International Journal of Modern Engineering Research (IJMER)
www.ijmer.com Vol.1, Issue1, pp-40-51 ISSN: 2249-6645

An Integrated Multistage And Multicriteria Analytical Hierarchy Process GIS Model For Landfill Siting: A Model

SS.Asadi [1],B.V.T.Vasantha Rao [2] M.V.Raju [3]and V.Padmaja[4]

[1]Associte professor,Dept.of. Civil Engineering, KL University, Green fields, Vaddeswaram-522502,Guntur(D.t),A.P,India

[2]Assistant Professor,Dept.of .Civil Engineering,p.v.p.siddhardha Institute of Technology,Kannure, Vijayawada.

[3] Assistant Professor,Dept.of.Civil Engineering, Vignan University, Vadllamudi, Guntur(D.t).

[4]Centre for Environment, J.N.T.University, kukatpally, Hyderabad

Abstract: Human activity, either domestic or industrial, produces waste materials to greater or lesser extent always. Each city produces tons of solid wastes daily from household, hospitals, industry, offices and market centers. By volume, municipal solid waste is by far the largest component of overall urban waste stream and includes a variety of potentially toxic substances making its disposal a problem. However, either due to resource crunch or inefficient infrastructure, not all of this waste gets collected and transported efficiently to final dumpsites leading to an improper management and disposal, resulting in serious impacts on health and problems to surrounding environment. The efficacy of solid waste disposal depends upon selection of proper site and there are several issues that have impact for site selection. Site selection is therefore one of the most critical areas of municipal planning involving a multi-disciplinary approach and a broad spectrum of considerations. As such, it is a multi-criteria decision-making process, a much-needed system for proper municipal solid waste management. This paper attempts to demonstrate the capabilities and utility of remote sensing and GIS technology for selection of suitable sites for waste disposal for Hyderabad City, India. The study illustrates the application of GIS techniques in the field of solid waste management, through the typical problem of preliminary disposal site selection, using a multi-criteria decision making technique called the Analytic Hierarchy Process (AHP) which provides a systematic approach for assessing and integrating the impacts of various factors, involving several levels of, dependent and independent, qualitative and quantitative information. Remote sensing images and

Survey of India topomaps are used to extract information on wastelands and other land use features, geology, hydrogeomorphology, drainage, road network and slope of the area. The approach used in this project was firstly to exclude all areas where the development of a waste disposal site would not be permitted viz., close proximity to residential areas, airfields, mountainous areas, nature reserves, indigenous forests, geological faults, the coast, dams or rivers. Once these areas had been identified, the remaining areas were then rated according to the geological, hydrological, topographical and environmental characteristics. From the combination of these factors, favorable areas were identified. In GIS, all conceivable requirements (e.g. site. should be at least 500 meters from the nearest dwelling unit) are initially specified, spatial data integrated and overlaid and based on the final output obtained suitable environmentally benign sites for waste disposal are identified.

Keywords: Solid waste, Multi criteria decision-making, Analytical hierarchy Process, Remote sensing and GIS

Introduction

In many countries with increase in population and the rising demand for food and other essentials, there has been a rise in the amount of solid waste being generated making its management and disposal problematic. The accumulation and improper disposal of waste leads to environmental pollution and accelerates the spread of communicable diseases (George Tchobanoglous, 1993). One of the serious and growing potential problems in most large urban areas is the shortage of land for waste disposal, and Hyderabad city in India with an alarming pace of population explosion and urbanization is no exception. Management of municipal solid waste (MSW) in urban centers is becoming more complex due to scarcity of land for disposal (Babyrani devi and Bhoyar, 2003). The waste generators find it difficult to dispose their wastes without causing environmental disturbance, as very few appropriate disposal facilities are available. An appropriate landfill site should therefore be selected carefully by considering both regulations and constraints on other sources in order to prevent environmental, economic and ecological impacts.

Keeping this in view, the present study is carried out with an objective of identifying a suitable site for disposal of municipal solid waste generated in Hyderabad city using Geographic Information System (GIS) and Analytical Hierarchy Process (AHP). According to the existing records of the Municipal Corporation of Hyderabad (MCH), the total solid waste generated in Hyderabad city is about 2200 MT/day of which 1500MT is disposed by landfilling and the remaining 700MT is utilized for power generation (JNTU, 2002). With the Autonagar dumping site being closed in 2005, there exists only one site operating at present located at Jawaharnagar for disposing this waste. Keeping in view the need for disposal sites, an attempt has been made in this study to identify potential sites for disposal of solid waste generated in Hyderabad city.

Objectives Of The Study

- To study the status of existing scenario of solid waste management in Hyderabad city by analyzing the trends in population growth, waste generation, existing transfer stations and solid waste disposal sites in order to evolve a strategic plan for future years.
- To create spatial digital database comprising base map, land use/ land cover, soil, slope, physiography, geology, geomorphology, drainage pattern, ground water potential, infiltration rate, watershed, transportation network and wasteland map with the help of IRS –1D, PAN & LISS-III merged satellite imagery and Survey of India (SOI) toposheets along with ground truth analysis on ARC/INFO GIS platform.
- To evaluate AHP and assign weightage factors for different digital thematic layers and to integrate them in GIS for evaluating risk suitability and to find probable solid waste disposal sites in and around Hyderabad based on this integrated study.

Study Area

Hyderabad city is situated in the Krishna basin and the river Musi, which is a tributary of river Krishna, passes through the city and bifurcates it into Northern and Southern Hyderabad. The study region covers an area of 179Km^2 and is situated between 78°22϶30∀ & 78°32϶30∀ east longitude & between 17°18϶30∀ & 17°28϶30∀ north latitude. The ground levels vary from 487 meters to 610 meters above mean sea level. The region of interest for site selection includes all area, which falls within the buffer distance of 50km from the center of Hyderabad city. This area comprises of Hyderabad Urban Development Area, parts of Rangareddy, Nalgonda, Medak and Mahabubnagar districts of Andhra Pradesh. It is covered by toposheet No. 56K on 1:2,50,000 scale. The city stands on gray and pink granites as foundation materials, which is suitable for building construction. According to 2001 census Hyderabad is one of the largest metropolis of India with a population of 38,29,753. The population of Hyderabad has increased from 0.448 million in 1901 to 1.429 million in 1961, between 1981 to 1991 the population went up to 4.34 million and the rate of the growth so far is 67.04% (Handbook of Statistics, Hyderabad District, 2001).

The physical composition of solid waste generated in Hyderabad includes 4% paper, <1% glass, 3.5% plastics, 40-45% biodegradable matter, 45-50% inert waste/silt/debris and 2-3% others. The average moisture content of the garbage is 21.05% where as the dump yard it is 19.25%. The net calorific value of Hyderabad household garbage is 1223 cal/gm (ASCI, 2004).

Methodology

The site selection is carried out in two phases. In the first phase, criteria to be considered for municipal solid waste disposal site selection are identified and broadly grouped into exclusionary and non-exclusionary criteria. These criteria are defined using the standards given in Municipal Solid Waste (Management and Handling) Rules 2000 and includes landfill area required, proximity to lakes and rivers, proximity to highways, distance to population centers, slope, etc. The non-exclusionary criteria are further categorized into four categories viz., geological criteria consisting of geology and soil characteristics, topographical criteria which include the land use, geomorphology and slope patterns, hydrological criteria comprising of groundwater level, potential and infiltration characteristics and environmental criteria encompassing groundwater and air quality (Figure 1).

Exclusionary Criteria:

- No landfill should be constructed within 200mts of any lake or pond
- No landfill must be constructed within 100mts of navigable river or stream
- No landfill should be constructed within a 100 yr flood plain
- No landfill should be constructed within 200mts of any state or national highway

- A landfill site must be at least 1000mts from a notified habitat area
- No landfill should be constructed within 300mts of public parks
- No landfill should be constructed within critical habitat areas
- No landfill should be constructed within wetlands
- A landfill should not be constructed in areas where water table is less than 5m below ground surface
- No landfill should be constructed within 2000mts of an airport
- No landfill should be constructed within 500mt of any water supply well
- A landfill should not be sited in a coastal regulation zone
- A landfill should not be located in potentially unstable zones such as landslide prone areas, fault zone etc

Non-Exclusionary Criteria:

Geological criteria - Geology, Structures and Soil
Topographical criteria - Road network, Slope, Land use/ Land cover, Geomorphology
Environmental criteria - Groundwater quality and Air quality
Hydrological criteria - Groundwater potential, Groundwater infiltration and Groundwater table

Once the parameters are organized into a decision hierarchy, Relative Importance Weightage (RIW) of each parameter over the other is calculated by pair-wise comparison using the 9-point scale shown in Table 1. The RIWs are the normalized eigenvectors corresponding to the maximum eigen values of the pair-wise comparison matrices constructed at each level of the decision hierarchy. The RIW assigned to each hierarchy element is determined by normalizing the eigenvector of the decision matrix. Eigenvector values are estimated by multiplying all the elements in a row and taking the nth root of the product, where n is the number of row elements (Saaty, 1980 and Siddiqui et al, 1996). Normalization of the eigenvector is accomplished by dividing each eigenvector element by the sum of the eigenvector elements of the decision matrix. Once the RIW of each element of each theme or layer to be considered for site selection are calculated, the individual weightages are aggregated/summarized to obtain a final suitability index (Ertan Yesilnacar and Vedat Doyuran, 2000 and Aditya et al, ICORG).

In the second phase, ERDAS and ARC/INFO software are used to generate topographic, thematic and spatial data corresponding to layers including settlements, roads, topography, geology, land use/ land cover, geomorphology, aquifers and surface water, soil etc. from fused data of IRS-1D PAN and LISS-III satellite imagery, Survey of India topomaps, existing datasets and field data. The methodology adopted for the study is shown in Figure 2. The land use/ land cover map prepared using visual interpretation technique from fused satellite imagery is presented in Figure 3. ArcView GIS tools were used to create buffers, calculate distances, and screen out areas that failed any minimum criteria (such as minimum distance from airports and bodies of water). After screening out unacceptable areas within each theme corresponding to some criteria, all themes are overlaid to prepare a composite suitability map. Areas not satisfying the minimum landfill criteria were eliminated and other parcel groups that remained are further evaluated based on suitability indices values and classified into excellent, good, moderate, poor and very poor sites. The sites within each of these five classes are further evaluated for their attributes such as distance from the point of waste generation, population density surrounding the site, proximity to settlement areas, presence of scrub forest, total area covered etc. resulting in selection of five best suitable sites within excellent, good and moderate suitability class for the entire study area.

Results And Discussions

By applying AHP and GIS various layers are categorized according to Relative Importance Weightage (RIW). For final weight all individual weightage are summarized and evaluated to obtain a final suitability index. As each of the RIW includes its importance from the first level, the final cumulative values will give more accurate results. According to the weightage allotted and the suitability index value obtained, entire area is categorized into five classes as excellent class with suitability index ranging from 0.5 to 0.6, good class with suitability index ranging from 0.4 to 0.5, moderate class with suitability index ranging from 0.3 to 0.4, poor class with suitability index ranging from 0.2 to 0.3 and very poor class with suitability index ranging from 0.1 to 0.2 with respect to landfill siting. Higher the suitability index, the more suited is the site for waste disposal and lower the value, lower is the suitability. The suitability map prepared for the present study is depicted in Figure 4. After the GIS analysis led to a short list of sites, the attribute evaluation (distance from the point of waste generation, area covered, distance to nearest road or water body, population density surrounding the site etc.) of each of these individual sites was performed to determine which site possessed the best compromise of features for developing a landfill and are ranked accordingly. Of the many sites identified, sites selected for solid waste dumping based on attribute evaluation are presented in Table 2.

Conclusions

The study presents an elaborate introduction to GIS, along with the operational details of building a database in a GIS environment. This study also illustrates, how the capabilities of GIS can be utilized for addressing problems of spatial nature, with the efficiency of handling large volumes of spatial data, and with speed, which is quite typical of computer-based operations. The choice of the decision factors for preliminary site selection for solid waste disposal was guided predominantly by the availability of data. In the process of the site selection study, a comprehensive description of AHP has been provided along with the records of the application of AHP for landfill siting. The present study is an attempt, in a similar direction, to preliminary site selection for open dumping of solid wastes of Hyderabad city. The gap between the preliminary and the final sage of site selection can be laid down as the scope for future work. The accuracy of the final modelling, integrating the GIS database with the AHP, depends on the quality of the database and on the fundamental assumptions of the AHP technique. The construction of the decision matrices, largely determines the final output, but the construction of these matrices are essentially subjective, as any other decision-making process, based on judgment.

References

1. George Tchobanoglous, Hilary Theisen, and Samuel Vigil, Integrated Solid Waste Management-Engineering Principles And Management Issues, Mc. Graw Hill, New York, 1993.
2. Babyrani Devi, S. and Bhoyar, R.V., Feasibility Of Some Treatments For Improving The Composting Of Municipal Solid Waste, Indian Journal of Environmental Health, Vol. 45, No. 3, pp 231-234, July 2003.
3. Inventorization of Municipal Solid Waste Management Practices in Municipalities/ Corporations of Andhra Pradesh, JNTU Project Report (Current Status On Management Of Municipal Solid Waste Hyderabad District), 2002.
4. District Census Handbook of Hyderabad, Director of Census Operations, Andhra Pradesh, Census of India, 2001.
5. Brainstorming Meeting on Improving the Solid Waste Disposal System in Hyderabad, Background Papers, Administrative Staff College of India (ASCI), Bella Vista: Hyderabad, October 2004.
6. A Support Manual For Municipal Solid Wastes (Management and Handling) Rules, 2000, Central Pollution Control Board (CPCB), Ministry of Environment and Forests, New Delhi.
7. Saaty, T. L., The Analytic Hierarchy Process, McGraw-Hill Book Co., New York, 1980.
8. Siddiqui, M.Z., Everett, J.W., and Vieux, B.E., Landfill Siting Using Geographic Information Systems: A Demonstration, Journal of Environmental Engineering, ASCE, 122 (6), pp 515-523, 1996.
9. Ertan Yesilnacar and Vedat Doyuran, Selection Of Settlement Areas Using GIS And Statistical Method (Spatial-AHP), Project Expo 2000, International Forum for Graduates and Young Researchers at EXPO 2000, Shaping the Future Hannover, The World Exposition in Germany, 2000.
10. Aditya Agrawal, Manish Katyan, Onkar Dikshit and Rajiv Sinha, Preliminary Selection Of Solid Waste Disposal Sites Using Remote Sensing And GIS Techniques, Proceedings of International Conference on Remote Sensing and GIS (ICORG), Vol. 1, pp 185-190, 2001.

Table 1: Analytic Hierarchy Measurement Scale

Reciprocal Measure of Intensity of Importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Weak importance of one over another	Experience and judgment slightly favour one activity over another
5	Essential or strong importance	Experience and judgment strongly favour one activity over another
7	Demonstrated importance	An activity is strongly favoured and its dominance is demonstrated in practice
9	Absolute importance	The evidence favouring one activity over another is of the highest possible order o affirmation
2,4,6,8	Intermediate values between two adjacent judgments	When compromise is needed
Reciprocal of the above	If activity I has one of the above non-zero numbers assigned to it when compared with activity j, then j has the reciprocal value when compared with i.	

Table 2 Suitable sites for solid waste dumping

Excellent	Location
Site 1	Near Kuntlur and Annaram villages – east of Hyderabad
Site 2	Between Pocharam and Yemnampet villages – east of Hyderabad
Site 3	Near Lakdaram – NW of Hyderabad
Site 4	Near Kisara, Peddaparvatapuram and Bhogawaram - NE
Site 5	Near Pratapasingaram, Koremalla and Choudariguda – E of Hyderabad
Good	**Location**
Site 1	Between Nerapalli, Polkampalli and Manyaguda villages – SE of Hyderabad
Site 2	Between Seriguda and Turka Yemjal - SE of Hyderabad
Site 3	Between Narapalli and Kachwani Singaram – east of Hyderabad
Site 4	Between Ismailkhanguda and Pocharam – SE of Hyderabad
Site 5	Near Upparpalli and Tumukunta – SE of Hyderabad
Moderate	**Location**
Site 1	Near Yadagiripalli and Kisara – east of Hyderabad
Site 2	Near Madhawaram, Gandigudem and Kazipalli – NW of Hyderabad
Site 3	Between Kondapuram, Charlapalli and Ghatkesar villages–east of Hyderabad
Site 4	Between Srirangaram, Dablipur and Girmapuram – north of Hyderabad
Site 5	Between Kisara, Bhogawaram and Peddaparvatapuram-east of Hyderabad

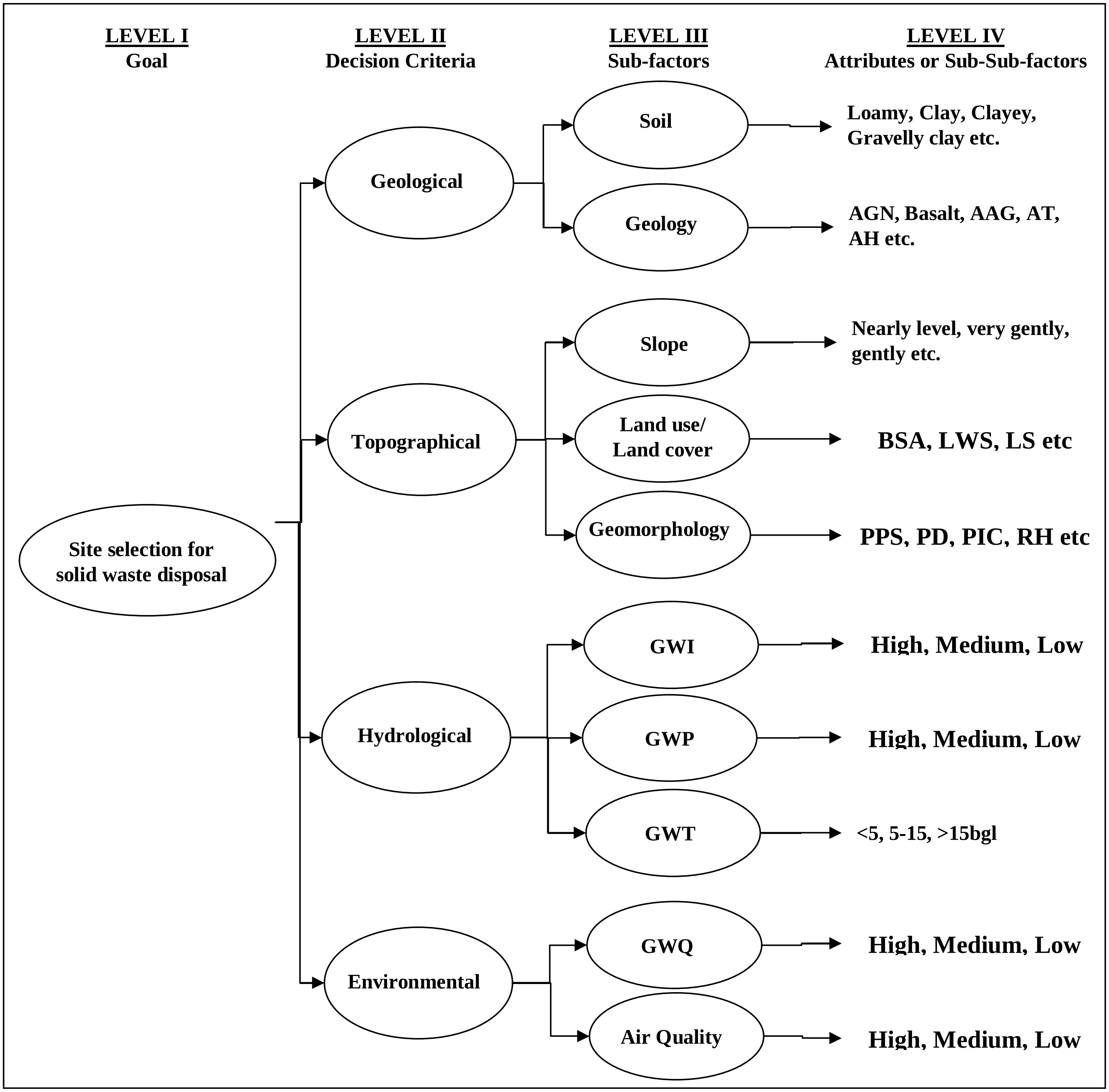

Figure 1: Structuring of decision hierarchy for a typical solid waste disposal site selection

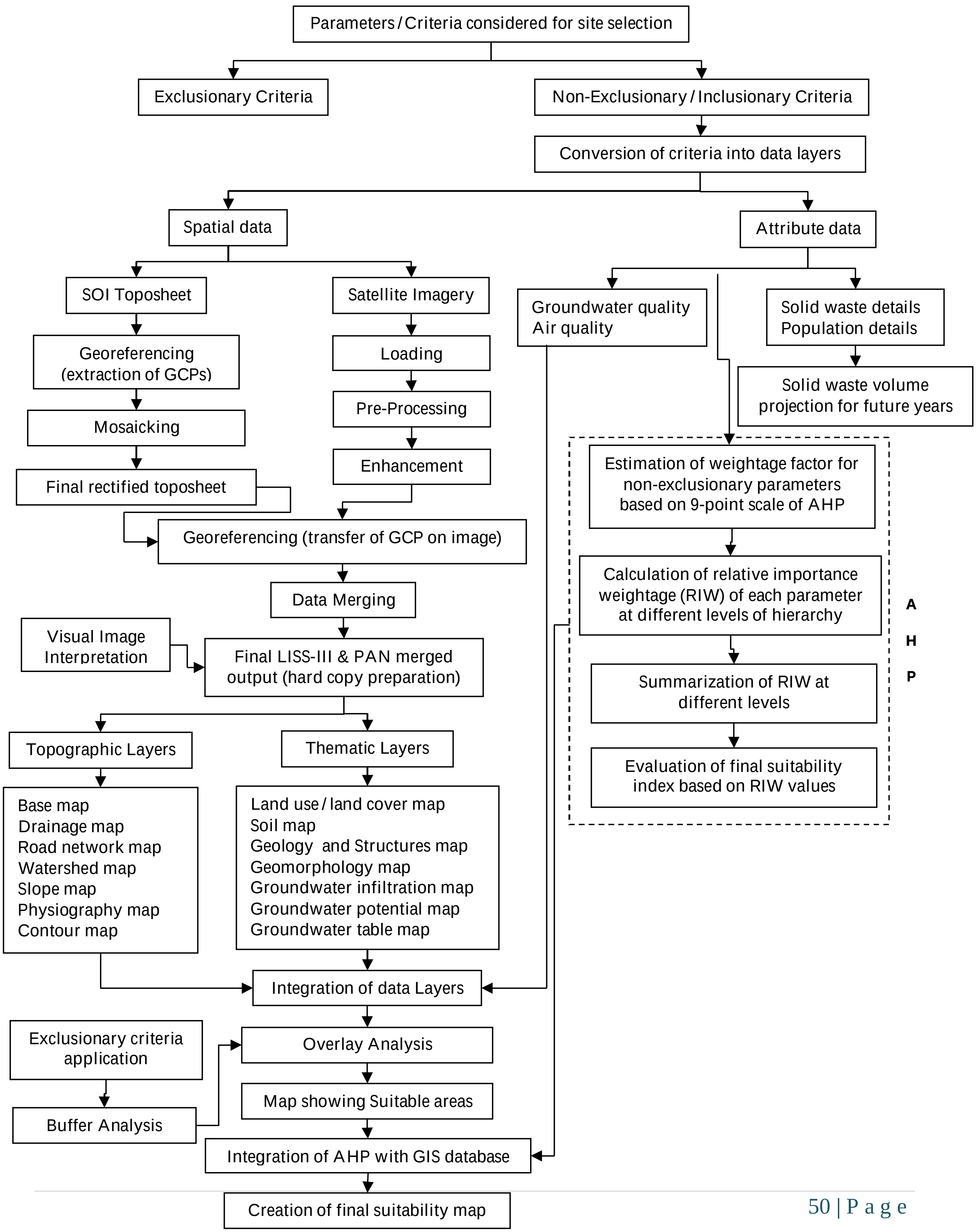

Figure 2: Flow chart showing the overall methodology adopted for the present study

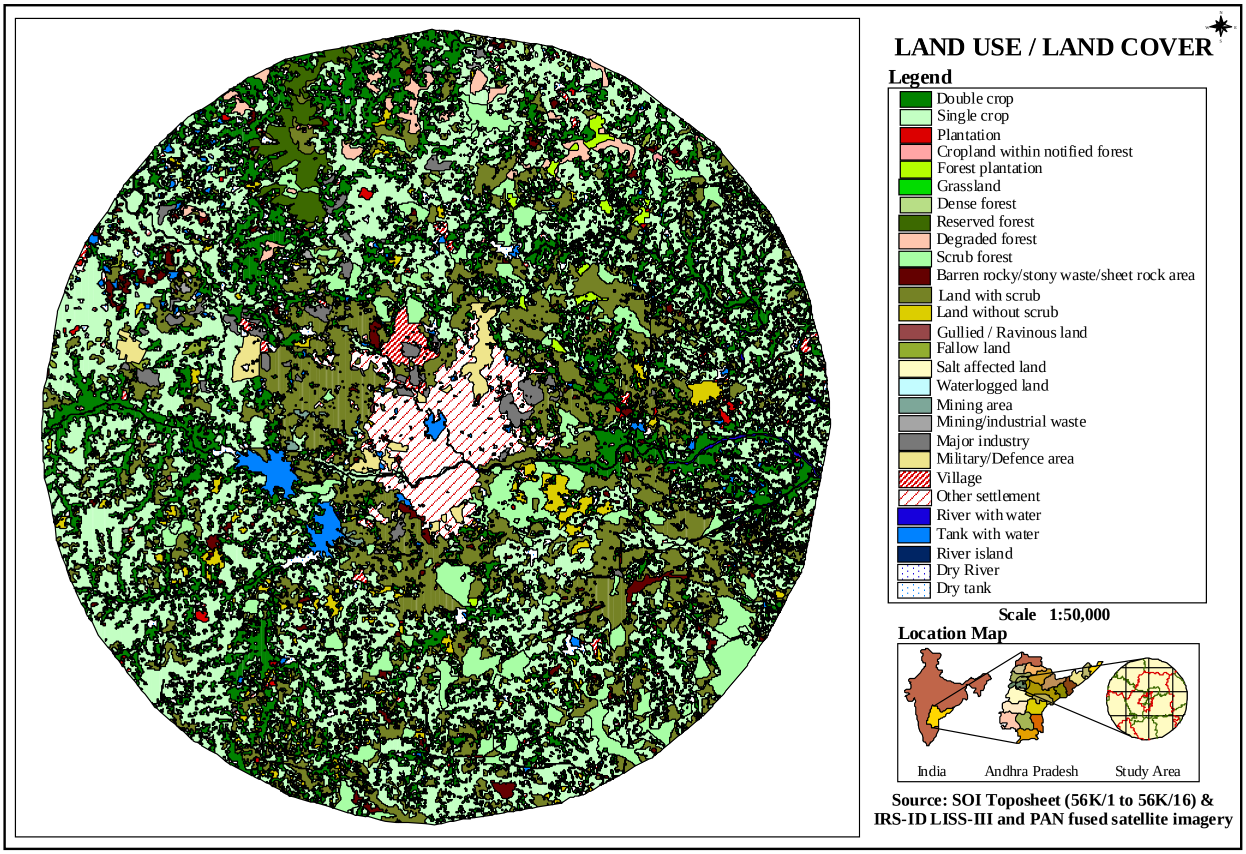

Figure 3: Land Use/ Land Cover map of the study area

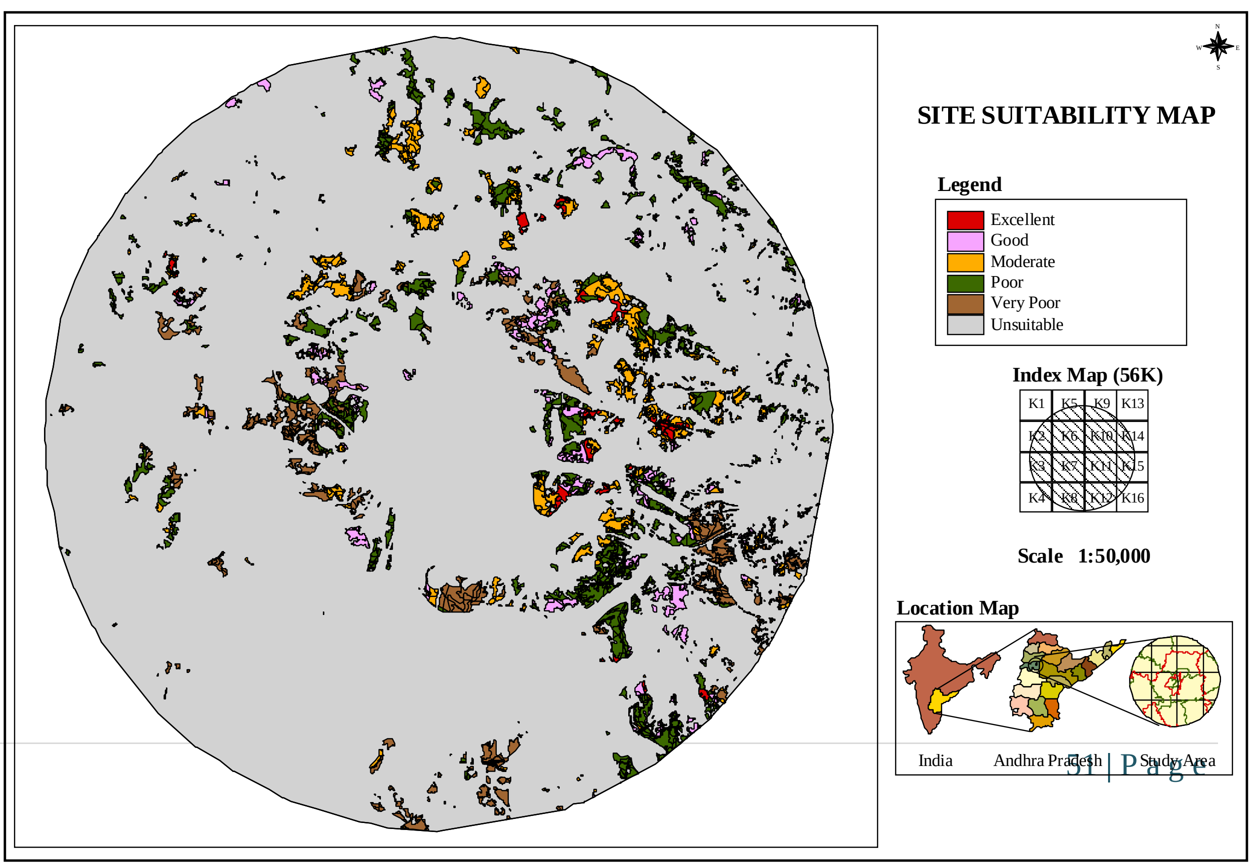

Figure 4: Site suitability map