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Land Suitability for Wheat Production under Dry Farming System in Erbil Plain Using Remote Sensing and GIS

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ABSTRACT

This study was conducted in order to evaluate land suitability for wheat production under dry farming system and to develop suitability maps for the dominant soil units in Erbil project using remote sensing and GIS techniques. Historical soil data were collected from previous work done in 2008, climatic data for the last twenty years, and two images for Landsat-7 (ETM+) acquired in 22/4/2008 and 22/3/2014, respectively, were collected. fourteen soil samples represent the dominant soil units in the study area were taken from(0-40 cm), and recorded the geographical information (Longitude, Latitude, and Elevation) by GPS receiver. Some soil properties were determined for each soil samples. Suitability rating scores of each soil properties and climatic characteristics were evaluated for wheat growing under dry farming system in Erbil project using Sys et al.,(1985 and 1993) and FAO, (2007) systems. The results indicated that soils of the study area have some predominant limitations for wheat growing including slope degree, rock fragments, calcium carbonate content and climatic characteristics. Accordingly, the land of Erbil project was moderately suitable to unsuitable for wheat production and they are within suitability classes (S2) and (N2)..

Keywords: Land, land suitability, Wheat crop, Climate

INTRODUCTION

Land resources are gradually becoming scarce as increases in population put pressure on natural resources. Population increases and urbanization have resulted in increased pressure on agricultural resources (Orhan et al .2003). The challenge in the next decades is to ensure that global and regional food security increases food production for the survival of the growing population. However, this puts increased pressure on land resources, which may result in land degradation, particularly in countries with restricted water and other natural resources. Therefore, increases in food production are urgently required to tackle poverty and land degradation problems in developing countries (Fredrick and Julie, 1997). As a result, food security is one of the top agricultural policies in developing countries, and arable land in these countries needs to be evaluated for current and future agricultural uses. Land suitability evaluation is well suited for identifying land boundaries, land use planning, specialization of crops in different regions, providing optimal cropping pattern and food policy (Mahler, (2005).) 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, 2005).

Land evaluation is concerned with the assessment of land performance when used for specified purposes. It involves the execution and interpretation of basic surveys of climate, soils, vegetation and other aspects of land in terms of the requirements of alternative forms of land use. Land evaluation is also part of the process of land use planning. The main objective of the land evaluation is the prediction of the inherent capacity of a land unit to support a specific land use for a long period of time without deterioration, in order to minimize the socio-economic and environmental costs (Rosa, et al. 2004). Finding suitable land area for demanding agriculture crops is the need of present day farming system. There for, it is necessary to provide a tool or an effective means of helping to build a powerful data base, durable and solid to be a reliable reference for many researchers and those interested in planning for the use of agricultural land. Tools used should be effective, modern and develop to build the necessary informational basis for this process is the use of geo-technologies included spatial geographic information systems and Remote sensing technology, that depend on the study of the distribution and spatial analysis of digital features. All these technologies are very important for different geographical to be ready for the retrieval of the question and the production of maps ,as well as, in support of politicians and administrators to take balanced decisions in relation to the assessment, land use planning and land suitability for the cultivation of strategic crops spatiality important in irrigated areas (Rossiter, 1996). Few studies were done on land suitability for crop production in some irrigated sites in the central and southern of Iraq (Al-Shafie and Muhaimeed, (2012); Al-Shafie et al. (2014) and; Muhaimeed et al., (2014) ; Mohammed et al., (2007) but studies are limited if any for such evaluation under dry farming system.

The main objectives of this study are:1)To evaluate land characteristics suitability(soil and climate) of Erbil plain for wheat growing under dry farming system using FAO, (2005) and Sys et al., (1985 and 1993) systems and adoption of Remote Sensing and GIS to develop land suitability maps for wheat production in Erbil project.

MATERIALS AND METHODS

The study area located at Erbil Governorate in Iraqi Kurdistan region .It is a part of Erbil plain project and covers an area of 618.79 km^2. Its geographical position extends from Latitude 36°0'0"N to 36°15'0" N and Longitude 43°37'30" E to 43°52'30"E (Figure 1).

The study area was used mainly for agricultural production to produce grain crops including Wheat, Barely under dry farming system, and for urban uses. The natural vegetation cover consists of low density of ***Cynodon dactylon, Silybum marianum, cochlearia armoracia*, *Lagonychium farctum*** …etc.

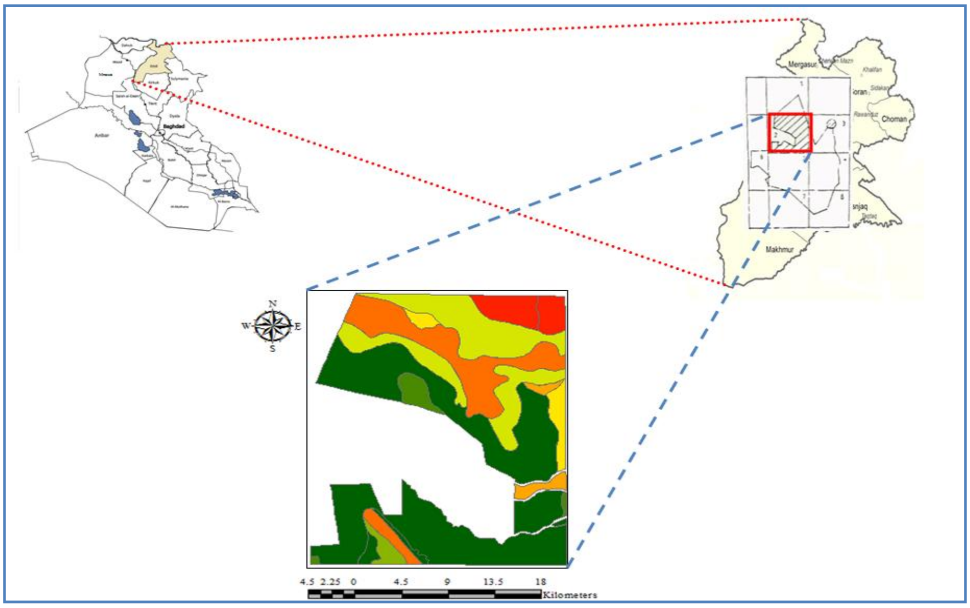

Figure1. *Location of the study area.*

DATA COLLECTION

Climatic data including temperature and rainfall for the last 20 years were collected from Agro meteorological/ Ministry of Agriculture,, (2012) . The climate of Erbil is characterized by a warm to hot in summer and a cold to pleasantly mild winter .This region is characterized by abundant rains and ranged 350 to 450 mm per year, The average temperature is approximately 22,4 °C. Soils have a torrid (aridic) moisture regime with Hyper thermic temperature regime(Soil Survey Staff, (1999).). Soil data which were collected from previous work done in 2008, show that soils of the study area classified into four soil orders including Aridisols, Entisols, Inceptisols, and Vertisols (Conulting Engineers Dar Baghdad, (Consulting Engineers Dar Baghdad ,2008).) (Table1 and Figure 2). To investigate the changes in land productivity for wheat growing in Erbil project, two scenes of the Landsat-7 ETM+ images (path 169/row 35) acquired on 22/4/2008, and 22/3/2014 covered the study area were assembled for the purpose of this study. respectively. Images were obtained from (USGS), the CC=3% for image 2008 and CC= 0% for image.

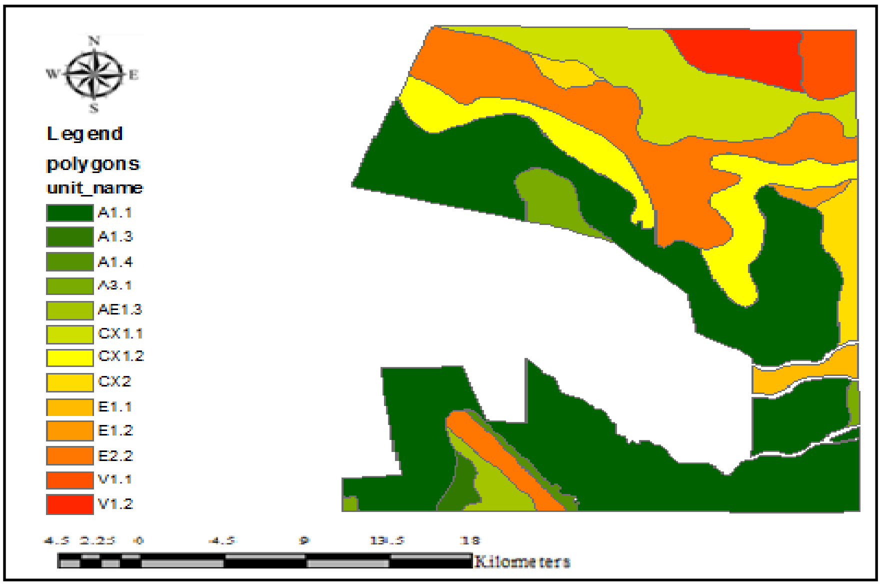

Figure2. *Spatial distribution of soil units in the study area, 2008*

Table1. *Description of soil units in the study area.*

SMU	Description
A1.1	Aridisols order, moderately fine texture and flat to almost flat
A1.3	Aridisols order moderately fine texture, slightly gravelly surface, undulating and slightly eroded
A1.4	Aridisols order moderately fine texture, slightly gravelly surface, rolling and slightly eroded
A3.1	Aridisols order moderately fine surface texture and flat to almost flat
CX1.1	Inceptisols order, moderately fine surface texture and flat to almost flat
CX1.2	Inceptisols order, moderately fine, slightly gravelly surface, undulating and slightly eroded
CX2	Inceptisols order, moderately silty clay loam texture
E1.1	Entisols order, medium texture surface and flat to almost flat
E1.2	Entisols order, medium texture, slightly gravelly surface, undulating and slightly eroded
E2.2	Entisols order, medium, sandy loam, gravelly, hilly and eroded
V1.1	Vertisols order, moderately fine texture, flat to almost flat
V1.2	Vertisols order, moderately fine and flat to almost flat
AE1.3	Aridisols and Entisols order, medium texture, hilly eroded, deep soils

Developing Soil Suitability Maps

Digital soil map was created by using (ArcGIS 10) program for traditional soil map (hardcopy map) of Erbil plain project. Land suitability evaluation for wheat production was done using the proposed systems of Sys et al., (1993) and FAO, (2005).

Calculating Climatic Index (Ci)

The standard proposal was adopted by the sys et al., (1993) dealing with the climate data including mainly the mean annual rainfall and temperature for the study area. The climatic index was calculated as shown in the following equation:

$$\textbf{Climate index (Ci)} = A1*A2*\ldots*An/10^{2n-2}\ldots\ [2]$$

Where: A1, A2, and An were the rating of climate characteristics of wheat, and n represents the number of growth stages, which was depend on the suitability of these properties for wheat crop growth stages . According to the available information about wheat growing under dry farming systems in Northern Iraq, there are two dates for wheat planting as shown in Tables 2 and 3.

Table2. *Stages for Early wheat growing under dry farming system*

Stage	From	To	Days
Growing cycle	28 Oct.	20 May	204
Vegetative	28 Oct.	30 Mar.	153
Flowering	30 Mar.	8 Apr.	9
Ripening	8 Apr.	20 May	42

Table3. *Stages for Late wheat growing under dry farming system*

Stage	From	To	Days
Growing cycle	15 Dec	5 Jun	172
Vegetative	15 Dec	25 Apr	131
Flowering	25 Apr	3 May	8
Ripening	3 May	5 Jun	33

Calculating Soil index (Si):

Soil index was calculated by using Sys .et al. (1993) equation as following:

$$\textbf{Soil index (Si)} = A1*A2 \ldots\ldots An/10^{2n-2} \ldots [3]$$

Where the A1, A2, and An were the evaluation for soil properties, and n represents the number of evaluated soil properties.

RESULTS AND DISCUSSION

The results (Tables 4 and 5) indicated that all soil units of the study area show common properties like: moderately deep profiles, low organic matter content, low soluble salts, moderate calcium carbonate content, low gypsum content, neutral pH and silty clay to silty clay loam texture with the presence of some rock fragment and gravel. Most of the soils are formed on nearly to gently slope segments. All soil units are very suitable with S1 class for wheat growth, except soil units E2 and AE1 which are not suitable (class N2) due to the effect of some permanent limitations factors. The following properties show high suitable rating scores include soil depth , EC , ESP, pH , CEC , drainage and gypsum content .While , other soil properties including O.C. , soil texture ,and calcium carbonate show lower suitability rating scores ranging from 60 to 95 due to their negative effects on wheat growing. The results reveled that E2 and AE1 soil units facing predominant limiting soil properties for wheat growing including slop degree and rock fragments.

Table4. *Weighted soil properties (average depth weighted 100cm) for soil units.*

No.	SMU	Pedon	Depth cm	Texture Class	Particle size Analysis			OC gm/kg	Gypsum gm/kg	Lime gm/kg	pH	EC dS/m	CEC cmole/kg	ESP mg/kg	Drainage	Rock Fragment	Slope %	Area km2
					Sand gm/kg	Silt gm/kg	Clay gm/kg											
1	A1	P5	120	CL	216.50	410.75	372.75	7.30	0.80	402.00	8.11	0.36	27.37	1.67	good	3	1	299.56
2	A3	P7	120	CL	199.50	486.80	313.70	3.12	0.81	407.50	7.85	0.33	23.35	1.56	good	3	1	13.09
3	CX1	P42	120	SiCL	76.00	538.00	386.00	6.78	1.44	324.60	7.80	0.34	23.80	1.54	good	3	1.5	19.43
4	E1	P20	140	SL	542.50	266.50	191.00	2.54	1.20	309.20	8.07	0.31	10.00	1.50	good	3	1.5	11.74
5	E2	P34	120	SiL	661.50	214.50	124.00	3.55	8.76	477.52	8.00	0.33	9.58	1.54	good	41	31	99.42
6	CX2	P40	120	SiCL	80.00	582.00	338.00	6.62	1.80	305.80	8.00	0.37	21.92	1.64	good	3	1.5	129.96
7	V1	P16	120	C	135.50	421.00	442.00	4.27	0.81	390.40	7.96	0.33	31.81	1.61	good	1	1.5	36.33
8	AE1	P32	110	L	442.00	323.00	235.00	2.68	1.00	459.40	7.82	0.46	17.44	1.84	good	16	17	9.26
																		Tot: 618.79

Table5. *Suitability rating scores of soil properties for wheat growing in the study area*

No.	SMU	Pedon	Depth Rating	Texture Rating	OC Rating	Gypsum Rating	Lime Rating	pH Rating	EC Rating	CEC Rating	ESP Rating	Drainage Rating	Rock frag. Rating	Slope Rating	Soil index Rating	Soil index Class	Area km2
1	A1	P5	95	100	95	100	60	95	100	95	100	100	95	95	93.6	S1	299.56
2	A3	P7	95	100	60	100	60	95	100	85	100	100	95	95	89.5	S1	13.09
3	CX1	P42	95	100	95	100	85	95	100	85	100	100	95	95	95.0	S1	19.43
4	E1	P20	100	60	60	100	85	95	100	80	100	100	95	95	88.2	S1	11.74
5	E2	P34	95	100	60	100	60	95	100	80	100	100	60	0.0	0.0	N2	99.42
6	CX2	P40	95	100	95	100	85	95	100	85	100	100	95	95	95.0	S1	129.96
7	V1	P16	95	95	85	100	85	95	100	100	100	100	100	95	95.0	S1	36.33
8	AE1	P32	95	95	60	100	60	95	100	85	100	100	85	0.0	0.0	N2	9.26
																	Tot: 618.79

The results (Tables 4 and 5) show that the soils of Erbil project are deep enough to be more suitable for wheat growth as there were no depth limitation i.c. no impermeable or rock layer within a depth of less than 140 cm) . Therefore, all soil units in the study area are very suited for wheat cultivation and have suitability rating score of (95) for pedons 5, 7, 42, 34, 40, 16, 32 while, for pedon 20 was (100). So, all soil units in Erbil project have very low to no depth limitation for wheat growing according to Sys et al., 1993) and FAO, 2005.

Soil texture is an important soil characteristic that influences many other soil properties including water infiltration rates, Drainage, Water holding capacity, Aeration, Susceptibility to erosion, Organic matter content, Cation exchange capacity (CEC), and pH buffering capacity (20). Soil texture may be become a "limited factor" for crops growth. As shown in table (4) the texture of all soil units in Erbil project ranged from clay to silty loam.

Figure (4) shows the spatial distribution of soil texture classes for soil units in Erbil project. The predominant soil texture classes observed in the study area at the soil surface (0-40 cm) is moderately fine texture and covered 81.5% of total area. According to Sys et al., (1993) it was not constitute a major limiting factor for wheat growing. The results (Table 5) indicated that the suitability rating score was (100) for pedons 5, 7, 42, 34, 40 and (95) for pedons 16 and 32, while pedon 20 shows a lower rating score (60) as it has coarse texture of sandy loam class. The lowest suitability rating score associated with soil unit E1 located at steeper slope for the landscape position which increases the activity of soil erosion process in comparison to other soil units. on many other soil properties and on plant growth. Soils with high organic carbon have a good physical chemical and fertility conditions which are more suitable for good crop production (FAO, 1976).

Figure (4) shows the spatial distribution of calcium carbonate in the study area. According to Sys et al., (1993) the suitability rating score for wheat growing is a moderate suitable and somewhat is suitable. The result indicated the soils of the study area show some variation with values of the suitability rating scores and ranging from 60 to 85. These variation in the values of the suitability rating scores due to the variation in content of calcium carbonate between soil units in the study area which have great effects on the suitability for wheat growing.

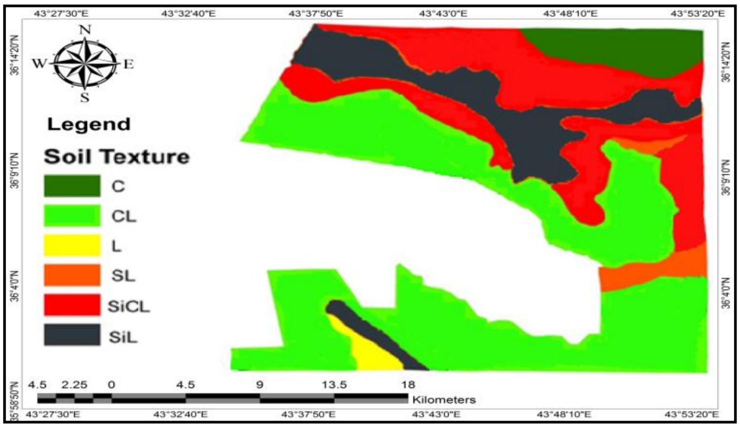

Figure3. *Spatial distribution of soil texture classes in the study area.*

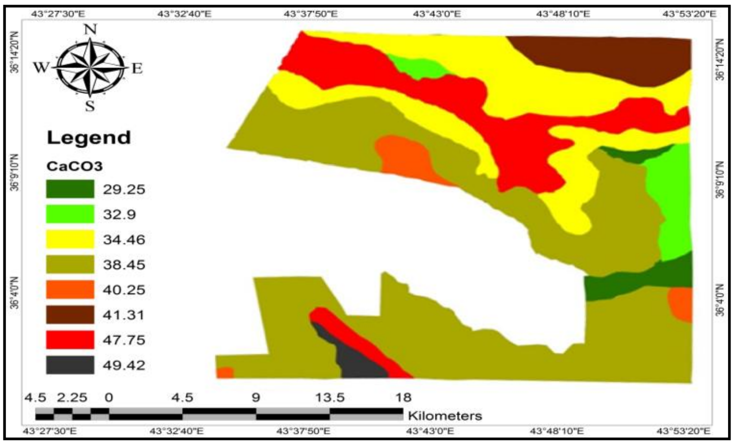

Figure4. *Spatial distribution of Calcium Carbonation in the study area.*

The results indicated that the values of pH for all soils in Erbil project ranged from (7.8 to 8.8). The suitability rating score of pH values of all soil units in Erbil project are very suitable for wheat production with value of (95), indicating slight limitation for wheat growth. The values of CEC for all the study soil units in Erbil project ranged from (9.58 cmole/kg) for pedon 16 to (31.81 cmole/kg) for pedon 34. These variations in the values of CEC reflect the effects of the differences with in soil texture of the study soils .In general, soils with coarse texture show lower values for the CEC and vise versa. Figure 5 shows the spatial distribution of the CEC value for soils in Erbil project. According to Sys, et al., (1993), the suitability rating scores of the CEC for growing wheat are very suitable to moderately suitable and ranged from (80 - 100) and have slight limitation for wheat production.

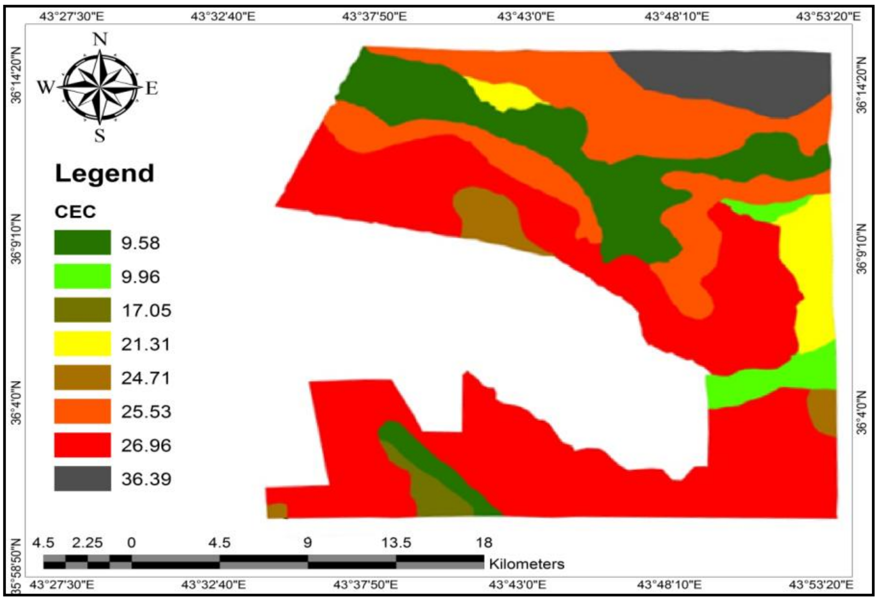

Figure5. *Spatial distribution of CEC values in the study area*

Rock fragment content in soils have some effects on plant growth and crop productivity. The presence of rock fragments influences the nutrient status, water movement, use and management of the soil. It also reflects the origin and stage of development of the soil (FAO,2007).The results of the previous studies on the soils of the study area indicated that there is some variation in the percentage of the rock fragments between soil units in Erbil project, so, these soils show different rate of suitability for wheat growing. It was slightly gravelly about (3%) on the surface of pedons 5, 7, 42, 20, 40 and the suitability rating score was (95). While, there is about (41%) rock fragments on the surface of pedon 34 so, its suitability rating score is (60). Pedon 34 located on highly eroded landscape position with slope degree of (31). While, the rock fragments in pedon 16 was (1) and the rating score is (100), and for pedon 32 was (16) with rating score (85).

The results indicated that the land of the study area show some variation with slope degree. Slope degrees in the study area ranged from 1% to 31 %. The lowest rating scores were shown in soil units located on steepest slope for landscape position. While, soil units located on nearly flat landscape position show the highest suitability rating scores which allow operating agricultural practices more easily in comparison to steep slope position. The results of suitability rating scores show that the slopes have the greatest permanent limitation for growing wheat compared to other land properties. The rating scores for Soil units (E2 and AE1) are zero. These soil units located on landscape position with slope degree of 31% and 17% respectively. These results indicated that soil units E2 and AE1 are not suitable for wheat cultivation due to the presence of the permanent limitation land properties that need time and great efforts to reclaim them.

Evaluation of Climatic Suitability for Wheat Productivity

According to the results of climatic data for the last 20 years, the suitability rating score (Table 6 and 7) for the mean annual rainfall (2008-2014), indicated that the climate is slightly suitable (S2) for early wheat planting while the rating score is (65.19), and it is not suitable (N1) for late planting system the rating score is (59.25) due to low amount of mean annual rainfall for wheat requirements during the germination stage and other growing stages. These results indicated that the climatic conditions have great effect on wheat production in comparison to other land properties.

Table6. *Rainfall Suitability rating score for early planted wheat*

No.	Climate characteristic	Mean precipitation(mm)	Rating score
1	Growing cycle	46.41	86.91
2	Vegetative stage	40.27	93.11
3	Flowering stage	46.86	90.62
4	Ripening stage	23.61	77.01
	Climate Index Ci	25-12	65.19
	Suitability class of climate	S2	

Table7. *Rainfall Suitability rating score for late planted wheat*

No.	Climate characteristic	Mean precipitation(mm)	Rating score
1	Growing cycle.	43.63	78.77
2	Vegetative stage	52.09	96.77
3	Flowering stage	30.89	85.30
4	Ripening stage	7.46	54.92
	Climate Index Ci	25-12	59.25
	Suitability class of climate	N1	

The suitability rating score (Table 8 and 9) for the mean annual temperature (2008-2014) for wheat crop under dry farming, indicated that the climatic suitability is moderately suitable (S3) for early wheat planting while the rating score is (77.87), and it is slightly suitable (S2) for late planting system the rating score is (95.10) due to the suitability of mean annual temperature for wheat requirements mainly during the germination stages. These results indicated that the climatic conditions have great effect on wheat production in comparison to other land properties.

Table8. *Temperature Suitability rating score for early wheat planted*

No.	Wheat Stages	Mean temperature(^{o}C)	Rating score
1	Growing cycle	10.77	69.63
2	Vegetative stage	10.30	99.25
3	flowering stage	17,13	98.91
4	Ripening stage	10.87	43.7
	Climate Index Ci	50-25	77.87
	Suitability class of climate	S3	

Table9. *Temperature Suitability rating score for late wheat planted*

No.	Wheat Stages	Mean temperature(^{o}C)	Rating score
1	Growing Cycle	14.47	93.23
2	Vegetative stage	11.48	96.3
3	flowering stage	16	97.5
4	Ripening stage	24.98	93.37
	Climate Index Ci	75-50	95.10
	Suitability class of climate	S2	

According to the results of planting date (Early and Late) the high rating score were in the mean annual temperature in early and late planting date compared with then mean annual rainfall. The highest and the best rating score in suitability temperature of late plating date (Table 8) for wheat crop growing under dry farming system, shown in Table 9.

In general, the overall evaluation of the suitability for all land characteristics (soil and climate) including the early and late planting systems in Erbil project in 2008.The results (Fig.6) indicated that about more than (80 %) the total area of Erbil project are classified as moderately suitable for wheat production according to Sys et al., (17), in class **S2** and other area are not suitable for wheat growing class **N2**. The main limitations for land suitability represented by high calcium carbonate content, steep slope, rock fragments and climatic conditions. Some of these limitations are predominate and need time and efforts to be reclaimed to be more suitable for wheat crop and other cannot be easily changed, mainly climatic condition.

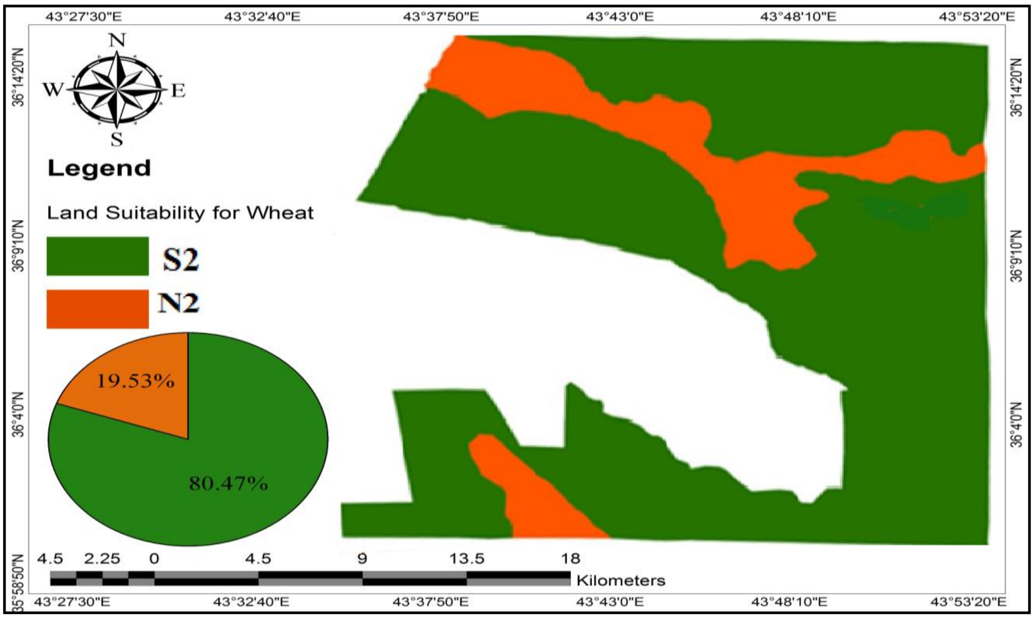

Figure6. *Land suitability classes for wheat production in study area*.

CONCLUSIONS

The results indicated that the land of Erbil project were moderately suitable to unsuitable for wheat production due to the effect of some predominant limitations including slope degree, rock fragments, calcium carbonate content and climatic characteristic.

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