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Identifying Appropriate Zones for Disposal of Urban Wastes Using Spatial-Place Analysis (GIS-TOPSIS Model) Case Study: Birjand County

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Abstract. Locating and finding appropriate place for waste disposal is one of the most important parts of the urban waste management system. Healthy burial of urban wastes needs to basic information and precise planning like any other engineering project. Selection of several factors has caused multiplicity of data layers and efforts to find a suitable solution for analysis large numbers of data layers and getting the correct result leads decision-makers unconsciously to use of a model and a method that is in high level in terms of speed and ease of doing in addition to having high accuracy. This study is functional and analytical-descriptive in terms of nature. Effective criteria were selected first in research process and then experts and professors of urban development and urban planning and biologists for determining the importance of criteria completed some questionnaires. Then criteria were valued in the area and fit maps were prepared using multiple criteria decision AHP model in Expert choice software and TOPSIS model. The results of studies showed that southeast and northwest parts of city are the most suitable places for burying waste and creating centers for waste disposal.

Keywords: locating, urban wastes, TOPSIS, AHP, Birjand

1. INTRODUCTION

The city is a series of complex phenomena that it's all components are in an organized way in full contact with each other so that creating disorder in each component of this set causes failure in the whole system. Human effect environment and are influenced by its results and consequences; this expresses the mutual relationship between human beings and environment (Meshkini et al, 2008). Urban waste is one of the city's components that lack of attention to it can affect prospect of urban units. The increasing growth of Iran's urban population along with creating new population centers, problems of policy issues, evaluation of performances and various urban activities based on comprehensive, massive and national program (spatial planning) and discharge continuation of various wastes and sewers to natural environment are crisis factors that have created variety risks and losses for environment, quality of wellness and human's health specially urban people. The management of urban wastes (solid urban, industrial, and sanitary waste, etc.) is one of the most important environmental problems and issues, which major cities of country are faced with it and irregular increasing of population in cities has caused producing various types of urban wastes. As a result, today, the quality of disposal and annihilation of urban waste has turned to a concern in urban environment (Abdoli, 2000). Also this research is focused on the first step of the last stage of waste management cycle i.e. finding a place for wastes burial; besides it has tried to propose optimum places to waste disposal using TOPSIS and GIS models in geographical scope of Birjand that are matched with global standards of burial locations.

2. BACKGROUND OF STUDY

There are several studies related to the locating of wastes disposal especially urban wastes in the form of various methods and models. Yet, TOPSIS method has been used rarely among conducted studies. Siddiqui (1999) has presented hierarchical analysis method by GIS for locating wastes burial. He has examined four criteria include closeness to the city, land use type, soil limitation

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(include slope, tissue, impermeability, bedrock depth) and depth of groundwater in this study for locating wastes disposal in Cleveland area in Oklahoma and has calculated weights by binary comparison method.

Vastava and Nathawat (2003) researched around the city of Rancy using geographical information system and remote sensing and considered some criteria like geology, faults, slope of land, type of main stone, soil, surface water and groundwater depth, urban centers, existing communication network, distance from the airport and etc. Then, they have selected 5 separate locations in different sizes to bury waste of this city with 800,000 population using these systems and weighting indices by paired comparisons. William Hendricks and David Biokli (1992) identified a suitable place for healthy burial of wastes of high tide region in Vermont State of America considering 6 variables include soil type, depth of main stone, land use, distance from surface water, groundwater depth and height levels. Omar Aljarrah and Hani Abu-Qeddais (2005) have attempted to locating the burial place of Oman wastes by the help of 15 data layers. Somati and Chinmoi soccer (2007) have selected the most suitable place for urban solid wastes of Keramandal in India using fourteen data layers. These researchers have paid attention to factors such as: slope direction, wind direction, urban equipments, natural ecology and ancient monuments in addition to variables that have been named. In case of Iran, Nilchian (2002), Pourahmad et al (2006) have proceed a same work in some cities like Tehran and Babolsar using such variables along with other information such as legal scope of city, ownership of land, the value of land and effect on urban landscape. Also other researchers using the same variables and with the help of modern tools like GIS have found suitable place for healthy burying of wastes in various cities of Iran like: Tabriz, Sanandaj, Razan and Damavand. Among those reserachers, it can be referred to Samadi et al (2007), Amini (2006), Nayerabadi et al (2008), Farhoodi et al (2003), Monavari et al (2006).

Aim and Method of Research

The overall goal of this research is to identify appropriate zones for disposal of urban waste of Birjand County that geographic information system (GIS) and multiple criteria model (TOPSIS) are used in this regard. The method of study in this research is descriptive-analytical. Documents and a library reviews are used for gathering required data. Since the object of this research is to identify and determine the appropriate zones for urban wastes burial, effective criteria of this field were selected at the beginning and then, some questionnaires were completed by experts in the field of urban development and urban planning, sociologists and expert biologists to determine the importance of criteria. Next, the weight of influencing criteria was determined in locating using AHP multiple criteria decision model in Expert choice software. Then, using TOPSIS model in ARC GIS software environment, the criteria were valued in considered scope and maps fitted with criteria were prepared and finally, a combined map of criteria were derived that represents the best zones for burial of urban wastes in this range.

The Brief Introduction of Birjand County

Birjand as the capital of South Khorasan province has a special economic, social, cultural, political and environmental position in the east of country. This county has a total area of 34893 km^2 and is located in 59 ° and 13 minutes of longitude and 32° and 53 minutes of latitude. Birjand has a population of 259506 people according to census of 2012 (Statistical Center of Iran, 2012). The height of this county from sea level is equal to 1480 m and its distance to Tehran, Mashhad, Zahedan is 486, 458, 120 km respectively.

Figure 1. The studied area.

Theoretical Foundations of Research

Growing waste management is one of the major problems that are observed today in planning and managing most cities of our country. Irregular expansion of cities and consequently irregular increasing of urban population in the country, especially in current years, have increased consumption more than before and as a result, has led to irregular increasing of various wastes production in urban areas (Majlesi et al , 1992). Lack of attention to environmental issues in many cities of country as a hidden enemy treats the environment of burial places. Perhaps in not too distant past, limited population of cities and low volume of produced waste by citizens, urban planning authorities suddenly faced with a new problem of the elimination of wastes. Nowadays, waste management issue has turned to an inevitable necessity in the country's cities and if it doesn’t planned exactly and quickly, it will apply its non-repairable effects on it’s around natural and human environment. A coherent and precise program of waste management includes six main elements of storage in place, collection, transport, processing, recycling and burial from the point of production to the final disposal location that each of these stages requires precise planning and designing. (Abdoli, 2009) Although in many countries, determining a location for disposal of wastes is difficult and often it is because of people’s no acceptance for construction waste burial place in the vicinity of their living place (Yaqout et al,2002), some areas are faced with limitations such as high density of population, specific geological structures, and high level of groundwater and etc that aren’t suitable for burial place in terms of choosing land. Meanwhile some wastes such as wastes of building and ashes resulting from waste burning aren’t recyclable or disposable in other methods due to special considerations; so they should be buried in a proper place. Anyhow and with regard to all these considerations, final burial of wastes is inevitable in final step of waste management process that an appropriate place should be considered for it. The problem of choosing a location of waste disposal has always troubled human. Selecting unsuitable place for burial contaminates water, soil and air of area (the Environmental Protection Agency, 2001). The issue of urban waste management will be complex and problematic when its negative and detrimental effects are examined in relation with other existing urban systems and their environmental system. One of the most important stages of studies parallel to designing the place of waste burial is locating and finding appropriate location for waste burial (Abdoli, 2000). Waste materials and generated residuum were evacuated in valleys, rivers and natural pits around the towns for a long time with no specific criterion. This action over the years depleted the resources of soil, surface water and underground aquifers. In addition, accumulation of insects, birds, and farm and wild animals in garbage dumping centers made a field for burst of various diseases (Abdoli, 2001). Several criteria and indicators are provided to select the appropriate location for burial of wastes that each of them raises limitations and special conditions for proper locating. In other words, each of parameters have been made based on one of scientific fields; so that locating studies have found a multidimensional identity and interdisciplinary structure (Shamsaei Fard, 2003, p12). The most important of these criteria is geomorphologic factors (bedrock, unstable lands, soil, fault, slope, geohydrology and etc). In addition to geomorphologic criteria, various factors like depth of underground water, status of climate, environmental factors, land use, network of roads, etc have also interfered in this field that they are useful in selecting the location of waste burial (Asghari Moghadam, 1999). The final goal of locating is access to the most convenient place that has the least harmful effects for environment and surrounding natural resources, and economically has the lowest-cost and the best features in terms of engineering (Ghazban, 2006).

Used Criteria in Locating

Various criteria are used in locating waste burial centers. Access to communication networks is one of the most important of these criteria. In spatial planning and urban network layout, communication networks are considered as important levers. The structure of road network is associated with areas' activities and has mutual effects. Improving this structure has caused the development of areas and resulted in economic and social development and diversity of activities and has prepared conditions for spreading people and activities to the other parts. Communication network has significant importance in urban waste disposal. The existence of an appropriate and strong communication network will facilitate transferring wastes to disposal centers and will prevent of problems' occurrence to some extent. In addition, rivers are not only important for human, but also are vital to survive everything in everywhere. Rivers are important not only for fun but also to provide drinking water, agricultural irrigation, power generation, river transportation (like Karun River), providing food and etc. Therefore, paying attention to rivers has high importance. In the case of waste disposal, we must do our best to define these places far from surface water and especially rivers, to not provide conditions for their pollution. Criteria that have been considered in locating in this study are: the proper distance from urban areas, proper distance from rural areas, proper distance from mines, proper distance from areas with forest cover, proper distance from rivers, around areas without vegetation, around salina areas, access to communication network, suitable slope, proper distance from farm crops.

TOPSIS Method

Generally, in TOPSIS method, the discussed issue can be considered as a geometric system includes m point in an n dimension space that each selected factor must be in lowest distance with positive ideal factor and in most distance with negative ideal factor (factor with the least negative effect). Utilizing this method requires passing eight steps as follows (Zarei et al, 2011: p 4; & Yoon, 1981, Hwang; Wang & Chang, 2007: p 871; Opricovic & Tzeng, 2004: p 448):

The first step: Building data matrix according to "m" desired criteria or indicator and "n" known option;

$$A_{ij} = \begin{pmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \cdot & \cdot & \cdots & \cdot \\ \cdot & \cdot & \cdots & \cdot \\ \cdot & \cdot & \cdots & \cdot \\ a_{m1} & a_{m2} & \cdots & a_{mn} \end{pmatrix}$$

Second step: Using relation (1) for data standardization and formation of standard matrix (R_{ij}):

$$R_{ij} = \begin{pmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ . & . & \cdots & . \\ . & . & \cdots & . \\ . & . & \cdots & . \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{pmatrix}$$

$$R_{ij} = \frac{a_{ij}}{\sqrt{\sum_{i=1}^{m} a_{ij}^2}} \quad (1)$$

Third step: weighting indicators (W_i) by equations (2) & (3) and building weight matrices (W_{n*n}) that is a diametric matrix (in this regard, indices with further importance will gain more weight);

$$w_i = \frac{r_i}{\sum_{i=1}^{n} r_i} \quad (2)$$

$$\sum_{i=1}^{n} w_i = 1 \quad (3)$$

Fourth step: Making weight with no scale and formation of matrix (V_{ij}) with the help of equation (4);

$$V_{ij} = R_{ij}.W_{n\times n} \qquad V_{ij} = \begin{bmatrix} w_1r_{11} & w_2r_{12} & \cdots & w_nr_{1n} \\ w_1r_{21} & w_2r_{22} & \cdots & w_nr_{2n} \\ . & & & . \\ . & & & . \\ . & & & . \\ w_1r_{m1} & w_2r_{m2} & \cdots & w_nr_{mn} \end{bmatrix} \quad (4)$$

Fifth step: Determination of maximum effect A^+ (The highest level of negative effects in any index) and minimum affect A^- (The lowest level of negative effects in any index) by equations (5) and (6) respectively;

$$A^- = \{(\max v_{ij} | j \in J), (\min v_{ij} | j \in J') \; i = 1,2,\dots,m\} = \{v_1^-, v_2^-, \dots, v_j^-, \dots, v_n^-\} \quad (5)$$

$$A^+ = \{(\max v_{ij} | j \in J), (\min v_{ij} | j \in J') \; i = 1,2,\dots,m\} = \{v_1^+, v_2^+, \dots, v_j^+, \dots, v_n^+\} \quad (6)$$

Sixth step: Calculating the distance value of item i_{th} according to Euclidean norm from maximum and minimum of effect (A^+ and A^-) by equations (7) and (8);

$$d_i^+ = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^+)^2} \; ; (i = 1,2,\dots,m) \quad (7)$$

$$d_i^- = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^-)^2} \; ; (i = 1,2,\dots,m) \quad (8)$$

Seventh step: Determination relative closeness coefficient of item i_{th} (C_i) to maximum of effect (A^+) with the help of the equation (9) where (di^-) is minimum alternative and (di^+) is maximum alternative;

$$C_i = \frac{d_i^-}{(d_i^- + d_i^+)} \; ; (i = 1,2, \dots, n) \quad (9)$$

Eighth step: Ranking the known items based on C_i value, which is between zero and one. $C_i = 1$ represents the highest rank and $C_i = 0$ represents the lowest rank.

Analytical Hierarchy Process (AHP)

Analytical hierarchy process is a flexible, simple and strong method that is used for decision making when opposite decision criteria make the selection between options difficult. This multiple criteria assessment method was primarily proposed by Thomas L. Saaty in 1980 (Abdoli, 2000). This method relies on judgments and consequently it is relative because judgments can be different from one person to another (Abdoli, 2001). Analytical hierarchy process is one of the most comprehensive systems designed for multiple criteria decision making and by definition is as follows: a decision-making method that decisions related to various criteria can be adopted by it. This approach provides the possibility of formulating the issue as a hierarchy and it has also the possibility of considering various quantitative and qualitative criteria in question. First step in analytical hierarchy process is creating a hierarchical structure of reviewed issue in which goals, criteria, options and relation between them are presented. Next four steps in analytical hierarchy process include calculation of significance coefficient of criteria and sub-criteria, calculation of significance coefficient of options, calculation of final score of options and checking logical compatibility of judgments (Abdoli, 2000). Analytical hierarchy process can effectively control both qualitative and quantitative data (Pourtaheri, 2010: 80). Of course, only criteria weighting in Expert choice software is used in this research. Basis of criteria weighting in AHP method is presented in table 1 (Gharagozloo & Barzegar, 2008).

Table 1. Basis of weighting in analytical hierarchy process (AHP).

Score	Definition
1	same preference
3	a little preferred
5	More preferred
7	much more preferred
9	Completely preferred
8,6,4,2	Halfway preferred

Source: (Gharagozloo & Barzegar, 2008)

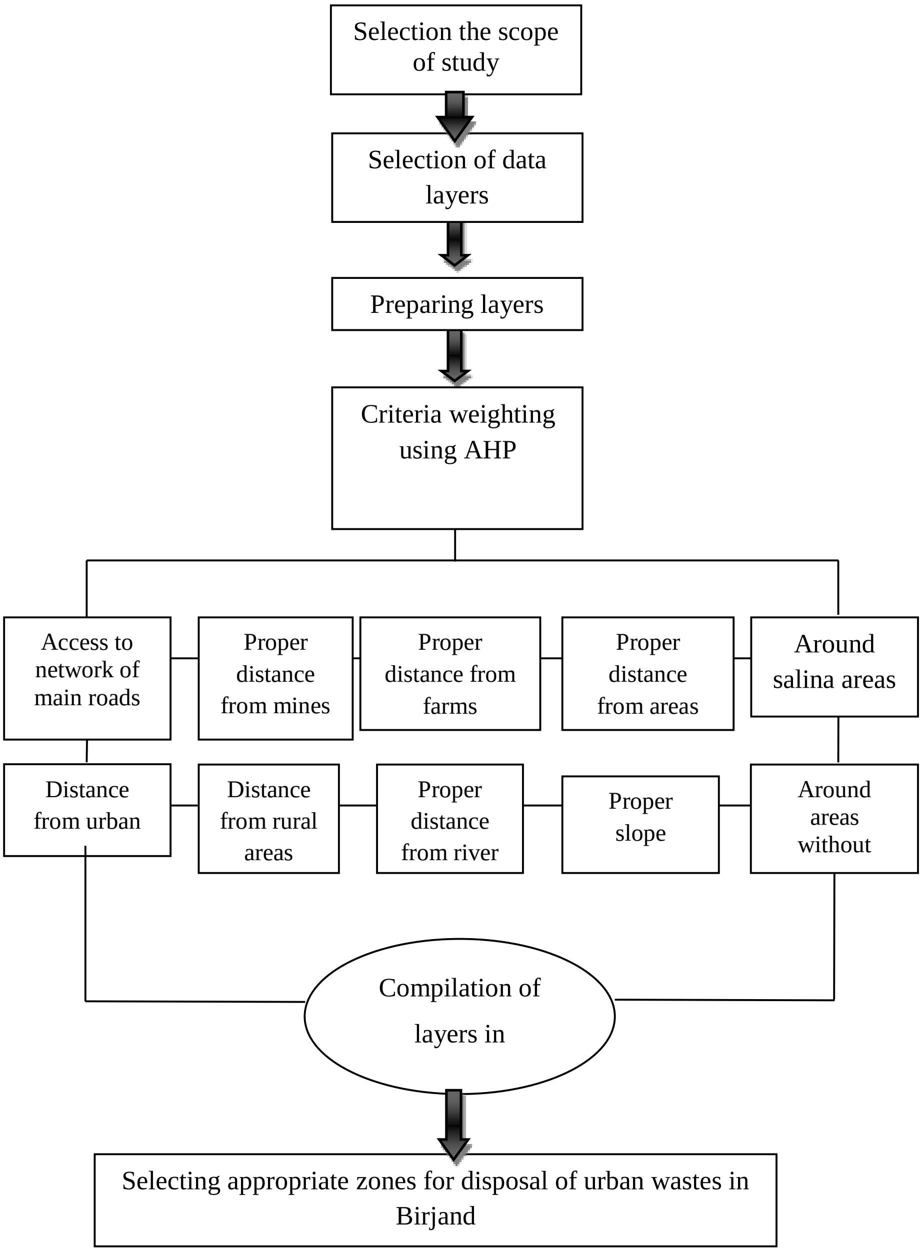

Figure 2. Steps of selecting appropriate zones for disposal of urban wastes.

Analysis of Findings

Analytical Hierarchy Process (AHP) Weighting Method

In order to select appropriate zones for disposal of urban wastes in Birjand, TOPSIS model has been used as a multiple indicators decision-making method that is considered a simple but efficient method in prioritization. This technique can be performed by calculating weight of influential criteria in prioritizing the selection of the best zone for disposal of urban wastes. There are multiple methods of weighting like entropy, ANP, and AHP for this end that can be used according to requirements. AHP method is used in this research and extracted weights from Expert choice software are shown in Table 2 and Figure 3.

Table 2. Weight of effective criteria in selecting appropriate zones for disposal of urban wastes

Criteria	Proper distance from urban areas	Proper distance from rural areas	Proper distance from mines	Proper distance from areas with forest cover	Proper distance from rivers
Weight	0.248	0.214	0.030	0.057	0.107
Criteria	Around areas without vegetation	Around salina areas	Access to communication network	Proper slope	Proper distance from farms
Weight	0.019	0.018	0.177	0.042	0.09
Total sum		1			

The coefficient of compatibility or degree of agreement for criteria is equal to 0.09 that is lesser than 0.1 (IFRATIO>0.1) and it is acceptable in paired comparative matrix.

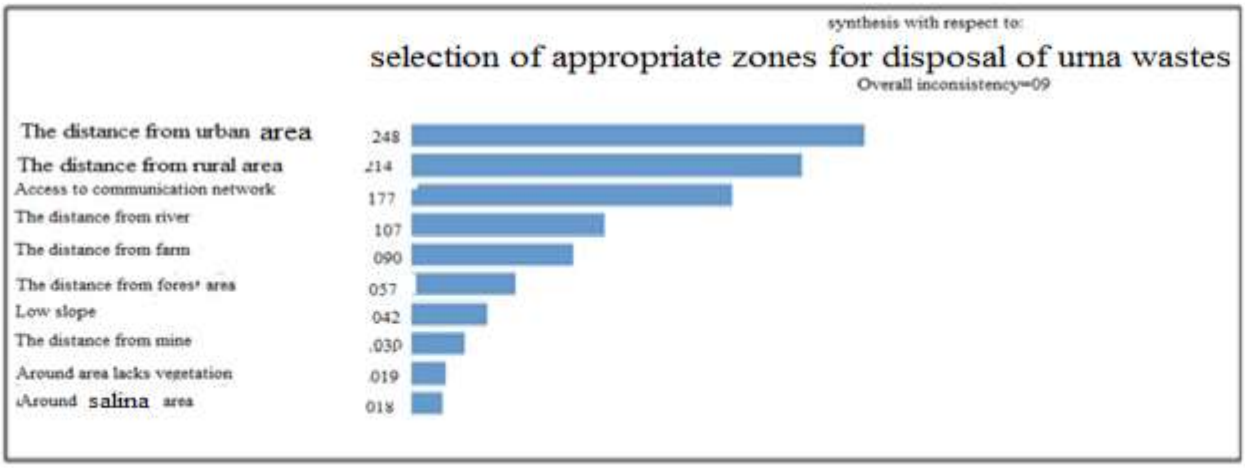

Figure 3. Determining the weight of criteria in hierarchical method (AHP)

Implementation of TOPSIS Model in GIS in Order to Determine the Best Zone for Disposal of Wastes:

Knowing the weights of research criteria, the context is provided for spatial-place analysis. So regarding to these weights, it is specified that criteria such as proper distance from urban areas, proper distance from rural residence, access to communicational network and proper distance from rivers (seasonal and unseasonal) have determinant importance in selecting appropriate zones for disposal of urban wastes; and other criteria are placed in next levels according to priority of expertise (such as proper distance from crop farms, proper distance from the areas with forest cover, low-slope, proper distance from mines, around areas without vegetation, around salina areas).

The context for spatial analysis criteria is provided with specifying weights of criteria so that in accordance with the following steps, overlap of spatial layers of studied area that represent research indicators is conducted by multiple criteria decision-making techniques (TOPSIS).

First Step- Forming Decision-Making Matrix

Spatial indexes are produced at this step, that is mathematical functions include distance function is defined in studied area such that each index is divided into specified class distances with maximum and minimum values to based on these values, the dimenionlessness of indices is done. Place layer of some effective criteria are shown in images (4 - 7) as sample.

(1) Equation $I=X_{ij}$ location index production

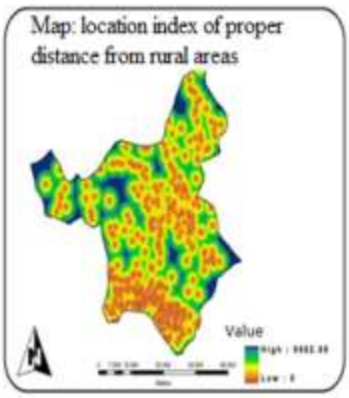

Figure (5): location index of distance from rural areas

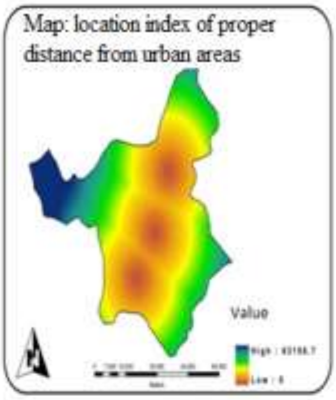

Figure (4): location index of distance from urban areas

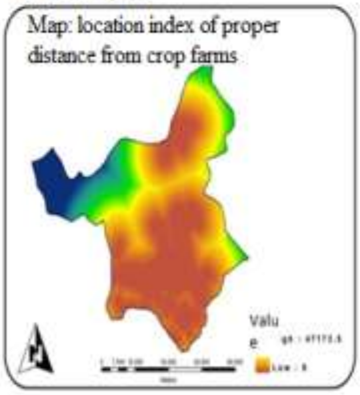

Figure (7): location index of distance from farms

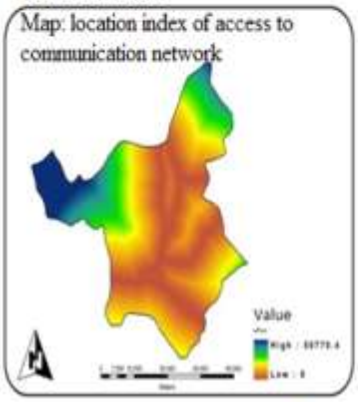

Figure (6): location index of access to communication network

Second Step- Forming of Standard or Dimensionless Decision- Making Matrix

At this step, standardization is done according to type of indices and dividing them into positive and negative indices and considering maximum and minimum values of class values of each index. Standardization means deletion of measurement units of criteria functions such that all criteria are dimensionless. The normalized value is set by "simple normalization". Standardized location layer of some criteria is shown in images 8 - 11. Pixels in blue color are the closest distance to positive ideal and vice versa approaching to red color represents the negative ideal.

Indicators' Standardization ⟶ r_{ij} the formation of standard decision matrix

Positive index $$r_{ij} = \frac{x_{ij}}{maxx_{ij}}$$

Negative index $$r_{ij} = 1 - \frac{x_{ij}}{maxx_{ij}}$$

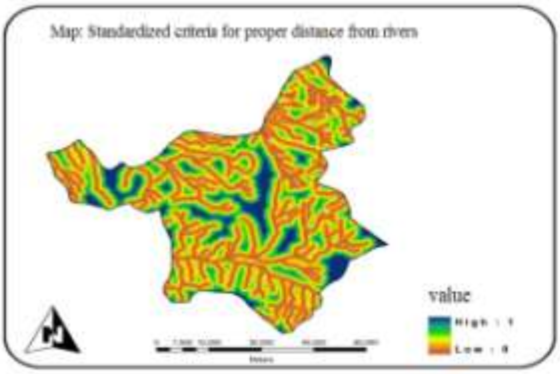

Figure (8): Standardized appropriate distance from rivers

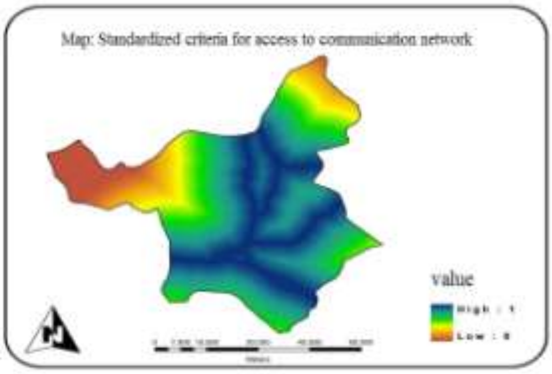

Figure (9): Standardized access to communication network

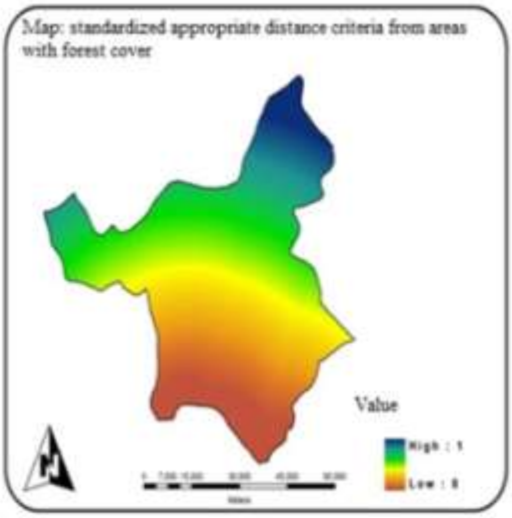

Figure (11): standardized distance from area with forest cover

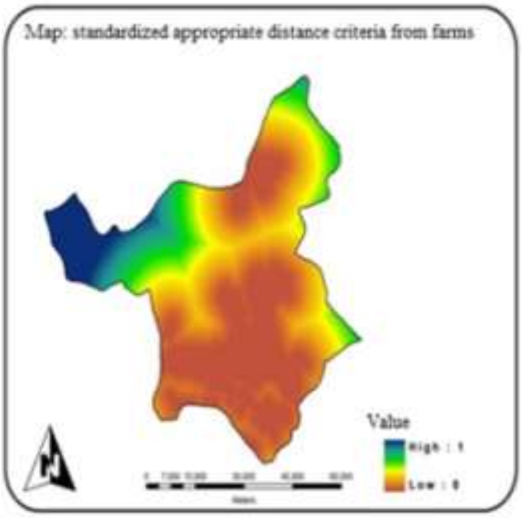

Figure (10): standardized distance from farms

Third Step: Forming Weighty Standard Matrix

At this step, according to previous steps and dimensionless indices and weights of study criteria that have been determined by hierarchical analysis process method (Table 2), the weights of criteria are interfered. Weighted standard location layer of criteria is shown in figures 12 - 15. Pixels in blue color are the closest distance to positive ideal and vice versa approaching to red color represents the negative ideal.

$$\text{Weighty standard matrix} \longrightarrow V_{ij}$$

$$V_{ij} = r_{ij} * W_i$$

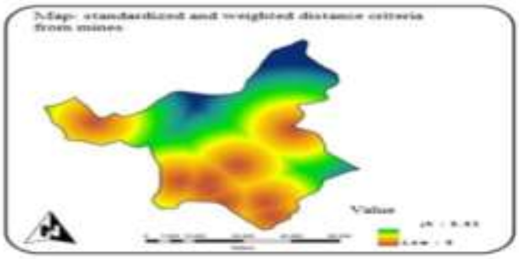

Figure (13): standardized and weighted distance from mines

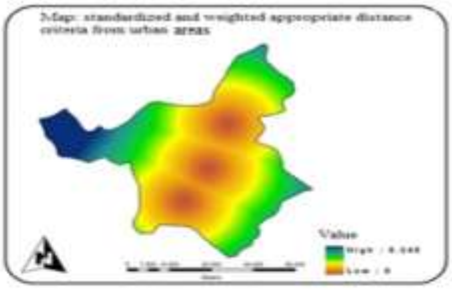

Figure (12): standardized and weighted distance from urban areas

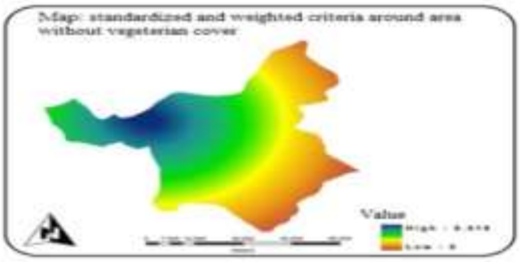

Figure (14): Standardized and weighted around areas without vegeterian cover

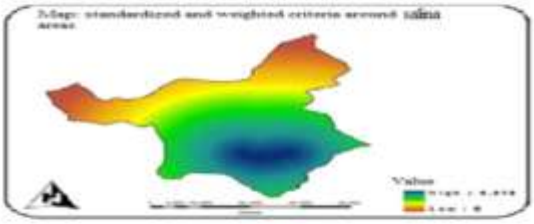

Figure (15): Standardized and weighted distance from salina areas

Forth Step- Calculation of Ideal Positive and Negative Distances:

Also at this step, according to positive and negative criteria of the research, maximum and minimum of the weighty and standard matrix values aren't interfered in the total of indicators. Its location layer is shown as Figures (16) and (17).

Positive ideal distances $S_i^+ = [\Sigma (V_{ij} - V_{ijmax})^2]^{1/2}$

Negative ideal distances $Si^- = [\Sigma (V_{ij} - V_{ijmim})^2]^{1/2}$

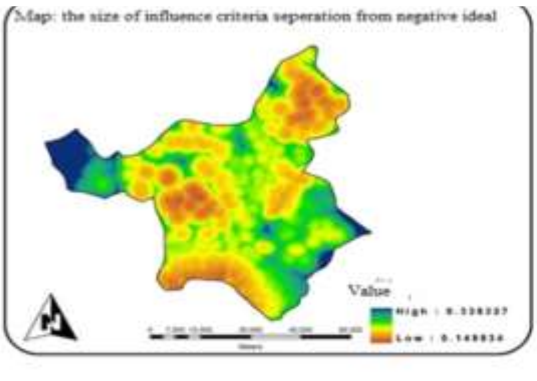

Figure (17): the size of criteria seperation from negative ideal:-s

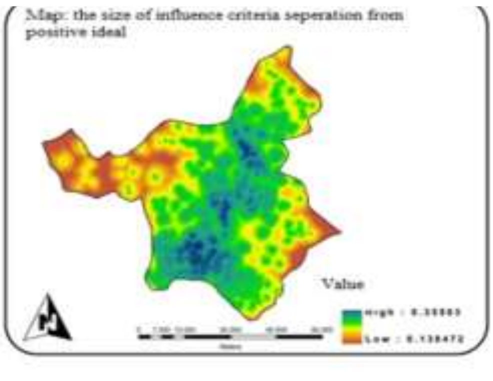

Figure (16): the size of criteria seperation from positive ideal:+s

Final Step- Indices Evaluation

In the final phase, the criteria of selecting the most appropriate zone is measured by C_i or compatibility index, so that utility of index is between 0 and 1. The more this value is close to 1, it is the most appropriate zone for waste disposal and vice versa, if it is close to 0, the zones are not appropriate to waste disposal.

Compatibility index ⟶ $C_i 0 < C_i < 1$

$$C_i = \frac{Si-}{Si+ + Si-}$$

In this step, that the result of research is determined as a result of integration ideal positive and negative distances, our value's domain moves to 1 and it is variable between values (0.377468-0.047454). Considering that utility of selecting the most appropriate area is acceptable because of compatibility index or closing this index to 1, this fact is true in this research and regions of the northwest and southeast of the Birjand County were selected as the best places for burying urban wastes. Figure (18).

Figure (18): map of appropriate zone for burying urban wastes of Birjand city

3. CONCLUSIONS

Wastes' burial has always been one of the basic problems of urban services administrators. Environmental and health hazards of burial of wastes need control and apply a special management system due to its connection with human life that gets more complicated in processing of development and population growth. According to problems of urban waste disposal problems and its different consequences, there has been the need to disciplined locating. Generally, waste management involves the use of ways such as use of burying and disposal places, burning, composting, recycling, reducing waste at the beginning as well as reuse of materials. Reduction, recycling and reuse should always be considered to be able to reduce total amount of waste, which results in reducing burning and waste burial places. The most common method of removing of urban waste is use of disposal method and health burial of wastes that geological considerations are remarkable in this method. Now, for transferring wastes to land, reduction of the waste and economic methods of reuse of waste are the best ways. In this research, we addressed identification of appropriate zones for burial of urban wastes in the form of TOPSIS model in ARC GIS software and analytical hierarchical process AHP. Final plan was obtained by integration and overlapping of information layers and it was determined that southeast and the northwest parts of Birjand county has more priority and points in terms of optimal location of wastes and garbage burial.

4. RECOMMENDATIONS

- Given to in many cases, borders of cities and towns of Iran do not comply with natural effects, selection of a place to create sanitary sites of waste disposal in a city may cause quarrel among citizens of adjacent cities. Therefore, it is recommended a comprehensive plan to be developed where to consider the health burying of urban wastes in local and regional form.

- Since emulsion generated from waste may partly penetrate into ground and reach to underground water and ducts, it is recommended that a plastic layer be used as cover of flooring hole after digging a hole to bury garbage.

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