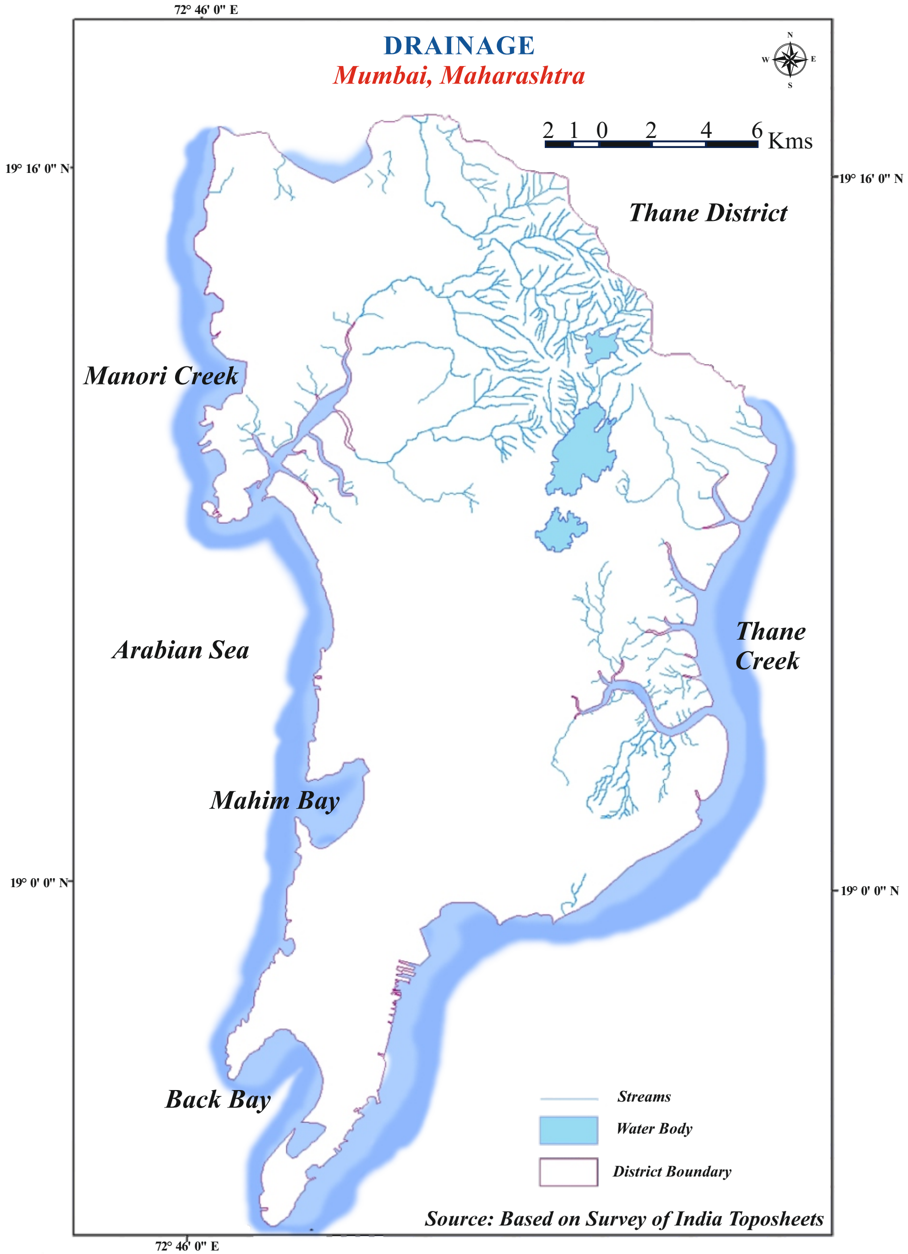

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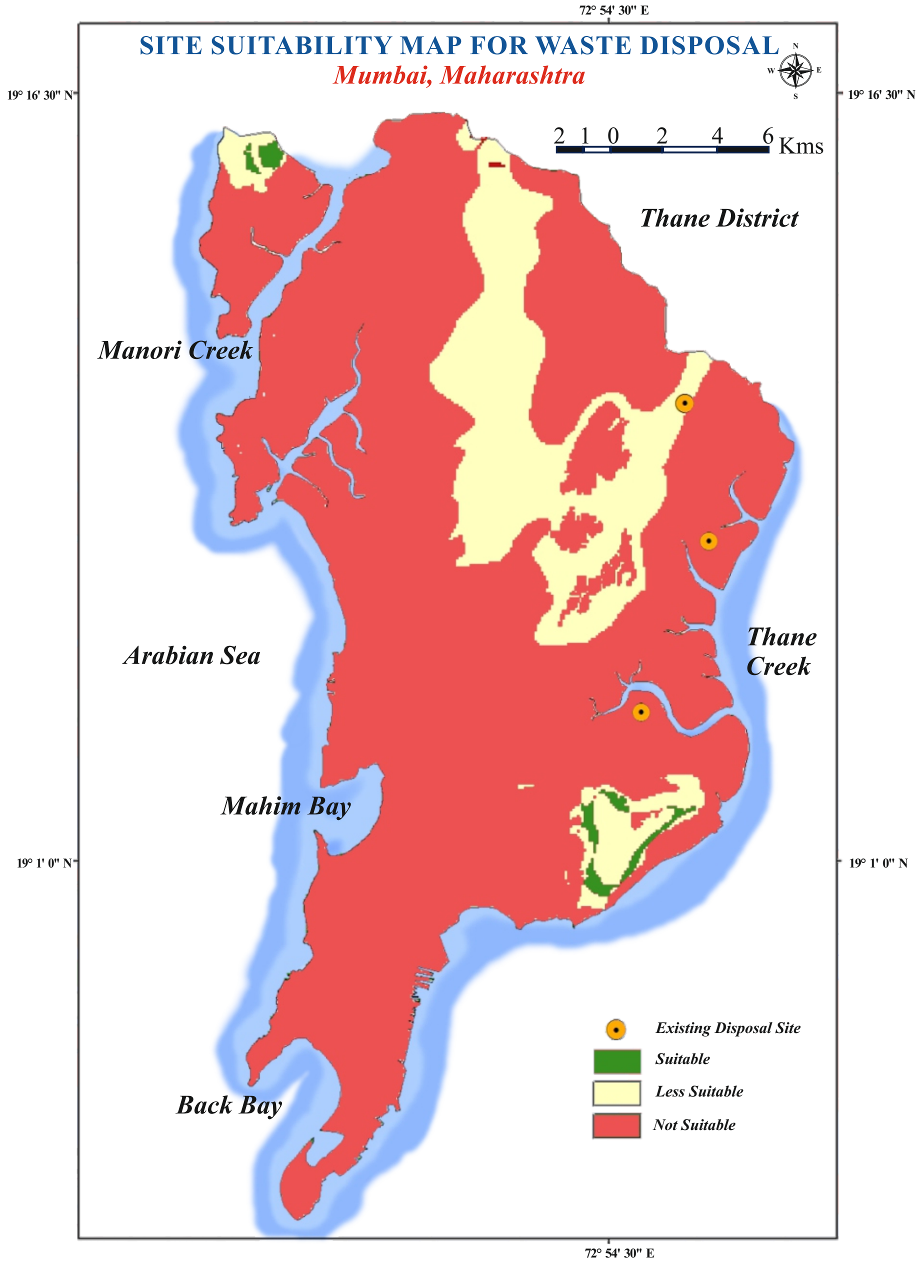
Fig 9



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