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Solid Waste Disposal Site Selection for Mangaluru City Corporation Using Multi-Criteria Analysis

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Abstract: With the rapid pace of urbanization and development, a huge amount of solid waste generated and its disposal is **becoming a huge challenge for the mankind**. The land **part on the Earth** has become more **and more** scarce and the decision of site selection for solid waste disposal is now facing more opposition by public. The solution to this problem can get easy public acceptance if the solution is approached by following a scientific methodology. In the present study, an integration of Geographical Information System (GIS) and Multi-Criteria Evaluation (MCE) is used for the decision making process. Mangaluru is one of the fastest developing city **in recent times and becoming a hub of huge waste**. Lack of scientific solid waste dumping site and insufficient capacity of the existing open dumping yard at Konchady suggest the **immediate** need of scientific approach towards site selection for solid waste disposal for Mangaluru City Corporation (MCC).

Site selection for solid waste disposal is influenced by many factors. But considering the availability of the data the study considers the factors: distance from water bodies, distance from road network, distance from airport site, LU/LC class and ground slope. Each factor is compared to other and its relative importance in the selection process is accessed using pairwise comparison matrix. One of the outputs of the study is a final suitability map along with the location and information of the most suitable site parcels. Out of the total area of study, 98.43% area is identified as 'unsuitable' for the solid waste disposal site, 0.18% as 'moderate suitable' and 1.39% area (7.87 sq.km. i.e. 786.76 Ha) 'most suitable' site for solid waste disposal. The area identified under 'most suitable' category in this study need further field research and cost-benefit analysis is essential before proposing the particular site for the solid waste disposal.

The other output of the study is the ArcGIS model developed. Use of the 'Site Suitability Model for Solid Waste Disposal' has resulted in saving of considerable time and efforts. The model provides the final suitability map along with the most suitable site parcels in vector file format. The final suitability map produced was **found more** accurate and precise. The use of the model developed and if not the model but the GIS-MCE integration will solve the problem of locating the potential site for solid waste disposal which will avoid the possible significant damage to the environment.

Keywords: Site selection, solid waste disposal, Geographical Information System, Multi-Criteria Evaluation, ArcGIS model

1. Introduction

Solid waste is any rejected or discarded material unwanted by the society. It is generated from street sweeping, domestic, industrial, commercial and recreational areas. An uncontrolled pace of urbanization and modernization has resulted in the increased solid waste generation beyond the present limits of its disposal capacity. Currently local government bodies are lagging in funds, local, natural resources and infrastructure to dispose of this huge amount of solid waste and as a result,

it has shown adverse impacts on human health and environment (Basagaoglu et al., 1997).

1.1. Factors affecting site selection

Site selection for solid waste disposal is a complex process which involves consideration of many interdependent criteria and their sub-criteria. A scientific approach towards site selection process requires an expertise in hydrogeology, LU/LC, economics, sociology, soil science and environmental science (Chang et al. 2008). As in the rapidly growing cities like

Mangaluru availability of land is a main problem moreover sight of garbage dumped site is not pleasant, there is a tremendous public opposition to the site selection process. The increasing cost of lands also requires a consideration of economic factor while selecting the site for solid waste disposal. Economic consideration involves the cost of land acquisition, the cost of plant establishment, operation and maintenance.

1.2. Significance of GIS

Multiple criteria with the spatial dimension influence solid waste disposal site. Geographical Information System (GIS) is an efficient tool to capture, store, retrieve, manipulate, analyze and represent the spatial data with aspatial attribute information. The importance of multiple criteria and their sub-criteria are evaluated by comparing each one with the other using Multi-Criteria Evaluation (MCE) technique. Integration of GIS and MCE is of great help for selecting potential land parcels

that fulfill the minimum criteria to avoid an adverse effect on health and environment.

2. Study area

Geographically, Mangaluru is located at 12°52'N latitude and 74°49'E longitude. Refer Figure (1) Western Ghats lie on the East side of the city and the Nethravathi and Gurupura rivers surround the city on the North and South, joining the Arabian Sea on the West. The topography of the city varies from plain to undulating. Ambient temperature varies from 17°C to 37°C. The city receives 90% of its annual average rainfall (4000mm) during the period of monsoon.

The city is connected to major cities in India through a network of 3 national highways, rail network and a domestic airport at Bajpe. Mangaluru also has an all-weather port which is a major source of its revenue generation.

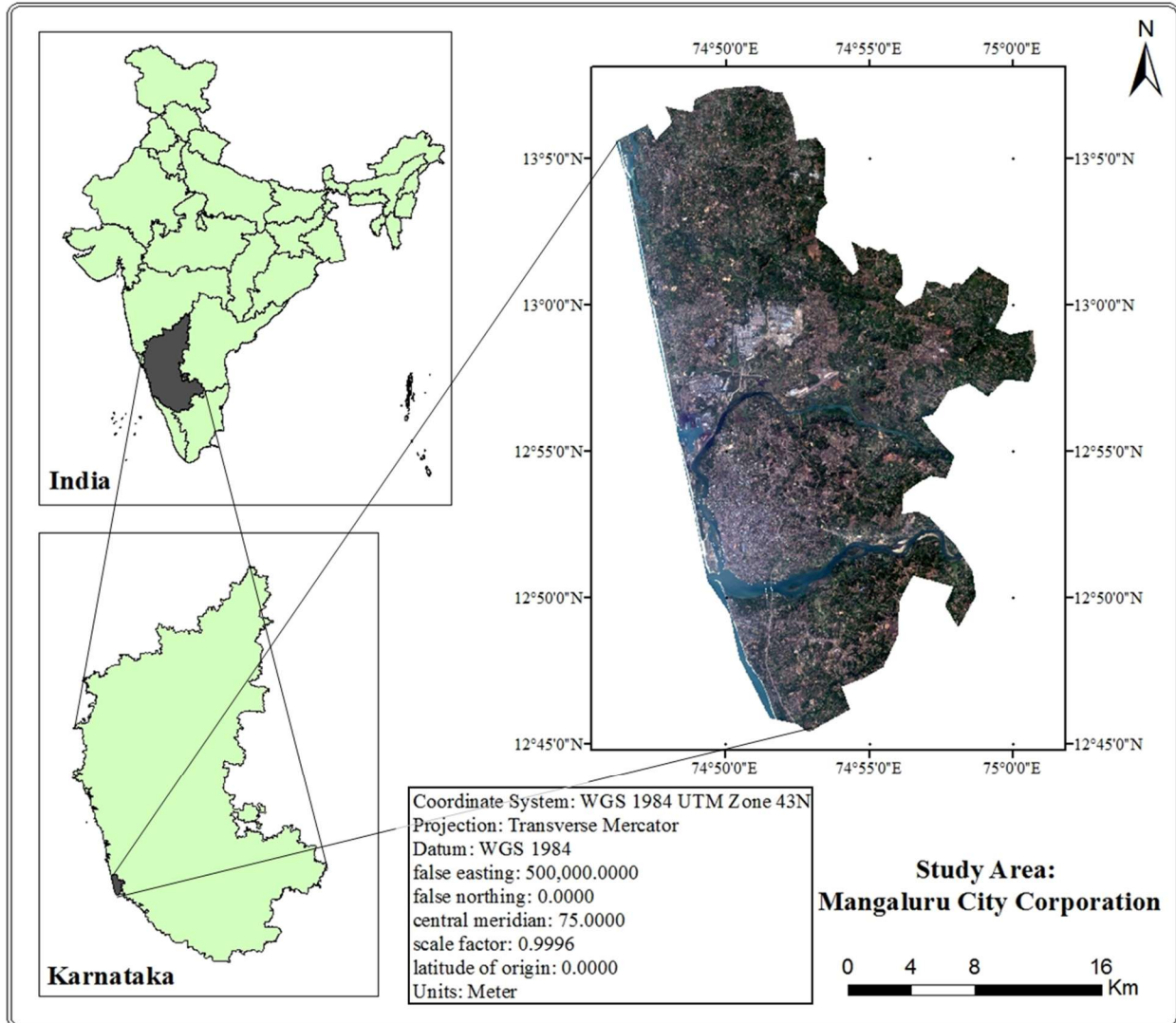


Figure 1. Study Area

2.1. Solid waste management in Mangaluru City Corporation (MCC)

Mangaluru is one of the fastest growing cities in India. With its fast rate of urbanization and industrialization, disposal of the huge amount of solid waste generated is one of the important challenges the city corporation is dealing with. The absence of scientific solid waste disposal site and insufficient capacity of existing dumping site at Konchady has given rise to the need for a scientific approach towards site selection for solid waste disposal.

The health department of Mangaluru City Corporation has major role to play in solid waste management. A Large portion of the municipal budget is spent on this issue. MCC’s efforts to tackle this problem has been appreciated by many organizations and MCC has been awarded for that. Average daily solid waste generation in the MCC area is approximately 226 tons per day. Whereas the average per capita solid waste generated is 0.4524 kg per capita per day (Vincent Sequeira et al. 2015). But in spite of putting so many efforts and spending huge money, this problem has yet not been solved. Most of the local bodies in MCC area, open dump the solid waste collected in low-lying areas. This open dumping of solid waste is always considered as unscientific as it leads to the foul smell, ground water contamination through leachate flow, breeding of rodents, pests and flies and spread of diseases, etc. These undesired consequences of unscientific disposal had shown an adverse effect on public health, aesthetics of the locality and environment.

3. Methodology and data used

In Erdas Imagine Software Maximum-likelihood algorithm is used for LU/LC classification of the MCC area. Airport boundary and streets are delineated from Google Earth. The kmz files thus created using Google Earth then converted to shape file format to use it in GIS platforms. ArcGIS desktop is used to generate slope maps using DEM data and mainly used for performing the analysis on the data available. Table (1) shows the details of the data used.

Table 1: Data used

| Data type | Date | Resolution | Source |
|-------------------------|--------|------------|--------|
| Landsat 8 | 2017 | 23.5 m | NRSC |
| SRTM DEM | 2011 | 30 m | USGS |
| Administrative Boundary | Recent | - | Bhuvan |

3.1. Methodology adopted

Figure (2) shows the flow diagram of the methodology adopted for the site selection process. It

starts with the important process of data collection. All the easily and freely available data is collected from Mangaluru Municipal Corporation. Freely available satellite data products are downloaded. Important features are identified and delineated from Google Earth using image visual interpretation techniques. Satellite data products are then downloaded from NASA’s USGS earth explorer website: <http://earthexplorer.usgs.gov/>

This available data is then registered to projected coordinate system UTM zone 43 North with datum WGS 84. The data is processed to get outputs like water body raster image, street shape file, airport shape file, LU/LC raster image and slope map.

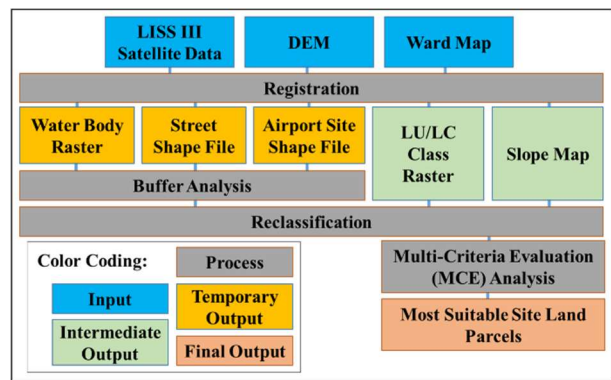


Figure 2. Methodology adopted

Around water body, streets and airport features buffer zones are plotted. Distances of the buffers plotted are as shown in Tables (2,5,6). Now, these buffer zones and LU/LC classes, as well as slope classes, are reclassified and assigned values ranging from 1 to 4 where 4 represents highest suitability agreement (i.e. no constraints) and 1 indicates unsuitability agreement (i.e. full constraints). Assigning of the values to the criteria and their sub-criteria is based on the experience of the MCC’s technical staff and other similar research works reviewed.

In this study, the site selection is carried out using Multi-Criteria Analysis (MCA) where we have multiple criteria and their sub-criteria. Each criterion and its sub-criterion have its weight in deciding the suitability of the site. To decide their importance in the site selection process, Satty’s AHP (Analytical Hierarchical Process) technique is used as a decision-making tool.

Every criterion is compared with the other on Satty’s scale of 1 to 4 score. A pairwise comparison matrix is formed which compares every criterion with other. The final output of the AHP process gives us an Eigen Vector showing us the relative suitability of every single site parcel over the other for waste disposal.

The model built in ArcGIS to make the repetitive processes automatic where the intermediate outputs are stored in temporary memory. It saves the user's time, efforts, avoids possibilities of errors in repetitive operations, avoids storage of unnecessary outputs in hard drives. The model is available for public use and modifications. It can be accessed and downloaded from the GitHub repository link provided below: <https://github.com/PrathamGitHub/WasteDisposalSiteSelection>

4. Results and discussion

The suitability criteria laid for the site selection follows international standard procedures considering Indian conditions and availability of data. All the considered criteria considered, their sub-criteria and level of suitability are summarized in Table (9). The criteria include distance from water bodies, distance from road network, distance from airport site, land use/ land cover classes and slope of the ground. Here distance from water body criterion is given maximum weight. Criteria and their suitability levels are finalized based on the inputs of the MCC's technical staff and the study of existing waste disposal sites, their present condition and problems faced. While finalizing the criteria the main emphasis was on reducing the pollution impact caused by the waste disposal on human health and environment, also the importance is given to minimize the cost of transportation and operation as far as possible.

4.1. Distances from water body

A site closer to the surface water body is considered as not suitable for the waste disposal as it may lead to surface water pollution. Dumping in and around the natural water body like lakes, rivers, etc. is strictly prohibited as per the guidelines of Central Pollution Control Board (CPCB). Gurupura and Netravati are the two main rivers in the study area. Using ArcGIS software buffer zones are plotted around the water body feature. The details of the buffer distance, their ranking values and suitability is summarized in Table (2).

Table 2: Distance from water body and area coverage of suitability levels

| Water body buffer | Level of suitability | Value | Area (Ha) | % of area |
|-------------------|----------------------|-------|-----------|-----------|
| >1000m | High | 4 | 33902.8 | 60.02 |
| 500–1000m | Moderate | 3 | 8626.6 | 15.27 |
| 300-500m | Less | 2 | 3692.2 | 6.54 |
| <300m | Unsuitable | 1 | 10262.7 | 18.17 |

Figure (3) shows the map produced after plotting buffers around the water body and then reclassification of the buffer zones.

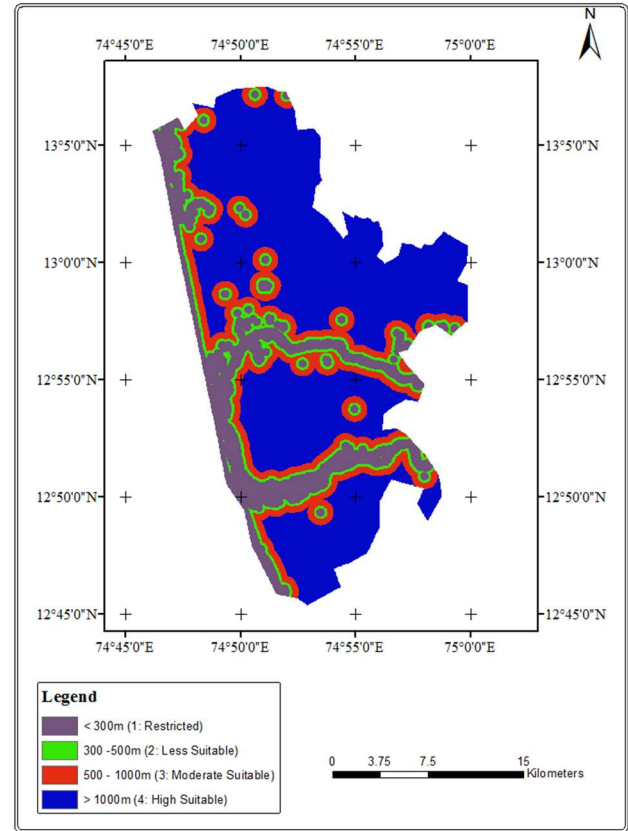


Figure 3. Reclassified distances from water body

4.2. Suitability of slope

Slope is one of the main factors considered for site selection as steeper slopes may lead to leachate flow underground polluting the ground water, rainwater flowing over steep slopes carries waste along with it polluting surface water source and flowing wind spreads the lighter waste like plastic bags over wider area which affects the local population health and surrounding aesthetics. The slope map is obtained from SRTM DEM data using ArcGIS software. It is then classified into the classes as mentioned in the table (3). Table (3) summarizes the details of the sub-criteria considered, their suitability levels.

Table 3: Slope class with respective suitability levels

| Slope (degree) | Level of suitability | Value | Area (Ha) | % of area |
|----------------|----------------------|-------|-----------|-----------|
| < 10 | High | 4 | 45643.7 | 80.81 |
| 10-15 | Moderate | 3 | 7341.2 | 13.00 |
| 15-20 | Less | 2 | 1099.0 | 1.95 |
| >20 | Unsuitable | 1 | 2400.4 | 4.25 |

Figure (4) shows the symbolized slope map after reclassification.

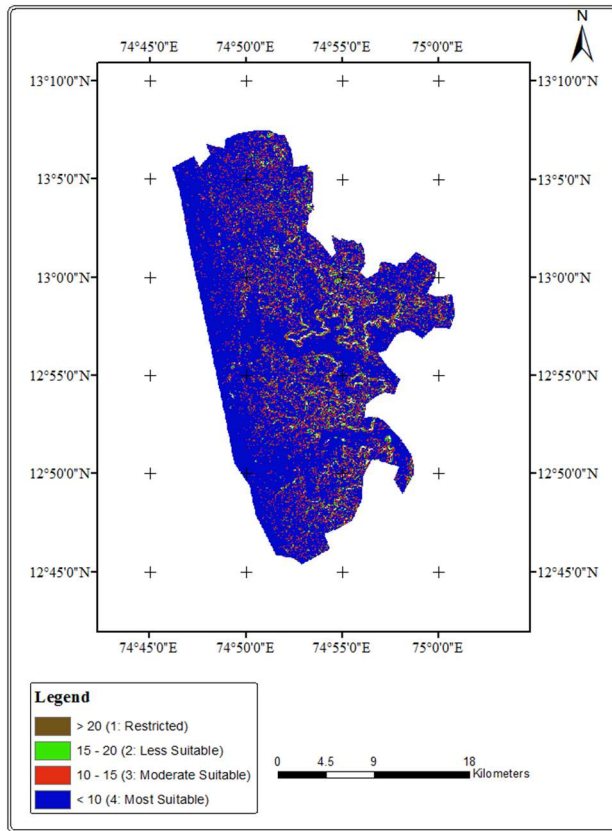


Figure 4. Reclassified slope

4.3. Suitability of Land Use/Land Cover

Landsat 8 satellite image is used for LU/LC classification. Classification is done with the use of Erdas Imagine software using maximum likelihood algorithm. The study area is classified into five classes: water body, built-up area, vegetation, agriculture land and barren land. For the present study barren land is considered as the most suitable site for the solid waste disposal. Solid waste disposal near and around the residential or built-up area is considered unsuitable as it may adversely affect the present population as well as the future growth of the locality. Table (4) summarizes the LU/LC classes and their suitability levels. Figure (5) shows the reclassified LU/LC map

Table 4: LU/LC class with suitability levels

| LU/LC Class | Level of suitability | Value | Area (Ha) | % of area |
|-----------------------------------|----------------------|-------|-----------|-----------|
| Barren Land | High | 4 | 5251.1 | 9.30 |
| Vegetation, Built-up, Agriculture | Unsuitable | 1 | 48685.3 | 86.19 |

| | | | | |
|------------|------------|---|--------|------|
| Water Body | Unsuitable | 1 | 2547.9 | 4.51 |
|------------|------------|---|--------|------|

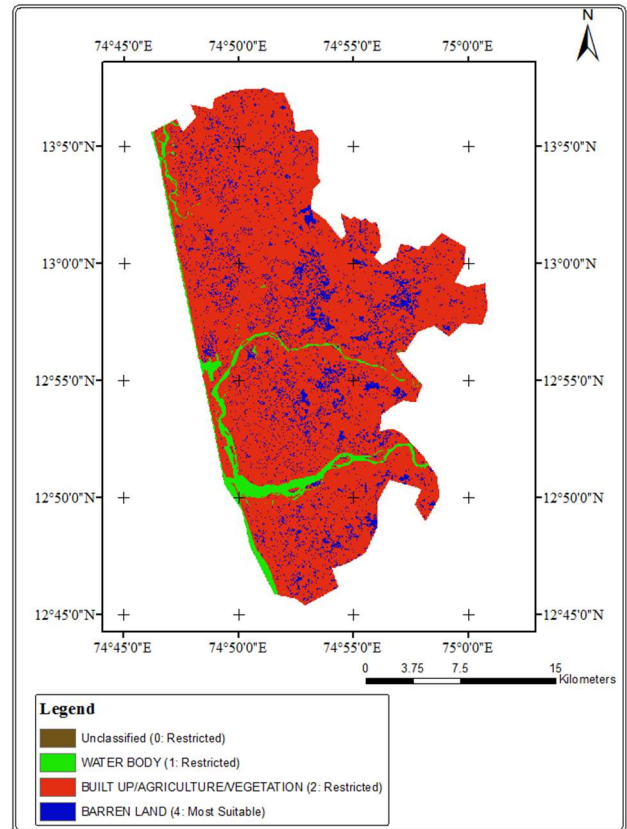


Figure 5. Reclassified land use land cover

4.4. Distances from road network

If we consider the aesthetics of the roadside, solid waste disposal along the major highways and city roads is considered as unsuitable. At the same time, the solid waste disposal site should not be located far away from the existing road network to avoid the extensive cost of the connecting road construction. For the present study sites which have their distance from major roads less than 500 meters and more than 1500 meters are considered as unsuitable. Table (5) summarizes the buffer distances and their suitability levels. Figure (6) shows the reclassified distance from road network map.

Table 5: Distance from road network and area coverage of suitability levels

| Road Buffer | Level of suitability | Value | Area (Ha) | % of area |
|-------------|----------------------|-------|-----------|-----------|
| 500-1000 m | High | 4 | 9816.2 | 17.38 |
| 1000-1300m | Moderate | 3 | 2402.0 | 4.25 |

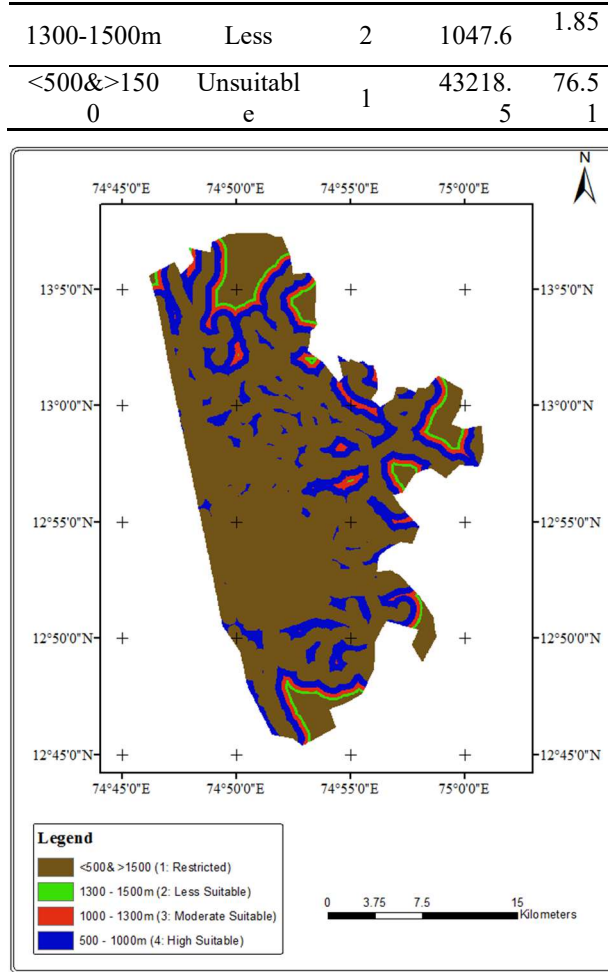


Figure 6. Reclassified distance from road network

4.5. Distances from airport site

As the presence of solid waste attracts flies and birds and it is observed that the birds flying around airport area have led to non-operational flights, emergency landings, and flight accidents. Considering the aesthetics but more importantly, the safety of the airport operations the solid waste dumping site should be as far from the airport site as possible. The details of the buffer distance from airport site and their suitability levels are summarized in table (6). Figure (7) shows the reclassified distance from airport site map.

Table 6: Distance from airport and area coverage of suitability levels

| Airport Buffer | Level of suitability | Value | Area (Ha) | % of area |
|----------------|----------------------|-------|-----------|-----------|
| >3000m | High | 4 | 51068.3 | 90.41 |
| 2000-3000m | Moderate | 3 | 2350.2 | 4.16 |
| 1000-2000m | Less | 2 | 1727.2 | 3.06 |
| <1000m | Unsuitable | 1 | 1338.5 | 2.37 |

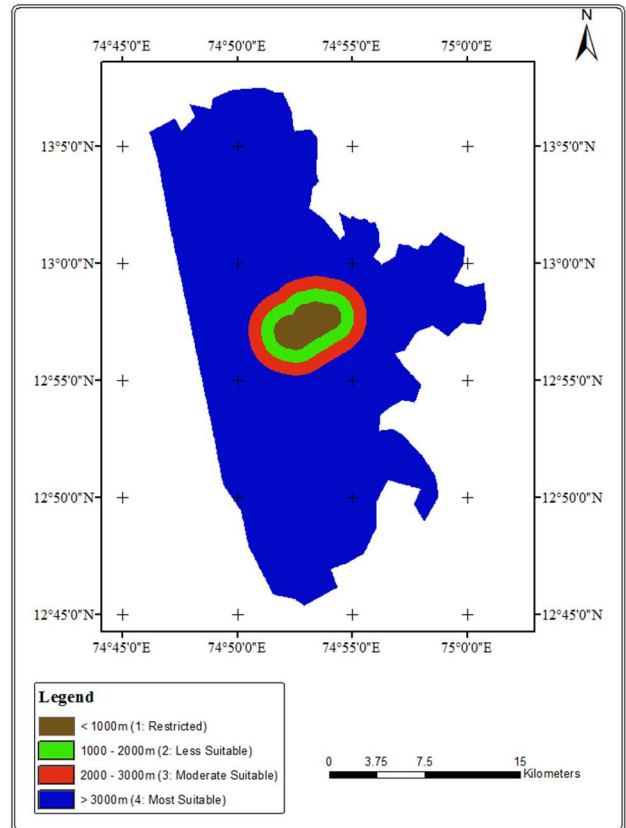


Figure 7. Reclassified distance from airport

The relative importance of one criterion over the other can be scientifically evaluated using Analytical Hierarchical Process (AHP) technique. In this a pairwise comparison matrix is formed as shown in Table (7).

Using AHP technique, an Eigen vector is obtained from pairwise comparison matrix. Table (8) shows the Eigen vector weights calculated.

Table 7: Pairwise comparison in 9-point continuous scale, 9 as extremely important, 1 as equally important

| Criteria | Airport | LU/LC | Road | Water Body | Slope |
|------------|---------|-------|------|------------|-------|
| Airport | 1 | 1/2 | 1/2 | 1/9 | 1/3 |
| LU/LC | 2 | 1 | 1 | 1/4 | 1 |
| Road | 2 | 1 | 1 | 1/6 | 1/2 |
| Water Body | 9 | 4 | 6 | 1 | 3 |
| Slope | 3 | 1 | 2 | 1/3 | 1 |

Table 8: Weights derived by calculating the principal Eigen vector of pair wise comparison matrix

| Criteria | Eigen Vector Weight | Percentage Weight (%) |
|----------|---------------------|-----------------------|
| Airport | 0.0599 | 6 |
| LU/LC | 0.1338 | 13 |

| | | |
|-------------------|--------|----|
| Road | 0.0955 | 10 |
| Water Body | 0.5549 | 55 |
| Slope | 0.1559 | 16 |

Table (9) summarizes the criteria considered, their sub-criteria, level of suitability and influence percentages of every criterion.

Table 9: Attribute ranking and Layer's weights for the maps used in the landfill site selection

| Criteria | Sub-Criteria | Level of Suitability | Value | Influence (%) |
|-------------------|-----------------------------------|----------------------|-------|---------------|
| Water Body | > 1000 m | High | 4 | 55 |
| | 500–1000m | Moderate | 3 | |
| | 300-500m | Less | 2 | |
| | < 300m | Unsuitable | 1 | |
| Slope | < 10 | High | 4 | 16 |
| | 10-15 | Moderate | 3 | |
| | 15-20 | Less | 2 | |
| | >20 | Unsuitable | 1 | |
| LU/LC | Barren Land | High | 4 | 13 |
| | Vegetation, Built-up, Agriculture | Unsuitable | 1 | |
| | Water Body | Unsuitable | 1 | |
| | 500-1000 m | High | 4 | |
| Road | 1000–1300m | Moderate | 3 | 10 |
| | 1300-1500m | Less | 2 | |
| | <500&>1500 | Unsuitable | 1 | |
| | >3000m | High | 4 | |
| Airport | 2000-3000m | Moderate | 3 | 6 |
| | 1000-2000m | Less | 2 | |
| | <1000m | Unsuitable | 1 | |

The output obtained at the end of this process is a final suitability map as shown in Figure (8).

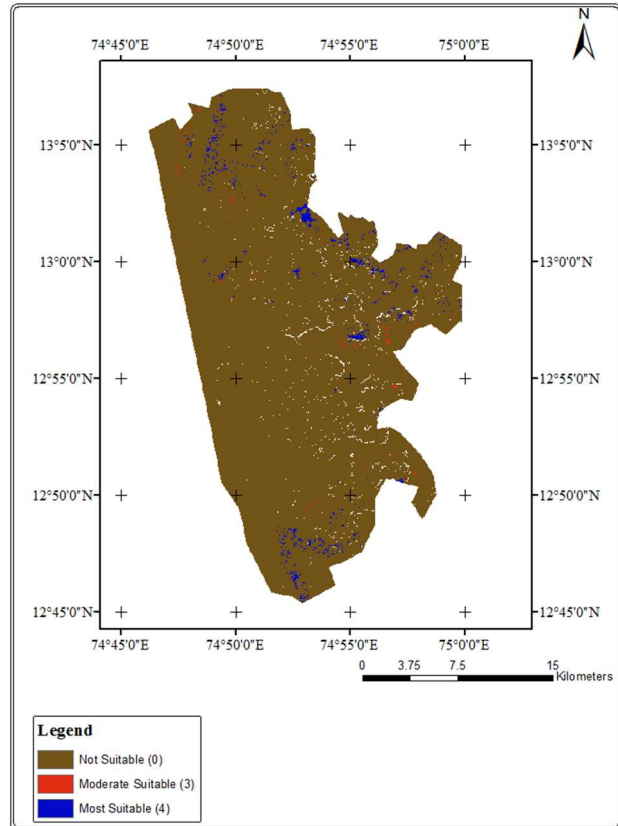


Figure 8. Final suitability map

The statistics of the suitability of total area for solid waste disposal site is summarized in Table (10).

Table 10: Suitability area level of suitability and the percent of total area coverage

| Criteria | Area (Ha) | Percent of Total Area (%) |
|--------------------------|-----------|---------------------------|
| Most Suitable | 786.76 | 1.39 |
| Moderate Suitable | 99.36 | 0.18 |
| Unsuitable | 55598.14 | 98.43 |

After inputting all the information in the model developed, the model performs reclassification, multi-criteria analysis using AHP technique and produces the output which is the final suitability map as shown in Figure (8). Out of the total area of study, 98.43% area is identified as 'unsuitable' for the solid waste disposal site, 0.18% as 'moderate suitable' and 1.39% area (7.87 sq.km. i.e. 786.76 Ha) 'most suitable' site for solid waste disposal. The areas identified under 'most suitable' category in this study need further field research before finalizing the particular site for the solid waste disposal.

5. Conclusion

The local government bodies lack in funds and technical expertise when it comes to adopting

scientific approach towards site selection of solid waste disposal. In India, the use of GIS for the site selection process is a relatively new concept. Integration of GIS and Multi-Criteria Evaluation (MCE) is of great help locating the suitable sites for solid waste disposal. Use of the 'Site Suitability Model for Solid Waste Disposal' has resulted in saving of considerable time and efforts. The model provides the final suitability map along with the most suitable site parcels in vector file format. The final suitability map produced was accurate and precise. The use of the model developed and if not the model but the GIS-MCE integration will solve the problem of locating the potential site for solid waste disposal which will avoid the possible significant damage to the environment.

The GIS is as good as its data. The accuracy of the data used has a huge impact on the GIS analysis carried out. There are many factors that potentially affect the site selection process for solid waste disposal. The key factors considered include distance from the water body, distance from road network, distance from the airport, LU/LC class and ground

slope. One of the limitations of the study was the poor availability of the detailed data in GIS compatible formats. There are some more factors if are considered for the analysis will improve the accuracy of the results obtained. Some of them are geology, faults, industrial area, flood plains, population density, wind direction, ground water table, hydraulic conductivity, soil type, protected areas and other social and economic factors.

The study provided land parcel information and location for the most suitable site for solid waste disposal for Mangaluru City Corporation area. The parcels identified satisfies the minimum requirement of the future solid waste disposal site, however, before finalizing the potential site and proposing for actual use all the identified land parcels are further studies for economic feasibility and the proposed site should be finalized by evaluating the cost-benefit ratio for every potential land parcel. Availability of the continuous land is also one of the factors that influence the final decision of proposing the site for solid waste disposal.

6. References

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