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Ensuring food security using geospatial technology

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Abstract

Food security has been an ongoing concern of governments and international organizations. This study aims at ensuring food security using geospatial technology to find suitable sites for building food industry plants. In this respect, geospatial technology including remote sensing, geospatial information system, and global positioning system was implemented to identify suitable sites for the construction of food industry plants in Qaemshahr County, Iran and an up-to-date and efficient geodatabase for this purpose was prepared. Since rice and citrus are the main products of the study area, to ensure food security and income for the people of the region, suitable site selection to build food industry plants to sort, package, store, convert, and process rice and citrus is very important. On the other hand, because Ghaemshahr is the main hub of rice and citrus production in the country as well as export, food security at the national level can also be ensured. To support the achieved result of selected sites for food industry plants, several analyses were carried out. The resulting suitability map was reclassified based on proximity to raw food materials as well as main roads and cities. Consequently, among the obtained suitable sites, the most suitable places based on these factors were identified. In addition, a comparative analysis was performed between the selected sites and the existing industrial zones in the study area. The findings of this study are useful to ensure food security in the region and country. The study also demonstrated the effectiveness of geospatial technology for this purpose.

Keywords: Food security, Food industry, Site selection, Geospatial technology
2020 MSC: 2544, 2546

1 Introduction

The concern of food security has been growing by the governments and international organizations. World population and the consequent increasing demand for food has increased linearly over the last fifty years, and if the trend grows continually, food consumption can be increased two times than the present for 9 billion peoples [8]. Therefore, food security is one of the most pressing issues in the society for the coming decades, especially for undeveloped and developing countries [16]. It was predicted that the world will need 70 to 100 more food by 2050. About 60 of the world's hungry are living in Asia. Consequently, eradication of hunger and malnutrition in this continent would be a top priority by 2025. It can be achieved if the rates of hunger and stunting drop annually at 4 and 9, respectively

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[5]. Food security is threatened by three major factors: the access to and availability of food to the consumers in local environments, the changing agroclimates, and the optimum and sustainable food production utilizing existing land resources which is often governed by country specific policy planning and decision strategies developed for the establishment of food industries [2]. One of the main issues that can affect ensuring food security is the proper site selection for food industry plants [19]. Food industry is one of the key factors that make balance between supply and demand markets and can improve the security level of population by supplying the food requirements [1].

Food conversion and complementary industry is known as the industry that convert the raw materials from food sources such as agriculture, cultivated, poultry, livestock, and fish to comestible products with higher shelf-life time. The processing operations include sorting, packaging, physical and chemical changes, storage, transportation, and distribution [6]. Exploring a suitable site prior to building food factories is considered as a key factor which is likely to influence success of food security programs [7]. Finding a suitable location for food industry is a complex process where multiple criteria and factors need to be simultaneously considered when choosing a proper place for new food factory [13]. Data required to match the criteria are collected via traditional methods which are tedious and time consuming, or suffer from lack of updated data in case of developing countries. To overcome these issues, geospatial technology can be considered as a suitable alternative to conquest the limitations of traditional methods. Geospatial technology is considered as a tool and methodology that is used to collect, manage and analyze geospatial data for different applications. It involves the advantages of remote sensing (RS), geographical information system (GIS), and global positioning system (GPS) [3]. In location science, integration of modeling and mapping with GIS allows the analyst to efficiently utilize data from multiple sources through delivering detailed models so as to assist decision makers in identifying potential places for future plans [4]. This study utilizes geospatial technology to prepare an efficient and up-to-date model which provides the suitable sites for constructing future food industry plants to ensure food security in the study area. The objectives are: (1) to identify the potential sites for food industry plants based on pre-defined criteria, (2) to analyze and classify the selected sites to different suitability levels based on proximity to raw food materials, and main roads and cities, and (3) to carry out a comparative analysis between the selected sites and the existing industrial zones in the study area.

2 Materials and Methods

In order to reach the aim of the study, the following tasks were performed: study area definition, defining the necessary criteria for site selection, data collection, preparing the layers, generating the suitable sites map, validation of the selected sites, classification of the potential areas based on proximity to raw food materials, and main roads and cities, and evaluation of the current industrial zones for food industry plants.

2.1 Study area

Qaemshahr County, located in north of Iran was chosen as the study area in this research (Figure 1). Qaemshahr is located between 36 21" N to 36 38" N and 52 43" E to 53 3" E of the Greenwich meridian. Elevation of the region is about 51 meters above mean sea level, and it covers a total area of about 459 km2. In Qaemshahr, mean annual temperature is 17.7° Celsius, total annual rainfall is 621.5 millimeter, and mean relative humidity is 79 percent [10]. The study site is composed of two towns including Qaemshahr (in the central part) and Kiakola (in the northern part), two sectors, and 165 villages. Qaemshahr has a prominent position due to its proximity to Tehran (the country's capital), and it is connected to Tehran by rail and road links that it makes Qaemshahr more accessible to primary material markets and food demand markets. Moreover, Qaemshahr is the main hub of country's rice and citrus production as well as export [9]. Figure 2 shows citrus and rice fields in the study area.

2.2 Determination of criteria and factors

Several criteria including environmental, geographical, and economic factors were considered for an optimal food industry site selection. According to the governmental rules in Iran, there are several criteria that must be considered before establishing a food industry plant. These criteria are presented in Table 1. All these information were provided through satellite image processing, GPS field surveying, on-screen digitizing of the maps in ArcGIS environment, and various organizations in the study region.

* Iran Department of Environment

** Iran Food and Drug organization

***Iran Construction Engineering Organization

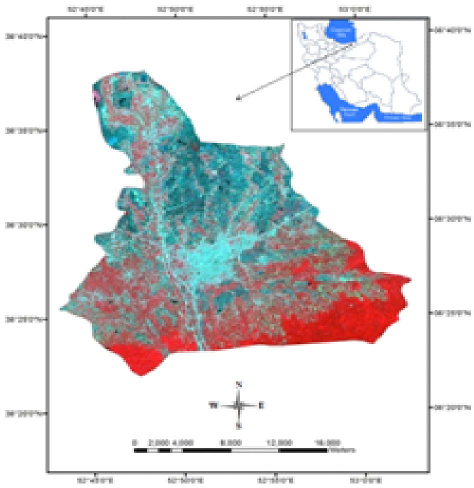

Figure 1: Location of the study area

Figure 2: Citrus trees and rice fields in the study area

Row	**Criteria**		**Distances from place (m)**						
	Places and facilities		Category1	Category2	Category3	Category4	Category5	Category6	**Source**
1	settlements	Provincial centers (last of residence)	-	500	1000	1500	2000	2500	*
2		City centers (last of residence)	-	250	500	1000	1500	2000	*
3		City	-	200	500	1000	1500	2000	*
4		Village	-	200	500	750	1000	1500	*
5	Medical and education centers		-	200	500	750	1000	1500	*
6	Military centers		50	200	500	750	1000	1500	
7	National park- Water body (pond-Lake) -Forest		150	150	500	1000	1500	2000	*
8	Wildlife refuge-protected area		-	150	200	250	500	1000	*
9	Permanent river of non-potable		100	100	150	150	250	500	*
10	Permanent river of potable		150	150	500	1000	1500	2000	*
11	Drinking water wells-agriculture- aqueducts		50	50	150	200	250	500	*
12	Cement plants, sand preparation, asphalt, Isogum		3000						*
13	First degree pollutants: poultry- cattle farms- traditional slaughterhouses- chalk and lime plants- accumulation of garbage or manure- tanned-leather and wastewater treatment		1000						**
14	Secondary pollutants include: casting- mosaics and ceramics-cemetery- industrial abattoir		250						**
15	villages that somehow have livestock- traditional poultry farming buildings		500						**
16	On a 100-year flood pass away		Not located						**
17	Fault		200						***
18	Main Road		100						***
19	Railway		100						***
20	Slope		10%						***

Table 1: The criteria for food industry plant site selection in Iran

Data	Number	Source
ASTER	2 scenes	NASA
Landsat TM	1 scene	NASA
Topographic map	1 sheet-1:250000-2003	INGO
Geology map	2 sheet-1:100000-2004	INGO
GPS data	Several	Field work

Table 2: The datasets used in this study

	Index	Equation	Reference
1	Normalized Difference Water Index	$NDWI{=}\frac{ASTER1-ASTER3N}{ASTER1+ASTER3N}$	[14]
2	Normalized Difference Built-up Index	$NDBI{=}\frac{Landsat\ TM\ band5-ASTER2}{LandsatTM\ band5+ASTER2}$	[20]
3	Enhanced Vegetation Index	$EVI{=}G\frac{N-R}{N\ +\ C1R\ -\ \ C2B+L}$	[12]
4	Enhanced Vegetation Index 2	$EVI2 = 2.5*[\frac{(ASTER3N-ASTER2)}{(ASTER3N+2.4*ASTER2+1)}]$	[11]
5	Normalized Difference Vegetation Index	$NDVI{=}\frac{ASTER\ 3N-ASTER\ 2}{ASTER\ 3N+ASTER\ 2}$	[15]

Table 3: Satellite-derived indices used for extraction of different land covers in the study area (N, R, and B are near-infrared, red, and blue bands respectively; G is a gain factor; C1 and C2 are the coefficients of the aerosol resistance term, which uses the blue band to correct aerosol influences in the red band; and L functions as the soil-adjustment factor attributed to the interaction and feedbacks between the soil-adjustment factor and the aerosol resistance term)

2.3 2.3 Datasets

In this study, two scenes of ASTER Level-1B images acquired on 27 May 2020 and one scene of Landsat-5 TM image acquired on 7 August 2020 were obtained from the US Geological Survey Global Visualization Viewer. The obtained ASTER images were mosaicked in order to cover the entire study area. Landsat imagery was used to fulfill the lack of blue and shortwave infrared bands of ASTER data. The satellite images were used to provide some of the required layers in site selection process, including water bodies, built-up areas, forests, citrus and rice fields, roads, and slope layer.

Furthermore, a topographic map, a geological map, and several GPS and GIS data were used as the input layers in this study. The topographic and geology maps of the study area were obtained from the National Geographical Organization (NGO) of Iran. Field observation was carried out using GPS machine to obtain locations of various features in the study area. The datasets used in this study are presented in Table 2.

2.4 2.4 Preparation of the input layers

The required layers for site selection were acquired through various sources as follows:

2.4.1 2.4.1 Image processing

Initially, atmospheric correction was performed using Fast Line-of-sight Atmospheric Analysis of Spectral Hypercubes (FLASH) method in ENVI 5.3 software to correct the satellite images. Subsequently, the input images were co-registered with a root mean square error of less than 0.5 pixel using the image to image registration method. The remote sensing based layers were obtained using satellite-derived indices, digital elevation model (DEM), and LOC-Road methods. The built-up areas, water bodies, and broadleaf forest layers were obtained through the calculation of normalized difference built-up index (NDBI), normalized difference water index (NDWI), and normalized difference vegetation index (NDVI), respectively. The citrus and paddy rice fields were extracted using NDVI and enhanced vegetation index (EVI). The satellite-derived indices used in this study are presented in Table 3.

In addition, the slope layer was obtained from the DEM of the study area which was created using ASTER stereo imagery. The stereo pair bands of ASTER imagery (3N and 3B) are capable of creating absolute DEM using defined ground control points. The processing steps to generate ASTER DEM are: input stereo images pair, defining GCPs, defining tie points, calculating epipolar geometry and images, specifying DEM output projection parameters, specifying DEM extraction parameters, and creating the DEM [17,18]. Using the ArcGIS software, the slope layer was derived from the generated ASTER DEM.

The layer of main roads was extracted using Lines of Communication (LOC)-Roads technique. The LOC-Roads algorithm streamlines spectral processing of multispectral data for mapping road lines of communication (LOCs). To implement LOC-Roads, a multispectral image containing Red, Green, Blue, and Near IR bands is required. In this study, a layer stacked image containing the ASTER Red, ASTER Green, ASTER NIR, and Landsat Blue bands was used for this purpose. To perform the LOC-Roads method, supervised technique using selected ROI was applied, and spectral matching, principal component, and red soil were selected as spectral processing parameters. The output image was a black and white image of which the roads were enhanced for the purpose of digitizing the main roads.

2.4.2 GPS survey

Some of the required data comprising the locations of educational centers, medical centers, military centers, villages, castings, abattoirs, cemeteries, aqueduct, waste accumulation centers, waste water treatment, and concrete, asphalt, and cement factories were collected through GPS survey around the study area. The GPS collected points were then imported to ArcGIS environment to create the layers.

2.4.3 Creation of topographic and geological data layers

The topographic and geological maps of the study area were collected from National Geographical Organization (NGO) of Iran. These maps were used to extract data layers on railway, river, tectonic, and fault through on-screen digitizing.

2.5 Identification of potential sites for food industry plant

After preparing the input layers, first, distancing for each layer was implemented using Euclidean (straight-line) Distance tools in ArcGIS Spatial Analyst based on the criteria defined for food industry plant site selection in Iran (as presented in Table 1). Subsequently, weighted and fuzzy overlay models were applied to extract the suitability maps displaying the selected sites for food industry plants. In weighted overlay method, since the input layers were in different numbering systems with different ranges each, cell for each criterion should have to be reclassified to combine them in a single analysis. In doing so, the distanced layers were reclassified into two classes: allowed and not-allowed. The reclassified layers were then weighted in raster format. At this stage, as one class was not suitable and the other class was suitable, evaluation scale was defined for each criterion. All the layers had equal influence and therefore, five percent was defined for each criterion (sum of them equal to 100). The obtained maps were then aggregated to generate the final suitability map and thus, the suitable sites were determined. To prepare the layers to be input in Fuzzy overlay model, the distanced layers were fazzified using linear membership (fuzzification). Subsequently, fuzzy overlay function was applied to fuzzified layers to identify the potential areas. The fuzzy “AND” method was applied for appropriate functioning of algorithm and to combine the data for this study.

2.6 Classification of the potential sites to different suitability levels

The potential areas identified for food industry plants were analyzed and classified based on various important factors. Proximity to raw food materials was given highest priority. Since the main raw food materials in the study area were rice and citrus, layers associated with them were separately overlaid with the resulted site selection map and thus, the potential areas were identified based on the proximity to the rice and citrus fields. Subsequently, the main roads and cities were considered as second priority to classify and determine the suitability level of selected sites. Proximity to main roads and cities has clear advantage of reducing the cost of food product processing (delivery) thought: a) facilitation of transportation to carry the primary materials to factory and again to transport the products to market place, b) proximity to sale markets, c) accessibility to primary materials, facilities and labors, and d) availability of water resources, fuel and energy.

Based on that above mentioned assumption, the main roads and city layers were reclassified into four classes by incorporating expert ideas of related organizations (Table 4). According to this classification, excellent group was designated for the sites that were located within the 500 − 1000 meter distance from the cities and 100 − 1000 meter distance from the main roads. The distance ranging between 1000 to 5000 meter from the main roads and cities was categorized as good sites and the distance more than 5000 meter was categorized as fair sites. The distances between 0 to 500 meter from the cities and 0 to 100 meter from the main roads was considered as restricted areas for food industry. Subsequently, the classified results of the main roads and cities layers were separately overlaid with the selected sites. Consequently, the potential areas within each layer and class were identified.

Condition	Scale value	Distance from cities (m)	Distance from main roads (m)
Restricted	1	0 – 500	0 – 100
Excellent	4	500 – 1000	100 – 1000
Good	3	1000 -5000	1000 -5000
Fair	2	5000 <	

Table 4: Classification of the main roads and city layers

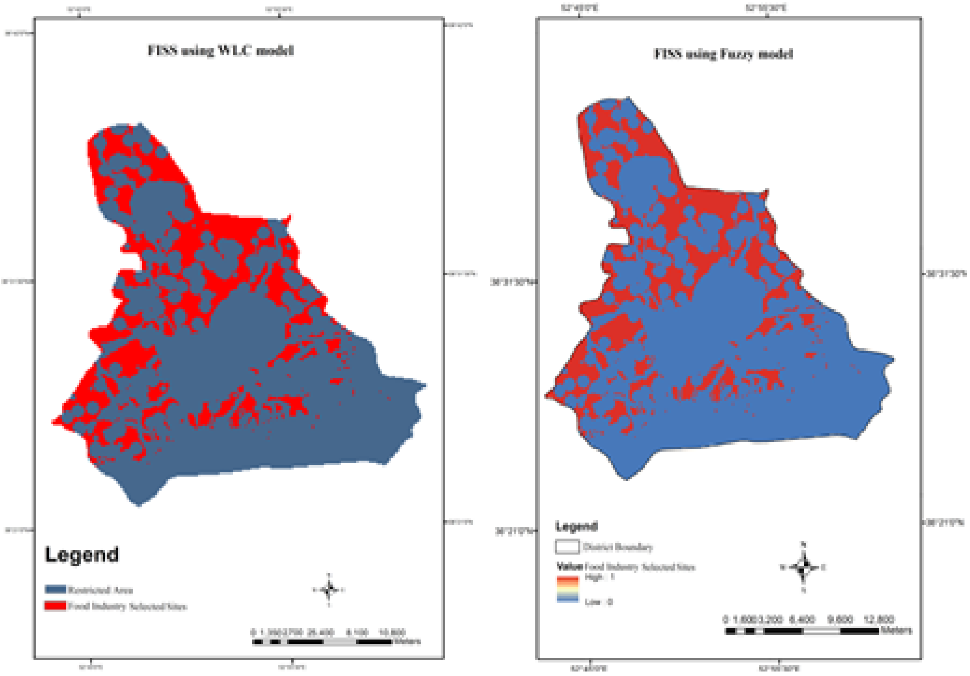

Figure 3: The generated suitability maps for food industry plants

2.7 Evaluation of the existing industrial zones for food industry plants

A comparative analysis was carried out between the selected sites for food industry plants in this study and the industrial zones existing in the study area. There are two industrial zones in the study area including Rostamkola and Sangtab industrial zones. Nevertheless, there is not any specified zone in the study area specialized for food industry. The suitability of the existing industrial zones for constructing food industry plants was investigated based on the food industry suitability map prepared in this study.

3 Results and Discussion

3.1 Identifying the suitable sites for food industry plant

To identify the potential areas for food industry plants, the required data were collected, the criteria for food industry plants were defined, the layers were prepared, and finally using the adopted overlay methods the suitability maps were generated. The site suitability maps generated using weighted and fuzzy overlay methods are displayed in Figure 3. The areas highlighted by red color indicate the suitable areas for constructing food industry plants based on the defined criteria and prepared layers.

3.2 Validation of the generated suitability maps

To evaluate the accuracy of the achieved results, a total of 20 sample points were randomly selected within the study area. And the suitability of these points for locating food industry plants was investigated through gathering expert ideas from the personnel of the Department of Environment and Ministry of Agricultural Jihad, Mazandaran branch, Iran. The results presented in Table 5 indicated that there is 90% (18 points) similarity between the reference inquiry and weighted overlay outcome, whereas the fuzzy overlay method yielded 80% (16 points) correct locations. Totally, six points were misclassified by the applied methods, in which the sample points number 8 and 13 were

Sample point Number	Suitability for food industry	Weighted overlay	Fuzzy overlay
1	Allowed		
2	Restricted		
3	Allowed		
4	Restricted		
5	Allowed		
6	Restricted		
7	Restricted		×
8	Restricted	×	
9	Allowed		
10	Allowed		
11	Restricted		
12	Restricted		
13	Allowed	×	
14	Restricted		
15	Allowed		×
16	Allowed		
17	Allowed		×
18	Allowed		
19	Allowed		
20	Restricted		×

Table 5: Validation of the selected sample points

misclassified by the weighted overlay method, while the sample points number 7, 15, 17 and 20 were misclassified by the fuzzy overlay method. The rest 14 points were correctly classified to allowed or restricted areas by the applied methods. The results demonstrated that the weighted overlay method can contribute higher accuracy for the food industry plants site selection compared to the fuzzy overlay method. This model could be useful for future food industry plans in the study area. Therefore, weighted overlay method was used for further assessments and analysis in this study. Afterward, the suitability map generated by using weighted overlay method was converted to polygon to find out the number of sites which could be considered suitable for food industry (Figure 4). The area of each polygon/site was then calculated, as presented in Table 6. The results showed that a total of 172 sites are suitable for establishing food industry plants in the study area, where the largest and smallest sites are about 31146793 m^2 and 8765 m^2, respectively.

3.3 Classification of the selected sites to different suitability levels

Figures 5 shows the reclassified road and city layers overlaid with the food industry potential sites, while the suitability map produced based on proximity to the main roads and cities is displayed in Figure 6. As shown in Figure 6, the green color is belonging to the excellent sites for food industry based on the proximity to the main roads and cities, which are located within 100-1000 m distance from the main roads and 500 – 1000 m distance from the cities. The yellow color which is classified as good is belonging to the sites that are located within 1000-5000 m distance from the main roads and cities, and the purple color which is classified as fair is belonging to the sites that are located more than 5000 m far from the main roads and cities.

Furthermore, availability of the raw food materials was considered as a key factor in locating food industry plants in this study. Therefore, the selected sites were analysed based on proximity to citrus and rice fields. Figure 7 illustrates the results of overlaying the citrus and rice layers with the food industry potential sites. As shown in Figure 7, density of the citrus fields in south of the study area is considerably higher than other areas of the region. Therefore, it was found that for food industry plants related to citrus (needing citrus as primary material), the potential areas (red) located in south of the study area are preferred. On the other hand, the results indicated that the density of rice fields in middle and north of the study area is considerably higher than other areas. Consequently, for locating food industry plants related to rice (needing rice as primary material), the potential areas (red) located in middle and north of the study area are preferred.

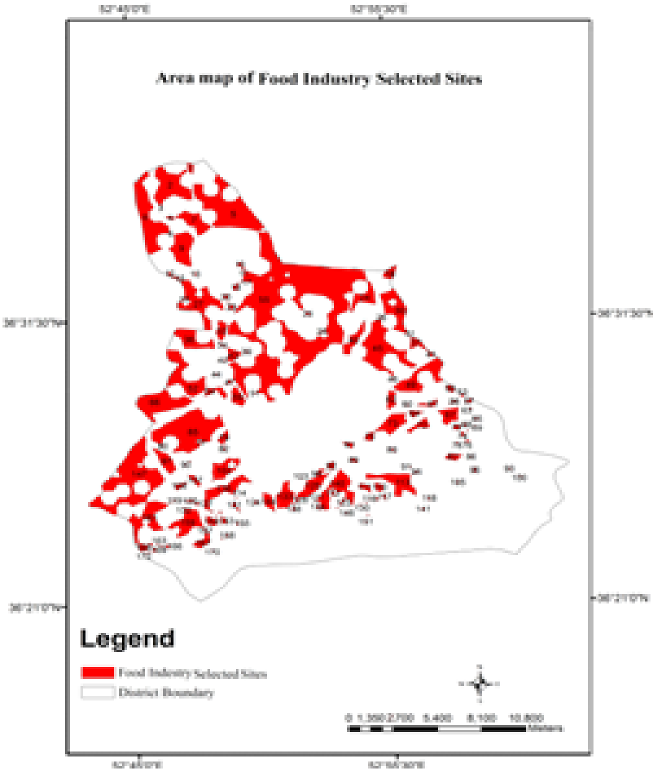

Figure 4: The identified sites for food industry

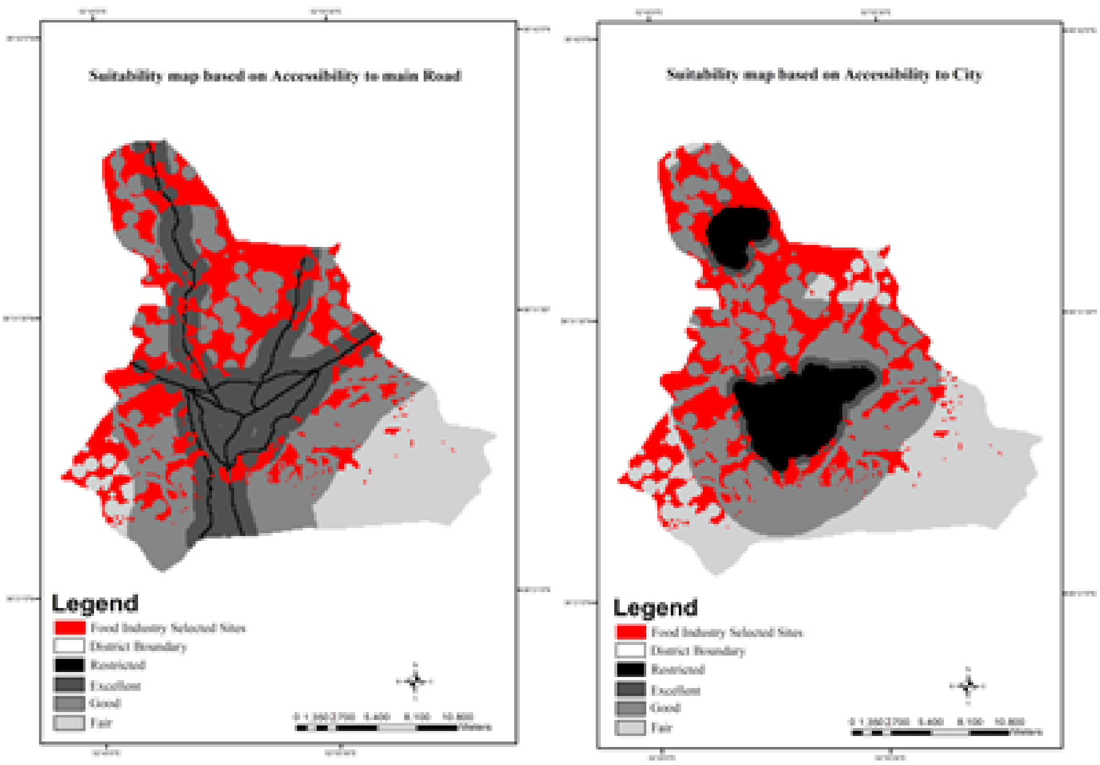

Figure 5: Overlaying the reclassified road and city layers with the food industry potential areas

Num.	**Area (m^2)**	**Num.**	**Area (m^2)**	**Num.**	**Area (m^2)**	**Num.**	**Area (m^2)**
1	204177.1	44	9370.83	87	317852	130	9370.83
2	3313584	45	4539713	88	9370.83	131	52248.23
3	9370.834	46	9370.83	89	85504.24	132	9370.83
4	77501.12	47	43786.91	90	9370.83	133	1301180
5	6590508	48	9370.83	91	9370.83	134	28252.46
6	9370.83	49	2565882	92	153669	135	9370.83
7	1534054	50	146485.5	93	9370.83	136	1828219
8	4435425	51	9370.83	94	9370.83	137	27373.79
9	2251981	52	3017816	95	18688.1	138	32426.07
10	76395.63	53	29992.5	96	38136.55	139	8764.929
11	27373.79	54	478106.1	97	1029404	140	2319008
12	36775.16	55	31146793	98	8764.929	141	18688.1
13	18688.09	56	38136.55	99	9370.83	142	18475.33
14	27373.79	57	57489.52	100	9370.83	143	9370.83
15	27373.79	58	9370.83	101	9370.83	144	528973.3
16	393580.2	59	684598.4	102	1379043	145	18688.22
17	9370.83	60	18475.26	103	9370.83	146	9370.83
18	85210.85	61	204218.4	104	9370.83	147	7720692
19	13686.89	62	479902.7	105	9370.83	148	9370.83
20	66137.07	63	18475.26	106	9370.83	149	9370.83
21	13686.89	64	213646	107	230498	150	9370.83
22	9370.83	65	18475.26	108	154352.4	151	9370.83
23	80382.71	66	3478239	109	13686.89	152	9370.83
24	1209047	67	929933.7	110	211504.5	153	100814.6
25	42259.23	68	31709.22	111	225233.1	154	300650.4
26	9370.83	69	9370.83	112	61788.52	155	38136.37
27	3266580	70	119978.1	113	2105502	156	9370.83
28	9370.83	71	9370.83	114	9370.83	157	27373.79
29	9370.83	72	484579.2	115	9370.83	158	18475.33
30	2348619	73	1431419	116	18688.1	159	1958902
31	9370.83	74	46204.14	117	54437.88	160	9370.83
32	575566.6	75	240995.4	118	28252.42	161	2415446
33	9370.83	76	36921.23	119	18688.16	162	9370.83
34	13686.89	77	13686.89	120	54174.17	163	31709.23
35	9370.83	78	18475.26	121	9370.83	164	9370.83
36	1779483	79	321611.3	122	36355.81	165	18688.16
37	425712.7	80	9370.83	123	9370.83	166	36775.29
38	13686.89	81	137584.3	124	32120.72	167	496511.9
39	18475.36	82	18688.22	125	1444155	168	215209.6
40	947224.7	83	18475.26	126	9370.83	169	36775.29
41	59771.52	84	9370.83	127	32426.01	170	9370.83
42	9370.83	85	6883768	128	18688.22	171	9370.83
43	475565.1	86	9370.83	129	18475.26	172	9370.834
Counted sites		172		Sum area (m^2)		116267775.597057	
Max. area (m^2)		31146793		Min. area (m^2)		8764.929	

Table 6: Statistics of the potential sites for food industry

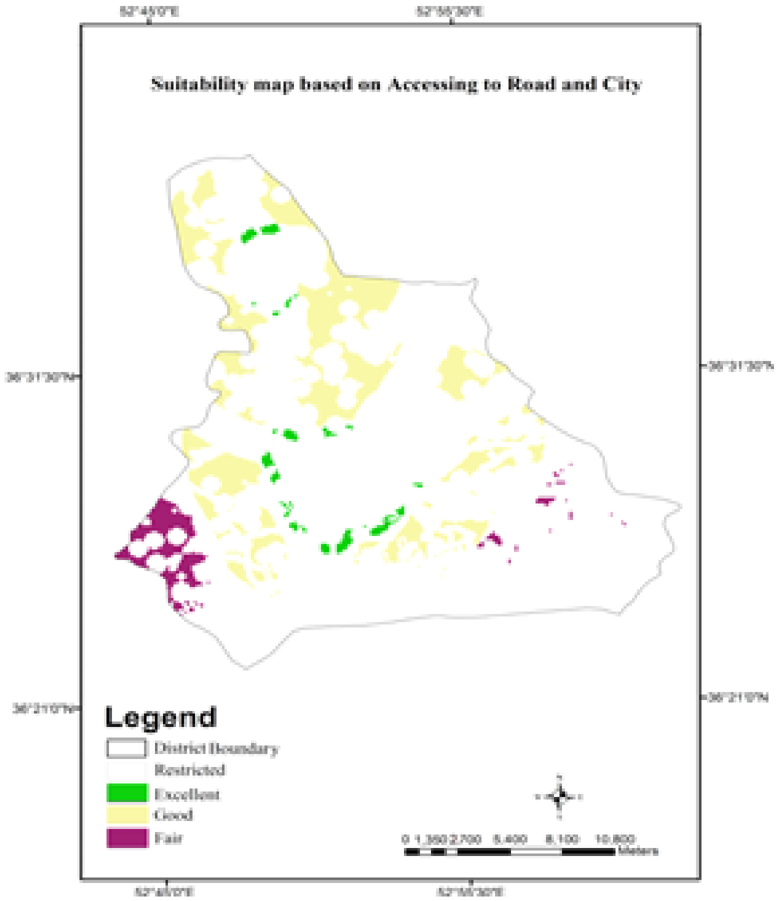

Figure 6: The final suitability map of the potential areas based on proximity to the main roads and cities

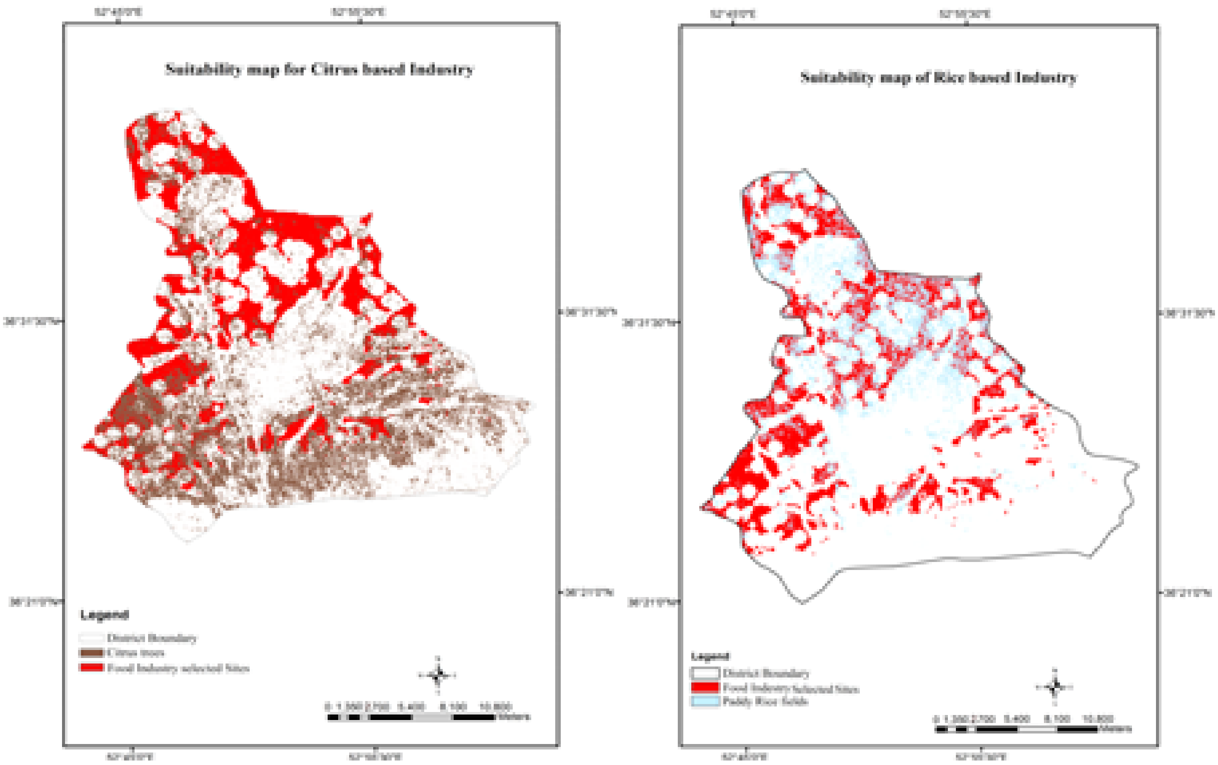

Figure 7: Overlaying the citrus and rice layers with the food industry potential areas.

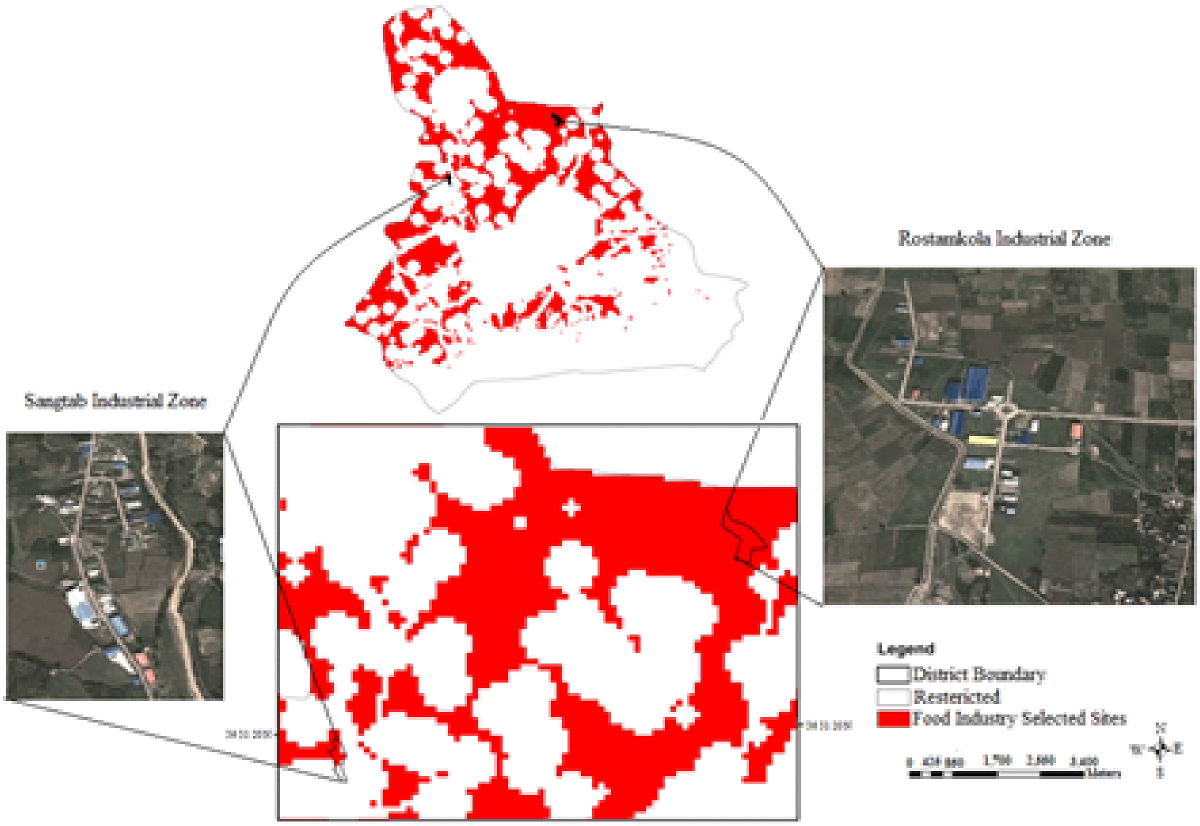

Figure 8: Overlaying the current industrial zones with the food industry potential areas

3.4 Evaluation of the existing industrial zones for food industry plants construction

Finally, a comparative analysis was carried out between the food industry plants suitable sites identified in this study and the existing industrial zones. In this respect, the Rostamkola and Sangtab industrial zones were overlaid with the food industry potential areas identified in this study to investigate the suitability of the existing industrial zones for food industry (Figure 8). The results showed that the Rostamkola industrial zone located in north-east of the study area with the area of about 34 hectares is entirely suitable for locating food industry plants, based on the food industry potential sites identified in this study. On the other hand, it was found that only the north half of the Sangtab industrial zone with the area of about 17 hectares is suitable for establishing food-related industries.

3.5 Overall discussion

In satellite image processing, we found that although NDVI and EVI techniques both were developed for detection of vegetation, but NDVI is good in separation and extraction of forest and citrus trees, while EVI is better for the extraction of rice fields. Overall, satellite-derived indices were found useful for the extraction of different land cover types.

The study indicated higher performance of the weighted overlay method compared with fuzzy overlay approach in identifying the food industry plants potential sites within the study region. In this study, primarily, the restricted and non-restricted areas for constructing food industry plants were identified. Moreover, the input layers for site selection had the same influence based on the criteria and all were reclassified into two specified classes: allowed and not-allowed. Therefore, the fuzzy-based site selection models are not appropriate in such applications. Nevertheless, different fuzzy overlay algorithms including AND, OR, SUM, and Gamma were tried in this study, but only fuzzy AND model could provide reliable site selection result for food industry. The fuzzy methods may be useful where the input layers have different values and different influences in final site selection result.

Initially, the suitable sites in the study area for food industry plants were identified. Since rice and citrus are the main products of the study area, to ensure food security and income for the people of the region, suitable site selection to build food industry plants to sort, package, store, convert, and process rice and citrus is very important.

In addition, because Ghaemshahr is the main hub of rice and citrus production in the country as well as export, food security at the national level can also be ensured. Therefore, we reclassified the generated site selection map based on the proximity to raw rice and citrus materials to find out the sites that are more suitable for building rice and citrus related plants among the selected sites.

The existing industrial zones in the study area are proposed for locating all industries. However, selecting a suitable site for food industry requires special criteria and considerations. The problem is that any specific zone for locating food related industries is not suggested in the study area. Since there is no any up-to-date geodatabase for siting food industries in the study area, and also selecting a site and then inquiry from the related organizations to see whether the selected site is suitable or not for locating a food industry is tedious and time consuming, usually investors prefer to use the existing industrial zones to locate food industries. Therefore, to ensure food security, this study provided an up-do-date geodatabase, in which the potential sites for locating food industries as well as the level of suitability of those sites were identified. The proposed model will be useful for policy makers in the region as well as the manufacturers and investors.

4 Conclusion

This study aimed at investigating the effectiveness of geospatial technology to identify the potential sites for food industry plants so as to ensure food security in study area. In this respect, the study provided an efficient and up-do-date database, in which the potential sites for establishing food industries as well as the level of suitability of those sites are determined. Since rice and citrus are the main products of Qaemshahr County and this region is the main hub of rice and citrus production in the country as well as export, to ensure food security at the regional and national level and ensuring the income of the people of the region, finding suitable sites for constructing the plants related to rice and citrus was also implemented. The study showed that the selected sites in south of the study area are more suitable for establishing the citrus-related industries and the selected sites in middle and northern parts of the study area are more suitable for establishing the rice-related industries based on the proximity to raw materials. Furthermore, the suitable sites in the existing industrial zones which can be considered for food industries were identified. Nevertheless, none of the existing industrial zones are located within the excellent sites for food industries. Besides, the effectiveness of geospatial technology for food industry site selection to ensure food security was demonstrated. The study concluded that the identified sites for food industry are reliable and could be used for future food industry plans at the study area. In addition, the findings of this study are useful to ensure food security in the region and country.

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