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GIS Based Approach for Site Selection in Waste Management

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Abstract

Strategic models identify areas of development opportunity and constraints for long term management strategies. A GIS based environmental decision support system for solid waste management under Indian socio-economic and regulatory conditions has been developed. For selection for primary landfill site selection using analytical hierarchy process (AHP) has been used to give weights to different criteria. The criteria were aggregated and suitability index (S) is generated using weighted linear combination (WLC) technique in GIS environment. The suitability index (0-10) values are classified into four categories (Excluded, Less Preferable, Suitable and Best Suitable) to select the landfill site.

Keywords: GIS; site selection; suitability; waste; management.

1. Introduction

The primary idea of superimposition of various thematic maps in order to define the most suitable location according to the properties of the complex spatial units derived after the map overlay, was first introduced in the late 60's [1]. The allocation of a landfill is a difficult task as it requires the integration of various environmental and socioeconomic data and evolves complicated technical and legal parameters. During this process the challenge is to make an environmentally friendly and financially sound selection. For this purpose, in the last few decades, many studies for landfill site evaluation have been carried out using GIS and multi-criteria decision analysis [2-4], GIS in combination with analytic hierarchy process [5-7], GIS and fuzzy systems [8-9], GIS and factor spatial analysis [10-11], as well as GIS-based integrated methods

[12-16]. A large fraction of these applications produce binary outputs while most recent ones aim at evaluating a ”suitability index” as a tool for ranking of the most suitable areas [16]. the study of complex waste management systems, in particular siting waste management and disposal facilities and optimizing WC&T, have been a preferential field of GIS applications, from the early onset of the technology [17-21]. Nowadays, integrated GIS technology has been recognized as one of the most promising approaches to automate the process of waste planning and management [22]. GIS technology has been successfully used for sites of recycling drop-off centres [23], optimizing waste management in coastal areas [24], estimating of solid waste generation using local demographic and socioeconomic data [25], and waste generation forecasting at the local level [26-27].

2. Methodology

A spatial database of operational waste processing facilities and locations suitable for potential future ones was developed with data collected from Local Authority interviews, Waste Local Plans, Planning and Waste Strategy Documents. The main objective of this study was to identify an appropriate solid waste disposal site using state-of-the-art technologies to ensure environmental sustainability and public health protection. Facility attributes, such as addresses, operators, regulatory and planning status, capacities, types of process and wastes processed were compiled and presented on suitable thematic maps. A database of excavated materials and processing locations (with properties including volumes, capacities, and types of transport, composition and generation sites) has been developed and is currently updated and managed. GIS is used for measurements of transport distances (for the assessment of environmental impacts or cost accounting) and processing locations mapping. The database can be rapidly updated and queried in order to assist the designers in timely project management decisions. Waste Local Plan, planning, policy and strategy documents, topographical, sensitive receptor, transport network and land use data are efficiently collected and quality assured prior to being imported and analysed in waste management GIS databases. The analysis can be used for everyday management decisions, planning and waste strategies and site selection exercises.

3. Soil Management Parameters

All important soil parameters that contribute to soil properties must be analyzed and study to identify suitable sites for waste management. Soils should be collected from the field following strict quality control/quality assurance (QA/QC) guidelines and standardized collection procedures. In addition to measuring the mass of chemicals of concern in each sample, other soil measurements and characteristics should be quantified. Depending on the purpose of the test and to select appropriate reference or control soils, the following parameters should be measured in each sample: pH, moisture content/soil porosity, bulk density, total organic matter/total organic carbon, soil type and texture (sand, silt, clay), grain size/mineralogy, cation exchange capacity, exchangeable cation concentrations (potassium, calcium, sodium, magnesium), salinity (as assessed by electrical conductivity), macronutrient levels (nitrogen, phosphorous). A common feature of soil toxicity tests is the use of negative, reference, and positive controls. Control groups are generally prepared and subjected to the exact experimental conditions as the treatment groups. When collecting soils from the field and performing toxicity tests, it is critical that an appropriate reference site(s) is selected. Soil parameters (e.g., pH, grain size, organic matter, nutrient levels and others discussed above) should be as closely matched as possible. Otherwise, these parameters may influence the outcome of the test to a greater extent than the chemical contamination itself.

4. GIS for Sustainable Waste Management

Geographic Information Systems (GIS) are one of the most sophisticated modern technologies to capture, store, manipulate, analyze and display spatial data. These data are usually organized into thematic layers in the form of digital maps. The combined use of GIS with advanced related technologies (e.g., Global Positioning System – GPS and Remote Sensing - RS) assists in the recording of spatial data and the direct use of these data for analysis and cartographic representation. GIS have been successfully used in a wide variety of applications, such as urban utilities planning, transportation, natural resources protection and management, health sciences, forestry, geology, natural disasters prevention and relief, and various aspects of environmental modeling and engineering. The most widespread application of GIS supported modeling on waste management lies in the areas of landfill sites and optimization of waste collection and transport.

5. GIS Based Modeling for Lanfill Site Selection

The main steps of a typical GIS – based landfill allocation model (fig.1) are as following: (a) conceptualization of the evaluation criteria and the hierarchy of the landfill allocation problem. This step is dedicated to the selection of the criteria related to the problem under investigation (b) creation of the spatial database. Here, the development of GIS layers for the modeling is implemented. These layers correspond to the primary variables (c) construction of the criteria – layers within the GIS environment. Criteria maps are primary or secondary variables (d) standardization of the criteria – layers. This step includes reclassification of the layers in order to use a common scale of measurement. Most often, the ordinal scale is used (e) estimation of the relative importance for the criteria. This estimation is implemented by weighting, e.g. with the use of Analytic Hierarchy Process (AHP) and pair wise comparison between variables (f) calculation of the suitability index. A standard procedure for this step is the weighted overlay of the standardized criteria/layers (g) zoning of the area under investigation is the next phase of the modeling. This classification action is based on the suitability index and reveals the most suitable areas for the application (h) sensitivity analysis and validation of the model (i) final selection – land evaluation. Figure 1 explains GIS based approach landfill site selection for solid waste management.

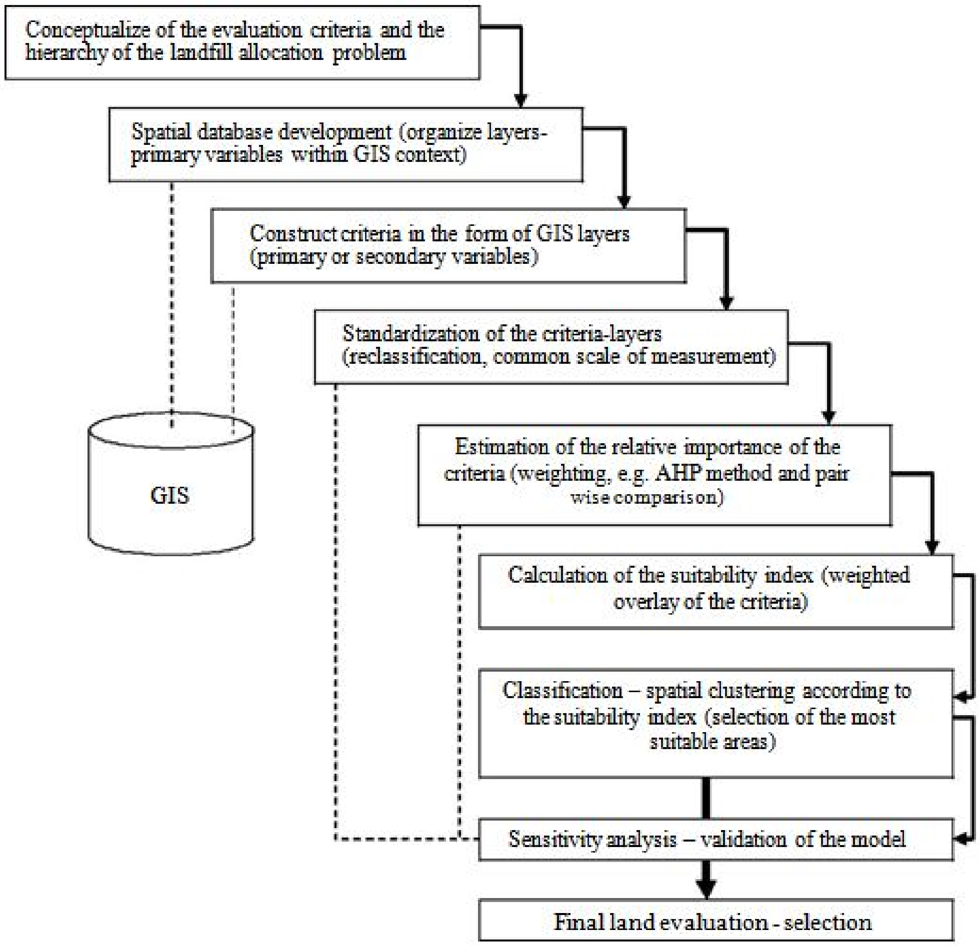

Fig. 1: GIS based approach landfill site selection for solid waste management.

6. Conclusion

Solid waste management is the most difficult task that many countries, both developing and developed, are facing now-a-days. Landfill is one of the easy and cost-effective management systems used in many parts of the world to dispose of solid wastes. The open dumping system that many cities have followed for many years is not environmentally sound and socially acceptable because of its inappropriate location. Criteria such as geology (lithology), groundwater depth, water supply well points, hydraulic conductivity/ soil structure, land-use/ land-cover, slope, drainage pattern (water bodies), roads, airport locations were used for selecting a suitable landfill within the study area. GIS-based Multi-Criteria Evaluation methodology was employed to perform the spatial decision making process for total study area was found to be highly, moderately, marginally and un- suitable for landfill, in that order, by considering suitable solid waste disposal sites with the least negative effects on environment as well as public health have been identified with first, second and third order suitability ranks.

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