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A GIS-EIP Model for a Mechanic Industrial Zone Site Selection in Al-Mafraq City, Jordan

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Abstract

Due to the lack of adequate infrastructure and management, the current busy mechanic industrial zone (MIZ) in the Mafraq City, Jordan is causing several negative effects on its surroundings, including a daily traffic congestion; visual-, air-, and noise pollution; and land-value degradation. The objective of the study presented in this paper is to integrate eco-industrial park principles (EIPs) into multi-criteria decision-making (MCDM) and geographic information systems (GIS) for the selection a new MIZ site in Mafraq. A GIS-EIP model was first developed by analyzing the different variables involved, which included the terrain slope suitability; proximity to transportation, utility networks, health centers, and schools; protected sites; stream networks; urban areas; and vacant land. The proposed GIS-EIP model was carried out in the following four steps: (i) identifying the potential areas for the new MIZ site based on specific EIP criteria, (ii) determining the weight and score values for each criterion, (iii) integrating the criteria using a map integration procedure, and (iv) evaluating suitable locations for the new MIZ site. A suitability map was created thereafter, based on five categories (equally suitable, slightly suitable, strongly suitable, very strongly suitable, and extremely suitable). Then, concentrating on the last three suitability categories only, twenty land parcels were identified as the best alternative sites. These identified parcels, which span an area greater than 0.7km^2 within a square of 1km and are located within vacant land, were determined to be the best fit to the EIP principles applied in this study. These results can be used by Mafraq's decision-makers to select the best place to relocate its busy MIZ and thereby reduce its current traffic congestion and environmental problems.

Keywords: MCDM; Delphi; Index overlay, Suitability analysis, GIS, Eco-industrial parks.

1. Introduction

The concept of eco-industrial park (EIP) emerged in the 1990s (Lowe, 2006). The most common definition of EIP, which has been cited by several international organizations working in this field, was introduced by Lowe (1998) as: a dedicated area for industrial use at a suitable site that ensures sustainability through the integration of social, economic, and environmental quality aspects into its siting, planning, management and operations. These EIP principles are of great value for reducing the long- and short-term impacts of industrial zones by considering the ecological and social aspects of their chosen sites. Several past studies adopted the EIP concept in a geospatial dimension to ensure the environmental sustainability and industrial ecology of an industrial zone (Shi et al., 2010; Tudor et al., 2007; Dohel, 2016). This geospatial dimension has added a new perspective to landscape ecology by providing definitive ways to identify suitable sites for industrial zones (Conticelli and Tondelli, 2014).

According to the United Nations Industrial Development Organization (UNIDO), selecting a location for an industrial zone is among the most critical steps in its development process. This selection strongly influences the demand, supply, cost, environment, and socioeconomic aspects, which in-turn can influence the overall success of the industrial zone; and this decision therefore should be made in the context of broader spatial and non-spatial geographical considerations, within which several alternative sites can be considered. The principal steps for planning an industrial zone include: (i) pre-feasibility studies, (ii) pre-identification of a shortlist of suitable sites, (iii) detailed feasibility analysis of the selected site, and (iv) financial structuring and management (UNIDO, 2016).

Furthermore, the selected site should be convenient to meet the daily needs of citizens in the immediate residential neighborhoods and the wholesaling stakeholders and distributors (Steiner et al., 2000). In this context, a detailed framework should be carefully established to ensure the sustainable development and environmental management of the industrial zone. This framework should incorporate all possible factors that could impact the optimal location,

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including social, environmental, human, economical, and morphological factors (Al-Shalabi et al., 2006; Bagdanavičiūtė and Valiūnas, 2013; Patil and Jamgade, 2019). The mismanagement of industrial sites could negatively impact the surrounding environment and reduce the quality of life for its surrounding neighborhoods (Arabsheibani et al., 2016). One of the most appropriate techniques for establishing such a framework is introducing multi-criteria decision-making (MCDM) within a geographic information systems (GIS) environment into the process. This technique has the capability to combine different types of spatial and non-spatial datasets to produce reliable solutions with less time and effort (Patil and Jamgade, 2019). By using MCDM-GIS, it is possible to successfully implement the EIP concept for industrial site selection (Banar et al., 2014), which could include a variety of key factors that can work with various categories in a GIS environment and could support decision-makers in solving the geospatial issues related to the area of interest (Kumar and Shaikh, 2013). It also can help decision-makers in their evaluation of the priorities of a specific location based on a set of preferences, criteria, and indicators (Johar, 2013).

In this study, a GIS-MCDM-based EIP approach was developed to select the optimal site for the potential relocation of the mechanic industrial zone (MIZ) in Mafraq City in the northeastern part of the Hashemite Kingdom of Jordan. Although MCDM has been used in several studies for site selection, combining it with EIP concepts, to the best of the authors' knowledge, has not been fully applied in Jordan. The proposed approach incorporates the concepts of sustainable and economic spatial planning by identifying two major goals: (i) the sustainable (environmental) variables including stream networks and valleys, health facilities, and topography and (ii) the economic variables, which include transportation and railway networks (the Hejaz railway, which operates passenger trains from Amman to Damascus in Syria and also operates freight trains on its tracks); protected sites; urban areas; and land vacancy. A newly-selected optimal MIZ site should strive to improve the level of services and accessibility to the area, protect the environment, and reduce pollution and traffic congestion in the city while having the least impacts on people, infrastructure, traffic, health facilities, heritage sites, and future urban development and expansion.

2. Study Area

Mafraq City is located in northeastern Jordan and covers a total area of 26km2; and its total population is about 216,900, which includes approximately 162,697 refugees (DOS, 2020; UNHCR, 2020). A rapidly growing city, Mafraq is suffering from a lack of urban planning and policies, which is contributing to problems that are lowering the quality of life, such as traffic congestion, accidents, pollution, land degradation, and the high demands on infrastructure (Sqour et al., 2016). The major economic activities of the area include agriculture, livestock herding, general services, and industry, which include the MIZ. The current location of the MIZ contains several types of activities, such as gas stations, mechanic shops, vehicle detailing shops, small-scale plastic recycling factories, and water-purifying manufactories. The wastes produced in the MIZ include oil, iron, plastic, cardboard, caoutchouc, metal liquids, and other materials. The MIZ is one of the major challenges faced by the local authorities and citizens in Mafraq. It spans an area of 0.27km2, and is surrounded by two major heavily-utilized highways and many facilities, including a new city center, the Mafraq gynecology hospital, Al al-Bayt University, the King Abdulla suburb, and many other residential areas within less than 500m from the MIZ site (Figure 1). This location has created severe traffic congestion and pollution in the area, examples are shown in Figure 2. Its land value is very high which could be invested in other high added-value commercial investments.

The study area is covered mainly by basaltic rocks, which belong to the Harrat Ash Shaam Basaltic Super Group of Neogene-Quaternary age. The Abed Olivine Phyric Basalt (Pliocene) lies unconformably above the Umm Rijam Chert Limestone Formation. Its Thickness is 20m and the distribution of this formation is in the northeast and eastern parts of the study area. The Pleistocene to recent deposits covers most of the basaltic rocks due to the high erosional rate. These deposits are composed of Plateau Gravels (Pleistocene-Recent) consists of heterogeneous mixture of gravels with different size, from 1cm to 1m. Two types of soil are mainly present. The red soil, "Terra rosa", is the Mediterranean Sea soil found in the southwest of the study area. the desert soils, yellow mostly, are a mixture aeolian sands located northeast, east, and southeast of Mafraq City (Smadi, 1997).

It would be important to mention here that the soil type could affect the selection of the location of a MIZ site, however, the soil in the entirety of the study area is considered to be the same type, so it has an equal spatial importance weight throughout the study area and therefore it would not affect the selection of the proposed MIZ sites.

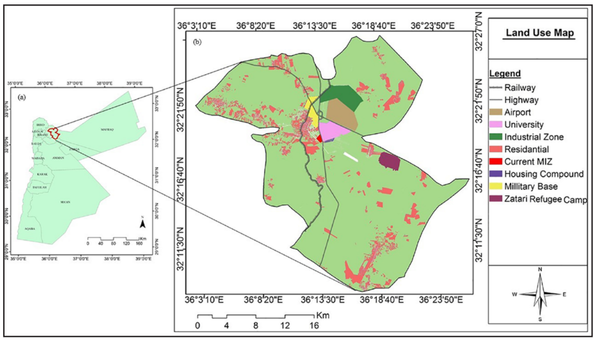

Figure 1. (a) Map of Jordan, (b) land use map of the city of Mafraq. Red polygon shows the current location of mechanic industrial zone (MIZ) dispersed throughout the city surrounded by several facilities and residential areas.

Figure 2. (a-c) are examples of plastic, cardboard, caoutchouc, metal, and oil spill pollution found in the mechanic industrial zone (MIZ); (d) illustrates the proximity of the hospital to the MIZ, which is in the upper left corner of the image.

3. Materials and Methods

A schematic diagram of the proposed GIS-EIP approach for selecting a new location for the MIZ is shown in Figure 3. The approach consists of three main steps: (i) data collection and preparation, (ii) developing the GIS-EIP model, and (iii) evaluating the new MIZ potential sites.

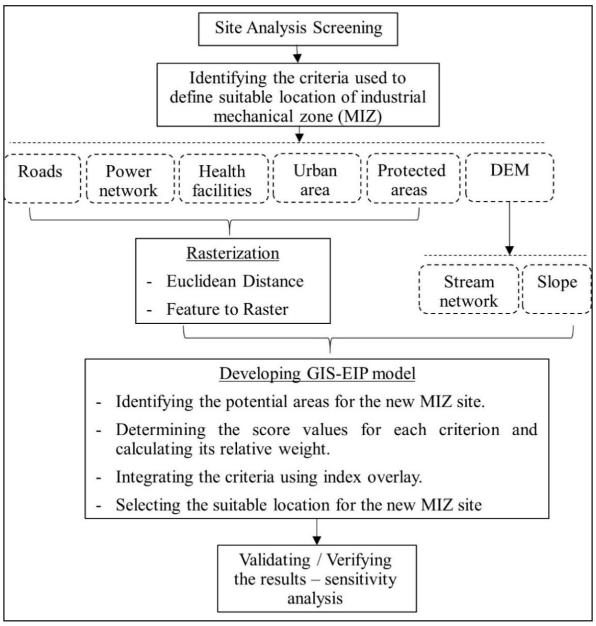

Figure 3. Schematic diagram of the proposed GIS-EIP model for selecting a new MIZ location in Mafraq city, Jordan.

3.1. Data Collection and Preparation

An intensive review of the literature and the different related sectors (i.e., ecology, environment, planning, local authority, stakeholders, and local citizens) was performed to determine the best practices' criteria. Three categories of major criteria were identified: (i) accessibility, (ii) availability, and (iii) ecological criteria, which are listed in Table 1.

The first category includes sub-criteria for the local transportation network, railways, highways, and power networks. Information about these sub-criteria were collected from open street maps and local authorities in the form of hard-copy maps and then georeferenced to the Jordan Transfers Mercator (JTM) coordinate system. The power network information was obtained from local authorities, and was added to the geodatabase. The second category contained the land parcels and information about their ownership, area, and vacancy. The built-up and protected areas, including military-owned parcels were stored with their attributes in the land parcels' database. These land use types were considered as protected lands for the MIZ site selection.. The third category (ecological criteria) included the stream network and slope values of the terrain. Both were extracted from the ALOS PALSAR digital elevation model (DEM) at 12.5m spatial resolution using the spatial analysis tools within the GIS environment. The stream network is very important as the MIZ could impose groundwater pollution and flood risk. Currently, the existing MIZ is not served with a sewage system infrastructure; and all the liquid and sewage waste produced are drained into nearby valleys and streams causing pollution to groundwater storage in the area and affecting water quality (Al-Mefleh et al., 2019). It is worth noting here that the study area has an arid climate that tends to have short but intensive rainfall during the winter season; and the area may receive water flows from the mountainous area of Al-Arab Mountain in southern Syria during different times of the year (Al-Olemat, 2019).

Table 1. Description of the major criteria and sub-criteria used to define suitable location of the MIZ) in Mafraq city.

Major criteria	sub-criteria	Data Source	Description
Accessibility	Transportation, and Power network	Open street map, 2019 and local authorities	The new MIZ site should be accessible by transportation and power networks to reduce the infrastructure cost. Condition: less than 5km from the networks.
	Health facilities	Digitized from Google Earth pro, 2019	The new MIZ site should be as far as possible from the city's health facilities, especially the central hospital, for health issues.
Availability	Land parcels	Ministry of Local Administration, 2019	The potential site should be at a distance of more than 2km from the current urban boundary, taking into consideration future urban sprawl and to reduce the potential pollution impacts on citizens.
	Urban area		
	Land vacancy		All vacant land is given priority in the selection to reduce the cost of compensating owners and restructuring.
	Protected areas		These areas include the land parcels of the military base and airport, Al al-Bait University, and Zatari Refugee Camp.
Ecologic criteria	Stream network and Slope	Derived from ALOS PALSAR DEM (Alaska Satellite Facility, 2019)	To decrease the chance of pollution affecting groundwater tables, by discarded oils, paints, and other chemical poisons draining into the streams (Gratzfeld, 2003).

3.2. Developing the GIS-EIP Model

The proposed GIS-EIP model was carried out in four steps: (i) identifying the potential areas for the new MIZ site based on specific EIP criteria; (ii) determining the weight and the score values for each criterion; (iii) integrating the criteria using a map integration procedure; and (iv) evaluating potentially suitable sites for the new MIZ site. According to the proposed GIS-EIP model, the new MIZ location must meet the following criteria: (i) It should be within the ecosystem capacity; (ii) establish an interconnected system to reduce waste and water consumption; (iii) use an intelligent grid system for the exchange of waste, energy and recycling, thus, increasing the environmental capacity; (iv) adopt and use environment-friendly systems and methods to match the natural perspective of the area; and, (v) have an area greater than 0.7km^2 as shown in Table 2. The design of the selected area should be divided into four main workspaces which include an industrial area, waste management, green corridors, and urban services.

3.2.1. Identifying the Potential Locations for the New MIZ Site

To identify potential locations for the new MIZ site, several spatial masks were applied to exclude all the non-suitable regions based on the specific EIP criteria. In the first step, the existing built-up areas, Al al-Bait University and the military base, were masked out. Then, the regions within the buffer zones that were less than 0.5km from protected areas, 2km from residential areas, and 0.5km from valleys and stream network were eliminated; and the areas greater than 5km from transportation and power transmission lines and terrain that had a slope greater than 15 degrees also were excluded. Conditional if/else functions (Con; Equation (1)) were applied to exclude these regions due to several environmental, technical, safety/security, social, and economic constraints.

Con (restriction_masks,2,0, ((R)+(P) +(H) +(U) +(Pr) +(PA) + (SN)+(S) ...(1)

where R = Road network, P = Power network, H = Health centers, U = Urban area, Pr = Protected areas, SN = Stream network, S = Slope, and V = vacant. Con is a geospatial tool that performs a conditional if/else evaluation on each of the input raster variables. The value 2 represents restricted areas, and 0 represents areas that have a zero score in the evaluation of criteria layers. In Equation (1), the condition function returns areas that are not equal to 2 or 0 in the restriction masks layer, and then the other criteria inputs were combined as potential areas for the next step of suitability analysis.

Table 2. The proposed design of the new MIZ site in Mafraq city according to EIP concepts.

Type of use	Sub-use	Area	
		m^2	%
Industrial use	Gasoline	455,000	65
	Mechanical		
	Large trucks		
	Vehicle paint workshops		
	Factories		
	Water filtering		
Waste management	Oils waste	49,000	7
	Iron waste		
	Plastic waste		
	Vehicle board waste		
	Caoutchouc		
	Metal		
	Liquid material		
Green corridors	Outer green barrier	91,000	13
	Natural draining path		
	Internal green barriers		
Urban services	Service facilities	105,000	15
	Pavements		
	Logistic support		
	Parking lots and transportation		
Total area		700,000	100

3.2.2. Determining the Score Values for each Criterion and Calculating its Relative Weight

The potential areas identified in the first step were tested for their suitability as the new MIZ site. An expert knowledge-based approach (the Delphi method) was used to determine the score values, which then were used to calculate the relative weights of each criterion using Equation (2). A pairwise comparison matrix designed based on the Saaty (1994) scale of preferences (Table 3) was designed and distributed to the experts, from which the analytical hierarchy process (AHP) measures were calculated. Note that the score values for each criterion defined the spatial proportional importance of a tested location compared to the other locations within a single criterion, while the relative weight values defined the proportional importance of a specific criterion compared to the other criteria (Hazaymeh et al., 2018). For the purpose of this study, the odd score values in Table 3 were used to define the spatial proportional importance of any location. The even score values were ignored as they represented transferring strata in the scale levels. Locations/criteria were deemed more suitable when they had higher scores/weight values depending on their relative importance when computing the final suitability map (Chen et al., 2010). Then, the consistency index (CI) and the consistency ratio (CR) were calculated using Equations (3) and (4), respectively, to measure the inconsistency associated with the pairwise comparison matrix. As a rule of thumb, when the CR value was less than or equal to 10%, then the pairwise matrix was considered consistent, and the relative weight values could be used for further suitability analysis.

$$W_i = \frac{\sum V_{ij}/S_j}{n} \quad (2)$$

$$CI = \frac{\lambda_{max} - P}{P - 1} \quad (3)$$

$$CR = \frac{CI}{RI} \quad (4)$$

where, is the relative weight for criterion (i), is the value of criterion (i) in column (j) in the pairwise matrix, is the sum of column (j), and n is the number of criteria. is the largest eigenvalue that can be obtained once its associated eigenvector is identified (this value is obtained from applying and calculating the AHP matrix.); P is the number of columns of the pairwise matrix. RI is the random inconsistency index as defined in Table (4).

Table 3. Saaty scale of performance used for generating the pairwise comparison matrix of AHP in this study.

Description	Score Value
equally suitable	1
slightly more suitable	3
strongly suitable	5
very strongly suitable	7
extremely suitable	9
intermediate values	2, 4, 6, 8

Table 4. Random inconsistency indices (RI) used for calculating the consistency ratio associated with the AHP pairwise comparison matrix.

n criteria	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

3.2.3. Integrating the Criteria Using the Index Overlay Method

All the input maps were converted into raster format to allow for map integration. The raster format is a grid commonly used to represent spatial continuous surfaces with varying values, and is considered a simple and flexible spatial data structure to perform map overlay and integration (Reddy, 2018). To accomplish this, the Euclidean distance function was used to generate arbitrary distance classes from each feature in the input layers, which included transportation, railway, power network, health facilities, stream network, and land parcel layers. The feature to raster function was used to convert the land parcel layers to raster format based on their attributes. These raster layers were then numerically standardized (reclassified) according to the score values obtained from the previous step (Section 3.2.2). Table 5 summarizes the score values of the standardization process. Finally, the suitability of each pixel (location) in the output suitability map for locating the new MIZ site was calculated using the index overlay method as in Equation (5). Note that the value of each pixel in the output suitability map represents the cumulative importance of the integrated scored pixel in the input maps which could be represented in more than two gradual classes of importance (Kamali et al., 2017; Rikalovic et al., 2014; Moghaddam et al., 2014).

$$Z_{ij} = \frac{\sum_{k=1}^{n} w_k * (C_{ij})_k}{\sum_{k=1}^{n} w_k}$$

where; Z_{ij} is the suitability index score value of pixel $(_{ij})$ in the final output map; $(C_{ij})_k$ is the corresponding score value of pixel $_{(ij)}$ in the criterion $_{(k)}$ of the input scored map; W_k is the weight value of criterion $_{(k)}$; (n) is the number of input criteria.

Table 5. Score values and their respective cut-off threshold proximities (intervals) used in the standardization process for each input layer in the index overlay method.

	Input Layers							
	Cut-off threshold distance values in meters							
Score value	Transport-ation	Utilities network	Health centers and schools	Urban area	Protected areas	Stream network	Slope°	Vacant land
9	100-200	100-200	>5000	>5000	>10000	>1000	< 5	9
7	200-400	200-400	4000-5000	4000-5000	7000-10000	700-1000	5-7	
5	400-700	400-700	3000-4000	3000-4000	4000-7000	400-700	7-10	
3	700-1000	700-1000	2000-3000	2000-3000	2000-4000	200-400	10-13	
1	>1000	>1000	1000-2000	1000-2000	1000-2000	100-200	13-15	
0	<100m	<100m	<1000m	<1000m	<1000	<100m	>15	

4. Results and Discussion

4.1. The Potential Regions for MIZ Sites

The potential areas for allocating the new MIZ site are shown in Figure 4. The conditional geospatial masks integrated the final outputs of the non-restricted proximities and were regained as a result of utilizing a conditional if/else function [Con; Equation (2)]. The potential map shows that approximately 5.4km^2 of the study area was identified as a potential site for relocating the MIZ, representing approximately 55.2% of the study area. These areas, thus, were used for performing further suitability analysis procedures.

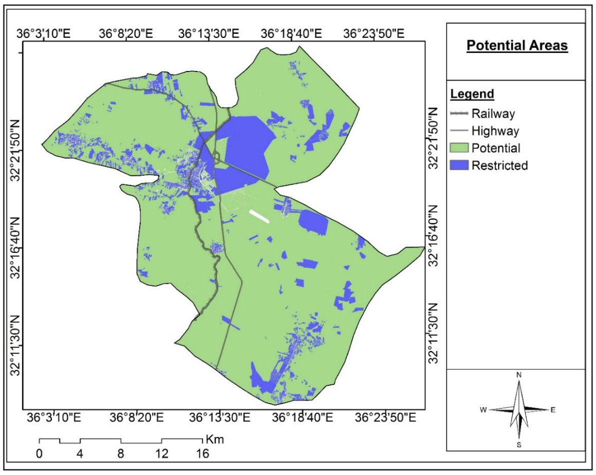

Figure 4. Potential regions for MIZ sites in Mafraq city; the unsuitable regions show the restricted areas according to the geospatial masks in equation (2).

4.2. The Score Values for each Criterion and its Relative Weight

The Delphi method showed that all the sub-criteria could influence the selection of the MIZ site in the study area. Table 6 shows the relevant weights for each sub-criterion as calculated in the AHP matrix. It shows that the distance to the transportation network, utilities network, and vacant land variables were found to be the highest influence criteria with relative weights of 23%, 19%, and 17%, respectively. The distance to health centers, urban areas, and stream network variables had moderate relative importance with weights of 10 %, 10%, and 9 %, respectively. Distance to protected areas and slope were found to have less influence on the MIZ site selection with relative weights as low as 7 % and 5 %, respectively. UNIDO (2016) and Kamali et al. (2015; 2017) also considered transportation and utilities networks as the most suitable criteria. The consistency ratio (Cr) was found to be 8%, indicating consistent relative weights and an acceptable pairwise matrix (Table 7). Note that if the Cr values were less than the acceptable threshold (10%), the relative weights were considered valid for further suitability analysis.

Table 6. The relative weight values for each sub-criterion for selecting the new MIZ site as calculated by the AHP matrix.

Sub-criterion	Weight (%)
Transportation	23
Utilities network	19
Health centers and schools	10
Urban area	10
Protected areas	7
Stream network	9
Slope	5
Vacant land	17
Total	100

Table 7. Pairwise matrix of the eight criteria for the MIZ site selection. Values in the crossed cells represent the Saaty scale of performance for the comparison pair in row i and column j as defined in Table (3) or its replication.

Criteria	R	P	H	U	Pr	SN	S	V
R	1.00	5.00	7.00	3.00	5.00	5.00	3.00	0.14
U	0.20	1.00	7.00	5.00	3.00	3.00	3.00	0.20
H	0.14	0.14	1.00	1.00	0.33	0.33	0.33	0.11
U	0.33	0.20	1.00	1.00	1.00	0.33	0.20	0.11
Pr	0.20	0.33	3.00	1.00	1.00	0.20	0.20	0.11
SN	0.20	0.33	3.00	3.00	5.00	1.00	1.00	0.11
S	0.33	0.33	3.00	5.00	5.00	1.00	1.00	0.14
V	7.00	5.00	9.00	9.00	9.00	9.00	7.00	1.00

** R = Road network, P = Power network, H = Health centers, U = Urban area, Pr = Protected areas, SN = Stream network, S = Slope, and V = vacant land.*

The suitability analysis was accomplished by aggregating the eight layers shown in Figure 5 and utilizing the map algebra function within the geospatial model. A map was generated showing the suitable locations for the new MIZ site as shown in Figure 6. It was classified into five categories (i) equally suitable: (ii) slightly more suitable, (iii) strongly suitable, (iv) very strongly suitable, and (v) extremely suitable. The classification of the cumulative score values from the index overlay method was performed using equal interval thresholds in which the extremely suitable areas collected score values of 634-750, very strongly suitable was 515-633, strongly suitable was 398-514, slightly more suitable was 278-397, and equally suitable was 41-158. The extremely and very strongly suitable areas were found to be close to the highway and were accessible to transportation and utility networks; and as a result of their accessibility to transportation and utility networks, they were given the highest weight value among the other sub-criteria. Meanwhile, there were locations identified that were away from urban areas, hospitals, schools, and protected areas which could contribute more to the conservation and sustainable use of the environment in the city.

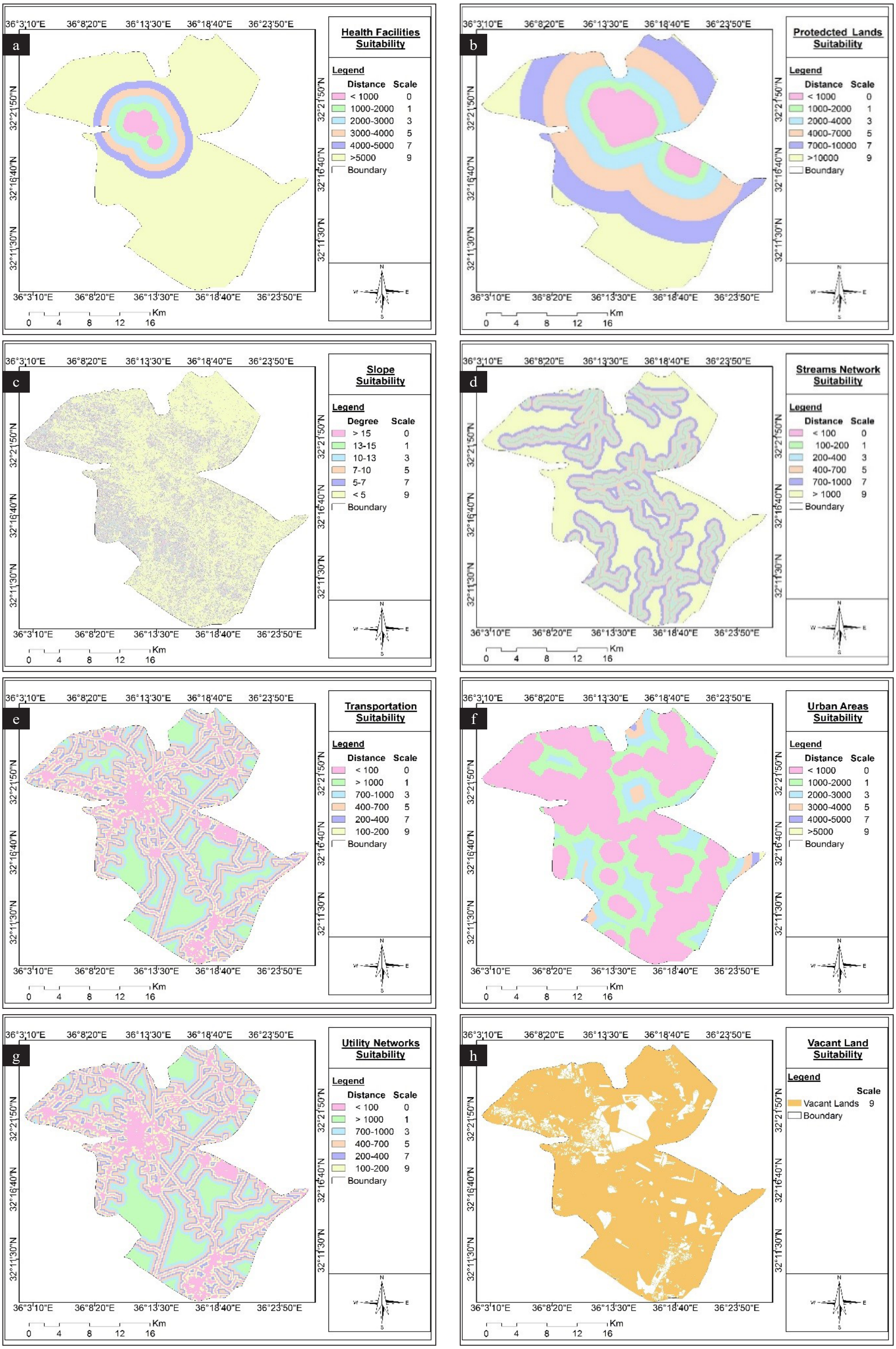

Figure 5. Suitable areas for allocating the new MIZ site in the study area according to the evaluation of each sub-criterion. (a) health facilities suitability, (b) protected lands suitability, (c) slope suitability, (d) stream network, (e) transportation suitability, (f) urban areas suitability, (g) utility network suitability, (h) vacant land suitability.

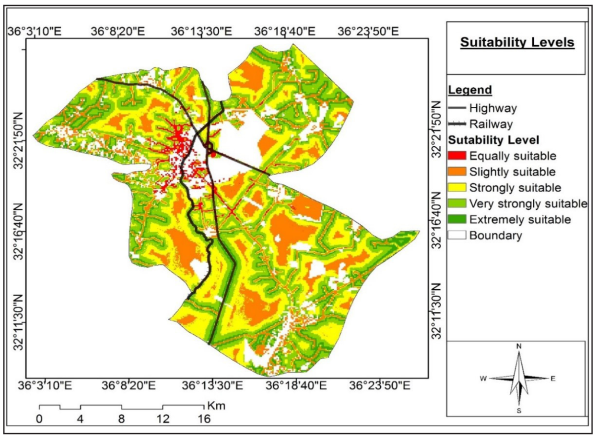

Figure 6. The spatial distribution map of suitable areas for allocating a MIZ site in the study area as a function of the weighted index overlay of the eight suitability maps of the sub-criteria.

Among the strongly suitable categories (levels 5, 7, and 9), the parcels that had (i) an area greater than 0.7km^2, (ii) a regular-shaped geometry (within a square of 1km^2), and (iii) within the vacant lands were subsequently identified as the set of optimal locations (best alternatives) for establishing the new MIZ site. As a result, 20 land parcels were identified as shown in Figure 7. Among these, parcels 1-9 were identified as preferred over the other parcels and, therefore, were designated as the optimal choices for establishing the new MIZ. These parcels offered easy access to the transportation network to the Amman-Zarqa highway that links Mafraq with these two major cities and could positively contribute to the acceleration of MIZ development. Also, the geometric shapes of these parcels were compatible with the structuring plan of the MIZ site according to the EIP principles. Parcels 13-16 were the next most appropriate as they were much closer to each other than the other alternatives, which could support potential future growth of the MIZ site, but they were not as close to the transportation network as parcels 1-9. Also note that further revision may be necessary in terms of land values and assessing the cost for possible future expansion.

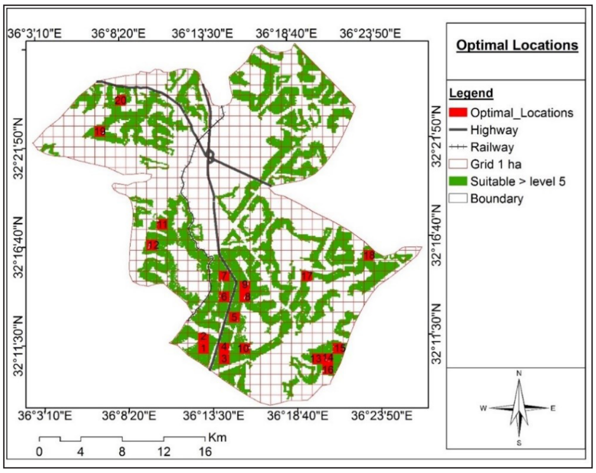

Figure 7. Map of the 20 selected optimal parcels for allocating a new MIZ site in Mafraq.

5. Conclusions

The emergence of the Eco-Industrial Park (EIP) concept has come as a much-needed solution to the growing population in global cities in terms of people and industries. The concept seeks to ensure sustainability by integrating environmental, economic, and social aspects in the planning of busy-cities. One such city is Al- Mafraq in Jordan, which is plagued by a busy mechanic industrial zone (MIZ). The city has faced several challenges due to inadequate infrastructure to accommodate people, machines, and industries. The resultant effects have been traffic congestion, land value degradation, and extreme pollution, which reduces visibility. From the study, it is evident that the implementation of Eco-Industrial Park (EIP) principles will come as a welcome addition to the city that is suffocating from its own population and industries. The implementation of EIP would involve a selection of a part of the city to be designed as the eco-industrial park, which can sustain multiple activities. The site is selected through multi-criteria decision-making (MCDM) through the involvement of strategic stakeholders of the city, including the government, residents, and industry owners. The EIP professionals would also use geographic information systems (GIS) to establish the site's viability for the industrial park. The aspects that will be considered will include accessibility, the possibility of developing recreational institutions, the terrain, and utility networks. A suitability analysis conducted in Al- Mafraq city, shows that several viable areas in the city can accommodate an Eco-Industrial Park (EIP). These conclusions have been made based on the study results, which took into consideration the requirements for the site of EIP. However, more studies need to be conducted to firmly establish the perfect part of the city that can be an EIP site. The site has to attain high suitability scores in the geological model.

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