The Use of Inverse Distance Weighted and Fuzzy Logic to Estimate Land Suitability by Geographic Information System in South of Iraq

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ABSTRACT

As soils considered an open system, adjacent of them are common in some characteristic. The use of inverse distance weighted (IDW) technology in geographic information systems (GIS) is one of the best ways of soil characteristic interpolation depending on the Inverse distance where there is a negative relationship between characteristic and the of the IDW, such as soil salinity and other characteristic. The main objective of this study is to estimate land suitability depending on fuzzy logic. The studied area are located in Thi-Qar province, Iraq in coordinate of 643949.033m X, 3441469.288m Y, 643949.033m X, 3417061.751m Y, 689849.773m X, 3417061.751 Y, 689849.7733m X, 3441469.288 Y, respectively. The results indicated that most of the studied area lands were influenced by salinity, the lowest value of soil salinity was 8.45 ds/m while the highest was 152.56 ds/m. Soil textures are tending to be in the range of silt clay loam, silt clay, silt loam and loam, the dominant drainage class was poorly to moderate, while there were some classes in well and imperfect drainage classes. Gypsum content was less than 2.94%, while lime content ranged from 24.40% to 38.19%. The studied area was classified into five classes, the first was non suitable (red color), second class was few suitable (yellow color), third class was moderate suitable(brown color), fourth class was suitable (green color) and very suitable (chartreuse color) for grain crops. Soil classified two order Entisols and Aridisols in two sub order fluvents and salids great groups in three great group Torrifluvents, Aquisalids and Haplosalids in five subgreat group of typic Torrifluvents, Aquic torrifluvent, typic Haplosalids, typic Aquisalids and calcids Aquisalids.

Keyword: Geographic Information System (GIS), Inverse Distance Weighted (IDW), Fuzzy logic, land suitability

INTRODUCTION

Geographic information system (GIS) is a computer-based tool that analyzes, stores, manipulates and visualizes geographic information on a map (Williams, 1987). The GIS is used to analyze, and interpret data to understand relationships, patterns, and trends (ESRI, 2015).The fuzzy representation allows us to apply fuzzy techniques for geographical information processing (Burrough, 1989).

Inverse distance weighted (IDW) is a method of interpolation that estimates cell values by averaging the values of sample data points in the neighborhood of each processing cell. The closer a point is to the center of the cell being estimated, the more influence, or weight; it has in the averaging process, This method assumes that the variable being mapped decreases in influence with distance from its sampled location (ESRI, 2004).

Fuzzy logic (FL) was initiated in 1965 by Lotfi A. Zadeh, professor for computer science at the University of California, Berkeley (Zadeh,1965). Basically, Fuzzy Logic (FL) is a multivalve logic that allows intermediate values to be defined between conventional evaluations like true/false, yes/no, high/low, etc. Notions like rather tall or very fast can be formulated mathematically and processed by computers, in order to apply a more human−like way of thinking in the programming of computers (Zadeh, 1984).In General, the employment of fuzzy logic might be helpful, for very complex processes, when there is no simple mathematical model (e.g. Inversion problems), for highly nonlinear processes or if the processing of (linguistically formulated) expert knowledge is to be performed. According to literature the employment of fuzzy logic is not recommendable, if the conventional approach yields a satisfying result, an easily solvable and adequate mathematical model already exists, or the problem is not solvable (Hellmann, 2001).

Land evaluation is formally defined as 'the assessment of land performance when used for a specified purpose, involving the execution and interpretation of surveys and studies of land forms, soils, vegetation, climate and other aspects of land in order to identify and make a comparison of promising kinds of land use in terms applicable to the objectives of the evaluation' (FAO, 1976). Using square root method in Tunisia on wheat, barley, sorghum, potato, Breda et al. 2004 found that the most influential limiting factors to the study area were land slope, coarse-grained soil texture of the area, dominant existence of stones and aggregates, alkaline pH and the excessive amount of the soil carbonate calcium.

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The problem of evaluation of agricultural land suitability is considered as a fuzzy modeling task. For assessment of land suitability, it is proposed to use fuzzy indicators. Application of individual fuzzy indicators gives opportunity for assessment of suitability of lands as degree or grade of performance when the lands are used for agricultural purposes. Using composite fuzzy indicator it is possible to obtain weighted average estimation of land suitability (Kurtener, 2008). The main objective of this research is to estimate land suitability depending on fuzzy logic.

MATERIALS AND METHODS

Study Area Description

The studied area is located in the South of Iraq, Thi-Qar province of 643949.033m X, 3441469.288m Y, 643949.033m X, 3417061.751m Y, 689849.773m X, 3417061.751 Y, 689849.7733m X, 3441469.288Y, respectively (fig.1).

Data collection

Soil properties data were collected from Alchabayish project/ ministry of water resources for 2013. Data were georeferenced (43 profiles) and the data base was used in the Arcmap9.3 environment (Table1). The data were converted to a vector data set then to raster by IDW technology (Alhessi, 2014).

$$Z(S_0) = \sum_{i=1}^{N} \lambda_i Z(S_i) \ldots \ldots \ldots \ldots \ldots \ldots (1)$$

Where:

- Z(S0) is the value we are trying to predict for location S0.
- N is the number of measured sample points surrounding the prediction location that will be used in the prediction.
- ƛi are the weights assigned to each measured point that we are going to use. These weights will decrease with distance.
- Z(Si) is the observed value at the location Si.

Soil Maps

To produce soil maps of soil texture, salinity, Drainage, ESP, Gypsum and Lime, Maps were reclassified and weights were given for each class depending on the influence of value (Table2). Weight for each character was given from 100 percentages using fuzzy logic to Produce maps for land suitability.

Suitability = Salinity*0.25 + Texture*0.25 + Drainage*0.2 + ESP*0.1 + Gypsum *0.1 + Lime*0.1….(2)

Fuzzy Logic (FL)

Fuzzy logic is an alternative logical foundation with several useful implications for spatial data handling. Major advantage of FL theory is that it allows the natural description, in linguistic terms, of problems that should be solved rather than in terms of relationships between precise numerical values. This advantage, dealing with the complex systems in simple way, is the main reason why fuzzy logic theory is widely applied in technique.

Fuzzy set theory is an extension of the classical set theory. A fuzzy set A is defined mathematically as follows:

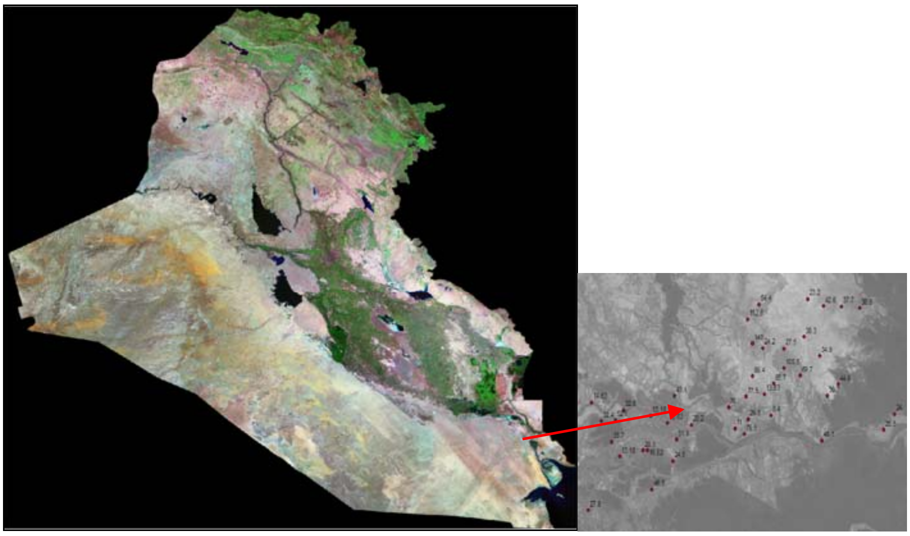


Figure 1. Shows the study area sites

Table 1. Number of samples with some soil characteristic

x	y	Depth(cm)	PH	Ece	Clay	Silt	Sand	Text.	ESP	Gypsum%	Lime%
690022.849979	3428283.619674	0-30	7.72	24	40	52.8	7.2	Sic-Sicl	26	1.2	29.4
688384.661888	3426375.236347	0-20	7.79	20.5	31	55.8	13.2	Sicl	22	0.1	31.4
677000.357042	3442072.750900	0-28	7.24	23.2	24	54.2	21.8	Sil	26	0.85	33.8
671394.915686	3428120.407546	0-15	7.9	8.4	25	63.2	11.8	Sil	6	0	34.2
668005.785523	3427604.728249	0-12	7.94	29.5	43	49.8	7.2	Sic	28.5	1.7	37.4
670425.409013	3430630.885294	0-30	7.52	13.63	23	66.2	10.8	Sil	14	0.5	36.6
667643.700232	3430370.752094	0-22	7.23	77.5	10	40.8	49.2	L	30	1.1	33
668656.858380	3436731.733906	0-27	7.1	148	7	48.4	44.6	SI-I	58	13.25	27
667396.292546	3425870.210970	0-20	7.44	79.5	19	62	29	Sil	42	6.35	38.2
665036.749916	3429097.671150	0-26	7.09	76	35	52.2	12.8	Sicl	49	2.26	28.6
666058.726046	3426557.169273	0-19	7.9	11	29	48.6	22.4	Cl	7	0.7	36
659443.770291	3426979.623508	0-15	7.66	20.2	39	42.8	18.2	Sicl	22	2.23	34.4
655812.198701	3427197.308167	0-30	7.49	15.03	33	59.5	7.5	Sicl	21	1.23	32
668639.683713	3432819.487110	0-20	7.45	99.4	18	48.6	33.4	l	51	2.17	37.2
644412.485469	3429690.667880	0-45	7.98	14.63	35	60.8	4.2	Sicl	19.5	0.59	27
653323.892716	3428060.185450	0-25	7.52	13.16	40	56.4	3.6	Sic-Sil	16.5	2.29	25.8
679115.126225	3425106.225000	0-40	7.36	49.1	29	54.8	16.2	Sicl	31	2.15	32.4
670176.952936	3436201.554271	0-28	7.28	24.2	36	48.8	15.2	L	21	0.2	31.4
671837.383386	3431916.367178	0-18	7.53	85.7	32	57.6	10.4	Sil	47	2	34.2
673398.423849	3433789.802909	0-15	7.54	105.5	14.5	67.1	18.4	Sil	63	1.58	32.2
675800.254930	3432905.400488	0-23	7.02	69.7	22	47.6	30.4	L-SiL	44	0.44	36.6
676360.095700	3437534.615444	0-30	7.21	38.3	33	52.8	14.2	Sicl	43	5.15	32.6
667948.258837	3439615.628377	0-26	7.3	152.6	12	53	35	Sil	54	1.6	29.8
669647.621710	3441428.980896	0-22	7.31	54.4	23	61	16	Sil	26	2.7	32.6
673360.801650	3436098.982308	0-27	7.2	27.5	30	43.8	26.2	CL	36	2.07	36
657225.392650	3425222.922690	0-40	7.32	51.9	30	52.5	17.5	Sicl	33	2.5	25.5
656912.428190	3430440.535321	0-22	7.94	43.1	39	53.6	7.4	Sicl	35	3.85	35.4
649228.055802	3428771.776965	0-40	7	32.6	33	51.1	15.9	Sic	45	4.5	27
648025.856875	3427523.384036	0-40	7.15	52.6	33	54.5	12.5	Sic	43	3.37	26.6
652836.962300	3423916.787256	0-31	7.38	16.52	40	57.4	2.6	Sic-Sicl	19	2.9	30.2
652162.529838	3423912.168000	0-25	7.24	20.1	45	52.4	2.6	Sic	22.5	2.56	25.8
656614.476871	3422626.819774	0-23	7.13	24.5	32	53.5	14.5	Sicl	23	0.09	26.4
653505.620434	3419225.786258	0-20	7.56	46.5	35	60.6	4.4	Sicl	30	0.92	28.4
678732.165478	3435264.344078	0-42	7.27	34.9	43	52	5	Sic	23	1.3	31.2
682052.359439	3441173.411904	0-40	7.9	37.7	30	53	17	SICL	33	3.77	28.4
679374.262119	3441219.905907	0-30	7.5	42.6	32.5	55.1	12.4	SICL	32	4.34	32.8
679928.590154	3430448.619272	0-36	7.34	30.7	37	54.6	8.4	SICL	35	2.4	37
648670.263216	3423190.386560	0-20	7.71	13.18	32	65.6	2.4	SICL	18	2.59	25.4
647451.896389	3424928.435921	0-18	7.43	33.7	45	52.2	2.8	SIC	37	4.7	24.4
645877.835738	3427430.996030	0-30	7.12	32.4	17	67.4	15.6	SIL	32	0.54	25
643924.984264	3416719.761599	0-34	7.15	27.9	47	47.2	5.8	SIC	27	2.9	29.8
684812.451115	3440975.077692	0-40	7.81	36.6	34	51.5	14.6	SICL	23	2.42	31.6
681538.451157	3431837.903910	0-23	7.56	44.6	32	46.3	21.7	CL	29	3.28	33

Table 2. Index value for soil texture

SOIL TEXTURE	INDEX VALUE FOR GRAIN
Silt Clay Loam	105
Silt Clay or Clay	100
Loam or Silt Loam	95
Loam or Loam Clay	85
Sandy Clay or Sand Clay Loam	75
Loam Sandy	85
Loamy Sand	55
Sandy	45

IF X = {x} denotes a space of objects, THEN the fuzzy set A in X is the set of ordered pairs:

$A = \{x, \mu A(x)\}, x \in X,$

Where the membership function µA(x) is known as the "degree of membership (d.o.m.) of x in A". Usually, µA(x) is a real number in the range [0, 1], where 0 indicates no-membership and 1 indicates full membership. Here µA(x) of x in A specifies the extent to which x can be regarded as belonging to set A (Sui1992).

RESULTS AND DISCUSSION

Results referred that most of the studied area Lands were influenced by salinity, the lowest value of soil salinity was 8.45 ds/m while the highest was 152.56 ds/m (fig (2).

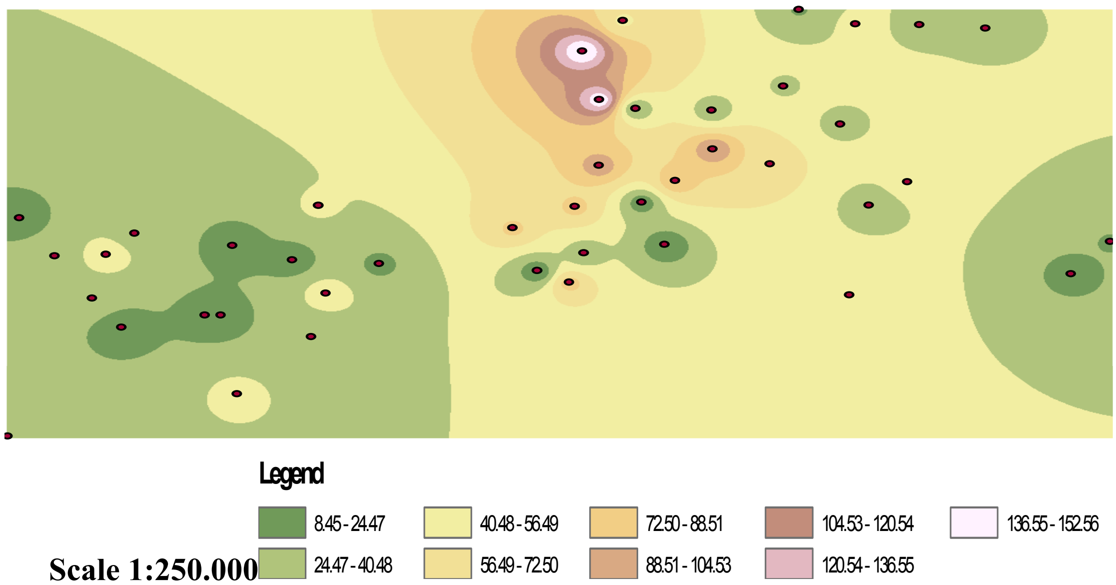
The dominant drainage class was poorly to moderate, while there were some classes in well and imperfect drainage classes (Fig.3). Lime content ranged from 24.40% to 38.19% as shown in Fig.4, while Gypsum content was less than 2.94 %(Fig.5).

Most of Exchange Sodium Percentage (ESP) values in the study area were more 18.76, while the smaller values of 18.76 were found in very small area (Fig.6). Soil textures were in the range of silt clay loam, silt clay, silt loam and loam (Fig.7).

The studied area was classified into five classes, the first was non suitable (red color), second class was few suitable (yellow color), third class was moderate suitable(brown color), fourth class was suitable (green color) and very suitable (chartreuse color) for grain crops (Fig.8).

Soil classification

According to USDA (2004), Soil classified two order Entisols and Aridisols in two sub order fluvents and salids subgroup in three great group Torrifluvents, Aquisalids and Haplosalids in five subgreat group of typic Torrifluvents, Aquic torrifluvent, typic Haplosalids, typic Aquisalids and calcids Aquisalids (Table 2 & Fig.9).



Scale 1:250.000

Figure 2. The prediction map by IDW of salinity

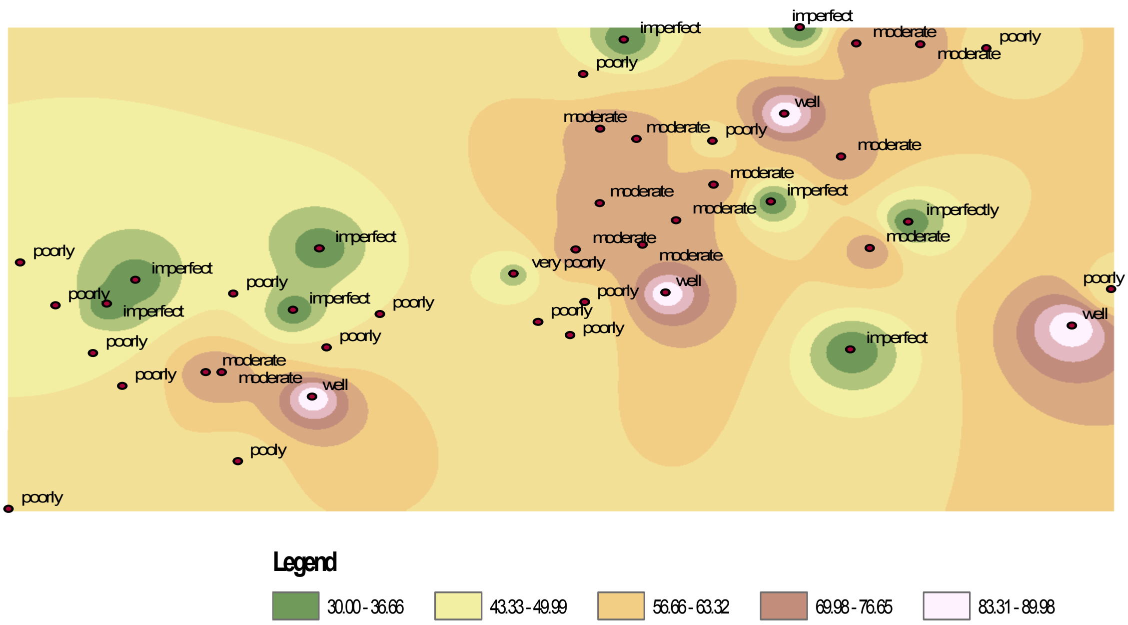


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Figure 3. The prediction map by IDW of drainage

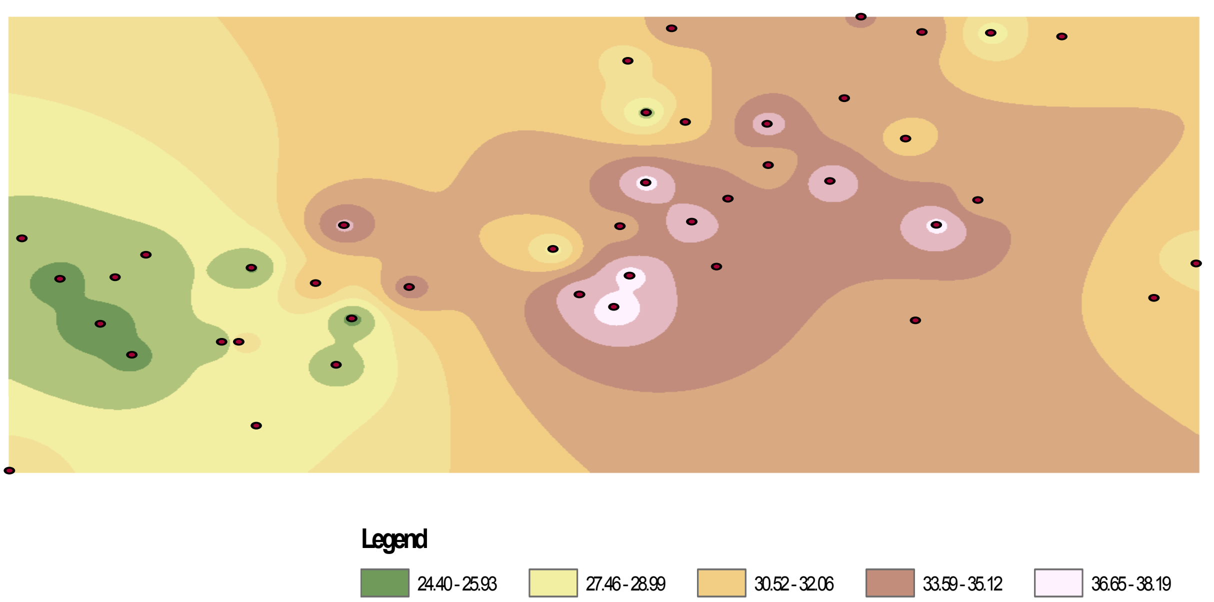

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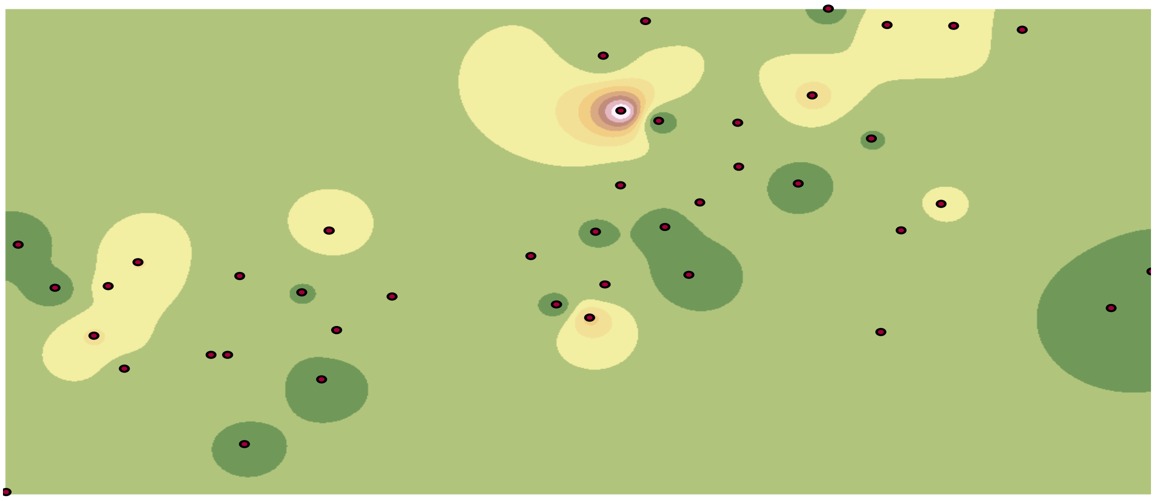
Figure 4. The prediction map by IDW of Lime



■ Scale 1:250,000

Figure 5. The prediction map by IDW of gypsum

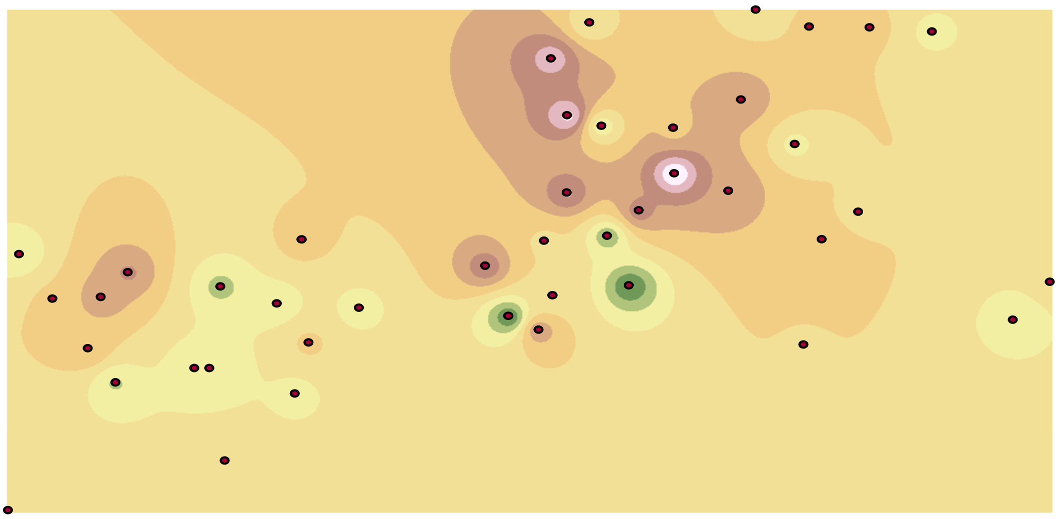


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Figure 6. The prediction map by IDW for ESP

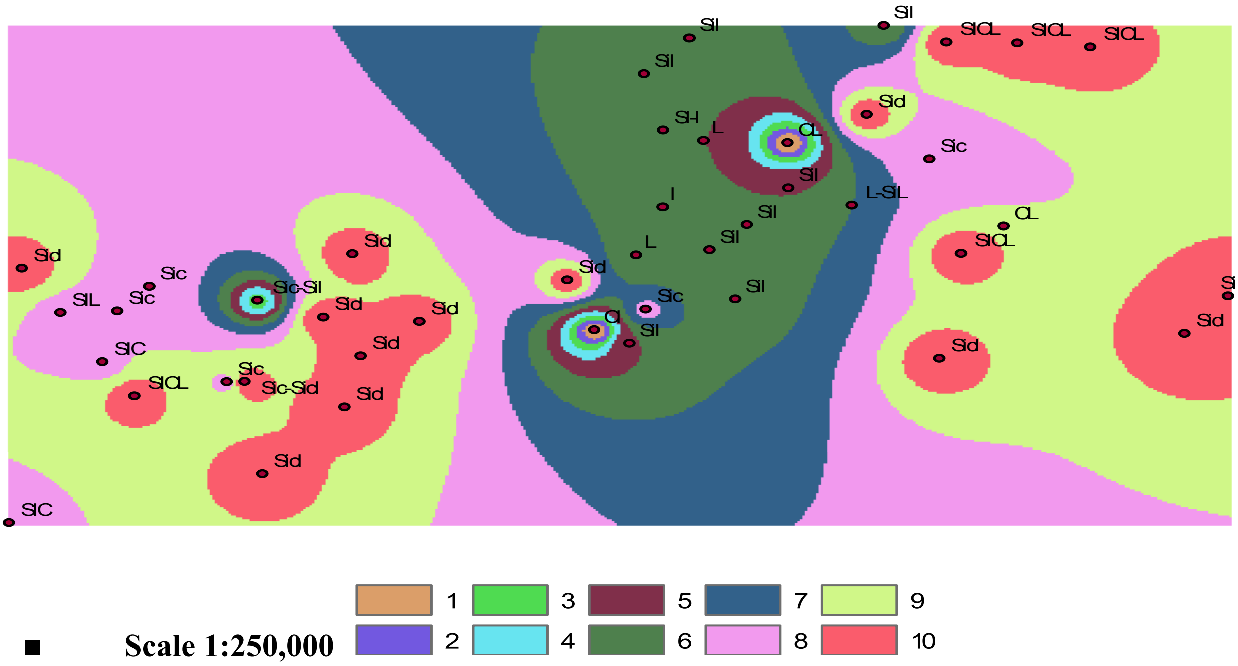

Figure 7. The prediction map by IDW soil texture for grain

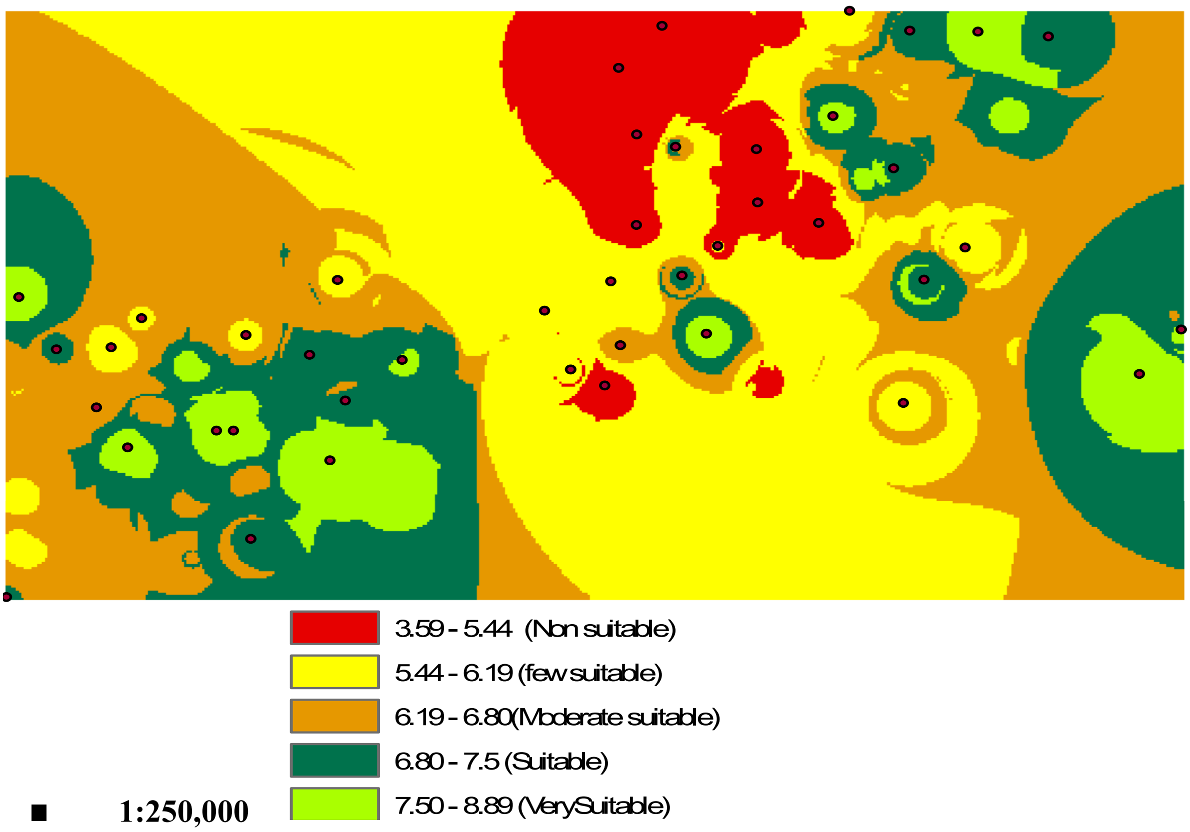

Figure 8. The land suitability map for grain

Table 2. Soil classification and soil units

Area %	Area Donum	Symbol	Subgreat group	Great group	Sub order	Order
3.3	8500	E1	Typic Torrifluvents	Torrifluvents	Fluvents	Entisols
4.3	10929	E2	Aquic Torrifluvents			
12.8	32950	E3				
4.7	12300	E4				
18.2	46642	A1	Typic Aquisalids	Aquisalids	Salids	Aridisols
8.1	20825	A2				
17.6	45500	A3				
8.6	22190	A4				
0.3	800	A5	Calcids Hapolsalids	Hapolsalids		
1.6	4200	A6				
9.1	23620	A7	Typic Hapolsalids			
1.5	3870	A8				
9.9	25610	A9				
100	257936					

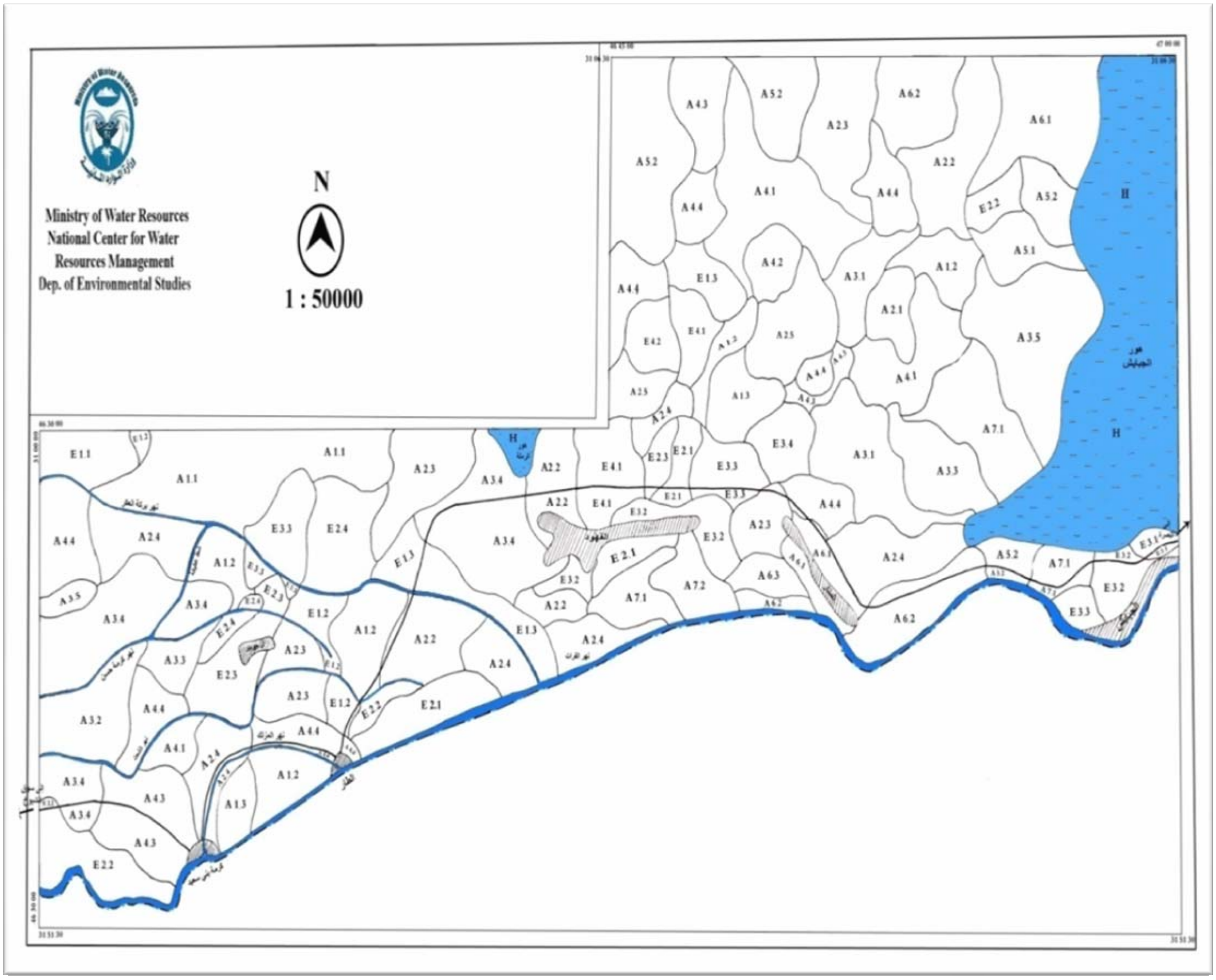

Figure 9. soil map

CONCLUSION

The use of Inverse Distance Weighted (IDW) technology in geographic information systems (GIS) is one of the best ways of soil characteristic interpolation depending on the Inverse distance where there is a negative relationship between characteristic and the of the IDW. In general that most of the studied area Lands were influenced by salinity. The few suitable class for the cultivation of grain covered most of the studied area. Fuzzy logic technology under geographic information systems helps in finding the suitability of land and the accuracy depends on the weight given to the specific factor for agriculture the. orders in study area were Entisols and Aridisols, The Entisols contains sub orders Fluvents while great groub were Typic Torrifluvents and Aquic Torrifluvents, The Aridisol order contain one sub orders salids while great groub were Haplosalids, Aquisalids.

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الملخص العربي

استخدام تقانة معكوس المسافة والمنطق المضبب في تقدير ملائمة الأرض بنظام المعلومات الجغرافية

عبد الغفور ابراهيم حمد

تعتبر التربة نظام مفتوح، فالترب القريبة من بعضها عادة تتشابه في بعض الخصائص. استخدمت تقنية المسافة المعكوسة (IDW) في نظام المعلومات الجغرافية (GIS) ، اذ تعتبر واحدة من أفضل الطرق للتنبؤ بصفات التربة لوجود علاقة عكسية بين المسافة وصفات التربة فكلما تبتعد الترب عن بعضها تقل قيمة الصفة مثل ملوحة التربة فضلا عن الصفات الأخرى. هدف الدراسة هو تقدير ملائمة الأرض باستخدام تقنية المنطق المضببFuzzy logic . تقع منطقة الدراسة في محافظة ذي قار، العراق ضمن الأحداثيات 643949.033 م، 3441469.288م، 643949.033م، 3417061.751م، 689849.773م، 689849.7733م، 3441469،288، على التوالي. أوضحت النتائج أن معظم اراضي المنطقة المدروسة متأثرة بالملوحة، وكانت أقل قيمة من ملوحة التربة ٨,٤٥ ديسيسمنز/ م في حين أعلى قيمة كانت ١٥٢,٥٦ ديسيسمنز / م، نسجة التربة السائدة مزيجية طينية غرينية، طينية غرينية، مزيجة غرينية ومزيجية، اصناف الصرف الداخلي فقيرة إلى معتدلة الصرف، بينما كانت هناك بعض اصناف الصرف جيدة وتامة الصرف، محتوى الجبس أقل من ٢,٩٤٪، في حين أن بعض المناطق القليلة كانت قيمة الجبس فيها اقل من ٢,٩٤٪، تراوحت نسبة الكلس من ٢٤,٤٠٪ إلى ٣٨,١٩٪، وقد صنفت منطقة الدراسة إلى خمسة اصناف ملائمة: الصنف الأول غير ملائم (اللون الأحمر)، والصنف الثاني قليل الملائمة(اللون الأصفر)، والصنف الثالث معتدل الملائمة(اللون البني)،

والصنف الرابع ملائم(اللون الأخضر) وملائم جدا (أخضر مصفر اللون) لمحاصيل الحبوب. ولقد صنفت التربة الى اثنين من الرتب Entisols و Aridisols في اثنين تحت الرتبة fluvents وsalids فرعية في ثلاثة مجاميع عظمىTorrifluvents، Aquisalids وHaplosalids في خمس مجاميع تحت العظمى من Torrifluvents، Aquic torrifluvent، Haplosalids، Aquisalids وcalcids Aquisalids.

الكلمات المفتاحية: نظام المعلومات الجغرافية، تقنية معكوس المسافة، المنطق المضبب ، ملائمة الأرض