ASSESSMENT AND MAPPING OF DESERTIFICATION USING SOIL QUALITY INDICATORS FOR SOME PARTS OF IRAQ

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ABSRTACT

This study was conducted to assess desertification for dry lands in some parts of Iraq. The study area located between longitudes 43⁰25¯ 41¨ - 46⁰ 28¯ 01¨ E and latitudes 34⁰ 18¯ 35¨ - 36⁰ 20¯ 56¨ N with an area of 26500Km²which include some parts of the governorates of Sulaimani, Diyala, Kirkuk, and Erbil in Iraq. Eighty nine surface soil samples were taken, air dried, sieved through a 2 mm sieve and then analyzed for some physical and chemical properties. Desertification is assessed according to Mediterranean Desertification and Land Use model (MEDALUS). ArcGIS 10.2 was used to analyze and prepare the layers of soil quality maps. In turn the geometric mean of all six quality maps was used to generate a single desertification status map .In calculating the weight of the soil quality indicator SQI it seems that it was divided into two classes, firstly, class 2(moderate quality) with an area of 25147 km², which occupied 95% of the study area and the rest is class3 (low quality) with an area of 1309 km² which equal to 5% of the total area.

Key words: drylands, evaluation of desertification, land degradation, medalus
***Part of Ph.D. thesis for the 1st author.**

تقييم وخارطة حالة التصحر باستخدام مؤشرات جودة التربة لبعض المواقع من العراق

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المستخلص

أجريت الدراسة بهدف تقييم حالة التصحر للأراضي الجافة في بعض مناطق العراق. تقع منطقة الدراسة بين خطي الطول ¨41 ¯25 ⁰43 – ¨01¯ 28 ⁰46 شرقا ودائرتي العرض ¨35¯ 18 ⁰34 – ¨ 56 20 ⁰36 شمالا والتي تشمل بعض أجزاء من محافظات السليمانية وديالى وكركوك و اربيل في العراق وبمساحة بلغت حوالي 26500 كم². اخذت تسعة وثمانون عينة من التربة السطحية لمنطقة الدراسة وتم تجفيفها هوائيا، ونخلها من خلال منخل قطر فتحاته 2 مم، ثم تحليل بعض الخصائص الفيزيائية والكيميائية لها. تم تقييم حالة التصحر باستخدام نموذج MEDALUS (Mediterranean Desertification and Land Use model). استخدم برنامج ArcView 10.2 لرسم خارطة مؤشر جودة التربة والخرائط الاخرى للمعايير المستخدمة. عند حساب وزن مؤشر جودة التربة SQI ، تبين أنه يقسم إلى فئتين، أولاً ، الفئة 2 (الجودة المعتدلة) بمساحة 25147 كم ² ، والتي تشغل 95 ٪ من مساحة منطقة الدراسة والباقي فئة 3 (منخفضة الجودة) تبلغ مساحتها 1309 كم ² أي ما يعادل 5 ٪ من المساحة الكلية.

الكلمات المفتاحية: الاراضي القاحلة، تقييم التصحر، تدهور الاراضي، ميدالوس
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INTRODUCTION

Land degradation in arid and semi-arid lands is usually called desertification in its irreversible form. Now a days, one of the most serious global environmental problems is the phenomenon of desertification (Dregne et al,1991, UNCED ,1992 , Reynolds et al,2002 Mihretab et al ,2019). The effects of desertification are the degradation of ecosystems, a complex phenomenon that leads to the reduction of land productivity and the decline of croplands, leading to problems of food availability and security (Sepehr et al,2007 , Lee et al,2019). The latest definition of the desertification is described by (Rozanov,1990) “the desertification does not need to lead to the development of deserts or desert-like conditions ,It simply refers to all types of land degradation in the dry lands of the world”. In addition, it is considered that the only cause of desertification phenomenon is anthropogenic activity(UNEP,1990). According to one of the article of the United Nations Convention to Combat Desertification (UNCCD,1994), the term of desertification refers to "Land degradation in arid, semi-arid and dry sub-humid areas resulting from many factors, including climate change and human activities" (Thiebaud and Philippe,2011). It is widely recognized that desertification is a serious threat to arid and semiarid environments which cover 40% of the global land surface(Wuhaib,2013). There are several factors that exacerbate this phenomenon, such as climate dryness, geological and morphological characteristics of the terrain, increasing populations and pressure on the exploitation of plant and water resources (lahlaoi et al,2017). Iraq is located in the range of semi-tropical latitude in the Northern Hemisphere between longitudes (38.45°-48.45°) east of Greenwich line and between latitudes (29.5°-37.5°) north of the equator. Iraq lies within the moderate northern region, a system similar to that of Mediterranean where rainfall occurs almost in winter, autumn, spring and disappears in summer. The general distribution of seasonal rainfall of Iraq in Climate Atlas illustrating, the lower rainfall in the south and southwest and increase towards to the north and north-east(Jawad et al,2018). In Iraq, almost all the area considered as arid land (more than 75%) and the rest of the land is semi-arid area where crops experience moisture stress. Because of the existence of large areas of dry lands in Iraq and Iraqi-Kurdistan Region and clear degradation of these lands for a number of reasons notably desertification and the lack of adequate studies in this area, so this study was conducted to assess the most important factors(climate and human activities) regarding to the soil and affecting desertification.

MATERIALS AND METHODS

The study area included arid and semi-arid lands located between longitudes 43° 25' 41"- 46° 28' 01" E and latitudes 34° 18' 34" - 36° 20' 56" N with an area of 26500Km^2 which include some parts of the governorates of Sulaimani, Diyala, Kirkuk, and Erbil in Iraq (Figure1).

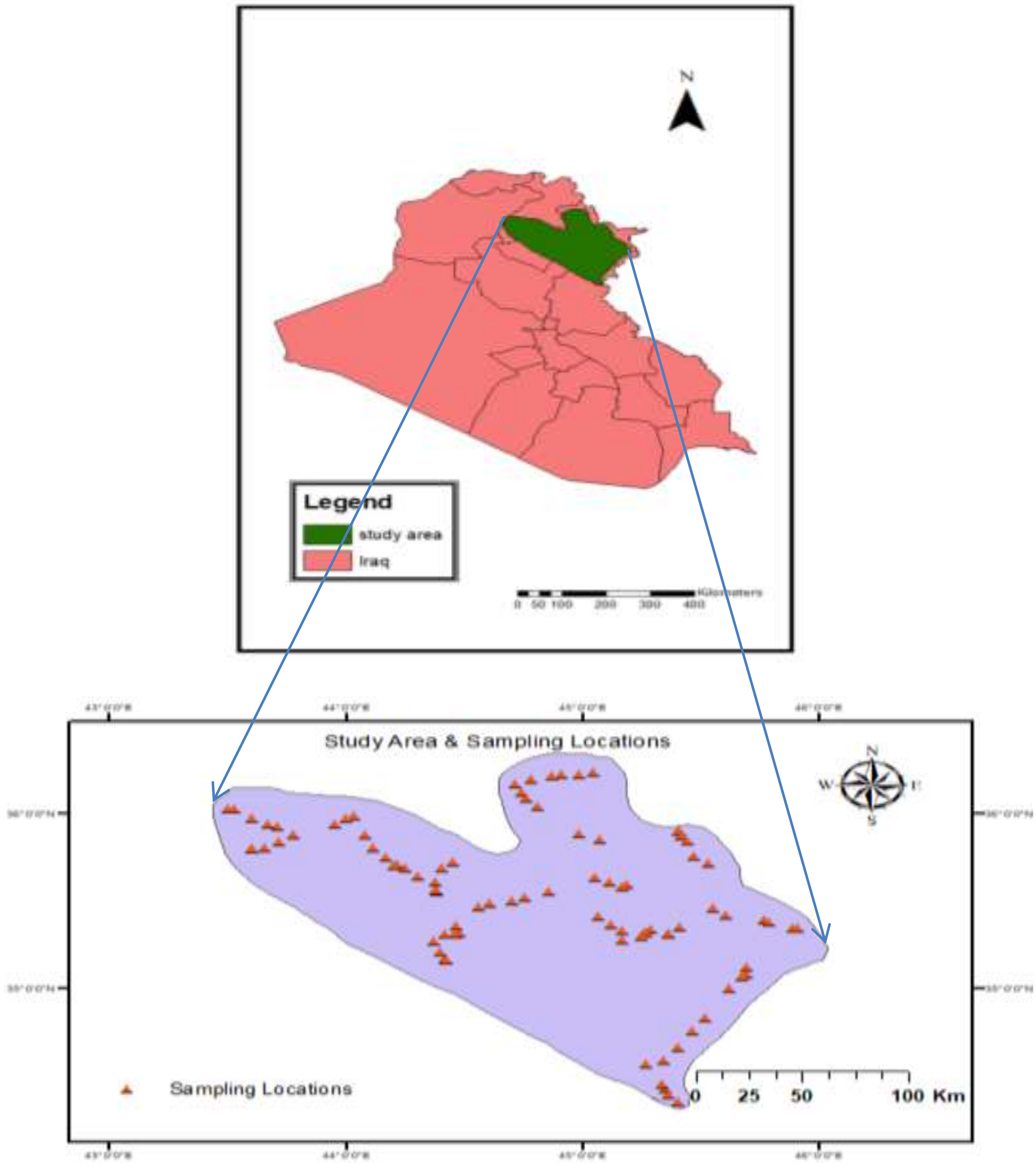

Figure 1. Location of the study area

From the beginning of December until the late of March represent the maximum precipitation in the year and account for nearly two-thirds of the annual mean.The mean annual air temperature is around 20^{o}C. The coldest month of the year is January, where the average temperature dose not drops below 5^{o}C annually. July and August are the hottest months of the year, where the average temperature exceeds 40^{o}C.

Desertification assessment

Desertification assessed according to Mediterranean Desertification and Land Use (MEDALUS) project (Kosmas et al., 1999). The MEDALUS model has been a widely recognized approach in different Mediterranean regions at national, regional, and local scales. Furthermore, it is very important to carry out a reliable database on the sensitivity to degradation/desertifi cation using GIS which enables spatial data analysis that can be presented in a graphic and/or cartographic form(Milosav et al ,2016). It was used in an entire Greek state to assess desertification sensibility using the four indicators recommended by the original MEDALUS report (Karamesouti et al,2018). Soil quality is calculated by providing a measure of the natural quality of the physical environment and the pressure of human-induced desertification (Figure2).

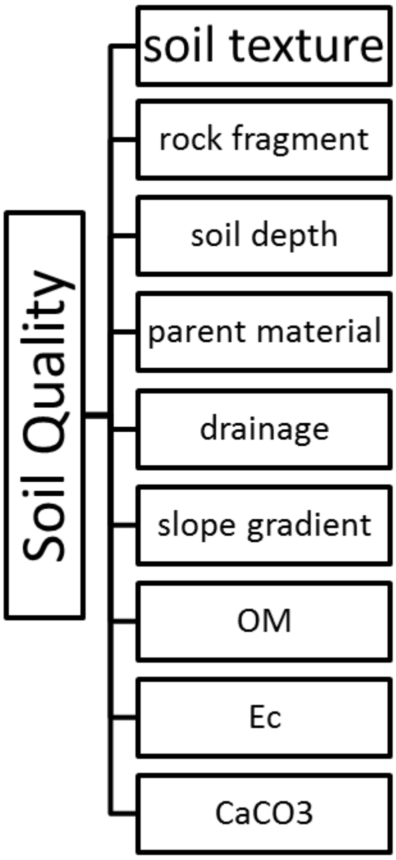

Figure 2. Various parameters used to assess soil quality indicators

Soil quality criteria

The properties of the soils obtained from the soil survey, which include soil texture, rock fragment, soil depth, parent material, drainage ,slope gradient, organic matter,EC and $CaCO_3$ are used to evaluate soil quality. A quantitative classification scheme with values ranging from 1 to 2 has been applied throughout the model for individual indices.. Values between 1 and 2 reflect relative vulnerability. The individual factors and their indicators are described in Table 1.

Table 1. Structure of range and weight index of the soil quality index according to medalus method. Kosmas et al. (1999).

Structure of range and weight index			
Soil texture class	**Description**	**Texture**	**Index**
1	Good	L, SCL, SL, LS,CL	1
2	Moderate	SC, SiL, SiCL	1.2
3	Poor	Si, C, SiC	1.6
4	Very poor	S	2
Soil parent material class	**Description**	**Parent material**	**Index**
1	Good	Shale, schist, basic, ultra basic, Conglomerates.	1
2	Moderate	Limestone, marble, granite, Rhyolite, Ignibrite, gneiss, siltstone, sandstone.	1.7
3	Poor	Marl, Pyroclastics	2
Soil slope class	**Description**	**Slope%**	**Index**
1	Very gentle to flat	>6	1
2	Gentle	6-18	1.2
3	Steep	18-35	1.5
4	Very steep	>35	2
Soil depth class	**Description**	**Depth (cm)**	**Index**
1	Deep	>75	1
2	Moderate	75-30	2
3	Shallow	15-30	3
4	Very shallow	<15	4
Soil rock fragment class	**Description**	**Depth (cm)**	**Index**
1	Very stone	>60	1
2	Stony	20-60	1.3
3	Bare to slightly stony	<20	2
Soil organic matter class	**Description**	**Organic matter (%)**	**Index**
1	Very good	>3	1
2	Good	2-3	1.2
3	Moderate	1-2	1.5
4	Poor	0.5-1	1.7
5	Very poor	<1	2
Soil electrical conductivity class	**Description**	**EC ($mmhos.cm^{-1}$)**	**Index**
1	Very low	>4	1
2	low	4-8	1.2
3	Moderate	8-16	1.4
4	Almost high	16-32	1.6
5	High	32-64	1.8
6	Very high	<64	2
Soil calcium Carbonates class	**Description**	**$CaCO_3$ Content %**	**Index**
1	Good	<2.5	1
2	Moderate	2.5-5	1.5
3	Poor	>5	2
Soil drainage class	**Description**		**Index**
1	Well drained		1
2	Imperfectly drained		1.2
3	Poorly drained		2

The SQI was calculated through the combination of different sub-indicators indicated in Equation (1) SQI = (texture × parent material × rock fragment × depth × slope × drainage × O.M% × Ec × CaCO3)$^{1/9}$……… (1)

Table 2.Structure of range and weight index soil quality indicator according to medalus method

Class	Description	Range
1	High quality	<1.13
2	Moderate quality	1.13-1.45
3	Low quality	>1.46

Soil quality indicators SQI mapping:-

ArcGIS 10.2 was used to analyze and prepare the layers of soil quality indicator maps using ordinary kriging method after interpolation by the spatial analyst tool.

RESULTS AND DISCUSSION

Soil quality criteria

The results shown in table (3) and Figure (3) indicated that the soil texture was ranged between class 2 (moderate) and class 3 (poor) with an area of 7371 and 19085 km^2, which covered 27.86 and 72.14%, respectively.In general, soil texture has a medium to poor risk on desertification in study area. As the results showed the soil texture in general were mostly silty clay to silty loam which leads to the risk of erosion, in particular wind erosion, as well as its effect on the soil water holding capacity, which is an important factor in the impact on desertification due to its effect on the vegetation cover and soil aggregation that affects desertification. The severe class of soil degradation dominated the areas was characterized by sandy soil texture (Wijitkosum and Yolpramote 2013).The sandy texture of the soil resulted in a low water holding capacity. For this reason, soil texture is a key factor affecting the desertification risk of the area (Wijitkosum et al.2013).The results also shown that the index of parent material of all the soils of the study area within class 2 (moderate), because the parent material is Limestone or looses deposits, which is rich in carbonate minerals and it is susceptible to erosion over time, which is dangerous in desertification. The rock fragment index reached the most dangerous level within the weight values. Index for all soils was generally within class 3 (bare to slightly stony) with an area of 99.25%,the remaining is class 2 with an area of 198 km^2 and a rate of 0.75%,this causes suitable conditions for the acquisition of both water and wind erosion in the absence of rough surfaces to protect the soil from erosion. Soil slope index is different in study area, but in general it did not reach the degree of risk and did not have a significant impact on the process of desertification, where the index in the largest part within class 2(gentle),with an area of 25610 Km^2, which occupies 96.80% of the study area, and the remaining space was divided to classes 1, 3 and 4, which occupied only 3.20% of total area. The effect of water erosion in the gentle to flatlands is almost non-existent; in addition, the water holding capacity is in larger quantities which help to alleviate the runoff, erosion and desertification. The soil depth index was classified as a class 1(deep). Soil depth is linked to water availability. A deep soil can assure water reserves and can then provide a good condition for vegetation development and growth (Lamqadem et al,2018) . This is causing the increasing of vegetation, which in turn reduces the surface runoff and water erosion, as well as rough surface formation that impairs wind erosion. Soil drainage classes were found to be in class2 (imperfectly drained) and class 3 (poorly drained) with an area of 21,506 and 4950 km^{2}as a rate of 81.28 and 18.72%, respectively. The slow process of water infiltration increases the probability of surface runoff during the rainfall, this leads to increase the risk of soil erosion, even if it is average. Study area contains different amounts of the organic matter, which was divided into class 2(good), class 3 (poor) and class 4(very poor).The area of the class 3 was 21443 km^{2}with a rate of 81% of the total study area, thus it succeeded the class 2 and class 4 that occupied the area of 2248 and 2765 Km^2 with a rate of 8.5 and 10.5% of the total study area respectively. It is clear from these results that organic matter has not played an important role in reducing the risk of desertification .The presence of organic matter helps to increase the growth of plants, especially herbal, which helps to increase vegetation, in addition to that the accumulation of organic matter helps to enhance of soil aggregation, all these help to increase the soil resistance to erosion. Calcium carbonate in the soil study area is within the class 3 (poor)which occupied

26082 km^2 with a rate of 98.60% of the total study area, resulting in poor soil resistance to desertification (Kodavić et al., 2016).

Table 3. Quantitative classes of considered criteria for the study area

		E	N	Texture	P.M	R.F	Depth	Slope	Drainage	Ec	O.M	CaCO3	SQI
	1	45.77	35.40	1.6	1.7	2	1	1	1	1	1.23	2	1.3
	2	45.89	35.35	1.6	1.7	2	1	1	1	1	1.02	1.02	1.2
	3	45.91	35.35	1.2	1.7	2	1	1	1	1	1.24	1	1.2
	4	45.61	35.42	1.6	1.7	1.3	1	1	1	1	1.55	1	1.2
	5	45.56	35.46	1.6	1.7	2	1	1.033	1	1	2	2	1.4
	6	45.79	35.38	1.6	1.7	2	1	1	1	1	1.66	2	1.4
	7	44.86	35.56	1.6	1.7	2	1	1.5	1.2	1	2	2	1.5
	8	44.76	35.52	1.2	1.7	1.3	1	1.15	1.2	1	1.45	2	1.3
	9	44.71	35.51	1.2	1.7	1.3	1	1.15	1.2	1	1.45	2	1.3
	10	44.61	35.49	1.2	1.7	1.3	1	1.15	1.2	1	1.45	2	1.3
	11	44.56	35.47	1.2	1.7	1.3	1	1.15	1.2	1	1.45	2	1.3
	12	45.06	35.64	1.2	1.7	2	1	1.017	1	1	1.4	2	1.9
	13	45.12	35.61	1.2	1.7	2	1	2	1	1	1.69	2	2.1
	14	45.19	35.60	1.2	1.7	1.3	1	1.15	1	1	1.24	2	1.8
	15	45.17	35.58	1.6	1.7	1.3	1	1	1	1	1.49	2	1.8
	16	45.40	35.90	1	1.7	2	1	1.13	1	1	1.66	2	1.3
	17	45.41	35.90	1.6	1.7	2	1	1	1	1	1.43	2	1.4
	18	45.42	35.88	1.6	1.7	2	1	1	1	1	1.43	2	1.4
	19	45.45	35.85	1	1.7	2	1	1.12	1	1	2	2	1.4
	20	45.48	35.76	1.2	1.7	2	1	1	1	1	1.25	2	1.3
	21	45.53	35.72	1.2	1.7	2	1	1	1	1	1.25	2	1.3
	22	45.36	35.31	1.2	1.7	1.3	1	1.07	2	1	1.02	2	1.3
	23	45.36	35.32	1	1.7	1	1	1.03	1	1	1.45	1.44	1.2
	24	45.41	35.36	1	1.7	2	1	1	2	1	1.19	1.22	1.3
	25	45.29	35.34	1.6	1.7	1.5	1	1.5	1.2	1	1	2	1.3
Sulaimany	26	45.27	35.32	1.6	1.7	1.5	1	1.5	1.2	1	1	2	1.3
	27	45.26	35.32	1.6	1.7	1.5	1	1.5	1.2	1	1	2	1.3
	28	45.25	35.30	1.2	1.7	1	1	1.12	1	1	1.34	2	1.2
	29	45.17	35.28	1.6	1.7	1.3	1	1.18	1	1	1.26	2	1.3
	30	45.17	35.34	1.2	1.7	1	1	1.03	1	1	1.56	2	1.2
	31	45.12	35.37	1.2	1.7	2	1	1	1	1	1.23	2	1.3
	32	45.07	35.41	1.2	1.7	2	1	1	1	1	1.23	2	1.3
	33	45.05	36.24	1.6	1.7	2	1	1	1	1	1.23	1.35	1.3
	34	44.99	36.23	1.2	1.7	2	1	1.017	1	1	1.16	2	1.3
	35	44.91	36.23	1.6	1.7	2	1	1.2	1	1	1.21	2	1.4
	36	44.88	36.22	1.6	1.7	2	1	1	1	1	1.34	2	1.3
	37	44.79	36.20	1.6	1.7	2	1	1	1	1	1.36	2	1.3
	38	44.72	36.17	1.2	1.7	1.3	1	1.017	1	1	1.33	2	1.2
	39	44.74	36.12	1.6	1.7	1	1	1.07	1	1	1.46	2	1.3
	40	44.76	36.09	1.2	1.7	2	1	1	1	1	1.34	2	1.3
	41	44.81	36.05	1.6	1.7	2	1	1.29	1	1	1.46	2	1.4
	42	44.98	35.89	1.2	1.7	1.3	1	1	1	1	1.37	2	1.2
	43	45.07	35.85	1.6	1.7	2	1	1.03	1	1	2	2	1.4
	44	45.70	35.13	1.6	1.7	1	1	1.24	1.2	1	1.13	2	1.3
	45	45.69	35.09	1	1.7	1	1	1.27	1.2	1	1.4	2	1.2
	46	45.67	35.07	1.2	1.7	2	1	1	2	1	1.35	2	1.4
	47	45.62	35.01	1.2	1.7	2	1	1.017	1.2	1	1.69	2	1.4
	48	45.52	34.84	1	1.7	1	1	1	1.2	1	1.34	2	1.2
	49	45.47	34.76	1	1.7	2	1	1	1.2	1	2	2	1.4
	50	45.41	34.67	1	1.7	2	1	1	1.2	1	1.24	2	1.3
	51	45.27	34.57	1.2	1.7	2	1	1	1.2	1	2	2	1.4
	52	45.35	34.43	1	1.7	1	1	1	1.2	1	1.61	2	1.2
	53	45.41	34.36	1	1.7	1	1	1	1.2	1	1.61	2	1.2
Dyala	54	45.36	34.40	1.2	1.7	2	1	1	1.2	1	1.33	2	1.3
	55	45.34	34.46	1	1.7	2	1	1	1.2	1	1.69	2	1.3

	56	45.35	34.59	1.2	1.7	1	1	1	2	1	2	2	1.4
	57	44.39	35.56	1.2	1.7	1.3	1	1.12	1.2	1	1.55	2	1.3
	58	44.38	35.56	1	1.7	1.3	1	1.29	1.2	1	1.58	2	1.3
	59	44.38	35.61	1.2	1.7	1.3	1	1	1.2	1	1.2	2	1.3
	60	44.41	35.69	1.2	1.7	1.3	1	1	1.2	1	1.2	2	1.3
	61	44.46	35.73	1.2	1.7	1.3	1	1.12	1.2	1	1.55	2	1.3
	62	44.30	35.65	1.2	1.7	2	1	1	1.2	1	1.33	2	1.3
	63	44.25	35.69	1.2	1.7	2	1	1	1.2	1	1.33	2	1.3
	64	44.22	35.72	1.2	1.7	2	1	1	1.2	1	1.33	2	1.3
Kirkuk	65	44.20	35.70	1.2	1.7	2	1	1	1.2	1	1.46	2	1.3
	66	44.17	35.75	1.2	1.7	2	1	1	1.2	1	1.46	2	1.3
	67	44.37	35.27	1.2	1.7	2	1	1	1.2	1	1.51	2	1.3
	68	44.40	35.21	1.2	1.7	2	1	1	1.2	1	1.51	2	1.3
	69	44.42	35.17	1.2	1.7	2	1	1	1.2	1	1.51	2	1.3
	70	44.43	35.17	1.2	1.7	2	1	1	1.2	1	2	2	1.4
	71	44.48	35.33	1.2	1.7	2	1	1.017	1.2	1	2	2	1.4
	72	44.42	35.32	1.2	1.7	2	1	1.017	1.2	1	2	2	1.4
	73	44.46	35.32	1.2	1.7	2	1	1	1.2	1	1.24	2	1.3
	74	44.47	35.36	1.2	1.7	2	1	1	1.2	1	2	2	1.4
	75	44.12	35.81	1.2	1.7	2	1	1	1.2	1	2	2	1.4
	76	44.09	35.89	1.2	1.7	2	1	1	1.2	1	2	2	1.4
	77	44.03	35.99	1.2	1.7	2	1	1.017	1.2	1	1.60	2	1.4
	78	44.00	35.98	1.2	1.7	2	1	1.017	1.2	1	1.60	2	1.4
	79	43.96	35.94	1.2	1.7	2	1	1	1.2	1	1.56	2	1.4
	80	43.78	35.88	1	1.7	2	1	1	1.2	1	2	2	1.4
	81	43.72	35.84	1	1.7	2	1	1	1.2	1	2	2	1.4
Erbil	82	43.66	35.81	1.2	1.7	2	1	1	1.2	1	2	2	1.4
	83	43.60	35.80	1	1.7	2	1	1	1.2	1	2	2	1.4
	84	43.61	35.80	1	1.7	2	1	1.2	1.2	1	1.58	2	1.4
	85	43.71	35.93	1.2	1.7	2	1	1	1.2	1	1.58	2	1.4
	86	43.67	35.94	1.2	1.7	2	1	1	1.2	1	1.58	2	1.4
	87	43.60	35.98	1.2	1.7	2	1	1	1.2	1	1.20	2	1.3
	88	43.53	36.03	1.2	1.7	2	1	1.2	1.2	1	1.53	2	1.4
	89	43.50	36.03	1	1.7	2	1	1	1.2	1	1.66	2	1.3

Soil quality indicator

In calculating the weight of the soil quality indicator (Fig.4) and comparing it with the quality classes in the MEDALUS model, it seems that the soil of the study area is divided into two classes, firstly, class 2 (moderate quality) 25147 km2, which occupied 95% of the study area and class 3 (low quality) with an area of 1309 km^2which equal to 5% of the total area. The low soil quality is due to a number of factors related to the properties of the soil, mainly the limestone soil parent material , which is has the low resistant to weathering and therefore they break down or dissolve by water. The lack of gravel and stones scattered in the study area (more than 99% is of class 3 - Bare to slightly stony) leads the soil to be very sensitive to erosion, as well as the effect of soil texture, which (class 3) reached more than 72% of study area , also the decline of organic matter, where class 3 (poor) occuped a rate of more than 80% of study area. Organic matter and clay increase the ability of soil water retention, improving soil aggregations thus minimizes runoff and soil erosion. The effects of salinity and drainage was not significant and no effect was shown for them, because the study soils are not saline in general, and the condition of the drainage is rather good.

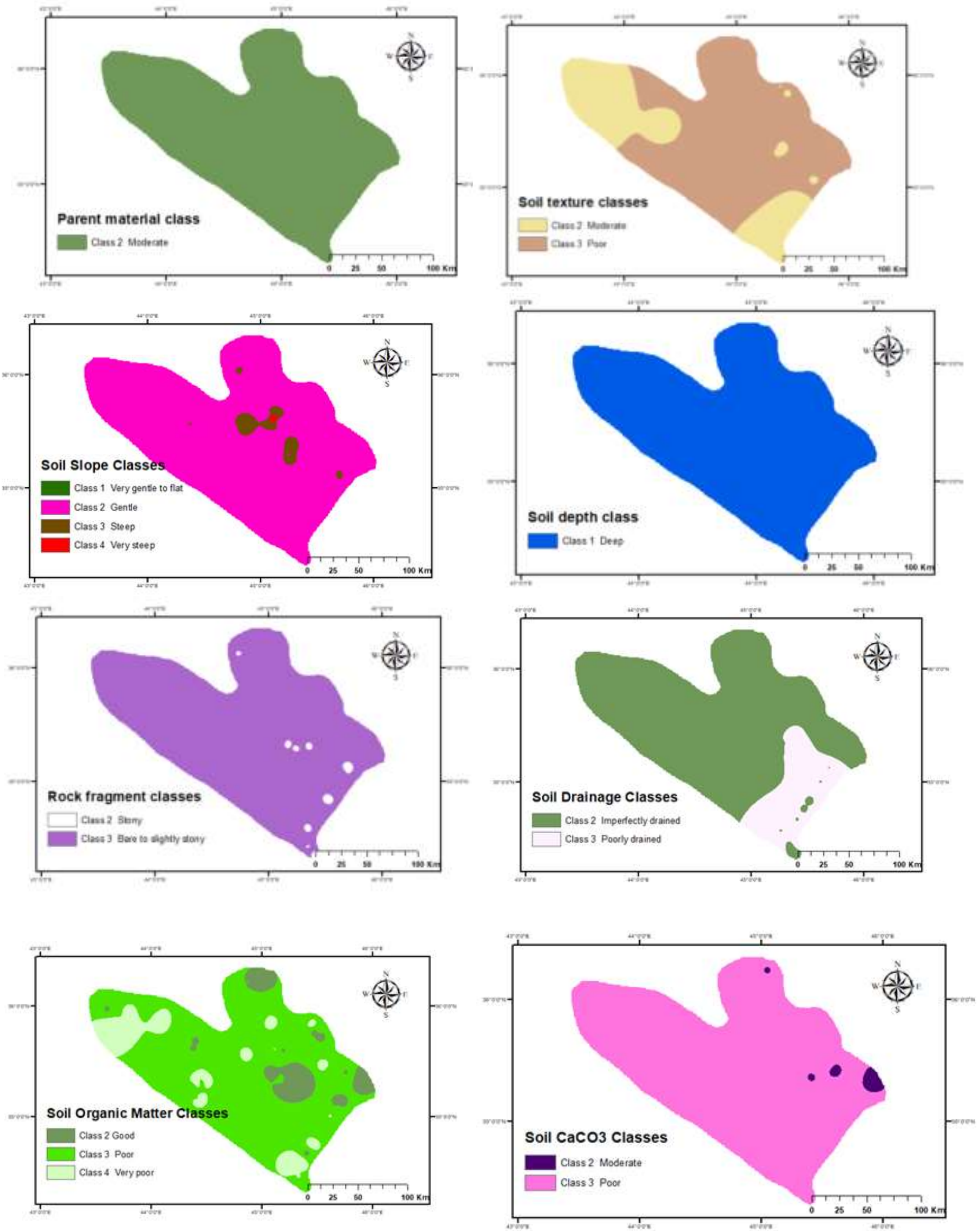

Figure 4. Soil quality indicator SQI for study area

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