# Applicability of Geospatial Technology and A Measure of Information for Assessing the Suitability of Land Fill Sites: A Case Study of Mysore City

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**Abstract – Urbanization being one of the important factors for the development of civilization, has contributed to the economic growth of the individual. It also led to uncontrolled growth of cities. Non planning of cities and unscientific management of wastes has altered the balance between the humans and the environment. Mysore city is the second largest city and a cultural hub in the state of Karnataka. In Mysore city, generation of wastes is increasing at an alarming rate parallel to the increase in population when compared to last decade. Existing land fill site in Mysore city has reached its maximum capacity and is over loaded. This has been creating nuisance to the surrounding inhabitants. There is a strong need of an alternative waste disposal site for land filling the Municipal Solid Waste (MSW) collected from Mysore city. Identifying an optimum land fill site to accommodate all the municipal solid wastes generated in Mysore city will be the major futuristic task for the local administrating authority. Identifying and locating a landfill site involves extensive study and surveys of the potential land fill sites. Various factors including topographical, environmental, social and geological factors have to be considered for identification and location of land fill sites. Selecting a waste land which fulfills all the important factors considered is a sensitive and responsible task, when many options are available. Conventional methods of identifying waste lands for land filling purpose are time consuming and involve lot of man power and financial requirement. Geospatial technologies integrated with fuzzy and information theories may be helpful in making decision regarding the suitability of waste lands for land filling purpose. The present study aims at identifying and ranking alternative sites for solid waste disposal collected from Mysore city using Shannon's entropy method.**

**Index Terms – Remote Sensing, Geographical information system (GIS), Municipal Solid Waste, Fuzzy Membership values, Shannon's Entropy**

## 1. INTRODUCTION

Human civilization from the time of evolution has been indulged in altering the surrounding environment to fulfill needs. In the context of improving their life styles, civilization produced substances which were rendered as useless for the community. These useless products generally termed as wastes, increased in their quantity and variety parallel to the urbanization. Migration of people in search of better living conditions to the urban centers resulted in overcrowding of cities. This sudden rise in the urban population altered the basic civic facilities like water supply, transportation and waste management in urban centers. People being less educated on the adverse effects of municipal solid wastes generated from their daily life followed unscientific methods for disposing them. Local governing bodies, which are responsible for managing solid wastes, became inefficient due to unavailability of suitable waste lands wherein the collected waste can be processed and disposed scientifically. Lack of proper infrastructure for collection, storage, segregation, transportation, processing and disposal of municipal solid wastes hindered the waste management in urban centers. Various methods such as incineration, composting, bio methanization and land filling are being practiced for effective waste management. Among these practices, land filling is the most commonly adopted method in most of the Indian cities [6]. In this method, collected wastes are dumped under controlled scientific procedure. The collected wastes are filled in a pit with a protected bottom to protect the contamination of ground water and a cover at the top to avoid contact with the air and animals.

Land filling sites which satisfy important criterion related to hydrological, socio economical, geological and lithological parameters should be analyzed. Identification of land fill site is itself a complex procedure. It requires a detailed study of the surrounding environment's geological, hydrological, geomorphological, socio economical and topographical features. These parameters should be analyzed spatially and temporally before deciding the suitability of sites for land filling purpose. In the conventional approach of selecting a land fill site for waste disposal, surveys are carried out using the required field equipments and measurements are recorded manually. Then the collected data is transferred into thematic maps like topographical, geological, maps etc. Since the identification of a land fill site is a sensitive issue regarding public health, environmental safety and the city's aesthetic view, vast data has to be collected. All the data collected should be stored in one platform. Data, thus collected are then interlinked and analyzed for decision making. This conventional approach is a long process, and requires huge man power and financial support. This process gets more complicated when there are options available. Hence, selecting an optimum waste land which satisfies all the major environmental, socio economical, geological, hydrological and lithological parameters is a sensitive and responsible task. Geospatial tools such as remote sensing and Geographic Information System (GIS) have been progressively utilized for identification of waste lands. These tools and techniques are capable of storing and retrieving large amount of data regarding the necessary parameters of various waste lands in a single platform

Mysore adds up for strong need of identifying an optimum landfill site located at a fair and safe distance from the city.

To select an optimum land fill site among the various sites available, a mathematical approach is helpful when there are uncertainties about the selection. The possible outcome in selecting a waste land usually varies from suitable to not suitable. The suitability conditions of each criterion are independent and play equal role in deciding the final suitability of waste lands for land filling purpose. To arrive at a value in order to decide the suitability of waste lands, a qualitative index is necessary. The final suitability of the waste lands depends on the additive value of all the considered criteria. To analyze the amount of information available from all criteria, Shannon's entropy may be used. Shannon's entropy is a measure of information available and can be useful in making decisions for environmental problems [7]. It depicts the degree of certainty from the amount of information available [8]. In 2005, for Sarein city of Iran country, to select an optimum land fill site, Shannon's entropy was used to calculate the weightages for all the considered criteria from the available of information [11]. In this paper an attempt has been made to identify the waste lands available for land filling purpose in Mysore city based on Shannon's entropy values.

## 2. STUDY AREA AND DATA USED

Mysore city, situated at $12^0$ 37' – $12^0$ 25' north latitudes and $76^0$56' -$76^0$71' east longitudes falls under Survey of India Topo sheets No. 57D11/2, 57D11/3, 57D11/5, 57D11/6, 57D12/NE and 57D12/NW. It is spread over an area of 128.4 Square kilometers. The city has been declared as number one cleanest city in India for consecutive years for 2014-15 and 2015-16 by the Ministry of Urban Development.

Thematic maps from mines and geology department, land use and land cover map from Karnataka remote sensing center, statistical report on MSW in Mysore city from City Corporation, satellite image from LISS III sensor have been used in this study. Waste lands within 10 km radius from Mysore city are considered for the purpose of selecting optimum land fill site. Figure 1 shows the location of study area.

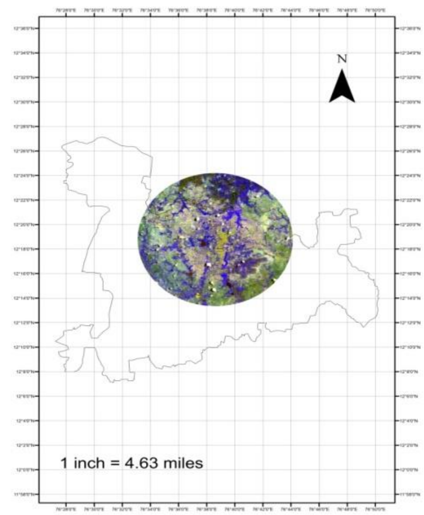


Figure1: Study area

## 3. METHODOLOGY

Analysis has been carried out in three stages. Thematic layers necessary for the study have been created using GIS. The ranges of suitability limits for each criterion are defined based on similar studies. In the second stage, with reference to the predefined suitability limits fuzzy membership values are derived using S shaped, Z shaped or Triangular shaped functions based on the prevailing conditions. Finally, Shannon's Entropy which is used to measure the degree of uncertainty has been adopted to rank the waste lands. Shannon's Entropy value for each site is calculated using Eqn (4). From the result obtained the certainty of waste lands are decided and wastelands are ranked based upon Shannon's Entropy score for decision making purpose. Figure 2 depicts the methodology adopted for the present study.

For the purpose of identifying potential waste lands, land use and land cover map of Mysore city for a radius of 10 km has been used as base map. Spatial data including thematic maps of hydrological, geological, lithological maps pertaining to the study area are first geo referenced. Separate layers for agriculture lands, surface water bodies, and forest cover, and villages are created. Road network within the study area has been digitized. Each of these maps is over laid on the base map. Figure 2 shows land use/cover details for the study area and the location of 14 potential candidate sites.

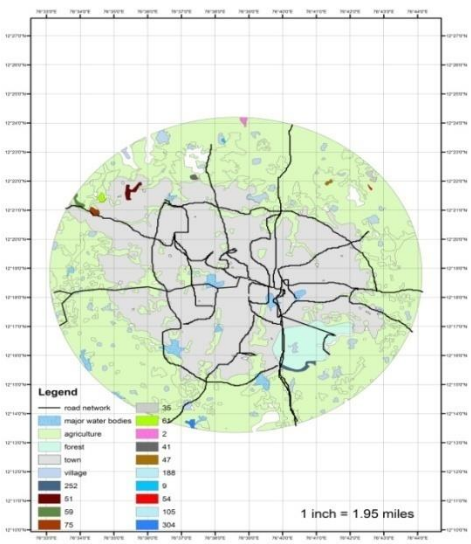


**Figure 2: Land use and land Cover details**

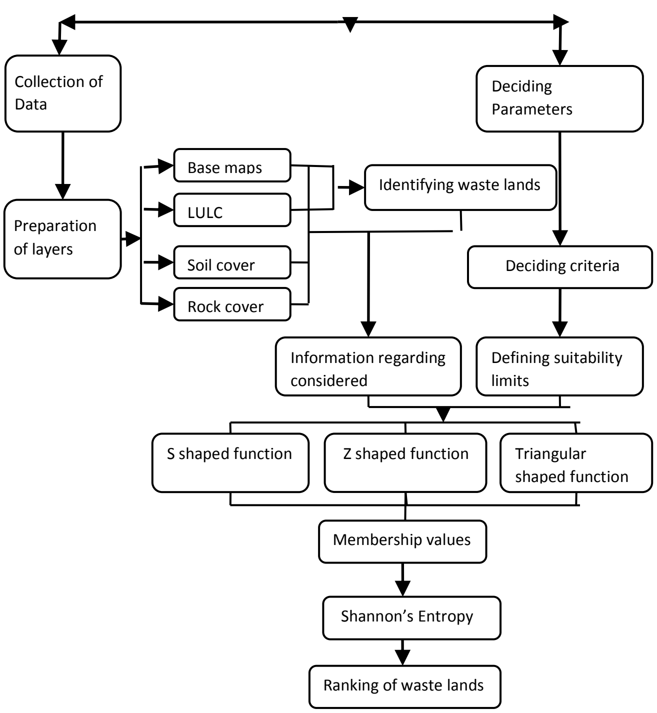


**Figure 3: Flow chart explaining the methodology adopted.**

Details regarding important socio economic parameters such as surrounding habitats, tourist places, accessibility to the waste lands, distance of waste lands from operating point, distance of airport are measured using the map shown in Figure 3. Limits for less, average and high suitability for each of the criterion are decided with the help of previous works [4], [5], and [9]. Table 2 gives the suitability limits for the important criteria considered under each parameter. 14 waste lands with area more than 10 hectares within 10 kms radius from Mysore city are identified for the present study. Details of the selected waste lands considered are given in Table 1. Type of soil cover and type of rock bed over the waste lands are noted down by overlaying thematic layers over the waste lands map. Geographical location of the waste lands are identified using the base map created using the topographic maps.

Table 1: Details of potential landfill site

| Site ID | Area in hectares | Type of Land cover |
|---|---|---|
| 2 | 16.5 | SL |
| 3 | 82.6 | SL |
| 16 | 68.2 | SL |
| 18 | 138 | SL |
| 35 | 18.2 | SL |
| 41 | 11.3 | SL |
| 51 | 35.2 | MI |
| 56 | 62.1 | SL |
| 59 | 26.1 | SL |
| 61 | 16.8 | MI |
| 75 | 20.5 | MI |
| 215 | 43 | SL |
| 252 | 40 | SL |
| 304 | 17.8 | SL |

SL=scrub land, MI=Mining/industrial waste land

Range of Suitability limits for the considered parameters are defined with the help of extensive literature review. Table 2 presents the range of suitability limits adopted in this study.

**Table 2: Range of Suitability limits for different parameters**

| Sl no | Parameters | Less suitable | Moderately suitable | Highly suitable |
|---|---|---|---|---|
| **Hydrological and hydro geological** | | | | |
| 1 | Distance from nearest surface water in kms. | 0 – 1 | 1 - 2 | 2 - 4 |
| 2 | Ground water depth from surface | 5 – 15mts | 15 – 60mts | >60mts |

| | | | | |
|---|---|---|---|---|
| 3 | Ground water yield at the site | >5.0 lts/sec | 5 – 1 lts/sec | <1.0 lit/sec |
| 4 | Distance from KRS reservoir. | 0 - 8 km | 8 - 17 kms | 17 – 25 kms |
| **Socio economical parameters** | | | | |
| 5 | Accessibility in kms | 0 - 2 | 2 - 3 | 3 - 4 |
| 6 | Distance from city | 12 - 8 kms | 8 – 5 kms | <5.0 kms |
| 7 | Type of land cover | Village/agricultural lands | Forest/mining | Waste lands |
| 8 | Area availability for disposal | <10 ha | 25 – 10 ha | 60 - 25 ha |
| 9 | Distance from airport | 0 – 5 km | 5 – 12 kms | 12 - 15 |
| 10 | Distance from nearest Village | 0 – 1km | 1 –2kms | >2kms |
| **Lithological parameters** | | | | |
| 11 | Type of rock | Sandstone/unconsolidated sand/gravel | limestone | Shale/unfractured crystalline |
| 12 | Type of soil | Clean sand/gravel | Loamy soils | Clay |
| **Geomorphological parameters** | | | | |
| 13 | Slope of the ground surface | <1% | 1 – 5% | >5% |

## 4. DERIVING FUZZY MEMBERSHIP VALUES

Fuzzy membership values represent the degree of truth about the information available when analyzed with a proper function [12]. The information related to each criterion is subjected to fuzzy logic to ascertain the level of suitability. With reference to the defined suitability limits from Table 2, for each criterion, the selected waste lands are analyzed by selecting suitable functions based upon their existing conditions. In the first condition, suitability of the waste land increases with the subjective value of that criterion. For example, the suitability of the waste land for land filling purpose is proportional to its distance from the nearest surface water. S-shaped functions, shown in Figure (4) and Eqn (1) are used to analyze these types of conditions. In the second type, suitability of waste land decreases with the increase in subjective value of considered criteria. Distance of waste lands from city or the accessibility to the waste lands is an example of second type. Z-shaped functions as shown in Figure (5) and Eqn (2) and triangular shaped functions shown in Figure (6) and Eqn (3) are used to calculate the membership values in such conditions.

S-shaped function

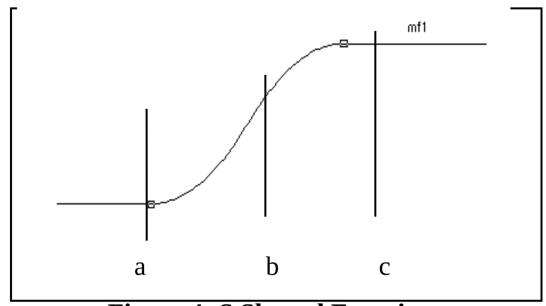


**Figure 4: S Shaped Function**

$$\mu(x, a, b, c) = \begin{cases} 0, & \text{for } x \le a \\ 2[(x-a)/(c-a)]^2, & \text{for } a \le x \le b \\ 1 - 2[(x-c)/(c-a)]^2, & \text{for } b < x \le c \\ 1, & \text{for } x \ge c \end{cases} \quad (1)$$

Z-shaped function

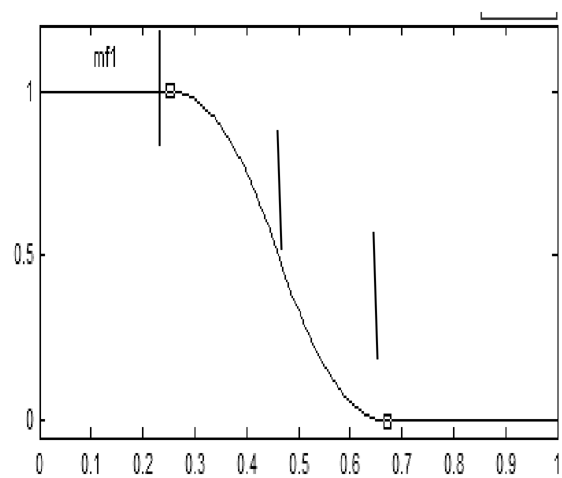


**Figure 5: Z Shaped Function**

$$\mu(x, a, b, c) = \begin{cases} 1, & \text{for } x \le a \\ 1 - 2[(x-a)/(c-a)]^2, & \text{for } a \le x \le b \\ 2[(x-c0/(c-a)]^2, & \text{for } b < x \le c \\ 0, & \text{for } x \ge c \end{cases} \quad (2)$$

Triangular-shaped function

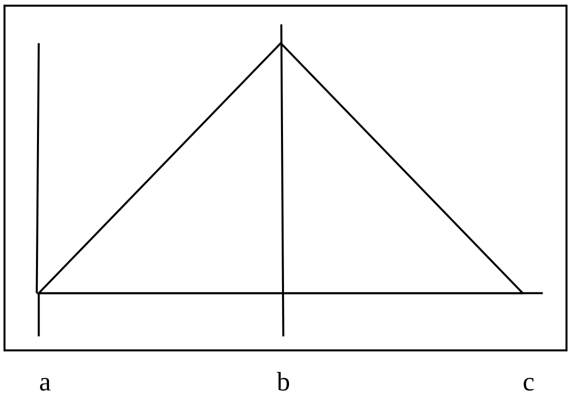


**Figure 6: Triangular Shape Function**

$$\mu(x, a, b, c) = \begin{cases} 0, & \text{if } x < a \\ (x-a)/(b-a), & \text{if } a \leq x \leq b \\ (c-x)/(c-b), & \text{if } b \leq x \leq c \\ 0, & \text{if } c < x \end{cases} \quad (3)$$

x = subjective value of the considered criteria.

In Figure (1) and 3, a, b, c corresponds to the less, average and highly suitability limits given in Table 2 respectively.

a, b, c in Figure (2). corresponds to high, average and less suitability limits given in Table 2 respectively.

Using these equations the suitability of each criterion related to the waste lands are analyzed. The available information of all the criterions is further subjected to Shannon's Entropy method to know the degree of certainty of the information available about the waste lands.

The result obtained from fuzzy membership logic for each of the criterion is subjected to Shannon's entropy method. From the output result, the waste lands are ranked based on the context that higher the information available lesser the entropy value and more certainty about the result. Eqn (4) represents Shannon's entropy.

$$E = -\Sigma \{\mu_i x \log_2(\mu_i)\} \quad (4)$$

$\mu_i$ = membership value of the $i^{th}$ criteria.

Where $\log_2$ of $\mu_i$ = $\log_{10}$ of $\mu_i$ / $\log_{10}(2)$

And $\log_{10}(2) = 0.301$.

## 5. RESULTS AND DISCUSSIONS

Out of the 14 candidate sites selected for analysis purpose, only 9 waste lands proves to satisfy all the considered parameters. Figure (7) shows the location of the selected waste lands for land filling purpose. Each waste lands are ranked based upon their Entropy scores. Waste lands with less entropy score is more reliable and is fair enough to make decision regarding land filling purpose. Table 5 gives the details of waste lands ranked based upon their Entropy scores. Site ID 59 with least entropy score among the selected 9 waste lands can be considered as an alternative for land filling municipal solid wastes collected from Mysore city. Remaining waste lands can be used for land filling purpose as per zonal requirements.

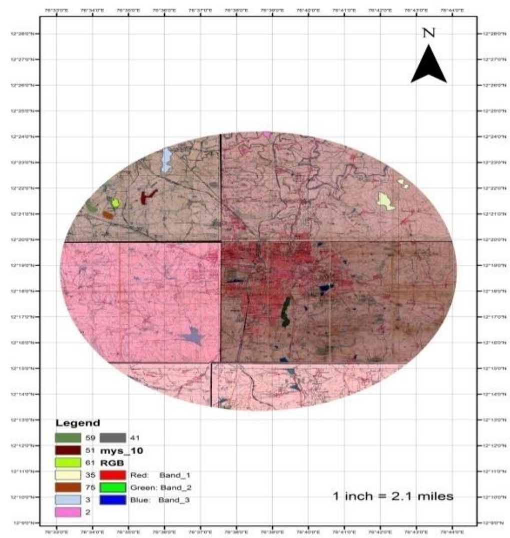


Figure 7: Selected Potential waste lands

Table 5: Potential waste lands with their entropy scores.

| Ranking | Site Id no | Entropy value | Remarks |
|---|---|---|---|
| 1 | 59 | 1.029 | Suitable |
| 2 | 51 | 1.229 | Suitable |
| 3 | 61 | 1.255 | Suitable |
| 4 | 56 | 1.296 | Suitable |
| 5 | 3 | 1.325 | Suitable |
| 6 | 35 | 1.574 | Suitable |
| 7 | 75 | 2.013 | Suitable |
| 8 | 41 | 2.231 | Suitable |
| 9 | 2 | 2.407 | Suitable |
| 10 | 16 | - | Not suitable |
| 11 | 18 | - | Not suitable |
| 12 | 215 | - | Not suitable |
| 13 | 252 | - | Not suitable |
| 14 | 304 | - | Not suitable |

## 6. CONCLUSIONS

The problem of selecting an optimum waste land for land filling the municipal solid wastes among number of waste lands involves uncertainty and need careful analysis. To make appropriate decisions for problems involving such uncertainties and huge data processing, geospatial methods such as GIS integrated with mathematical models involving fuzzy and information theory may be useful. In this study, Mysore city in Karnataka was considered to test the applicability of geospatial technology with a measure of information, *viz.*, and Shannon's entropy to identify and locate suitable land fill sites. Among fourteen potential landfill sites considered, nine sites have been identified and ranked based on the information available. The identified waste lands may be analyzed further to determine their sensitivity towards other important criteria according to the zonal requirements of Mysore city.

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