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Using Geological and Topographic Maps in Site Selection of Solid Waste Disposal

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Abstract: Currently, land shortage for solid waste in most urban areas is a significant and growing potential problem. Although some efforts are made to decrease and recover the waste, landfill is still the most common process for waste disposal. Site selection of solid waste dumping in urban areas is a serious subject because of its huge effect on the economy, ecology, and environmental health. Consequently, several criteria must be created because of the difficulty of the parameters to select the process for combination in social, environmental and technical parameters. In this research, the most appropriate sites for locating dumping garbage are determined using the Geographical Information System (GIS) by implementing both methods Boolean logic model and Index overlay model. Based on several objectives, a provided spatial data set consisting of several maps in the form of layers, such as land use, geological distribution, landslides, etc., were used in the modeling process to choose the best site to dump the garbage of Chinchina city that used as a case in this application. The findings show that the Boolean logic model identified only two areas that met the criteria, whereas the Index overlay model identified three important classes through weight; unsuitable, moderate and suitable regions for construction waste disposal.

Keywords: Boolean logic and Index overlay models; Chinchina; Geological and topographic maps; Geographic information system; Site selection of waste disposal.

INTRODUCTION

There is an increasing commercial in terms of residential and infrastructure improvement because of the growth of population, which negatively affects the environment, such as waste disposal and the selection of unsuitable areas that leads to various problems, such as groundwater contamination and no control of gas emissions of a landfill that cause an explosion. Moreover, the permitting and sitting requirements and its operation, also, people's awareness and rising degradation, increasing cost, community and political opposition, the shortage of areas availability and concerning of public health to participate in the difficulty of selecting suitable land for waste dumping Şener et al. (2006). Nowadays, there is no uncertainty that waste management is essential for the environment; it includes; reducing the waste, recycling, high tech collection, compacting the waste, thermal treatment and sanitary landfills. The mentioned strategies focus on environmental protection in waste management (Daneshvar et al., 2005). Therefore, locating a waste disposal site in a suitable area is time-consuming.

Waste management is one of the issues that face decision-makers around the world. This issue is mainly squeaky in the town, where

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increased urban development, poor planning, and adequate deficiency contribute to worse waste disposal management (Obirih-Opareh & Post, 2002). The main problem related to unsuitable waste disposal management includes the transmission of diseases, fire risks, inconvenience smell, atmospheric, water contamination, visual harassment and economic damages (Jilani, 2002).

Selecting a waste disposal site (landfill) is a significant question facing domestic authorities because it represents a meeting point of planning, social science, and science (UNEP-IETC, 1996). (Kao & Lin, 1996) mentioned that many factors have to be considered and assessed carefully, which caused minimum impacts to the environment, economy, and society and conforming with the regulations that are finally accepted by the public. This issue faces the managers and planers of the municipality as decision-makers around the world. The criteria and rules for site selection of solid waste are almost similar around the world, with some limitations related to locality. On the other hand, some criteria factors may conflict with each other; so, several compromises are required if the process occurs (Michael, 1991).

Kao and Lin (1996) pointed out that site selection analysis can enhance by using GIS 'Geographic Information System'. It is a proper tool to select the best site because it has planning and operations that depend on spatial data that derive from different sources and can process a large amount of data and information displayed according to operator-defined specifications. GIS is a tool that could be time-saving and reduce the cost of the selection of the land, moreover produce a bank of digital data to be used as a monitor program in the future. In addition, GIS can be beneficial to decrease uncommonly the sites that should be tested on the location and the decision of selecting site has been taken after field trip observation (Daneshvar et al., 2005).One of the most critical data inputs for the modelling of site selection of the solid waste dumping is the geological maps and topographical maps, which appears in this study as Digital Elevation Model (DEM). Geological maps are used to manage the Earth's resources and resolve environmental hazards; it is an essential source of information related to planning and land use management, locating places that could be polluted, including solid waste dumping, as well as defining aquifers to be safe from the pollution (Bernknopf, 1993).

Geological maps sheets are converted into digital maps that are used as interactive spatial documents, where all the displayed data are combined with the interpretation of physical and chemical phenomena of the earth. Then set them as geological maps, which are collected with the databases of the geographical information system (GIS) to contribute in resolve much geological and hydrology suspended issues, including the bedrock spatial distribution of the permeable and non-permeable stratigraphic and prospective places of pollution, as well as the volume of landuse (Tudor & Ion, 2009). This detailed information collected about the geology of an area helps decision-makers suggest the best decisions to participate in the development and sustainability plans (Bernknopf, 1993).

Topographic maps display elevation or three-dimensional topography and two-dimension-ally and the topographic maps contain contour lines that show elevation. However, the maps were primarily utilized for military planning and later used for many purposes (Kauffman, 2015). These maps are most commonly produced of Digital Elevation Model (DEM) and could be derived from a set of source data such as; ground surveys, aerial photographs, and Stereo-pairs such as with ASTER, SPOT and IRS satellite imagery. Digital Elevation Model is a computer performance of the land surface from topographic parameters, for instance, slope, upslope area, and the topographic index, which can be digitally produced. (Liu et al., 2009).

In this research, multiple maps methods for empirical modelling were combined in a geographic information system (GIS) using ILWIS software incorporated into ITC's. In this case, two techniques were done to analyze multiple maps as described by (Bonham-Carter, 1994) to inspect the study area to obtain a suitable site for throwing solid waste.

MATERIALS AND METHODS

The study area of this project was Chinchina town, which is located in Colombia, south of America, as shown in Figure 1. This town requested to explore suitable areas to dump waste because around 150,000 populations dump their garbage in the river. Due to raising awareness of the environment, the town's Municipality has established working with decision-makers to find out the best location for that purpose

Figure: (1). The study area of chinchina city

GIS models are used to carry out the analysis for the chosen area selected. Six criteria were developed based on the input data maps done by the planning department teams, including specialists in geology, geomorphology, hydrology, and engineering (Van Westen, 1997). The following six criteria have been taken into account in order to select suitable areas for waste disposal;

1. It should be built away from active landslides, or later maybe it will be active.
2. The landfill must be built on a ground with a slope of fewer than 20 degrees to reduce erosion.
3. Construction areas and agricultural lands and forests should be excluded, as the city of Chinchina are one of the most critical coffee-growing areas in the Republic. It is recommended to select areas that are not of economic or environmental importance.
4. The site is being built up at a distance of at least 2 km from the city center and more than 300 meters from the countryside around the town.
5. Soil layers should be rich in clay, with a thickness of five meters or more, and the permeability of the soil should be less than 0.05 meters/day.
6. The area of the site to be selected should be one hectare or more.

The model and analysis are required using the ILWIS software. Various methods have been tried to gain a better understanding and results. The following Table 1 shows the input data set available for these models. Also, the methodology uses a Geographic information system (GIS) in order to evaluate the whole region related to specific criteria for the analysis and select suitable landfill sites (Abesi & Saeidi, 2009). Two methods were used in this work; *Boolean logic model* and *Index overlay model,* which are presented in the flowcharts below as shown in Figures 2a and 2b, respectively

Boolean logic model: In this technique, each input map is represented for each factor (Sastry, 2020), the user looks for areas that meet definite conditions to create a binary map. After a condition is met, it is indicated with a 'true' and takes Value 1; if it is not met, that means; it is indicated with a 'false' and takes Value 0. This shows each criterion's suitable and unsuitable pixel locations 'Bitmaps' to select areas suitable for waste disposal. Then, input maps 'Bitmaps' are combined using Boolean AND operation to create a binary output map, representing suitable pixels containing value 1. The output map shows the places satisfying all criteria needed for this application. The main advantage is its easiness, but the disadvantage is the equal importance of each criterion.

After confirming the input data of the modeling in this case study which presents criteria for the site selection. Then starting to delineate the areas that are suitable locations for waste disposal for every of the input maps individually by originating a series of bitmaps from the input maps to create binary maps.

All the analysis will be explained in 8 steps by using the formula ;each formula is matched by one of the conditions that have been previously mentioned.

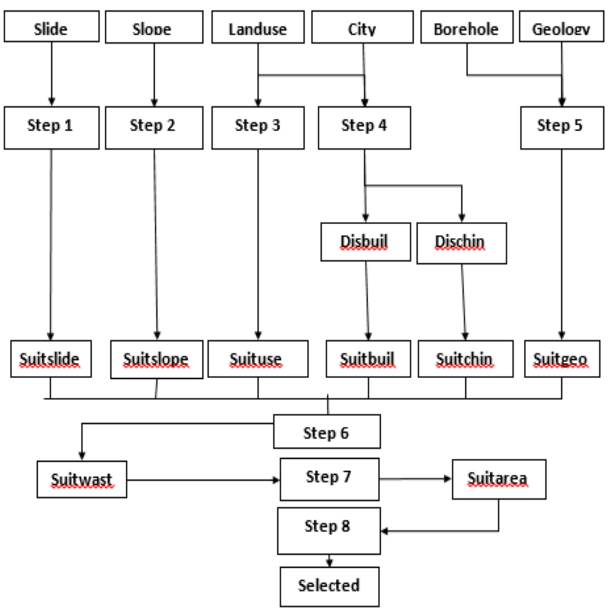

Figure: (2a). Flowchart of Boolean logic model

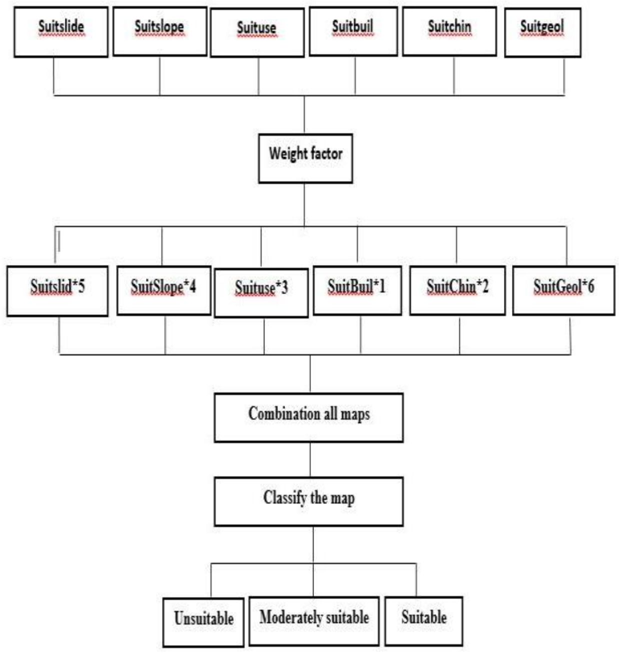

Figure: (2b). Flowchart of the Index overlay model

Index overlay model:

The index overlay technique can provide a method for assigning various weights to all of the effective factors maps depending on the importance of the pattern to the model under consideration. These weights are defined as a positive integer number in a specified interval. In this method, input factors maps are index weighting with functional on Binary Evidence Maps with only two classes (true or false) where each map carries a single different weight factor, and it is multiplied by its weight factor, as given in Eq. (1);

$$Wi = MAPi \qquad (1)$$

Table :(1). Data availability used in the project (Van Westen, 1997)

NO.	Input map as named in the software system	Description	Classes contain	Source of data
1	Slope	Topography	slopes indicated in degrees with values from 0 to 49 meter	A digital elevation model (DEM).
2	Landuse	Land use areas	Built up areas, Coffee areas, Forest and shrubs, Green pastures, Degraded land, River and Lake.	Supervised Classification of a SPOT image, improved using photo interpretation and field trip.
3	Geol	Surface lithology	Chloritic/amfibolitic schists, Dioritic gabbro, Gneissic intrusive, Lahar deposits, Lake deposits, Metasedimentary rock, Mixed debris flow, Ashes and alluvial material, Mixed pyroclastic, Flow and debris flow deposits, Porfyritic andesite, Pyroclastic flow material, Recent alluvial material, Sedimentary rocks, Subaquatic lava flows, Weathered debris flow material	Existing geologmethadical maps and fieldwork.
4	Slide	Topography and morphology	Stable, dormant, active, no landslides	Photo- interpretation.
5	City	Boundary of Chinchina city	Chinchina and Outside chinchina	The topographic map and photo-interpretation
6	Borehole	Geological unit, Geological units age, thickness of the soil cover, permeability of the soil cover and percentage clay of the soil cover	203 boreholes, X-Coordinate of the borehole , Y-coordinate of the borehole, Thickness of the soil cover, Percentage clay of the soil cover, Permeability of the soil cover, Geological unit from which the soil is derived	Data base
7	Road	Main roads	Road	Photo- interpretation.

Then all weighted factors maps are combined with each other, Eq. (2):

$$\sum_i^n Wi\ x\ MAPi \qquad (2)$$

Finally, the output map is integrated by the sum of the weights, as given in Eq. (3):

$$\frac{(\sum_i^n Wi\ x\ MAPi\ \ )}{\sum_i^n Wi} \qquad (3)$$

The value of the output binary map is between 0, which represents an extremely unfavorable to the criteria and one which represents highly favorable to the criteria.

RESULTS AND DISCUSSION

All the results of the analysis will be displayed separately as follows; According to criterion about the waste disposal must be built away from active landslides or later maybe it will be active that applied for map Slide is indicated with pixel value 0 (unsuitable) and the rest with pixel value 1 (suitable) by using the formula;

SuitLandslid =iff ((SLIDE="stable") OR

(SLIDE=" no landslides"),1,0), as shown in Figure 3.

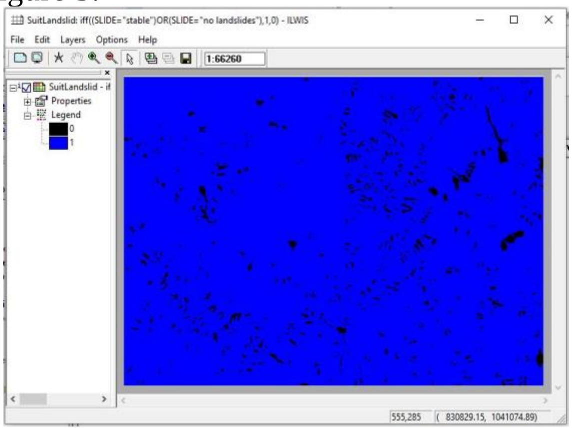

Figure: (3). Suitable landslide for waste disposal

The landfill must be built on a ground with a slope of less than 20 degrees for each cell of the raster map. Slope to calculate a map SuitSlope is indicated with pixel value 1 (suitable) and the rest of the map with pixel value 0 (unsuitable), by using the formula; SuitSlope=iff (SLOPE<20,1,0), as shown in Figure 4.

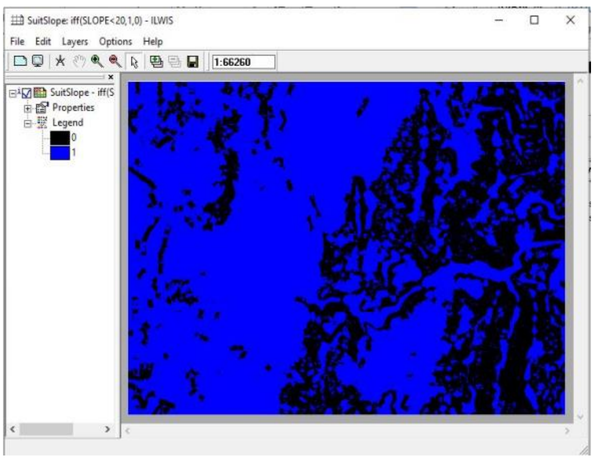

Figure: (4). The suitable slope for waste disposal

It is recommended to select areas, not of economic or environmental importance. The only suitable land use classes are shrubs and bare. To calculate a map SuitLanduse in which the areas with land use classes Shrubs and Bare are indicated with pixel value 1(suitable) and the rest of the map with pixel value 0 by using the formula; SuitLanduse=iff((LANDUSE="Shrubs")OR(LANDUSE="Bare"),1,0), as shown in Figure 5.

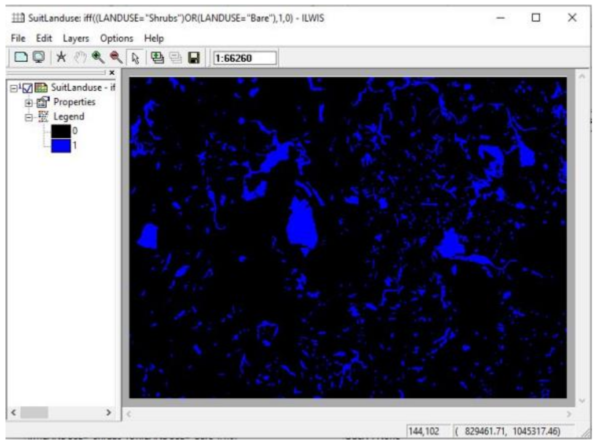

Figure (5). Suitable land use areas for waste disposal

The site has been located within 2 km distance from the city center of Chinchina, but less than 300 m from any existing built-up area, The calculation of distances is achieved using the function **Distance program** and the source areas (Chinchina and built-up area) from which distances are calculated and assigned zero values, and the areas through which distances are calculated with values 1). This criterion will be divided into two criteria:

The first calculation is done to assign the map *SuitChinchina* in which the areas located at distances less than 2000 meters from the city of Chinchina are indicated with pixel value 1(suitable) and the rest with 0 (unsuitable) by using the formula;
SuitChinchna =iff ((Citydistance<2000) AND (Citydistance<>0),1,0), as shown in Figure 6.

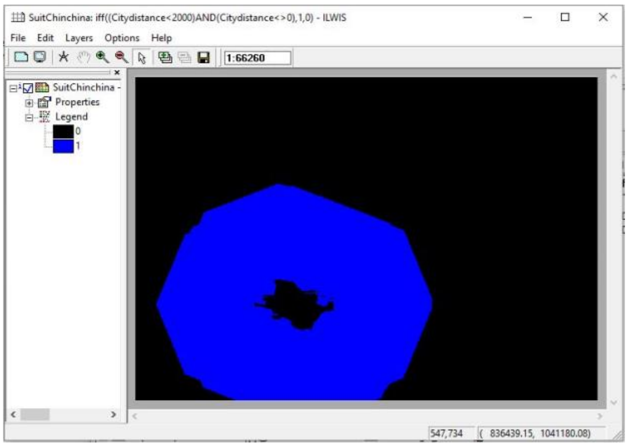

Figure: (6). Suitable city boundary for waste disposal

The second calculation is to create the map *SuitBuilt* in which the areas located less than 300 m from the country side around the town that indicated with pixel value 0 (unsuitable) and the rest with 1(suitable) by using the formula; SuitBuilt =iff (Builtdistance >300,1,0), as shown in Figure 7.

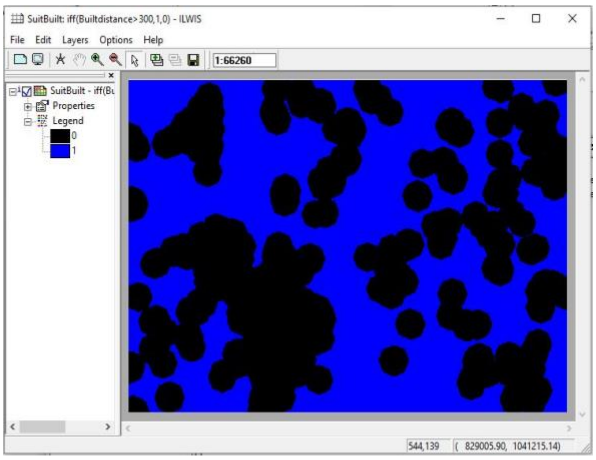

Figure: (7). Suitable built-up areas for waste disposal

The landfill site has been constructed on clay-rich soils (with more than 50 percent of clay), with a soil thickness of more than 5 meters and a permeability lower than 0.05 meters/day. To create the suitability map for this criterion, analyze the borehole data is needed and stored in the table *Borehole* which contains 203 borehole records, using the function **Table Calculation**. The original borehole records were already restructured in such a way that for each borehole, the geological unit, the thickness of soil cover, the percentage of clay and the permeability are given, then the average of each of the three variables (average thickness, average clay content and average permeability) in the same table, all of the mentioned averages have been calculated and derived in a column *Suit*. From these columns, the geological units will collect a value of 1 if the conditions mentioned above are met.

The last step in the calculation of this criterion is to calculate a map SuitGeological in which the areas with suitable geological units (average thickness >5 m, average clay percentage > 50, and average permeability <0.05 m/day) are indicated with a value of 1 (suitable) and the rest with a 0 (unsuitable). This can be done by reclassifying the map Geology with the column Suit from the table Geological unit by using the function **Attribute Map**, as shown in Figure 8.

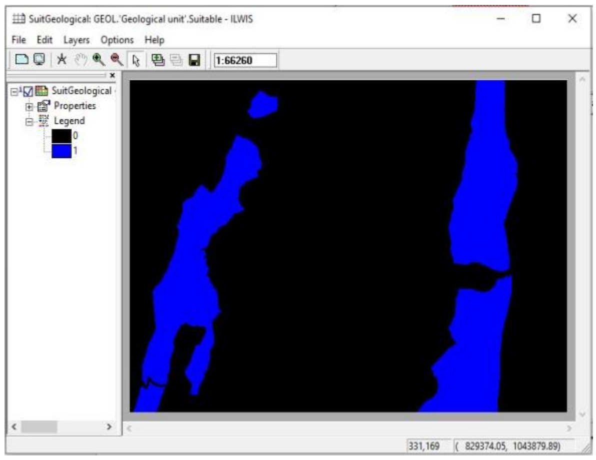

Figure: (8). Suitable geological unit for waste disposal

In this step, combine the suitability maps mentioned in the five steps above by using Boolean **AND** operator to intersect all six binary patterns in order to get one map named *SuitAll*. by using the formula; SuitAll=iff((SuitLandslid=1)AND(SuitSlope =1)AND(SuitLanduse=1)AND(SuitBuilt=1) AND(SuitChinchna=1) AND (SuitGeological=1) ,1,0), as shown in Figure 9.

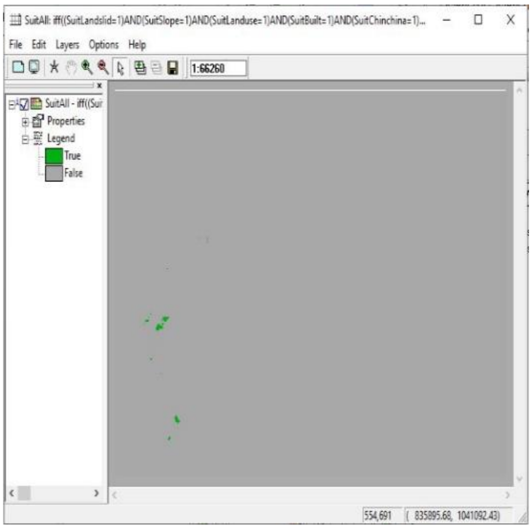

Figure: (9). Combination of all suitable bitmaps

After selecting the most suitable areas in the previous steps for waste disposal, the next criterion to meet the suitable areas is large enough for dumping the waste for a long time with a minimum area of more than 1 hectare (10.000 m^2). For this purpose surface area of each pattern have to be known. It can be calculated for each area by using the calculation of the histogram to select the met areas with a map named *WasteDisposalSite***,** as shown in Figure 10.

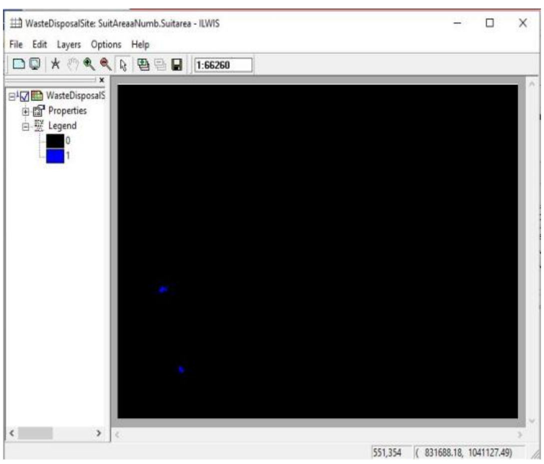

Figure: (10). Suitable areas more than one hectare for waste disposal

This is the final site selection that deals between the different sites by using other criteria that may play a role in this project the availability of the site by the road map, as shown in Figure 11.

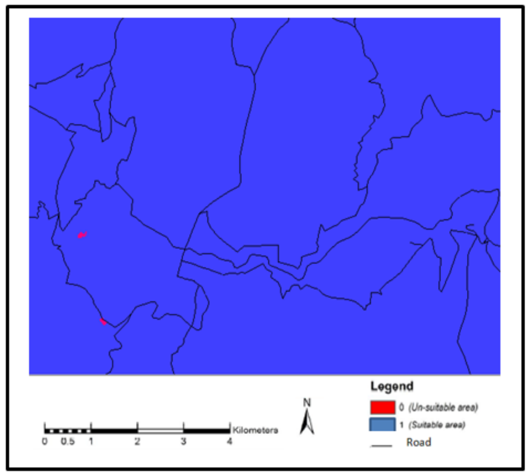

Figure: (11). Final Suitable area for waste disposal

The significant advantage of the Boolean logic model is simple and offers more facilities to decision-makers to simulate the real world by creating models and using spatial data combined with the disadvantage of the equal importance of each of the criteria (Malczewski, 1999); however, the disadvantage of this model is equal importance of each of the criterion “If, for example, the team judges that criterion 5 is much more important in determining the suitability for constructing a waste disposal compared to criterion 2” (Van Westen, 1997). moreover, the model cannot give us more information about the chosen areas, as well as, if criteria are rigorous, most of the land is considered as unsuitable land then is rejected without any additional consideration (Hatzichristos & Giaoutzi, 2006). In comparison, the index overlay method is a more flexible and quick combination of maps than with Boolean logic by incorporation of expert knowledge through weights (Van Westen, 1997), because of that the method of Index overlaying with functional on Binary Evidence Maps was applied in this project as the second method by assign weights proportional to the importance assigned to each of the six binary maps ranging from 0 to10 that created only two classes (true or false), where each map carries a single different weight factor, and it is multiplied by its weight factor. All weighted factors maps are combined with each other. Finally, the output map is integrated by the sum of the weights to create a value between 0, which represents an extremely unfavorable to the criteria and 1 which represents highly favorable to the criteria, the output score S is defined as;

$$S = \frac{\left(\sum_{i}^{n} Wi\, class(MAPi)\right)}{\sum_{i}^{n} Wi} \qquad (4)$$

The following formula is represented in the software by assigning different weights as shown in Eq.4;
SuitAllWeight=((SuitGeological*6)+(SuitChinchina*2)+(SuitLanduse*3)+(SuitLandslid*5)+(SuitSlope*4)+(SuitBuilt*1))/2, as shown in Figure 12.
Classify the map SuitAllWeight in three classes: Unsuitable, Moderately suitable, Suitable, and compare it with the map SuitAll.

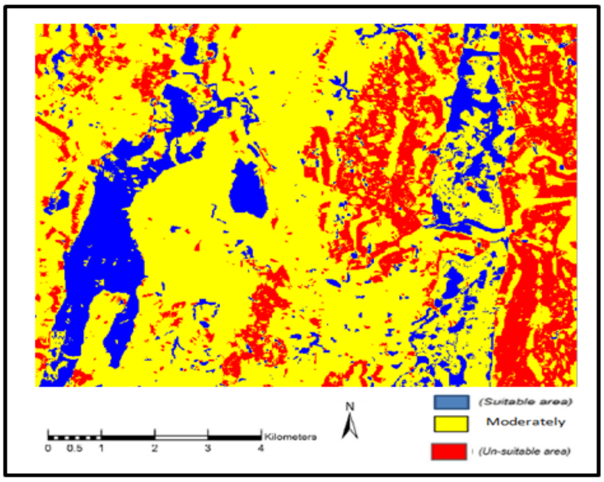

Figure: (12). Suitable, moderately, and unsuitable classes depends on the weight

Table 2 shows areas meter square of suitable, moderate, and unsuitable cells gained from the Boolean logic model and Index overlay model.

Table: (2). Suitable, moderate, and unsuitable areas obtained from Boolean logic and Index overlay model

NO.	Suitable map name	suitable areas m^2	Moderate areas m^2	Unsuitable areas m^2
1	SuitLandslid	65827812.5	-	2456406.3
2	SuitSlope	44872968.8	-	23411250.0
3	SuitLanduse	6430312.5	-	61853906.3
4	SuitChinchina	20195312.5	-	48088906.3
5	SuitBuilt	34001406.3	-	34282812.5
6	SuitGeological	13089218.8	-	55195000.0
7	SuitAll	45468.8	-	68238750.0
8	WasteDisposalSite	25625.0	-	68258593.8
9	SuitAllWeight	5009375.1	51812500.2	46803125.1

CONCLUSION

In this study, a decision-making model that explicitly uses geological maps and topographical maps are used and applied. This study shows that improvement in the information of geological and topographical maps have an additional and net positive value to society, which can help planners and enable them to make superior and solid decisions regarding land use. It is clear that the detailed information obtained from these maps con

tributed effectively and directly to the determination of the solid waste dump site and enabled decision-makers to participate in planning for sustainable development. The principles developed and improved in this study are generally applicable to many other uses of geological map information.

By utilizing a GIS, spatial modeling of geo-referenced maps can be done effectively and easy to allow the decision makers to contribute to the zoning process better than submitting a hard copy of main plans for them; therefore it is considered a perfect tool for this purpose. In this project, wide criteria can develop even if the siting situation is well defined. To confirm that the decision makers take consistent and right decisions to evaluate the location selected. The criteria used in this work are inconstant factors because it can differ from site to site and can be changed depending on the analysis. Many simulations can be achieved by creating different scenarios and different results which are obtained.

Boolean logic model and index overlay method make them effective and proper for spatial phenomena to be site selected. It is better to compare the results of both methods with each other to verify the effectiveness of the work.

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استخدام الخرائط الجيولوجية والطبوغرافية في اختيار موقع التخلص من النفايات الصلبة

على ابراهيم اعليوة

قسم الجيولوجيا، جامعة الزيتونة، ترهونة، ليبيا

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المستخلص: في الوقت الحالي يعد نقص الأراضي المخصصة للنفايات الصلبة في معظم المناطق الحضرية أحد المشاكل الكبيرة والمتنامية. على الرغم من بذل بعض الجهود للتقليل من ازدياد النفايات واستعادتها، فإن طمر النفايات لا يزال العملية الأكثر شيوعًا للتخلص منها. يعد اختيار أفضل المواقع للتخلص من النفايات الصلبة في المناطق الحضرية موضوعًا خطيرًا بسبب تأثيره الضخم على الاقتصاد، والبيئة، والصحة البيئية. وبالتالي يجب إنشاء العديد من المعايير التي تجمع بين المعايير الاجتماعية، والبيئية، والتقنية. في هذا البحث تم تحديد أنسب المواقع المختارة لتحديد مواقع إلقاء القمامة باستخدام نظام المعلومات الجغرافية (GIS) من خلال تطبيق كلا الأسلوبين المنطق المنطقي، ونموذج تراكب الفهرس عليها. وبناءً على عدة أهداف تم استخدام مجموعة بيانات مكانية تتكون من عدة خرائط على شكل طبقات، مثل استخدام الأراضي، والتوزيع الجيولوجي، والانهيارات الأرضية، وما إلى ذلك. تظهر النتائج أن نموذج المنطق المنطقي حدد مجالين فقط لاستيفاء كل المعايير، بينما حدد نموذج تراكب الفهرس ثلاث فئات مهمة من خلال الوزن، وهي مناطق غير مناسبة، ومتوسطة، ومناسبة كمواقع مناسبة للتخلص من النفايات الصلبة.

الكلمات المفتاحية: نموذج المنطق المنطقي ونموذج تراكب الفهرس؛ شينشينا؛ الخرائط الجيولوجية والطبوغرافية؛ نظم المعلومات الجغرافية؛ اختيار موقع التخلص من النفايات.

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