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Site Selecting for Dumping Urban Waste Using MCDA Methods and GIS Techniques

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Abstract: Currently, due to the increased consumption of different natural and man-made composite resources, particularly in urban areas of developing countries, an enormous quantity of garbage and other waste materials are being produced. Tabriz, a city located in the northwest of Iran and with the population of over 1.6 million is regarded as one of the major metropolitan industrial areas in the country. However, it has never been equipped with an organized ravage system. During the last decades, garbage and other refused materials were mostly discarded outside the city without applying any specific managed strategy Such an unreasonable procedure could inflict a seriously heavy damage on the environment and, consequently a number of associated diseases could be introduced in the context of study area. Consequently, the main objective of the current investigation was to apply a waste-tailored GIS to all available data by referencing to the spatial analysis procedures in selecting of an appropriate dumping site. To this end, in the first stage, all important environmental and concerned conservation observations were collected to the Microsoft office Access to accomplish an inclusive database of the study area. In the second stage, all spatial data layers were weighted and categorized accorrung to the well-known standards in the IDRISI software package by addressing the three dissimilar Multi-Criteria Decision Analysis (MCDA) algorithms such as: Simple Additive Weighting (SAW), Analytic Hierarchy Process (AHP), and Weighted Linear combination (WLC) which have been progressively applied to the presented data in the ArcGIS setting. Concurrent analysis of revealed models and ground control points (GCPs) confirm that an exact examination of AHP model shows a few uncertainties on the associated results. Yet, maps created by applying of SAW and WLC algorithms could be entirely trusted regarding very small variations on their spatial sizes. Therefore, an overlaying technique was applied to all common suitable parts -exposed by AHP, WLC and SAW models-to locate the final proper waste dumping site which is positioned somewhere in the northwest of Tabriz City. An initial calculation confines that the selected geographical location with the area of 201 hectares could possibly support removal of 1000 tone (on a daily basis) garbage for the next 20 years.

Key words: GIS · MCDA Algorithms · Urban waste · Tabriz

INTRODUCTION

In many of developing countries the rate of population is growing very fast and accordingly the major cities are expanding without regarding the furure development plan rules [1]. Increasing population growth and urban development combined with a dwindling critical natural resource base is exacerbating environmental conflicts. In such countries the increased consumption of different natural and man-made composite resources particularly in urban areas could produce a huge quantity of refuses and other waste materials needing to be managed in a logical manner. Traditionally, there have been some ways of discarding urban produced waste, of which one of the most coherent ways is dumping ravages in suitable landfills outside the cities, if the garbage marerials are not to be recycled.

Tabriz City, with more than 1.6 million residents is a metropolitan industrial area located in the northwest of Iran. Such an ancient and cultural city has never been equipped with an organized ravage system and consequently garbage and other refused materials are mostly discarded outside of the city without applying any specific managed strategy. Such an unsuitable procedure has inflicted a substantial damage on the environment and consequently a number of associated diseases have been introduced in the context of affected areas. In order to address the issue, the main aim of the current research is to use a GIS technological system based on the three

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dissimilar MCDA algorithms to aid the decision-making process by selecting an appropriare dumping site in the Tabriz district.

A great deal of research has been carried out on the process of managing the urban waste conflict and addressing techniques for ways of dumping straregies [2, 3] . GIS as a tool for landfill sitting has been satisfactorily proven to be useful in many parts of the worlds [4]. Undoubtedly, this methodological approach could help the planners of the regional planning to make the good decisions in order to initially preserve the strength of the decision made. Accordingly, GIS could be defined as a computer-based system that integrates the data input, data storage and management, data manipulation and analysis, and information output for both spatial and attribute data to support decision-making activities [5]. Generally speaking, GISs have emerged as functional computer-based tools for spatial description and manipulation. Although often described as a decision support system, there have been some disputes regarding whether the GIS decision support capabilities are sufficient.

To be much more constructive for spatial planning, particularly in the finding of a precise dumping site, GIS must be linked to the other advanced mathematical modeling capabilities such as MCDA algorithms [6]. Such techniques could be applied to identify a single most preferred option, to rank options to list a limited number of options for subsequent evaluation, or to distinguish acceptable from unacceptable possibilities [5]. There are many MCDA approaches which differ in how they combine and utilize the data, which were formerly classified on the basis of the major components of multicriteria decision analysis that could be found in reference sources in detail [7]. Spatial multicriteria decision problems typically involve a set of geographically-defined alternatives (events) from which a choice of one or more alternatives is made with respect to a given set of evaluation criteria [7, 8]. Nearly, all of researchers consider that spatial multicriteria analysis techniques could be enclosed with an explicit geographic component on the modeling of the real world issues such as waste management systems [9].

Similarly, this study integrates the IDRSI and ArcGIS software's facilities of data acquisition, storage, retrieval, manipulation, analysis and the capabilities of MCDA algorithms for aggregating all available layers to locate a proper waste dumping site. In the current research, three different, but the main MCDA algorithms such as: SAW, AHP and WLC have been progressively applied to the data in the software setting, supporting the removal of garbage for a prospective scientific waste management in the vicinity of Tabriz.

Study Area: Tabriz City, center of the East Azerbaijan province, is located in the Northwest of Iran. The study area is restricted between the latitudes 38°1′ N to 38°9′ N and longitudes 46°11′ E to 46°23′ E. Tabriz County, with its sprawling rural districts, and a population of approximately 1.6 million, is Iran's largest city located in the northwest of the country. It is externally expanding rapidly and contains metropolitan area and highly industrialized pockets. This city is a nearly bowl-shaped with a low plain the middle of which is effectively walled in on three sides by hills and mountains. In the centre of the region there is the flat plain opening to the Urmia Lake from the west, which is the largest water body in Iranian plateau. Fig. 1. indicates the geographical location of the study area as well as position of the Tabriz City in the region.

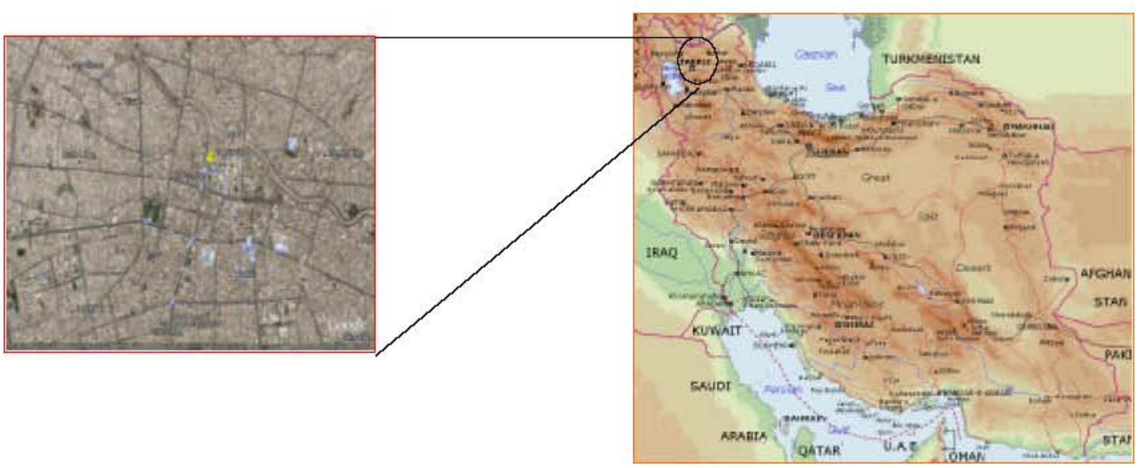

Fig. 1: Study Area , Location of Tabriz City, Located in the Northwest of Iran

Urban and suburban area's waste materials have been traditionally collected, taken out and dumped in a place located in the vicinity of international airport of Tabriz by municipal and associated local authorities. During the past 25 years, the quantity of domestic garbage received by the collective installations has tripled and presently the average production of domestic garbage for each person in Tabriz City is about 0.65 kg per day. According to this estimate, the quantity of garbage in the area is continuously increasing and it could be concluded that the more people consume, the more garbage will be produced. Undoubtedly, the waste materials could be regarded as a serious menace to the human life, the possessions and the environment. They are accountable for degradation of the cleanliness of the cities, the beauty of the landscapes as well as the depletion of soil, water and air in the context of the study area.

MATERIALS AND METHODS

This section consists of checking the nature of each data available and ways of analyzing all data based on the criteria which meet the laws and standards of a required dumping site, in order to achieve the final goal of the current research.

Data Analyzed: All accessible and relevant data have been assembled and analyzed to determine the most prospective suitable site for future landfills in the study area. The criteria were both constraints and factors for an ideal sitting of dumping of wastes and were related to topographic factors, under ground water level, roads, open water, protected areas, urban, rural residential areas, soil type, land use / land cover, mine and geology factors and distance to transportation routes. The main characteristics of data layers are given in Table 1.

The main digital layers of the study area including terrain parameters, natural resources and human infrastructures are wroted in Table1. All these data were analyzed on the basis of MCDA modeling processes regarding some of standards and constraints which have been progressively imposed on the introducing of SAW, AHP and WLC algorithms to locate the best site for dumping of waste materials.

Process Applied: The present investigation has applied tree GIS-based MCDA algorithms by aggregating all relevant layers to locate the proper waste dumping sit and to reduce the search area over vast land coverage to leave only those areas that are suitable for sitting a prospect landfill [10]. This research began with problem identification and thereby establishing the objective, which was tied to a specific srudy area [5]. The methodology for the current research is based on the following sequences.

Derived from the yearly growth rate of the population of Tabriz Ciry (about 1.6) and emoval of 1000 tones on a daily basis, the area (size) of dumping site was calculated nearly about 130 hectares addressing the following equation:

Table 1: The Main (Wide-Ranging) Characteristics of Data Layers Analyzed

Criteria	Items	Standards	constrains
Terrain parameters	Size	>130 hectares	Minimum lot size
	Elevation	1300-1400	To minimize pumping costs
	Floods	>200m	Buffer zone to avoid catastrophes
	Slopes	>15%	Erosion ,drainage, stability and strength
	Faults	>100m	Avoid land environ/cultural sensivity
Natural resources	Land cover/land use	>200m	Lands with less erosion rate
	Water bodies	>300m	Vacant lots to minimize acquisition costs
	Soil type*	<5% GW , GpandGM	To minimize pipeline construction
	Under ground water level	20m	
	Vegetation cover	2-20%	
	Erosion rate	minimum	
Human infrastructures	Roads	>300m	Distance to existing roads
	Transportation networks	>100m	Distance to waste water facility
	Wells	>100m	Distance to residential properties
	Mines	>150m	Distance to communications, power and water connections
	Power networks	>100m	
	Population centers	>100m	
	Airport	>3km	
	City center	5-30km	

*Note:The soil erosin model followed the MPSEIAC systems and G=Gravel,S=sand,M=silt,C=clay,W=well graded,P=poorly graded. It should be noted that the content of Table 1 offers of a general characteristics of data layers and it differs from type of MCDA techniques to another noticeably.

$$S = P (1 + T)^{40}$$ with:

S: Surface of the Dump. p: population of the agglomeration and, T: the growth rate of the population per year. Subsequently, three MCDA methods such as: SAW, AHP and WLC were progressively introduced [11]. Interfering these techniques, all layers have been primary standardized and accorrling to the rules and principles were changed to fuzzy sets: a collection of elements or objects without well-defined boundaries [12].

SAW Procedure: A SAW method was primary applied to the data for tackling spatial multi-attribute decision making on the context of the proposed dumping site [7]. This technique was also referred to a scoring method which is based on the concept of a weighted average [13]. By this technique the relative importance of each layer and its attribute could be directly assigned by using the following formula:

$$Ai = \Sigma jwjxij$$

Where xij is the score of the ith alternative with respect to the jth attribute, and the weight wj is a normalized weight, so that $\Sigma wj=1$. Accordingly, weights were estimated which representing the relative importance of attributes in each layer.

Then a GIS-based SAW method was involved using IDRISI software capabilities and results were imported to the ArcGIS to recalculate and to map the final model (Figure 2, SAW outcomes). Using this technique, a proposed site was defined in the northwest of Tabriz City with an area of 180 hectares for dumping of waste materials.

AHP Method: The AHP evaluation criterion is then applied to establish the dumping site of interest. This method, developed by Saaty (1980) is based on three principles: decomposition, comparative judgment, and synthesis of priorities [14]. The AHP is a comprehensive, logical and structural framework, which allows improving the understanding of complex decisions by decomposing the problem in the hierarchical structure [13]. In this study, to suggest the relative importance of priority of a dumping site, initially a pat wise compatison matrix was constructed on the judgment of all data layers involved [15]. Then, a wide range of suitable areas of importance was standardized and the criteria were weighed using pairwise comparison based on AHP method. Final results have been combined with an ArcGIS functions to transform data to the spatial information context. As it is represented in Figure 3 (see AHP components), a spot located in the northwest of Tabriz City with the area size of more than 1000 hectares was mapped.

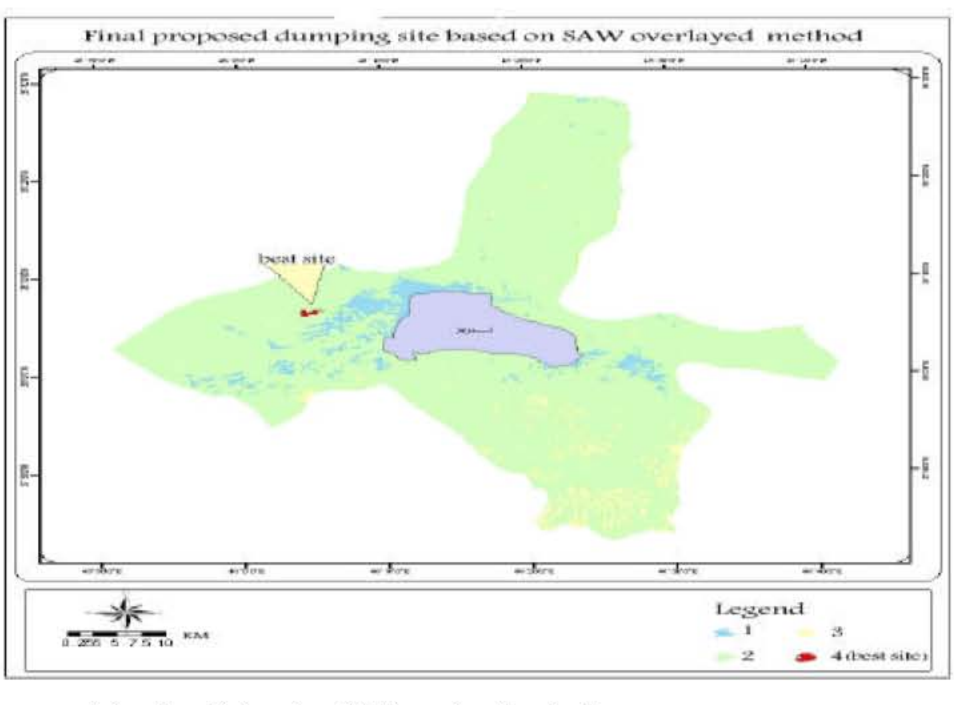

Fig. 2: Final proposed dumping site based on SAW overlayed method

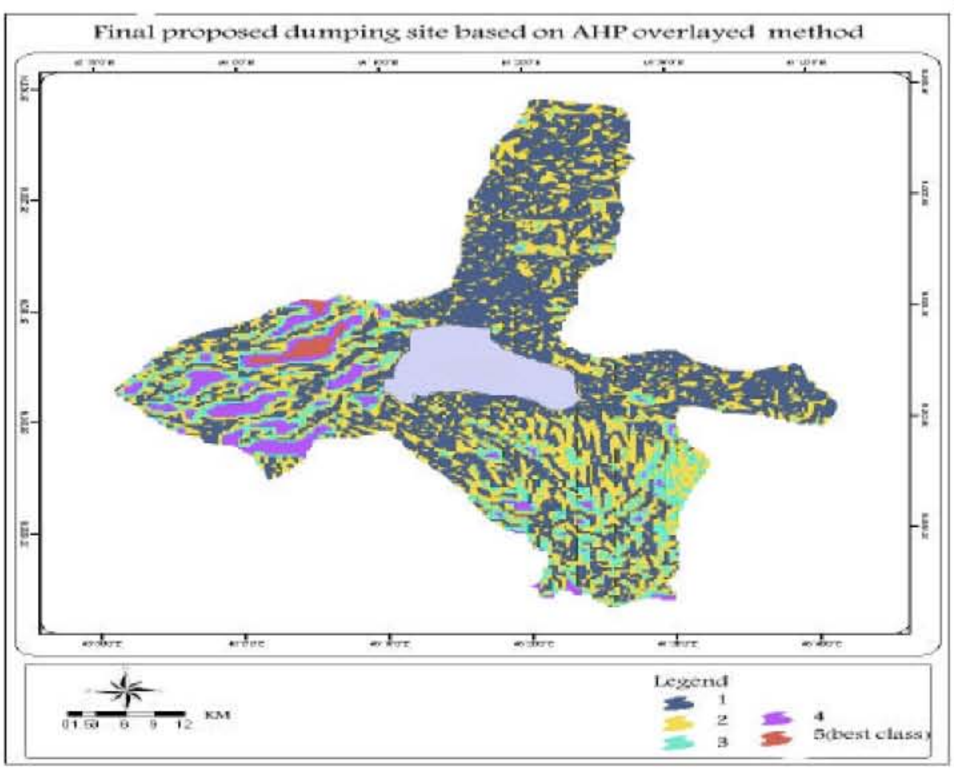

Fig. 3: Final proposed dumping site based on AHP overlayed method

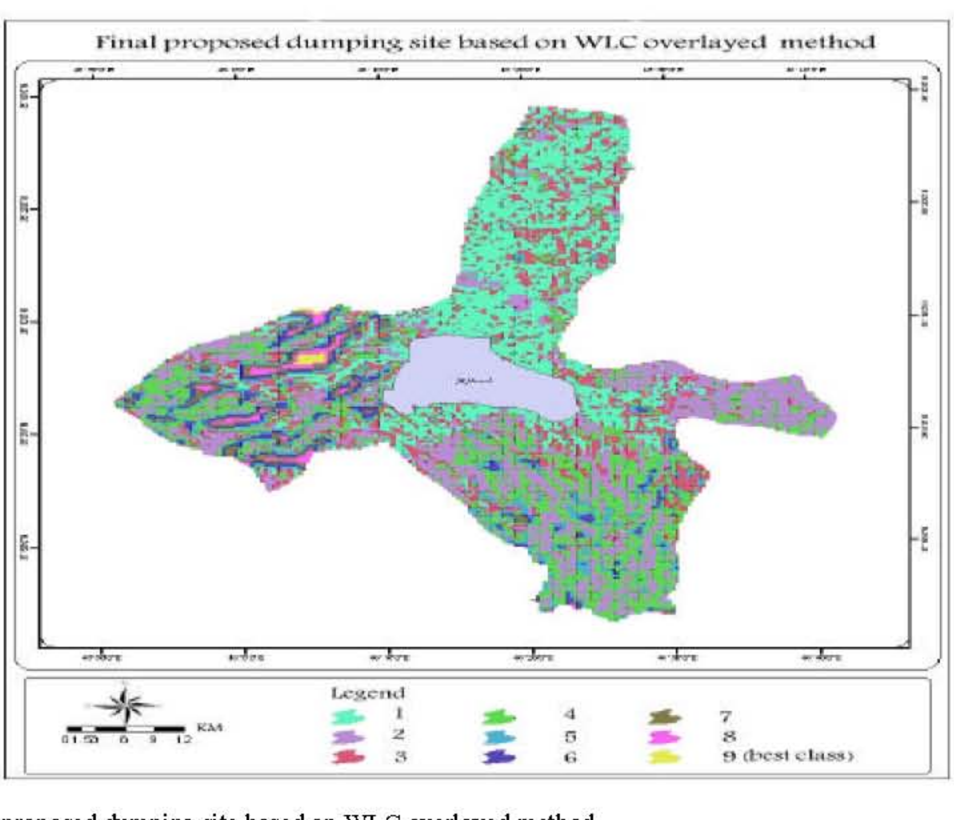

Fig. 4: Final proposed dumping site based on WLC overlayed method

WLC Technique: As indicated earlier, the primary issue in multi-criteria evaluation is concerned with how to combine the information from several criteria to form a single index of evaluation [14]. For this reason, a WLC method was additionally applied to the data which is similar to SAW method, but it could be modified and used as multi attribute combination decision technique [7]. WLC method is generally based on the weighed averages and an evaluation scores are calculated for each alternative by multiplying the scaled values given to the alternative of that attribute with the weights of relative importance. Such weights directly have to be assigned by decisionmakers followed by summing of the products for all criteria [12]. The continuous factors related to the study area are combined by applying a weight to each followed by a summation of the results to yield a suitability map of proposed dumping site according to the following equation.

$$S = \Sigma\, wi\, xi$$

Where;
S = suitability;
wi = weight of factor I;
xi = criterion score of factor i

Relevant standardized fuzzy values based on WLC method are applied for all layers. After standardizing the scores in IDRISI software setting and by applying a module named MCE, a special function has been introduced to map the results provided by WLC method (Figure 4, related outcomes). At the final stage, an ArcGIS's overlaying function was lastly applied to model a universal area of dumping site, anticipated by above-mentioned methods.

CONCLUSION

projected population rates Selecting the sites for waste removal could be regarded as a complex process of involving not only technical requirement, but also economic, social, environmental and physical requirements that may result in conflicting objectives. In the current srudy, such complexities necessitated the simultaneous use of several decision-supporting tools such as the mosr essential MCDA algorithms in a GIS-based background, indicating that, Planning for furure decisions on the appropriate zoning for dumping site (particularly in case of Tabriz City) demands a comprehensive analysis and sound judgment. These processes often take longer to achieve but with the introduction of appropriate tools, decision making can be made faster and more reliable. The use of MCDA processes, for instance, SAW, AHP and WLC methods in waste management sector has many advantages. Originally, the set of factors is clearly described and if there is a lack of data, the need of completion is obvious. Lastly, the sensitivity of the data analysis reveals the main characteristics of the future dumping site in the vicinity of Tabriz City. Such advanced methods could be consequently adapted and customized by using complete layers in a real installation stage in a professional GIS setting by avoiding misleading conclusions, in cases that there is either a lack of critical data and/or weighting of the critical factors is mistaken.

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