SUITABILITY MODEL BASED ON GIS AND MCDA FOR SPATIAL DISTRIBUTION OF SETTLEMENTS IN DIFFERENT GEOGRAPHIC ENVIRONMENTS

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Abstract

The spatial structure of settlements in Duhok Governorate in Iraq has changed over the last two decades, far from the comprehensive spatial planning. The study was carried out in two different geographical environments, one is in plain area (Semil), and the other is in mountainous area (Amidy). This study aims to detect the spatial distribution patterns of settlements in each district, and to develop a spatial suitability model for settling in each part of the study area. This model helps researchers, governmental sectors, and decision makers to develop a general framework of rural development.

Inter-disciplinary methodology has been used, based on combination between MCDA (Mulit-Criteria Decision Analysis) and GIS capabilities. The process was conducted based on eleven criteria, which were prepared using ENVI, ArcGIS10.1, and Global Mapper15. The AHP (Analytical Hierarchy Process) method were used to build weights for criteria, while WLC (weighted linear combination) approach was implemented to formulate suitability models in each district.

The study demonstrates a slight discrepancy between the spatial pattern of existing suitability potential and the actual distribution of settlements. According to the model, about 53.7% of study area is either suitable or highly suitable to build new settlements, and the remaining area 46.3% rated as either moderately, poorly suitable or unsuitable. However, the study found clearly different between Amidy and Semil. The model used in this study is applicable elsewhere in Iraqi Kurdistan Region.

Keywords: Suitability, spatial, settlements, GIS, models

Introduction

The spatial structure of the settlements has changed rapidly in Duhok Governorate, in Iraq, over the last two decades, precisely, after war in Iraq in 2003.. The most important consequence is the changes in the structure of settlements in terms of the spatial distribution (dispersion or cluster). In addition, the structure of the spatial distribution of Settlements (rural and urban) has taken a different shape, comparing to last two decades (before 2003).

Accordingly, the main problem of this research is the absence of the comprehensive planning overview by the institutions working on planning, and the Incompatibility between the distribution of settlements and the elements of the natural environment.

Before embarking on analyzing the study's phenomena, it is important to describe and highlight some terms that would respond in the study, the most prominent term is GIS- and Multi-Criteria Decision analysis (MCDA). MCDA is a tool includes the use of GIS to help decision making using multiple data sources (lioyd, 2010). There is great synergy between these two fields of knowledge, they benefit from each other (Malczewski, 2006). In spite of the multiplicity of views about MCDA (Henig & Buchanan, 1996; Silva & Blanco, 2003; Lloyd, 2010) but there is a consensus on main concept. Stewart explained that “the aim of any (MCDA) technique is to provide help and guidance to the decision maker in discovering his or her most desired solution to the problem"(Henig & Buchanan,1996,p.3). Malczewaki

(2006) concluded from the survey that the (MCDA) most often used for tackling land suitability problems, in comparing with the other types of problems. The bulk of the research undertaken in the scope of site suitability analysis, are used GIS based multi-criteria approaches, in field researches of human and natural aspect (Vahidnia, Alesheikh, & mohammadi, 2009; Wang, Guoxue , & Chen , 2009; Zamorano, Molero, Hurtado, Grindlay, & Ramos,2008;Demesouka,Vavatsikos,&Anagnostopoulos, 2013; Mohajeri & Amin,2010 ;Koc-San,San, Bakis, Helvaci, & Eker, 2013; Effat & Hegazy, 2012; Sharifi etal,2009;Jeong,Moruno,&Blanco,2013;Jeong,Moruno, & Blanco, 2012;Hossain, Chowdhury,Das,& Rahaman, 2007; Al-Mumaiz, 2012; Akıncı, Ozalp, & Turgut, 2013; Sener , Sener, Nas, & Karaguzel ,2010 , Anane, Bouziri, Limam, & Jellali, 2012).

The other terms are Multicriteria Evaluation (MCE) and Suitability Models (SM), (MCE) could be understood as a group of analytical methods that fall within the field of multicriteria decision analysis (MCDA) , in this approach relative importance of different criteria must be taken in to account ,(lioyd, 2010). This means that each variable has its weight. These techniques are used mainly as spatial decision support tools when addressing land suitability/facilities location and evaluation/assessment problems (Kemp, 2008).

While suitability analysis in its broadest sense involves the application of criteria to the land use, to assess where land is most and least suitable for development (Heacock & Hollander, 2011).The result of this process is the evaluation of the suitability for the entire study area based on a suitability index, which is useful for making a preliminary ranking of the most suitable lands (Malczewski, 2004, Malczewski, 2006).

The main objective of the study is to develop a general framework for regional and spatial planning in study area by creating suitable model with the aid of GIS, through the compatibility between the elements of both natural and human environments, to help decision makers to develop a platform to achieve sustainable spatial development.

Materials and Methodology

Study area

The study was carried out on the area which occupies extremely north parts of Iraq, north and northwest parts of Iraqi Kurdistan Region , within Duhok governorate (Fig. 1) ,first region (Amidy district) lies between latitudes which are (37°,21′,35″ N) and (36°,25′,11″ N) ,and longitudes (43°,04′,10″ E) (44°,06′,12″ E), this district is mainly composed of complex reliefs, covers an area of (2723 km^2)or (25.2%) of total area of governorate, and the population is (94703) which is compose of about (8%) of total population. While second region (Semil district) lies between latitudes (37° , 05′ , 48″ N)(36° , 25′ ,11″ N) and longitudes (42°,22′,43″ E)(43°,08′,47″ E) The area is plain with a simple combination of reliefs, especially in the northern parts, and occupies an area of (1270 km^2)or (11.7%) of total governorate's area ,and the population is (154074) which approximate (13.1%) of total population of the governorate .The entire study area occupies of about (3993 km^2) or nearly (37%) of governorate's area, and population (248777) which constitute nearly (21%) of total population of governorate (Table. 1).

Table. 1 Some geographic characteristics of study area (Compared to Governorate in percentage)

Standards	Area/km^2		No of cities	
Destricts	%	No	%	No
Amidy	25.2	2723	23.1	9
Semil	11.7	1270	20.5	8
Study area	36.9	3993	34.6	17
Duhok Governorat		10808		39

Standards	No of villages		Proportional distribution of villages			
			Inhabited		Deserted	
Destricts	%	No	%	No	%	No
Amidy	26.7	382	34.8	133	65.2	249

Semil	9.9	141	84.4	119	15.6	22
Study area	36.6	523	48.2	252	51.8	271
Duhok Governorat		1428				

Standards Destricts	Population Structure					
	Total Population		Urban Population		Rural Population	
	%	No	%	No	%	No
Amidy	8	94703	7.7	64414	8.8	30289
Semil	13.1	154074	13.6	113472	11.7	40602
Study area	21.1	248777	21.3	177886	20.5	70891
DuhokGovernorate		1177714		832184		345530

Materials

There is a variety data utilized in this study, which is assembled from a variety of sources. Firstly the essential population data were obtained from the last population estimates in 2009 which are made by the ministry of planning , Iraqi Kurdistan Region Government , cooperatively with the ministry of planning in Iraqi Government .Other data like administrative basic map, roads map and locations of villages and towns, all were obtained from the information centre in the governorate office, while the digital elevation model (DEM)and satellite image(Landsat7) of study area was downloaded from this website (Global land cover facility):ftp://ftp.glcf.umd.edu/glcf/Landsat/.Whereas the other data utilized, has been derived from previous data.

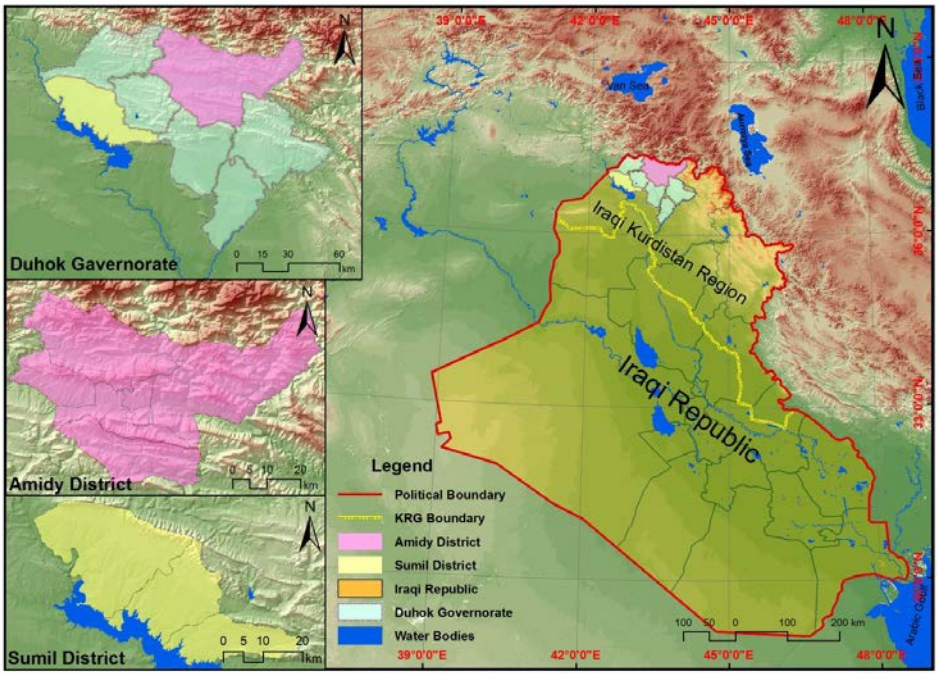

Fig. 1. Geographical location of the study area

Methodology

Methodology overview

The methodology involved the following precise steps (Fig. 2):

1. Selecting main criteria and sub-criteria to be used in the analysis process.
2. Collecting data from different sources, converted to layers in form to be manipulated in GIS environment, via aids of ArcGIS10.1, ENVI 5, Global Mapper 15.
3. Determinate the spatial distribution patterns of settlements by using nearest neighbour analysis (NNA).
4. Sub-parameters scored were assigned within the range of 0–10, in this scoring, the diversity of level of suitability, was taken into consideration. While high points

were given to the sub-parameters that more suitable, lower points were given to those that less suitable.

5. Determine prioritization of sub-criteria, based on the AHP and pair-wise comparison matrix, to obtain relative weights of each criterion.
6. Generating suitability models through applying the weighted linear combination (WLC) in a GIS environment.
7. Reclassification models according to increasing suitability levels to five main classes, highly suitable, suitable, moderately suitable, poorly suitable, and unsuitable.
8. Finally evaluating the results obtained from the previous steps.

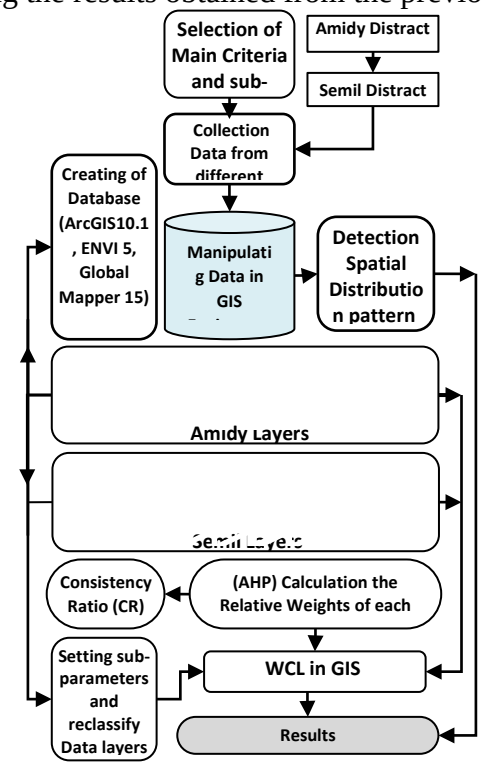

Fig. 2. Flowchart of methodology

Formulate Suitability Models

The study identifies two groups of criteria impact the suitability models of settling, physical and infrastructure criteria, which is in turn divided into sub-criteria, as shown in the Table. 2 and Fig. 3-4, namely: Land use type(LUT), topography (elevation, slope, and aspect), distance from water bodies (rivers(DR), lakes(DL), streams(DS)), distance from main road(DMR), distance from cities(DC), distance from villages (DV), Density of inhabited villages as a points(DIVP), density of rural population(DRP).

Description of criteria

Land use type (LUT)

An image of LANDSAT 7 acquired on 11 Jun 2006 was used to determine and classify the types of land use in study area. The sub-classes of land categories are classified to six classes, these classes are: Class 1,2, land covered by forest or utilized in diverse agriculture, it was considered with class 7 as a less convenient for establishing the settlements and utilize it in developing of the rural sector . Class 3, land moderately covered by vegetation or a mountainous valleys moderately covered in vegetation. Class 4, land partially covered by natural vegetation, which is grasses in general. Class 5, characterized either in slight vegetation or it is a rain-fed agriculture land, howsoever, it is unexploited in agriculture, but significantly arable and flat in general, so it is valid for human settling .Class 6, moderately

covered by vegetation, unexploited in agriculture processes, but affected by the human activities for being close to human settlements, or actually exploited by rural and urban settlements. Class 7, land with slight vegetation , susceptible for erosion processes, or it is rocky areas with complex topography , therefore this kind of lands are inappropriate for establishing settlements and utilizing in developing rural sector.

Elevation

Elevation status was derived from the digital elevation model (DEM), in study area, the status of elevation factor considered as an important factor that constrains the human activities. The elevation types were divided to ten categories, areas with high altitude assigned as less suitable, and areas low altitude assigned more suitable for settling.

Slope

Slope plays a crucial part in variation of the levels of land suitability for human habitation. Generally slope restricts all human activities spatially potential cultivation. Accordingly, the land suitability for human inhabitation decreases with increasing slope and increases with decreasing slope. The bulk of study area were very steep and rugged, especially in Amidy district. Relative grades were assigned according to degrees of steepness.

Table 2 Main criteria, sub-criteria used in formulation models and relative sub-parameter and scores

Main Criteria	Physical criteria										
Topography Elevation (km)				Slope (Degrees)				Aspect			
Amidy		Semil		Amidy		Semil		Amidy		Semil	
Sub-Parameters	Score	Sub-Parameters	Score	Sub-Parameters	Score	Sub-Parameters	Score	Sub-Parameters	Score	Sub-Parameters	Score
0.5>	10	0.4>	9	2>	9	2>	10	Flat	9	Flat	9
0.5-0,7	9	0.4-0,5	8	2.1-4	9	2.1-4	9	S	9	S	9
0.7-0.9	8	0.51-0.6	8	4.1-8	8	4.1-8	8	SE	8	SE	8
0.9-1.1	7	0.61-0.7	6	8.1-12	7	8.1-12	7	SW	8	SW	8
1.1-1.3	6	0.71-0.8	3	12.1-16	6	12.1-16	6	E	6	E	6
1.3-1.5	5	0.81-0.9	2	16.1-20	4	16.1-20	4	W	5	W	5
1.5-1.7	4	0.91<	1	20.1-24	3	20.1-24	3	NE	3	NE	3
1.7-1.9	3			24.1-28	0	24.1-28	0	NW	2	NW	2
1.9-2.1	2			28.1-32	0	28.1-32	0	N	1	N	1
2.1<	1			32<	0	32<	0				
Main Criteria			Physical criteria								
Distance from water bodies Lakes (km)				Streams (km)				Rivers (km)			
Amidy		Semil		Amidy		Semil		Amidy		Semil	
Sub-Parameters	Score	Sub-Parameters	Score	Sub-Parameters	Score	Sub-Parameters	Score	Sub-Parameters	Score	Sub-Parameters	Score
-	-	3>	9	1>	1	0.5>	1	1>	10	10>	9
-	-	3.1-6	8	1-2	2	0.5-1	2	1-2	9	10.1-20	8
-	-	6.1-9	7	2-3	3	1-1.5	4	2-3	8	20.1-30	7
-	-	9.1-12	6	3-4	4	1.5-2	6	3-4	7	30.1-40	6
-	-	12.1-15	5	4-5	5	2-2.5	8	4-5	6	40.1-50	5
-	-	15.1-18	4	5-6	6	2.5-3	9	5-6	5	50.1<	4
-	-	18.1-21	3	6-7	7	3-3.5	6	6-7	4		
-	-	21.1-24	2	7-8	8	3.5-4	3	7-8	3		
-	-	24.1<	1	8<	9	4-4.5	2	8-9	2		
						4.5<	1	9<	1		
Main	Physical criteria			infrastructure and socio-economic factors							

Criteria										
Land use type(LUT)				Density of Rural population(DRP)				Density of inhabitant villages as a points(DIVP)			
Amidy		Semil		Amidy		Semil		Amidy		Semil	
Sub-Parameters	Score	Sub-Parameters	Score	Sub-Parameters	Score	Sub-Parameters	Score	Sub-Parameters	Score	Sub-Parameters	Score
Class 1-2	2	Class 1-2	2	20>	9	25>	9	0.05>	9	0.05>	9
Class 3	3	Class 3	3	21-40	8	25.1-50	8	0.05-0.1	8	0.05-0.1	8
Class 4	8	Class 4	5	41-60	7	50.1-75	7	0.1-0.15	7	0.1-0.15	7
Class5	9	Class5	9	61-80	5	75.1-100	6	0.15-0.2	5	0.15-0.2	6
Class6	6	Class6	7	81-100	3	101-125	4	0.2-0.25	3	0.2-0.25	5
Class7	0	Class7	4	110-120	2	151-200	3	0.25-0.3	2	0.25-0.3	4
				130<	1	201<	1	0.3<	1	0.3-0.35	3
										0.35<	1
Main Criteria	infrastructure and socio-economic factors										
Distance from villages(DV)(km)				Distance from cities(DC)(km)				Distance from main road(DMR)(km)			
Amidy		Semil		Amidy		Semil		Amidy		Semil	
Sub-Parameters	Score	Sub-Parameters	Score	Sub-Parameters	Score	Sub-Parameters	Score	Sub-Parameters	Score	Sub-Parameters	Score
1>	9	0.7>	10	5>	6	3>	6	3>	10	2>	10
1-2	8	0.7-1.4	9	5.1 -10	7	3.5 -7	7	3-6	9	2-4	9
2-3	7	1.4-2.1	8	10.1-15	9	7.1-10.5	9	6-9	8	4-6	8
3-4	6	2.1-2.8	7	15.1-20	5	10.6-14	8	9-12	7	6-8	7
4-5	5	2.8-3.5	6	20.1-25	4	14.1-17.5	5	12-15	6	8-10	6
5-6	4	3.5-4.2	5	25.1-30	2	17.6-21	4	15-18	5	10-12	5
6-7	3	4-2.4.9	4	30.1-35	0	21.1-24.5	2	18-21	4	12<	4
7-8	2	4.9-5.6	3	35<	0	24.6-28	0	21-24	3		
8<	1	5.6-6.3	2			28<	0	24-27	2		
		6.3<	1					27<	1		

Aspect

As known that the southern and western aspects are more suitable for setting up human settlement, because they are more exposed to sunlight, and receive a large portion of solar radiation during the days of the year .Accordingly, the flat and southern aspects are considered as more suitable, followed by south east and south west aspects, while eastern and western aspects comes in third ranks, northern, north west, and north east aspects are less suitable. Depending on the digital elevation model of, the aspect map was generated.

Distance from water bodies

In general term, proximity to lakes and permanent rivers mean that the settlements population can easily access to the potable fresh water. In addition to, preserve affordable permanent source of water for agricultural processes. On the other hand, it is more suitable for settlements to be far as possible from rugged wadies and dry streams. Subsequently, between 6-10 buffer zones has been drawn around lakes, streams and rivers, and relative suitability were assigned, buffers near to lakes and permanent rivers are more suitable, while buffers near to streams are less suitable.

Distance from main road(DMR)

Settlements should not be located too far from the roads, but near to the main roads as much as possible, hence closeness to roads is preferable. The closeness map to the roads were obtained through 7-10 buffer zones, and its relative suitability of zones were assigned according to the degree of closeness to the roads.

Distance from cities(DC)

As long as the cities and nearby area are more crowded and has a high population density, it is better to set up new settlements, or re-develop the existing ones, a little away from urban area, to ensure the re-distribution of the population in better way, but within distance not impact the mutually supportive relationships between settlements and cities. Accordingly, the closeness map to the cities were generated through 8-9 buffer zones, and its relative suitability were assigned.

Distance from villages(DV)

Sites of settlements has been selected in accordance with the long experience of human being in the exploitation of land surrounding it, Therefore the settlements and surrounding land is suitable for human settling compared with proportionally farthest areas. So 9-10 buffer zone has been drawn around settlements and relative suitability were assigned.

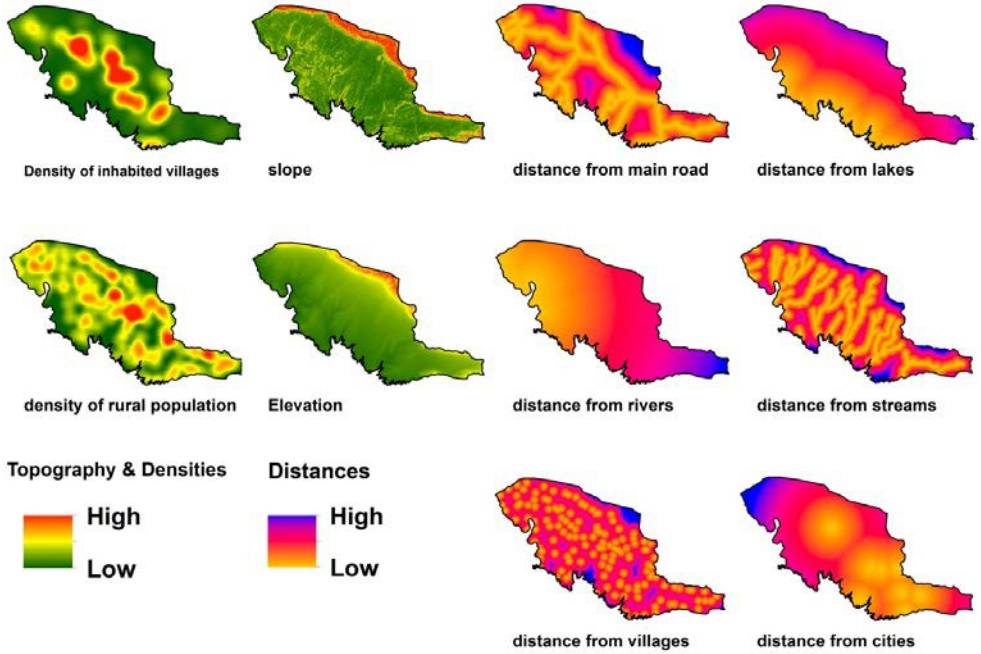

Fig. 3. Criteria for suitability model in Amidy district (except land use type and Aspect)

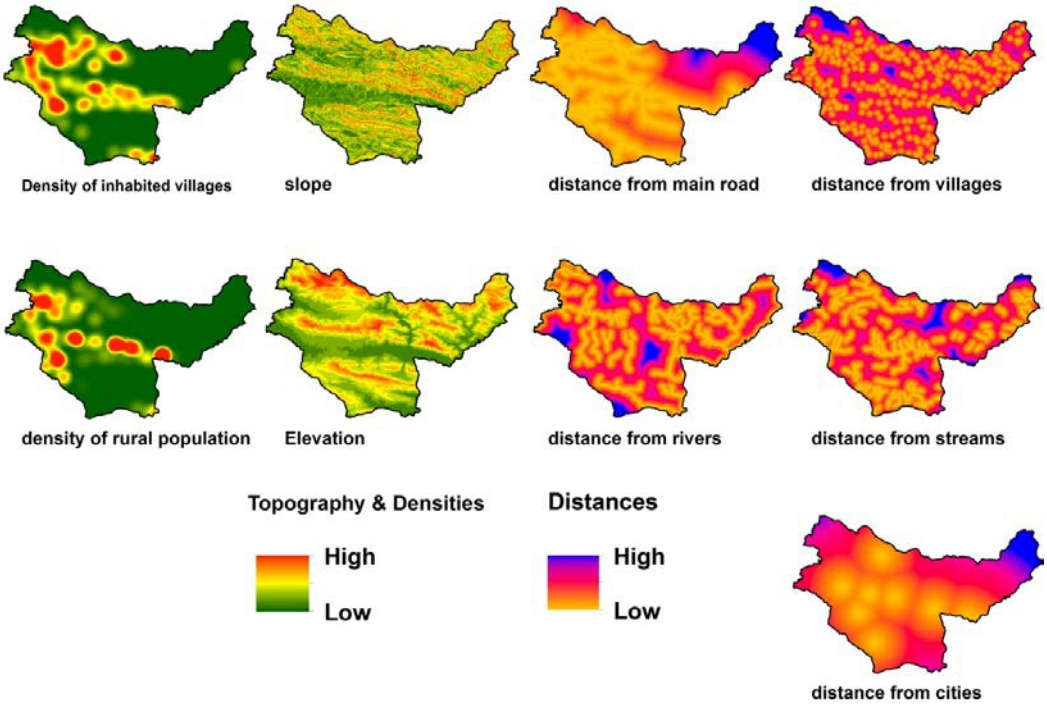

Fig. 4 Criteria for suitability model in Semil district (except land use type and Aspect)

Density of inhabited villages as a points(DIVP)

Map of density villages were derived from the layer of points locations of villages without taking into account the attributes of population of villages , because in this matter we only want to know the density of the existing (inhabited) villages, just as points, and so the villages deserted were excluded .The main objective of this criterion is to aid the designation vacant zones of villages, but valid for human habitation, and to insure the new settlements, or re-develop the existing ones, to be far from the inhabited ones .The density maps were generated using the tool of kernel density in spatial analysis extension in ArcGIS 10.1 , and classified to 7-8 classes according to density levels . The classes with more density are less convenient, and classes with less density are more convenient.

Density of Rural population(DRP)

Density rural population map was obtained using the same process as for creating the map of density villages, also deserted villages were excluded, but taking into account the attributes of population of villages as weight field, in order to obtain a map describing the characteristics of the distribution of rural population .It is preferable to avoid setting up new settlements, or re-development the existing ones, inside the areas which have high rural density.

Determination of Weights

One of the crucial points in this context of analysis is to assig weights to the criteria involved, the most powerful tool to solve this problem is AHP method (Akıncı et al 2013). The first step is to establish priorities of criteria or relative weights (Reciprocal matrix) to differentiate the importance of the criteria(Hossain et al ,2007), in this study the priority of factors and criteria were assigned, depending on the author experience and field literatures related .The second step is to determine the weights by normalizing the pairwise comparison matrix (Erden & kun , 2010), finally a consistency ratio is calculated for the pairwise comparison matrix to verify the degree of credibility of the relative weights , by using the following ratio(Bunruamkaew ,2001 ; Hossain et al ,2007):

$$CR = \frac{CI}{RI}$$

Where (RI) is the random consistency index. For n = 11 or 12, $RI = 1.51 or 1.48$.

The consistency index (CI) is determined using the following equation (Anane et al, 2012):

$$CI = \frac{\lambda_{\max} - n}{n-1}$$

Where $\lambda_{\max}$ the maximum value of eigenvector, and (n) is the criteria number.

If the value of consistency rate (CR) is above (0.10), then there are inconsistencies in the evaluation process, but if the (CR) value is less than (0.10) indicating the consistency in evaluation process .The calculations of reciprocal matrix, pair wise comparison matrix, consistency ratio, random consistency index, consistency index, related to the study area criteria, can be seen in Table. 3 and 4 .Many researchers mentioned accurate details about theoretical framework and how to apply the AHP method (Hossain et al ,2007; Anane et al ;2012 ; Tudes & Yigiter, 2010 ; Sener et al, 2010 ;Thirumalaivasan, Karmegam & Venugopal, 2003; Vaidya, & Kumar, 2004 ; Xiaoguo,2010)

Table 3 Pairwise comparison matrix for suitability model in Amidy district and assigned weights of criteria

	LUT	Slope	DMR	DR	Aspe	Eleva	DS	DC	DRP	DIVP	DV	Weights
LUT	1	1	2	2	3	4	5	6	7	9	9	0.2196
Slope	1	1	1	1	2	3	4	5	6	8	9	0.1689
DMR	0.50	1	1	1	2	3	4	5	6	7	8	0.1552
DR	0.5	1	1	1	1	2	3	4	5	7	8	0.1318
Aspect	0.33	0.5	0.5	1	1	2	3	3	4	6	7	0.1047

Elevation	0.25	0.33	0.33	0.5	0.5	1	2	2	3	5	6	0.0697
DS	0.2	0.25	0.25	0.33	0.33	0.5	1	2	2	4	5	0.0505
DC	0.16	0.2	0.2	0.25	0.33	0.5	0.5	1	2	3	4	0.0390
DRP	0.14	0.16	0.16	0.2	0.25	0.33	0.5	0.5	1	2	3	0.0281
DIVP	0.11	0.125	0.14	0.14	0.16	0.2	0.25	0.33	0.5	1	2	0.0184
DV	0.11	0.11	0.12	0.12	0.14	0.16	0.2	0.25	0.33	0.5	1	0.0141

Lambda Max λ_{max} =(11.429) ,Consistency Index (CI)=(0.0429), Consistency Ratio (CR)=(0.028428882), Random Consistency Index (RI)=(1.51), n=(11)

Table 4 Pairwise comparison matrix for suitability model in Semil district and assigned weights of criteria

	LUT	Slope	DMR	DR	Aspe	Lake	Eleva	DS	DC	DRP	DIVP	DV	Weights
LUT	1	1	2	2	3	4	4	5	6	7	9	9	0.2086
Slope	1	1	1	1	2	3	3	4	5	6	8	9	0.1601
DMR	0.50	1	1	1	2	3	3	4	4	6	7	8	0.1456
DR	0.5	1	1	1	1	2	2	3	4	5	7	8	0.1235
Aspect	0.33	0.5	0.5	1	1	1	2	3	3	4	6	7	0.0950
Lake	0.33	0.33	0.33	0.5	1	1	1	2	3	4	5	7	0.0762
Elevation	0.25	0.33	0.33	0.5	0.5	1	1	1	2	3	4	5	0.0589
DS	0.2	0.25	0.25	0.33	0.33	0.5	1	1	1	2	3	4	0.0428
DC	0.16	0.2	0.25	0.25	0.33	0.33	0.5	1	1	1	2	3	0.0326
DRP	0.14	0.16	0.16	0.2	0.25	0.25	0.33	0.5	1	1	1	3	0.0240
DIVP	0.11	0.125	0.14	0.14	0.16	0.2	0.25	0.33	0.5	1	1	1	0.0175
DV	0.11	0.11	0.125	0.125	0.14	0.14	0.2	0.25	0.33	0.5	1	1	0.0145

Lambda Max λ_{max} =(12.344) ,Consistency Index (CI)=(0.0313), Consistency Ratio (CR)=(0.0211), Random Consistency Index (RI)=(1.48), n=(12)

Derivation of suitability models

The final step is to overly criteria layers, by combining the weights and criteria's maps to obtain an overall suitability score in composite maps. WLC was applied via below equation (Moeinaddini, Khorasani, Danehkar, Darvishsefat,& Zienalyan ,2010 ; Malczewski, 2006 ; Xu & Zhang , 2013 ; Bunruamkaewa ,2001) :

$$R = \sum_{i=1}^{n} W_i \times C_i$$

Where R is the suitability index, W_i is the weight of $i-th$ criterion derived from the pairwise comparison matrix in AHP method, $(\sum W = 1)$, C_i is the standard score of the $i-th$ criterion, n number of criteria.

Results and Discussions

Distribution patterns of settlements

Tables 5 summarize the results of applying (NNA) tool in study area, it shows quite clearly that there is different patterns of settlements distribution, between random, clustered, and dispersed.

Table. 5 Results of NNA in study area.

Districts / Standards	Amidy			semil		
	Total villages	inhabited	Deserted	Total villages	inhabited	Deserted
Observed Mean Distance	1338.6	1726.7	1712.6	1844.5	1979.6	3555.7
Expected Mean Distance	1335	2262.5	1653.6	1500.8	1633.7	3799.6
Nearest Neighbor Ratio(NNR)	1.00	0.76	1.03	1.22	1.21	0.93
Critical Value (Z-score)	0.10	-5.22	1.07	5.2	4.41	-0.57
Significance Level(P-value)	0.91	0.00	0.28	0.00	0.00	0.56
Distribution Pattern	random	clustered	random	dispersed	dispersed	random

The most important values in Table 5 are that related to the pattern distribution of inhabited settlements. In Amidy district the pattern distribution is clustered (NNR is 0.76) in a high statistically significant, as long as the Z-Score is negative (-5.22) and out of the range of critical value (+2.58 and - 2.58), and at a very high confident level (P-value) , so in a high confident level we reject the null hypothesis and accept the alternative hypothesis which states that the settlements are distributed according to special pattern far from randomization .While in Semil district the pattern distribution is dispersed (NNR is 1.21) also in a high statistically significant , as long as the Z-Score is positive (4.41) and out of the range of critical value (+2.58 and - 2.58), and also at a very high confident level (P-value) . As set forth above, these results enhance our attitude, in to proceed towards formulate an alternative models, suitable to achieve sustainable rural development in study area.

Suitability Distribution models

According to the implementation of suitability concept techniques which utilized in this study, two suitability maps were obtained, highlighted the level of suitability of land for redeveloping rural sector in both districts of study area. In general the end products are generalized maps showing areas that are having either low, moderate, or high land suitability as shown in Fig 5, 6 and Table 6.

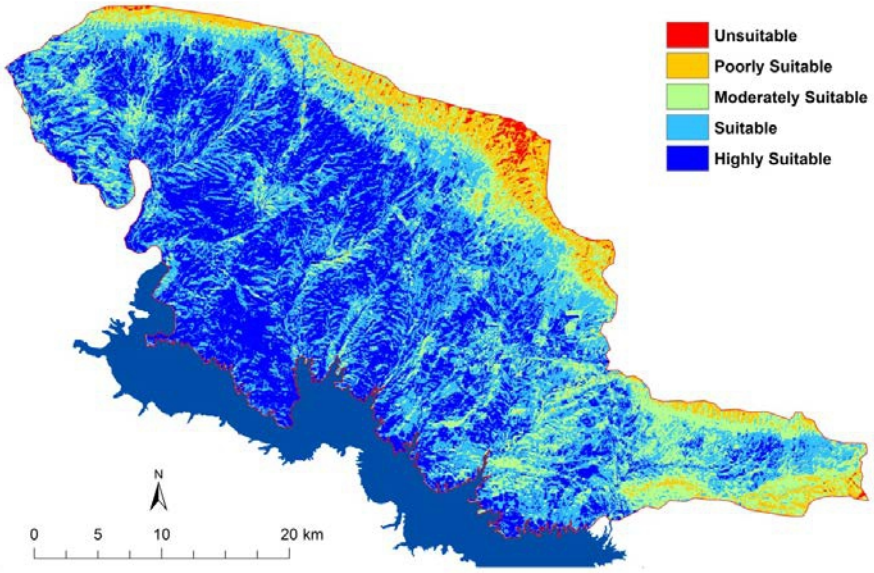

Fig. 5 Suitability map of Semil distric

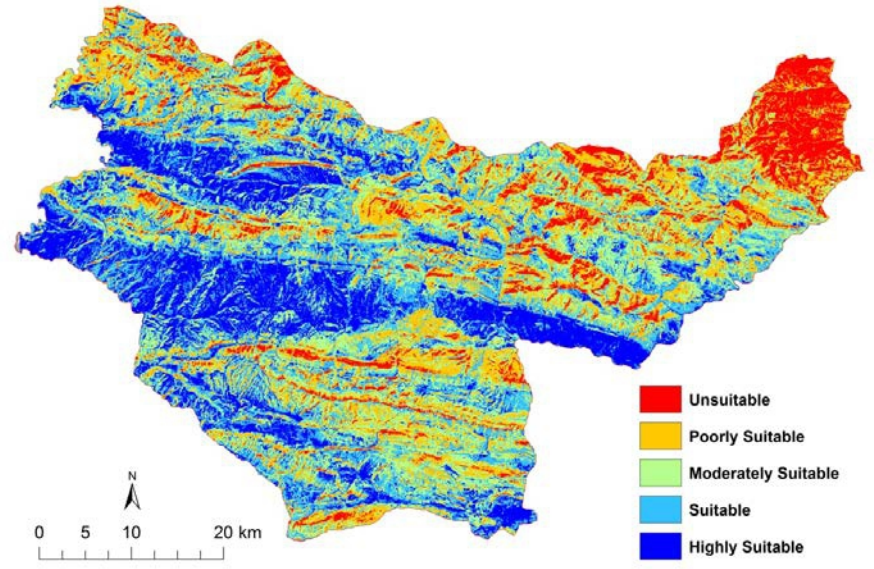

Fig. 6 Suitability map of Amidy district

The results show that more than half area of the study region, of about (53.7%)(2144.5 km^2), is either suitable or highly suitable to build new settlements, which make up(28.6%)and (25%) respectively, so it's clearly favorable for human being living, while the remaining area (1848.5 km^2) are clearly rated as either moderately, poorly suitable , or unsuitable,(22.81%),(16.29%),(7.19%) respectively and this area is more or less unfavorable for human being living.

But the data in this regard has demonstrated clearly different picture than above in Amidy and Semil district. Only about (0.67%)(8.5 km^2) from the whole of Semil region was rated unsuitable, and (5.87%)(74.5 km^2) as poorly suitable ,(18.27%) (232 km^2) moderately suitable , In return a very large portion of the area, more than three-quarters of the total area of the region about (955 km^2) or (75.19%) comes under suitable or highly suitable area, make up (39.46%)and(35.73%) respectively. This area mainly located in the central, south and south west parts of region, while unsuitable area coincident with the mountainous area in the north and north east parts of the region (Fig. 3).

Table. 6 Total and percentage area according to the suitability levels in study area

Level of suitability	Amidy District		Semil District		Study area	
	Area km^2	%	Area km^2	%	Area km^2	%
unsuitable	278.4	10.22	8.5	0.67	286.9	7.19
poorly suitable	576.1	21.16	74.5	5.87	650.6	16.29
moderately suitable	679	24.94	232	18.27	911.0	22.81
suitable	642.1	23.58	501.2	39.46	1143.3	28.63
highly suitable	547.4	20.10	453.8	35.73	1001.2	25.07
	2723	100	1270	100	3993.0	100

in Amedy district the proportional distribution of area on suitable classes depicts a kind of proportionality, more than (10%)(278.4 km^2) of the area region are rated as unsuitable, and it is clearly unfavourable for human being living ,(%21.16)(576.1km^2) rated poorly suitable , (24.94%)(679km^2) rated as moderately suitable. while a large portion of the area of region rated as either suitable or highly suitable, (23.58%)(20.10%) respectively , or (642.1 km^2) and (547.4 km^2) of the total area of region .the last two classes stretches crosswise in the form of a cross section, between eastern and western parts of the region , while unsuitable and poorly suitable area are more concentrated in the northern and north eastern parts of region (Fig. 4)

Conclusion

At the final of analytical process the study concluded that there are an extensive areas unexploited, If it is exploited in a rational manner, it could play a pivotal role in development of rural sector. Additionally, the study indicated that there was a slight discrepancy between the spatial pattern of existing suitability potential and the actual distribution of settlements , therefore the study proposed to construct a new settlements, or candidate some of the deserted ones to be revived (Fir 7 and 8). The results show also that the spatial patterns of distribution of settlements, are not coincides with the spatial pattern of distribution of suitability areas.

In spite of all the aforementioned, the suitability analysis attempted in this study must be viewed as a basic prioritization of land for rural development, therefore, further study should be undertaken to carry out and determine land use suitability index for this purpose. A more refined result will be obtained if study conducted on criteria with more details. Therefore, more efforts are needed to put on survey and fieldwork to collect accurate data on criteria being used. Moreover, the results of the study could be considered as preliminary index for local authorities and decision makers to guide them to take adequate decisions, beside the fact that, the adopted methodology may be also applicable elsewhere in Iraqi Kurdistan Region to assess and re-develop rural sector.

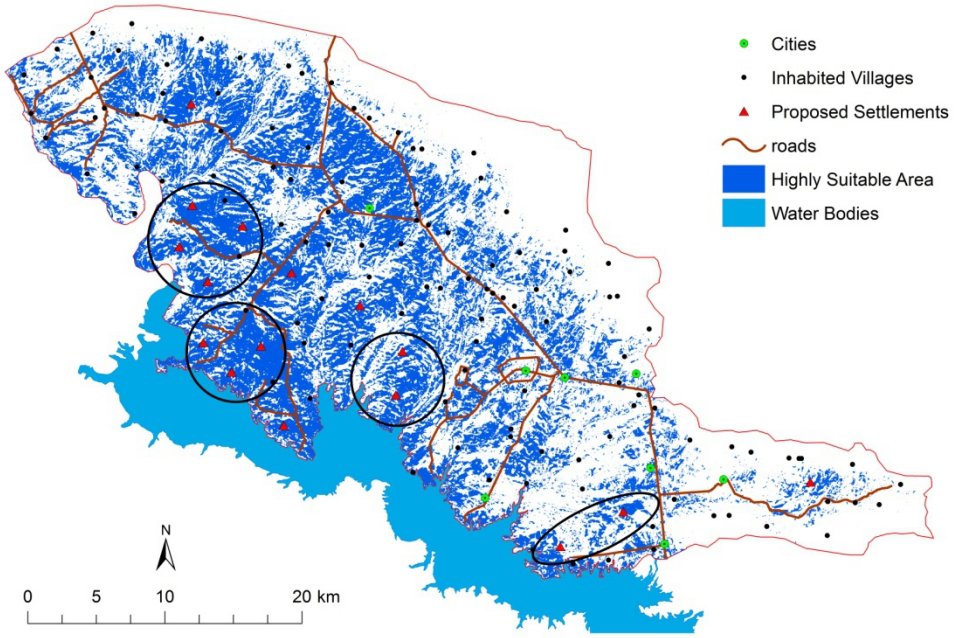

Fig. 7 Proposed model for redevelopment of rural sector in Semil district

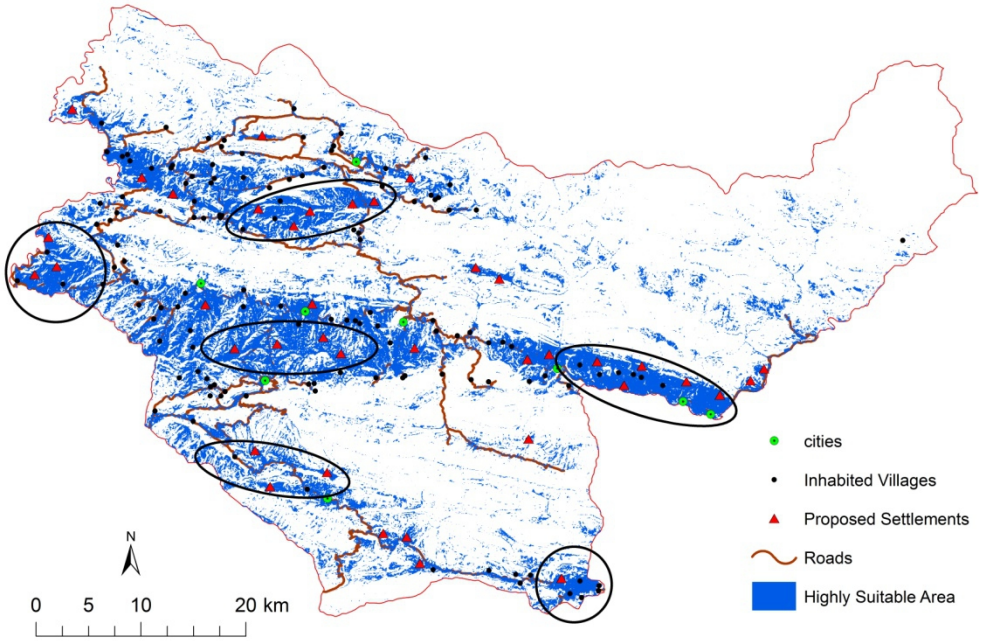

Fig. 6 Proposed model for redevelopment of rural sector in Amidy district

References:

Akıncı, Halil, Ayse, Yavuz, Ozalp , & Bulent, Turgut.(2013). Agricultural land use suitability analysis using GIS and AHP technique. *Computers and Electronics in Agriculture*, 97, 71–82. Retrieved from http://dx.doi.org/10.1016/j.compag.2013.07.006

Al-Mumaiz, Maha O. (2012). Spatial Multi-Criteria Assessment to Select Optimum Route To Improve Transportation Network in Al-Omarah City. *Eng. & Tech. Journal*, .30(8), 1351-1361.

Anane, Makram, Lamia. Bouziri, Atef. Limam, & Salah. Jellali. (2012). Ranking suitable sites for irrigation with reclaimed water in the Nabeul-Hammamet region (Tunisia) using GIS and AHP-multicriteria decision analysis. Resources. *Conservation and Recycling*, 65, 36– 46. Retrieved from http://dx.doi.org/10.1016/j.resconrec.2012.05.006

Bunruamkaew, Khwanruthai. (2011). and Yuji Murayamaa. Site Suitability Evaluation for Ecotourism Using GIS & AHP: A Case Study of Surat Thani Province. Thailand. *Procedia Social and Behavioral Sciences*, 21,269–278.doi:10.1016/j.sbspro.2011.07.024

Campagna, Michele.(2006).*GIS for Sustainable Development*. New York: CRC Press.

Demesouka, O.E., A.P. Vavatsikos , & K.P. Anagnostopoulos .(2013). Suitability analysis for siting MSW landfills and its multicriteria spatial decision support system: Method, implementation and case study, *Waste Management*,33(5),1190–1206.

Effat, Hala A., & Mohamed N. Hegazy. (2012). Mapping potential landfill sites for North Sinai cities using spatial multicriteria evaluation, *The Egyptian Journal of Remote Sensing and Space Science*, 15(2), 125–133.Retrieved from http://dx.doi.org/10.1016/j.ejrs.2012.09.002

Erden, T., & M. Z. Cos¸kun.(2010). Multi-criteria site selection for fire services: the interaction with analytic hierarchy process and geographic information systems. Nat. Hazards Earth Syst. Sci.,10, 2127–2134. doi:10.5194/nhess-10-2127-2010 . Retrieved from www.nat-hazards-earth-syst-sci.net/10/2127/2010/

Heacock, Erin, & Justin, Hollander. (2011). A grounded theory approach to development suitability analysis. *Landscape and Urban Planning*, 100,(1–2), 109–116. Retrieved from http://dx.doi.org/10.1016/j.landurbplan.2010.12.001

Henig, Mordechai, I., & John T. Buchanan. (1996). Solving MCDM Problems: Process Concepts, *Journal of Multi-Criteria Decision Analysis*, 5, 3-21.

Hossain, M. Shahadat, Sayedur. Rahman Chowdhury,Nani Gopal Das, & M. Moshiur Rahaman.(2007).Multi-criteria evaluation approach to GIS-based land suitability classification for tilapia farming in Bangladesh. *Aquacult Int*, 15,425–443. doi:10.1007/s10499-007-9109-y.

Jeong, J.S., L. García-Moruno, & J. Hernández-Blanco.(2012). Integrating buildings in to a rural landscape using a multi-criteria spatial decision analysis in GIS-enabled web environment, *Biosystems Engineering*,112(2), 82–92.

Jeong, Jin. Su, Lorenzo García-Moruno, & Julio Hernández-Blanco.(2013). A site planning approach for rural buildings into a landscape using a spatial multi-criteria decision analysis methodology. *Land Use Policy*, 32, 108–118. Retrieved from http://dx.doi.org/10.1016/j.landusepol.2012.09.018

Kemp, Karen.K,(ed).(2008).*Encyclopedia of Geographic Information Science*.London: SAGE Publications.

Koc-San, D. , B.T. San ,V. Bakis , M. Helvaci , & Z. Eker.(2013). Multi-Criteria Decision Analysis integrated with GIS and remote sensing for astronomical observatory site selection in Antalya province, Turkey. *Advances in Space Research*, 52(1), 39–51.

Lloyd, Christopher,D.(2010). *Spatial data analysis, an introduction for gis users*. New York: Oxford University Press.

Malczewski, Jacek.(2004). GIS-based land-use suitability analysis: a critical overview. *Progress in Planning*, 62. 3–65. doi:10.1016/j.progress.2003.09.002

Malczewski, Jacek.(2006). GIS based multicriteria decision analysis: a survey of the literature. *International Journal of Geographical Information Science*,20(7),703–726 , dio:10.1080/13658810600661508. Retrieved from http://dx.doi.org/10.1080/13658810600661508

Moeinaddini, Mazaher, Nematollah Khorasani, Afshin Danehkar,Ali Asghar Darvishsefat, & Mehdi zienalyan.(2010). Sitting MSW landfill using weighted linear combination and analytical hierarchy process (AHP) methodology in GIS environment (case study: Karaj), *Waste Management*,30, 912–920.doi:10.1016/j.wasman.2010.01.015

Mohajeri, Nahid, & Gholam, R. Amin. (2010). Railway station site selection using analytical hierarchy process and data envelopment analysis. *Computers & Industrial Engineering*,59(1),107–114.

Sener, Sehnaz,. Erhan Sener , Bilgehan Nas ,& Remzi Karaguzel.(2010). Combining AHP with GIS for landfill site selection: A case study in the Lake Beys_ehir catchment area (Konya, Turkey). *Waste Management*, 30, 2037-2046, doi:10.1016/j.wasman..05.024.

Sharifi, Mozafar, Mosslem Hadidi , Elahe Vessali , Parasto Mosstafakhani , Kamal Taheri , Saber Shahoie, & Mehran Khodamoradpour.(2009). Integrating multi-criteria decision analysis for a GIS-based hazardous waste landfill sitting in Kurdistan Province, *western Iran. Waste Management*, 29(10), 2740–2758.

Silva, Ceballos, A. & Lopez, Blanco, J.(2003). Delineation of suitable areas for crops using a Multi Criteria Evaluation approach and land use cover mapping: a case study in Central Mexico, *Agricultural Systems*,77,117–136.

Thirumalaivasan, D., M. Karmegam, & K. Venugopal.(2003). AHP-DRASTIC: software for specific aquifer vulnerability assessment using DRASTIC model and GIS. *Environmental Modelling & Software*, 18,645–656.doi:10.1016/S1364-8152(03)00051-3.

Tudes, Sule , & Nazan Duygu Yigiter.(2010). Preparation of land use planning model using GIS based on AHP: case study Adana-Turkey. *Bull Eng Geol Environ* ,69, 235–245: doi: 10.1007/s10064-009-0247-5 .

Vahidnia, Mohammad .H, Ali A.Alesheikh , & Abbas Ali, mohammadi.(2009). Hospital site selection using fuzzy AHP and its derivatives, *Journal of Environmental Management*, 90(10),3048–3056. doi:10.1016/j.jenvman.2009.04.010 .

Vaidya, Omkarprasad S., & Sushil Kumar.(2006). Analytic hierarchy process: An overview of applications. *European Journal of Operational Research*, 169,1–29. doi:10.1016/j.ejor.2004.04.028.

Wang, Guiqin, Li. Qin. Guoxue. Li. , & Lijun, Chen.(2009). Landfill site selection using spatial information technologies and AHP: A case study in Beijing, China. *Journal of Environmental Management* ,90(8),2414–2421.

Xiaoguo, Jiang. (2010). *Integration of Interval Numbers and the Method of AHP along with its Improvement and Application*. 3rd International Conference on Information Management, Innovation Management and Industrial Engineering.doi: 10.1109/ICIII.2010.108 .

Xu, Erqi, & Hongqi Zhang.(2013).Spatially-explicit sensitivity analysis for land suitability evaluation, *Applied Geography*,45, 1-9. Retrieved from http://dx.doi.org/10.1016/j.apgeog.2013.08.005

Zamorano, Montserrat, Emilio Molero, Álvaro Hurtado , Alejandro Grindlay , & Ángel Ramos .(2008). Evaluation of a municipal landfill site in Southern Spain with GIS-aided methodology, *Materials*, 30.473–481.