Uses GIS in Town Planning Case Study: Landfill Site Selection of Al-Nasiriyah City in Iraq.

استخدامات نظم المعلومات الجغرافية في تخطيط المدينة دراسة حالة : اختيار موقع مكب النفايات لمدينة الناصرية في العراق

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الخلاصة:

عملية اختيار مكب النفايات (مكان تجميع القمامة ومعالجتها) في اي منطقة عمرانية هو من اهم الموضوعات المصيرية في تخطيط المدن. ويؤثر اختيار الموقع تأثيرا مباشرا على الوضع الاقتصادي وعلى البيئة و الصحة في المنطقة المحيطة. كما انه يرتبط ارتباطا مباشرا بعدد السكان و كمية المخلفات المرفوعة يوميا .اختيار موقعا لمكب هي عملية معقدة تعتمد على عدة معايير ومؤثرات تختلف من مدينة الى أخرى منها على سبيل المثال مركزالمدينة،استخدامات الأراضي،المطارات ،السكك الحديدية ،الميل، الأنهار، والمناطق الصناعية،أنابيب النفط،الموارد الطبيعية شبكات الطرق المختلفة والمناطق الاثرية والسياحية.كما يختلف تاثير هذه المعايير باختلاف القوانين المستخدمة ,الاراضي المتوفرة وكذلك الطبيعة الجغرافية للمنطقة.

الهدف الرئيسي لهذه الدراسة هو التطبيق المتكامل لتحليل القرار متعدد المعايير (MCDA) مع نظم المعلومات الجغرافية لتحديد انسب المواقع المحتملة لطمرالنفايات في مدينة الناصرية في العراق مع تطبيق المعايير المختلفة والمقارنة مع الموقع الحالي الموجود بالمدينة. وكشفت نتائج هذه الدراسة أن نظم المعلومات الجغرافية مع (MCDA) يقدم حلا جيدا لاختيار أفضل موقع لمكب النفايات ويشكل بديلا جيدا للطرق التقليدية كونها تعتمد مبدا التحليل العلمي لكافة التاثيرات المتوقعة للمكب الجديد من خلال اعطاء اوزان مختلفة لكل معيار حسب حساسيته و مدى تاثيره.

Abstract

Select a landfill site in an urban area is one of the most crucial topics in an urban planning process. The landfill site has a direct impact on the economic situation environmental and the health in the city. It is also directly related to the growth of the population which leads to increase the amount of waste brought daily. Select the landfill site is a complex process depends on many criteria. these criteria are varying from city to another, for example, the city center location, land use, airport, rail, various networks roads, steep, rivers, industrial zones, oil pipelines, natural resources and areas of archaeological and tourist. The impact of these criteria varies depending on the laws used, available land, and the geographical nature of the area.

The main objective of the study is an integrated application for multi-criteria decision analysis MCDA with geographic information systems (GIS) to determine the most appropriate potential landfill in Al-Nasiriyah city in Iraq. The selected site was compared with the current landfill site in the city to explain if the old conforms criteria or not. The results of the study showed that the GIS with MCDA presents a good solution to select the best site for a landfill and is a good alternative instead of using the classical method. GIS and MCDA present a scientific analysis of all the expected effects of the new landfill by giving different weights for each criterion used in the study. These weights are according to the sensitivity and the impact of each criterion.

Keywords

Multi criteria Decision Analysis MCDA, Geographic Information System GIS, landfill site selection.

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1. Introduction

Waste management has become a global problem, due to accelerated process of urbanization and industrialization, population growth, standard of living improvement and fast economic development in most cities of developing countries. Solid waste management is a complex process involving the incorporation of much geography, environmental, geology and urban information from different disciplines with many parties either responsible or affected by the results **(Athena and Hassan 2015).** Solid waste management is a complex process involving the incorporation of much information such as geography, environmental, geology and urban information from different disciplines with many parties either responsible or affected by the results **(Ravindraet al., 2014).** In the present time, many innovative solutions associated with the control of generation, handling, storage collection, transfer, transportation, processing, and disposal of solid wastes applied to protect the public health and the environment. **(Debishree et al., 2014).** Basic goal to select good landfill site is to minimize the landfill gases generated due to the decomposition of organic waste, which contributes greenhouse gases, emitted into the atmosphere. It is also lead to the transmission of diseases and the impact on public health and the environment responsible for causing landfill fires, and explosions if trapped in buildings **(Sharholy et al., 2007).** GIS have the capability to handle and integrate the necessary economic, environmental, social, technical, and political factors and constraints **(Al-anbari et al., 2014).** Furthermore, many of the attributes involved in the process of decision making for the selection of sanitary landfill sites have a spatial dimension, which in the last few years has motivated the predominance of geographical approaches that allow for the integration of multiple attributes using geographic information systems **(Al-Ansari et al ., 2014)**. In order to determine landfill site that is good for the inhabitants and the environment several criteria (e.g. as Urban centers, Land use, Airports, Railways, Roads, Slope, Streams, River, Industrial areas, Heritage site, Oil pipes) were used to select the proper site (**Dimitrios et al ., 2013).**The Multi Criteria Decision Analysis “MCDA” used to measure the relative importance weighting for each criterion used. Multi Criteria Decision Analysis (MCDA) encompasses a set of techniques to support decision-making processes. It provides a framework to integrate multiple opinions and evaluation criteria, to weight them according to their importance, and select the most suitable courses of action documented the increase in use of MCDA in synergy with the capabilities of the geographical information systems (GIS) in the last two decades **(David et al.,2014).**

2. Materials and Methods

2.1 Study Area

Al-Nasiriyah is a city in Iraq located to the east of ThiQar governorate. It is on the Euphrates River about 370 km southeast of Baghdad, near the ruins of the ancient city of Ur. According to the 1987 census, the population was 265,937 people. The population in 2014 was 560,968 **(see Figure 1)**

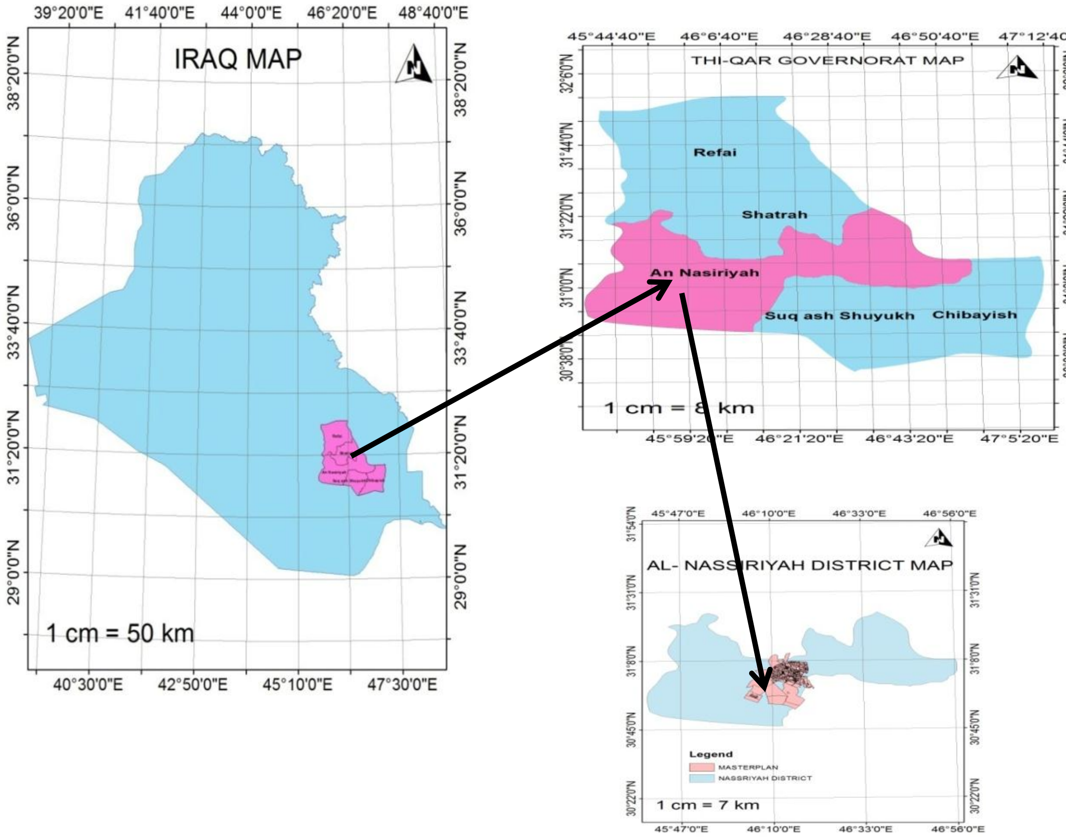


Figure (1) study area Iraq map, ThiQar map and Al-Nasiriyah map

2.2 Methodology

The criteria of landfill site selection in Al-Nasiriyah was identified from department guideline for waste disposal siting (http://www.thiqarpc.gov.iq/) guideline from the department of Environment (http://thiqar.gov.iq/) and Local guidelines of Town and Country Planning (http://www.thiqarpc.gov.iq/). to identify the best landfill site in Al-Nasiriyah city, we used Fourteen criteria. The used criteria were urban centers, Land use, Airports, Oil Pipes, Highways, Railways, network Roads, Slope, Natural Resource, Surface Water Rivers, Industrial areas and Heritage. GIS and MCDA was used to select a new landfill site.

For imaging and analysis of spatial data, ARCGIS 10.1 software from (http://www.esri.com/) is used. Many GIS analysis tools were used in the study such as buffer zoning, Euclidean distance, reclassify and overlay analysis. In order to evaluate the site selection, MODEL BUILDER technique designed to display all used tools and to explain the result of each tool until display final results. MCDA used to measure the relative importance weights for individual evaluation criteria. MCDA dividing the decision problems into smaller understandable parts, analyze each part separately, and then integrate the parts in a logical manner. Assigned weights did by two methods; the first called Simple Additive Weighting method (SAW) and the second called Direct Assigning Method (DAM) .we make a comparison between results to identify the best landfill site.

2.3 Population Growth Rate

ThiQar governorate Population growth rate (**R) = 3.1%, is** calculated from the following equation:

$$R = \ln (Pt/P)\ /t$$

Where: **t** is the number of years.
P is population in1987.
Pt is population in 2015.

Table (1) shows the basic information of population, growth rate, and compacting Density of Iraqi municipal solid waste

Table (1) basic information about Al-Nasiriyah city		
		Data source
Rate of growth	3.1%	Statistics department
Population 2015	577792	Statistics department
Population 2030	900180	Statistics department
Landfill site area until 2030	486685 m^2	Nasiriyah municipality
Compacting density of Iraqi municipal solid waste	0.45	Nasiriyah municipality
Land use map		Nasiriyah municipality

Table (2): Criteria of Landfill site selection

Sr. No	Criteria Name	**Reasons**	**Zoon**
1	Urban	Prevent the negative impact on the environment and its public health	Distance of at least 5 km from urban and 500 m from isolated homes
2	Industrial site	The industrial site may be include Industries cannot tolerate any contamination rate	Distance of at least 2-5 km
3	Heritage site	To protect , preserve heritage of the surrounding areas of the cities heritage candidate to enter within the tourism development	Distance of at least 5 km
4	Airport site	Pollution prevention , aesthetics and tourism development .as well as to prevent birds gathered that negatively affect the landing and departure of aircraft combines	Distance between 7 - 12 km to the airport site boundary
5	Rivers	The selection is far from any water site available to protect it from pollution as the nearby areas of the river can be used in high-value tourism development	Areas distance from the river is always a favorite
6	roads network	Aesthetics and protect road users from pollution	At distance of at least 1000 m
8	Slope	Depressions favorite over the highlands, which could lead to a drift in the seasons of rain and floods	Appropriate slope for constructing a landfill is about 5–15%
9	Natural resources	Stay away from these areas and maintain a clean environment requires select the more convenient landfill distant from this part of the city.	The location of landfill should be at a distance of at least 3-5 km.
10	Railways	Aesthetics , protection from pollution and the effect of the animals that you always want to gather near the landfill	Distance of at least 1000 m
11	Land use	Table 3 shows all details and land use types in Al-Nasiriyah	Undersigned, in boundary, open space and free lands is preferable.
12	Oil pipes	Sensitive area and incombustible.	Distance of at least 1000-1500 m
13	Aspects and wind	Wind of the fact that a way to transfer pollution and toxic gases	In areas where the prevailing winds are moving towards it

2.4 Multi criteria decision analysis (MCDA)

The study aims to apply GIS integrated with MCDA methods to select a landfill site and in the same time evaluate the old landfill site in the city. The old site was selected by conventional expert based methods. In order to achieve this goal, we used 14 different criteria layers produced for Al-Nasiriyah city. MCDA include three steps each step implements in ARCGIS 10.1 as shown in coming details. The first step of MCDA process is assigning the used criteria, which varied from city to another based on geographic and demographic variables as well as urban (Jia Pei Ch. 2014). Table (2) shows all criteria that were used in Al-Nasiriyah city case study.

The second step in MCDA process is assigning weights of each criterion (layer) introduced in the appropriate decision-making process for the landfill site selection. (Sharifi et al., 2009). In this study, two methods namely, **Direct Assigning Method (DAM)** and **Simple Additive Weighting (SAW)** are used.

Direct assigning method (DAM) is a research method to determine the impact of natural and artificial criteria on the final analysis. This method depending on dividing used layers into two types natural and artificial regardless of their number.

- The first weighting: give 66% of the total weight for one type and 34% given to another.
- The second weighting: reflects the weights.

The purpose of the application of this method is to know the impact of natural and artificial layers on the selection **(Table 3a, 3b).**

Table (3a):first weighting process

Data layer	Weight
Primary Roads	3.4
Secondary roads	3.4
Highway	3.4
Bypass way	3.4
Industrial	3.4
Natural resources	16.5
Heritage	16.5
Airport	3.4
Land use	3.4
Railway	3.4
Oil pipes	3.4
Urban	3.4
Slope	16.5
Rivers	16.5

Table (3b):second weighting process

Data layer	Weight
Primary Roads	6.6
Secondary roads	6.6
Highway	6.6
Bypass way	6.6
Industrial	6.6
Natural resources	8.5
Heritage	8.5
Airport	6.6
Land use	6.6
Railway	6.6
Oil pipes	6.6
Urban	6.6
Slope	8.5
Rivers	8.5

While **Simple Additive Weighting method (SAW)** is the simplest and most commonly used multi-attribute decision technique based on the weighted. The decision maker directly assigns the weights of ‘relative importance’ to each thematic map layer. A total score obtained for each alternative by multiplying the importance weight assigned for each attribute by the scaled value given to the alternative of that attribute, and summing the products over the attributes. When the overall scores calculated for all of the alternatives, the alternative with the highest score is selected **(Irfanet al., 2012).** The decision rule evaluates each alternative, Ai, by the following equation:

$$A_i = \sum W_j * X_{ij}$$

Where: Xij is the score of the i-th alternative with respect to the j-th attribute, and the weight wj is the normalized weight. The weights represent the relative importance of the different layers **(table 4).**

Table (4): The criterion weights (Wj) defined by SAW method.

Data layer	Weight	Weight class
Urban	**13**	**High**
Land use	**13**	**High**
Heritage	**11**	**High**
Natural resources	**11**	**High**
Rivers	**9**	**Middle**
Airport	**8**	**Middle**
Oil pipes	**5**	**Low**
Industrial	**4**	**Low**
Highways	**5**	**Low**
Railway	**5**	**Low**
Bypass ways	**4**	**Low**
Primary roads	**4**	**Low**
Secondary roads	**4**	**Low**
Slope	**4**	**Low**

The third step includes intersection process for all layers in accordance to assigned weights to get the appropriate sites for a landfill in the city. **(Nashwan S. 2014)**

3. Analysis Techniques

In this study we used many tools and analysis techniques to implements MCDA and to select the best landfill site the process passed in the following analysis **(Chattopadhyay et al., 2009).**

3.1Euclidean Distance Analysis

The Euclidean distance tools describe each cell's relationship to a source or a set of sources based on the straight-line distance. The outcome of this tool is raster map include specific number of areas classes depend on its distance from known feature. Euclidean distance calculated from the center of the source cell to the center of each of the surrounding cells. True Euclidean distance calculated in each of the distance tools. Conceptually, the Euclidean algorithm works as follows: for each cell, the distance to each source cell is determined by calculating the hypoten use with x_max and y_max as the other two legs of the triangle. This calculation derives the true Euclidean distance, rather than the cell distance. The shortest distance to a source is determined, and if it is less than the specified maximum distance, the value assigned to the cell location on the output raster. After entering all the layers used to select the best location for the establishment a landfill in the study area in Euclidean distance analysis we will get the maps shown in **figure (2).** Each raster map divided into many areas depends on distance. The use of yellow color to encode the nearby area and the blue color-coded remote region.

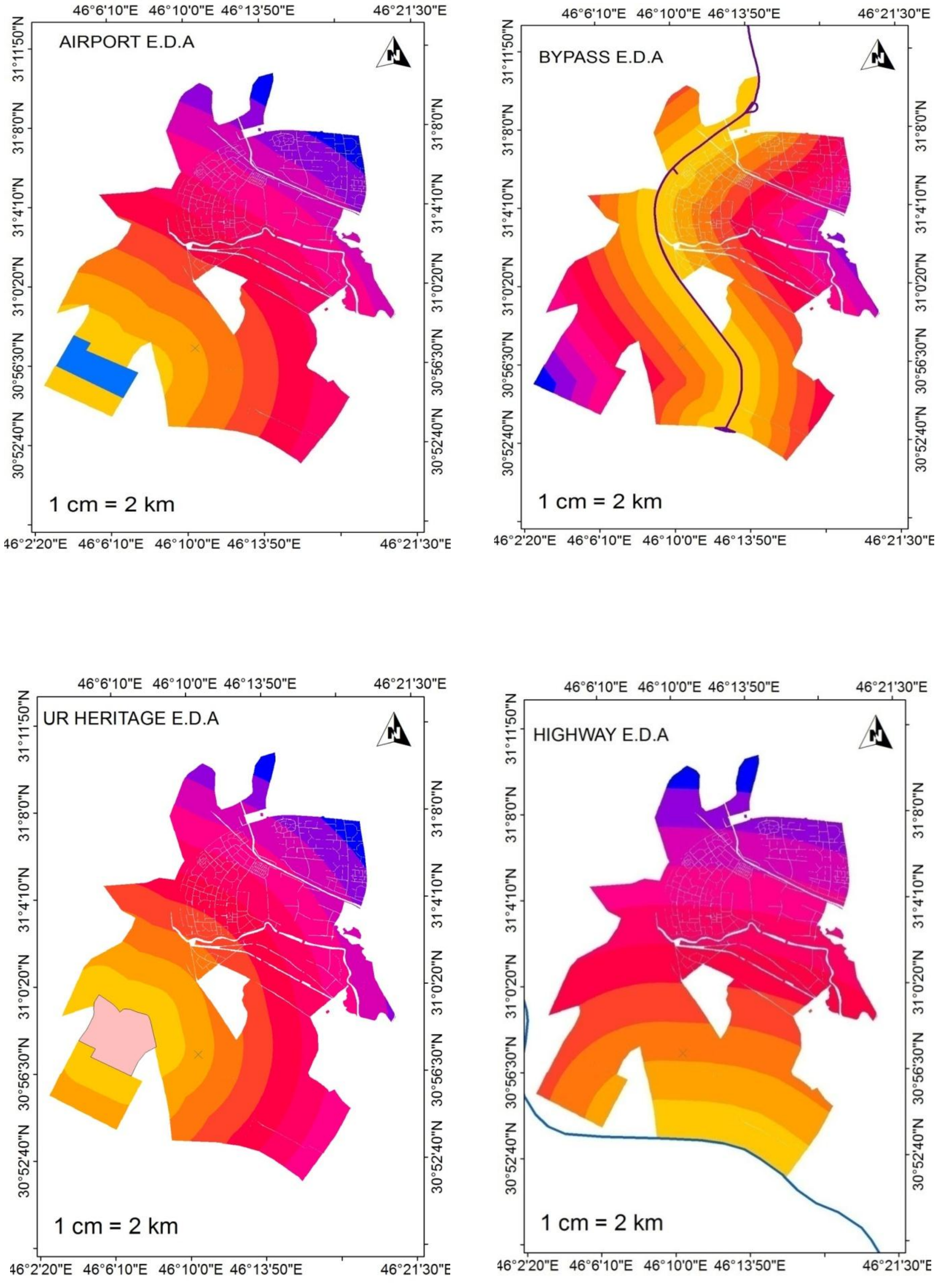


Figure (2. a) Euclidean distance analysis

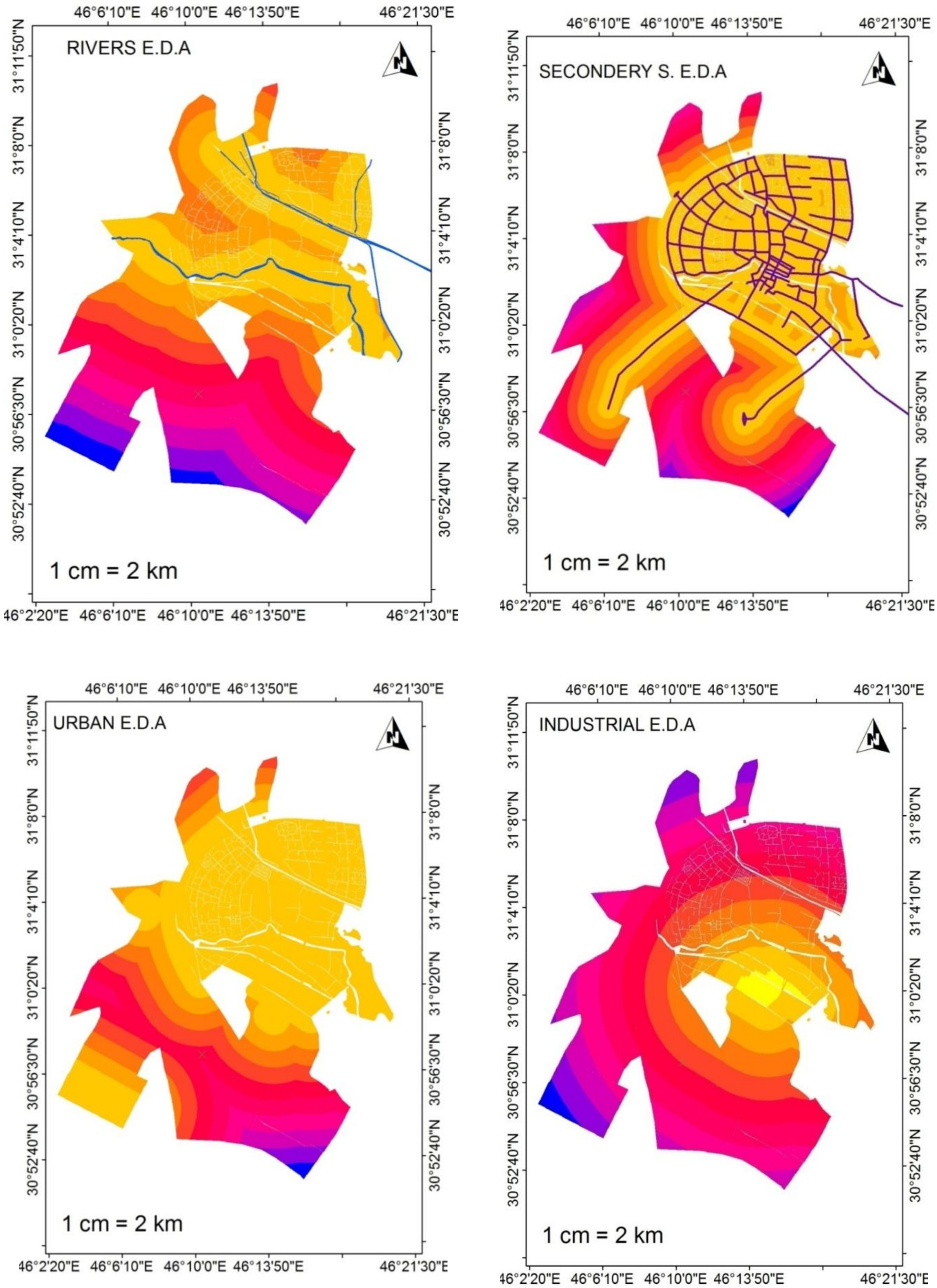


Figure (2. b) Euclidean distance analysis

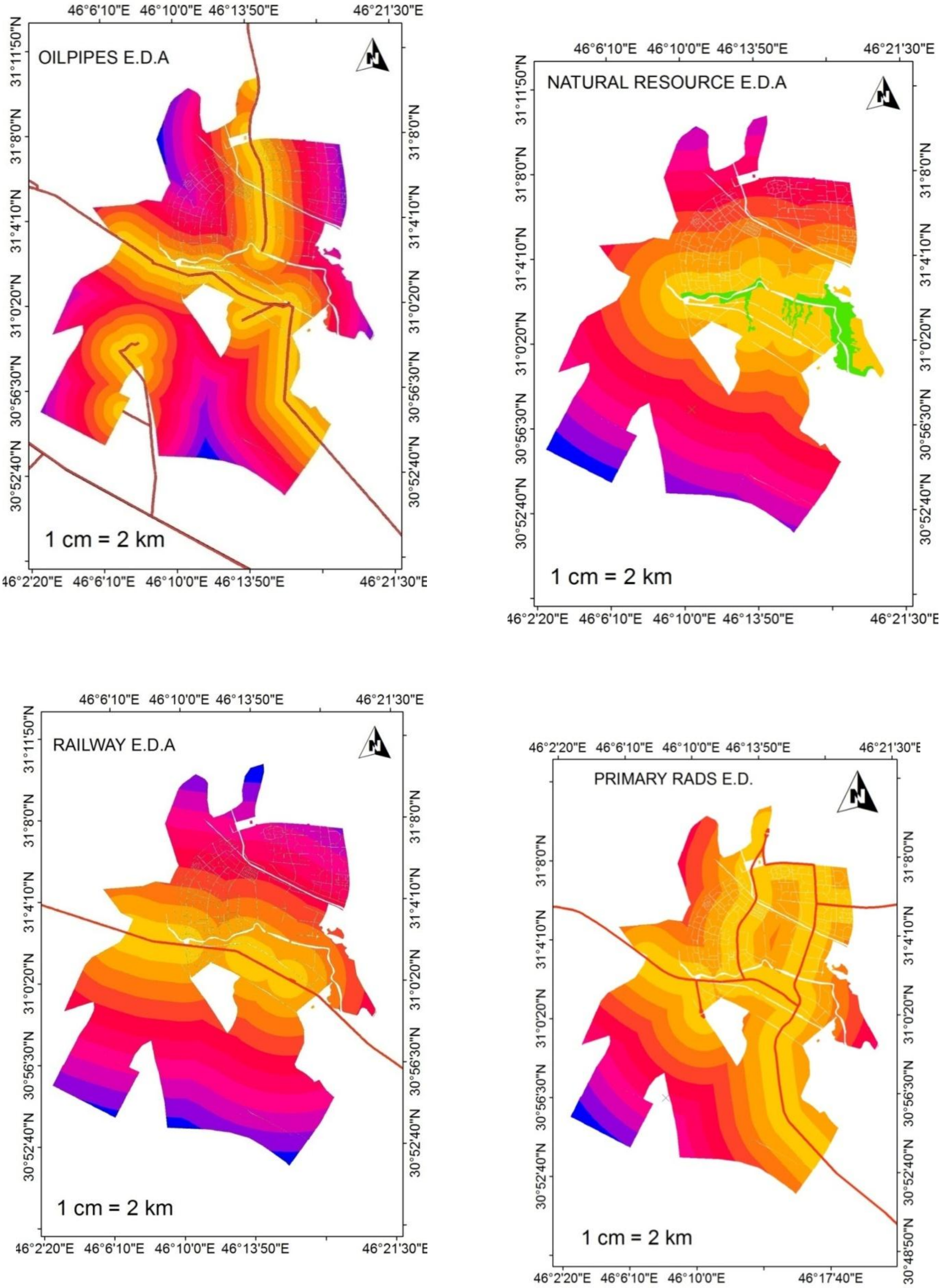


Figure (2. c) Euclidean distance analysis

3.2 Reclassify Analysis

Slices or reclassifies the range of values of the input cells into zones of equal interval, equal area, or by natural breaks. Slice works best on data that is normally distributed. When using input raster data that is skewed the output, result may not contain all of the classes that you had expected or specified. **Figure (3)** explains the output of this tool for each layer used

3.3 Surface Analysis

Spatial analysis tool used to convert DEM map to SLOPE raster map to indicate situation of study area. A slope used as criterion as shown in Table (2).

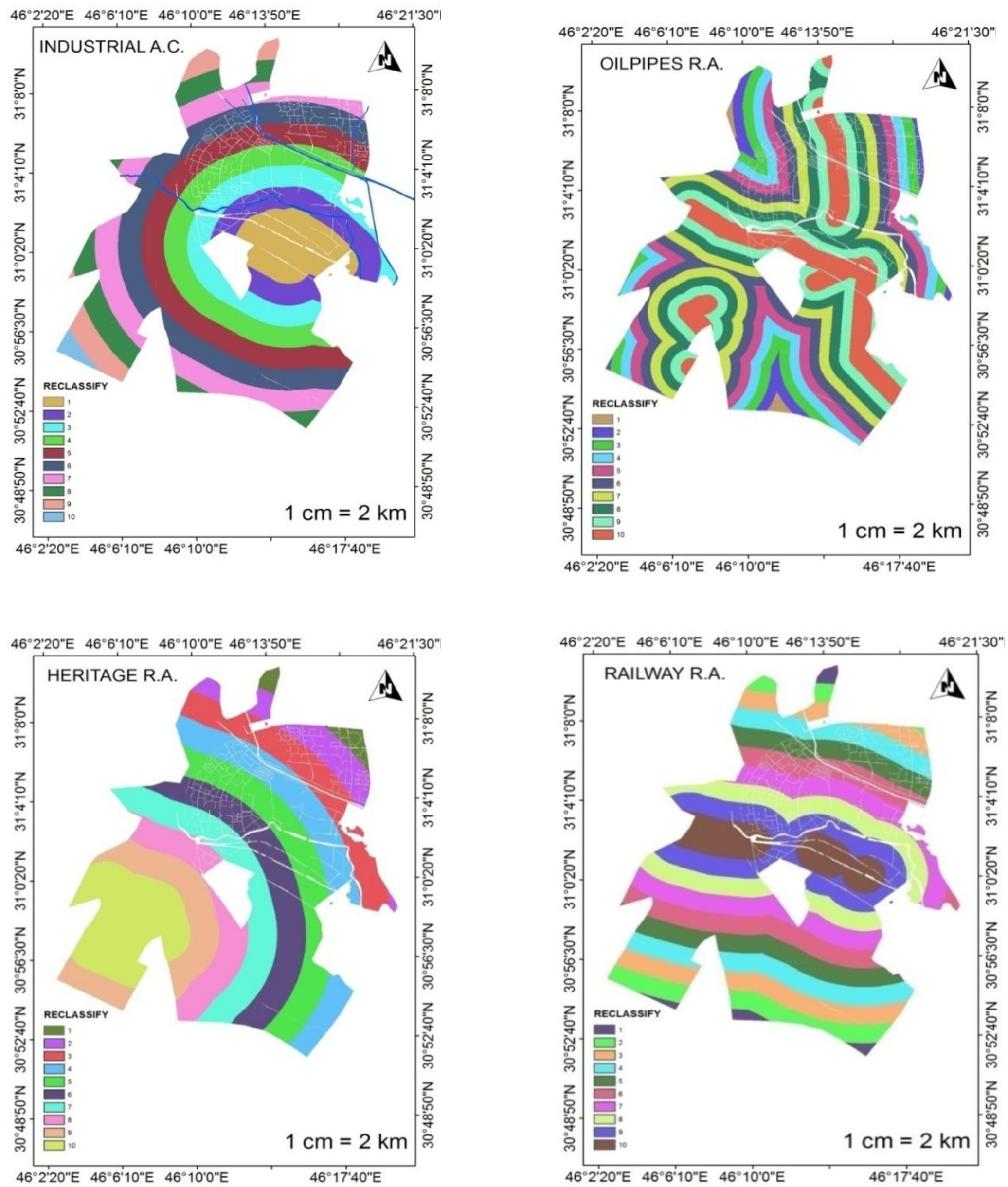


Figure (3.a): Reclassify analyses.

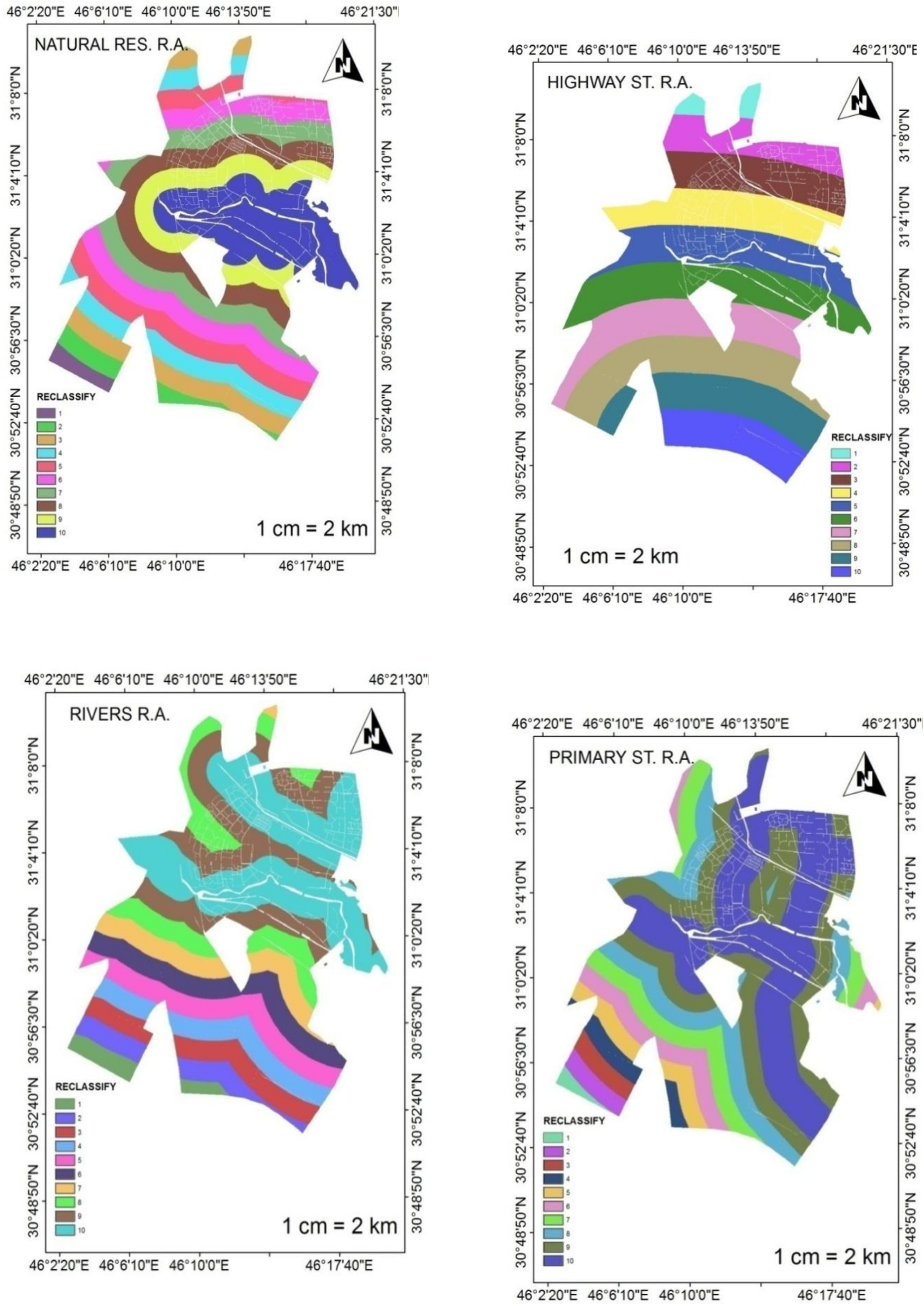


Figure (3.b) Reclassify analyses.

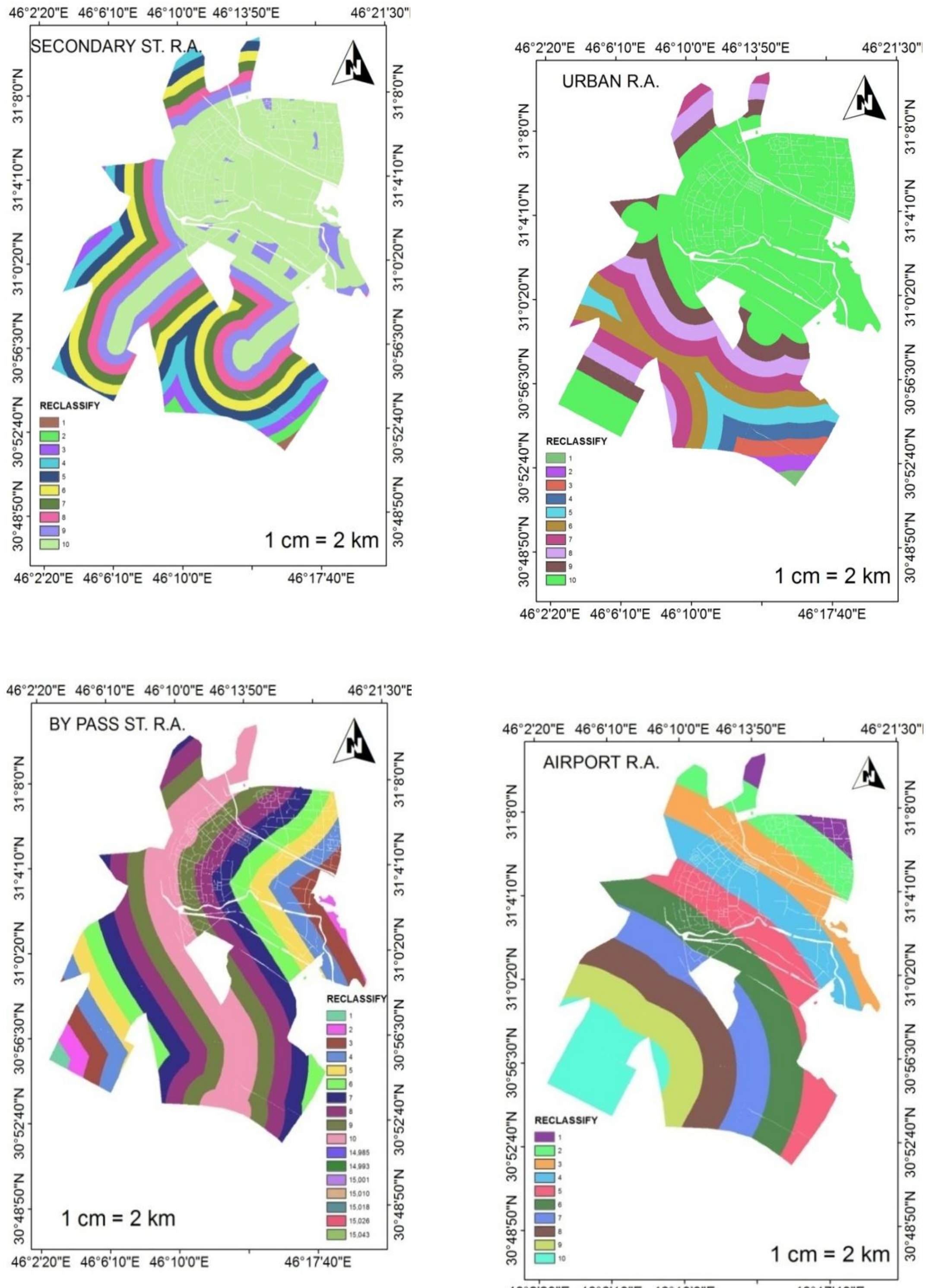


Figure (3.c) Reclassify analyses.

3.4 Weighted overlay analysis

Spatial analyst tool is used to overlays several raster using a common measurement scale and weights each according to its importance. F**igure (4)** explains the illustration of this analysis

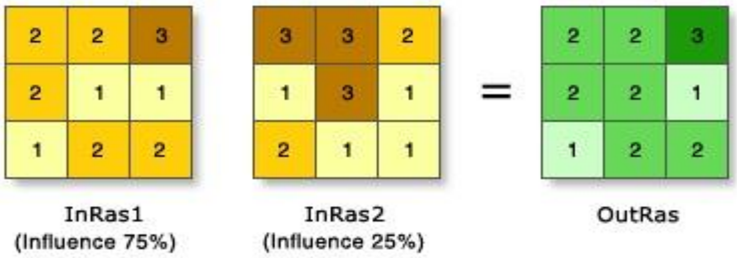


Figure (4) overlay analysis illustration.

3.5 Model builder technique

Through this technique, which collects all analyzes used in a special environment. As shown in (figure 5) we can get the result on the outcome of the study. After applying all these analyzes on the layers used to determine the best location for the establishment of a landfill we get the result of the analysis since we have used three groups of weights, so we will get three final maps. In **(figure 5**) , Blue ellipse represents layers (criteria) used in study, E.D is Euclidean distance analysis stage, R.C is reclassify analysis stage and finally, the outcome of these stages were used as inputs for overlay analysis stage which give us the result

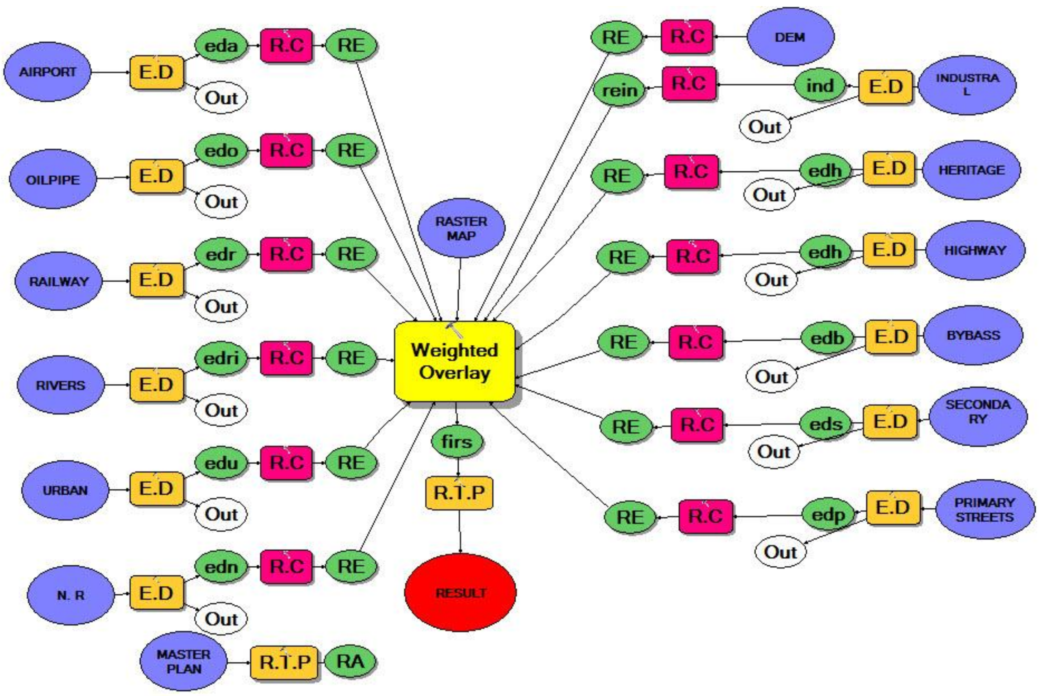


Figure (5) Model builder technique

4. Results

4.1 First and second map

These maps explain the suitable and unsuitable areas for landfill use after applying DAM method. Each pixel in study area raster map have a degree from 1-10 with special color varies from dark red to dark green as shown in (Figure 6, 7), (Figure 8a, 8b) and (Figure 9a, 9b) which explain ARCGIS10.1 statistics of the maps. (Table 6 and Table 7) explain each degree counts

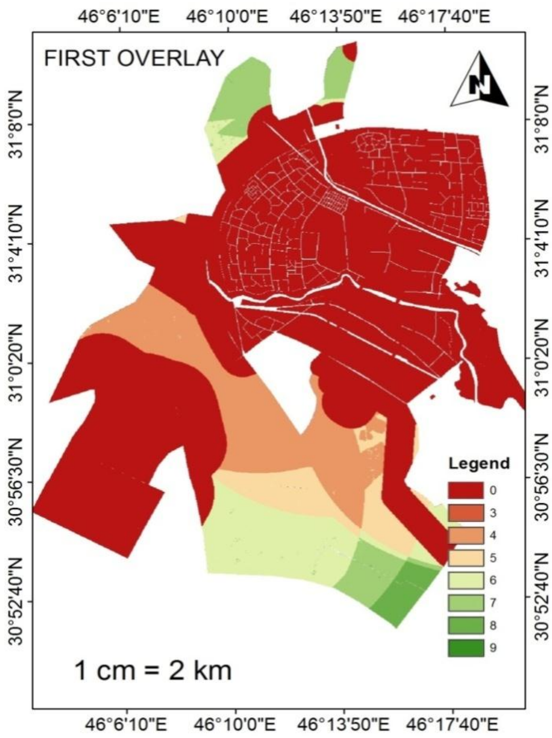


Figure (6) first analysis map

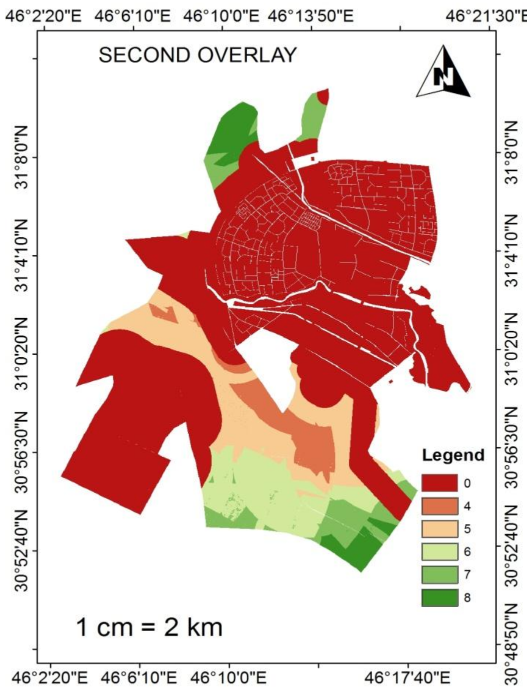


Figure (7) second analysis map

Table (5) First map counts.

Value	Counts	Suitable
0	381477	No
3	3	No
4	66302	Middle
5	25601	Yes
6	46164	Yes
7	25974	Yes
8	7972	Yes
9	2	Yes

Table (6) Second map counts.

Value	Counts	Suitable
0	381477	No
4	22630	Middle
5	59325	Yes
6	44435	Yes
7	26627	Yes
8	19001	Yes

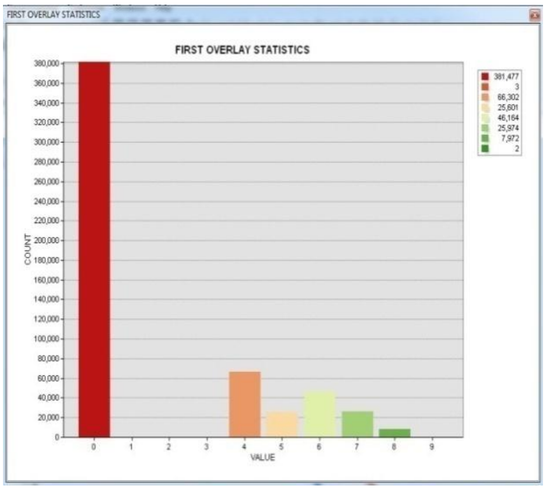


Figure (8-a): first overlay statistics

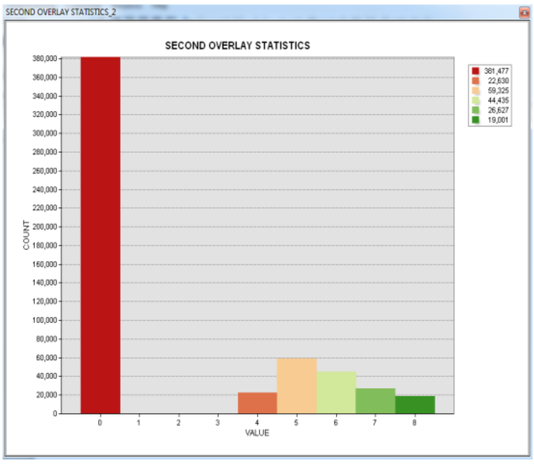


Figure (9-a): second overlay statistics

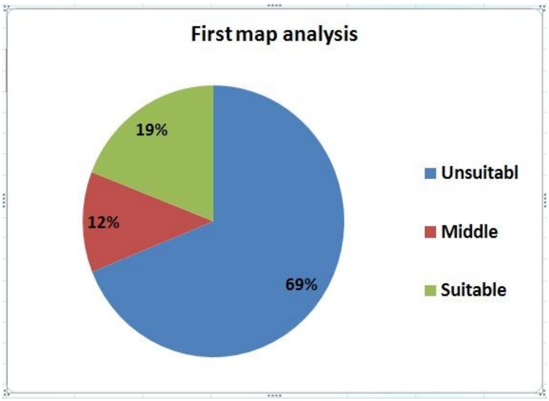


Figure (8-b): first suitability analysis

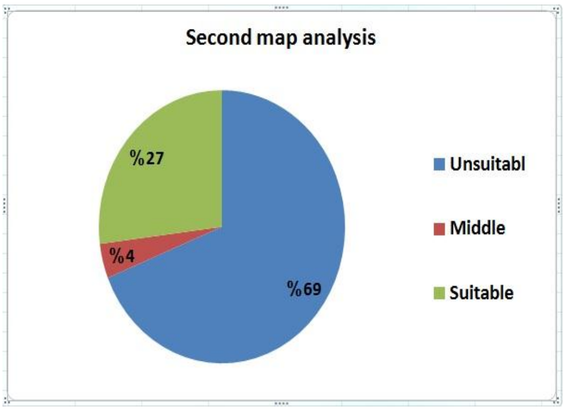


Figure (9-b): second suitability analysis

4.2 Third map

This map explain the suitable and unsuitable areas for lanfill use after applying SAWmethod . Each pixel in study area raster map have a degree from 1-10 with special color varies from dark red to dark green as shown in **figure (10). Figures (11-a, 11-b)** explain ARCGIS statistics of the map**. Table (8)** explains each degree counts.

Table (7): Third map counts.

Value	Counts	Suitable
0	361158	No
4	4331	Middle
5	79480	Yes
6	47275	Yes
7	38648	Yes
8	22522	Yes
9	45	Yes

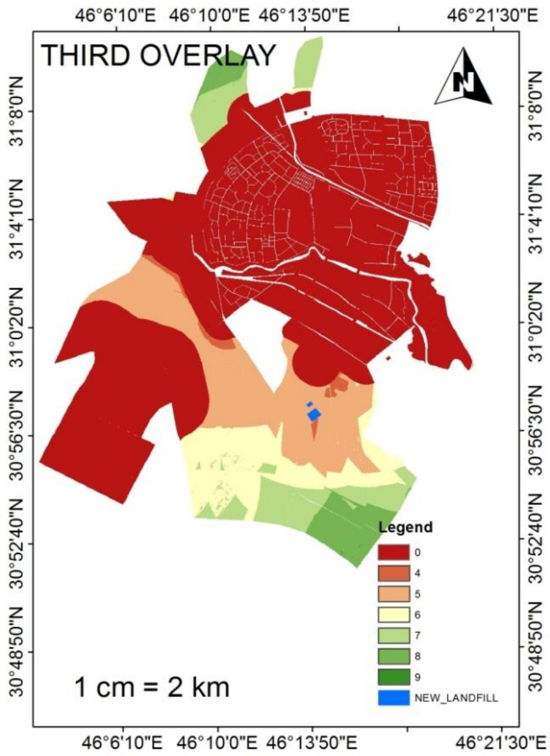
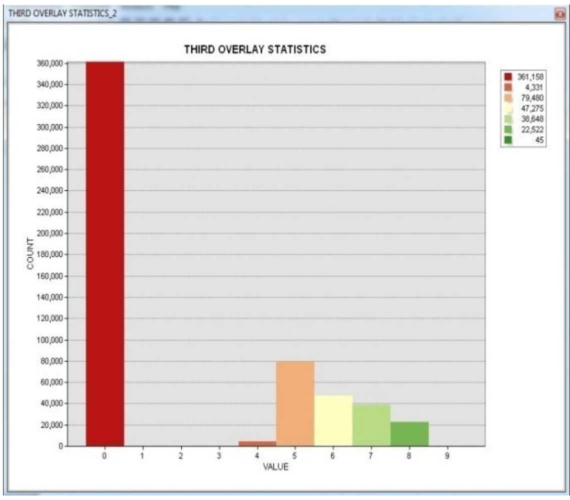


Figure (10): third map analysis



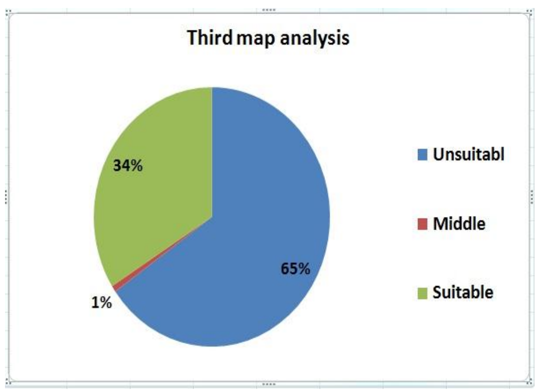


Figure (1-a): third overlay statistic

Figure (11-b): third suitability analysis

5. Discussion and conclusions

Other criteria must study to select landfill sites such as the prevailing wind in the study area and the anticipated uses of not designed zones. All these criteria are considered additional factors affect the selection of new landfill site. Additional criteria lead to exclusion other areas. Soil test and an integrated analysis of its properties are made on areas that have been selected and met the standard selection criteria. Through this test the best site would be chosen, which has a kind of soil that allows for the lowest level of filtering preventing polluting groundwater or surface water bodies near ulcer formed and deposited extinction of organic waste buried in a landfill. Any Increasing in restrictions and criteria lead to select the best site if those restrictions and criteria applied properly and scientifically. The used methods in the study led to good results and appropriate sites chosen. Finally the final decision is subject to the field check and technical assessment to get the best landfill site. The financial, economic and administrative constraints affect on the select site operation. Also, the accuracy of the information, layers, and maps used in the analysis affect on the choice. Also, the criteria used, constraints, weights assigning and analysis methods have clear influential on the final selection. The results of this study show a comparison between traditional methods for the assigning weights with the methods depending on scientific foundations. Any changing in any weight value leads to a change in the analysis outputs and the selected sites. As it is clear from this study that there is a clear difference between direct weights assigning methods such as DAM method and those that depend on scientific equations such as SAW, but all these methods subject to the vision of planner who assigned these weights. Results also showed that the GIS and MCDA give good solutions to the appropriate spatial planning analysis for the landfill site selection process better than the conventional solutions which always depending on personal diligent.

References

[1] Al-anbari, Nadhir and Hadeal (2014). GIS and Multi criteria Decision Analysis for Landfill Site Selection in Al-Hashimyah Qadaa. Natural science, 6, 282-304

[2] Al-Ansari, N.A., Knutsson, S. and Almuqdadi, K. (2014). Engineering Solution for Radioactive Waste in Iraq. Journal of Advanced Science and Engineering Research, 4, 18-36.

[3] Athena and Hassan (2015). Municipal solid waste landfill site selection using analytic hierarchy process method for Tafresh town. Journal of Biodiversity and Environmental Sciences (JBES), Vol. 6, No. 1, p. 9-21.

[4] Chattopadhyay, S., Dutta, A., and Ray, S., 2009. Municipal solid waste management inKolkata, India a review. Waste Management, 29 (4), 14491458.

[5] David, Rafael , and Francesco (2014). Integrating Stakeholder Preferences and GIS-Based MCDA Identify Forest Landscape Restoration Priorities. Sustainability journal, 6, 935-951.

[6] DebishreeKh. and S. Samadder(2014). Municipal solid waste management using GIS aided methods: A mini review. Waste Management & Research, 32(11), 1049–1062.

[7] Dimitrios, Alexakis, and Sarris. (2013).Integrated GIS and remote sensing analysis for landfill sitting in Western Crete, Greece. Environ Earth Sci Springer, DOI. 10.1007.

[8] ESRI company website at http://www.esri.com.

[9] Irfan ,Lutfi,basak and Vedat D. (2012).Municipal solid waste landfill site selection for the city of Sanliurfa-Turkey: an example using MCDA integrated with GIS.

International journal of digital earth,5,2,147-164.

[10] Jiapei Ch. (2014) GIS-based MCDA for land use suitability assessment in City of Regina, Environmental Systems Research(springeropen journal), 3:13.

[11] Nashwan Shukri.(2014). Suitability model based on GIS and MCDA for spatial distribution of settlements in different geographic environments, European Scientific Journal June /SPECIAL/ edition vol.2.

[12] Official Site of the province of Thi Qar at: (www.thiqar.gov.iq).

[13] Ravindra, Nitin and Bhalachandra (2014) Site Suitability for Urban Solid Waste Disposal Using Geoinformatics: A Case Study of Pune Municipal Corporation, Maharashtra, India, Cloud Publications journal, Volume 3, Issue 1, pp. 769-783.

[14] Sharholy M, Ahmad K, Vaishya RC, et al. (2007). Municipal solid waste characteristics and management in Allahabad, India. Waste Manag v27 (4): 490–496.

[15] Sharifi M, Hadidi M Vessali E, Mosstafakhani P, Taheri K, Shahoie S.&Kh. M.2009. “Integrating MCDA For a GIS Based Hazardous Waste Landfill Siting In Kurdistan Province, Western Iran”. Journal of Waste Management. Vol. 29.No. 10, p. 2740- 2758.