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College of Agricultural Engineering Sciences

CLASSIFICATION AND STATUS OF LAND DEGRADATION AND DESERTIFICATION OF DRYLANDS IN KURDISTAN REGION - IRAQ

A Dissertation

Submitted to the Council of the College of Agricultural Engineering Sciences at the University of Sulaimani in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy in

(Soil Survey and Classification)

By

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بِسْمِ اللَّهِ الرَّحْمَٰنِ الرَّحِيمِ

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تَذْرُوهُ الرِّيَاحُ وَكَانَ اللَّهُ عَلَى كُلِّ شَيْءٍ مُقْتَدِرًا

سورة الكهف ﴿ آية ٤٥ ﴾

Supervisor Certification

I certify that this dissertation was prepared under my supervision at the Department of Natural Resources, College of Agricultural Engineering Sciences, University of Sulaimani in partial fulfillment of the requirements for the degree of **Doctor of Philosophy** in **Soil Survey and Classification**.

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Dedication

I dedicate this thesis to:

My dear father's soul

My Merciful mother who encouraged me

to continue this thesis.

My brothers & sisters

My nieces & nephews........

And those who left bright memory

in my mind & heart.

With love and respect.......

Mahtab

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SUMMARY

The study was conducted to assess land desertification, soil quality, land suitability and land capability classification for drylands in some parts of Iraq and Iraqi Kurdistan Region.

The study area included arid and semi-arid lands located between longitudes 43° 25' 41"- 46° 28' 1" E and latitudes 34° 18' 33"- 36° 20' 56" N which include some parts of the governorates of Sulaimani, Diyala, Kirkuk, and Erbil in Iraq covering area of 2645600 ha.

Twenty pedons were drilled and described morphologically. In addition to that, eighty nine surface soil samples were taken from the neighboring area for these pedons. All soil samples were taken to the laboratory and air dried, sieved through a 2mm screen and analyzed for physical and chemical properties.

Desertification was assessed according to MEDALUS project (Kosmas et al., 1999b) and using GIS technique.

According to the mean annual precipitation (mm), the study area was found to fall into three zones included zone 2 [Arid (100-300) mm], zone 3 [Semiarid (300-500) mm] and zone 4 [dry subhumid (>500) mm] as classified by (FAO, 1998). Soil quality was then assessed in each zone.

Land suitability classes for the study area were determined according the proposal of Sys et al. (1993).

The land capability classes and subclasses were arrived at according to the guidelines in Soil Survey Manual (AISLUS, 1971).

The results obtained from this study were as following:-

1- Desertification assessment

a- Soil quality indicator (SQI)

- Soil texture ranged between class 2 (moderate) and class 3 (poor) with an area of 737100 ha and 1908500 ha, which covered 27.86% and 72.14%, of the study area respectively.
- The parent materials of all the soil of the study area were within class 2 (moderate).
- The index of rock fragment for all the soils of the study area was generally within class 3 (bare to slightly stony) which occupied 99.25% of the total area.

- The index of soil slope in the largest part of the study area was within class2 (gentle), with an area of 2561000 ha, which occupied 96.80% of the study area, and the remaining space was between classes 1, 3 and 4, which occupied only 3.20% of total study area.
- The soil depth index was classified as class 1(deep).
- The soil drainage classes were found to be in class 2 (imperfectly drained) and class3 (poorly drained) with an area of 2150600 ha and 495000 ha at a rate of 81.29 and 18.71%, respectively.
- The organic matter index was divided into class 2 (good), class 3 (poor) and class 4 (very poor).The area of class 3 was 2144300 ha with a rate of 81% of the total study area; thus it succeeded the class 2 and class 4 that occupied the area of 224800 ha and 276500 ha with a rate of 8.5 and 10.5% of the total study area respectively.
- Calcium carbonate index was found to be in class 3 (poor) which occupied 2608200 ha with a rate of 98.59% of the total study area.

In calculating the weight of the soil quality indicators it seemed that the soil of the study area could be divided into two classes, firstly, class 2 (2514700 ha), which occupied 95% of the study area and secondly class 3 (low quality) with an area of 130900 ha which was 5% of the total area.

b- Vegetation quality indicator (VQI)

- It was found that the plant cover to be in class 2 (low), so the study area was not well protected against desertification.
- The risk of fires was found to be of class 2 (moderate).
- The drought resistance was found to be in class 5 (very poor).
- The study area was divided into two classes according to protection from erosion. The area of class 3 (Low) was 803700 ha and the area of class 4 (very low) was 1841900 ha, which occupied 30.38% and 69.62% of the total study area respectively.

Vegetation quality indicator consisted of class 2 (moderate quality) with an area of 760100 ha and class3 (low quality) whose its area was 1885500 ha, they occupy 28.73% and 71.27% of the total study area, respectively.

c- Climate Quality indicator (CQI)

- The study area was divided into two classes in terms of the quantity of precipitation. Class 1(high quality) its area was 289800 ha, which was about 10.95% of the total study area, but class2 (moderate quality) which occupied an area of 2355800 ha and was about 89.05% of the total study area.
- Aridity index for the study area was found to be in classes 4 and 5 which occupied an area of 706500 ha and 1939100 ha with a rate of 26.70% and 73.30% respectively.
- The climate quality of the study area was found to fall in class 2 (moderate class).

d- Management quality indicator (MQI)

- Cropland for the study area was within the class 2 (medium landuse intensity).
- Policy criteria was divided into three main classes, class 1 (high), class 2 (moderate) and class 3 (low) with an area of 486500 ha (18.39%),715000 ha (27.03%) and 1444100 ha (54.58%) respectively.

Management quality indicator for the study area was divided into three classes, includes the class 1 (high) and its area was 456200 ha, class2 (moderate) its area was 747100 ha and finally class3 (low) and its area 1442300 ha they occupied 17.24, 28.24 and 54.52% of total study area respectively.

e- Environmentally sensitive areas to desertification (ESAs)

The most common type of Environmentally Sensitive Areas to Desertification (ESA) for the study area was class C3 (Critical) with an area of 1112700 ha (42.06%) of the study area, followed by classes C2 and C1 with an area of 759700 ha and 364000 ha which covered 28.71% and 13.76% of the study area respectively. The Fragile classes (F3 and F2) occupied 309300 ha and 99900 ha with a rate of 11.69 and 3.78%, respectively.

2- Soil quality for the study area

a. The clay% in zone 4 and zone3 was 38.6 and 37.5% respectively, with a significant difference with zone2, which reached 20.7%, while there was not significant difference between zone 3 and zone 4.

b. Insignificant differences (P= 0.163) was found between arid zones in means of bulk density. Zone 4 outperformed zone 3, which surpassed zone 2 with values of (1.66, 1.62 and 1.59) Mg m^{-3} respectively.

c. Significant differences between zone3 and zone 4 in the mean organic carbon content at rate of 0.90%, 0.81% respectively whereas zone 3 outperformed zone 4, and both outperformed zone 2 significantly which reached 0.46%.

d. Soil pH did not show any significant variation across zone 2 (7.89), zone 3 (7.86), and zone 4 (7.77) (P>0.05). However, there were little differences in values, where zone 2 was higher than zone 3, which in turn surpassed zone 4.

e. Soils of all zones were not saline where values of EC were 0.48, 0.38 and 0.20 dS m^{-1} for zone 2, zone 3 and zone 4 respectively, showing no significant differences among zones of the study area.

f. There was no significant differences among zones in available potassium (P>0.05), but they varied in values, Available potassium was higher in zone 4 (0.614 $Cmol_c$ kg^{-1}) followed by zone 3 (0.564 $cmol_c$ kg^{-1}) and zone2 (0.451 $cmol_c$ kg^{-1}).

g. Available nitrogen significantly varied between zone 2 in one hand, and zone 3 and zone 4 the other, with a value of 1.567 g kg^{-1}, 2.334 g kg^{-1} and 2.222 g kg^{-1} for zone 2, zone 3 and zone 4 respectively, but there were not significant differences between zone3 and zone 4.

h. The available P did not show any significant differences in arid zone classes giving values of 4.32 µg kg^{-1}, 5.65 µg kg^{-1} and 4.78 µg kg^{-1} for zone 4, zone 3 and zone 2 respectively.

i. Concentration of exchangeable calcium did not show any significant variation across all zones, the zone 4 has the highest value followed by zone 3 and zone 2 with values of 22.5 $cmol_c$ kg^{-1}, 22.3 $cmol_c$ kg^{-1} and 18.2 $cmol_c$ kg^{-1} respectively.

j. Exchangeable Mg^{2+} showed no significant variation between zone 3 and zone 4, but they varied with zone 2 by a mean value of (5.1, 7.4 and 1.6) $cmol_c$ kg^{-1} for zone 4, zone 3 and zone 2 respectively.

k. The values of exchangeable Na^+ were (0.215, 0.221 and 0.193) $cmol_c$ kg^{-1} for zone 4, zone 3 and zone 2 respectively. Zone 2 differed significantly with zone 3, but not significantly with zone 4.

l. The exchangeable Potassium K^+ values were (0.40, 0.53 and 0.59) $cmol_c\ kg^{-1}$ for zone 2, zone 3 and zone 4 respectively. Zone 2 varied significantly with zone 4, but there was insignificant variation between zone 2 and zone 3, also between zone 3 and zone 4. The pattern distribution of exchangeable Potassium K^+ was similar to the available K^+.

m. Cation exchange capacity varied significantly within all arid zone classes. The highest value occurred in zone 4 (26.1 $cmol_c\ kg^{-1}$) followed by zone 3 (21.9 $cmol_c\ kg^{-1}$) and zone 2 (15.7 $cmol_c\ kg^{-1}$).

n. Significant differences were found among carbonate minerals content in arid zone classes, least value appeared in zone 2 (316.4 g kg^{-1}) followed by zone 3 (204.0 g kg^{-1}) and then zone 4 (171.0 g kg^{-1}).

3- Land suitability for wheat crops

a. The soil of the study area was deep and there were no depth limitations, with rate values of 90, 95, and 100 for most pedons.

b. The soil texture rate value was ranged between 98 and 100 for the study area. In general, this was not considered as limitation factor for growing of wheat crop.

c. The estimated value of carbonate was between 40-100, indicating that the carbonates; in general, considered as a limitation factor for wheat growing.

d. The value of soil salinity rating was 95.2 and 95.3 for most parts of the study area indicating that there are simple limitations.

e. The rate value of soil reaction was between 87-100.The degree of soil reaction did not reach the alkalinity that could be effective in the growth of wheat.

f. The value of cation exchange capacity may have a different effect on soil suitability. In some locations, the value reached 60 indicating a specific effect for soil suitability, but in most other locations the value was 100 indicating that there was no limitation.

g. Values of organic carbon rating differed among the study sites, where in most sites it was 100 indicating no specific limitation where as it decreased in other sites to reach 73.

h. Flooding characteristic did not have any effect on soil suitability for wheat growing throughout the study area, where the value was 100 for all sites.

i. Soil drainage did not play an important role in soil suitability and the rate value was 95 and 100 for most locations.

j. The rate value for base saturation was 100 for all sites of the study area. This indicated that there was no effect on soil suitability.

k. The rate value for total cations was 100 for all sites of the study area. This indicates that they had no effect on soil suitability.

l. The results showed the dominance of three classes that represent the land suitability of the study area for Wheat crop as follows:

- **Class S2 (moderately suitable):-** The land of this class could be moderately suitable for wheat growth, with an area of 260800 ha, which is about 10% of the study area.
- **Class S3 (marginally suitable):-** This land is characterized as marginal. Land area was 1844700 ha, which occupied 69.72% of the study area.
- **N1 (currently unsuitable):-** This area was 539100 ha, which occupied 20.37% of the study area.

4- Land capability classification

Land Capability Classes were divided into five main categories including:

- Class II: This class covers 42500 ha, which accounts for 1.6%. Capability sub-class of this class included IIe1 and IIs1e1.
- Class III: The land capability class III covers an area of 77000 ha, which accounts for 2.9% of the total study area. Capability sub-class of this class included IIIe, IIIs, IIIew, IIIc, and IIIce.
- Class IV: Covering an area of 2090600 ha (79%). Capability sub-class of this class included IVe, IVs, IVes, and IVc.
- Class V: covering 420000 ha, which account for 15.9% of total area.
- Class VI: covering an area of 15500 ha (only 0.6% from the study area).

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CHAPTER ONE

INTRODUCTION

Drylands cover 47% of Earth's land surface. These include four categories according to their aridity index: hyperarid, arid, semiarid, and dry sub humid regions (FAO, 1998).

Drylands have been defined by FAO on the basis of the length of the growing season, as zones which have between 1-74 and 75-199 growing days and represent the arid and semi-arid drylands respectively (FAO, 1998). They are located between latitudes of 15º to 30º in both Northern and Southern Hemispheres and termed as arid zone. Roughly one fifth of the world's populations live in these areas.

Land degradation is defined as the long-term loss of ecosystem function and productivity caused by disturbances from which the land cannot recover unaided (Bai et al., 2008). Land degradation occurs slowly and cumulatively and has long lasting impacts on rural areas people where become increasing vulnerable (Muchena, 2008).

Land degradation is caused by multiple factors, including extreme weather condition particularly drought, human activities that pollute or degrade the quality of soils and land utility negatively affecting food production, livelihoods, and the production and provision of other ecosystem good and services. The importance of land degradation among global issues is enhanced because of its impact on world food security and quality of the environment (Eswaran et al., 2001), and globally 33% of earth's land surface is affected by some type of soil degradation (Lal, 2009).

Land degradation in arid, semi-arid and dry sub humid areas resulting from adverse human impact. Land in this concept includes soil and local water resources, land surface and vegetation or crops (UNEP, 1992).

Desertification is the diminution destruction of the biological potential of land, and can lead ultimately to desert-like conditions. It is an aspect of the widespread deterioration of ecosystems, and has diminished or destroyed the biological potential, plant and animal production (UN, 1977).

Desertification is a worldwide phenomenon resulting from a set of geological, climatic, biological and humanistic factors leading to a reduction of the land's physical, chemical and biological potentiality in arid, semiarid and semi humid areas. Over 20% of lands in two thirds of the world's countries are directly threatened by desertification. The most effective desertification on the soil is to soil quality (Farajzadeh and Mahbobeh, 2007).

There have been many definitions of soil quality since the introduction of the term by Warkentine and Fletcher (1977). Two of the most concise definitions of soil quality are:

“Fitness for use” (Larson and Pierce, 1991) and “the capacity of a soil functions” (Karlen et al., 1997). Considering both definitions indicate that soil quality is the ability of the soil to perform the functions necessary for its intended use.

Soils have an inherent quality as related to their physical, chemical and biological properties within the constraints set by climate and ecosystems, but the ultimate determinant of soil quality is the land management (Doran, 2002).

Although soil quality was fully recognized in the early 1990’s, little research has been done to find a way to measure soil quality until early to mid-2000.

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, more than 75% of the land is considered as arid land and the rest of the land is semi-arid area (Abdulla and Dawood. 2005) where crops experience moisture stress.

Because of the existence of large areas of dry lands in Iraq and Iraqi-Kurdistan Region and due to the clear degradation of these lands for a number of reasons notably desertification plus the lack of adequate studies in this area, this study was conducted to:

1) To identify and assessment the most important factors causing and affecting desertification in the study area.
2) To test appropriate method for the evaluation and monitoring of desertification of the study area.
3) To detect and assess soil quality for the study area
4) To identify key information relating to land suitability, capability for the study area.
5) To classify the soils for the study area.

CHAPTER TWO

LITERATURE REVIEW

2.1 Drylands

Drylands (arid, semi-arid and dry sub-humid areas) cover 6150 million ha, that is 47.2% of Earth's total and land surface area. Roughly one fifth of the world populations live in these areas. They are located between latitudes of 15º to 30º in both Northern and Southern Hemispheres in what is termed the arid zone. Approximately 41% of the Earth's surface and approximately 10 to 20% of these regions are experiencing degradation processes (Deichmann and Eklundh, 1991; Reynold *et al*., 2007), resulting in a decline in agricultural productivity, loss of biodiversity and the breakdown of ecosystems. Arid and semi-arid environments make up a large portion of the Earth's surface (Fig. 2.1), and present challenges for human ecosystems located within them (Millennium Ecosystem Assessment, 2005). These regions are generally know as having low average rainfall, often associated with high temperatures, which impose fundamental limits on animal and plant populations, and on human activities such as agriculture (CSIRO 2011, Ludwig & Asseng, 2006, Ribot *et al*., 2005, Vörösmarty *et al*., 2000, and Watson *et al*., 1997).

Arid lands were previously addressed as deserts or drylands; these are regions where a combination of high temperatures and low rainfall causes evaporation that exceeds precipitation. They are characterized by extreme diurnal temperature fluctuations as dry air temperature drops abruptly after sunset. Precipitation is also highly variable, sporadic, and unpredictable. There is also a wide interannual variability of rainfall in arid lands.

Drylands have been defined by FAO on the basis of the length of the growing season, as zones which fall between 1-74 and 75-199 growing days to represent the arid and semi-arid drylands respectively (FAO, 1978).

They are also characterized by low, erratic and highly inconsistent rainfall levels, receiving between 100 to 600 mm rainfalls annually. The main feature of "dryness" is the negative water balance between the annual rainfall (supply) and the evaporative demand. Many of the world's drylands are grazing rangeland. All rangelands are characterized by the need to manage and cope with erratic events that constrain opportunities for development (Squires and Sidahmed, 1998).

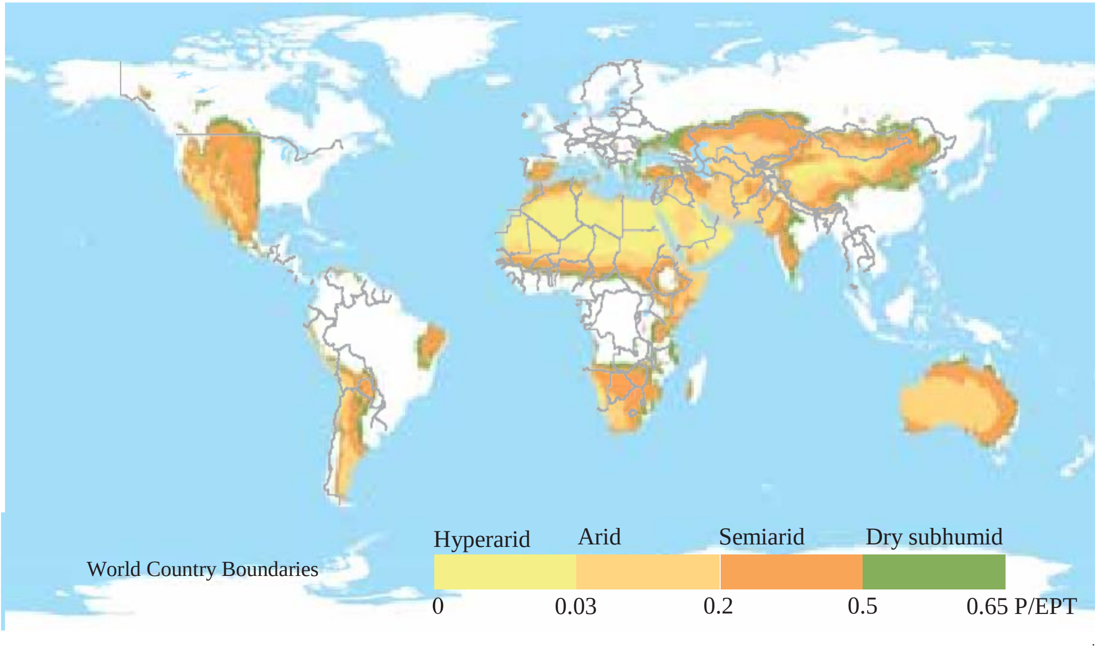

Figure 2.1 Distribution of drylands in the world

2.1.1 Meaning of aridity:

Arid environments are extremely diverse in terms of their land forms, soils, fauna, flora, water balances, and human activities. Because of this diversity, no practical definition of arid environments can be derived. However, the one binding element to all arid regions is aridity.

Aridity is usually expressed as a function of rainfall and temperature. A useful "representation" of aridity is the following climatic aridity index.

$$\text{Aridity index} = P/ETP \qquad (2.1)$$

Where

P= precipitation

ETP= potential evapotranspiration, calculated by the method of Penman, taking into account atmospheric humidity, solar radiation, and wind.

As classified by (FAO, 1998), four arid zones can be delineated by this index: namely, hyper-arid, arid, semi-arid, and dry sub-humid zones, as follows.

- <u>Hyper-arid zone</u> (arid index 0.03) comprises dryland areas without vegetation, with the exception of a few scattered shrubs. True nomadic pastoralism is frequently practiced.

Annual rainfall is low, rarely exceeding 100mm. The rains are infrequent and irregular, sometimes with no rain during long periods of several years.

- Arid zone (arid index 0.03-0.20) is characterized by pastoralism and no farming except with irrigation. For the most part, the native vegetation is sparse, being comprised of annual and perennial grasses and other herbaceous vegetation, and shrubs and small trees. There is high rainfall variability, with annual amounts ranging between (100-300) mm.
- Semi-arid zone (arid index 0.20-0.50) can support rain-fed agriculture with more or less sustained level of production. Sedentary livestock production also occurs. Native vegetation is represented by a variety of species, such as grasses and grass-like plants, fortes and half-shrubs, and shrubs and trees. Annual precipitation varies from 200-250 to 450-500 mm.
- Dry sub-humid zone (arid index 0.50-0.65). Annual precipitation varies from 500 to 750 mm.

The term "arid zone" is used here to collectivity represent the hyper-arid, arid, semi-arid, and sub-humid zones.

These zones distributed in the world as shown in Fig. (2.2).

The total land area of the world, the hyper-arid zone covers 4.2%, the arid zone 14.6%, and the semi-arid zone 12.2%. Therefore, almost one-third of the total area of the world is arid land (Table 2.1).

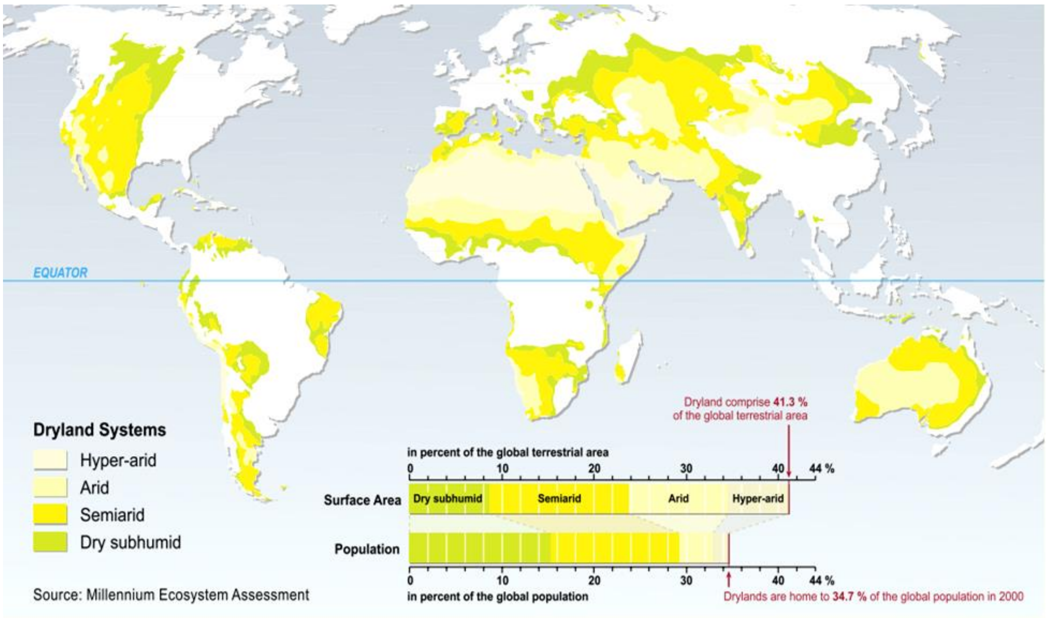

Figure 2.2 Global map showing arid and semi-arid areas (Millennum Ecosystem Assessment).

Table 2.1 Arid zone distribution in the world (UNSO/UNDP, 1997)

ARID ZONES								
Regions	**Arid**		**Semi-arid**		**Dry sub-humid**		**All drylands**	
	1000 Km^2	**%**	**1000 Km^2**	**%**	**1000 Km^2**	**%**	**1000 Km^2**	**%**
Asia (incl. Russia)	6164	13	7649	16	4588	9	18401	38
Africa	5052	17	5073	17	2808	9	12933	43
Oceania	3488	39	3532	39	996	11	8016	89
North America	379	2	3436	16	2081	10	5896	28
South America	401	2	2980	17	2223	13	5614	32
Central America and Caribbean	421	18	696	30	242	10	1359	58
Europe	5	0	373	7	961	17	1359	24
World total	**15910**	**12**	**23739**	**18**	**13909**	**10**	**53558**	**40**

2.2 Degradation in Arid Lands:

Williams and Balling (1996) defined land degradation in drylands as a "reduction of biological productivity of dryland ecosystems, including rangeland, pastures, rainfed and irrigated croplands, as a result of an acceleration of certain natural physical, chemical and hydrological processes., including erosion and deposition by wind and water, salt accumulation in soils and groundwater, surface runoff, a reduction in the amount or diversity of natural vegetation, and a decline in the ability of soils to transmit and store water for plant growth". Key components in semi-arid ecosystem degradation processes are increased surface albedo (reflectance of solar radiation) and increased generation of dust, both of which are consequences of the exposure of the bare soil as dry ground following removal of the original vegetative cover (Hillel and Rosenzweig, 2002).

Land degradation can be considered in terms of the loss of actual or potential productivity or utility as a result of natural or anthropic factors: it is the decline in land quality or reduction in its productivity. In the context of productivity, Land degradation results from a mismatch between land quality and land use (Beinroth *et al*., 1994). Mechanisms that initiate land degradation include physical, chemical, and biological processes (Lal, 1994).

Land degradation will remain an important global issue for the 21st century because of its adverse impact on agronomic productivity, the environment, and its effect on food security and the quality of life. Productivity impacts of land degradation are due to a decline in land quality on site where degradation occurs (Eswaran *et al*., 2001).

Accelerated soil degradation has reportedly affected as much as 500 million hectare (Mha) in the tropics (Lamb *et al*., 2005), and globally 33% of Earth's land surface is affected by some type of soil degradation (Bini, 2009), in (Lal, 2009).

Conceptually, there are four types of soil degradation: (i) physical, (ii) chemical, (iii) biological, (iv) ecological (Fig. 2.3). Soil physical degradation generally results in a reduction in structural attributes including pore geometry and continuity, thus aggravating a soil's susceptibility to crusting, compaction, reduced water infiltration, and increased surface runoff, wind and water erosion, greater temperature fluctuations, and an increased propensity for desertification (Lal, 2015).

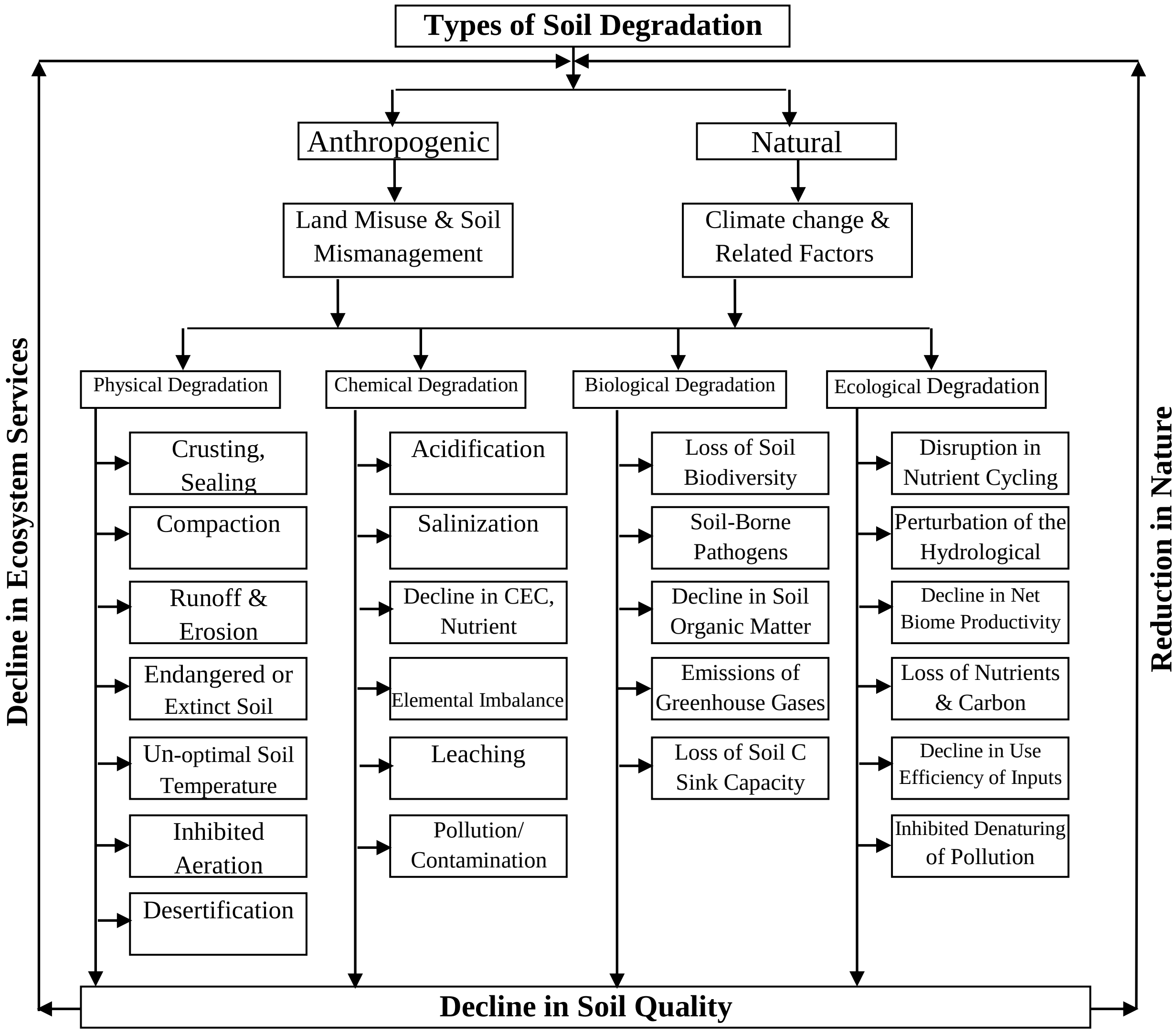

Figure 2.3 Types of soil degradation (Lal, 2015).

Soil chemical degradation is characterized by acidification, salinization, nutrient depletion, reduced cation exchange capacity (CEC), increased Al or Mn toxicities, leaching of NO_3-N and essential plant nutrients, or contamination by industrial wastes or by-products. Soil biological degradation reflects depletion of the soil organic carbon (SOC) pool, loss in soil biodiversity, a reduction in soil C sink capacity, and increased greenhouse gas (GHG) emissions from soil into the atmosphere. Ecological degradation reflects a combination of the three, and leads to disruption in ecosystem functions such as elemental cycling, water infiltration and perturbations of the hydrological cycle, and a decline in net biome productivity (Lal, 2015).

Land degradation is a severe environmental problem confronting the world today (Taddese, 2001). It has detrimental impacts on agricultural productivity and on ecological function that ultimately affect human sustenance and quality of life (Taddes, 2001; Zehtabian and Jafari, 2002; Eliasson *et al*., 2003; Masoudi, 2010; Masoudi, 2014; Pan and Li, 2013; Barzani and Khairulmaini, 2013; Masoudi and Amiri, 2015). Nearly 25% of the global biomass has been degraded (ManhQuyet, 2014) because of environmental factors on multiple scales of time and space, comprehending land degradation needs a multi-scale approach (ManhQuyet, 2014; Masoudi, 2014; Masoudi and Amiri, 2015). This approach is important in relation to land management goals.

2.3 Desertification

Desertification is a land degradation problem of most or importance in the arid and semi-arid regions of the world. Desertification in its irreversible form, due to human impact and/or climatic change has been much debated since the mid 1970s. It is believed to be one of the most serious global environmental problems of our time (Dregne *et al*., 1991; UNCED, 1992; Reynolds and Stafford, 2002; Mihretab *et al*., 2019).

The effects of desertification are the degradation of ecosystems, adverse effects on human health such as respiratory problems, and a reduction in cropland, leading to in food availability issues (Lee *et al.*, 2019).

2.3.1 Desertification definitions

An accepted definition of desertification was introduced by Drenge (1977): "Desertification is the impoverishment of terrestrial ecosystems under the impact of man. It is a process of deterioration in these ecosystems that can be measured by reduced productivity of desirable plants, undesirable alterations in the biomass and the diversity of the micro and macro flora and fauna, accelerated soil deterioration, and increased hazards for human occupancy". As national and global databases improved, the anthropic role became more evident and the accelerated nature of the process resulted in the call for combating actions (Reich *et al*., 2001).

Desertification is acknowledged to be a complex phenomenon requiring the expertise of researchers in such disciplines as climatology, soil science, metrology, hydrology, range science, agronomy, veterinary medicine, geography, political science, economies and anthropology. It has been defined in many different ways by researchers in these and other disciplines, as well as from many national and bureaucratic (institutional) perspectives, each emphasizing different aspects of the phenomenon (Glantz, and Orlovsky, 1983).

Some researchers consider desertification to be a process of change, while others view it as the end result of a process of change. This distinction underlies one of the main disagreements about what constitutes desertification. Desertification-as-process has generally been viewed as a series of incremental (sometimes step-wise) changes in biological productivity in arid, semi-arid, and sub humid ecosystems. It can encompass such changes as a decline in yield of the same crop or, more drastically, the replacement of one vegetative species by another maybe equally productive or equally useful, or even a decrease in the density of the existing vegetative cover. Desertification-as-event is the creation of desert-like conditions (where perhaps none had existed in the recent past) as the end result of a process of change. To many, it is difficult to accept incremental changes as a manifestation of desertification (Glantz and Orlovsky, 1983).

The new definition introduces the idea that 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 drylands of the world. Human adverse impact on the environment is considered to be the only cause of desertification (Rozanove, 1990; UNEP, 1991).

Based on special studies the UNEP (1991) the following definition of desertification was adopted desertification/ land degradation is land degradation in arid, semi-arid and dry sub-humid areas resulting from adverse human impact. They further concluded that "Land" in this concept included soil and local water recourse, land surface and vegetation or crops (Helldén, 2003).

According to Article 1 of the United Nations Convention to Combat Desertification (UNCCD, Paris, 1994), desertification means "land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities.

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). Several factors exacerbate this phenomenon such as the climate dryness, the geological and morphological characteristics of the terrain, the irrational use of space, population growth and the over-exploitation of vegetation and water resources (Lahlaoi *et al.*, 2017).

Barrow (2009), indicated that desertification implies degradation toward 'desert' conditions, some danger of irreversibility, and more prevalent in periodically dry regions.

The United Nation Conventional Combat Desertification (UNCCD, 2000) has emphasized on biological productivity. It concluded that such a focus on ecosystems highlights reduction in the productivity of desirable plants, an altered biomass and reduce diversity of life forms.

2.3.2 What causes desertification

Desertification is a worldwide phenomenon resulting from a set of geological, climatic, biological and humanistic factors leading to a reduction of the land's physical, chemical and biological potentiality in arid, semiarid and semi humid areas.

The causes of desertification have been attributed to the combination of natural and socio-economic processes which are responsible for the degradation of soils (Samantha, 1997).

2.3.2.1 Natural processes

There are three main climatic factors that influence the onset and continuation of desertification processes (Samantha, 1997).

1. The occurrence of droughts (periods of below-average rainfall), which can last for years.
2. High temperatures which cause a high rate of evapotranspiration (the loss of moisture from the Earth's surface by a combination of direct evaporation and transpiration from plants) and therefore a high rate of moisture loss from soils.
3. Infrequent and often intense periods of rainfall which compact soils, increasing their erodibility.

2.3.2.2 Socio-economic processes

There are four main **human** actions which accelerate desertification (Samantha, 1997).

1. **Overgrazing**. This occurs where herd sizes exceed **carrying capacity** (the number of cattle that can graze a sustainability i.e. without long term damage occurring). If this capacity is exceeded:
   (a) Vegetation changes, e.g. drought-resistant species replace edible species.
   (b) Soil quality is reduced. e.g. grazing animals compact and break down the soil structure, increasing its vulnerability to erosive processes.
   (c) The health of livestock and their productivity decreases.
2. **Overcultivation**. May occur when increasing food production is needed.
   (a) To support increasing populations.
   (b) When rural people are encouraged to grow ´cash crops` for sale in city markets and for export.
3. **Deforestation and excessive fuelwood cutting**. Forest is cleared for agriculture or fuelwood. This leads to reduced shade and greater desiccation of the soil, a lowered water table and an increase in the use of dung (otherwise used as fertilizer) as a fuel source. The resulting loss of organic matter reduces both the ´stikiness` of the soil peds and the water-holding capacity of the soil: its erodibility therefore increases.
4. **Inappropriate irrigation practices**. Fertility is reduced through **salinisation** (the buildup of salt around the roots of plants) and **waterlogging** (caused by poor drainage and the formation of an impermeable salt crust on the soil surface).

The combination of these and other biological, soil and water factors are summarized in (Fig. 2.4).

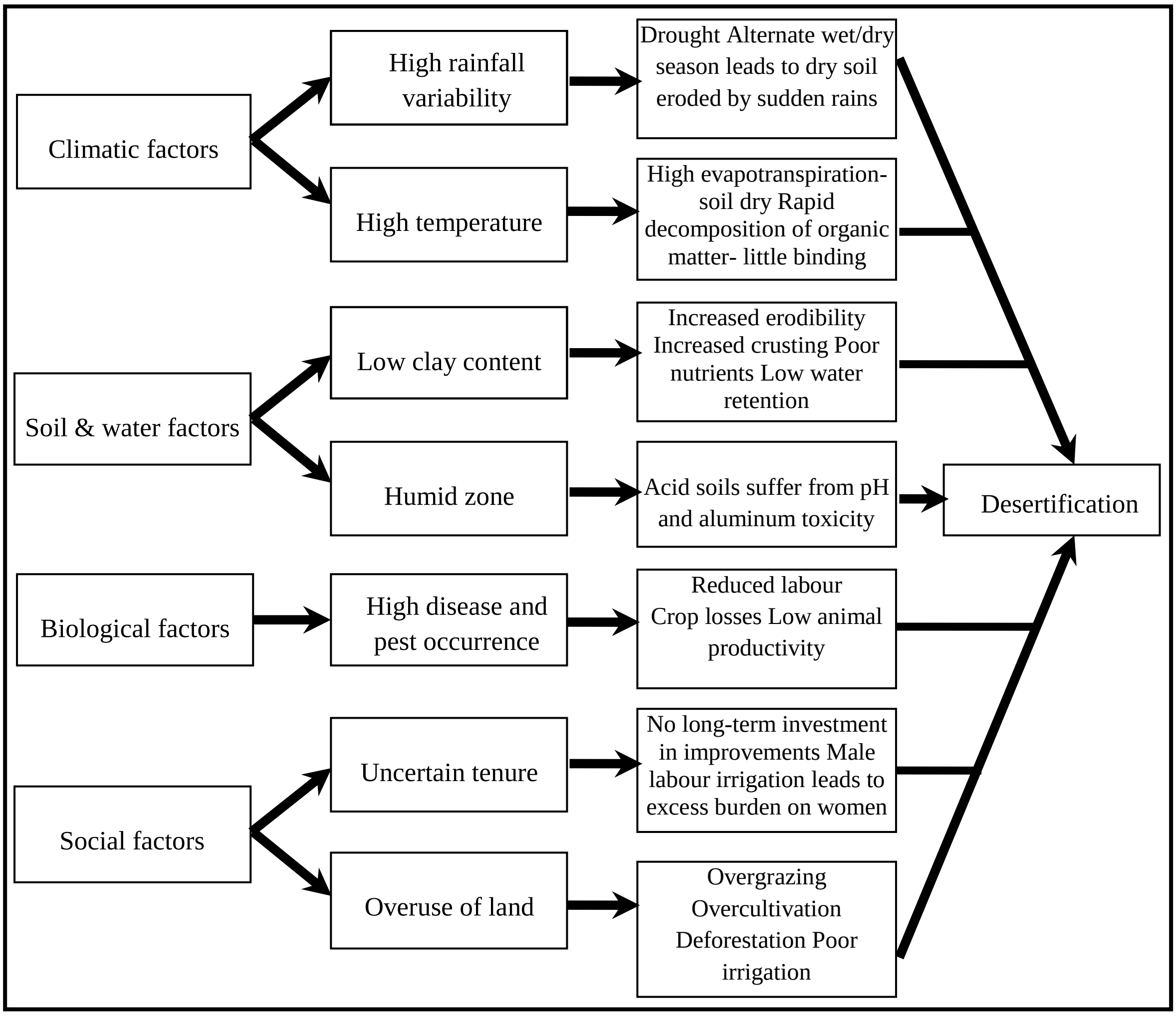

Figure 2.4 Summary of the causes of desertification (Samantha, 1997).

In (Fig. 2.5) which is the map form the Natural Resource Conservation Service shows global desertification vulnerability. This map is based on a reclassification of the global soil climate map and global soil map (soil type is closely linked to climate, and so varies across the global in response to the local environmental conditions).

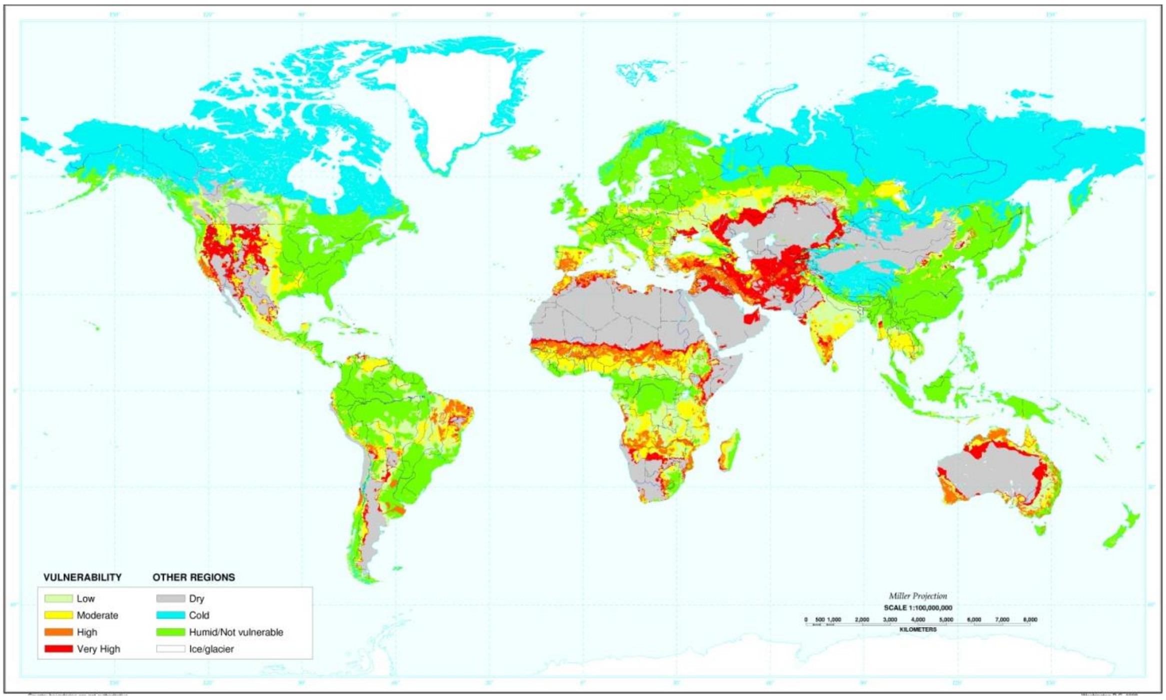

Figure 2.5 Global desertification vulnerability (U.S Department of Agriculture map, 1998).

Some researchers consider climate to be the major contributor to desertification processes, with human factors playing a relatively minor supporting role. Other researchers disagree with the significance of these two factors (Glantz and Orlovsky, 1983).

2.3.3 Assessment of desertification

Desertification has been and still is a controversial issue. In the previous decades, this was largely due to the lack of a common understanding of "what to measure" and "how to measure it". In the 1970s, the desertification indicators sought were those able to measure the advance of the desert. During the 1980s the need for a general and flexible approach to combat desertification became more keenly felt. Indicators of desertification may demonstrate that desertification has already proceeded to its end point of irreversibly unproductive soil (Kosmas *et al*., 2014).

Ekhtesasi and Mohajeri (1995) developed the ICD (Iranian Classification Deserts) model for the classification of Iranian deserts. One of the advantages of the ICD model is its capability to identify the type of desert environments such as natural and anthropogenic deserts. ICD was developed in four steps: separation of deserts types using plant types and land use maps, determination of desertification causes including the major and minor causes, classification of desertification and desertification mapping. This method classifies the severity of desertification to five classes: slight, low, moderate, severe and very severe. The most well-known result produced by this approach was the estimate that 75% of studied area was affected by anthropogenic factors of desertification.

Rubio and Bochet (1998) tackled the subject of desertification indicators in considerable detail and proposed a synthesized list of criteria, and a procedure for the selection, evaluation, and application of indicators.

The MEDALUS model was designed by the European Commission based on the results of Mediterranean European research project (Kosmas *et al*, 1999c) and was adopted here instead of more traditional models due to inefficiency of traditional methods in GIS environment.

The MEDALUS model has also been used in some Middle Eastern countries. For example, Basso *et al*. (1999) have used the MEDALUS model for defining ESA on the Lesvos island of Greece and Kosmas *et al*. (1999b) applied this model in the Agri basin of Italy. The ministry of Agriculture of Lebanon (2001) used the model to prepare a map of Lebanon showing area where desertification was being combated.

In Iran this model was used in the Varamin plain (RafieiEmam, 2002) and the Kashan plain (Khosravi, 2003) and discussed by (Zehtabian *et al*, 2004).

The MEDALUS model has been a widely recognized approach in different Mediterranean regions at national, regional, and local scales. 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). Ladisa *et al*. (2012) assessed desertification sensibility in the Apulia region (southeastern Italy) using this method and the results indicated good performance for this technique. In another work, Trotta *et al*. (2015) applied MEDALUS at a local scale in Castel Porziano (central Italy). Similarity, Contador *et al*. (2009) applied this method in Extremadura (southwestern Spain). In a separate paper, Symenoakis assessed sensitivity to land degradation and desertification using Environmental Sensitive Area Index at Levos Island (Symeonakis *et al*., 2014). In Lebanon, the method was applied in an arid region by adding certain parameters (i.e., rock hardness, permeability, soil organic matter, clogging, and erodibility) and excluding others (i.e., texture, parent material and soil depth) (Kamel *et al*., 2015). The method has also been applied in Mediterranean African countries, such as Algeria (Boudjemline and Semar, 2018). In Morocco the approach was applied in the arid regions of the Sous Massa River Basin to propose an action plan of potential interventions to mitigate the desertification problems in this region Bouabid *et al*. (2010) and in Oued El Maleh, central Morocco (Lahlaoi *et al*., 2017). However, the MEDALUS model has been elaborated and developed in the context of Mediterranean areas prone to desertification, and most applications have been done in semi-arid, arid, and hyper-arid zones. The model was adopted in the same climate context of the study area, which can be considered to be a hyper-arid climate. For example, Benmessaud assessed a desertification sensitive area in the Biskra region (South Aures) in Algeria using the MEDALUS model (Benmessaud *et al*., 2010).

Desertification hazard Zonation methods are divided into two groups: (1) Methods based on extensive field operations such as FAO/UNEP and Turkmen academy of sciences methods. (2) Methods based on minimum field operations like MEDALUS and desertification risk index methods (Mashayekhan and Farhad, 2011).

Other methods for evaluating the desertification process such as mathematical methods, parametric equations, remote sensing, direct observation and measurement have been developed. Recently, several models of desertification and land degradation have been presented (Sepehr *et al*., 2007).

Kharin *et al*. (2000) prepared the desertification map of West Asia by presenting several method of desertification assessment.

2.4 Soil Quality of Dryland

2.4.1 The concept of soil quality

The concept of soil quality was first suggested by (Warkentin and Fletcher, 1977). While they started the discussion, it did not become a real focal point until the early 1990s. In 1990, the U.S Forest Service and Soil Science Society of America sponsored a Soil Quality symposium with the purpose of opening a discussion into soil quality. Larson and Pierce (1991) came up with a working definition of soil quality and suggested that soil quality is a combination of chemical, physical and biological properties. These three properties work together to maintain plant growth, regulate water flow, and act as an environmental buffer.

The terms soil quality and soil health are often considered to be the same. Soil health is a broader term related to the overall condition of the soil, while soil quality is more confined term focused on the chemical, physical, and biological properties (Doran and Zeiss, 2000).

According to the soil factors considered, the soil quality could be physical, chemical, and biological. Most of the physicochemical factors are related to inherent soil quality, and biological and some physical factors with the dynamic soil quality. Although soil quality often focuses on biological aspects, this must not diminish the importance of physical and chemical factors (Ball & De la Rosa, 2006)

2.4.2 Definition of soil quality

Soil quality refers to the soil's ability to perform the functions expected of it (Karlen *et al*., 1994). Soil quality also is "the capacity of a soil to function". More specifically, soil quality has been defined by a committee for the Soil Sciences Society of America (Karlen *et al*.,1997) "as the capacity of a specific kind of soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation". Also, soil quality has been defined as the ability of a soil to fulfill its functions in the ecosystem, which determined by the integrated actions of different soil properties. With respect to agriculture, soil quality would be the soil's fitness to support crop growth without becoming degraded or otherwise harming the environment. Warkentin (1995) has proposed that soil quality is simply related to the quantity of crop production. However, others have emphasized that the importance of demonstrating how soil quality affects feed and food quality, or how soil quality affects the habitat provided for a wide array of biota.

According to the Soil Quality Institute (SQI) (USDA, 2006), the soil-quality is related to the concepts of sustainability of soil use and management, although in some cases the focus has been predominantly on contaminated land. The SQI has indicated that notion of soil quality must include soil productivity, soil fertility, soil degradation, and environmental quality.

An expanded definition presents soil quality as: "the capacity of a specific kind of soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation" (Karlen *et al*., 1997). However, no soil is likely to provide all these functions, some of which occur in natural ecosystems and some of which are the result of human modification (Govaerts *et al*., 2006).

2.4.3 Soil quality indices

Soil quality indices are a way to incorporate multiple points of information into one tool that can be used for decision making (Karlen and Stott, 1994). They indicated that a soil quality index will be most useful when the goal is sustainability as well as yield.

Larson and Pierce (1991) suggested that a minimum data set needed to be accepted when measuring the quality of soils and that a standard set of methodologies needed to be instituted. Most of the indicators that are used to create soil quality indices have procedures established well before the soil quality interest become dominant. Wienhold *et al*. (2004) noted that measuring these factors together and producing an index will help in improving the sustainability of the land.

When choosing parameters for the minimum data set, the reason soil quality is being measured needs to be remembered (Andrews *et al*., 2004). Since soil quality can be site-specific, different tests may need to be performed for different agro-ecosystems (Shukla *et al*., 2006).

According to Herrick (2000), soil quality indices would be more readily adopted if the measurements are simplified, the costs are reduced, and the time between sampling and computation of analysis is shortened. Soil quality measurements needs to be easily performed, incorporated into management decisions, and made widely available to land managers (Shukla *et al*., 2006).

Glover *et al*. (2000) conducted a study using aggregate stability, porosity, worms, organic C, microbial biomass C and N, cation exchange capacity, pH, total N, and nitrate-N as indicators of soil quality.

Andrews *et al*. (2002) were the first to compare methods of indicator selection. Indicators selected by experts were compared with those selected by statistical methods. Principle component analysis was used to determine which indicators should be selected for the function they wanted to measure. Expert opinion chose soluble phosphorus, pH, electrical conductivity, sodium adsorption ratio, and soil organic matter as indicators. Principle components selected were soluble phosphorus, pH, calcium, sodium and total nitrogen. Both types of indices were found to be equally representative of soil quality, but principle component analysis would not work with a study of low observation that was missing crop rotation data. Total C was the dominant attribute for every factor. Cornell University is one of the first public soil testing laboratories to use a Soil Quality Index for the purpose of making it available to the public. Cornell's indicators were selected from potential soil health indicators (Idowu *et al*., 2008; Gugino *et al*., 2009). The most basic indicators included soil texture, wet aggregate stability, available water capacity, surface/sub-surface hardness, organic matter, and active carbon in addition to standard fertility tests and recommendations.

When Soil Quality Indicators are selected, natural and anthropogenic changes should be measured (Wienhold *et al*., 2004). The indicators chosen should be easy to measure and able to show any existing problems in the soil (Schloter *et al*., 2003).

Some of the most common indicators to assess soil quality used in research are pH, aggregate stability, SOM, and those relating to microbial activity (Bastida *et al*., 2008). Other indicators included electrical conductivity, soil respiration, CEC, and metal contamination. Many of these indicators have been found to be strongly correlated with each other (Arshad and Martine, 2002).

Soil organic matter has been found to be one of the most important soil quality indicators. When studying the correlation between indicators, SOM was found to be correlated or has an effect on almost all other indicators (Arshad and Martine, 2002). SOM has been found to be related better to soil fertility, nutrient retention, and plant available water (Friedman *et al*., 2001).

2.4.4 Assessment of soil quality

Soil quality cannot be measured directly; it must be inferred from a wide range of soil quality properties (physical, chemical, and biological) that influence the capacity of soil to perform its functions. However, a genetic set of basic properties, commonly known as soil quality indicators, has not been agreed upon, largely due to the difficulties in defining and identifying what soil quality represents and how it can be measured. Identification of indicators and assessment approaches are further complicated by the multiplicity of physical, chemical, and biological factors that interact and control soil functions and their variation in intensity over time and space (Doran and Parkin, 1996). Moreover, to objectively and simultaneously consider the outcomes of all the soil quality indicators for all three major performance indicator-production. Sustainability and environmental impact - is a difficult task (Sojka and Upchurch, 1999).

An approach to more objectively assess soil quality is evaluating several soil indicators simultaneously using statistical procedures that account for correlations. Multivariate statistical methods are used to select a minimum data set (MDS) from large data sets. In this way just few indicators have to be determined to assess soil quality. Various Such MDSs have been proposed at plot and field scales (Doran and Parkin, 1996), on a regional scales (Brejda *et al*., 2000a,b) and on a national scales (Saprling and Schipper, 2002; Saprling and Schipper, 2004; Saprling *et al*., 2004). The use of this approach has shown the potential to integrate biological, chemical and physical data. As a result, the concept of a MDS of soil quality indicators has become widely accepted as the minimum needed to effectively monitor soil quality and to simplify interpretation in terms of sustainable land use, while reducing costs. Yet, methodologies to arrive at MDSs are the subject of ongoing discussions (Wander and Bollero, 1999; Brejda *et al*., 2000a,b; Saprling and Schipper, 2002; Govaerts *et al*., 2006; Rezaei *et al*., 2006).Karlen *et al*. (1994), studied the effects of different residue applications on soil quality in soils from Illinois, Wisconsin, Minnesota, and Iowa. This study was one of their first attempts to develop a multiparametric index of soil quality. Aggregate stability, porosity, worms, microbial biomass, respiration, total C, total N, bulk density, available water, pH, and electrical conductivity were used as indicators. They indicated that the index was weighted based on the equation.

Soil Quality= qwe (wt) + qwma (wt) + qrd (wt) + qfqp (wt) (2.2)

Where (wt) was a weight assigned to each function and qwe was how well the soil could accommodate water; qwma was how well the soil could transfer water; qrd was how well the soil could withstand degradation; and qfqp was how well the soil supported plant growth. The weights were subjectively assigned a value between zero and one. There was no mathematical or statistical backing; the number was based on what the researcher felt to be the more important factor for the function being studied. Hussain *et al*. (1999) have studied aggregate stability, organic C, crop residues, porosity, exchangeable K, and pH as indicators of soil quality. The objective of their study was to adjust soil quality indices to determine the effect of three differing tillage treatments on soil in south Illinois. They used the equation:

Index= f(y nutrient + y water+ y rooting) (2.3)

Where y was the weight assigned to each function. Six indexes were created with this equation and compared using analysis of variance and general linear modeling. The purpose of their study was to determine which tillage system scored the highest. They found that the eight years no-till treatment scored the highest among indices used comparison with the more intensive tillage practices. They found that when the index thresholds were adjusted to the local conditions, it became more sensitive to the management practices they which has been evaluated.

CHAPTER THREE

MATERIAL AND METHODS

3.1 Study Area

The study area included some arid and semi-arid lands located between longitudes 43° 25' 41''- 46° 28' 01'' E and latitudes 34° 18' 34''- 36° 20' 56'' N which located in the governorates of Sulaimani, Diyala, Kirkuk, and Hawler in Iraq and Iraqi Kurdistan Regional covering an area of 2645600 ha (Fig.3.6) and (Table3.2).

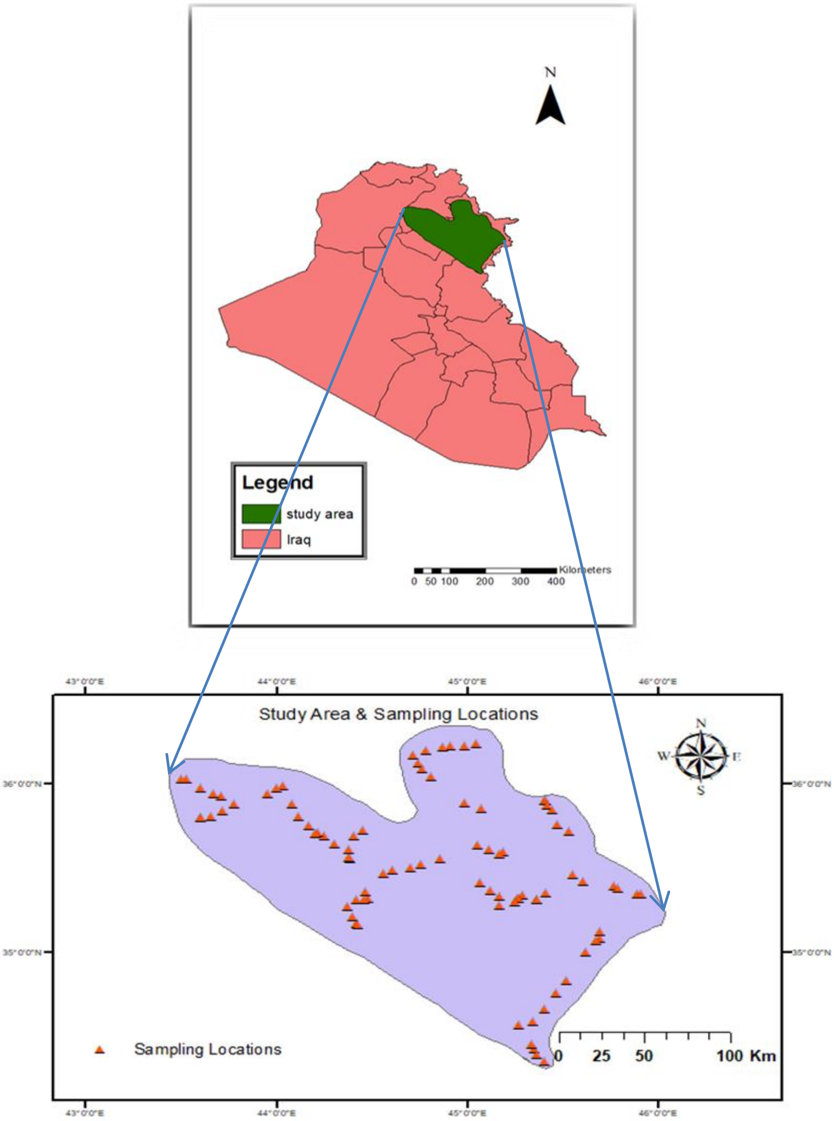

Figure 3.6 Study areas and soil sampling location

Table 3.2 Sites, pedons and coordination of soil samples for the study area

Governorate	Sites	Pedon No.	Longitude	Latitude
Sulaimani	Said Sadiq	1	35º 23′ 52″	45º 45′ 61″
	Chamchamal	2	35º 33′ 41″	44º 51′ 23″
	Bazian	3	35º 36′ 55″	45º 06′ 98″
	Mawat	4	35º 53′ 70″	45º 23′ 68″
	Qaradakh 1	5	35º 18′ 53″	45º 21′ 48″
	Qaradakh 2	6	35º 18′ 61″	45º 21′ 47″
	Sangaw	7	35º 16′ 51″	45º 09′ 75″
	Sangasar	8	36º 14′ 26″	45º 02′ 47″
	Chwarqurna	9	36º 12′ 00″	44º 46′ 75″
	Dukan	10	35º 53′ 15″	44º 59′ 02″
	Darbandikhan	11	35º 05′ 21″	45º 40′ 96″
	Kalar	12	34º 34′ 17″	45º 16′ 06″
Diyala	Khanaqin	13	34º 25′ 44″	45º 20′ 60″
Kirkuk	Shwan	14	35º 33′ 53″	44º 22′ 52″
	Altuncopri	15	35º 41′ 77″	44º 11′ 70″
	Daquq	16	35º 10′ 06″	44º 25′ 43″
	Lailan	17	35º 19′ 10″	44º 27′ 83″
Hawler	Qushtapa	18	35º 55′ 88″	43º 56′ 78″
	Makhmoor	19	35º 47′ 75″	43º 36′ 08″
	Gwer	20	36º 02′ 02″	43º 29′ 65″

3.2 Soil Forming Factors for Study Area

3.2.1 Climate

Fig. (3.7) shows the mean annual precipitation for Iraq included the study area based on the rate observed in the period 1980 to 2011(UNESCO, 2014).

Rainfall is very seasonal and occurs in winter from November to April, where the average annual rainfall is estimated to be 216 mm to 650 mm. Winters are cool to cold, with a day temperature of about 16 ºC dropping at night with a possibility of frost. Summers are dry and hot to extremely hot, with a shade temperature of over 40ºC during July and August, yet dropping at night to 26ºC.

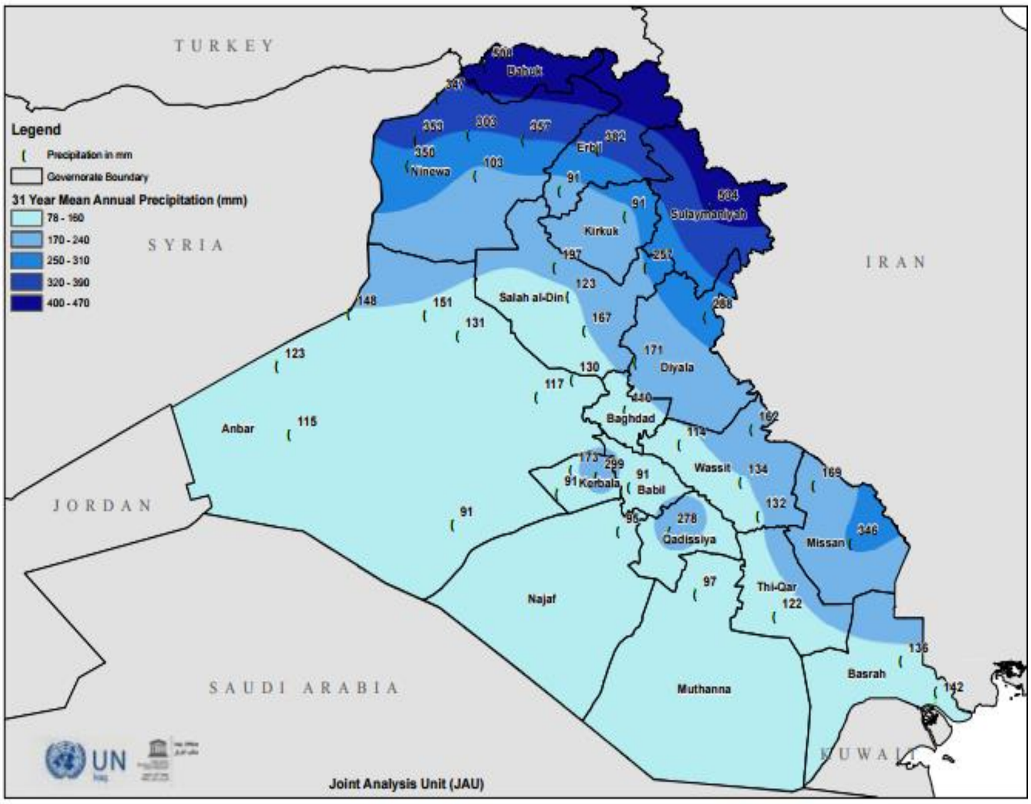

Figure 3.7 Mean annual precipitation for Iraq, (UNESCO, 2014)

Fig. (3.8) shows the mean annual temperature for the study area based on the rate observed in the period 1980 to 2011 (UNESCO, 2014).

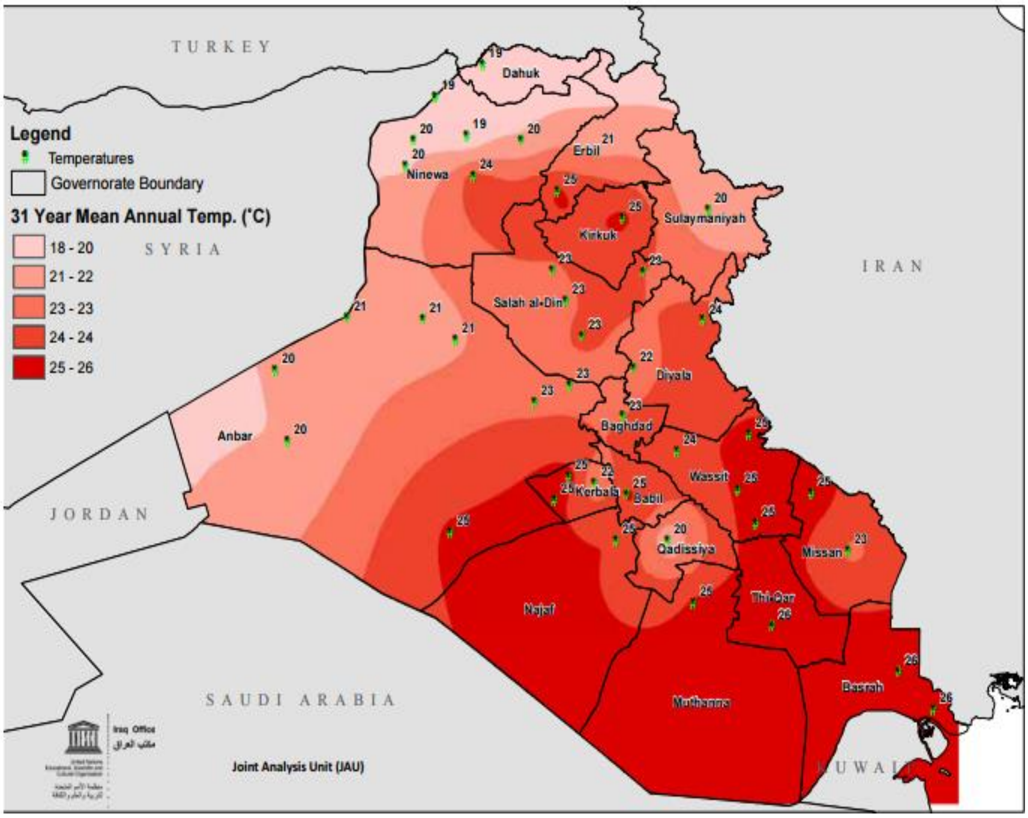

Figure 3.8 Mean annual temperature for Iraq, (UNESCO, 2014)

The mean annual air temperature in the study area has approximately 21^oC, January was the coldest month of the year, but generally, the mean temperature does not drop below 5^oC. The mean temperature in July and August exceeds 40^oC. Because of the high frequency of days with sun radiation, the 24-hour temperature amplitude often reached a high value. In winter, winds from the northern sector prevail, while in summer, western and south-western winds occur most frequently. Generally, the average wind velocity in the individual months of the year does not exceed five m/s. In summer, the total cloud cover is limited and clear weather predominates. The mean annual air humidity is 40-45%, and it exhibits a high seasonal diversity. In January, humidity approaches approximately 70% while it drops to below 20% in July and August. Fog occurs rarely, usually in December and January. Generally, the total number of foggy days throughout the year does not exceed 20.

Climate conditions of this region are characterized by a Mediterranean climate with warm dry summers and cool moist winters, with mean annual precipitation ranging from 300-700 mm and mean annual temperature ranging from 20 to 22.5^oC (Muhaimeed, *et al*., 2014).

According to (FAO, 2003), study area has been divided into three agro-ecological zones as follows:

- Arid and semi-arid zones with a Mediterranean climate. A growing season of about nine months, over 400 mm of annual winter rainfall, and mild/warm summers prevail. This zone covers mainly the northern governorates of Iraq. Major crops include wheat, barley, rice and chickpea. Other field crops are also produced in smaller quantities. There is some irrigation, mainly from springs, streams and bores.
- Steppes with winter rainfall of 200-400 mm annually. Summers are extremely hot and winters are cold. This zone is located between the Mediterranean zone and the desert zone. It includes the feed barley production areas, limited wheat production, and it has limited irrigation.
- The irrigated area includes areas that are irrigated through the Lower Zab River and Artesian wells. Serious hazards for this area are poor drainage and salinity. The majority of the country’s vegetables are produced in this zone.

3.2.2 Topography

Iraq can be divided into four main physiographic regions, each region has its specific geological, hydrological and climatologically conditions, and consequently specific soil conditions (Fig. 3.9)

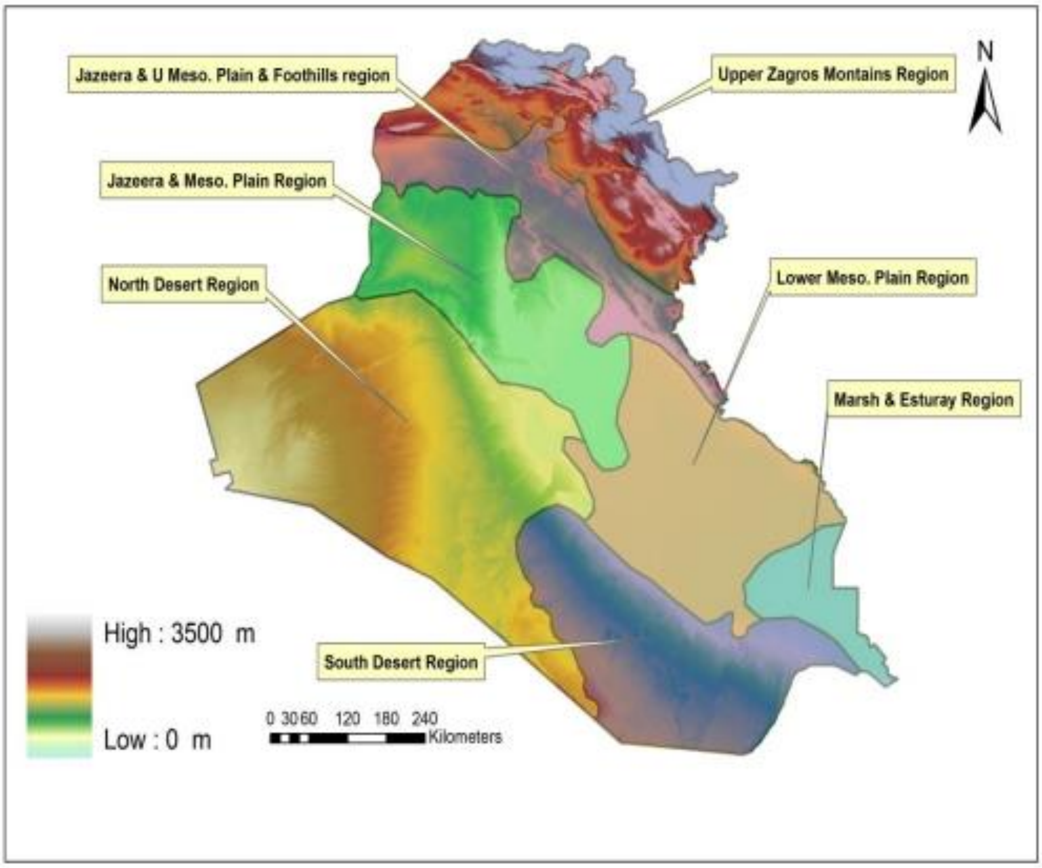

Figure 3.9 Physiographic regions for Iraq (Muhaimeed, *et al*., 2014).

3.2.2.1 Mountains region

The mountains consist mainly of parallel anticline ridges separated by elongated synclinal valleys. But they are united by narrow gorges, the outlets of the drainage of the interior basins. The mountains, for the greater part, are eroded and the detritus material has been deposited in the valleys and in the area in front of the mountains (Muhaimeed, *et al*., 2014).

3.2.2.2 Undulating region

This area is comprised of a fairly hilly landscape, located south and west of the mountain region. It consists of low parallel hill ridges, wide shallow valleys and extensive plains, in which various streams have cut their valleys. In general, average altitude varied from 200 to 1000 meters. Local relief ranged from a minimum of 200 to a maximum of 800 meters per square Kilometer (Muhaimeed, *et al*., 2014).

3.2.3 Parent materials

Beds of gravel, conglomerate and sandstone made up the area. It could be divided, in terms of geomorphic landforms structure, surface rocks and degree of erosion process, into a number of plains, plateaus, mountains and hill ridges. The southern edge of the mountain range is a highly dissected part according to (Muhaimeed, *et al*., 2014).

3.2.4 Vegetation

Following Guest (1966), the mountains region included the forest vegetation zone which merged gradually into a steppe zone dominated by Savannah. Land in the plains is used mainly to grow wheat and barley. Other areas supported luxurious grasses dominated by *Poabulbosa* and *Hordeumbulbosum* (Guest, 1966).

3.3 Soil Orders

The study area consists of different soil orders according to the Soil Survey Staff, Soil Taxonomy, USDA system, (2014) (Fig. 3.10):-

3.3.1 *Aridisols*

The concept of Aridisols is based on limited soil moisture available for the growth of most plants. In areas bordering desert, the absolute precipitation may be sufficient for the growth of some plants. Because of runoff or a very low storage capacity of the soils, or both, however, the actual soil moisture regime is aridic.

Aridisols show variations with the common soil properties reflecting the effect of the dominant local conditions. These differences represented by the presence of different diagnostic horizons. The common subsurface horizons are associated with the accumulation of different type of salts. The accumulation of salts is the second most important constraint to land use. According to the amount and types of salt accumulation, the Aridisols order are subdivided to three suborders including Salids, Gypsids and Calcids (Muhaimeed, *et al*., 2014).

3.3.2 *Entisols*

Entisols are the second dominant order in study area. They occurred in different physiographic units starting from the mountain to the flood plain. Entisols are soils with little or no evidence of the development of pedogenic horizons. Most Entisols have no diagnostic horizons other than an ochric epipedon.

3.3.3 *Inceptisols*

Inceptisols also covered some parts of soils of study area. In some areas these soils have minimal development, whereas in other areas these soils have diagnostic horizons that merely fait the criteria of other soil orders. They have many kinds of diagnostic horizons and epipedons. The most common horizon sequence is ochric epipedon over a cambic horizon.

3.3.4 *Vertisols*

Vertisols are clayey soils that have deep, wide cracks for some time during the year and have slickensides within 100 cm of the mineral soil surface. These soils have long been well known for their characteristic color, cracks they produce during the dry season, and the difficulty of their engineering properties. Vertisols occur in some parts in study area. Typically, these soils are deep and clayey, with shrink-swell processes resulting in cracking during the dry season.

3.3.5 *Mollisols*

Mollisols commonly are dark-colored, base-rich mineral soils of the steppes. Nearly all of these have a mollic epipedon and calcic horizon. Many of these soils developed under grass and many apparently were forested. Mollisolos occur in the northeastern mountain area particularly on the foot slope plain of intermountain valleys (Muhaimeed, *et al.*, 2014).

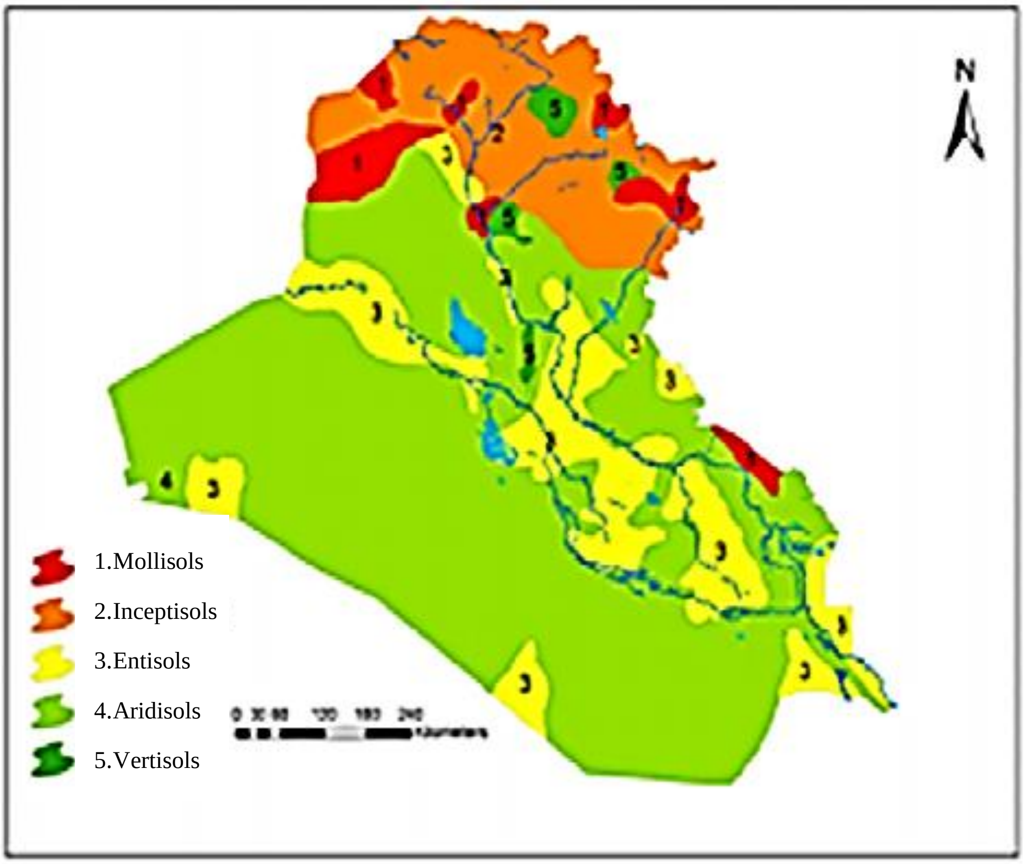

Figure 3.10 Distribution of soil orders in Iraq, (Muhaimeed, *et al.*, 2014)

3.4 Desertification Assessment According to MEDALUS Project

The assessment involved two stages (Kosmas *et al*., 1999a). In the first stage, the four indices for soil quality, climate quality, vegetation quality, and management quality were calculated providing a measure of the inherent quality of the physical environment and the man induced stress of desertification as in the following discussion (Fig.3.11).

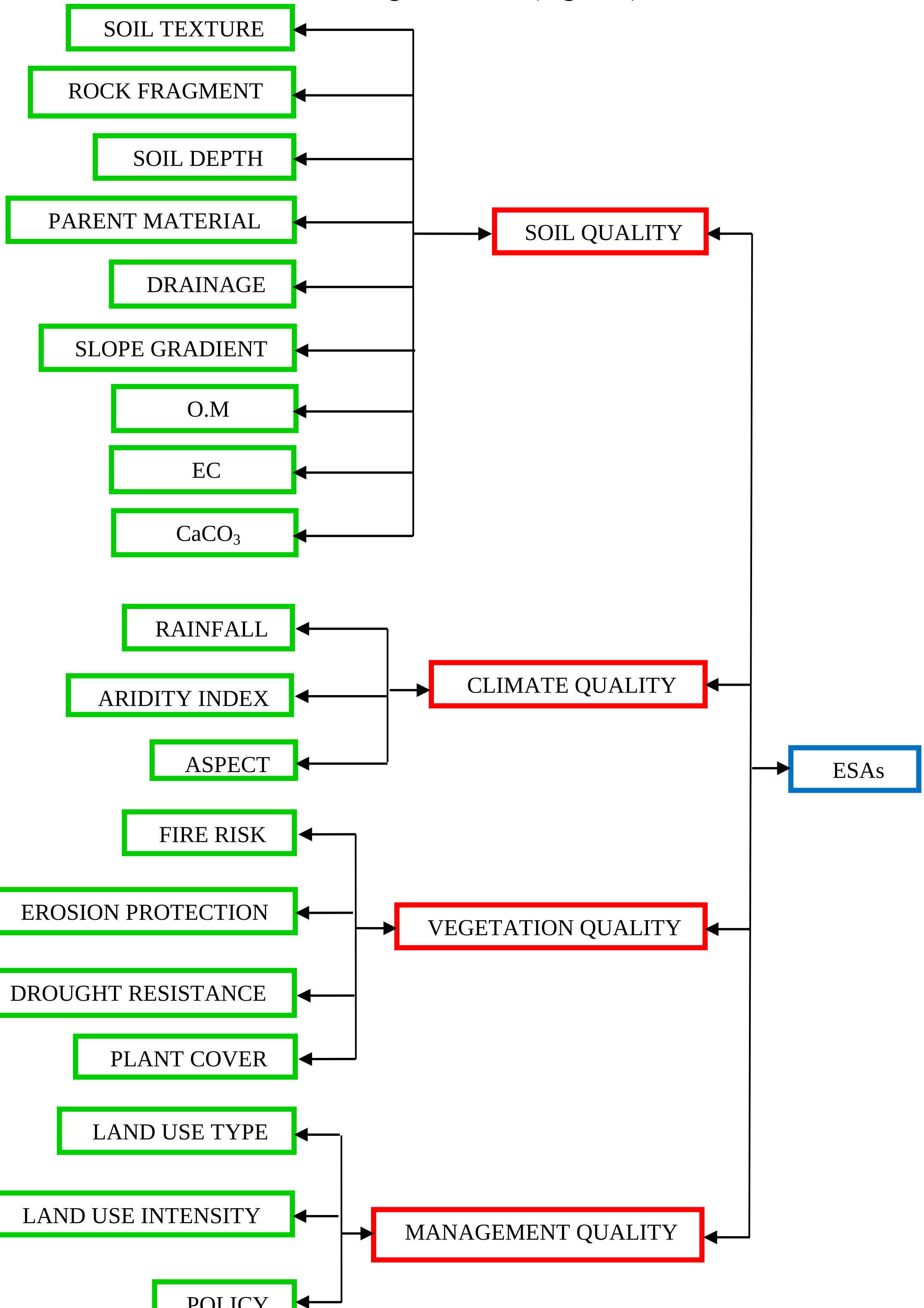

Figure 3.11 Parameters used for the definition and mapping of the ESAs to desertification (Kosmas *et al*., 1999a)

3.4.1 Soil quality indicator (SQI)

Soil is a dominant factor of the terrestrial ecosystems in the semi-arid and dry sub-humid zones, particularly through its effect on biomass production. Soil quality indicator for mapping ESAs can be related to water availability, and erosion resistance. These qualities can be evaluated by using simple soil properties or characteristics given in regular soil survey reports such as texture, parent material, soil depth, slope angle, drainage, stoniness, ect (Table 3.3). The use of these properties for defining and mapping ESAs requires the definition of distinct classes with respect to degree of land protection from desertification.

Table 3.3 Classes and weighting indices for the soil quality assessment (Kosmas *et al*., 1999a)

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

Soil quality index (SQI) was then calculated as the product of the mentioned attributes, namely soil texture, parent material, rock fragment, soil depth, slope grade, organic matter, electrical conductivity, Calcium carbonate content, and drainage conditions as the following algorithm. The soil quality was then defined using Table 3.4.

$$SQI = (\text{texture} \times \text{parent material} \times \text{rock fragment} \times \text{depth} \times \text{slope} \times \text{drainage} \times O.M\% \times EC \times CaCO_3)^{1/9} \quad (3.4)$$

Table 3.4 Classes of soil quality (Kosmas *et al*., 1999a)

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

3.4.2 Climate quality indicator (CQI)

Climate quality was assessed by using parameters that influence water availability to the plants such as amount of rainfall, air temperature and aridity, as well as any climate hazards as frost which might inhibit or even prohibit plant growth. Annual precipitation is classified in three classes considering the annual precipitation of 280 mm as a crucial value for soil erosion and plant growth (Table 3.5).

Table 3.5 Classes and weighting indices for climate quality assessment (Kosmas *et al*., 1999a)

Structure of range and weight index		
Rainfall class	**Rainfall (mm)**	**Index**
1	>650	1
2	280-650	2
3	<280	4
Aspect class	**Description**	**Index**
1	NW, NE	1
2	SW, SE	2
Aridity class	**Climate type**	**Index**
>55	Extremely humid	1
35-55	Very humid	1.1
28-35	Humid	1.5
24-28	Semi-humid	1.6
20-24	Mediterranean	1.7
10-20	Semi-arid	1.8
0-10	Arid	2

The below three attributes are then combined to assess the climate quality indicator (COI) using the following algorithm. The climate quality is then defined using Table 3.6, Classified into three classes.

$$CQI = (rainfall \times aspect \times aridity)^{1/3} \qquad (3.5)$$

Table 3.6 Classes of climate quality (Kosmas *et al*., 1999a)

Climate quality index	Description	Range
1	High quality	<1.15
2	Moderate quality	1.15-1.81
3	Low quality	>1.81

3.4.3 Vegetation quality indicator (VQI)

Vegetation quality was assessed in terms of (a) fire risk and ability to recover, (b) erosion protection to the soil, (c) drought resistance, and (d) plant cover. The existing in the Mediterranean region dominant types of vegetation was grouped into four categories according to the fire risk. Also four categories were used for classifying the vegetation according to the protection to the soil form erosion. Five categories were used for classification of vegetation with respect to drought resistance. Finally, plant cover was distinguished into three classes (Table 3.7).

Table 3.7 Classes and weighting indices of parameters used for vegetation quality assessment (Kosmas *et al*., 1999a)

Structure of range and weight index			
Fire risk class	**Description**	**Type of vegetation**	**Index**
1	Low	Bare land, perennial agriculture crops, annual agricultural crops (maize, tobacco, sunflower	1
2	Moderate	agricultural crops (cereals, grasslands), deciduous oak, (mixed), mixed Mediterranean, macchia /evergreen forests	1.3
3	High	Mediterranean macchia	1.6
4	Very high	Pine forest	2
Erosion protection class	**Description**	**Vegetation types**	**Index**
1	Very high	Mixed Mediterranean, macchia/evergreen forests	1
2	High	Mediterranean, macchia, pine forests, Permanent grass lands, evergreen perennial crops	1.3
3	Moderate	Deciduous forests	1.6
	Low	Deciduous perennial agricultural crops (almonds, orchards)	1.8
4	Very low	Annual agricultural crops (cereals), annual grasslands, vines	2
Drought resistance class	**Description**	**Types of vegetation**	**Index**
1	Very high	Mixed Mediterranean, macchia/evergreen forests, Mediterranean, macchia	1
2	High	Conifers, deciduous, olives	1.2
3	Moderate	Perennial agricultural trees(vines, almonds, orchards)	1.4
4	Low	Perennial grasslands	1.7
5	Very low	Annual agricultural crops, annual grasslands	2
Plant cover class	**Description**	**Plant cover (%)**	**Index**
1	High	>40	1
2	Low	10-40	1.8
3	Very low	<10	2

The vegetation quality indicator (VQI) was assessed as the product of the above vegetation characteristics related to sensitivity to desertification using the following algorithm. Then the vegetation quality indicator was classified into three classes defining the quality of vegetation with respect to desertification (Table 3.8).

$$VQI = (\text{fire risk} \times \text{erosion protection} \times \text{drought resistance} \times \text{vegetation cover})^{1/4} \qquad (3.6)$$

Table 3.8 Classes of vegetation quality (Kosmas *et al*., 1999a)

Vegetation quality index	Description	Range
1	High quality	1-1.6
2	Moderate quality	1.7-3.7
3	Low quality	3.8-16

3.4.4 Management quality or degree of human induced stress indicator (MQI)

The land was classified in the following categories according to the major land use for assessing the management quality or the degree of human induced stress.

a. Land use intensity

Agricultural land-cropland: The intensity of land use of a cropland was classified into three classes (Table 3.9) based on the frequency of irrigation, degree of mechanization of cultivation, application of fertilizers and agrochemicals, types of plant varieties used,…. ect, described previously.

b. Policy

The policies related to environmental protection were classified according to their degree in which they were enforced for each case of land use. The information on the existing policies was collected and then the degree of implementation/enforcement was evaluated. Three classes related to the policy on environmental protection are defined (Table 3.9).

Table 3.9 Classes and weighting indices of parameters used for land management quality assessment (Kosmas *et al*., 1999a)

Structure of range and weight index			
Cropland class	**Description**		**Index**
1	Low land use intensity (LLUI)		1
2	Medium land use intensity (MLUI)		1.5
3	High land use intensity (HLUI)		2
Pasture class	**Description**	**Stocking rate**	**Index**
1	Low	ASR < SSR	1
2	Moderate	ASR = SSR to 1.5*SSR	1.5
3	High	ASR > 1.5*SSR	2
Natural area class	**Description**	**Management characteristics**	**Index**
1	Low	A/S = 0	1
2	Moderate	A/S < 1	1.2
3	High	A/S = 1 0r greater	2
Mining area class	**Description**	**Erosion control measurement**	**Index**
1	Low	Adequate	1
2	Moderate	Moderate	1.5
3	High	Low	2
Recreation area class	**Description**	**A/P visitor ratio**	**Index**
1	Low	> 1	1
2	Moderate	1-2.5	1.5
3	High	> 2.5	2
Policy class	**Description**	**Degree of enforcement**	**Index**
1	High	Complete: >75% of the area under protection	1
2	Moderate	Partial: 25-75% of the area under protection	1.5
3	Low	Incomplete: <25% of the area under protection	2

*SSR: the sustainable stocking rate, ASR: the actual stocking rate, **A**: assessing the actual, **S**: sustainable yield

The management quality indicator (MQI) was assessed as the product of land use intensity and the enforcement of policy for environmental protection using the following algorithm. Then the management quality was defined using Table 3.10.

$$MQI = (\text{land use intensity} \times \text{policy enforcement})^{1/2} \qquad (3.7)$$

Table 3.10 Classes of management quality (Kosmas *et al*., 1999a)

Class	Description	Range index
1	High	1-1.25
2	Moderate	1.26-1.50
3	Low	>1.51

3.4.5 Matching the results

The final step comprised the matching of the physical environment qualities (soil quality, climate quality, vegetation quality) and the management quality for the definition of the various types of ESAs (Environmentally Sensitive Areas) to desertification. The four derived indices were multiplied for the assessment of the ESAs index as following:

$$ESAs = (SQI \times CQI \times VQI \times MQI)^{1/4} \qquad (3.8)$$

The ranges of ESAs for each of type of the ESAs (as they were defined above), included three subclasses in each type appear in Table 3.11. Each type of ESAs was defined on a three-point scale, ranging from 3 (high sensitivity) to 1 (lower sensitivity), in order the boundaries of the successive classes of ESAs to be better integrated.

Table 3.11 Types of ESAs and corresponding ranges of indices (Kosmas *et al*., 1999a)

Type	**Subtype**	**Range of ESAI**
Critical	C3	>1.53
«	C2	1.42-1.53
«	C1	1.38-1.41
Fragile	F3	1.33-1.37
«	F2	1.27-1.32
«	F1	1.23-1.26
Potential	P	1.17-1.22
Non affected	N	<1.17

The mapping symbol of each type of ESAs included the class and subclass, four suffixes corresponding to the used land qualities (´c` for climate, ´s` for soil, ´v` for vegetation and ´m` for management) and four numbers indicated the degree of limitation for each quality (Fig. 3.12).

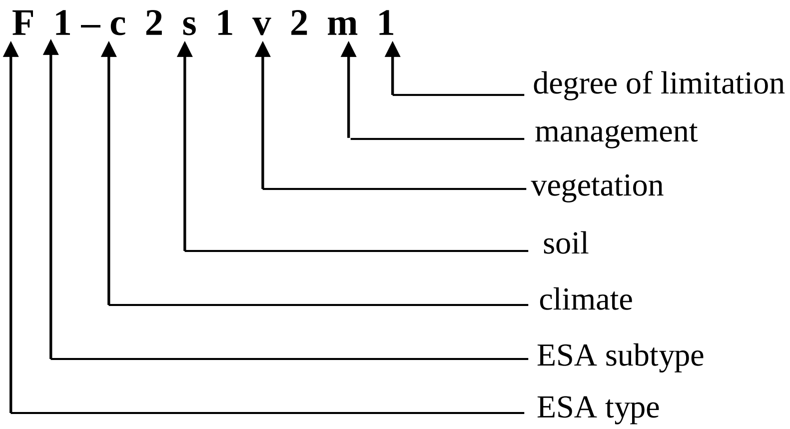

Figure 3.12 Mapping symbol used for characterization of the ESAs to desertification

3.5 Soil Sampling and Analysis

Soil samples were carried out during the month of Oct., Nov. and Dec. 2016.Twenty pedons were selected, twelve in Sulaimani area, one in Diyala, four in Kirkuk, and three in Erbil soils were morphologically described according to (Schoeneberger *et al*., 2002). Soil samples from each horizon were taken for laboratory. As well as 89 samples were collected from surface soil up to depth 0-30cm (fifty one in Sulaimani area, five in Diyala, eighteen in Kirkuk, and fifteen in Erbil) for the determination of desertification, soil quality, land suitability, and land capability.

3.6 Preparation of Soil Samples

The collected soil samples from each horizon of the pedons and locations were air dried, mixed to be homogenous, ground by using plastic mortar, then sieved through 2 mm sieve and saved in plastic containers until various analyses are carried out.

3.7 Methods of Soil Analysis

3.7.1 Physical properties

3.7.1.1 Particle size analysis

Particle size distribution of soil samples was determined following international pipette method as described by Piper (1966).

3.7.1.2 Bulk density (Mg m^{-3})

Bulk density in each treatment was recorded by clod method as described by Black (1965).

3.7.1.3 Particle density (Mg m^{-3})

Particle density of each sample was determined by pycnometer method as described by Blake and Hartge (1986).

3.7.1.4 Water content (Pw%)

Soil moisture content was measured by gravimetric method according to the methods described by (Gardner, 1986).

3.7.2 Chemical properties

3.7.2.1 Soil reaction (pH)

The soil pH was determined in 1:2.5 soil-water suspensions with glass electrode using pH-meter (Jackson, 1967).

3.7.2.2 Electrical conductivity (EC)

Electrical conductivity was determined in 1:2.5 soil-water extract using Conductivity Bridge and expressed as dSm^{-1} (Jackson, 1973).

3.7.2.3 Soluble cations

The soluble cations measured in 1:2.5 soil-water extract as follows:

Soluble Ca^{+2} and Mg^{+2} were measured by titration with EDTA, whilst soluble Na^{+} and K^{+} were measured by flame photometer (Model Corning 400 flame photometer) (Estefan *et al*., 2013).

3.7.2.4 Exchangeable cations

Exchangeable cations were extracted by neutral normal ammonium acetate. Calcium and magnesium in the extract were determined by EDTA titration and sodium and potassium by flame photometry (Model Corning 400 flame photometer) (Estefan *et al*., 2013).

3.7.2.5 Cation exchange capacity

The cation exchange capacity (CEC) of the soil samples was measured by using Polemio and Raods methods according to Page *et al*., (1982).

3.7.2.6 Base saturation

The base saturation for each sample was determined according to Reeuwijk (2002).

3.7.2.7 Soil organic matter

The soil organic matter was determined according to Smith Weldon modification of the Walkey-Black method which described in Abdul Hady (1986).

3.7.2.8 Calcium carbonate

The calcium carbonate of soil samples were determined by rapid titration method (Piper, 1966).

3.7.2.9 Available phosphorous

Available phosphorous was measured by Olsen method (Olsen *et al*., 1954).

3.7.2.10 Available nitrogen

Available nitrogen content in soil samples were determined by Kjeldahl method (model Buchi Digester Unit K-424) (Jackson, 1956).

3.8 Soil Quality

According to the mean annual precipitation (mm), the study area was found to fall into three zones included zone 2 [Arid (100-300)mm], zone 3 [Semiarid (300-500)mm] and zone 4 [dry subhumid (>500)mm] as classified by (FAO, 1998) Fig.3.13. For each zone areas have been selected. zone 2 (Kalar, Khanaqin, Shwan, Altuncopri, Daquq, Qushtapa, Makhmoor, and Gwer), zone 3 (Said Sadiq, Chamchamal, Bazian, Qaradakh, Sangaw, Darbandikhan, and Lailan) and zone 4 (Mawat, Sangasar, Chwarqurna, and Dukan).

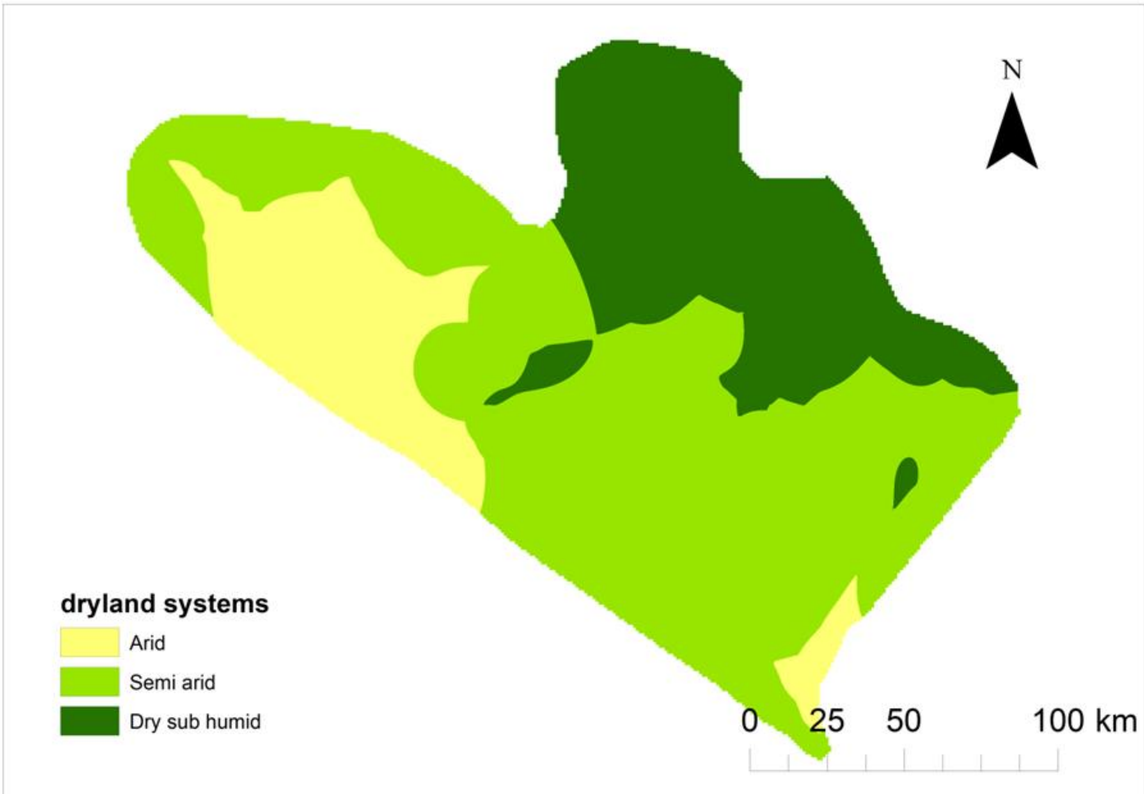

Figure 3.13Dryland Systems for the study area

3.8.1 Analysis of data

All the data regarding soil physical and chemical properties were recorded in respective excel spread sheet and Statistical Package for the Social Sciences (SPSS). The main statistical tests applied were one-way ANOVA to determine significant difference with respect to each zone.

3.9 Land Capability Classification

The land capability was mainly based on the inherent soil characteristics, external land features and environmental factors. The land capability classes and sub classes were arrived at as per the guidelines in Soil Survey Manual (AISLUS, 1971) (Table 3.12).

The capability class (often shown as a numeral) tells you how limited the soil is for agricultural uses. The subclass designation (shown as a letter; e.g. VIIs) tells you what kind of limitation is the main problem.

Class codes I, II, III, IV, V, VI, VII and VIII are used to represent both irrigated and non-irrigated land capability classes.

Class I soils have slight limitations that restrict their use.

Class II soils have moderate limitations that reduce the choice of plants or require moderate conservation practices.

Class III soils have severe limitations that reduce the choice of plants or require special conservation practices, or both.

Class IV soils have very severe limitations that restrict the choice of plants or require very careful managements, or both.

Class V soils have little or no hazard of erosion but have other limitations, impractical to remove, that limit their use mainly to pasture, range, forestland, or wildlife food and cover.

Class VI soils have severe limitations that make them generally unsuited to cultivation and that limit their use mainly to pasture, range, forestland, or wildlife food and cover.

Class VII soils have very severe limitations that make them generally unsuited to cultivation and that restrict their use mainly to grazing, forestland, or wildlife.

Class VIII soils and miscellaneous areas have limitations that preclude their use for commercial plant production and limit their use to recreation, wildlife, or water supply or for esthetic purposes.

Capability subclass is the second category in the land capability classification system.

Class code e, w, s, and c are used for land capability subclasses.

Subclass e is made up of soils for which the susceptibility to erosion is the dominant problem or hazard affecting their use. Erosion susceptibility and past erosion damage are the major soil factors that affect soils in this subclass.

Subclass w is made up of soils for which excess water is the dominant hazard or limitation affecting their use. Poor soil drainage, wetness, a high water table, and overflow are the factors that affect soils in this subclass.

Subclass s is made up of soils that have soil limitations within the rooting zone, such as shallowness of the rooting zone, low moisture-holding capacity, low fertility that is difficult to correct, and salinity or sodium content.

Subclass c is made up of soils for which the climate (the temperature or lack of moisture) is the major hazard or limitation affecting their use.

The subclass represents the dominant limitation that determines the capability class. Within a capability class, where the kinds of limitations are essentially equal, the subclasses have the following priority: e, w, s, and c. Subclasses are not assigned to soils or miscellaneous areas in capability classes 1 and 8.

Table 3.12 Land capability classification – quantification of the criteria (Sehgal 1996)**.**

Characteristics	Class-I	Class-II	Class-III	Class-IV	Class-V	Class-VI	Class-VII	Class-VIII
Topography (t)								
Slope (%)	0-1	1-3	3-8	8-15	upto 3	15-35	35-50	>50
Erosion	Nil	Slight	Moderate	Severe	Nil	Severe	Severe	
Wetness (w)								
Flooding	nil (F0)	nil (F0) (F0/F1)	nil to slight (F1/F2)	slight to mod. (F3)	mod. to severe (F0/F3)	nil to severe (F0/F4) excessive	nil to very	
Drainage (I)	Well	Mod. well	Imperfect	Poor	V. poor	Excessive	Excessive	Excessive
Permeability	Moderate	Mod. rapid	Rapid slow	V. rapid, v. slow	-	-	-	-
Infiltration rate (cm/hr)	2-3.5	1-2.0, 3.0-5.0	0.5-1.0, 5.0-10.0	<0.5, >10.0	2.0			
Physical Characteristics								
Surface texture	Loam	Sil& cl	Si & c	Scl	S, c (m)	ls – cl	Ls, s, c	Ls, s, c (m)
Surface coarse fragments (vol%)	1-3	3-15	15-40	40-75	15-75	75+		
Surface stoniness (%)	<1	1-3	3-5	5-8	8-15	15-40	40-75	>75
Subsurface coarse fragments (%)	<15	<15	15-35	35-50	50-75	50-75	50-75	>75
Soil depth (cm)	>150	150-100	100-50	50-25	-	25-10	25-10	<10
Profile development	Cambic/ Argillic hor. A-(B)-C	A-B-C	Stratified A-C; A-B-C	Salic (z)/ Calcic (k) hor. A-Bz-C/A-Bk-C	Az-C, A-B, C	Gypsic (y) hor. A-Cy	A-C (stony)	A-C (bouldary)
Fertility								
CEC (cmol (p+)kg^{-1})	40-16	16-12	16-12	-	-	-	-	-
Base saturation (%)	80+	80+	80-50	50-35	50-35	35-15	<15	-
OC (0-15 cm) (%)	>10	0.75-10	0.5-0.75	<0.5	<0.5	-	-	-
Salinity EC (dS m^{-1})	<1.0	1-2	2-4	4-8	8-15	15-35	35-50	>50
Gypsum	0.3-2.0	2-5	5-10	10-15	15-25	>25	-	-

3.10 Land Suitability Classes

Land suitability classes for the study area were determined according the proposal of Sys *et al*. (1993). By using the requirement of soil, hydrological conditions and topography of wheat in Table (3.13). Equation (3.9) was used to calculate land index as fallow:

$$LandIndex(LI) = \frac{A1 * A2 * A3 \ldots\ldots\ldots An}{10^{2n-2}} \qquad (3.9)$$

Where: *LI* = Land index

A1, A2, ……, An = evaluation of land properties

n = number of land properties

Table 3.13 Requirement of soil, hydrological conditions and topography of Wheat crop (Sys *et al*. 1993)

Land characteristics		Class Degree of Limitation and Rating Value					
		S1		S2	S3	N1	N2
		0	1	2	3	4	
		100	95	85	60	40	25 0
Topography	**(t)**						
Slope%		0-1	1-2	2-4	4-6	-	>6
Wetness	**(w)**						
Flooding		F0	-	F1	F2	-	$F3^{+}$
Drainage		Good	Moderate	Imperf.	Poor and acric	Poor, but drainable	Poor, not drainable
Physical soil characteristics (s)	**(s)**						
Texture struct.		C< 60s, Co, SiC..SiL, Si, CL	C< 60v. SC, C> 60s, L	C> 60s, SCL	LS, LfS	-	Cm, SiCm, LcS, fS, cS
Coarse fragment. (vol%)		0-3	3-15	15-35	35-55	-	>55
Soil Depth (cm)		> 90	90-50	50-20	20-10	-	<10
$CaCO_3$ (%)		3-20	20-30	30-40	40-60	-	> 60
Gypsum (%)		0-3	3-5	5-10	10-20	-	> 20
Soil fertility characteristics (f)	**(f)**						
Apparent CEC ($cmol_c$ kg^{-1} soil)		> 24	24-16	< 16	-	-	-
Base Saturation (%)		> 80	80-50	50-35	< 35	-	-
Sum of basic cation ($cmol_c$ kg^{-1} soil)		> 8	8-5	5-3.5	3.5-2	< 2	-
pH_{H2O}		7.0-7.6	7.6-8.2	8.2-8.4	8.4-8.5	-	> 8.5
Organic carbon (%)		> 6	0.6-0.4	< 0.4	-	-	-
Salinity and Alkalinity (n)	**(n)**						
ECe (d Sm^{-1})		0-4	4-8	8-12	12-16	16-20	20-24
ESP (%)		0-15	15-20	20-35	35-45	-	> 45

Cm: massive clay

C+60, V: very fine clay, Vertisol structure

C+60, s: very fine clay, blocky structure

C-60, V: clay, Vertisol structure

C-60, s: clay, blocky structure

Co: clay, Oxisol structure

fS: Fine sand

Cs: coarse sand

Table 3.14 Value of index and suitability classes

Suitability class	**Index**
S1: Very suitable	80-100
S2: Moderately suitable	60-80
S3: Marginally suitable	40-60
N1: Currently unsuitable	25-40
N2: Permanently Not suitable	0-25

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Desertification:

4.1.1 Soil quality indicator SQI

4.1.1.1 Soil texture

The results shown in Fig. (4.14) indicate that the soil texture of the study area ranged between the class 2 (moderate) and the class 3 (poor) with an area of 737100 ha and 1908500 ha, which covered 27.86 and 72.14%, respectively.

In general, the soil texture was mostly silty clay loam to silty loam (Appendix 3) which indicated the risk of erosion, in particular wind erosion, as well as their 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.

Wijitkosum and Yolpramote (2013) found that the severe class of soil degradation dominated the areas they studied was characterized by sandy soil texture. The sandy texture of the soil resulted in a low water holding capacity. They concluded that soil texture is a key factor affecting the desertification risk of the area (Wijitkosum *et al.*, 2013).

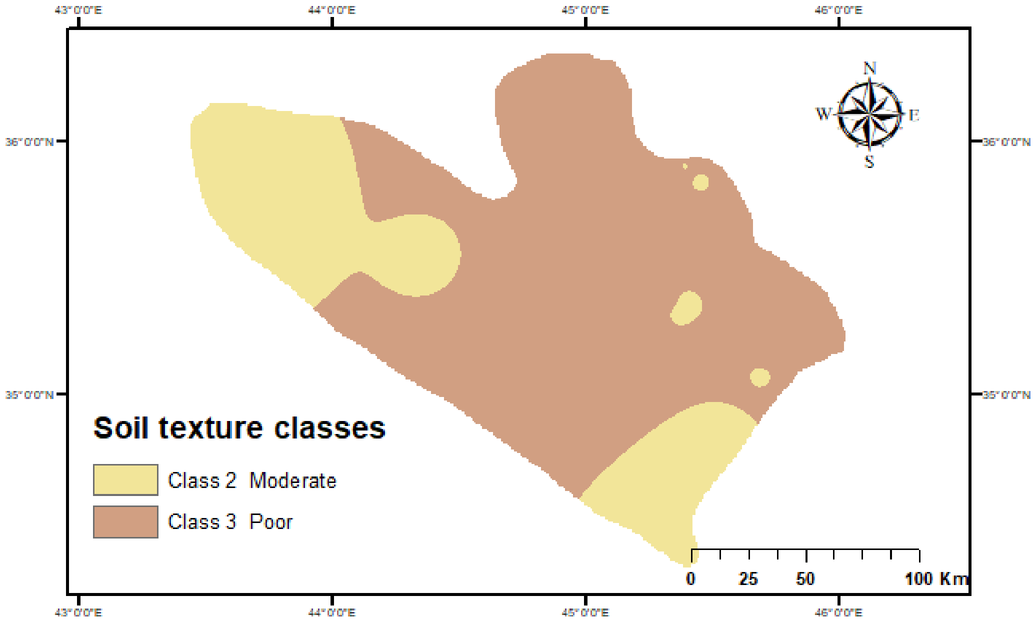

Figure 4.14 Soil texture classes in the study area

4.1.1.2 Soil parent material

The results shown in (Fig. 4.15) indicate that the index of the parent material of all the soil were within the class 2 (moderate), because the parent material is Limestone or loess deposits, which is rich in carbonate minerals and it is susceptible to erosion over time, which plays a big role in desertification.

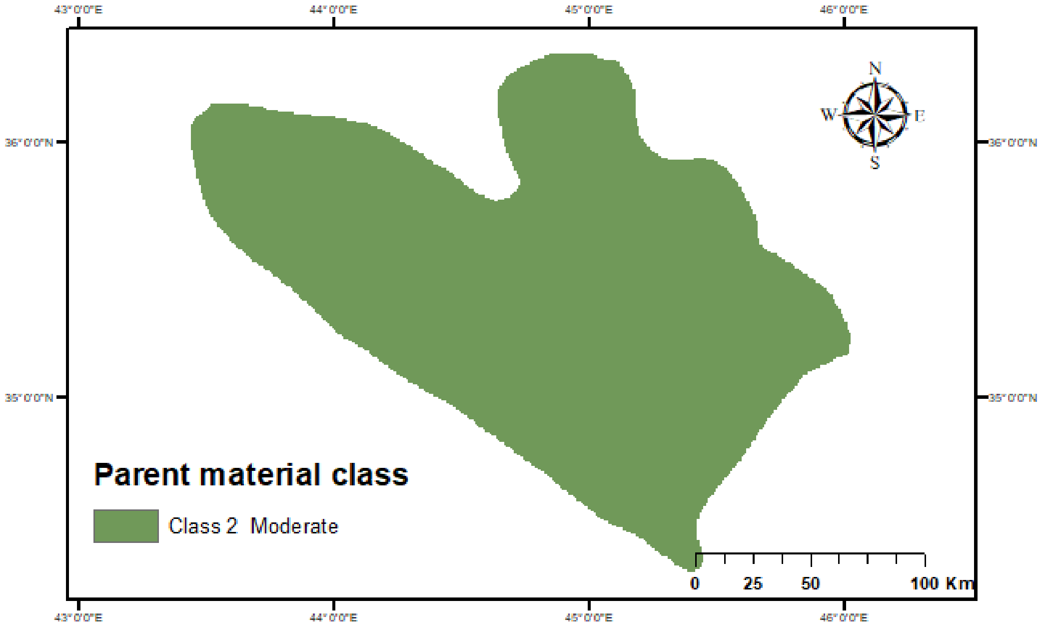

Figure 4.15 Parent material classes in the study area

4.1.1.3 Rock fragments

The results in Fig. (4.16) shows that the rock fragment index reached the most dangerous level within the weight values. The index for all the soil of the study area were generally within class 3 (bare to slightly stony) with a rate of 99.25%.The results also showed a small area of class 2 with an area of 19800 ha with a rate of 0.75%. This might causes suitable conditions for the acquisition of both water and wind erosion in the absence of rough surfaces to protect the soil from erosion.

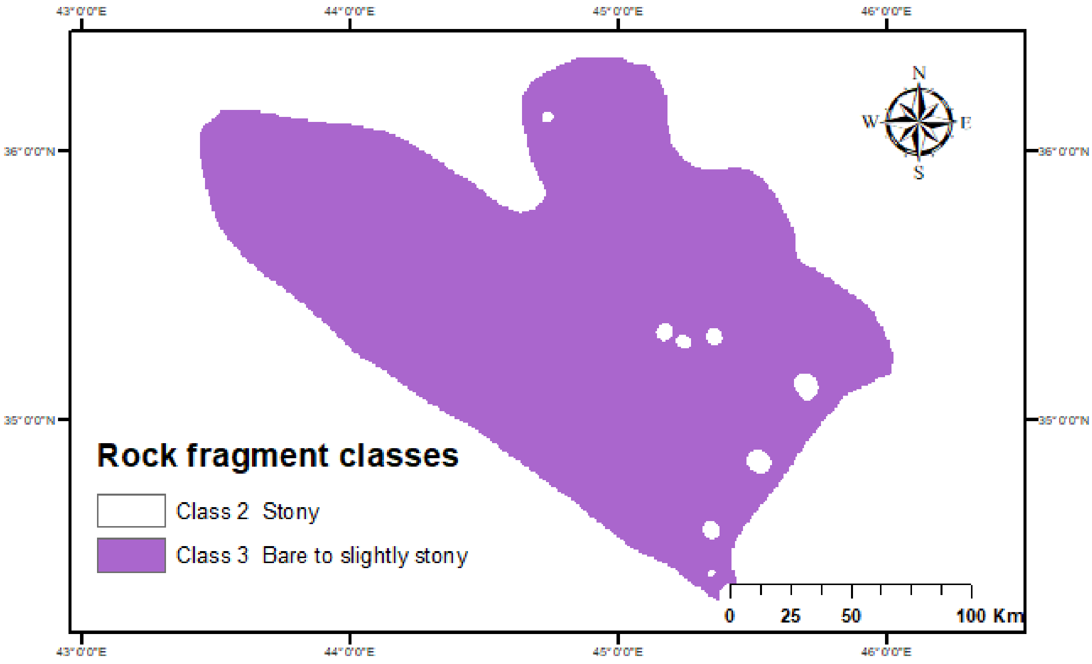

Figure 4.16 Rock fragment classes in the study area

4.1.1.4 Slope grade

Fig. (4.17) showed that the soil slope grade index was 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 of the study area was within class 2(gentle), with an area of 2561000 ha, which occupied 96.80% of total area, and the remaining area was divided to classes 1, 3 and 4, which occupied only 3.20% of total study area.

The effect of water erosion in the gentle to flatlands was almost non-existent; in addition, the water holding capacity was larger which helped to alleviate the runoff, erosion and desertification.

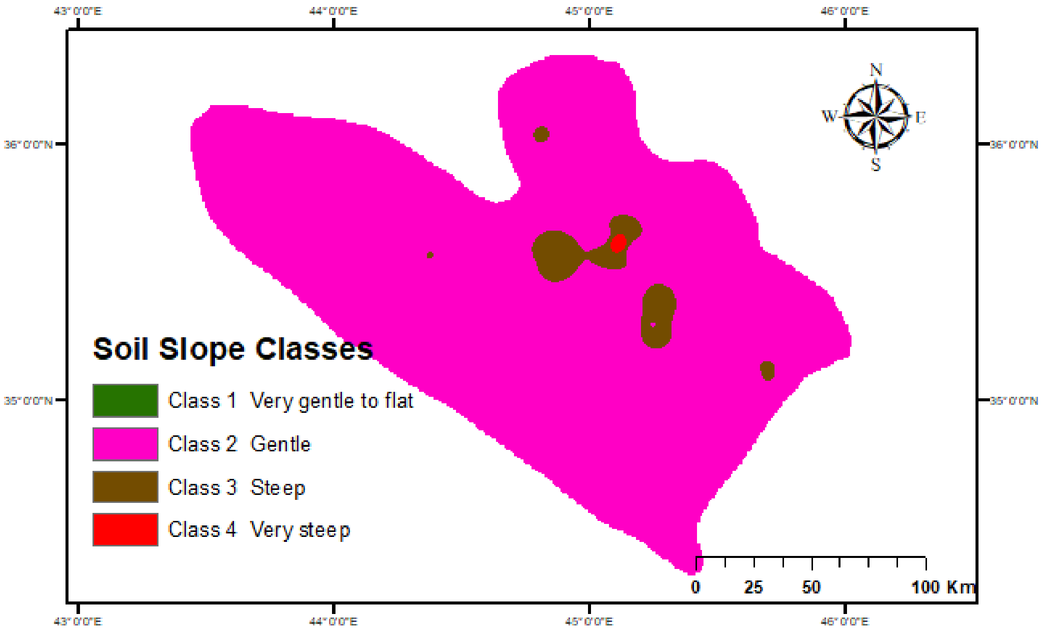

Figure 4.17 Soil slope classes in the study area

4.1.1.5 Soil depth

As shown in (Fig. 4.18) the soil depth index was classified as a class 1(deep). This might cause the increasing of vegetation, which in turn reduces the surface runoff and water erosion, as well as rough surface formation that impairs wind erosion. A deep soil can assure water reserves and can then provide a good condition for vegetation development and growth (Lamqadem *et al.*, 2018).

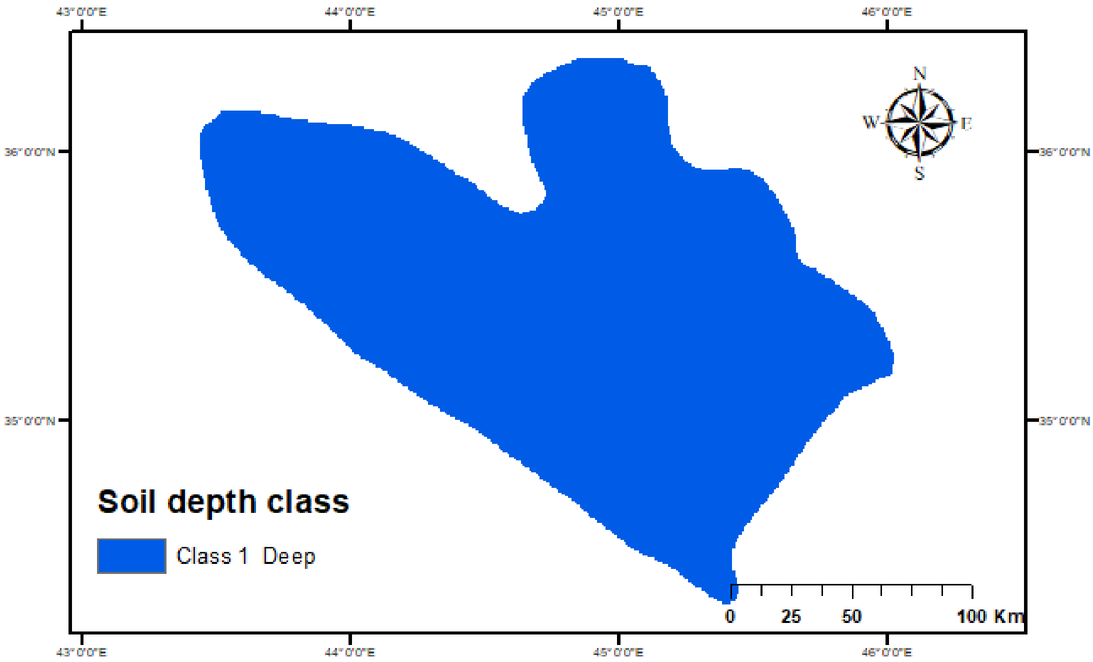

Figure 4.18 Soil depth classes in the study area

4.1.1.6 Drainage

However, the soil drainage classes of the study area (Fig. 4.19) were found to be in class2 (imperfectly drained) and class 3 (poorly drained) with an area of 2150600 ha and 495000 ha with a rate of 81.29% and 18.71%, respectively.

The slow process of water infiltration increased the probability of surface runoff during the rainfall; this could to leads increase the risk of soil erosion.

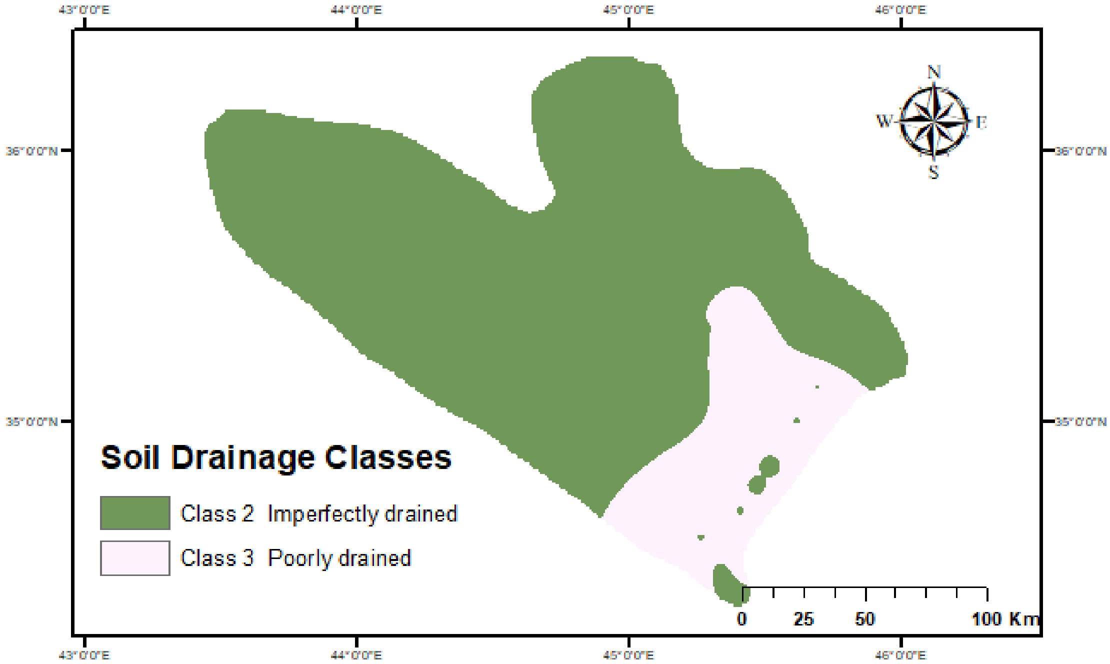

Figure 4.19 Soil drainage classes in the study area

4.1.1.7 Soil organic matter

Fig. (4.20) shows the organic matter index. It showed that it contained different amounts of the organic matter, which was divided into class 2 (good), class 3 (moderate) and class 4 (poor).

The area of class 3 was 2144300 ha with a rate of 81% of the total study area; thus it succeeded the class 2 and class 4 that occupied the area of 224800 ha and 276500 ha with a rate of 8.5 and 10.5% of the total study area respectively. It is clear from these results that organic matter had not played an important role in reducing the risk of desertification .The presence of organic matter is helping to increase the growth of plants, especially herbal, which increase vegetation, in addition to that the accumulation of organic matter enhance of soil aggregation, these factors are expected to increase the soil resistance to erosion.

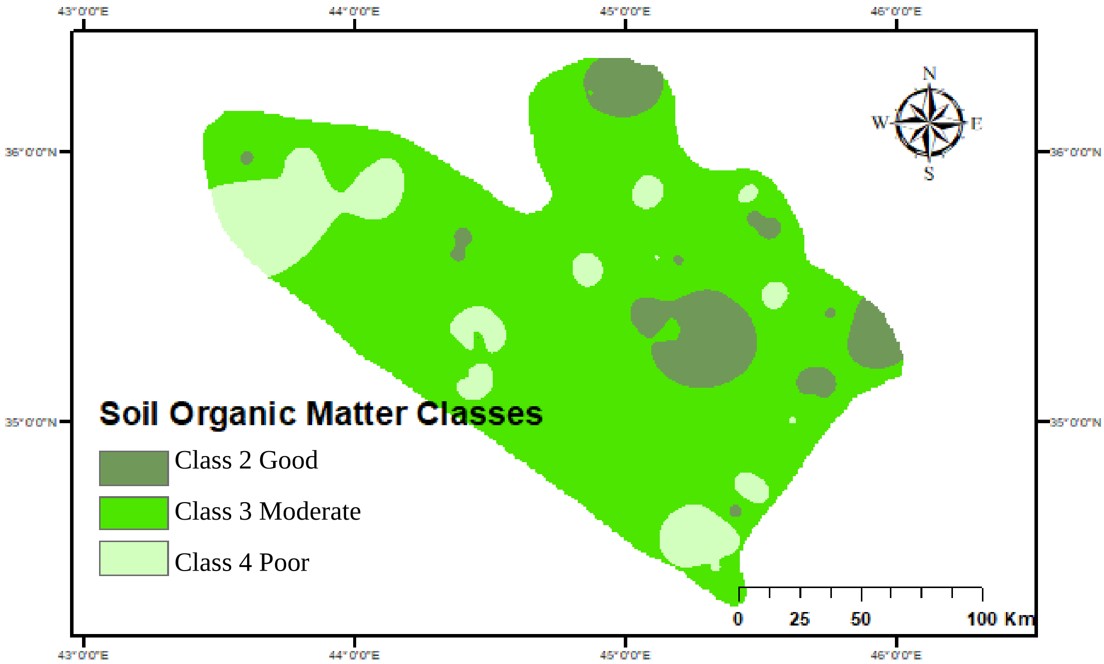

Figure 4.20 Soil organic matter classes in the study area

4.1.1.8 Soil Calcium carbonates ($CaCO_3$)

Fig. (4.21) illustrates the effect of calcium carbonate in the soil study area and its role in desertification. Class 3 (poor) occupied 2608200 ha with a rate of 98.59% of the total area, resulting in poor soil resistance to desertification, (Kadović *et al*., 2016).

While class 2 (moderate) occupied 37400 ha with rate of 1.41% of total area.

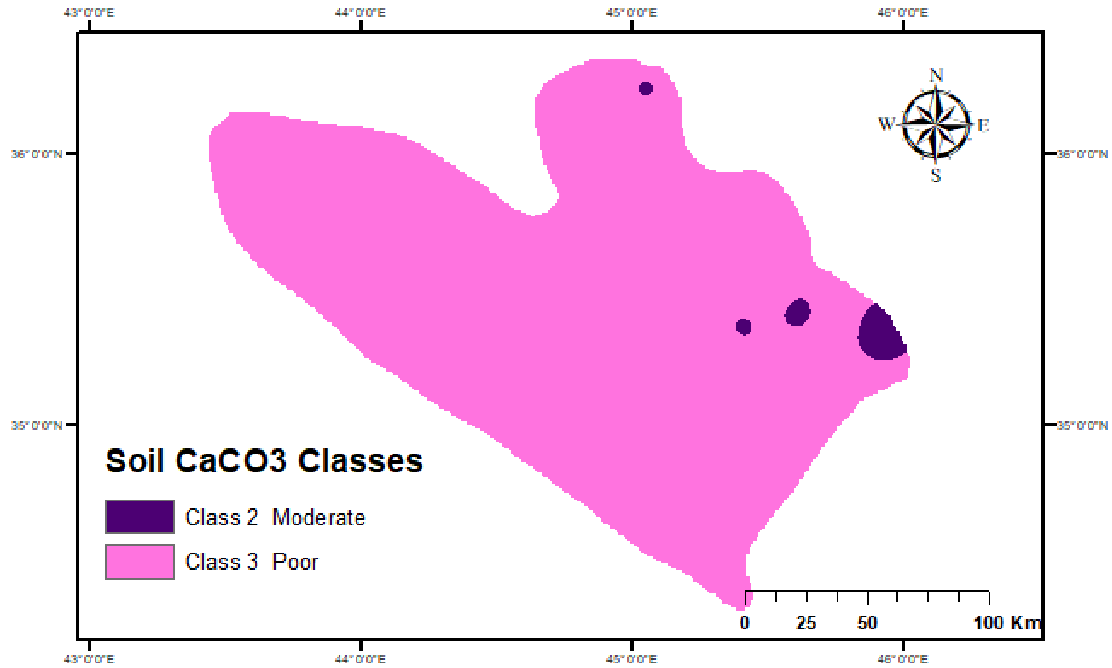

Figure 4.21 Soil calcium carbonate classes in the study area

4.1.1.9 Soil quality indicator SQI

In calculating the weight of the soil quality indicator (Fig. 4.22) and comparing it with the quality classes in the MEDALUS model, it seemed that the soil of the study area was divided into two classes, firstly, class 2 (moderate quality) (2514700 ha), which occupied 95% of the study area and the rest was class3 (low quality) with an area of 130900 ha which was equal to 5% of the total area.

The low soil quality could be due to a number of factors related to the properties of the soil, mainly the limestone soil parent material (Fig.4.15), which had a low resistant to weathering and therefore they may be broken down or dissolved by water. The lack of gravel and stones scattered in the study area (more than 99% was of the class 3 - Bare to slightly stony) and so the soils could be very sensitive to erosion, as well as the effect of soil texture (class 3), which reached more than 72% of study area plus the decline of organic matter, at class 3 (poor) with a rate of more than 80% of study area. Organic matter and clay increase the ability of soil water retention, improve soil aggregations thus minimizes runoff, soil erosion, and desertification.

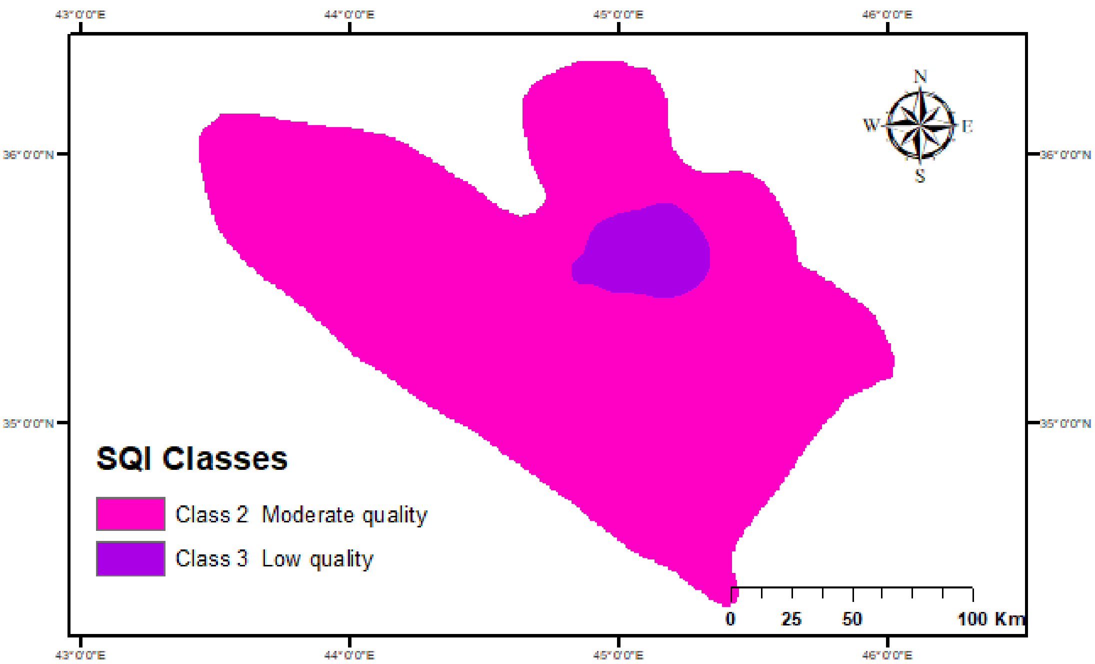

Figure 4.22 Soil quality indicator classes in the study area

4.1.2 Vegetation quality indicator VQI:

4.1.2.1 Plant cover

Fig.(4.23) shows the distribution of vegetation in the study area. It was found to fall in class 2 (low), so the study area was not well protected against desertification. Several studies have shown that vegetation plays an important role in reducing surface runoff and the amounts of sedimentation. Both surface runoff and loss of sediment content are increased as vegetation decreases, this could erosion lead to high, especially if accompanied by increasing soil sloping.

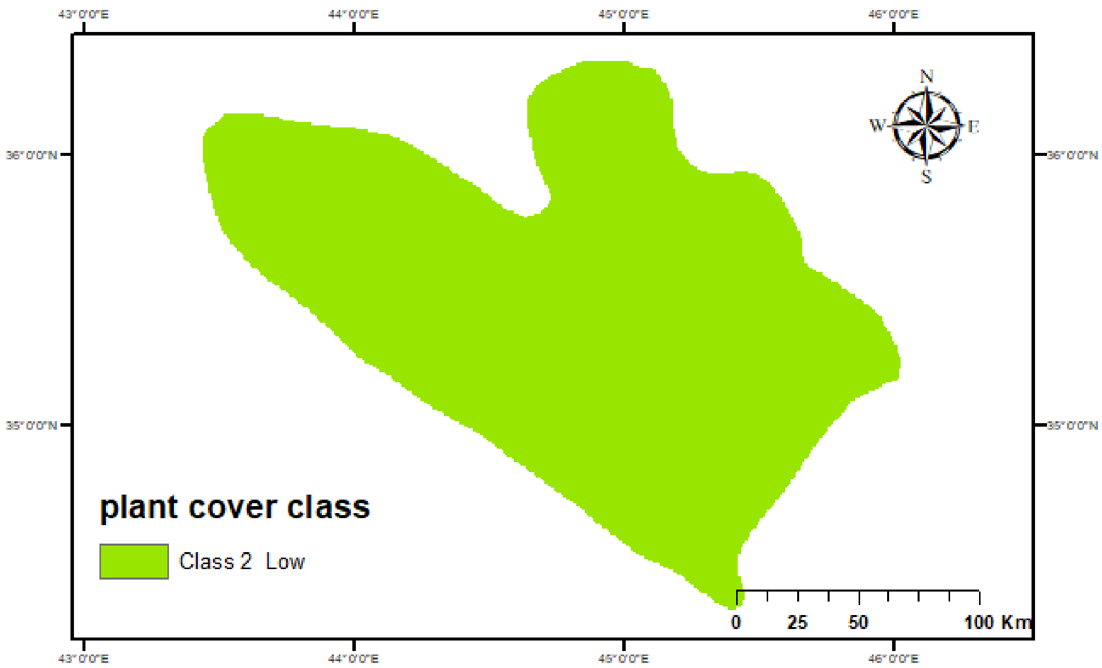

Figure 4.23 Plant covers classes in the study area

4.1.2.2 Fire risk

Fig. (4.24) shows the risk of fires in the study area .It appeared to be of the class 2 (moderate). Forest, trees and grasslands fires on the slopes of the highlands, as well as fires in cereal fields such as wheat and barley during the summer, had a serious impact on soil degradation and desertification due to the effects of soil erosion in the rainy season.

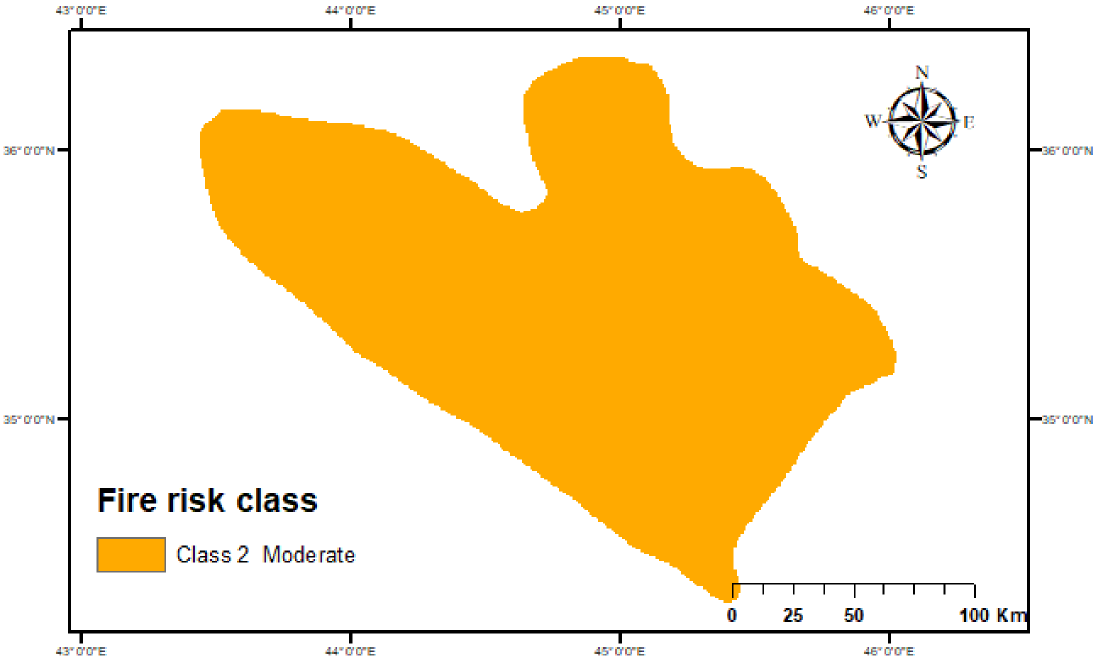

Figure 4.24 Fire risk classes in the study area

4.1.2.3 Drought protection

Fig. (4.25) shows the drought resistance class which was classified as class 5 (very low).

The study area was mainly used for cereal crops, including wheat and barley, as well as seasonal herbs which are used as animal feeders. These crops were seasonal that grow for a certain period and then end, leaving barren land without protection from harsh environmental conditions. Otherwise, forest land or land planted with permanent trees tend to hold more water and maintains greater moisture.

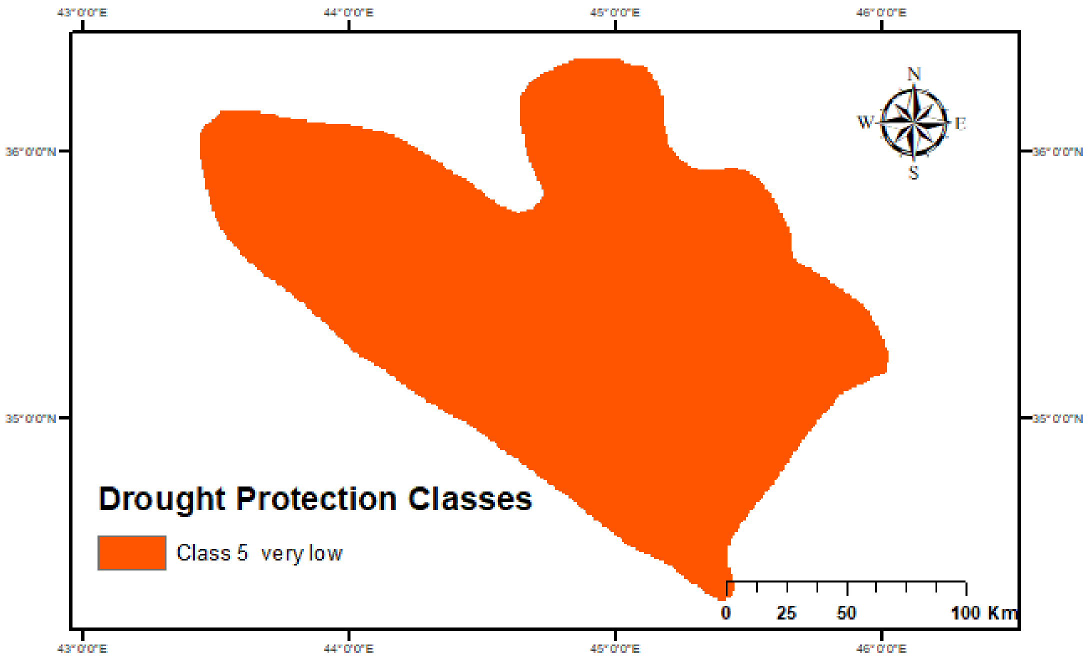

Figure 4.25 Drought protection classes in the study area

4.1.2.4 Erosion protection

Fig.(4.26) shows that the study area was divided into two classes according to protection from erosion. The area of class 3 (Low) was 803700 ha and class 4 (very low) was 1841900 ha, which occupied 30.38% and 69.62% of the total area respectively.

It is evident that the classes of these criteria are low quality and that the soil of the study area is almost devoid of natural protection against erosion. The qualities of the plant cover and its duration in the field may play an important role in determining this, as we noted that it consisted of cereal crops and pastures which remain for a period of time, this leaves possibility for erosion that may lead to desertification.

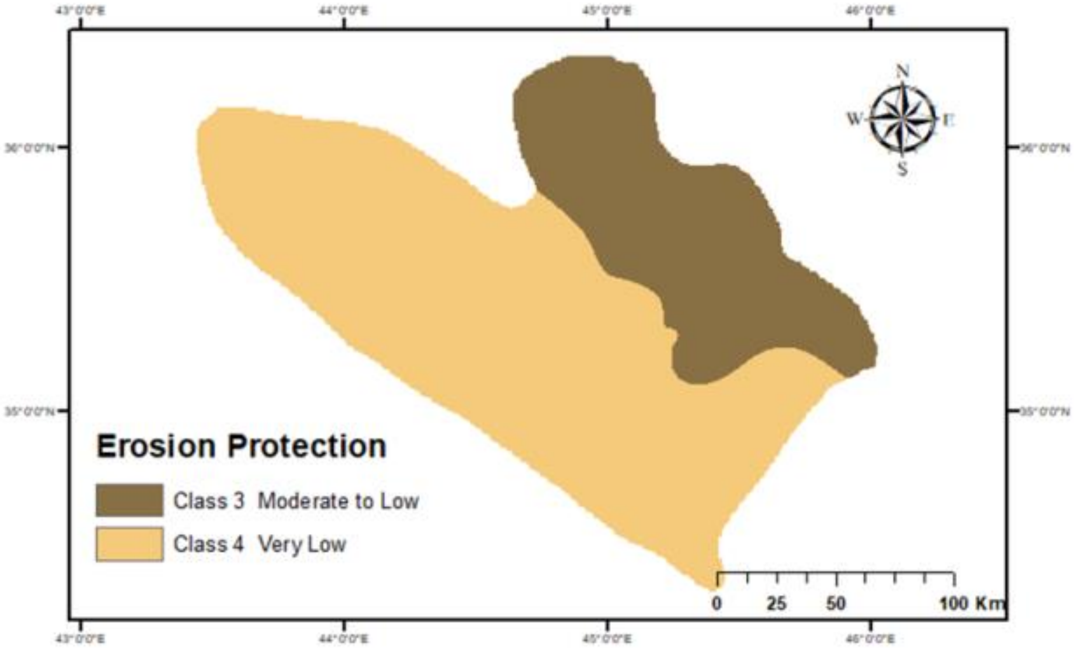

Figure 4.26 Erosion protection classes in the study area

4.1.2.5 Vegetation quality indicator VQI

Fig. (4.27) illustrates the nature of vegetation quality indicator. It shows that it consisted of class 2 (moderate quality) with an area of 760100 ha and class3 (low quality) which its area was 1885500 ha, they occupied 28.73% and 71.27% of the total area, respectively. This could be due to the lack of vegetation, especially in the plain areas, which were cultivated by cereal crops or used as a natural pastures, this might lead to a low resistance to drought. Also note that one-third of the study area is within class 3 (low quality) , this was due to the presence of some natural forests and more natural grazing than its predecessor, which leaded to more resistance to drought and erosion together, because the vegetation is considered an important factor in the process of soil erosion.

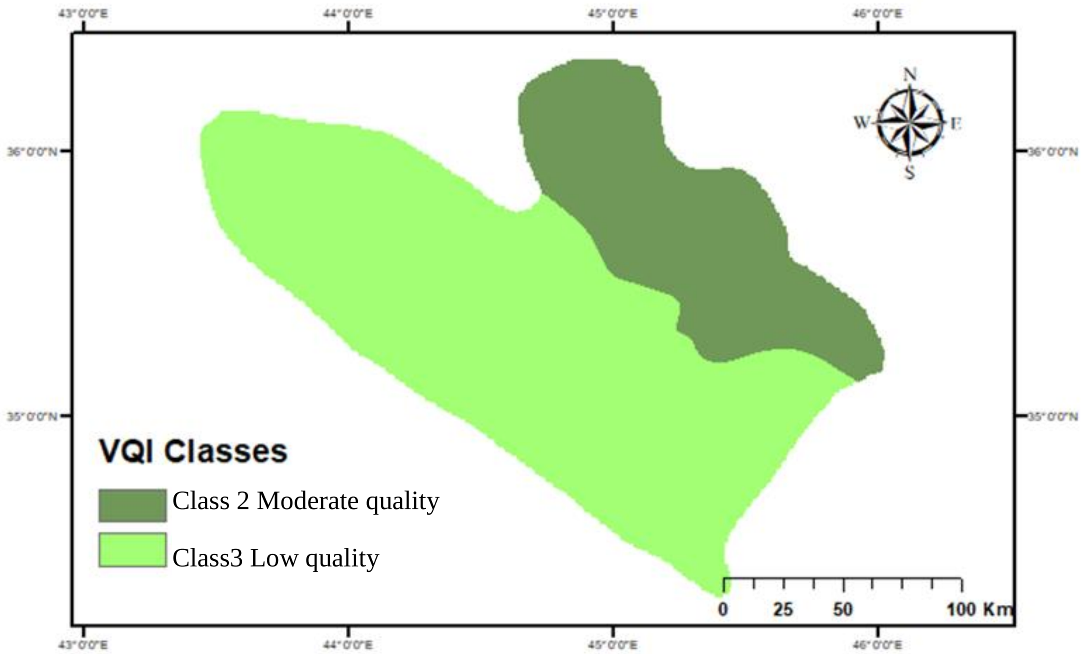

Figure 4.27 Vegetation quality index classes in the study area

4.1.3 Climate quality indicator CQI

4.1.3.1 Rainfall

Fig. (4.28) shows that the study area was divided into two classes in terms of the quantity of precipitation. Class 1 (high quality) where its area was 289800 ha, by about 10.95% of the total area, but class 2 (moderate quality) occupied an area of 2355800 ha which was about 89.05% of the total area.

The rainfall amount increases with altitude above sea level; we observed that class1 was found in limited areas with a rainfall average of more than 500 mm in the mountainous areas near the Iranian border. The class 2 occupied the largest part of the study area and was located in the foothill areas and adjacent plains for mountainous areas with an average rainfall of 250-500 mm.

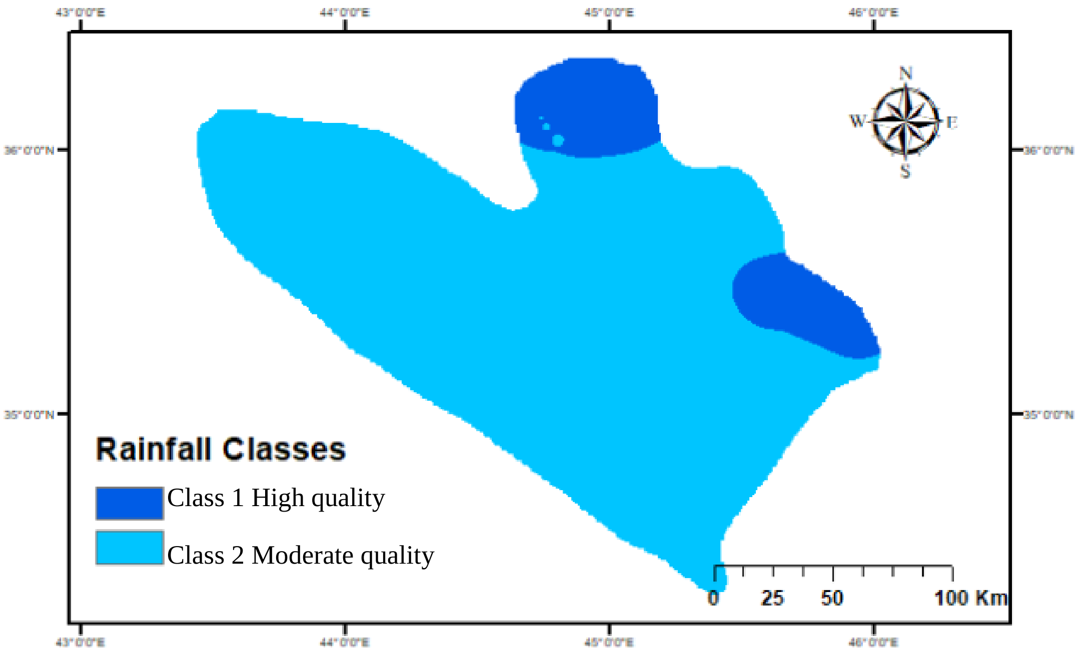

Figure 4.28 Rainfall classes in the study area

4.1.3.2 Aridity index

Fig. (4.29) shows that the aridity index was divided into two classes 4 and 5 which occupied an area of 706500 ha and 1939100 ha with a ratio of 26.70% and 73.30% respectively.

The aridity index is important in the knowledge of available water in the soil. It is directly related to the amount of rainfall, the annual rate of temperature and the evapotranspiration, thus, the quality, quantity and distribution of the plant cover. Therefore, it was considered that the low quality throughout the study area might be due to high temperature, especially in summer season, which leads to increase evapotranspiration, reduce available water in the soil and thus reduced vegetation density.

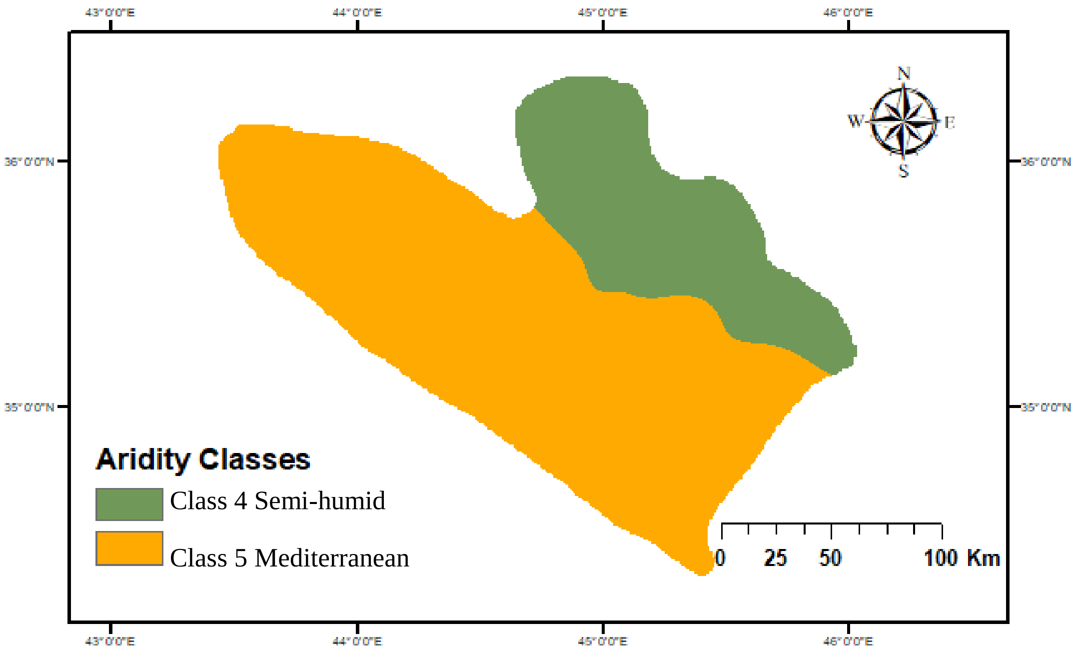

Figure 4.29 Aridity classes in the study area

4.1.3.3 Climate quality indicator CQI

It is seen in Fig. (4.30) that the climate quality was of the class 2 (moderate quality). This was due to the amounts moderate of rain falling in the study area, especially areas that somewhat higher than sea level. High summer temperatures and increased evapotranspiration has leaded to an increase in the value of the drought index and decrease the amounts of available water in the soil and thus decrease the quality of the climate to moderate class. All of the factors mentioned above have leaded to a lack of vegetation and therefore a lack of soil resistance to the erosion process which inturn leaded to soil degradation and then causing desertification.

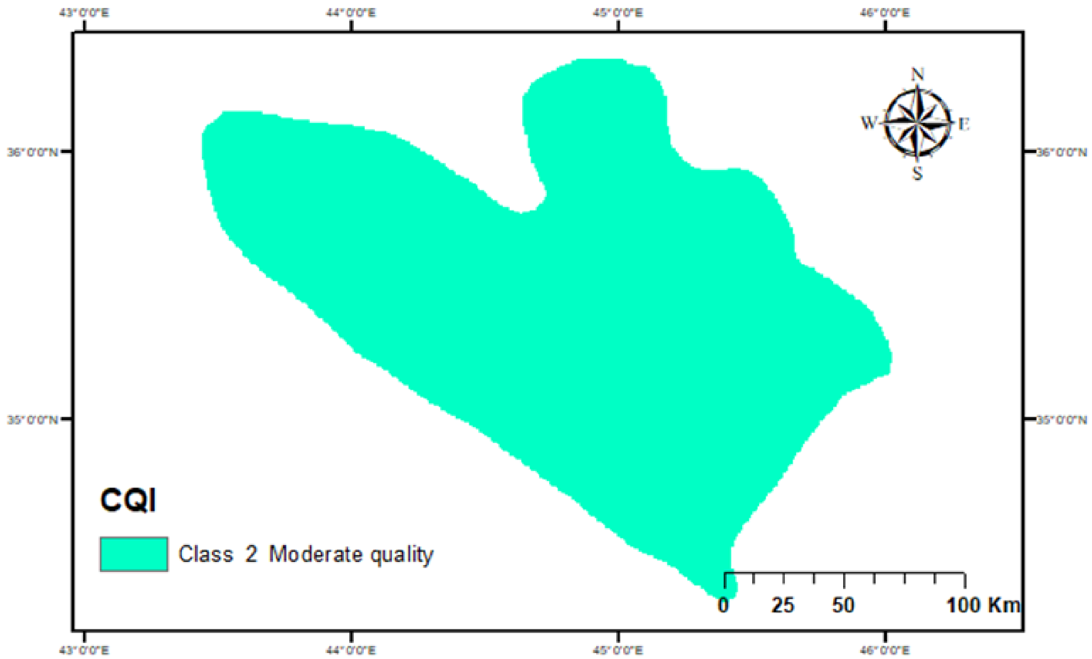

Figure 4.30 Climate quality index classes in the study area

4.1.4 Management quality indicator MQI

4.1.4.1 Cropland

It is clear from (Fig. 4.31) that the all study area was within class 2 (medium landuse intensity), which was located within the agricultural lands that were used to produce cereal crops or natural pastures.

These lands are characterized by the intensity of land use in terms of the use of agricultural mechanization, the addition of fertilizers and chemical pesticides, as well as the types of cultivated plants and their varieties.

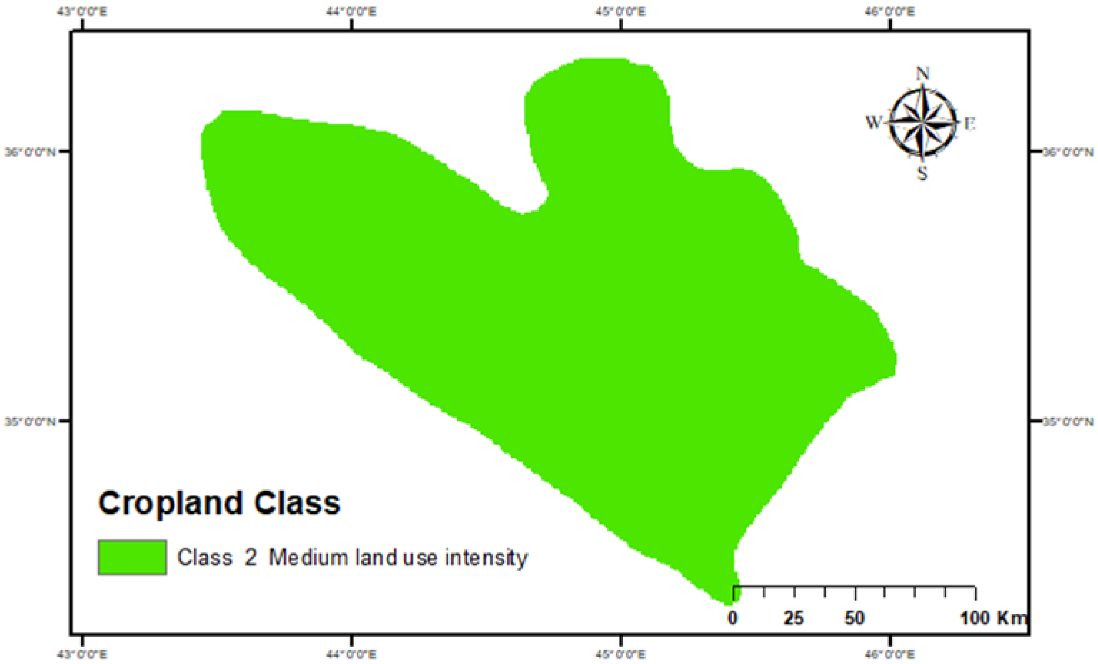

Figure 4.31 Cropland classes in the study area

4.1.4.2 Policy

Figure (4.32) shows that this criteria was divided into three main classes, included class 1 (high), class 2 (moderate) and class 3 (low) with an area of 486500 ha (18.39%), 715000 ha (27.03%) and 1444100 ha (54.58%) respectively.

These could be related to environmental protection that was imposed for any land use. High areas, with a rainfall of more than 650 mm and a dense vegetation cover of trees, was in the class1, because more than 75% was under protection, while the other part was in class 2, because it was protected by natural vegetation partly, comparatively to the remaining part which was in class 3 where it was protected incompletely.

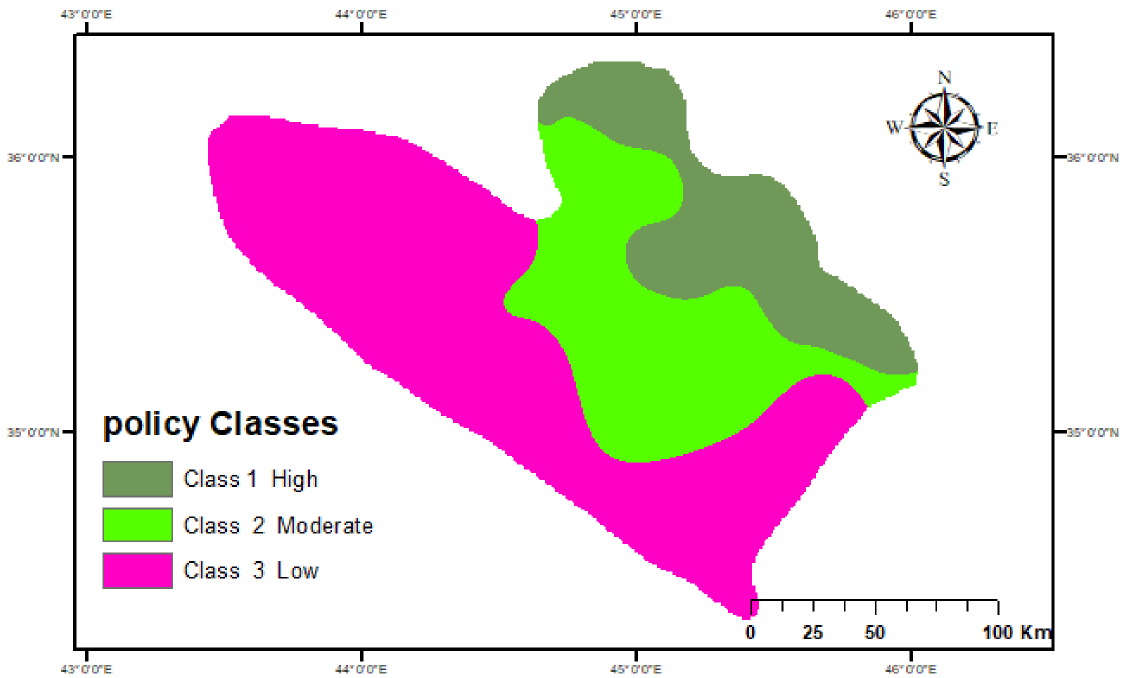

Figure 4.32 Policy classes in the study area

4.1.4.3 Management quality indicator MQI

Fig. (4.33) shows that the study area was divided into three classes, these were class 1 (high) and its area was 456200 ha and class 2 (moderate) its area was 747100 ha and finally class 3 (low) where it was area of 1442300 ha by a rate of 17.24, 28.24 and 54.52% of total study area respectively.

Class 1 was located within the natural forest areas on the Iranian border so it is under natural environmental protection against soil erosion process, but the class 3 is located in areas where natural grazing areas are exposed to overgrazing by farm animals or it may be used for growing wheat and barley crops relying on rain. Thus, they are vulnerable to erosion because of the weak natural environmental protection of soil through vegetation.

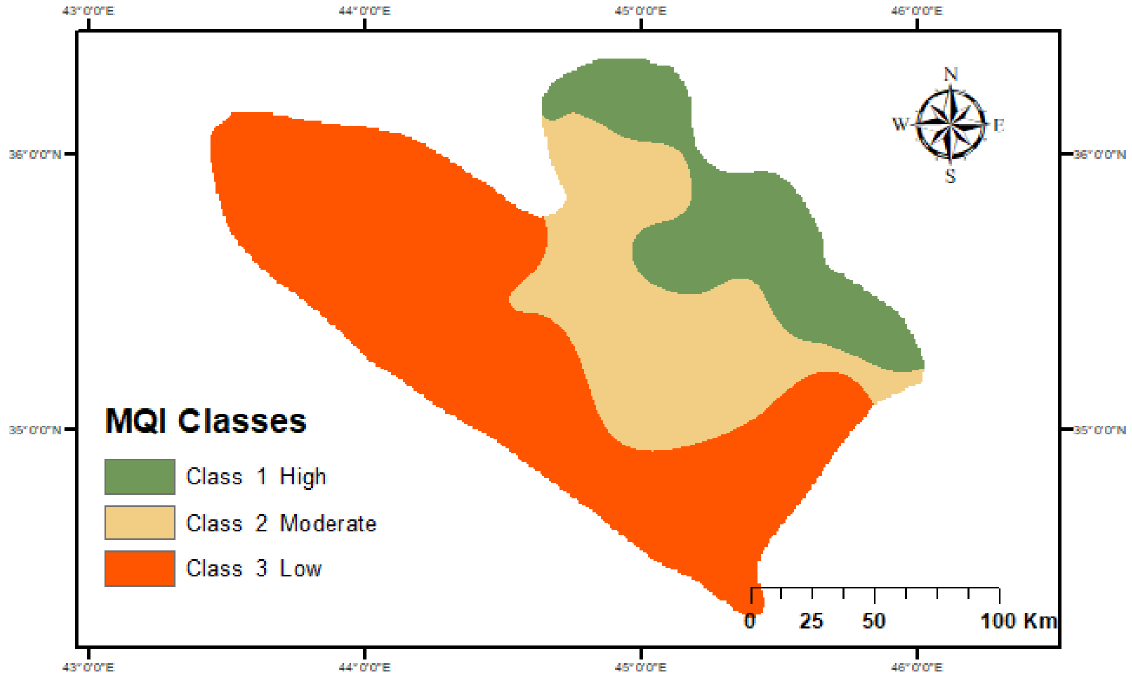

Figure 4.33 Management quality indicator classes in the study area

4.1.5 Environmentally sensitive areas to desertification ESAs

The Environmentally Sensitive Areas to Desertification ESAs for the study area were shown in (Fig. 4.34). It is clear that the most common type is class C3 (Critical) with an area of 1112700 ha (42.06%), followed by classes C2 and C1 with an area of 759700 ha and 364000 ha which covered 28.71% and 13.76% of the study area respectively. The Fragile classes (F3 and F2) occupied 309300 ha and 99900 ha with a rate of 11.69% and 3.78%, respectively.

The classes C1, C2 and C3 are located in the central and southern parts of the study area. These areas are characterized by low organic matter, low vegetation, low conservation practices, low rainfall, high aridity, poor environmental conservation, and overgrazing. All these are serious problem and could lead to soil degradation, thus they are more variable to desertification. Northern regions of the study area which was characterized by the presence of classes F2 and F3 are less sensitive to desertification; it is characterized by the presence of more vegetation cover, more organic matter, higher environmental conservation, more rainfall, and less drought, so the impact of desertification is less.

Overall, the whole study area is under threat of desertification because of the low quality of the soil indicator, climate indicator, and vegetation cover indicator.

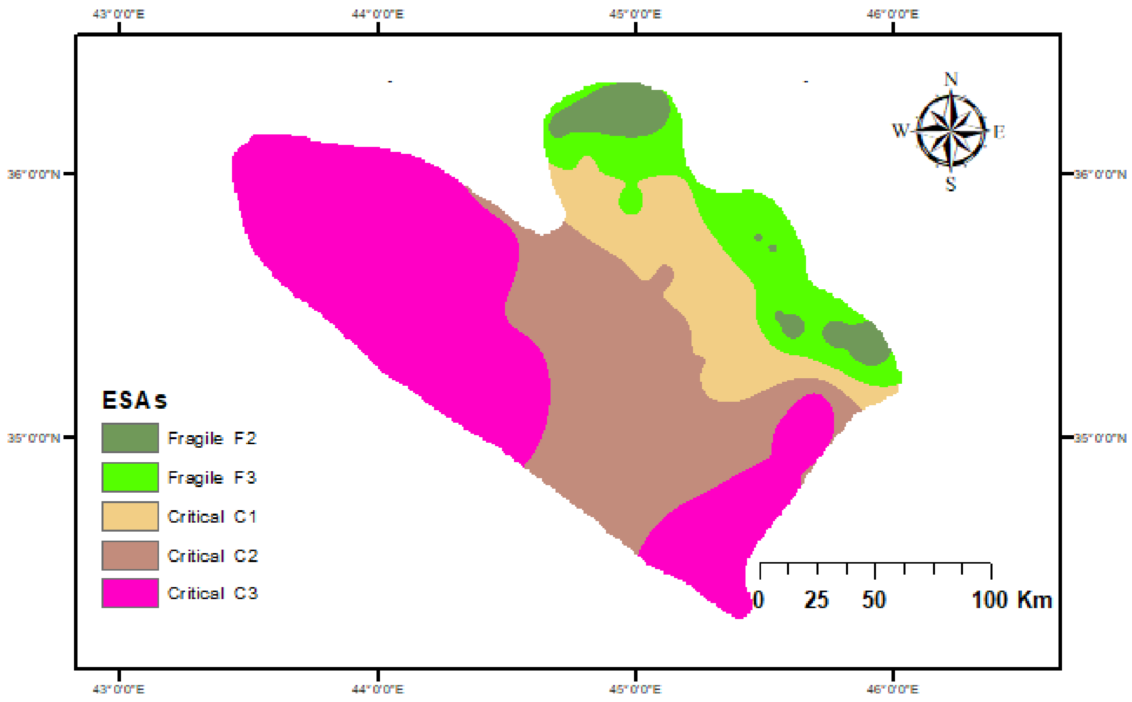

Figure 4.34 Environmentally sensitive areas to desertification classes in the study area

4.2 Soil Quality

According to mean annual precipitation as mentioned by FAO (1998), the study area was found to fall in to three zones, included zone 2, zone 3 and zone 4. One way ANOVA tests were applied to determine significant differences among these zones in soil characteristics.

4.2.1 Soil physical properties

4.2.1.1 Clay fraction

The results in Fig. 4.35 and Table (4.15) show a significant difference ($P< 0.05$) in clay% among arid zones in study area. The clay ratio in zone 4 and zone3 was 38.6 and 37.5% respectively, with a significant difference with zone2, which reached 20.7%.

These differences might be due to the difference in the intensity of the weathering processes in arid zones, which inturn resulted from a difference in precipitation that might have led to the breakage of primary minerals and soil coarse fractions into secondary clay minerals, which is considered as one of the end products of the weathering process. However, over a period of time and with the continuation of pedogenic process weathering change the soil texture (Foth, 1990; Brady and Weil, 2002).

Figure 4.35 Soil quality according to the clay% in the study area

4.2.1.2 Bulk density

Fig. (4.36) and Table (4.15) shows insignificant differences (*P*= 0.163) among arid zones in the means of bulk density. Zone 4 outperformed zone 3, which surpassed zone 2 with values of (1.66, 1.62 and 1.59) Mg m^{-3} respectively. These results which consistent with those of (Moges *et al.*, 2013), could be due to the differences in the amount of precipitation and temperature in the study area which inturn could affect the type and intensity of plant cover and may reflect organic matter concentration and the corresponding decrease in bulk density.

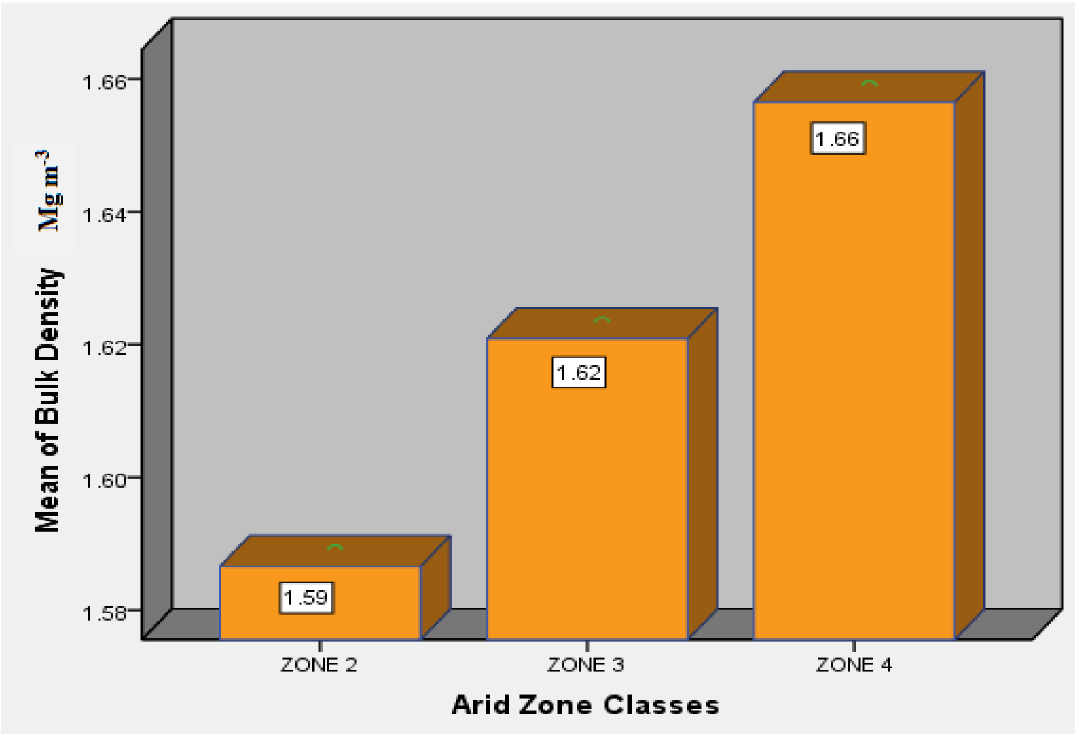

Figure 4.36 Soil quality according to the bulk density in the study area

Table 4.15 Summary of the one-way ANOVA table for two physical characteristics of arid zones in the study area.

Sources of variations	Df	Clay%		Bulk density	
		MS	*P*	MS	*P*
Between groups	2	3225.29	0.000	0.030	0.163
Within groups	86	105.61		0.016	
Total	88				

4.2.2 Soil chemical properties

4.2.2.1 Soil organic carbon content

Fig. (4.37) and table 4.16 show significant differences in organic carbon content among arid zones where the rate of organic carbon were 0.90%, 0.81% and 0.46% for zone 3, zone 4 and zone 2 respectively whereas zone3 outperforming zone4 and both outperforming zone2 significantly.

These differences could be due to variation in temperatures in the study area in general, which could lead to variation in organic matter oxidation, The results also show that zone 2 contains less organic carbon compared to zone 3 and zone 4, this might be due to the high mean annual temperature in zone 2. The other reason could be due to the differences in the mean annual precipitation among the zones area, where higher precipitation occurred in zone 4 because of this a variation in plant coverage occurs that encourage higher accumulation of organic matter through higher inputs from root biomass and above ground biomass (Yimer *et al*., 2007; Wakene and Heluf, 2003)

The lower SOC content under zone 2 compared to zone 3 and zone 4 could be due to the reduced amount of organic material being returned to the soil system and higher rate of oxidation of soil organic matter as a result of continuous high temperature and low precipitation (Moges *et al*., 2013).

The results also showed that the SOC content was lower that took place in zone 4 compared to zone 3. This could be due to the cultivation which promoted SOC loss due to the exposure of micro aggregate organic carbon to microbial decomposition by the changing moisture and temperature regimes (Reicosky and Forcella, 1998).

Figure 4.37 Soil quality according to the mean organic carbon content in the study area

4.2.2.2 Soil pH

Fig. 4.38 shows that the overall pH of the studied soils was found to be moderately alkaline. Soil pH did not show any significant variation across zone 2 (7.89), zone 3 (7.86), and zone 4 (7.77) (*P*>0.05, Table 4.16). However, there were differences in values, where in zone2 was higher than zone3, which inturn surpassed zone4.

The lower soil pH in zone4 might be due to the presence of relatively higher organic carbon compared to zone2 and zone3.

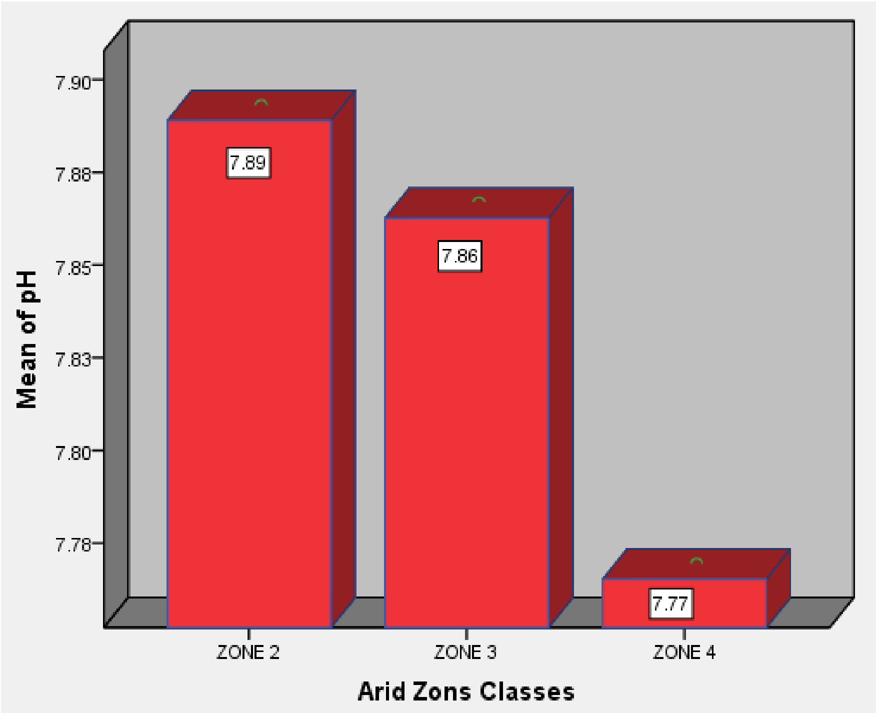

Figure 4.38 Soil quality according to the soil pH in the study area

4.2.2.3 Soil salinity EC

The results in Table 4.16 showed insignificant differences among zones of the study area (P>0.05). Soils of all zones were not saline where values were 0.48, 0.38 and 0.20 dS m^{-1} for zone 2, zone 3 and zone 4 respectively (Fig. 4.39). This could be due to that the ground water was deep, soils were well drained and the nature of parent materials which has protected the soil from being saline.

Figure 4.39 Soil quality according to the soil salinity in the study area

4.2.2.4 Available potassium

There was no significant differences among zones in available potassium content (*P*>0.05, Table 4.16), but they varied in values (Fig. 4.40). Available K was higher in zone 4 (0.614 $cmol_c\ kg^{-1}$) followed by zone 3 (0.564 $cmol_c\ kg^{-1}$) and zone 2 (0.451 $cmol_c\ kg^{-1}$).

The observed higher concentration of available K^+ in zone 4 and relatively in zone 3 was attributed to the application of fertilizers and the intensive land use for agriculture compared to zone 2. The lower available K^+ in the zone 2 could be probably due to soil degradation and losses by leaching as in this zone the open grassland and grazing land were denuded of vegetation cover.

Figure 4.40 Soil quality according to the available potassium in the study area

4.2.2.5 Available nitrogen

Available nitrogen was the highest in zone 3 (2.334 g kg^{-1}) which in significantly followed by zone 4 (2.222 g kg^{-1}) and both significantly varied with zone 2 (1.567 g kg^{-1}) (Fig. 4.41).

However, the distribution of available nitrogen content (Fig. 4.41) followed a similar pattern as organic carbon distribution (Fig. 4.37) and was as the following zone 3 > zone 4 > zone 2. Such results is expected since most of the soil nitrogen is bound to organic carbon which has been originated from plant and root biomass as well as residues being returned to the soil system. This is in agreement with the results of (Khresat *et al*., 2008) who reported a significant difference in total nitrogen between the forest and cultivated land due to the differences in soil organic matter content, intensities of erosion, and cultivation.

According to (Landon, 1991), the principal cause for lower contents of available nitrogen comes from biomass removal by organic matter oxidation and insufficient replenishment through manure or fertilizers.

Figure 4.41 Soil quality according to the available nitrogen in the study area

4.2.2.6 Available phosphorus

The available P did not show any significant difference in arid zone classes (*P*>0.05, Table 4.16), with values of (4.32, 5.65 and 4.78) µg kg^{-1} for zone4, zone3 and zone 2 respectively. The low amount of available phosphorus in all zones might be due the fixation of P by calcium carbonate which included a large part of the soil components (Sheraz *et al.*, 2012).

Figure 4.42 Soil quality according to the available phosphorus in the study area

4.2.2.7 Exchangeable calcium Ca^{2+}

Concentration of exchangeable calcium did not show any significant variation across all zone classes (*P*>0.05, Table 4.16).

As observed in Fig. 4.43, zone 4 had the highest value followed by zone 3 and zone 2 by value of (22.5, 22.3 and 18.2) $cmol_c\ kg^{-1}$ respectively.

Figure 4.43 Soil quality according to the exchangeable calcium in the study area

4.2.2.8 Exchangeable magnesium Mg^{2+}

Concentration of exchangeable Mg^{2+} showed a significant variation in arid zone classes (*P*<0.05, Table 4.16). The values of exchangeable Mg^{2+} were (5.1, 7.4 and 1.6) $cmol_c\ kg^{-1}$ for zone 4, zone 3 and zone 2 respectively.

Zone 2 gave the lowest value and varied with zone 3 and zone 4 significantly, zone 3 exceeded zone 4 insignificantly (Fig. 4.44).

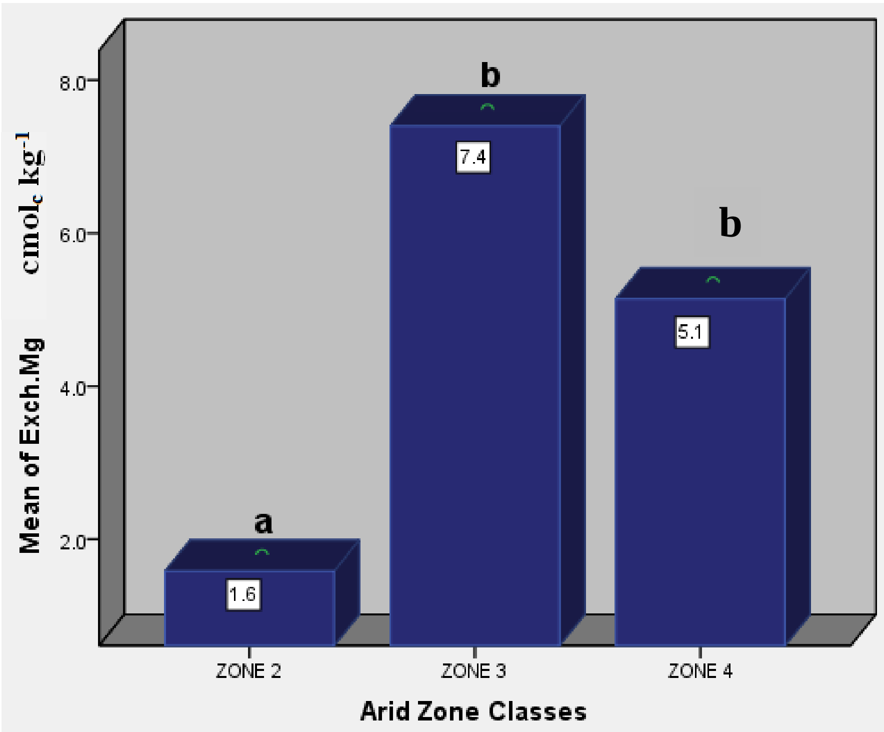

Figure 4.44 Soil quality according to the exchangeable magnesium in the study area

4.2.2.9 Exchangeable sodium Na^+

Concentration of exchangeable Na^+ showed a significant variation with arid zone classes (*P*<0.05, Table 4.16). The values of exchangeable Na^+ were (0.2152, 0.2211 and 0.1926) $cmol_c\ kg^{-1}$ for zone 4, zone 3 and zone 2 respectively. Zone 3 varied insignificantly with zone 4 and both varied significantly with zone 2 (Fig.4.45). The concentration of exchangeable Na^+ was the smallest component in the exchange complexes. Since the concentration of exchangeable Na^+ did not exceed **1** $cmol_c\ kg^{-1}$ (Landon, 1991), accordingly results the study area was not regarded as sodic soil (Fig. 4.45).

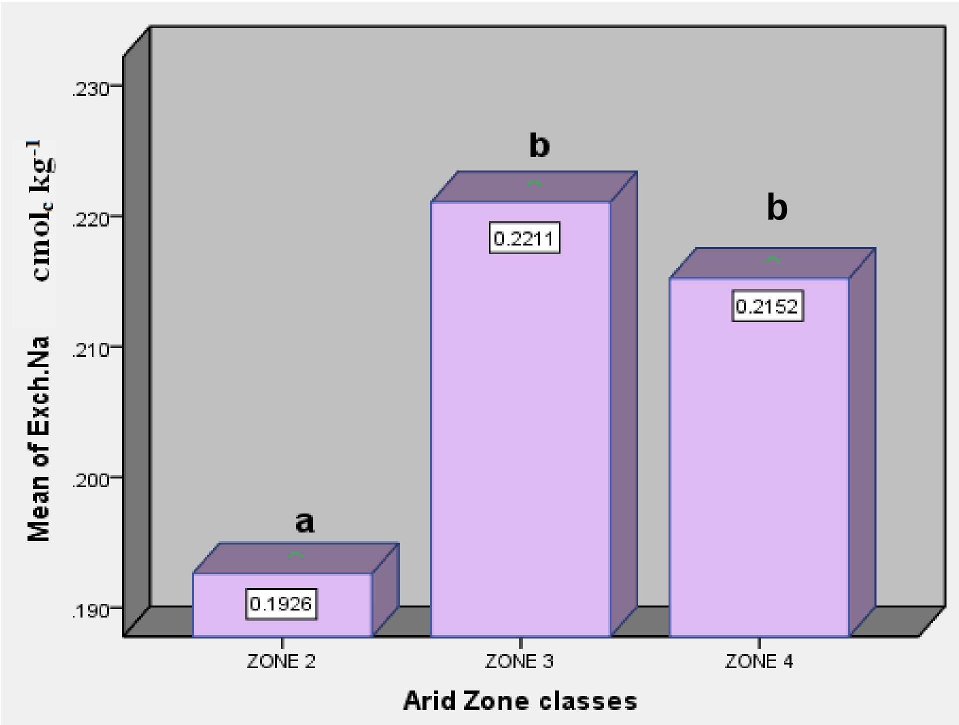

Figure 4.45 Soil quality according to the exchangeable sodium in the study area

4.2.2.10 Exchangeable potassium K^+

The results showed significant differences among zone classes of the study area (*P*<0.05, Table 4.16). The K^+ values of zones were (0.40, 0.53 and 0.59) $cmol_c\ kg^{-1}$ for zone 2, zone 3 and zone 4 respectively (Fig. 4.46).

Zone 2 varied significantly with zone 4, but there was insignificant variation between zone 2 and zone 3, also between zone 3 and zone 4. The pattern distribution of exchangeable Potassium K^+ was similar to the available K^+ (Fig. 4.40), this could be because the exchangeable K^+ is consider as part of the available K^+.

The observed highest concentration of exchangeable K^+ in zone4 and relatively zone3 could be due to the application of fertilizers and the intensive land use for agriculture compared to zone2. The lower exchangeable K^+ in zone2 could be probably due to soil degradation and losses by leaching where the open grassland and grazing land were denuded of vegetation cover.

Figure 4.46 Soil quality according to the exchangeable potassium in the study area

4.2.2.11 Cation exchange capacity CEC

Cation exchange capacity significantly varied in arid zone classes in the study area (*P*>0.05, Table 4.16).

Zone 2 was varied significantly with zone 3, and both varied significantly with zone 4.

The highest value was obtained from zone 4 (26.1 $cmol_c$ kg^{-1}) followed by zone 3 (21.9 $cmol_c$ kg^{-1}) and zone2 (15.7 $cmol_c$ kg^{-1}) (Fig. 4.47) indicating the lower fertility status of the soil in zone 2 due to low content of organic carbon (Fig. 4.37) and clay percent (Fig. 4.35), which are known to play an important role in soil fertility through their exchange sites.

Figure 4.47 Soil quality according to the cation exchange capacity in the study area

4.2.2.12 Carbonate mineral $CaCO_3$

The results in Table (4.16) shows significant variations in carbonate minerals content among arid zone classes in the study area ($P < 0.05$). As shown in Fig. 4.48, the lowest value was obtained in zone 4 (171.0 g kg^{-1}) followed by zone 3 (204.0 g kg^{-1}) and then zone 2 (316.4 g kg^{-1}).These differences could be attributed to the mean annual precipitation in the study area which affects the variation in weathering processes and therefore releasing of Ca^{2+}, which leads to access of calcification and decalcification processes more strongly in zone 3 and zone 2.

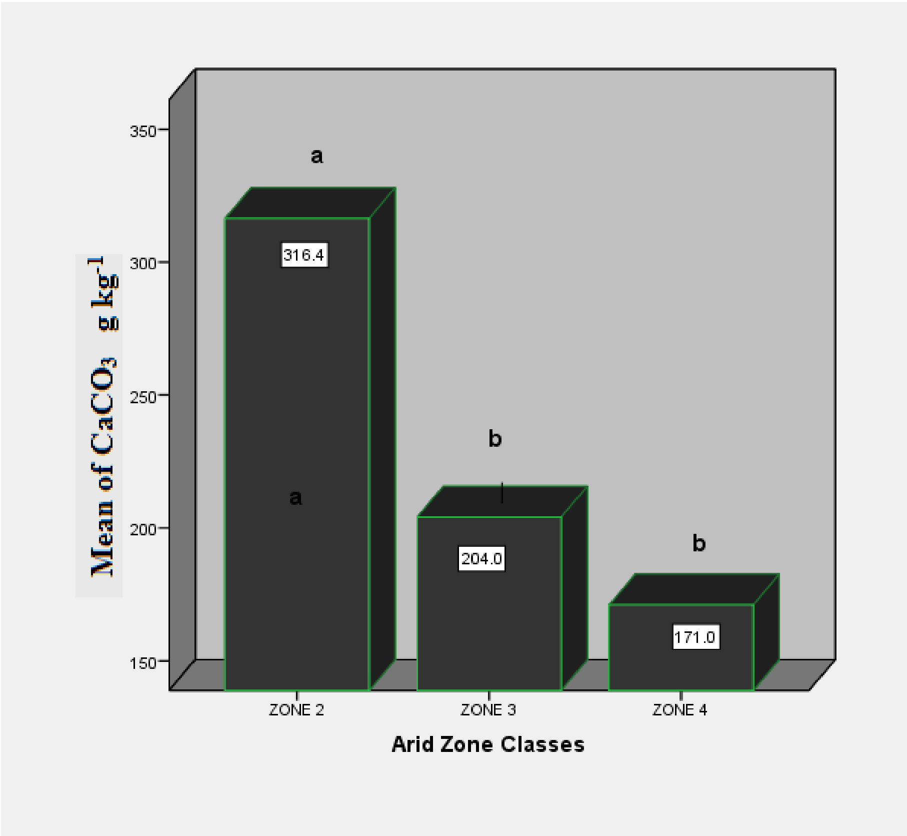

Figure 4.48 Soil quality according to the calcium carbonate in the study area

Table 4.16 Summary of the one-way ANOVA table for some chemical characteristics of arid zones in the study area.

Sources of variations	Df	SOC g kg^{-1}		pH		EC dS m^{-1}		Ava. N g kg^{-1}		Ava. P μg kg^{-1}		Ava. K^{+} cmol$_c$ .g^{-1}		Exch. Cations cmol$_c$ kg^{-1}								CEC cmol$_c$ kg^{-1}		Total carbonate g kg^{-1}	
														Ca^{++}		Mg^{++}		Na^{+}		K^{+}					
		MS	*P*	MS	*P*	MS	*P*	MS	*P*	MS	*P*	MS	*P*	MS	*P*	MS	P	MS	P	MS	P	MS	P	MS	P
Between Groups	2	1.855	0.000	0.091	0.139	0.480	0.172	5.871	0.001	11.964	0.205	0.198	0.078	182.269	0.444	308.139	0.000	0.008	0.033	0.258	0.028	1136.691	0.000	94769.902	0.000
Within Groups	86																								
Total	88																								

4.3 Land Suitability

The study area was evaluated to see its suitability for wheat crops by adopting the method proposed and revised by Sys *et al*. (1993) (Table 3.13 and 3.14) and it is presented in Table (4.17).

4.3.1 Soil depth

The results in Table (4.17) showed that the soils of study area were deep and there were no depth limitations in the form of hardpan or gypsum accumulation. A 100 rate value was given to the higher pedons, but pedons in Sangasar, Chwarqurna, Darbandikhan, Altuncopri and Gwer were given a rate of 90, and the Dukan, Shwan, Lailan and Qushtapa pedons were given a rate of 94-95 due to the presence of petrocalcic horizons or approximately to the parent material presence on the highlands.

4.3.2 Soil texture

The data in Table (4.17) shows that soil texture rate values ranged between 98 and 100 for the study area, except for Said Sadiq, Mawat, Qaradakh, Darbandikhan, Khanaqin, Kalar and Makhmoor pedons which were rated 85.

Soil texture is considered one of the important characteristics affecting other soil characteristics such as water holding capacity, cation exchange capacity and porosity. The results showed that soil textures for the soil of the study area were mostly loamy to medium coarse. Therefore, it can be concluded that soil texture was not a limited factor for growing of wheat crop.

4.3.3 $CaCO_3$

The results in Table (4.17) showed that the estimated value of calcium carbonate was between 40-100, indicating that calcium carbonates, could be considered as a limitation factor for wheat growing in most parts of study area, because the percentage of calcium carbonates were high and this has affected some of the other physical and chemical properties of the soils, and caused a limitation for wheat cultivation in most of the pedons.

4.3.4 Soil salinity (EC)

It is seen from Table (4.17) that the value of soil salinity was more than 90 for most soil. Although salinity is one of the major problems in arid and semi-arid region, but the result show that there are simple limitations, because the salinity of the soils were not high, this might due to the nature of the topography of the area, good drainage and the type of the parent material, which leads to the non-salinity of the soil.

4.3.5 Soil reaction (pH)

The results in Table (4.17) show that the rate value of soil reaction was between (63 -100). It could be concluded that most sites of the study area had a moderate and simple limiting factor, except for some sites that had no limitation where the value of soil pH was 100. Soil reaction did not reach alkalinity which could affect wheat growth.

4.3.6 Cation exchange capacity (CEC)

It is clear from Table (4.17) that the value of this characteristic may have a different effect on soil suitability. In some locations, there was 60 indicating a specific effect for soil suitability, but in other locations are 100, indicating there is no limitation. CEC is an important characteristic for plant growth, because it reflects soil susceptibility to nutrient retention and its availability, thus it is very relevant to the amount of clay and soil organic matter, which differ among the sites of the study area.

4.3.7 Organic carbon (O.C)

Table (4.17) shows that the values of this rating differed among the study sites, where in most sites it was 100 indicating no specific limitation but decreased in others to reach 73. This variation is due to differences in the annual temperature and precipitation, which affect the density and quality of vegetation and the decomposition of organic carbon.

4.3.8 Flooding

This characteristic did not have any effect on soil suitability for wheat growing throughout the study area. Where the value is 100 for all sites (Table 4.17). There is no hazard of flooding due to lack of rainfall on one hand and the topographical status of the study area in another.

4.3.9 Soil drainage

Soil drainage did not play an important role in soil suitability. The Table (4.17) showed that the rate value is between (95 -100). This is due to the state of natural drainage characteristic of the study area due to the physiography of the area as well as the depth of the ground water.

4.3.10 Base saturation

Table (4.17) showed that the rate value is 100 for all sites of the study area. This indicates that there is no effect on soil suitability according to this.

4.3.11 Total cations (∑cations)

Table (4.17) shows that the rate value is 100 for all sites of the study area. This indicates that there is no effect on soil suitability.

4.3.12 Classification of land suitability of study area for wheat crop growth

The results in Fig. (4.49) show the dominance of three classes that represent the land suitability of the study area for this crop, including S2 (moderately suitable), S3 (marginally suitable) and N1 (currently unsuitable).

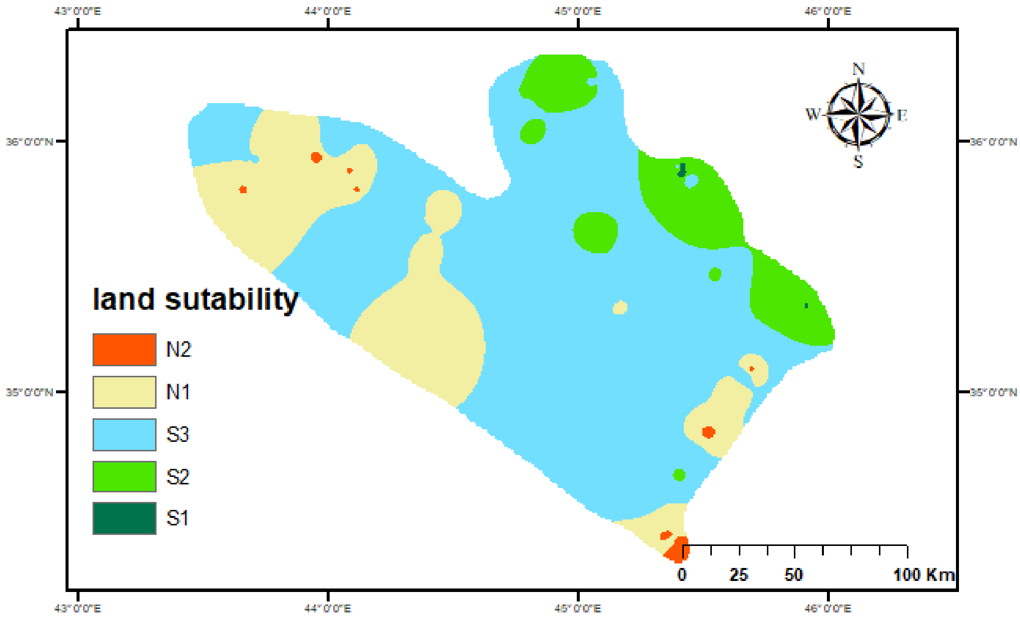

Figure 4.49 Classes of land suitability in the study area

4.3.12.1 Class S2 (moderately suitable)

The land of this class is to be moderate suitable for wheat growth, with an area of 260800 ha, which about 10% of the study area.

Land has limitations that are moderately severe for the continued application of a particular use, limitations will reduce productivity. The most important limiting affecting of this class is soil alkalinity and high calcium carbonates.

4.3.12.2 Class S3 (marginally suitable)

There are restrictions on land, which is largely for the continued application of a particular use and will therefore reduce productivity or benefits, or increase the inputs required, so that this expenditure is only marginally justified, and the land is characterized by marginal. Land area is of 1834200 ha, which occupied 69.35% of the study area.

The limitations of this class are due to soil texture, rock fragments, absence of organic matter and soil alkalinity.

4.3.12.3 Class N1 (currently unsuitable)

Land having limitations that can be overcome in a timely manner cannot be corrected with current knowledge at the current acceptable cost; Limits are so severe that they prevent the successful sustainable use of the land in the prescribed manner.

This area is covered 539100 ha, which occupies 20.37% of the study area.

The most important limiting of this class is related to the amount of rain falling, the proportion of $CaCO_3$, soil alkalinity and a decrease in the CEC value.

In addition, to mentioned, there are very few S1 (high suitable) and N2 (permanently not suitable) areas that do not exceed 1% of the study area.

Table 4.17 Classes of land suitability in the study area

	Location	Latitude	Longitude	Flooding	Drainage	Texture	Coarse Fragment vol%	Depth (cm)	$CaCO_3$%	CEC cmolc kg^{-1}	BS%	∑cations cmolc kg^{-1}	pH	O.C%	EC (dS m^{-1})	L.S.1	L.S.C
Said Sadiq	Said Sadiq1	35º 23′ 52″	45º 45′ 61″	100	95	85	100	100	97	100	100	100	94	100	95.2	69.9	S3
	Said Sadiq2	35º 21′ 10″	45º 53′ 39″	100	95	98	100	100	100	94.8	100	100	87	100	95.3	72.7	S2
	Said Sadiq3	35º 20′ 50″	45º 54′ 47″	100	95	100	100	100	100	100	100	100	90	100	95.4	81.5	S1
	Said Sadiq4	35º 25′ 17″	45º 36′ 27″	100	100	98	50	100	100	100	100	100	87	100	95.2	40.4	S3
	Said Sadiq5	35º 27′ 51″	45º 32′ 78″	100	100	98	100	100	92	94.9	100	100	91	100	95.3	74	S2
	Said Sadiq6	35º 22′ 58″	45º 47′ 15″	100	100	98	100	100	96	100	100	100	93	92	95.2	76.2	S2
Chamchamal	Chamchamal1	35º 33′ 41″	44º 51′ 23″	100	95	98	100	100	94	91.9	100	100	90	73	95.2	49.8	S3
	Chamchamal2	35º 30′ 84″	44º 45′ 23″	100	95	100	72.5	100	91	93.5	100	100	90	100	95.3	50.1	S3
	Chamchamal3	35º 30′ 23″	44º 41′ 84″	100	95	100	72.5	100	91	93.5	100	100	90	100	95.3	50.1	S3
	Chamchamal4	35º 28′ 99″	44º 36′ 41″	100	95	100	72.5	100	91	93.5	100	100	90	100	95.3	50.1	S3
	Chamchamal5	35º 28′ 08″	44º 32′ 98″	100	95	100	72.5	100	91	93.5	100	100	90	100	95.3	50.1	S3
Bazian	Bazian1	35º 38′ 33″	45º 03′ 22″	100	100	100	100	100	92	100	100	100	88	100	95.3	76.7	S2
	Bazian2	35º 36′ 45″	45º 07′ 03″	100	100	100	100	100	87	94.8	100	100	93	94	95.2	68.2	S2
	Bazian3	35º 35′ 48″	45º 11′ 19″	100	100	100	72.5	100	89	100	100	100	88	100	95.2	54.2	S3
	Bazian4	35º 35′ 04″	45º 09′ 77″	100	100	98	72.5	100	100	100	100	100	86	100	95.3	58.3	S3
Mawat	Mawat1	35º 53′ 70″	45º 23′ 68″	100	100	85	90	100	96	88.8	100	100	91	92	91.2	49.6	S3
	Mawat2	35º 53′ 77″	45º 24′ 52″	100	100	100	100	100	97	100	100	100	100	100	95.3	92	S1
	Mawat3	35º 52′ 33″	45º 24′ 64″	100	100	100	100	100	97	100	100	100	100	100	95.3	92	S1
	Mawat4	35º 50′ 59″	45º 26′ 52″	100	100	85	100	100	97	86.7	100	100	90	73	95.3	44.5	S3
	Mawat5	35º 45′ 41″	45º 28′ 34″	100	100	97	92	100	96	100	100	100	97	100	95.2	79.2	S3
	Mawat6	35º 42′ 77″	45º 31′ 58″	100	100	97	92	100	96	100	100	100	97	100	95.2	79.2	S3

Table (4.17) continued…

Location		Latitude	Longitude	Flooding	Drainage	Texture	Coarse Fragment vol%	Depth (cm)	$CaCO_3$%	CEC cmolc kg^{-1}	BS%	∑cations cmolc kg^{-1}	pH	O.C%	EC (dS m^{-1})	L.S.1	L.S.C
Qaradakh	Qaradakh1	35º 18′ 53″	45º 21′ 48″	100	95	85	90	100	95	92.7	100	100	100	100	95.4	61	**S3**
	Qaradakh2	35º 18′ 61″	45º 21′ 47″	100	95	98	72.5	100	97	94.7	100	100	90	100	95.3	52.9	**S3**
	Qaradakh3	35º 21′ 32″	45º 24′ 36″	100	95	98	72.5	100	97	94.7	100	100	90	100	95.3	52.9	**S3**
	Qaradakh4	35º 20′ 40″	45º 16′ 88″	100	95	98	72.5	100	97	94.7	100	100	90	100	95.3	52.9	**S3**
	Qaradakh5	35º 19′ 22″	45º 15′ 76″	100	95	100	72.5	100	99	100	100	100	88	100	95.2	56.7	**S3**
	Qaradakh6	35º 18′ 72″	45º 14′ 99″	100	95	85	72.5	100	96	100	100	100	86	100	95.2	45.7	**S3**
Sangaw	Sangaw2	35º 16′ 51″	45º 09′ 75″	100	100	100	72.5	100	90	89.4	100	100	90	100	95.2	50.1	**S3**
	Sangaw3	35º 19′ 66″	45º 09′ 68″	100	100	98	40	100	86	87.8	100	100	91	100	95.7	25.7	**S3**
	Sangaw4	35º 22′ 21″	45º 07′ 25″	100	100	100	100	100	72	87.8	100	100	92	100	95.3	55.2	**S3**
	Sangaw5	35º 24′ 51″	45º 04′ 16″	100	100	100	100	100	72	87.8	100	100	92	100	95.3	55.2	**S3**
Sangasar	Sangasar1	36º 14′ 26″	45º 02′ 47″	100	95	98	90	90	95	100	100	100	87	100	95.2	59.8	**S3**
	Sangasar2	36º 12′ 99″	44º 58′ 73″	100	95	100	90	90	97	100	100	100	92	100	95.3	64.9	**S2**
	Sangasar3	36º 13′ 43″	44º 54′ 44″	100	95	98	100	90	87	100	100	100	92	100	95.2	63.9	**S2**
Chwarqurna	Chwarqurna1	36º 12′ 84″	44º 52′ 32″	100	95	98	100	90	99	100	100	100	90	100	95.2	70.7	**S2**
	Chwarqurna2	36º 12′ 00″	44º 46′ 75″	100	95	98	100	90	85	100	100	100	91	100	95.3	62.2	**S2**
	Chwarqurna3	36º 10′ 17″	44º 42′ 62″	100	95	100	72.5	90	100	100	100	100	87	100	95.2	51.2	**S3**
Dukan	Dukan1	36º 07′ 26″	44º 43′ 93″	100	100	100	90	95	80	90.7	100	100	90	100	95.3	52.9	**S3**
	Dukan2	36º 04′ 91″	44º 45′ 47″	100	100	100	100	95	73	93.6	100	100	89	100	95.3	55.4	**S3**
	Dukan3	36º 02′ 44″	44º 48′ 34″	100	100	98	90	95	98	100	100	100	86	100	95.3	67.6	**S2**
	Dukan4	35º 53′ 15″	44º 59′ 02″	100	100	100	72.5	95	89	94.8	100	100	86	100	95.3	47.6	**S3**

Table (4.17) continued…

Location		Latitude	Longitude	Flooding	Drainage	Texture	Coarse Fragment vol%	Depth (cm)	$CaCO_3$%	CEC cmolc kg^{-1}	BS%	∑cations cmolc kg^{-1}	pH	O.C%	EC (dS m^{-1})	L.S.1	L.S.C
	Dukan5	35º 50′ 74″	45º 03′ 89″	100	100	98	90	95	82	93.5	100	100	94	73	95.2	41.6	**S3**
Darbandikhan	Darbandikhan2	35º 05′ 21″	45º 40′ 96″	100	95	85	40	90	99	88.7	100	100	88	100	95.2	21.2	**N2**
	Darbandikhan3	35º 03′ 73″	45º 39′ 82″	100	95	98	100	90	88	85	100	100	87	100	95.3	51.6	**S3**
	Darbandikhan4	35º 00′ 23″	45º 36′ 76″	100	95	98	72.5	90	71	91.2	100	100	92	93	95.3	32.1	**N1**
Kalar	Kalar1	34º 50′ 16″	45º 31′ 21″	100	95	95	40	100	74	92.6	100	100	90	100	95.2	21.2	**N2**
	Kalar2	34º 45′ 34″	45º 27′ 69″	100	95	85	100	100	100	86.7	100	100	91	73	95.2	43.7	**S3**
	Kalar3	34º 39′ 68″	45º 23′ 90″	100	95	95	100	100	91	89.6	100	100	91	100	95.3	63.5	**S2**
	Kalar4	34º 34′ 17″	45º 16′ 06″	100	95	98	100	100	98	85	100	100	100	73	97.2	54.3	**S3**
Khanaqin	Khanaqin1	34º 25′ 44″	45º 20′ 60″	100	95	100	40	100	76	86.6	100	100	88	100	95.5	21	**N2**
	Khanaqin2	34º 21′ 39″	45º 23′ 92″	100	95	85	40	100	78	60	100	100	90	88	95.2	11.4	**N2**
	Khanaqin3	34º 23′ 52″	45º 21′ 43″	100	95	85	100	100	78	60	100	100	90	88	95.2	28.5	**N1**
	Khanaqin4	34º 26′ 83″	45º 19′ 78″	100	95	85	100	100	78	60	100	100	86	94	96.8	29.3	**N1**
Shwan	Shwan1	35º 33′ 20″	44º 22′ 76″	100	85	98	72.5	95	94	85	100	100	90	86	95.5	34	**N1**
	Shwan2	35º 33′ 53″	44º 22′ 52″	100	95	95	72.5	95	94	85	100	100	88	86	95.2	35.5	**N1**
	Shwan3	35º 36′ 50″	44º 22′ 59″	100	95	98	72.5	95	87	87	100	100	91	94	95.3	39.3	**N1**
	Shwan4	35º 40′ 87″	44º 24′ 24″	100	95	98	72.5	95	87	87	100	100	91	94	95.3	39.3	**N1**
	Shwan5	35º 43′ 42″	44º 27′ 25″	100	85	98	72.5	95	65	85	100	100	90	94	95.5	25.5	**N1**

Table (4.17) continued…

Location		Latitude	Longitude	Flooding	Drainage	Texture	Coarse Fragment vol%	Depth (cm)	$CaCO_3$%	CEC cmolc kg^{-1}	BS%	∑cations cmolc kg^{-1}	pH	O.C%	EC ($dS\ m^{-1}$)	L.S.1	L.S.C
Altunkopri	Altunkopri1	35º 38′ 54″	44º 17′ 72″	100	95	98	100	90	92	86.7	100	100	90	100	95.3	57.4	**S3**
	Altunkopri2	35º 40′ 98″	44º 14′ 66″	100	95	98	100	90	92	86.7	100	100	90	100	95.3	57.4	**S3**
	Altunkopri3	35º 42′ 61″	44º 12′ 54″	100	95	98	100	90	92	86.7	100	100	90	100	95.3	57.4	**S3**
	Altunkopri4	35º 41′ 77″	44º 11′ 70″	100	85	100	100	90	94	89.1	100	100	90	100	95.3	54.9	**S3**
	Altunkopri5	35º 44′ 66″	44º 10′ 15″	100	85	100	100	90	94	89.1	100	100	90	100	95.3	54.9	**S3**
Daquq	Daquq1	35º 15′ 82″	44º 21′ 82″	100	85	98	100	100	67	85	100	100	92	73	95.3	30	**N1**
	Daquq2	35º 12′ 47″	44º 23′ 60″	100	85	98	100	100	67	85	100	100	92	73	95.3	30	**N1**
	Daquq3	35º 10′ 18″	44º 25′ 12″	100	85	98	100	100	67	85	100	100	92	73	95.3	30	**N1**
	Daquq4	35º 10′ 06″	44º 25′ 43″	100	85	98	100	100	88	60	100	100	98	73	97.6	30.6	**N1**
Lailan	Lailan1	35º 18′ 93″	44º 28′ 45″	100	85	100	100	94	71	85	100	100	100	73	97.6	34	**N1**
	Lailan2	35º 18′ 58″	44º 24′ 70″	100	85	100	100	94	71	85	100	100	100	73	97.6	34	**N1**
	Lailan3	35º 19′ 01″	44º 26′ 97″	100	85	100	100	94	61	88.7	100	100	69	100	95.4	28.2	**N1**
	Lailan4	35º 21′ 39″	44º 28′ 00″	100	85	100	100	94	71	85	100	100	100	73	97.6	34	**N1**
Qushtapa	Qushtapa1	35º 48′ 35″	44º 06′ 56″	100	85	98	100	94	81	85	100	100	63	73	95.2	23.2	**N2**
	Qushtapa2	35º 53′ 10″	44º 04′ 70″	100	85	100	100	94	81	85	100	100	63	73	95.2	23.7	**N2**
	Qushtapa3	35º 59′ 16″	44º 02′ 02″	100	95	100	100	94	80	85.1	100	100	92	87	95.3	46.5	**S3**
	Qushtapa4	35º 58′ 46″	43º 59′ 74″	100	95	100	100	94	80	85.1	100	100	92	87	95.3	46.5	**S3**
	Qushtapa5	35º 55′ 88″	43º 56′ 78″	100	95	100	100	94	40	88.2	100	100	89	73	95.7	19.6	**N2**

Table (4.17) continued…

Location		Latitude	Longitude	Flooding	Drainage	Texture	Coarse Fragment vol%	Depth (cm)	$CaCO_3$%	CEC cmolc kg^{-1}	BS%	∑cations cmolc kg^{-1}	pH	O.C%	EC (dS m^{-1})	L.S.1	L.S.C
Makhmoor	Makhmoor1	35º 52′ 63″	43º 46′ 40″	100	85	100	100	100	88	60	100	100	93	73	95.2	28.8	**N1**
	Makhmoor2	35º 50′ 40″	43º 42′ 76″	100	85	100	100	100	88	60	100	100	93	73	95.2	28.8	**N1**
	Makhmoor3	35º 48′ 33″	43º 39′ 23″	100	95	98	100	100	44	85	100	100	92	73	95.3	21.9	**N2**
	Makhmoor4	35º 47′ 75″	43º 36′ 08″	100	95	85	90	100	95	85.1	100	100	99	73	97.4	41.1	**S3**
	Makhmoor5	35º 47′ 62″	43º 35′ 85″	100	95	85	90	100	68	85	100	100	87	86	95.9	30.2	**N1**
Gwer	Gwer1	35º 55′ 38″	43º 42′ 30″	100	95	98	100	90	78	85.4	100	100	90	85	95.3	40.8	**S3**
	Gwer2	35º 56′ 31″	43º 39′ 66″	100	95	98	100	90	78	85.4	100	100	90	85	95.3	40.8	**S3**
	Gwer3	35º 57′ 99″	43º 35′ 71″	100	95	98	100	90	76	87.6	100	100	89	94	95.4	44.6	**S3**
	Gwer4	36º 01′ 59″	43º 31′ 57″	100	95	98	90	90	85	86.9	100	100	99	92	98.1	50.1	**S3**
	Gwer5	36º 02′ 02″	43º 29′ 65″	100	85	100	90	90	90	85	100	100	91	92	95.5	42	**S3**

L.S.1: Land suitability index **L.S.C: Land suitability classes**

4.4 Land capability classification

The results in (Fig.4.50) and (Table 4.18) showed that the Land Capability Classes were divided into five main categories including Class II, Class III, Class IV, Class V and Class VI as follows:

Table 4.18 Land Capability Classes for study area

Class	Area (ha)	% to total area
II	42500	1.6
III	77000	2.9
IV	2090600	79
V	420000	15.9
VI	15500	0.6
Total	2645600	100

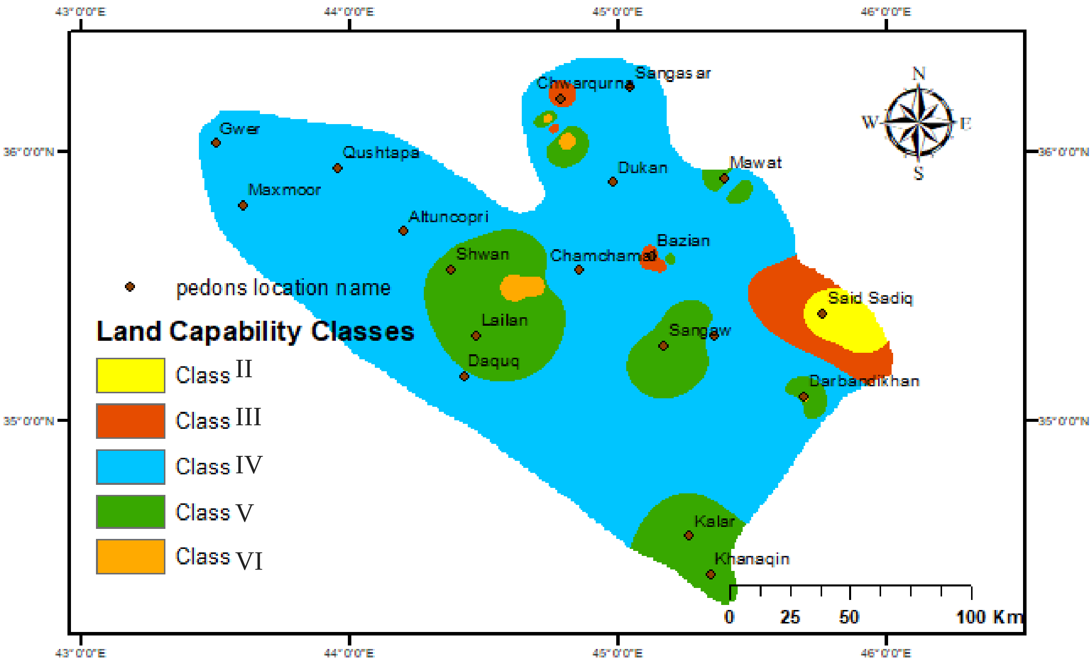

Figure 4.50 Land Capability Classes for the study area

Class II:

Capability sub-class of this class included IIe1 and IIs1e1

This class covers 42500 ha, which accounts for 1.6%. It is distributed mainly in the eastern of the study area which mainly included Said Sadiq or Sharazoor plain.

This capability class is characterized by gentle slope (1-5 %) and very deep soil with none to moderate erosion. Clayey to silty clay soil texture increases the available water capacity. Nearly level land coupled with fined texture soil inhibits the free drainage of excess water. Thus this class is characterized by moderately well drainage soil and moderately rapid permeability. This class is very suitable for agriculture with very minor or no physical limitations.

Class III:

Capability sub-class of this class included IIIe, IIIs, IIIew, IIIc, and IIIce.

The land capability class III covers an area of 77000 ha, which accounts for 2.9% of the total study area (Table 4.18) distributed in eastern, southeastern and isolated parts in the middle and north of the study area which mainly included Said Sadiq, Bazian, Chwarqurna and Sangasar plain (Fig. 4.50).

This capability class is characterized by moderate slope (5-7 %). Soils are deep to very deep with none to moderate soil erosion. This capability class is characterized by moderately well to imperfect soil drainage.

Class IV:

Covering an area of 2090600 ha (79%) (Table 4.18). This indicates that this class occupies more than two-thirds of study area.

Capability sub-class of this class included IVe, IVs, IVes, and IVc.

This capability class has some inherent physical limitations, moderate soil depth in more parts and moderate available water capacity, slight to moderate soil erosion resulting from moderate sloping.

Class V:

This capability class is sporadically distributed all over the study area ,where it was found in Daquq, Lailan, Shwan, Khanaqin, Kalar, Sangaw, and Darbandikhan (Fig. 4.50), covering 420000 ha, which account for 15.9% of total area (Table 4.18).

This capability class is characterized by physical limitations with undulating land surface, sloping land and moderate to severe soil erosion. Productive potential of this class is very low so it is marginally suitable for agriculture.

Class VI:

This class is distributed in a narrow range in the center and north covering an area of 15500 ha (only 0.6% from the study area).

This land class is characterized by very severe physical characteristics where the slope is severe in some parts leading to severe erosion and shallow soil, relative high temperature and low precipitation so it is hardly or non suitable for agricultural, but it is suitable for pasture.

4.5 Soil Classification of the Study Area

Based on data obtained in the field and laboratory analysis, soils were classified according to the Soil Taxonomy USDA, (2014) to level subgroup as follows:-

Table 4.19 Soil classification for study area

Pedon No.	Pedon location	Latitude	Longitude	Soil classification
1	Said Sadiq	35º 23′ 52″	45º 45′ 61″	Vertic Calcixerolls
2	Chamchamal	35º 33′ 41″	44º 51′ 23″	Vertic Haplocalcids
3	Bazian	35º 36′ 55″	45º 06′ 98″	Vertic Haploxerolls
4	Mawat	35º 53′ 70″	45º 23′ 68″	Typic Haploxerolls
5	Qaradakh 1	35º 18′ 53″	45º 21′ 48″	Aridic Calcixerolls
6	Qaradakh 2	35º 18′ 61″	45º 21′ 47″	Aridic Calcixerolls
7	Sangaw	35º 16′ 51″	45º 09′ 75″	Vertic Calcixerepts
8	Sangasar	36º 14′ 26″	45º 02′ 47″	Chromic Calcixererts
9	Chwarqurna	36º 12′ 00″	44º 46′ 75″	Vertic Calcixerepts
10	Dukan	35º 53′ 15″	44º 59′ 02″	Lithic Calcixerepts
11	Darbandikhan	35º 05′ 21″	45º 40′ 96″	Fluventic Haploxerepts
12	Kalar	34º 34′ 17″	45º 16′ 06″	Xeric Haplocalcids
13	Khanaqin	34º 25′ 44″	45º 20′ 60″	Xeric Haplocalcids
14	Shwan	35º 33′ 53″	44º 22′ 52″	Lithic Xeric Haplocalcids
15	Altuncopri	35º 41′ 77″	44º 11′ 70″	Xeric Haplocalcids
16	Daquq	35º 10′ 06″	44º 25′ 43″	Xeric Haplocalcids
17	Lailan	35º 19′ 10″	44º 27′ 83″	Xeric Haplocalcids
18	Qushtapa	35º 55′ 88″	43º 56′ 78″	Xeric haplocalcids
19	Makhmoor	35º 47′ 75″	43º 36′ 08″	Xeric Haplogypsids
20	Gwer	36º 02′ 02″	43º 29′ 65″	Xeric Haplocalcids

CHAPTER FIVE

CONCLUSIONS

By completing the study, the following points were concluded:-

1. Large areas of Iraq and the Iraqi Kurdistan region are exposed to soil degradation, especially desertification hazard.
2. Geographic information system GIS is an effective technique for determining desertification and mapping, which helps to explain and predict many causes of desertification.
3. Soil quality varies according to changes in climatic conditions in study area.
4. Soils differed in their suitability for wheat cultivation according to the variation in soil conditions.
5. Land capability classification of the study area varied, this is mainly due to the mean annual precipitation and temperature.

CHAPTER SIX

RECOMENDATIONS

After achievement of the study, we recommend the following:

1. Conduct studies in other parts of Iraq and Iraqi Kurdistan Region to assess soil degradation and desertification.
2. Mapping an environmental map of the dry lands in Iraq and Iraqi Kurdistan Region requires the diagnosis of degraded land, especially, deserted, eroded and saline affected soils.
3. Conduct studies on narrowband areas to determine soil quality especially for the fertile and productive soils.
4. Carry out studies to compare other methods for estimating desertification and to find special models for conditions of Iraq.
5. Conduct studies to assess soil quality quantitatively, by means of special equation related to this.

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APPENDICES

Appendix (1) Some soil physical properties of the pedons

Locations	Latitude	Longitude	Horizon	Depth (cm)	Pw%	Pb (Mg m^{-3})	ρs (Mg m^{-3})	Sand (g kg^{-1})	Silt (g kg^{-1})	Clay (g kg^{-1})	Texture Class
Said Sadiq	35° 23′ 52″	45° 45′ 61″	Ap	0-6	8.7	1.9	2.6	32.4	161.7	805.9	C
			B1	6-37	6.5	1.8	2.4	24.3	378.3	597.4	C
			B2	37-60	8.5	1.7	2.6	31.9	361.8	606.3	C
			Ck	+60	8.0	1.9	2.7	48.0	458.8	493.2	SiC
Chamchamal	35° 33′ 41″	44° 51′ 23″	Ap	0-17	2.3	1.8	2.6	50.4	495.7	453.9	SiC
			Ck1	17-40	4.9	1.9	2.8	51.0	458.0	491.0	SiC
			Ck2	40-133	4.9	1.9	2.8	59.6	447.9	492.5	SiC
			Ck3	+133	4.9	1.8	2.7	43.1	577.3	379.6	SiCL
Bazian	35° 36′ 55″	45° 06′ 98″	Ap	0-8	5.4	1.7	2.5	43.8	528.3	427.9	SiC
			Bk	8-40	6.5	1.9	2.7	48.3	480.5	471.2	SiC
			Ck1	40-81	6.5	1.9	2.6	45.6	464.2	490.2	SiC
			Ck2	+81	7.4	1.9	2.5	46.9	486.4	466.7	SiC
Mawat	35° 53′ 70″	45° 23′ 68″	Ap	0-22	3.5	1.6	2.4	297.2	426.8	276	CL
			Bk	22-53	3.5	1.9	2.7	557.7	347.6	94.7	SL
			Ck1	53-99	3.8	2.1	2.7	307.1	489.5	203.4	SL
			Ck2	99-129	4.3	1.9	2.7	535.6	349.1	115.3	SiL
			Ck3	+129	4.6	2.0	2.7	267.0	513.6	219.4	CL
Qaradakh 1	35° 18′ 53″	45° 21′ 48″	Ap	0-42	5.1	1.5	2.5	283.4	368.6	348.0	SiCL
			B	42-94	4.3	1.5	2.5	187.5	501.3	311.2	SiC
			C	+94	6.4	1.6	2.6	121.1	467.4	411.5	CL
Qaradakh 2	35° 18′ 61″	45° 21′ 47″	A	0-32	4.5	1.7	2.6	275.0	390.3	334.7	L
			B	32-78	3.7	1.7	2.6	445.1	337.1	217.8	SiCL
			Ck1	78-131	5.1	1.6	2.7	69.5	642.3	288.2	SiCL
			Ck2	+131	5.7	1.8	2.6	47.3	621.5	331.2	SiC
Sangaw	35° 16′ 51″	45° 09′ 75″	Ap	0-36	3.3	1.8	2.6	150.5	420.9	428.6	C
			Bw	36-87	3.1	1.8	2.7	60.2	356.0	583.8	SiCL
			Ck	+87	4.1	1.9	2.7	31.8	614.2	354.0	SiC
Sangasar	36° 14′ 26″	45° 02′ 47″	Ap	0-9	6.4	1.5	2.6	59.9	413.4	526.7	C
			Bss1	9-35	6.4	1.6	2.6	39.6	391.1	569.3	C
			Bss2	35-49	7.1	1.6	2.6	75.0	381.2	543.8	C
			Bss3	+49	6.7	1.7	2.7	106.5	393.3	500.2	C

Appendix (1) continued…

Locations	Latitude	Longitude	Horizon	Depth (cm)	Pw%	ρb	ρs	Particle size distribution (g kg^{-1})			Texture Class
						Mg m^{-3}		Sand	Silt	Clay	
Chwarqurna	36º 12′ 00″	44º 46′ 75″	Ap	0-7	5.6	2.0	2.5	86.0	291.2	622.8	C
			Bw	7-46	7.3	2.0	2.7	69.2	400.0	530.8	C
			Ck	+46	10	1.8	2.7	84.7	417.5	497.8	SiC
Dukan	35º 53′ 15″	44º 59′ 02″	Ap	0-19	5.3	1.5	2.4	191.4	373.8	434.8	C
			Bw	19-33	4.9	1.6	2.5	187.6	366.6	445.8	SiC
			Ck1	33-63	4.8	1.7	2.7	94.1	456.4	449.5	SiC
			Ck2	+63	4.5	1.7	2.7	52.5	504.9	442.6	SiC
Darbandikhan	35º 05′ 21″	45º 40′ 96″	A	0-30	2.9	1.6	2.3	306.6	468.2	225.2	L
			Bw	30-46	3.2	1.5	2.6	182.5	561.4	256.1	SiL
			C	+46	3.1	1.6	2.6	219.1	578.7	202.2	SiL
Kalar	34º 34′ 17″	45º 16′ 06″	A	0-16	2.5	1.7	2.4	244.8	553.2	202.0	SiL
			C1	16-61	3.8	1.6	2.7	213.7	515.9	270.4	SiCL
			C2	61-81	4.2	1.6	2.7	13.5	656.3	330.2	SiCL
			C3	81-108	5.2	1.6	2.7	61.6	617.0	321.4	SiCL
			C4	+108	5.2	1.6	2.7	45.2	605.1	349.7	L
Khanaqin	34º 25′ 44″	45º 20′ 60″	A	0-30	2.0	1.7	2.6	451.6	388.7	159.7	L
			Ck1	30-90	3.4	1.7	2.7	201.9	499.1	299.0	CL
			Ck2	90-143	5.7	1.5	2.6	208.9	737.7	53.4	SiL
			Ck3	+143	4.9	1.6	2.6	98.5	841.7	59.8	Si
Shwan	35º 33′ 53″	44º 22′ 52″	Ap	0-29	2.4	1.5	2.5	508.9	342.7	148.4	L
			C1	29-68	3.2	1.5	2.6	319.0	445.8	235.2	L
			C2	+68	4.1	1.8	2.6	116.9	628.1	255.0	SiL
Altuncopri	35º 41′ 77″	44º 11′ 70″	Ap	0-20	3.8	1.4	2.6	94.4	528.1	377.5	SiCL
			C1	20-37	4.3	1.6	2.7	61.6	546.6	391.8	SiCL
			C2	37-50	4	1.6	2.6	65.0	555.9	379.1	SiCL
			C3	+50	5.4	1.7	2.1	57.0	549.4	393.6	SiCL
Daquq	35º 10′ 06″	44º 25′ 43″	A	0-29	7.9	1.5	3.0	365.0	569.1	65.9	SiL
			Ck1	29-87	8.3	1.4	2.9	256.1	677.9	66.0	SiL
			Ck2	+87	8.5	1.4	2.9	124.3	797.6	78.1	SiL

Appendix (1) continued...

Locations	Latitude	Longitude	Horizon	Depth (cm)	Pw%	ρb	ρs	Particle size distribution (g kg^{-1})			Texture Class
						Mg m^{-3}		Sand	Silt	Clay	
Lailan	35º 19′ 10″	44º 27′ 83″	A	0-7	5.4	1.5	2.5	45.4	602.8	351.8	SiCL
			Ck1	7-23	5.2	1.6	2.6	56.1	580.9	363.0	SiCL
			Ck2	23-60	6.2	1.7	2.7	39.7	555.6	404.7	SiC
			Ck3	+60	5.2	1.8	2.7	53.3	535.3	411.4	SiC
Qushtapa	35º 55′ 88″	43º 56′ 78″	A	0-14	4.8	1.4	2.5	47.5	628.2	324.3	SiCL
			Ck1	14-58	4.5	1.7	2.6	21.5	603.7	374.8	SiCL
			Ck2	+58	6.1	1.8	2.6	11.6	596.4	392.0	SiCL
Makhmoor	35º 47′ 75″	43º 36′ 08″	A	0-23	4.2	1.6	2.6	427.9	398.0	174.1	L
			Ck1	23-79	3	1.5	2.5	503.1	322.8	174.1	L
			Ck2	79-110	1.4	1.4	2.5	417.6	506.7	75.7	SiL
			Ck3	+110	2.3	1.6	2.7	689.1	181.2	129.7	SL
Gwer	36º 02′ 02″	43º 29′ 65″	A	0-14	2.4	1.6	2.7	522.6	291.4	186.0	SL
			Ck	14-48	2.4	1.8	2.7	427.6	364.6	207.8	L

ρs: Particle density

ρb: Bulk density

Appendix (2) Some soil chemical properties of the pedons

Locations	Horizon	Depth (cm)	pH	EC dS m^{-1}	Soluble Cations $cmol_c\ kg^{-1}$				CEC $cmol_c\ kg^{-1}$	BS%	O.M	$CaCO_3$
					Na^+	K^+	Ca^{2+}	Mg^{2+}			g kg^{-1}	
Said Sadiq	Ap	0-6	7.67	0.27	0.056	0.041	0.703	0.027	31.77	98.964	17.667	59.806
	B1	6-37	7.82	0.15	0.047	0.024	0.425	0.104	30.84	98.966	15.301	74.522
	B2	37-60	7.90	0.13	0.065	0.012	0.289	0.136				
	Ck	+60	8.00	0.14	0.075	0.012	0.223	0.142				
Chamchamal	Ap	0-17	7.90	0.15	0.056	0.012	0.322	0.114	28.10	98.777	5.545	103.08
	Ck1	17-40	8.04	0.13	0.084	0.012	0.245	0.136	25.45	96.902	4.196	296.87
	Ck2	40-133	8.21	0.17	0.14	0.012	0.223	0.180				
	Ck3	+133	8.41	0.11	0.112	0.012	0.213	0.174				
Bazian	Ap	0-8	7.63	0.21	0.047	0.030	0.523	0.136	23.80	97.65	19.787	301.65
	Bk	8-40	7.79	0.15	0.047	0.018	0.322	0.174	28.43	98.234	15.381	283.09
	Ck1	40-81	7.98	0.14	0.084	0.012	0.223	0.164				
	Ck2	+81	8.21	0.15	0.168	0.012	0.213	0.169				
Mawat	Ap	0-22	7.68	0.12	0.037	0.030	0.458	0.109	26.82	98.015	18.144	262.17
	Bk	22-53	8.14	0.1	0.037	0.018	0.180	0.087	24.40	98.902	0.520	283.13
	Ck1	53-99	8.25	0.09	0.037	0.012	0.142	0.136				
	Ck2	99-129	8.39	0.09	0.037	0.012	0.164	0.114				
	Ck3	+129	8.41	0.08	0.028	0.012	0.136	0.153				
Qaradakh	Ap	0-42	7.76	0.16	0.019	0.024	0.24	0.136	30.06	98.053	21.044	189.75
	B	42-94	8.09	0.13	0.047	0.012	0.322	0.049	27.02	98.209	4.595	212.91
	C	+94	8.12	0.12	0.037	0.012	0.273	0.055				

Appendix (2) continued…

Locations	Horizon	Depth (cm)	pH	EC dS m^{-1}	Soluble Cations $cmol_c\ kg^{-1}$				CEC $cmol_c\ kg^{-1}$	BS%	O.M	$CaCO_3$
					Na^+	K^+	Ca^{2+}	Mg^{2+}			g kg^{-1}	
Qaradakh 2	A	0-32	7.65	0.19	0.056	0.018	0.447	0.082	30.82	98.088	18.389	223.61
	B	32-78	7.76	0.12	0.047	0.006	0.240	0.104	25.99	98.032	5.451	247.13
	Ck1	78-131	8.17	0.11	0.056	0.006	0.218	0.082				
	Ck2	+131	8.23	0.10	0.047	0.006	0.223	0.065				
Sangaw	Ap	0-36	7.89	0.16	0.047	0.030	0.425	0.049	24.37	96.953	12.167	144.93
	Bw	36-87	8.32	0.11	0.056	0.012	0.234	0.071	23.39	97.464	5.765	305.25
	Ck	+87	8.40	0.11	0.093	0.012	0.240	0.060				
Sangasar	Ap	0-9	7.93	0.14	0.028	0.024	0.343	0.060	32.61	98.757	13.045	358.06
	Bss1	9-35	8.00	0.12	0.028	0.018	0.273	0.093	33.66	98.734	11.991	239.88
	Bss2	35-49	8.15	0.13	0.037	0.012	0.251	0.093				
	Bss3	+49	8.16	0.14	0.056	0.018	0.305	0.055				
Chwarqurna	Ap	0-7	7.51	0.48	0.065	0.101	1.008	0.452	31.84	99.014	20.264	516.23
	Bw	7-46	7.81	0.21	0.075	0.012	0.371	0.256	32.75	97.730	11.089	308.54
	Ck	+46	8.08	0.21	0.075	0.006	0.338	0.294				
Dukan	Ap	0-19	7.5	0.27	0.047	0.035	0.687	0.191	29.05	98.689	27.852	224.92
	Bw	19-33	7.89	0.16	0.047	0.018	0.322	0.164	26.536	98.025	9.532	152.39
	Ck1	33-63	7.98	0.16	0.075	0.018	0.316	0.185				
	Ck2	+63	8.22	0.13	0.065	0.012	0.202	0.191				

Appendix (2) continued…

Locations	Horizon	Depth (cm)	pH	EC dS m^{-1}	Soluble Cations $cmol_c$ kg^{-1}				CEC $cmol_c$ kg^{-1}	BS%	O.M	$CaCO_3$
					Na^+	K^+	Ca^{2+}	Mg^{2+}			g kg^{-1}	
Darbandikhan	A	0-30	7.75	0.16	0.047	0.018	0.343	0.18	23.69	97.597	16.649	47.02
	Bw	30-46	8.03	0.12	0.047	0.012	0.256	0.114	23.18	97.204	4.497	25.93
	C	+46	8.16	0.11	0.065	0.012	0.245	0.016				
Kalar	A	0-16	7.80	0.24	0.103	0.030	0.534	0.093	19.53	93.388	7.213	194.48
	C1	16-61	7.55	2.11	0.373	0.024	6.524	1.128	21.64	96.245	2.299	132.16
	C2	61-81	7.81	0.81	0.355	0.012	0.883	1.150				
	C3	81-108	8.03	0.57	0.383	0.012	0.872	0.349				
	C4	+108	8.01	0.43	0.401	0.012	0.534	0.273				
Khanaqin	A	0-30	7.92	0.18	0.084	0.047	0.382	0.055	17.32	95.645	7.763	253.00
	Ck1	30-90	7.92	0.43	0.159	0.024	0.856	0.278	20.39	95.808	0.892	293.87
	Ck2	90-143	7.52	1.97	0.075	0.035	7.788	0.234				
	Ck3	+143	7.46	2.12	0.056	0.041	7.892	0.158				
Shwan	Ap	0-29	7.75	0.19	0.084	0.030	0.332	0.294	17.51	93.852	7.173	275.81
	C1	29-68	7.74	0.42	0.205	0.018	0.649	0.458	17.98	95.261	1.862	74.46
	C2	+68	8.12	0.44	0.327	0.018	0.441	0.561				
Altunkopr	Ap	0-20	7.63	0.27	0.065	0.089	0.561	0.131	23.93	96.857	21.085	74.48
	C1	20-37	7.94	0.15	0.037	0.047	0.305	0.087	22.92	94.469	9.415	117.79
	C2	37-50	8.08	0.12	0.037	0.035	0.256	0.071				
	C3	+50	8.29	0.11	0.028	0.030	0.202	0.093				

Appendix (2) continued…

Locations	Horizon	Depth (cm)	pH	EC dS m^{-1}	Soluble Cations cmol$_c$ kg^{-1}				CEC cmol$_c$ kg^{-1}	BS%	O.M	$CaCO_3$
					Na^+	K^+	Ca^{2+}	Mg^{2+}			g kg^{-1}	
Daquq	A	0-29	7.36	2.08	0.047	0.053	7.832	0.011	14.53	99.871	1.707	272.17
	Ck1	29-87	7.50	2.14	0.112	0.035	7.706	0.283	14.76	99.643	0.152	200.10
	Ck2	+87	7.57	2.30	0.140	0.024	7.069	1.030				
Lailan	A	0-7	8.00	0.27	0.065	0.077	0.332	0.087	25.51	94.345	16.102	335.77
	Ck1	7-23	7.97	0.21	0.056	0.024	0.256	0.185	25.22	95.495	6.805	246.29
	Ck2	23-60	8.03	0.28	0.159	0.018	0.431	0.169	24.33	96.903	3.413	329.31
	Ck3	+60	8.14	0.27	0.187	0.018	0.332	0.240				
Qushtapa	A	0-14	7.86	0.34	0.112	0.024	0.332	0.114	24.05	96.885	10.961	195.34
	Ck1	14-58	7.73	0.68	0.336	0.018	1.003	0.485	25.10	96.491	6.461	209.18
	Ck2	+58	8.08	0.38	0.159	0.018	0.545	0.267				
Makhmoor	A	0-23	7.53	1.94	0.149	0.035	6.229	0.398	20.07	95.166	4.591	208.96
	Ck1	23-79	7.46	2.10	0.261	0.024	5.396	1.504	18.70	94.837	2.875	159.45
	Ck2	79-110	7.46	2.47	0.289	0.030	7.140	0.965				
	Ck3	+110	7.50	2.08	0.252	0.024	5.385	1.275				
Gwer	A	0-14	8.28	0.24	0.149	0.083	0.332	0.093	16.66	92.222	1.676	288.84
	Ck	14-48	8.15	0.23	0.149	0.035	0.398	0.027	17.14	94.063	1.152	226.78

Appendix (3) Some soil physical properties of the surface soils for study area

Locations		Latitude N	Longitude E	Particle size distribution ($g\ kg^{-1}$)			Texture Class	Particle den. $Mg\ m^{-3}$	Bulk density $Mg\ m^{-3}$
				Sand	Silt	Clay			
Said Sadiq	Said Sadiq1	35º 23′ 52″	45º 45′ 61″	38.8	345.2	616.0	C	2.596	1.706
	Said Sadiq2	35º 21′ 10″	45º 53′ 39″	141.3	440.2	418.5	SiC	2.482	1.433
	Said Sadiq3	35º 20′ 50″	45º 54′ 47″	64.9	547.7	387.4	SiCL	2.362	1.726
	Said Sadiq4	35º 25′ 17″	45º 36′ 27″	26.9	448.3	524.8	SiC	2.540	1.731
	Said Sadiq5	35º 27′ 51″	45º 32′ 78″	57.3	430.8	511.9	SiC	2.639	1.717
	Said Sadiq6	35º 22′ 58″	45º 47′ 15″	25.0	432.2	542.8	SiC	2.612	1.463
Chamchamal	Chamchamal1	35º 33′ 41″	44º 51′ 23″	10.6	522.5	466.9	SiC	2.768	1.754
	Chamchamal2	35º 30′ 84″	44º 45′ 23″	33.8	601.7	364.5	SiCL	2.507	1.542
	Chamchamal3	35º 30′ 23″	44º 41′ 84″	33.8	601.7	364.5	SiCL	2.507	1.542
	Chamchamal4	35º 28′ 99″	44º 36′ 41″	33.8	601.7	364.5	SiCL	2.507	1.542
	Chamchamal5	35º 28′ 08″	44º 32′ 98″	33.8	601.7	364.5	SiCL	2.507	1.542
Bazian	Bazian1	35º 38′ 33″	45º 03′ 22″	136.3	390.6	473.1	SiCL	2.456	1.712
	Bazian2	35º 36′ 45″	45º 07′ 03″	38.9	611.1	350.0	SiCL	2.629	1.834
	Bazian3	35º 35′ 48″	45º 11′ 19″	94.3	565.5	340.2	SiCL	2.550	1.68
	Bazian4	35º 35′ 04″	45º 09′ 77″	41.6	469.5	488.9	SiC	2.571	1.681
Mawat	Mawat1	35º 53′ 70″	45º 23′ 68″	455.6	382.1	162.3	L	2.607	1.775
	Mawat2	35º 53′ 77″	45º 24′ 52″	89.9	399.8	510.3	C	2.566	1.607
	Mawat3	35º 52′ 33″	45º 24′ 64″	89.9	399.8	510.3	C	2.566	1.607
	Mawat4	35º 50′ 59″	45º 26′ 52″	464.1	451.9	84.0	L	2.505	1.532
	Mawat5	35º 45′ 41″	45º 28′ 34″	91.7	665.7	242.6	SiL	2.635	1.665
	Mawat6	35º 42′ 77″	45º 31′ 58″	91.7	665.7	242.6	SiL	2.635	1.665
Qaradakh	Qaradakh1	35º 18′ 53″	45º 21′ 48″	280.0	474.0	246.0	L	2.392	1.609
	Qaradakh2	35º 18′ 61″	45º 21′ 47″	80.7	476.8	442.5	SiC	2.363	1.573
	Qaradakh3	35º 21′ 32″	45º 24′ 36″	80.7	476.8	442.5	SiC	2.363	1.573
	Qaradakh4	35º 20′ 40″	45º 16′ 88″	80.7	476.8	442.5	SiC	2.363	1.573
	Qaradakh5	35º 19′ 22″	45º 15′ 76″	283.5	368.5	348.5	SiCL	2.525	1.539
	Qaradakh6	35º 18′ 72″	45º 14′ 99″	275.0	390.3	334.7	L	2.570	1.712
Sangaw	Sangaw1	35º 17′ 66″	45º 14′ 71″	232.1	546.1	221.8	SiL	2.508	1.499
	Sangaw2	35º 16′ 51″	45º 09′ 75″	150.5	420.9	428.6	C	2.558	1.753
	Sangaw3	35º 19′ 66″	45º 09′ 68″	251.8	609.1	139.1	SiL	2.534	1.695
	Sangaw4	35º 22′ 21″	45º 07′ 25″	130.1	594.5	275.4	SiCL	2.542	1.556
	Sangaw5	35º 24′ 51″	45º 04′ 16″	130.1	594.5	275.4	SiCL	2.542	1.556

Appendix (3) continued…

Locations		Latitude N	Longitude E	Particle size distribution (g kg^{-1})			Texture Class	Particle den. Mg m^{-3}	Bulk density Mg m^{-3}
				Sand	Silt	Clay			
Sangasar	Sangasar1	36º 14′ 26″	45º 02′ 47″	44.5	422.9	532.6	SiC	2.532	1.606
	Sangasar2	36º 12′ 99″	44º 58′ 73″	83.3	614.8	301.9	SiCL	2.440	1.757
	Sangasar3	36º 13′ 43″	44º 54′ 44″	46.1	435.6	518.3	SiC	2.580	1.848
Chwarqurna	Chwarqurna1	36º 12′ 84″	44º 52′ 32″	73.7	416.9	509.4	SiC	2.572	1.646
	Chwarqurna2	36º 12′ 00″	44º 46′ 75″	67.9	430.1	502	SiC	2.569	1.942
	Chwarqurna3	36º 10′ 17″	44º 42′ 62″	42.4	601.7	355.9	SiCL	2.601	1.800
Dukan	Dukan1	36º 07′ 26″	44º 43′ 93″	239.4	245.4	515.2	C	2.483	1.592
	Dukan2	36º 04′ 91″	44º 45′ 47″	160.8	490.9	348.3	SiCL	2.522	1.610
	Dukan3	36º 02′ 44″	44º 48′ 34″	116.2	451.1	432.7	SiC	2.374	1.328
	Dukan4	35º 53′ 15″	44º 59′ 02″	162.8	481.4	355.8	SiCL	2.448	1.434
	Dukan5	35º 50′ 74″	45º 03′ 89″	104.0	461.5	434.5	SiC	2.646	1.747
Darbandikhan	Darbandikhan1	35º 07′ 31″	45º 41′ 47″	95.8	388.9	515.3	C	2.314	1.803
	Darbandikhan2	35º 05′ 21″	45º 40′ 96″	306.6	468.2	225.2	L	2.337	1.582
	Darbandikhan3	35º 03′ 73″	45º 39′ 82″	246.6	526.9	226.5	SiL	2.563	1.624
	Darbandikhan4	35º 00′ 23″	45º 36′ 76″	200.9	541.8	257.3	SiL	2.356	1.697
Kalar	Kalar1	34º 50′ 16″	45º 31′ 21″	240.5	433.6	325.9	CL	2.602	1.676
	Kalar2	34º 45′ 34″	45º 27′ 69″	313.0	486.8	200.2	L	2.573	1.649
	Kalar3	34º 39′ 68″	45º 23′ 90″	223.0	483.5	293.5	CL	2.411	1.471
	Kalar4	34º 34′ 17″	45º 16′ 06″	241.0	535.5	223.3	SiL	2.570	1.587
Khanaqin	Khanaqin1	34º 25′ 44″	45º 20′ 60″	92.7	602.5	304.8	SiCL	2.475	1.451
	Khanaqin2	34º 21′ 39″	45º 23′ 92″	451.6	388.7	159.7	L	2.589	1.667
	Khanaqin3	34º 23′ 52″	45º 21′ 43″	451.6	451.6	159.7	L	2.589	1.667
	Khanaqin4	34º 26′ 83″	45º 19′ 78″	281.4	490.8	227.8	L	2.522	1.793
	Khanaqin5	34º 34′ 88″	45º 20′ 49″	241.4	548.1	210.5	SiL	2.574	1.753
Shwan	Shwan1	35º 33′ 20″	44º 22′ 76″	243.1	649.3	107.6	SiL	2.596	1.514
	Shwan2	35º 33′ 53″	44º 22′ 52″	508.9	342.7	148.4	L	2.509	1.506
	Shwan3	35º 36′ 50″	44º 22′ 59″	229.1	617.4	153.5	SiL	2.529	1.681
	Shwan4	35º 40′ 87″	44º 24′ 24″	229.1	617.4	153.5	SiL	2.529	1.681
	Shwan5	35º 43′ 42″	44º 27′ 25″	243.1	649.3	107.6	SiL	2.596	1.514
Altunkopri	Altunkopri1	35º 38′ 54″	44º 17′ 72″	140.1	671.9	188	SiL	2.457	1.529
	Altunkopri2	35º 40′ 98″	44º 14′ 66″	140.1	671.9	188	SiL	2.457	1.529
	Altunkopri3	35º 42′ 61″	44º 12′ 54″	140.1	671.9	188	SiL	2.457	1.529
	Altunkopri4	35º 41′ 77″	44º 11′ 70″	72.0	564.8	363.2	SiCL	2.533	1.510
	Altunkopri5	35º 44′ 66″	44º 10′ 15″	72.0	564.8	363.2	SiCL	2.533	1.510

Appendix (3) continued…

Locations		Latitude N	Longitude E	Particle size distribution (g kg^{-1})			Texture Class	Particle den. Mg m^{-3}	Bulk density Mg m^{-3}
				Sand	Silt	Clay			
Daquq	Daquq1	35º 15′ 82″	44º 21′ 82″	216.1	603.4	180.5	SiL	2.533	1.388
	Daquq2	35º 12′ 47″	44º 23′ 60″	216.1	603.4	180.5	SiL	2.533	1.388
	Daquq3	35º 10′ 18″	44º 25′ 12″	216.1	603.4	180.5	SiL	2.533	1.388
	Daquq4	35º 10′ 06″	44º 25′ 43″	365.0	569.1	65.9	SiL	2.973	1.524
Lailan	Lailan1	35º 18′ 93″	44º 28′ 45″	75.1	596.5	328.4	SiCL	2.646	1.492
	Lailan2	35º 18′ 58″	44º 24′ 70″	75.1	596.5	328.4	SiCL	2.646	1.492
	Lailan3	35º 19′ 01″	44º 26′ 97″	95.4	534.6	370.0	SiCL	2.487	1.720
	Lailan4	35º 21′ 39″	44º 28′ 00″	75.1	596.5	328.4	SiCL	2.646	1.492
Qushtapa	Qushtapa1	35º 48′ 35″	44º 06′ 56″	231.2	526.4	242.4	SiL	2.643	1.961
	Qushtapa2	35º 53′ 10″	44º 04′ 70″	231.2	526.4	242.4	SiL	2.643	1.961
	Qushtapa3	35º 59′ 16″	44º 02′ 02″	160.8	559.0	280.2	SiCL	2.561	1.512
	Qushtapa4	35º 58′ 46″	43º 59′ 74″	160.8	559.0	280.2	SiCL	2.561	1.512
	Qushtapa5	35º 55′ 88″	43º 56′ 78″	32.9	608.0	359.1	SiCL	2.513	1.629
Makhmoor	Makhmoor1	35º 52′ 63″	43º 46′ 40″	646.0	234.3	119.7	SL	2.637	1.556
	Makhmoor2	35º 50′ 40″	43º 42′ 76″	646.0	234.3	119.7	SL	2.637	1.556
	Makhmoor3	35º 48′ 33″	43º 39′ 23″	219.7	533.7	246.6	SiL	2.580	1.640
	Makhmoor4	35º 47′ 75″	43º 36′ 08″	427.9	398.0	174.1	L	2.580	1.564
	Makhmoor5	35º 47′ 62″	43º 35′ 85″	300.0	493.0	207.0	L	2.603	1.695
Gwer	Gwer1	35º 55′ 38″	43º 42′ 30″	114.8	644.6	240.6	SiL	2.448	1.450
	Gwer2	35º 56′ 31″	43º 39′ 66″	114.8	644.6	240.6	SiL	2.448	1.450
	Gwer3	35º 57′ 99″	43º 35′ 71″	112.7	679.2	208.1	SiL	2.451	1.510
	Gwer4	36º 01′ 59″	43º 31′ 57″	121.6	797.1	81.3	SiL	2.778	1.687
	Gwer5	36º 02′ 02″	43º 29′ 65″	551.2	308.3	140.5	SL	2.539	1.705

Appendix (4) Some soil chemical properties of the surface soils for study area

Locations		Latitude N	Longitude E	pH	EC dS m^{-1}	Soluble Cations $cmol_c\ kg^{-1}$				Exchangeable Cations $cmol_c\ kg^{-1}$				CEC $cmol_c\ kg^{-1}$	BS%	O.M	$CaCO_3$	Ava.N	Ava.P µg g^{-1} soil	Ava.K^+ $cmol_c\ kg^{-1}$
						Na^+	K^+	Ca^{2+}	Mg^{2+}	Na^+	K^+	Ca^{2+}	Mg^{2+}			g kg^{-1}				
Said Sadiq	Said Sadiq1	35º 23′ 52″	45º 45′ 61″	8.15	0.15	0.037	0.024	0.365	0.011	0.269	0.728	19.970	10.96	26.277	98.09	10.989	80.475	1.015	11.15	0.752
	Said Sadiq2	35º 21′ 10″	45º 53′ 39″	7.69	0.24	0.047	0.106	0.409	0.087	0.277	2.280	20.795	1.930	23.827	97.23	21.059	26.354	2.162	9.267	2.386
	Said Sadiq3	35º 20′ 50″	45º 54′ 47″	7.90	0.30	0.149	0.030	0.572	0.087	0.304	0.723	19.054	10.63	25.606	97.41	11.277	21.226	3.148	7.574	0.753
	Said Sadiq4	35º 25′ 17″	45º 36′ 27″	7.70	0.18	0.037	0.030	0.398	0.076	0.252	0.843	13.486	15.06	25.086	96.60	6.3323	21.18	1.897	2.314	0.873
	Said Sadiq5	35º 27′ 51″	45º 32′ 78″	7.98	0.21	0.075	0.024	0.382	0.153	0.269	0.570	15.160	12.66	23.921	96.19	4.8345	265.14	2.459	10.26	0.594
	Said Sadiq6	35º 22′ 58″	45º 47′ 15″	8.09	0.16	0.047	0.024	0.409	0.022	0.223	0.774	18.834	12.06	26.016	98.08	9.0886	58.559	1.312	6.429	0.798
Chamchamal	Chamchamal1	35º 33′ 41″	44º 51′ 23″	8.23	0.16	0.056	0.018	0.224	0.196	0.253	0.424	13.678	9.907	21.491	97.08	2.6965	287.77	1.753	4.538	0.442
	Chamchamal2	35º 30′ 84″	44º 45′ 23″	7.88	0.20	0.037	0.024	0.442	0.049	0.231	0.468	11.972	12.36	22.802	97.57	18.409	261.12	1.308	3.073	0.492
	Chamchamal3	35º 30′ 23″	44º 41′ 84″	7.88	0.20	0.037	0.024	0.442	0.049	0.231	0.468	11.972	12.36	22.802	97.57	18.409	261.12	1.308	3.073	0.492
	Chamchamal4	35º 28′ 99″	44º 36′ 41″	7.88	0.20	0.037	0.024	0.442	0.049	0.231	0.468	11.972	12.36	22.802	97.57	18.409	261.12	1.308	3.073	0.492
	Chamchamal5	35º 28′ 08″	44º 32′ 98″	7.88	0.20	0.037	0.024	0.442	0.049	0.231	0.468	11.972	12.36	22.802	97.57	18.409	261.12	1.308	3.073	0.492
Bazian	Bazian1	35º 38′ 33″	45º 03′ 22″	7.75	0.22	0.037	0.018	0.414	0.136	0.241	0.514	11.976	17.42	25.391	97.56	16.672	269.69	2.861	2.585	0.532
	Bazian2	35º 36′ 45″	45º 07′ 03″	8.07	0.16	0.047	0.018	0.267	0.098	0.243	0.456	11.149	18.55	23.857	97.32	9.8545	219.2	2.049	4.074	0.474
	Bazian3	35º 35′ 48″	45º 11′ 19″	7.80	0.19	0.037	0.024	0.349	0.169	0.215	0.464	11.383	17.49	24.956	98.60	11.378	237.6	2.944	4.920	0.488
	Bazian4	35º 35′ 04″	45º 09′ 77″	7.68	0.22	0.037	0.024	0.491	0.082	0.233	0.702	18.862	10.93	24.821	98.17	19.731	190.51	2.044	4.268	0.726
Mawat	Mawat1	35º 53′ 70″	45º 23′ 68″	7.96	0.15	0.037	0.024	0.234	0.136	0.292	0.314	13.952	3.63	19.073	96.66	9.1316	67.091	1.611	8.476	0.338
	Mawat2	35º 53′ 77″	45º 24′ 52″	7.55	0.25	0.037	0.036	0.654	0.125	0.207	0.712	18.157	10.07	24.845	97.95	17.731	95.403	1.706	5.080	0.748
	Mawat3	35º 52′ 33″	45º 24′ 64″	7.55	0.25	0.037	0.036	0.654	0.125	0.207	0.712	18.157	10.07	24.845	97.95	17.731	95.403	1.706	5.080	0.748
	Mawat4	35º 50′ 59″	45º 26′ 52″	7.89	0.21	0.037	0.03	0.523	0.087	0.154	0.252	14.668	0.575	17.372	87.81	2.4568	107.39	2.463	4.896	0.282
	Mawat5	35º 45′ 41″	45º 28′ 34″	7.25	0.15	0.028	0.024	0.376	0.104	0.222	0.637	14.478	15.83	26.399	96.15	11.912	63.987	1.748	5.523	0.661
	Mawat6	35º 42′ 77″	45º 31′ 58″	7.25	0.15	0.028	0.024	0.376	0.104	0.222	0.637	14.478	15.83	26.399	96.15	11.912	63.987	1.748	5.523	0.661

Appendix (4) continued…

Locations		Latitude N	Longitude E	pH	EC dS m^{-1}	Soluble Cations $cmol_c$ kg^{-1}				Exchangeable Cations $cmol_c$ kg^{-1}				CEC $cmol_c$ kg^{-1}	BS%	O.M	$CaCO_3$	Ava.N	Ava.P µg g^{-1} soil	Ava.K^+ $cmol_c$ kg^{-1}
						Na^+	K^+	Ca^{2+}	Mg^{2+}	Na^+	K^+	Ca^{2+}	Mg^{2+}			g kg^{-1}				
Qaradakh	Qaradakh1	35º 18′ 53″	45º 21′ 48″	7.56	0.30	0.047	0.047	0.632	0.153	0.183	0.559	15.463	5.987	22.171	95.11	29.691	36.405	2.613	4.379	0.606
	Qaradakh2	35º 18′ 61″	45º 21′ 47″	7.89	0.22	0.037	0.024	0.469	0.180	0.213	0.534	15.182	9.044	23.743	94.10	37.230	88.807	4.090	5.731	0.558
	Qaradakh3	35º 21′ 32″	45º 24′ 36″	7.89	0.22	0.037	0.024	0.469	0.180	0.213	0.534	15.182	9.044	23.743	94.10	37.230	88.807	4.090	5.731	0.558
	Qaradakh4	35º 20′ 40″	45º 16′ 88″	7.89	0.22	0.037	0.024	0.469	0.180	0.213	0.534	15.182	9.044	23.743	94.10	37.230	88.807	4.090	5.731	0.558
	Qaradakh5	35º 19′ 22″	45º 15′ 76″	7.76	0.16	0.019	0.024	0.24	0.133	0.194	0.388	23.870	1.957	24.087	97.68	21.044	152.39	1.905	8.764	0.412
	Qaradakh6	35º 18′ 72″	45º 14′ 99″	7.65	0.19	0.056	0.018	0.447	0.082	0.179	0.302	24.513	2.457	24.691	97.74	18.389	47.015	4.442	7.062	0.320
Sangaw	Sangaw1	35º 17′ 66″	45º 14′ 71″	7.42	0.20	0.037	0.024	0.485	0.033	0.206	0.418	11.745	13.95	23.428	96.39	14.769	380.02	2.301	8.42	0.442
	Sangaw2	35º 16′ 51″	45º 09′ 75″	7.89	0.16	0.047	0.030	0.425	0.049	0.168	0.449	18.203	0.965	19.529	96.4	12.167	253.00	4.583	5.008	0.479
	Sangaw3	35º 19′ 66″	45º 09′ 68″	7.97	0.59	0.140	0.053	1.112	0.229	0.18	0.111	8.7047	0.830	10.618	92.34	6.5418	204.47	1.853	10.86	0.164
	Sangaw4	35º 22′ 21″	45º 07′ 25″	8.03	0.22	0.065	0.03	0.447	0.055	0.219	0.445	16.638	0.683	18.271	95.12	11.158	346.03	2.008	8.804	0.475
	Sangaw5	35º 24′ 51″	45º 04′ 16″	8.03	0.22	0.065	0.03	0.447	0.055	0.219	0.445	16.638	0.683	18.271	95.12	11.158	346.03	2.008	8.804	0.475
Sangasar	Sangasar1	36º 14′ 26″	45º 02′ 47″	7.74	0.14	0.028	0.018	0.333	0.060	0.218	0.643	30.264	1.824	40.021	96.12	11.083	42.477	1.720	2.042	0.661
	Sangasar2	36º 12′ 99″	44º 58′ 73″	7.99	0.23	0.047	0.041	0.572	0.044	0.251	0.997	28.056	2.789	26.88	96.14	28.022	90.863	2.854	7.459	1.038
	Sangasar3	36º 13′ 43″	44º 54′ 44″	8.04	0.18	0.028	0.024	0.409	0.038	0.206	0.688	27.758	1.353	26.062	94.99	10.600	218.22	2.361	4.425	0.712
Chwarqurna	Chwarqurna1	36º 12′ 84″	44º 52′ 32″	7.87	0.16	0.037	0.024	0.354	0.055	0.237	0.65	29.532	1.644	26.238	96.18	14.673	169.44	2.080	4.541	0.674
	Chwarqurna2	36º 12′ 00″	44º 46′ 75″	7.98	0.26	0.047	0.041	0.518	0.207	0.208	0.887	27.228	2.080	25.279	97.62	15.603	202.63	2.372	4.398	0.928
	Chwarqurna3	36º 10′ 17″	44º 42′ 62″	7.72	0.17	0.047	0.024	0.371	0.136	0.228	0.607	29.495	3.215	26.359	95.76	14.367	192.06	2.524	0.911	0.631
Dukan	Dukan1	36º 07′ 26″	44º 43′ 93″	7.89	0.23	0.037	0.036	0.545	0.055	0.199	0.458	19.684	0.414	20.528	95.12	18.884	378.57	2.236	1.65	0.494
	Dukan2	36º 04′ 91″	44º 45′ 47″	7.86	0.21	0.047	0.03	0.376	0.207	0.186	0.508	20.051	4.104	22.852	95.57	14.687	353.34	2.344	2.765	0.538
	Dukan3	36º 02′ 44″	44º 48′ 34″	7.67	0.25	0.028	0.041	0.534	0.125	0.204	0.369	36.316	6.183	43.701	96.72	18.890	141.21	1.755	5.781	0.410
	Dukan4	35º 53′ 15″	44º 59′ 02″	7.67	0.23	0.047	0.024	0.447	0.180	0.188	0.445	20.409	3.416	23.858	94.68	15.878	236.91	3.109	4.208	0.469
	Dukan5	35º 50′ 74″	45º 03′ 89″	8.13	0.16	0.047	0.018	0.256	0.120	0.23	0.435	18.991	4.371	22.789	94.93	2.912	387.73	3.443	0.685	0.453

Appendix (4) continued…

Locations		Latitude N	Longitude E	pH	EC dS m^{-1}	Soluble Cations $cmol_c\ kg^{-1}$				Exchangeable Cations $cmol_c\ kg^{-1}$				CEC $cmol_c\ kg^{-1}$	BS%	O.M	$CaCO_3$	Ava.N	Ava.P µg g^{-1} soil	$Ava.K^+$ $cmol_c\ kg^{-1}$
						Na^+	K^+	Ca^{2+}	Mg^{2+}	Na^+	K^+	Ca^{2+}	Mg^{2+}			g kg^{-1}				
Darbandikhan	Darbandikhan1	35º 07′ 31″	45º 41′ 47″	7.67	0.24	0.047	0.024	0.485	0.174	0.207	0.541	30.689	1.895	27.285	97.23	26.694	117.09	4.287	2.431	0.565
	Darbandikhan2	35º 05′ 21″	45º 40′ 96″	7.75	0.16	0.047	0.018	0.343	0.180	0.146	0.276	16.523	0.570	18.981	97.11	16.649	159.45	3.790	6.084	0.294
	Darbandikhan3	35º 03′ 73″	45º 39′ 82″	7.69	0.27	0.075	0.036	0.512	0.229	0.180	0.210	11.003	2.354	15.478	93.52	15.225	228.04	2.964	7.318	0.246
	Darbandikhan4	35º 00′ 23″	45º 36′ 76″	8.02	0.2	0.056	0.024	0.458	0.071	0.192	0.268	20.764	1.911	20.915	94.92	9.802	343.10	2.023	2.915	0.292
Kalar	Kalar1	34º 50′ 16″	45º 31′ 21″	7.91	0.18	0.056	0.03	0.392	0.104	0.179	0.419	21.402	1.762	22.036	95.32	14.878	354.84	3.413	1.566	0.449
	Kalar2	34º 45′ 34″	45º 27′ 69″	7.94	0.16	0.065	0.036	0.273	0.131	0.181	0.294	14.496	2.201	17.371	92.81	4.785	190.41	1.432	0.974	0.33
	Kalar3	34º 39′ 68″	45º 23′ 90″	7.93	0.2	0.084	0.036	0.387	0.115	0.153	0.491	17.018	1.976	19.652	93.41	11.319	260.88	1.792	7.412	0.527
	Kalar4	34º 34′ 17″	45º 16′ 06″	7.55	1.72	0.215	0.041	5.112	0.365	0.112	0.221	13.694	2.422	15.279	92.95	2.905	128.93	0.582	2.318	0.262
Khanaqin	Khanaqin1	34º 25′ 44″	45º 20′ 60″	7.80	0.41	0.159	0.083	0.649	0.22	0.170	0.528	17.489	2.791	17.266	93.48	14.518	362.38	1.755	4.042	0.611
	Khanaqin2	34º 21′ 39″	45º 23′ 92″	7.92	0.18	0.084	0.047	0.382	0.055	0.193	0.319	10.266	1.186	13.880	94.91	7.763	372.45	1.796	2.329	0.366
	Khanaqin3	34º 23′ 52″	45º 21′ 43″	7.92	0.18	0.084	0.047	0.382	0.055	0.193	0.319	10.266	1.186	13.880	94.91	7.763	372.45	1.796	2.329	0.366
	Khanaqin4	34º 26′ 83″	45º 19′ 78″	7.65	1.41	0.299	0.077	2.899	1.030	0.029	0.081	19.714	0.636	10.924	94.47	9.887	370.55	1.166	5.593	0.158
	Khanaqin5	34º 34′ 88″	45º 20′ 49″	7.96	0.23	0.121	0.03	0.501	0.033	0.446	0.403	15.897	2.339	13.811	94.44	2.356	623.53	1.145	7.384	0.433
Shwan	Shwan1	35º 33′ 20″	44º 22′ 76″	7.92	0.41	0.131	0.101	0.758	0.136	0.156	0.545	15.522	1.599	15.106	93.50	6.347	317.92	2.025	4.671	0.646
	Shwan2	35º 33′ 53″	44º 22′ 52″	7.75	0.19	0.084	0.030	0.332	0.294	0.171	0.173	10.342	1.527	14.029	92.76	7.173	291.90	1.779	2.963	0.203
	Shwan3	35º 36′ 50″	44º 22′ 59″	7.94	0.22	0.093	0.030	0.458	0.093	0.201	0.377	17.552	0.332	17.619	95.60	10.010	217.00	1.338	5.767	0.407
	Shwan4	35º 40′ 87″	44º 24′ 24″	7.94	0.22	0.093	0.030	0.458	0.093	0.201	0.377	17.552	0.332	17.619	95.60	10.010	217.00	1.338	5.767	0.407
	Shwan5	35º 43′ 42″	44º 27′ 25″	7.92	0.41	0.131	0.101	0.758	0.136	0.156	0.545	15.522	1.599	15.106	93.50	6.347	317.92	2.025	4.671	0.646
Altunkopri	Altunkopri1	35º 38′ 54″	44º 17′ 72″	7.90	0.25	0.131	0.059	0.458	0.120	0.205	0.577	18.741	1.633	17.315	94.73	14.556	270.73	1.497	9.910	0.636
	Altunkopri2	35º 40′ 98″	44º 14′ 66″	7.90	0.25	0.131	0.059	0.458	0.120	0.205	0.577	18.741	1.633	17.315	94.73	14.556	270.73	1.497	9.910	0.636
	Altunkopri3	35º 42′ 61″	44º 12′ 54″	7.90	0.25	0.131	0.059	0.458	0.120	0.205	0.577	18.741	1.633	17.315	94.73	14.556	270.73	1.497	9.910	0.636
	Altunkopri4	35º 41′ 77″	44º 11′ 70″	7.88	0.22	0.047	0.077	0.480	0.142	0.209	0.910	18.681	1.689	19.267	95.73	18.731	292.23	2.384	9.902	0.987
	Altunkopri5	35º 44′ 66″	44º 10′ 15″	7.88	0.22	0.047	0.077	0.480	0.142	0.209	0.910	18.681	1.689	19.267	95.73	18.731	292.23	2.384	9.902	0.987

Appendix (4) continued…

Location		Latitude	Longitude	pH	EC dS m^{-1}	Soluble Cations $cmol_c\ kg^{-1}$				Exchangeable Cations $cmol_c\ kg^{-1}$				CEC $cmol_c\ kg^{-1}$	BS%	O.M	$CaCO_3$	Ava.N	Ava.P $\mu g\ g^{-1}$ soil	Ava.K^+ $cmol_c\ kg^{-1}$
						Na^+	K^+	Ca^{2+}	Mg^{2+}	Na^+	K^+	Ca^{2+}	Mg^{2+}			g kg^{-1}				
Daquq	Daquq1	35º 15′ 82″	44º 21′ 82″	8.02	0.22	0.103	0.041	0.409	0.136	0.172	0.396	18.103	0.880	14.862	95.35	5.324	326.95	1.038	6.901	0.437
	Daquq2	35º 12′ 47″	44º 23′ 60″	8.02	0.22	0.103	0.041	0.409	0.136	0.172	0.396	18.103	0.880	14.862	95.35	5.324	326.95	1.038	6.901	0.437
	Daquq3	35º 10′ 18″	44º 25′ 12″	8.02	0.22	0.103	0.041	0.409	0.136	0.172	0.396	18.103	0.880	14.862	95.35	5.324	326.95	1.038	6.901	0.437
	Daquq4	35º 10′ 06″	44º 25′ 43″	7.36	2.08	0.047	0.053	7.832	0.011	0.189	0.14	70.338	9.766	11.638	99.61	1.707	231.88	0.595	7.023	0.193
Lailan	Lailan1	35º 18′ 93″	44º 28′ 45″	7.58	2.09	0.121	0.095	7.510	0.943	0.194	0.389	86.256	0.294	15.946	98.55	4.096	344.16	0.747	4.208	0.484
	Lailan2	35º 18′ 58″	44º 24′ 70″	7.58	2.09	0.121	0.095	7.510	0.943	0.194	0.389	86.256	0.294	15.946	98.55	4.096	344.16	0.747	4.208	0.484
	Lailan3	35º 19′ 01″	44º 26′ 97″	8.27	0.32	0.252	0.030	0.300	0.551	0.32	0.454	16.132	2.309	18.962	94.24	11.549	303.16	1.195	1.690	0.484
	Lailan4	35º 21′ 39″	44º 28′ 00″	7.58	2.09	0.121	0.095	7.51	0.943	0.194	0.389	86.256	0.294	15.946	98.55	4.096	344.16	0.747	4.208	0.484
Qushtapa	Qushtapa1	35º 48′ 35″	44º 06′ 56″	8.22	0.17	0.084	0.024	0.382	0.022	0.185	0.185	15.259	0.435	13.944	88.06	2.969	383.71	0.581	2.064	0.209
	Qushtapa2	35º 53′ 10″	44º 04′ 70″	8.22	0.17	0.084	0.024	0.382	0.022	0.185	0.185	15.259	0.435	13.944	88.06	2.969	383.71	0.581	2.064	0.209
	Qushtapa3	35º 59′ 16″	44º 02′ 02″	8.00	0.26	0.093	0.059	0.491	0.049	0.182	0.637	16.30	0.504	16.098	91.70	7.717	380.57	1.637	5.484	0.696
	Qushtapa4	35º 58′ 46″	43º 59′ 74″	8.00	0.26	0.093	0.059	0.491	0.049	0.182	0.637	16.30	0.504	16.098	91.70	7.717	380.57	1.637	5.484	0.696
	Qushtapa5	35º 55′ 88″	43º 56′ 78″	7.86	0.55	0.345	0.024	0.758	0.283	0.338	0.294	17.448	0.195	18.521	89.37	6.675	402.78	1.673	5.555	0.318
Makhmoor	Makhmoor1	35º 52′ 63″	43º 46′ 40″	8.09	0.18	0.056	0.047	0.349	0.044	0.197	0.207	12.624	0.462	10.427	90.15	3.603	228.53	1.327	0.254	0.254
	Makhmoor2	35º 50′ 40″	43º 42′ 76″	8.09	0.18	0.056	0.047	0.349	0.044	0.197	0.207	12.624	0.462	10.427	90.15	3.603	228.53	1.327	0.254	0.254
	Makhmoor3	35º 48′ 33″	43º 39′ 23″	8.03	0.26	0.084	0.018	0.485	0.098	0.187	0.204	16.240	0.321	14.500	90.49	2.561	434.62	2.347	6.175	0.222
	Makhmoor4	35º 47′ 75″	43º 36′ 08″	7.53	1.94	0.149	0.035	6.229	0.398	0.179	0.185	14.894	0.771	16.084	93.89	4.591	296.94	2.922	6.813	0.22
	Makhmoor5	35º 47′ 62″	43º 35′ 85″	7.72	0.70	0.131	0.036	1.51	0.273	0.189	0.283	17.632	0.664	15.624	93.89	7.181	332.87	1.425	0.603	0.319
Gwer	Gwer1	35º 55′ 38″	43º 42′ 30″	7.89	0.24	0.093	0.030	0.529	0.033	0.220	0.420	12.199	4.761	16.276	94.86	6.962	373.35	1.039	3.599	0.4501
	Gwer2	35º 56′ 31″	43º 39′ 66″	7.89	0.24	0.093	0.030	0.529	0.033	0.220	0.420	12.199	4.761	16.276	94.86	6.962	373.35	1.039	3.599	0.450
	Gwer3	35º 57′ 99″	43º 35′ 71″	7.82	0.31	0.121	0.030	0.632	0.087	0.206	0.421	18.706	2.117	18.068	95.38	10.091	365.19	1.892	0.854	0.451
	Gwer4	36º 01′ 59″	43º 31′ 57″	7.52	2.51	0.177	0.101	7.935	0.698	0.189	0.383	50.05	0.137	17.521	97.99	5.757	202.73	1.607	1.172	0.484
	Gwer5	36º 02′ 02″	43º 29′ 65″	7.97	0.38	0.159	0.172	0.469	0.185	0.184	0.534	10.647	1.050	11.879	93.06	9.199	249.49	2.161	2.596	0.706

Appendix (5) Profile description report and morphological characteristics of Said Sadiq

USDA-NRCS | PEDON DESCRIPTION | PEDON ID:1 | DRAFT 3/2002

Series of component Name: Said Sadiq | **Map Unit Symbol:** | **Photo: 1** | **Classification:** Vertic Calcixerolls | **Soil Moist. Regime (Tax):** Xeric

Describer(s): Mahtab | **Date:** 3/10/2016 | **Weather:** Sunny | **Tepm:** **Air:** ***Soil:*** ***Depth:*** | **Latitude:** 35º 23′ 52″ N **Datum:** GPS **Longitude:** 45º 45′ 61″ E | **Location:** Said Sadiq

UTM: ***Zone:*** ***mE:*** ***mN:*** | **Topo Quad:** | **Site ID:** ***Yr:*** ***State:*** ***Country:*** ***Pedon:***1 Sulaimani-Iraq | **Soil Survey Area:** | **MLRA / LRU:** | **Transect:** ***ID:*** ***Stop #:*** ***Interval:***

Landscape: Foothill | **Landform:** Plain | **Micro feature:** Gilgai | **Anthro:** — | **Elevation:** 590 m | **Aspect:** 1º N | **Slope(%):** 3% | **Slope Complexity:** | **Slope Shape:** *(UP &Dn / Across)*

Hill slope Profile Position: | **Geom. Component:** | **Micro relief:** | **Physio. Division:** | **Physio. Province:** | **Physio. Section:** | **State Physio. Area:** | **Local Physio. Area:**

Drainage: MW Moderate well Drained | **Flooding:** None | **Ponding:** none | **Soil Moisture Status:** Dry | **Permeability:** Moderate Rapid | **Land Cover / Use:** Wheat (CCG)

Parent Material: Colluvium | **Bedrock:** ***Kind:*** Limestone ***Fract:*** ---- ***Hard:*** ***Depth:*** | **Lithostrat. Units:** ***Group:*** ***Formation:*** ***Member:***

Erosion: ***Kind:*** ***Degree:*** None | **Runoff:** | **Surface Frag %:** ***GR*** ***CB:*** ***ST:*** ***BD:*** ***CN:*** ***FL:*** | **Diagnostic Hor. / Prop.:** ***Kin*** ***Depth:***

P.S. Control Section : ***Ave. Clay %:*** ***Ave. Rock Frag %:***
Depth Range: 62.6%

Appendix (5) continued…

Pedon NO. 1 Said-sadiq					**Matrix Color**		**Texture**	**Structure**	**Consistence**				**Mottles**
	Obser. Method	**Depth (cm)**	**Horizon**	**Horizon Boundary**	**Dry**	**Moist**		**Grade Size Type**	**Dry**	**Moist**	**Wet: Stickiness**	**Wet: Plasticity**	
1	SP	0-6	Ap	AS Abrupt Smooth	10 YR 4/3 Brown	10 YR 3/3 Dark Brown	C	2 VC GR Moderate Very Coarse Granular	EH Extremely Hard	FI Firm	SS Slightly Sticky	VP Very Plastic	No
2	SP	6-37	B1	CW Clear Wavy	10 YR 4/3 Brown	10 YR 3/3 Dark Brown	C	3 CO ABK Strong Coarse Angular Blocky	SH Slightly hard	FR Friable	SS Slightly Sticky	VP Very Plastic	No
3	SP	37-60	B2	GW Gradual Wavy	10 YR 5/3 Brown	10 YR 3/3 Dark Brown	C	2 CO ABK Moderate Coarse Angular Blocky	SH Slightly hard	FR Friable	MS Moderately Sticky	VP Very Plastic	No
4	SP	+60	Ck	——	10 YR 5/3 Brown	10 YR 4/3 Brown	SiC	2 M ABK Moderate Medium Angular Blocky	MH Mod. Hard	FR Friable	SS Slightly Sticky	VP Very Plastic	No

* Observation Method, SP = Small Pit, hand dug (<1m-2m),*C: Clay, SiC: Silty Clay.

Appendix (6): Profile description report and morphological characteristics of Chamchamal

USDA-NRCS	PEDON DESCRIPTION	PEDON ID : 2		DRAFT 3/2002

Series of component Name: Chamchamal	**Map Unit Symbol:**	**Photo:** 2	**Classification:** Vertic Haplocalcids	**Soil Moist. Regime (Tax):** Xeric

Describer(s): Mahtab	**Date:** 15/10/2016	**Weather:** Sunny ***Soil:Depth:***	**Tepm:**	**Air:**	**Latitude:** 35º 33′ 41″ **Longitude:** 44º 51′ 23″	**Datum:** GPS	**Location:** Chamchamal

UTM: ***Zone:*** ***mE:*** ***mN:***	**Topo Quad:**	**Site ID:** ***Yr:*** ***State:*** ***Country:*** ***Pedon:***2 Sulaimani-Iraq	**Soil Survey Area:**	**MLRA / LRU:**	**Transect:** ***ID:*** ***Stop #:*** ***Interval:***

Landscape: Hills	**Landform:** Hill slope	**Micro feature:** Hillock	**Anthro:**	**Elevation:** 693 m	**Aspect:** 347º N	**Slope(%):** 18%	**Slope Complexity:**	**Slope Shape:** *(UP &Dn / Across)*

Hill slope Profile Position:	**Geom. Component:**	**Microrelief:**	**Physio. Division:**	**Physio. Province:**	**Physio. Section:**	**State Physio. Area:**	**Local Physio. Area:**

Drainage:(WD) Well Drained	**Flooding:** None	**Ponding:** none	**Soil Moisture Status:** Dry	**Permeability:** Moderate slow	**Land Cover / Use:** Wheat (CCG)

Parent Material: Colluvium	**Bedrock:** Limestone	***Kind:***	***Fract:*** ----	***Hard:***	***Depth:***	**Lithostrat. Units:**	***Group:***	***Formation:***	***Member:***

Erosion: G (Gully)	***Kind:*** 1	***Degree:***	**Runoff:**	**Surface Frag %:** ***GR:*** ***CB:*** ***ST:*** ***BD:*** ***CN:*** ***FL:***	**Diagnostic Hor. / Prop.:**	***Kind:***	***Depth:***

P.S. Control Section : ***Depth Range:***	***Ave. Clay %:*** 45.4%	***Ave. Rock Frag %:***

Appendix (6) continued…

Pedon NO. 2 Chamchamal					Matrix Color		Texture	Structure	Consistence				Mottles
											Wet		
	Obser. Method	Depth (cm)	Horizon	Horizon Boundary	Dry	Moist		Grade Size Type	Dry	Moist	Stickiness	Plasticity	
1	SP	0-17	Ap	AS Abrupt Smooth	7.5 YR 6/4 Light Brown	7.5 YR 4/4 Brown	SiC	1 CO SBK Weak Coarse Sub-angular Blocky	HA Hard	FR Friable	SS Slightly Sticky	VP Very Plastic	No
2	SP	17-40	Ck1	AS Abrupt Smooth	7.5 YR 5/4 Brown	7.5 YR 4/4 Brown	SiC	1 M ABK Weak Medium angular Blocky	SH Slightly Hard	VFR Very Friable	SS Slightly Sticky	VP Very Plastic	No
3	SP	40-133	Ck2	AS Abrupt Smooth	7.5 YR 5/4 Brown	7.5 YR 4/4 Brown	SiC	2 CO ABK Moderate Coarse angular Blocky	HA Hard	FR Friable	SS Slightly Sticky	VP Very Plastic	No
4	SP	+133	Ck3	----	7.5 YR 6/4 Light Brown	7.5 YR 4/4 Brown	SiCL	2 M ABK Moderate Medium angular Blocky	HA Hard	FI Firm	SS Slightly Sticky	VP Very Plastic	No

* SiCL: Silty Clay Loam, SiC: SiltyClay

Appendix (7): Profile description report and morphological characteristics of Bazian

USDA-NRCS	PEDON DESCRIPTION	PEDON ID : 3		DRAFT 3/2002

Series of component Name:	**Map Unit Symbol:**	**Photo:** 3	**Classification:**	**Soil Moist. Regime (Tax):**
Bazian			Vertic Haploxerolls	Xeric

Describer(s):	**Date:**	**Weather:**	**Tepm:**	**Air:**	**Soil:**	**Depth:**	**Latitude:** 35º 36′ 55″	**Datum:** GPS	**Location:**
Mahtab	15/10/2016	Sunny					**Longitude:** 45º 06′ 98″		Bazian

UTM: ***Zone:*** ***mE:*** ***mN:***	**Topo Quad:**	**Site ID:** ***Yr:*** ***State:*** ***Country:***	**Soil Survey Area:**	**MLRA / LRU:**	**Transect:** ***ID:*** ***Stop #:*** ***Interval:***
		Pedon: 3 Sulaimani-Iraq			

Landscape:	**Landform:**	**Micro feature:**	**Anthro:**	**Elevation:**	**Aspect:**	**Slope (%):**	**Slope Complexity:**	**Slope Shape:** *(UP &Dn / Across)*
Plateau	Plateau	Gilgai		824 m	215º SW	2%		

Hill slope Profile Position:	**Geom. Component:**	**Micro relief:**	**Physio. Division:**	**Physio. Province:**	**Physio. Section:**	**State Physio. Area:**	**Local Physio. Area:**

Drainage:	**Flooding:**	**Ponding:**	**Soil Moisture Status:**	**Permeability:** Moderate rapid	**Land Cover / Use:**
Moderate well drained	none	none	Dry	K_{sat}:	Wheat (CCG)

Parent Material:	**Bedrock:** ***Kind:*** ***Fract:*** ***Hard:*** ***Depth:***	**Lithostrat. Units:** ***Group:*** ***Formation:*** ***Member:***
Colluvium	Limestone ----	

Erosion: ***Kind:*** ***Degree:***	**Runoff:**	**Surface Frag %:** ***GR:*** ***CB:*** ***ST:*** ***BD:*** ***CN:*** ***FL:***	**Diagnostic Hor. / Prop.:** ***Kind:*** ***Depth:***
None			

P.S. Control Section :	***Ave. Clay %:***	***Ave. Rock Frag %:***
Depth Range:	46.6%	

Appendix (7) continued…

Pedon NO. 3 Bazian					**Matrix Color**		**Texture**	**Structure**	**Consistence**				**Mottles**
	Obser. Method	**Depth (cm)**	**Horizon**	**Horizon Boundary**	**Dry**	**Moist**		**Grade Size Type**	**Dry**	**Moist**	**Wet**		
											Stickiness	**Plasticity**	
1	SP	0-8	Ap	AS Abrupt Smooth	10 YR 5/2 Grayish Brown	10 YR 3/2 Very Dark Grayish Brown	SiC	1 CO GR Weak Coarse Granular	SH Slightly Hard	VFR Very Friable	SS Slightly Sticky	VP Very Plastic	No
2	SP	8-40	Bk	AS Abrupt Smooth	10 YR 5/2 Grayish Brown	10 YR 3/2 Very Dark Grayish Brown	SiC	3 CO ABK Strong Coarse Angular Blocky	VH Very Hard	VFI Very Firm	MS Moderately Sticky	VP Very Plastic	No
3	SP	40-81	Ck1	CW Clear Wavy	10 YR 5/2 Grayish Brown	10 YR 3/2 Very Dark Grayish Brown	SiC	3 CO ABK Strong Coarse Angular Blocky	VH Very Hard	FI Firm	SS Slightly Sticky	VP Very Plastic	No
4	SP	+81	Ck2	—	10 YR 5/2 Grayish Brown	10 YR 3/2 Very Dark Grayish Brown	SiC	2 CO ABK Moderate Coarse Angular Blocky	VH Very Hard	FI Firm	MS Moderately Sticky	VP Very Plastic	No

* SiC: Silty Clay

Appendix (8): Profile description report and morphological characteristics of Mawat

USDA-NRCS	PEDON DESCRIPTION	PEDON ID: 4		DRAFT 3/2002

Series of component Name:	**Map Unit Symbol:**	**Photo:** 4	**Classification:**	**Soil Moist. Regime (Tax):**
Mawat			Typic Haploxerolls	Xeric

Describer(s):	**Date:**	**Weather:** **Tepm:** **Air:**	**Latitude:** 35º 53′ 70″ **Datum:** GPS	**Location:**
Mahtab	18/10/2016	Sunny ***Soil:*** ***Depth:***	**Longitude:** 45º 23′ 68″	Mawat

UTM: ***Zone:*** ***mE:*** ***mN:***	**Topo Quad:**	**Site ID:** ***Yr:*** ***State:*** ***Country:***	**Soil Survey Area:**	**MLRA / LRU:**	**Transect:** ***ID:***
		Pedon:4 Sulaimani-Iraq			***Stop #:*** ***Interval:***

Landscape:	**Landform:**	**Micro feature:**	**Anthro:**	**Elevation:**	**Aspect:**	**Slope (%):**	**Slope Complexity:**	**Slope Shape:** *(UP &Dn / Across)*
Mountain	Mountain valley			439 m	48º NE	14%		

Hill slope Profile Position:	**Geom. Component:**	**Micro relief:**	**Physio. Division:**	**Physio. Province:**	**Physio. Section:**	**State Physio. Area:**	**Local Physio. Area:**

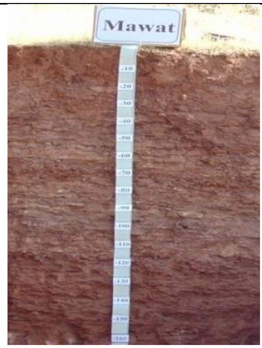
Drainage:	**Flooding:**	**Ponding:**	**Soil Moisture Status:**	**Permeability:** Moderate rapid	**Land Cover / Use:**
Moderate well drained	none	none	Dry	K_{sat}**:**	Oak (THW) and grasses (GML)

Parent Material:	**Bedrock:** ***Kind:*** ***Fract:*** ***Hard:*** ***Depth:***	**Lithostrat. Units:** ***Group:*** ***Formation:*** ***Member:***
Colluvium	Limestone ----	

Erosion: G (Gully) ***Kind:*** ***Degree:*** 0	**Runoff:**	**Surface Frag %:** ***GR:*** ***CB:*** ***ST:*** ***BD:*** ***CN:*** ***FL:***	**Diagnostic Hor. / Prop.:** ***Kind:*** ***Depth:***

P.S. Control Section : ***Ave. Clay %:*** ***Ave. Rock Frag %:***

Depth Range: 18.2%



Appendix (8) continued…

Pedon NO. 4 Mawat					Matrix Color		Texture	Structure	Consistence				Mottles
	Obser. Method	Depth (cm)	Horizon	Horizon Boundary	Dry	Moist		Grade Size Type	Dry	Moist	Wet		
											Stickiness	Plasticity	
1	SP	0-22	Ap	AS Abrupt Smooth	2.5 YR 4/4 Reddish Brown	2.5 YR 3/4 Dark Reddish Brown	CL	1 VC GR Weak Very Coarse Granular	S Soft	VFR Very Friable	SO Non-Sticky	MP Moderately Plastic	No
2	SP	22-53	Bk	AS Abrupt Smooth	2.5 YR 5/3 Reddish Brown	2.5 YR 3/3 Dark Reddish Brown	SL	1 M ABK Weak Medium Angular Blocky	SH Slightly Hard	VFR Very Friable	SO Non-Sticky	PO Non-Plastic	No
3	SP	53-99	Ck1	AS Abrupt Smooth	2.5 YR 5/3 Reddish Brown	2.5 YR 3/3 Dark Reddish Brown	SL	3 M ABK Strong Medium Angular Blocky	EH Extremely Hard	EF Extr. Firm	SO Non-Sticky	PO Non-Plastic	No
4	SP	99-129	Ck2	AS Abrupt Smooth	2.5 YR 5/3 Reddish Brown	2.5 YR 3/3 Dark Reddish Brown	SiL	3 M ABK Strong Medium Angular Blocky	EH Extremely Hard	EF Extr. Firm	SO Non-Sticky	PO Non-Plastic	No
5	SP	+129	Ck3	—	2.5 YR 5/3 Reddish Brown	2.5 YR 3/4 Dark Reddish Brown	CL	3 M ABK Strong Medium Angular Blocky	EH Extremely Hard	VFI Very Firm	SO Non-Sticky	PO Non-Plastic	No

* SiL: Silty Loam, SL: Sandy Loam, CL: Clay Loam

Appendix (9): Profile description report and morphological characteristics of Qaradakh 1

USDA-NRCS	PEDON DESCRIPTION	PEDON ID: 5		DRAFT 3/2002

Series of component Name:	**Map Unit Symbol:**	**Photo:**5	**Classification:**	**Soil Moist. Regime (Tax):**
Qaradakh 1			Aridic Calcixerolls	Xeric

Describer(s):	**Date:**	**Weather:**	**Tepm:**	**Air:**	**Latitude:** 35º 18′ 53″	**Datum:** GPS	**Location:**
Mahtab	19/10/2016	Sunny	***Soil:***	***Depth:***	**Longitude:** 45º 21′ 48″		Qaradakh 1

UTM: ***Zone:*** ***mE:*** ***mN:***	**Topo Quad:**	**Site ID:** ***Yr:*** ***State:*** ***Country:***	**Soil Survey Area:**	**MLRA / LRU:**	**Transect:** ***ID:***
		Pedon:5 Sulaimani-Iraq			***Stop #:*** ***Interval:***

Landscape:	**Landform:**	**Microfeature:**	**Anthro:**	**Elevation:**	**Aspect:**	**Slope (%):**	**Slope Complexity:**	**Slope Shape:** *(UP &Dn / Across)*
Mountain	Mountain valley			867 m	53º NE	10%		

Hill slope Profile Position:	**Geom. Component:**	**Micro relief:**	**Physio. Division:**	**Physio. Province:**	**Physio. Section:**	**State Physio. Area:**	**Local Physio. Area:**

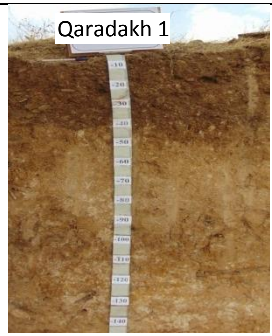
Drainage:	**Flooding:**	**Ponding:**	**Soil Moisture Status:**	**Permeability:** very slow	**Land Cover / Use:**
Somewhat poorly drained	none	none	Dry	K_{sat}**:**	Oak (THW) and grasses (GML)

Parent Material:	**Bedrock:** ***Kind:*** ***Fract:*** ***Hard:*** ***Depth:***	**Lithostrat. Units:** ***Group:*** ***Formation:*** ***Member:***
Colluvium	Limestone ----	

Erosion: G	***Kind:***	***Degree:***	**Runoff:**	**Surface Frag %:** ***GR:*** ***CB:*** ***ST:*** ***BD:*** ***CN:*** ***FL:***	**Diagnostic Hor. / Prop.:** ***Kind:*** ***Depth:***
(Gully)	0				

P.S. Control Section : ***Ave. Clay %:*** ***Ave. Rock Frag %:***

Depth Range: 35.7%



Appendix (9) continued…

Pedon NO. 5 Qaradakh1					**Matrix Color**		**Texture**	**Structure**	**Consistence**				**Mottles**
	Obser. Method	**Depth (cm)**	**Horizon**	**Horizon Boundary**	**Dry**	**Moist**		**Grade Size Type**	**Dry**	**Moist**	**Wet Stickiness**	**Wet Plasticity**	
1	SP	0-42	Ap	DW DiffuseWavy	10 YR 4/3 Brown	10 YR 3/3 Dark Brown	SiCL	1 C GR Weak Coarse Granular	S Soft	FR Friable	MS Moderately Sticky	VP Very Plastic	No
2	SP	42-94	B	CW Clear Wavy	10 YR 6/4 Light Yellowish Brown	10 YR 5/6 Yellowish Brown	SiC	2 F ABK Moderate Fine Angular Blocky	SH Slightly Hard	FI Firm	SO Non-Sticky	MP Moderately Plastic	No
3	SP	+94	C	—	10 YR 6/6 Brownish Yellow	10 YR 4/4 Dark Yellowish Brown	CL	2 M ABK Moderate Medium Angular Blocky	H Hard	FI Firm	MS Moderately Sticky	MP Moderately Plastic	No

* SiCL: Silty Clay Loam, SiC: SiltyClay, CL: Clay Loam

Appendix (10): Profile description report and morphological characteristics of Qaradakh 2

USDA-NRCS	PEDON DESCRIPTION	PEDON ID:6		DRAFT 3/2002

Series of component Name:	**Map Unit Symbol:**	**Photo:** 6	**Classification:**	**Soil Moist. Regime (Tax):**
Qaradakh 2			Aridic Calcixerolls	Xeric

Describer(s):	**Date:**	**Weather:**	**Tepm:** **Air:**	**Latitude:** 35° 18′ 61″ **Datum:** GPS	**Location:**
Mahtab	19/10/2016	Sunny	***Soil:*** ***Depth:***	**Longitude:** 45° 21′ 47″	Qaradakh 2

UTM: ***Zone:*** ***mE:*** ***mN:***	**Topo Quad:**	**Site ID:** ***Yr:*** ***State:*** ***Country:***	**Soil Survey Area:**	**MLRA / LRU:**	**Transect:** ***ID:***
		Pedon: 6 Sulaimani-Iraq			***Stop #:*** ***Interval:***

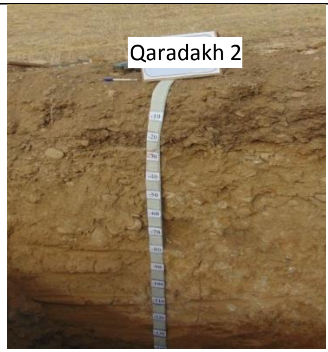
Landscape:	**Landform:**	**Micro feature:**	**Anthro:**	**Elevation:**	**Aspect:**	**Slope (%):**	**Slope Complexity:**	**Slope Shape:** *(UP &Dn / Across)*
Mountain	Mountain valley			588 m	207° SW	8%		

Hill slope Profile Position:	**Geom. Component:**	**Micro relief:**	**Physio. Division:**	**Physio. Province:**	**Physio. Section:**	**State Physio. Area:**	**Local Physio. Area:**

Drainage:	**Flooding:**	**Ponding:**	**Soil Moisture Status:**	**Permeability:** Moderate rapid	**Land Cover / Use:**
Moderate well drained	none	none	Dry	K_{sat}:	Grasses (GML)

Parent Material:	**Bedrock:** ***Kind:*** ***Fract:*** ***Hard:*** ***Depth:***	**Lithostrat. Units:** ***Group:*** ***Formation:*** ***Member:***
Colluvium	Limestone ----	

Erosion: G ***Kind:*** ***Degree:***	**Runoff:**	**Surface Frag %:** ***GR:*** ***CB:*** ***ST:*** ***BD:*** ***CN:*** ***FL:***	**Diagnostic Hor. / Prop.:** ***Kind:*** ***Depth:***
(Gully) 0			

P.S. Control Section : ***Ave. Clay %:*** ***Ave. Rock Frag %:***		
Depth Range: 29.3%		

Appendix (10) continued…

Pedon NO. 6 Qaradakh 2					Matrix Color		Texture	Structure	Consistence				Mottles
											Wet		
	Obser. Method	Depth (cm)	Horizon	Horizon Boundary	Dry	Moist		Grade Size Type	Dry	Moist	Stickiness	Plasticity	
1	SP	0-32	A	CW Clear Wavy	10 YR 5/3 Brown	10 YR 3/3 Dark Brown	L	1 VC GR Weak Very Coarse Granular	S Soft	VFR Very Friable	SS Slightly Sticky	MP Moderately Plastic	No
2	SP	32-78	B	CW Clear Wavy	2.5 Y 5/3 Light Olive Brown	10 Y 4/4 Olive Brown	SiCL	2 M SBK Moderate Medium Sub-angular Blocky	SH Slightly Hard	FR Friable	SS Slightly Sticky	MP Moderately Plastic	No
3	SP	78-131	Ck1	AS Abrupt Smooth	2.5 Y 7/3 Pale Brown	10 YR 5/4 Yellowish Brown	SiCL	1 M SBK Weak Medium Sub-angular Blocky	H Hard	FR Friable	SS Slightly Sticky	MP Moderately Plastic	No
4	SP	+131	Ck2	---	10 YR 6/4 Light Yellowish Brown	10 YR 5/6 Yellowish Brown	SiC	2 F SBK Moderate Fine Sub-angular Blocky	VH Very Hard	FI Firm	SS Slightly Sticky	MP Moderately Plastic	No

* SiCL: Silty Clay Loam, L: Loam, SiC: SiltyClay

Appendix (11): Profile description report and morphological characteristics of Sangaw

USDA-NRCS	PEDON DESCRIPTION	PEDON ID:7		DRAFT 3/2002

Series of component Name: Sangaw	**Map Unit Symbol:**	**Photo:** 7	**Classification:** Vertic Calcixerepts	**Soil Moist. Regime (Tax):** Xeric

Describer(s): Mahtab	**Date:** 19/10/2016	**Weather:** Sunny	**Tepm:** *Soil:*	**Air:** *Depth:*	**Latitude:** 35º 16′ 51″ **Longitude:** 45º 09′ 75″	**Datum:** GPS	**Location:** Sangaw

UTM:	*Zone:*	*mE:*	*mN:*	**Topo Quad:**	**Site ID:** *Pedon:* 7	*Yr:*	*State:*	*Country:* Sulaimani-Iraq	**Soil Survey Area:**	**MLRA / LRU:**	**Transect:** *Stop #:*	*ID:* *Interval:*

Landscape: Hill	**Landform:** High hill	**Micro feature:**	**Anthro:**	**Elevation:** 809 m	**Aspect:** 120º SE	**Slope (%):** 17%	**Slope Complexity:**	**Slope Shape:** *(UP &Dn / Across)*

Hill slope Profile Position:	**Geom. Component:**	**Micro relief:**	**Physio. Division:**	**Physio. Province:**	**Physio. Section:**	**State Physio. Area:**	**Local Physio. Area:**

Drainage: Moderate well	**Flooding:** none	**Ponding:** none	**Soil Moisture Status:** Dry	**Permeability:** Moderate rapid K_{sat}**:**	**Land Cover / Use:** Grasses (GML)

Parent Material: Colluvium	**Bedrock:** Limestone	*Kind:*	*Fract:* ----	*Hard:*	*Depth:*	**Lithostrat. Units:**	*Group:*	*Formation:*	*Member:*

Erosion: **G** (Gully)	*Kind:* 0	*Degree:*	**Runoff:**	**Surface Frag %:**	*GR:*	*CB:*	*ST:*	*BD:*	*CN:*	*FL:*	**Diagnostic Hor. / Prop.:**	*Kind:*	*Depth:*

P.S. Control Section : *Depth Range:*	*Ave. Clay %:* 45.6%	*Ave. Rock Frag %:*

Appendix (11) continued…

Pedon NO. 7 Sangaw					Matrix Color		Texture	Structure	Consistence				Mottles
	Obser. Method	Depth (cm)	Horizon	Horizon Boundary	Dry	Moist		Grade Size Type	Dry	Moist	Wet		
											Stickiness	Plasticity	
1	SP	0-36	Ap	AS Abrupt Smooth	7.5 YR 6/3 Light Brown	7.5 YR 4/3 Brown	C	1 CO GR Weak Coarse Granular	SH Slightly Hard	FR Friable	SS Slightly Sticky	MP Moderately Plastic	No
2	SP	36-87	Bw	CW Clear Wavy	7.5 YR 6/3 Light Brown	7.5 YR 4/3 Brown	SiCL	1 M ABK Weak Medium angular Blocky	HA Hard	FI Firm	MS Moderately Sticky	VP Very Plastic	No
3	SP	+87	Ck	-----	7.5 YR 5/4 Brown	7.5 YR 3/3 Dark Brown	SiC	2 M ABK Moderate Medium angular Blocky	VH Very Hard	VH Very Hard	MS Moderately Sticky	VP Very Plastic	No

* C: Clay, SiCL: Silty Clay Loam, SiC: Silty Clay.

Appendix (12): Profile description report and morphological characteristics of Sangasar

USDA-NRCS	PEDON DESCRIPTION	PEDON ID: 8		DRAFT 3/2002

Series of component Name: Sangasar	**Map Unit Symbol:**	**Photo:** 8	**Classification:** Chromic Calcixererts	**Soil Moist. Regime (Tax):** Xeric

Describer(s): Mahtab	**Date:** 21/10/2016	**Weather:** Sunny **Tepm:** **Air:** ***Soil:*** ***Depth:***	**Latitude:** 36° 14′ 26″ **Datum:** GPS **Longitude:** 45° 02′ 47″	**Location:** Sangasar

UTM: ***Zone:*** ***mE:*** ***mN:***	**Topo Quad:**	**Site ID:** ***Yr:*** ***State:*** ***Country:*** ***Pedon:***8 Sulaimani-Iraq	**Soil Survey Area:**	**MLRA / LRU:**	**Transect:** ***ID:*** ***Stop #:*** ***Interval:***

Landscape: Plains	**Landform:** Plains	**Micro feature:**	**Anthro:**	**Elevation:** 558 m	**Aspect:** 113° SE	**Slope (%):** 5%	**Slope Complexity:**	**Slope Shape:** *(UP &Dn / Across)*

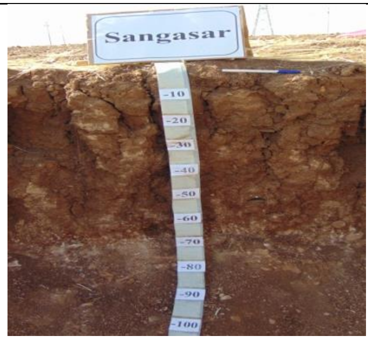
Hill slope Profile Position:	**Geom. Component:**	**Micro relief:**	**Physio. Division:**	**Physio. Province:**	**Physio. Section:**	**State Physio. Area:**	**Local Physio. Area:**

Drainage: Moderate well drained	**Flooding:** none **Ponding:** none	**Soil Moisture Status:** Dry	**Permeability:** Moderate rapid K_{sat}:	**Land Cover / Use:** Wheat (CCG)

Parent Material: Colluvium	**Bedrock:** ***Kind:*** ***Fract:*** ***Hard:*** ***Depth:*** Limestone ----	**Lithostrat. Units:** ***Group:*** ***Formation:*** ***Member:***

Erosion: S (Sheet) ***Kind:*** 0 ***Degree:***	**Runoff:**	**Surface Frag %:** ***GR:*** ***CB:*** ***ST:*** ***BD:*** ***CN:*** ***FL:***	**Diagnostic Hor. / Prop.:** ***Kind:*** ***Depth:***

P.S. Control Section : ***Ave. Clay %:*** ***Ave. Rock Frag %:*** ***Depth Range:*** 53.5%	



Appendix (12) continued…

Pedon NO. 8 Sangasar					Matrix Color		Texture	Structure	Consistence				Mottles
	Obser. Method	Depth (cm)	Horizon	Horizon Boundary	Dry	Moist		Grade Size Type	Dry	Moist	Wet		
											Stickiness	Plasticity	
1	SP	0-9	Ap	AS Abrupt Smooth	10 YR 4/3 Brown	10 YR 3/3 Dark Brown	C	2 M SBK Moderate Medium Sub-angular Blocky	H Hard	FI Firm	SS Slightly Sticky	VP Very Plastic	No
2	SP	9-35	Bss1	CW Clear Wavy	7.5 YR 4/4 Brown	7.5 YR 3/3 Dark Brown	C	2 CO SBK Moderate Coarse Sub-angular Blocky	H Hard	FI Firm	SS Slightly Sticky	MP Moderately Plastic	No
3	SP	35-49	Bss2	CW Clear Wavy	7.5 YR 4/3 Brown	10 YR 3/3 Dark Brown	C	2 M SBK Moderate Medium Sub-angular Blocky	SH Slightly Hard	FR Friable	SS Slightly Sticky	MP Moderately Plastic	No
4	SP	+49	Bss3	-----	7.5 YR 6/4 Light Brown	7.5 YR 4/4 Brown	C	1 F SBK Weak Medium Sub-angular Blocky	SH Slightly Hard	VFR Very Friable	SS Slightly Sticky	VP Very Plastic	No

* C: Clay

Appendix (13): Profile description report and morphological characteristics of Chwarqurna

USDA-NRCS	PEDON DESCRIPTION	PEDON ID:9		DRAFT 3/2002

Series of component Name: Chwarqurna	**Map Unit Symbol:**	**Photo:** 9	**Classification:** Vertic Calcixerepts	**Soil Moist. Regime (Tax):** Xeric

Describer(s): Mahtab	**Date:** 21/10/2016	**Weather:** Sunny **Tepm:** **Air:** ***Soil:*** ***Depth:***	**Latitude:** 36º 12′ 00″ **Datum:** GPS **Longitude:** 44º 46′ 75″	**Location:** Chwarqurna

UTM: ***Zone:*** ***mE:*** ***mN:***	**Topo Quad:**	**Site ID:** ***Yr:*** ***State:*** ***Country:*** ***Pedon:*** 9 Sulaimani-Iraq	**Soil Survey Area:**	**MLRA / LRU:**	**Transect:** ***ID:*** ***Stop #:*** ***Interval:***

Landscape: Plains	**Landform:** Plains	**Micro feature:** Gilgai	**Anthro:**	**Elevation:** 532 m	**Aspect:** 274º W	**Slope (%):** 1%	**Slope Complexity:**	**Slope Shape:** *(UP &Dn / Across)*

Hill slope Profile Position:	**Geom. Component:**	**Micro relief:**	**Physio. Division:**	**Physio. Province:**	**Physio. Section:**	**State Physio. Area:**	**Local Physio. Area:**

Drainage: Moderate well drained	**Flooding:** none **Ponding:** none	**Soil Moisture Status:** Moist	**Permeability:** Moderate rapid K_{sat}:	**Land Cover / Use:** Wheat (CCG)

Parent Material: Colluvium	**Bedrock:** ***Kind:*** ***Fract:*** ***Hard:*** ***Depth:*** Limestone ----	**Lithostrat. Units:** ***Group:*** ***Formation:*** ***Member:***

Erosion: ***Kind:*** ***Degree:*** None	**Runoff:**	**Surface Frag %:** ***GR:*** ***CB:*** ***ST:*** ***BD:*** ***CN:*** ***FL:***	**Diagnostic Hor. / Prop.:** ***Kind:*** ***Depth:***

P.S. Control Section ***:*** ***Ave. Clay %:*** ***Ave. Rock Frag %:*** ***Depth Range:*** 55.1%	

Appendix (13) continued…

Pedon NO. 9 Chwarqurna					**Matrix Color**		**Texture**	**Structure**	**Consistence**				**Mottles**
	Obser. Method	**Depth (cm)**	**Horizon**	**Horizon Boundary**	**Dry**	**Moist**		**Grade Size Type**	**Dry**	**Moist**	**Wet**		
											Stickiness	**Plasticity**	
1	SP	0-7	Ap	AS Abrupt Smooth	7.5 YR 5/2 Brown	7.5 YR 4/2 Brown	C	3 VC GR Strong Very Coarse Granular	VH Very Hard	FI Firm	MS Moderately Sticky	VP Very Plastic	No
2	SP	7-46	Bw	CW Clear Wavey	7.5 YR 4/2 Brown	7.5 YR 3/2 Dark Brown	C	3 CO ABK Strong Coarse angular Blocky	H Hard	FR Friable	MS Moderately Sticky	VP Very Plastic	No
3	SP	+46	Ck	—	7.5 YR 4/2 Brown	7.5 YR 3/2 Dark Brown	SiC	3 CO ABK Strong Coarse angular Blocky	H Hard	FI Firm	MS Moderately Sticky	VP Very Plastic	No

* C: Clay, SiC: Silty Clay.

Appendix (14): Profile description report and morphological characteristics of Dukan

USDA-NRCS	PEDON DESCRIPTION	PEDON ID: 10		DRAFT 3/2002

Series of component Name: Dukan	**Map Unit Symbol:**	**Photo:** 10	**Classification:** Lithic Calcixerepts	**Soil Moist. Regime (Tax):** Xeric

Describer(s): Mahtab	**Date:** 21/10/2016	**Weather:** Sunny	**Tepm:** *Soil:*	**Air:** *Depth:*	**Latitude:** 35º 53′ 15″ **Longitude:** 44º 59′ 02″	**Datum:** GPS	**Location:** Dukan

UTM: *Zone:* *mE:* *mN:*	**Topo Quad:**	**Site ID:** *Yr:* *State:* *Country:* *Pedon:* 10 Sulaimani-Iraq	**Soil Survey Area:**	**MLRA / LRU:**	**Transect:** *ID:* *Stop #:* *Interval:*

Landscape: Mountains	**Landform:** Mountains valley	**Micro feature:**	**Anthro:**	**Elevation:** 476 m	**Aspect:** 350º N	**Slope (%):** 5%	**Slope Complexity:**	**Slope Shape:** *(UP &Dn / Across)*

Hill slope Profile Position:	**Geom. Component:**	**Micro relief:**	**Physio. Division:**	**Physio. Province:**	**Physio. Section:**	**State Physio. Area:**	**Local Physio. Area:**

Drainage: Moderate well drained	**Flooding:** none	**Ponding:** none	**Soil Moisture Status:** Dry	**Permeability:** Moderate rapid K_{sat}:	**Land Cover / Use:** Oak (THW) and grasses (GML)

Parent Material: Colluvium	**Bedrock:** Limestone	*Kind:*	*Fract:* ----	*Hard:*	*Depth:*	**Lithostrat. Units:**	*Group:*	*Formation:*	*Member:*

Erosion: G (Gully)	*Kind:* 0	*Degree:*	**Runoff:**	**Surface Frag %:** *GR:* *CB:* *ST:* *BD:* *CN:* *FL:*	**Diagnostic Hor. / Prop.:** *Kind:* *Depth:*

P.S. Control Section : *Depth Range:*	*Ave. Clay %:* 44.3%	*Ave. Rock Frag %:*

Appendix (14) continued…

Pedon NO. 10 Dukan					Matrix Color		Texture	Structure	Consistence				Mottles
	Obser. Method	Depth (cm)	Horizon	Horizon Boundary	Dry	Moist		Grade Size Type	Dry	Moist	Wet		
											Stickiness	Plasticity	
1	SP	0-19	Ap	AS Abrupt Smooth	10 YR 5/3 Brown	10 YR 3/3 Dark Brown	C	1 F GR Weak Fine Granular	SH Slightly Hard	VFR Very Friable	SS Slightly Sticky	VP Very Plastic	No
2	SP	19-33	Bw	CW Clear Wavy	10 YR 5/3 Brown	10 YR 3/3 Dark Brown	SiC	1 VF GR Weak Very Fine Granular	S Soft	VFR Very Friable	SS Slightly Sticky	VP Very Plastic	No
3	SP	33-63	Ck1	CW Clear Wavy	10 YR 6/4 Light Yellowish Brown	10 YR 4/4 Dark Yellowish Brown	SiC	2 F ABK Moderate Fine angular Blocky	SH Slightly Hard	FR Friable	MS Moderately Sticky	VP Very Plastic	No
4	SP	+63	Ck2	—	10 YR 5/4 Yellowish Brown	10 YR 4/6 Dark Yellowish Brown	SiC	2 MABK Moderate Medium Angular Blocky	SH Slightly Hard	FR Friable	MS Moderately Sticky	VP Very Plastic	No

* C: Clay, SiC: Silty Clay.

Appendix (15): Profile description report and morphological characteristics of Darbandikhan

USDA-NRCS	PEDON DESCRIPTION	PEDON ID: 11		DRAFT 3/2002

Series of component Name:	Map Unit Symbol:	Photo: 11	Classification:	Soil Moist. Regime (Tax):
Darbandikhan			Fluventic Haploxerepts	Xeric

Describer(s):	Date:	Weather:	Tepm:	Air:	Latitude: 35º 05′ 21″ Datum: GPS	Location:
Mahtab	23/10/2016	Sunny	*Soil:*	*Depth:*	Longitude: 45º 40′ 96″	Darbandikhan

UTM: *Zone:* *mE:* *mN:*	Topo Quad:	Site ID: *Yr:* *State:* *Country:*	Soil Survey Area:	MLRA / LRU:	Transect: *ID:*
		Pedon: 11 Sulaimani-Iraq			*Stop #:* *Interval:*

Landscape:	Landform:	Micro feature:	Anthro:	Elevation:	Aspect:	Slope (%):	Slope Complexity:	Slope Shape: *(UP &Dn / Across)*
Mountains	high hill			400 m	73º E	22%		

Hill slope Profile Position:	Geom. Component:	Micro relief:	Physio. Division:	Physio. Province:	Physio. Section:	State Physio. Area:	Local Physio. Area:

Drainage:	Flooding:	Ponding:	Soil Moisture Status:	Permeability: Moderate rapid	Land Cover / Use:
Moderate well drained	none	none	Dry	K_{sat}:	Grasses (GML)

Parent Material:	Bedrock: *Kind:* *Fract:* *Hard:* *Depth:*	Lithostrat. Units: *Group:* *Formation:* *Member:*
Colluvium	Limestone ----	

Erosion: G (Gully)	*Kind:*	*Degree:*	Runoff:	Surface Frag %: *GR:* *CB:* *ST:* *BD:* *CN:* *FL:*	Diagnostic Hor. / Prop.: *Kind:* *Depth:*
	0				

P.S. Control Section :	*Ave. Clay %:*	*Ave. Rock Frag %:*
Depth Range:	22.8%	

Appendix (15) continued…

Pedon NO. 11 Darbandikhan					Matrix Color		Texture	Structure	Consistence				Mottles
											Wet		
	Obser. Method	Depth (cm)	Horizon	Horizon Boundary	Dry	Moist		Grade Size Type	Dry	Moist	Stickiness	Plasticity	
1	SP	0-30	A	AS Abrupt Smooth	10 YR 4/3 Brown	10 YR 3/3 Dark Brown	L	1 CO GR Weak Coarse Granular	SH Slightly Hard	VFR Very Friable	SS Slightly Sticky	VP Very Plastic	No
2	SP	30-46	Bw	CW Clear Wavy	7.5 YR 5/4 Brown	7.5 YR 3/3 Dark Brown	SiL	1 M SBK Weak Medium Sub-angular Blocky	SH Slightly Hard	FR Friable	SS Slightly Sticky	MP Moderately Plastic	No
3	SP	+46	C	—	7.5 YR 6/4 Light Brown	7.5 YR 4/6 Strong Brown	SiL	1 M SBK Weak Medium Sub-angular Blocky	SH Slightly Hard	FR Friable	SS Slightly Sticky	MP Moderately Plastic	No

* L: Loam, SiL: Silty Loam.

Appendix (16): Profile description report and morphological characteristics of Kalar

USDA-NRCS	PEDON DESCRIPTION	PEDON ID: 12		DRAFT 3/2002

Series of component Name: Kalar	**Map Unit Symbol:**	**Photo:** 12	**Classification:** Xeric Haplocacids	**Soil Moist. Regime (Tax):** Xeric

Describer(s): Mahtab	**Date:** 23/10/2016	**Weather:** Sunny	**Tepm:** ***Air:*** ***Soil:*** ***Depth:***	**Latitude:**34º 34′ 17″ **Longitude:** 45º 16′ 06″	**Datum:** GPS	**Location:** Kalar

UTM: ***Zone:*** ***mE:*** ***mN:***	**Topo Quad:**	**Site ID:** ***Yr:*** ***State:*** ***Country:*** ***Pedon:***12 Sulaimani-Iraq	**Soil Survey Area:**	**MLRA / LRU:**	**Transect:** ***ID:*** ***Stop #:*** ***Interval:***

Landscape: Plains	**Landform:** Plains	**Micro feature:**	**Anthro:**	**Elevation:** 196 m	**Aspect:** 139º SE	**Slope (%):** 2%	**Slope Complexity:**	**Slope Shape:** *(UP &Dn / Across)*

Hill slope Profile Position:	**Geom. Component:**	**Micro relief:**	**Physio. Division:**	**Physio. Province:**	**Physio. Section:**	**State Physio. Area:**	**Local Physio. Area:**

Drainage: Moderate well drained	**Flooding:** none	**Ponding:** none	**Soil Moisture Status:** Dry	**Permeability:** Moderate rapid ***K_{sat}*:**	**Land Cover / Use:** Wheat (CCG)

Parent Material: Colluvium	**Bedrock:** ***Kind:*** Limestone ***Fract:*** ---- ***Hard:*** ***Depth:***	**Lithostrat. Units:** ***Group:*** ***Formation:*** ***Member:***

Erosion: S (Sheet) ***Kind:*** ***Degree:*** 0	**Runoff:**	**Surface Frag %:** ***GR:*** ***CB:*** ***ST:*** ***BD:*** ***CN:*** ***FL:***	**Diagnostic Hor. / Prop.:** ***Kind:*** ***Depth:***

P.S. Control Section *:* ***Ave. Clay %:*** ***Ave. Rock Frag %:*** ***Depth Range:*** 29.5%	

Appendix (16) continued…

Pedon NO. 12 Kalar					Matrix Color		Texture	Structure	Consistence				Mottles
	Obser. Method	Depth (cm)	Horizon	Horizon Boundary	Dry	Moist		Grade Size Type	Dry	Moist	Wet		
											Stickiness	Plasticity	
1	SP	0-16	A	AS Abrupt Smooth	10 YR 6/4 Light Yellowish Brown	10 YR 4/4 Dark Yellowish Brown	SiL	1 F SBK Weak Fine Sub-angular Blocky	S Soft	VFR Very Friable	S0 Non- Sticky	MP Moderately Plastic	No
2	SP	16-61	C1	AS Abrupt Smooth	7.5 YR 6/4 Light Brown	7.5 YR 4/4 Brown	CL	1 M SBK Weak Medium Sub-angular Blocky	SH Slightly Hard	VFR Very Friable	SS Slightly Sticky	VP Very Plastic	No
3	SP	61-81	C2	AS Abrupt Smooth	7.5 YR 6/3 Light Brown	7.5 YR 4/4 Brown	SiCL	2 M SBK Moderate Medium Sub-angular Blocky	H Hard	FR Friable	SS Slightly Sticky	VP Very Plastic	No
4	SP	81-108	C3	AS Abrupt Smooth	7.5 YR 6/3 Light Brown	7.5 YR 4/3 Brown	SiCL	2 CO SBK Moderate Coarse Sub-angular Blocky	H Hard	FI Firm	SS Slightly Sticky	VP Very Plastic	No
5	SP	+108	C4	—	10 YR 6/4 Light Yellowish Brown	10 YR 5/6 Yellowish Brown	SiCL	2 M SBK Moderate Medium Sub-angular Blocky	H Hard	FI Firm	MS Moderately Sticky	VP Very Plastic	No

* SiL: Silty Loam, CL: Clay Loam, SiCL: Silty Clay Loam.

Appendix (17): Profile description report and morphological characteristics of Khanaqin

USDA-NRCS	PEDON DESCRIPTION	PEDON ID: 13		DRAFT 3/2002

Series of component Name: Khanaqin	**Map Unit Symbol:**	**Photo:** 13	**Classification:** Xeric Haplocacids	**Soil Moist. Regime (Tax):** Xeric

Describer(s): Mahtab	**Date:** 23/10/2016	**Weather:** Sunny	**Tepm:** ***Soil:***	**Air:** ***Depth:***	**Latitude:** 34º 25′ 44″ **Longitude:** 45º 20′ 60″	**Datum:** GPS	**Location:** Khanaqin

UTM: ***Zone:*** ***mE:*** ***mN:***	**Topo Quad:**	**Site ID:** ***Pedon:***13	***Yr:***	***State:*** Diyala-Iraq	***Country:***	**Soil Survey Area:**	**MLRA / LRU:**	**Transect:** ***Stop #:***	***ID:*** ***Interval:***

Landscape: Plains	**Landform:** Plains	**Micro feature:**	**Anthro:**	**Elevation:** 179 m	**Aspect:** 200º S	**Slope (%):** 5%	**Slope Complexity:**	**Slope Shape:** *(UP &Dn / Across)*

Hill slope Profile Position:	**Geom. Component:**	**Micro relief:**	**Physio. Division:**	**Physio. Province:**	**Physio. Section:**	**State Physio. Area:**	**Local Physio. Area:**

Drainage: Moderate well drained	**Flooding:** none	**Ponding:** none	**Soil Moisture Status:** Dry	**Permeability:** Moderate rapid K_{sat}**:**	**Land Cover / Use:** Wheat (CCG)

Parent Material: Colluvium	**Bedrock:** Limestone	***Kind:***	***Fract:*** ----	***Hard:***	***Depth:***	**Lithostrat. Units:**	***Group:***	***Formation:***	***Member:***

Erosion: S (Sheet)	***Kind:*** 0	***Degree:***	**Runoff:**	**Surface Frag %:**	***GR:***	***CB:***	***ST:***	***BD:***	***CN:***	***FL:***	**Diagnostic Hor. / Prop.:**	***Kind:***	***Depth:***

P.S. Control Section : ***Depth Range:***	***Ave. Clay %:*** 14.3%	***Ave. Rock Frag %:***	

Appendix (17) continued…

Pedon NO. 13 Khanaqin					**Matrix Color**		**Texture**	**Structure**	**Consistence**				**Mottles**
	Obser. Method	**Depth (cm)**	**Horizon**	**Horizon Boundary**	**Dry**	**Moist**		**Grade Size Type**	**Dry**	**Moist**	**Wet**		
											Stickiness	**Plasticity**	
1	SP	0-30	A	AS Abrupt Smooth	7.5 YR 6/3 Light Brown	7.5 YR 4/4 Brown	L	2 M SBK Moderate Medium Sub-angular Blocky	SH Slightly Hard	VFR Very Friable	S0 Non- Sticky	MP Moderately Plastic	No
2	SP	30-90	Ck1	CW Clear Wavy	7.5 YR 6/4 Light Brown	7.5 YR 4/6 Strong Brown	CL	2 M SBK Moderate Medium Sub-angular Blocky	SH Slightly Hard	FR Friable	MS Moderately Sticky	VP Very Plastic	No
3	SP	90-143	Ck2	AS Abrupt Smooth	7.5 YR 8/3 Pink	7.5 YR 7/4 Pink	SiL	2 CO SBK Moderate Coarse Sub-angular Blocky	SH Slightly Hard	VFR Very Friable	SS Slightly Sticky	MP Moderately Plastic	No
4	SP	+143	Ck3	—	7.5 YR 6/4 Light Brown	7.5 YR 5/6 Strong Brown	Si	2 M SBK Moderate Medium Sub-angular Blocky	H Hard	VFR Very Friable	SS Slightly Sticky	VP Very Plastic	No

* L: Loam, CL: Clay Loam, SiL: Silty Loam, Si: Silty

Appendix (18): Profile description report and morphological characteristics of Shwan

USDA-NRCS	PEDON DESCRIPTION	PEDON ID: 14		DRAFT 3/2002

Series of component Name: Shwan	**Map Unit Symbol:**	**Photo:** 14	**Classification:** Lithic Xeric Haplocalcids	**Soil Moist. Regime (Tax):** Xeric

Describer(s): Mahtab	**Date:** 26/11/2016	**Weather:** Sunny **Tepm:** **Air:** ***Soil:*** ***Depth:***	**Latitude:** 35º 33′ 53″ **Datum:** GPS **Longitude:** 44º 22′ 52″	**Location:** Shwan

UTM: ***Zone:*** ***mE:*** ***mN:***	**Topo Quad:**	**Site ID:** ***Yr:*** ***State:*** ***Country:*** ***Pedon:*** 14 Kirkuk-Iraq	**Soil Survey Area:**	**MLRA / LRU:**	**Transect:** ***ID:*** ***Stop #:*** ***Interval:***

Landscape: Hills	**Landform:** Hill slope	**Micro feature:**	**Anthro:**	**Elevation:** 435 m	**Aspect:** 180º S	**Slope (%):** 23%	**Slope Complexity:**	**Slope Shape:** *(UP &Dn / Across)*

Hill slope Profile Position:	**Geom. Component:**	**Micro relief:**	**Physio. Division:**	**Physio. Province:**	**Physio. Section:**	**State Physio. Area:**	**Local Physio. Area:**

Drainage: Moderate well drained	**Flooding:** none	**Ponding:** none	**Soil Moisture Status:** Dry	**Permeability:** Moderate rapid K_{sat}**:**	**Land Cover / Use:** Wheat (CCG) and Grasses (GML)

Parent Material:	**Bedrock:** ***Kind:*** ***Fract:*** ***Hard:*** ***Depth:*** Limestone	**Lithostrat. Units:** ***Group:*** ***Formation:*** ***Member:***

Erosion: G (Gully) ***Kind:*** ***Degree:*** 0	**Runoff:**	**Surface Frag %:** ***GR:*** ***CB:*** ***ST:*** ***BD:*** ***CN:*** ***FL:***	**Diagnostic Hor. / Prop.:** ***Kind:*** ***Depth:***

P.S. Control Section : ***Ave. Clay %:*** ***Ave. Rock Frag %:***
Depth Range: 21.3%

Appendix (18) continued…

Pedon NO. 14 Shwan					Matrix Color		Texture	Structure	Consistence				Mottles
	Obser. Method	Depth (cm)	Horizon	Horizon Boundary	Dry	Moist		Grade Size Type	Dry	Moist	Wet		
											Stickiness	Plasticity	
1	SP	0-29	Ap	CW Clear Wavy	10 YR 6/4 Light Yellowish Brown	10 YR 4/4 Dark Yellowish Brown	L	1 CO GR Weak Coarse Granular	S Soft	VFR Very Friable	S0 Non- Sticky	MP Moderately Plastic	No
2	SP	29-68	C1	CW Clear Wavy	10 YR 6/3 Pale Brown	10 YR 4/3 Brown	L	1 M SBK Weak Medium Sub-angular Blocky	SH Slightly Hard	FR Friable	SS Slightly Sticky	MP Moderately Plastic	No
3	SP	+68	C2	—	10 YR 7/3 Very Pale Brown	10 YR 4/3 Brown	SiL	3 CO ABK Strong Coarse Angular Blocky	H Hard	FI Firm	SS Slightly Sticky	MP Moderately Plastic	No

* L: Loam, SiL: Silty Loam

Appendix (19): Profile description report and morphological characteristics of Altuncopri-Prdei

USDA-NRCS	PEDON DESCRIPTION	PEDON ID: 15		DRAFT 3/2002

Series of component Name: Altuncopri	**Map Unit Symbol:**	**Photo:** 15	**Classification:** Xeric Haplocacids	**Soil Moist. Regime (Tax):** Xeric

Describer(s): Mahtab	**Date:** 26/11/2016	**Weather:** Sunny **Tepm:** **Air:** ***Soil:*** ***Depth:***	**Latitude:** 35º 41′ 77″ **Datum:** GPS **Longitude:** 44º 11′ 70″	**Location:** Altuncopri

UTM: ***Zone:*** ***mE:*** ***mN:***	**Topo Quad:**	**Site ID:** ***Yr:*** ***State:*** ***Country:*** ***Pedon:*** 15 Kirkuk-Iraq	**Soil Survey Area:**	**MLRA / LRU:**	**Transect:** ***ID:*** ***Stop #:*** ***Interval:***

Landscape: Plains	**Landform:** Plains	**Micro feature:**	**Anthro:**	**Elevation:** 303m	**Aspect:** 8º N	**Slope (%):** 3%	**Slope Complexity:**	**Slope Shape:** *(UP &Dn / Across)*

Hill slope Profile Position:	**Geom. Component:**	**Micro relief:**	**Physio. Division:**	**Physio. Province:**	**Physio. Section:**	**State Physio. Area:**	**Local Physio. Area:**

Drainage: Somewhat poorly drained	**Flooding:** none **Ponding:** none	**Soil Moisture Status:** Dry	**Permeability:** Rapid slow K_{sat}:	**Land Cover / Use:** Wheat (CCG) and corn (CRC)

Parent Material: Colluvium	**Bedrock:** ***Kind:*** ***Fract:*** ***Hard:*** ***Depth:*** Limestone ----	**Lithostrat. Units:** ***Group:*** ***Formation:*** ***Member:***

Erosion: S (Sheet) ***Kind:*** ***Degree:*** 0	**Runoff:**	**Surface Frag %:** ***GR:*** ***CB:*** ***ST:*** ***BD:*** ***CN:*** ***FL:***	**Diagnostic Hor. / Prop.:** ***Kind:*** ***Depth:***

P.S. Control Section : ***Ave. Clay %:*** ***Ave. Rock Frag %:***

Depth Range: 38.6%

Appendix (19) continued…

Pedon NO. 15 Altuncopri-Prdei					**Matrix Color**		**Texture**	**Structure**	**Consistence**				**Mottles**
	Obser. Method	**Depth (cm)**	**Horizon**	**Horizon Boundary**	**Dry**	**Moist**		**Grade Size Type**	**Dry**	**Moist**	**Wet**		
											Stickiness	**Plasticity**	
1	SP	0-20	Ap	CW Clear Wavy	10 YR 5/3 Brown	10 YR 3/3 Dark Brown	SiCL	1 M SBK Weak Medium Sub-angular Blocky	SH Slightly Hard	VFR Very Friable	SS Slightly Sticky	SP Moderately Plastic	No
2	SP	20-37	C1	CW Clear Wavy	10 YR 6/3 Pale Brown	10 YR 4/3 Brown	SiCL	2 CO ABK Moderate Coarse Angular Blocky	H Hard	FI Firm	SS Slightly Sticky	VP Very Plastic	No
3	SP	37-50	C2	CW Clear Wavy	10 YR 5/4 Yellowish Brown	10 YR 3/6 Dark Yellowish Brown	SiCL	1 M SBK Weak Medium Sub-angular Blocky	SH Slightly Hard	VFR Very Friable	MS Moderately Sticky	MP Moderately Plastic	No
4	SP	+50	C3	—	10 YR 6/4 Light Yellowish Brown	10 YR 4/4 Dark Yellowish Brown	SiCL	2 M SBK Moderate Medium Sub-angular Blocky	SH Slightly Hard	FR Friable	MS Moderately Sticky	VP Very Plastic	No

* SiCL: Silty Clay Loam

Appendix (20):Profile description report and morphological characteristics of Daquq

USDA-NRCS	PEDON DESCRIPTION	PEDON ID: 16		DRAFT 3/2002

Series of component Name: Daquq	**Map Unit Symbol:**	**Photo:** 16	**Classification:** Xeric Haplocalcids	**Soil Moist. Regime (Tax):** Xeric

Describer(s): Mahtab	**Date:** 10/12/2016	**Weather:** Sunny **Tepm:** **Air:** ***Soil:*** ***Depth:***	**Latitude:** 35º 10′ 06″ **Datum:** GPS **Longitude:** 44º 25′ 43″	**Location:** Daquq

UTM: ***Zone:*** ***mE:*** ***mN:***	**Topo Quad:**	**Site ID:** ***Yr:*** ***State:*** ***Country:*** ***Pedon:***16 Kirkuk-Iraq	**Soil Survey Area:**	**MLRA / LRU:**	**Transect:** ***ID:*** ***Stop #:*** ***Interval:***

Landscape: Plains	**Landform:** Plains	**Micro feature:**	**Anthro:**	**Elevation:** 229 m	**Aspect:** 352º N	**Slope (%):** 3%	**Slope Complexity:**	**Slope Shape:** *(UP &Dn / Across)*

Hill slope Profile Position:	**Geom. Component:**	**Micro relief:**	**Physio. Division:**	**Physio. Province:**	**Physio. Section:**	**State Physio. Area:**	**Local Physio. Area:**

Drainage: Well drained	**Flooding:** none **Ponding:** none	**Soil Moisture Status:** Dry	**Permeability:** Moderate K_{sat}**:**	**Land Cover / Use:** Wheat (CCG)

Parent Material: Colluvium	**Bedrock:** ***Kind:*** ***Fract:*** ***Hard:*** ***Depth:*** Limestone ----	**Lithostrat. Units:** ***Group:*** ***Formation:*** ***Member:***

Erosion: S (Sheet) ***Kind:*** ***Degree:*** 0	**Runoff:**	**Surface Frag %:** ***GR:*** ***CB:*** ***ST:*** ***BD:*** ***CN:*** ***FL:***	**Diagnostic Hor. / Prop.:** ***Kind:*** ***Depth:***

P.S. Control Section *:* ***Ave. Clay %:*** ***Ave. Rock Frag %:*** ***Depth Range:*** 7.0%	 

Appendix (20) continued…

Pedon NO. 16 Daquq					**Matrix Color**		**Texture**	**Structure**	**Consistence**				**Mottles**
	Obser. Method	**Depth (cm)**	**Horizon**	**Horizon Boundary**	**Dry**	**Moist**		**Grade Size Type**	**Dry**	**Moist**	**Wet**		
											Stickiness	**Plasticity**	
1	SP	0-29	A	CW Clear Wavy	10 YR 6/4 Light Yellowish Brown	10 YR 5/4 Yellowish Brown	SiL	1 M GR Weak Medium Granular	S Soft	VFR Very Friable	S0 Non- Sticky	SP Slightly Plastic	No
2	SP	29-87	Ck1	CW Clear Wavy	10 YR 6/4 Light Yellowish Brown	10 YR 3/6 Dark Yellowish Brown	SiL	1 M SBK Weak Medium Sub-angular Blocky	SH Slightly Hard	VFR Very Friable	S0 Non- Sticky	MP Moderately Plastic	No
3	SP	+87	Ck2	—	10 YR 6/4 Light Yellowish Brown	10 YR 4/4 Dark Yellowish Brown	SiL	2 M SBK Moderate Medium Sub-angular Blocky	SH Slightly Hard	FR Friable	SS Slightly Sticky	VP Very Plastic	No

* SiL: Silty Loam

Appendix (21): Profile description report and morphological characteristics of Lailan

USDA-NRCS	PEDON DESCRIPTION	PEDON ID: 17		DRAFT 3/2002

Series of component Name: Lailan	**Map Unit Symbol:**	**Photo:** 17	**Classification:** Xeric Haplocalcids	**Soil Moist. Regime (Tax):** Xeric

Describer(s): Mahtab	**Date:** 10/12/2016	**Weather:** Sunny	**Tepm:** ***Soil:***	**Air:** ***Depth:***	**Latitude:** 35º 19′ 10″ **Longitude:** 44º 27′ 83″	**Datum:** GPS	**Location:** Lailan

UTM: ***Zone:*** ***mE:*** ***mN:***	**Topo Quad:**	**Site ID:** ***Yr:*** ***State:*** ***Country:*** ***Pedon:*** 17 Kirkuk-Iraq	**Soil Survey Area:**	**MLRA / LRU:**	**Transect:** ***ID:*** ***Stop #:*** ***Interval:***

Landscape:	**Landform:**	**Micro feature:**	**Anthro:**	**Elevation:**	**Aspect:**	**Slope (%):**	**Slope Complexity:**	**Slope Shape:** *(UP &Dn / Across)*
Plains	Plains			310 m	155º SE	2%		

Hill slope Profile Position:	**Geom. Component:**	**Micro relief:**	**Physio. Division:**	**Physio. Province:**	**Physio. Section:**	**State Physio. Area:**	**Local Physio. Area:**

Drainage:	**Flooding:**	**Ponding:**	**Soil Moisture Status:**	**Permeability:** Moderate K_{sat}:	**Land Cover / Use:**
Well drained	none	none	Dry		Wheat (CCG)

Parent Material:	**Bedrock:**	***Kind:***	***Fract:***	***Hard:***	***Depth:***	**Lithostrat. Units:**	***Group:***	***Formation:***	***Member:***
Colluvium	Limestone		----						

Erosion: S (Sheet)	***Kind:*** 0	***Degree:***	**Runoff:**	**Surface Frag %:** ***GR:*** ***CB:*** ***ST:*** ***BD:*** ***CN:*** ***FL:***	**Diagnostic Hor. / Prop.:**	***Kind:***	***Depth:***

P.S. Control Section :	***Ave. Clay %:***	***Ave. Rock Frag %:***
Depth Range:	38.3%	

Appendix (21) continued…

Pedon NO. 17 Lailan					Matrix Color		Texture	Structure	Consistence				Mottles
											Wet		
	Obser. Method	Depth (cm)	Horizon	Horizon Boundary	Dry	Moist		Grade Size Type	Dry	Moist	Stickiness	Plasticity	
1	SP	0-7	A	AS Abrupt Smooth	10 YR 6/4 Light Yellowish Brown	10 YR 4/4 Dark Yellowish Brown	SiCL	1 CO GR Weak Coarse Granular	SH Slightly Hard	VFR Very Friable	SS Slightly Sticky	VP Very Plastic	No
2	SP	7-23	Ck1	CW Clear Wavy	10 YR 5/3 Brown	10 YR 3/3 Dark Brown	SiCL	1 M SBK Weak Medium Sub-angular Blocky	SH Slightly Hard	FR Friable	SS Slightly Sticky	VP Very Plastic	No
3	SP	23-60	Ck2	CW Clear Wavy	10 YR 5/4 Yellowish Brown	10 YR 3/4 Dark Yellowish Brown	SiC	2 M SBK Moderate Medium Sub-angular Blocky	H Hard	FI Firm	MS Moderately Sticky	VP Very Plastic	No
4	SP	+60	Ck3	—	10 YR 5/4 Yellowish Brown	10 YR 4/4 Dark Yellowish Brown	SiC	3 CO SBK Strong Coarse Sub-angular Blocky	H Hard	FI Firm	MS Moderately Sticky	VP Very Plastic	No

* SiCL: Silty Clay Loam, SiL: Silty Clay

Appendix (22): Profile description report and morphological characteristics of Qushtapa

USDA-NRCS	PEDON DESCRIPTION	PEDON ID: 18		DRAFT 3/2002

Series of component Name:	**Map Unit Symbol:**	**Photo:** 18	**Classification:**	**Soil Moist. Regime (Tax):**
Qushtapa			Xeric haplocalcids	Xeric

Describer(s):	**Date:**	**Weather:** **Tepm:** **Air:**	**Latitude:** 35° 55′ 88″ **Datum:** GPS	**Location:**
Mahtab	13/12/2016	Sunny ***Soil:*** ***Depth:***	**Longitude:** 43° 56′ 78″	Qushtapa

UTM: ***Zone:*** ***mE:*** ***mN:***	**Topo Quad:**	**Site ID:** ***Yr:*** ***State:*** ***Country:***	**Soil Survey Area:**	**MLRA / LRU:**	**Transect:** ***ID:***
		Pedon:18 Hawler-Iraq			***Stop #:*** ***Interval:***

Landscape:	**Landform:**	**Micro feature:**	**Anthro:**	**Elevation:**	**Aspect:**	**Slope (%):**	**Slope Complexity:**	**Slope Shape:***(UP &Dn / Across)*
Plains	Plains			350 m	244° W	5%		

Hill slope Profile Position:	**Geom. Component:**	**Micro relief:**	**Physio. Division:**	**Physio. Province:**	**Physio. Section:**	**State Physio. Area:**	**Local Physio. Area:**

Drainage:	**Flooding:**	**Ponding:**	**Soil Moisture Status:**	**Permeability:** Moderate rapid	**Land Cover / Use:**
Moderate well drained	none	none	Moist	K_{sat}**:**	Wheat (CCG) and corn (CRC)

Parent Material:	**Bedrock:** ***Kind:*** ***Fract:*** ***Hard:*** ***Depth:***	**Lithostrat. Units:** ***Group:*** ***Formation:*** ***Member:***
Colluvium	Limestone ----	

Erosion: S ***Kind:*** ***Degree:***	**Runoff:**	**Surface Frag %:** ***GR:*** ***CB:*** ***ST:*** ***BD:*** ***CN:*** ***FL:***	**Diagnostic Hor. / Prop.:** ***Kind:*** ***Depth:***
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P.S. Control Section : ***Ave. Clay %:*** ***Ave. Rock Frag %:***

Depth Range: 36.4%

Appendix (22) continued…

Pedon NO. 18 Qushtapa					Matrix Color		Texture	Structure	Consistence				Mottles
	Obser. Method	Depth (cm)	Horizon	Horizon Boundary	Dry	Moist		Grade Size Type	Dry	Moist	Wet: Stickiness	Wet: Plasticity	
1	SP	0-14	A	CW Clear Wavy	10 YR 6/3 Pale Brown	10 YR 4/3 Brown	SiCL	1 M GR Weak Medium Granular	S Soft	VFR Very Friable	SS Slightly Sticky	VP Very Plastic	No
2	SP	14-58	Ck1	CW Clear Wavy	10 YR 5/4 Yellowish Brown	10 YR 4/4 Dark Yellowish Brown	SiCL	1 F SBK Weak Fine Sub-angular Blocky	SH Slightly Hard	FR Friable	MS Moderately Sticky	VP Very Plastic	No
3	SP	+58	Ck2	—	10 YR 6/4 Light Yellowish Brown	10 YR 4/4 Dark Yellowish Brown	SiCL	2 F SBK Moderate Fine Sub-angular Blocky	SH Slightly Hard	FR Friable	SS Slightly Sticky	VP Very Plastic	No

* SiCL: Silty Clay Loam

Appendix (23): Profile description report and morphological characteristics of Makhxmoor

USDA-NRCS	PEDON DESCRIPTION	PEDON ID: 19		DRAFT 3/2002

Series of component Name:	**Map Unit Symbol:**	**Photo:** 19	**Classification:**	**Soil Moist. Regime (Tax):**
Makhmoor			Xeric Haplogypsids	Xeric

Describer(s):	**Date:**	**Weather:**	**Tepm:**	**Air:**	**Latitude:** 35° 47′ 75″	**Datum:** GPS	**Location:**
Mahtab	13/12/2016	Sunny	***Soil:***	***Depth:***	**Longitude:** 43° 36′ 08″		Makhmoor

UTM: ***Zone:*** ***mE:*** ***mN:***	**Topo Quad:**	**Site ID:** ***Yr:***	***State:*** ***Country:***	**Soil Survey Area:**	**MLRA / LRU:**	**Transect:** ***ID:***
		Pedon: 19	Hawler-Iraq			***Stop #:*** ***Interval:***

Landscape:	**Landform:**	**Micro feature:**	**Anthro:**	**Elevation:**	**Aspect:**	**Slope (%):**	**Slope Complexity:**	**Slope Shape:** *(UP &Dn / Across)*
				303 m	245° SW	5%		

Hill slope Profile Position:	**Geom. Component:**	**Micro relief:**	**Physio. Division:**	**Physio. Province:**	**Physio. Section:**	**State Physio. Area:**	**Local Physio. Area:**

Drainage:	**Flooding:**	**Ponding:**	**Soil Moisture Status:**	**Permeability:** Moderate rapid	**Land Cover / Use:**
Moderate well drained	none	none	Moist	K_{sat}**:**	Wheat (CCG)

Parent Material:	**Bedrock:** ***Kind:*** ***Fract:*** ***Hard:*** ***Depth:***	**Lithostrat. Units:** ***Group:*** ***Formation:*** ***Member:***
Colluvium	Limestone ----	

Erosion:S ***Kind:*** ***Degree:***	**Runoff:**	**Surface Frag %:** ***GR:*** ***CB:*** ***ST:*** ***BD:*** ***CN:*** ***FL:***	**Diagnostic Hor. / Prop.:** ***Kind:*** ***Depth:***
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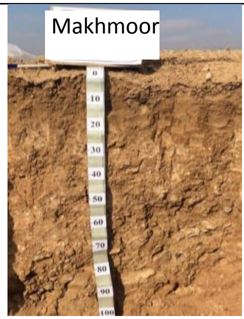
P.S. Control Section : ***Ave. Clay %:*** ***Ave. Rock Frag %:***

Depth Range: 13.8%



Appendix (23) continued…

Pedon NO. 19 Makhmoor					Matrix Color		Texture	Structure	Consistence				Mottles
											Wet		
	Obser. Method	Depth (cm)	Horizon	Horizon Boundary	Dry	Moist		Grade Size Type	Dry	Moist	Stickiness	Plasticity	
1	SP	0-23	A	AS Abrupt Smooth	10 YR 6/4 Light Yellowish Brown	10 YR 4/6 Dark Yellowish Brown	L	1 M GR Weak Medium Granular	S Soft	VFR Very Friable	S0 Non- Sticky	MP Moderately Plastic	No
2	SP	23-79	Ck1	CW Clear Wavy	10 YR 7/4 Very Pale Brown	10 YR 4/6 Dark Yellowish Brown	L	1 M SBK Weak Medium Sub-angular Blocky	S Soft	VFR Very Friable	SS Slightly Sticky	MP Moderately Plastic	No
3	SP	79-110	Ck2	AS Abrupt Smooth	10 YR 6/4 Light Yellowish Brown	10 YR 4/4 Dark Yellowish Brown	SiL	2 M SBK Moderate Medium Sub-angular Blocky	H Hard	FI Firm	SS Slightly Sticky	MP Moderately Plastic	No
4	SP	+110	Ck3	—	7.5 YR 6/4 Light Brown	7.5 YR 4/6 Strong Brown	SL	1 F SBK Weak Fine Sub-angular Blocky	SH Slightly Hard	FR Friable	SS Slightly Sticky	SP Slightly Plastic	No

* L: Loam, SiL: Silty Loam, SL: Sandy Loam

Appendix (24): Profile description report and morphological characteristics of Gwer

USDA-NRCS	PEDON DESCRIPTION	PEDON ID: 20		DRAFT 3/2002

Series of component Name:	**Map Unit Symbol:**	**Photo:** 20	**Classification:**	**Soil Moist. Regime (Tax):**
Gwer			Xeric Haplocalcids	Xeric

Describer(s):	**Date:**	**Weather:**	**Tepm:**	**Air:**	**Latitude:** 36º 02′ 02″	**Datum:** GPS	**Location:**
Mahtab	13/12/2016	Sunny	***Soil:***	***Depth:***	**Longitude:** 43º 29′ 65″		Gwer

UTM: ***Zone:*** ***mE:*** ***mN:***	**Topo Quad:**	**Site ID:** ***Yr:*** ***State:*** ***Country:***	**Soil Survey Area:**	**MLRA / LRU:**	**Transect:** ***ID:***
		Pedon: 20 Hawler-Iraq			***Stop #:*** ***Interval:***

Landscape:	**Landform:**	**Micro feature:**	**Anthro:**	**Elevation:**	**Aspect:**	**Slope (%):**	**Slope Complexity:**	**Slope Shape:** *(UP &Dn / Across)*
				210 m	257º W	4%		

Hill slope Profile Position:	**Geom. Component:**	**Micro relief:**	**Physio. Division:**	**Physio. Province:**	**Physio. Section:**	**State Physio. Area:**	**Local Physio. Area:**

Drainage:	**Flooding:**	**Ponding:**	**Soil Moisture Status:**	**Permeability:** very slow	**Land Cover / Use:**
Poorly drained	none	none	Moist	$\boldsymbol{K_{sat}}$**:**	Wheat (CCG)

Parent Material:	**Bedrock:** ***Kind:*** ***Fract:*** ***Hard:*** ***Depth:***	**Lithostrat. Units:** ***Group:*** ***Formation:*** ***Member:***
Colluvium	Limestone ----	

Erosion: S ***Kind:*** ***Degree:***	**Runoff:**	**Surface Frag %:** ***GR:*** ***CB:*** ***ST:*** ***BD:*** ***CN:*** ***FL:***	**Diagnostic Hor. / Prop.:** ***Kind:*** ***Depth:***
(Sheet) 0			

P.S. Control Section : ***Ave. Clay %:*** ***Ave. Rock Frag %:***

Depth Range: 19.7%

Appendix (24) continued…

Pedon NO. 20 Gwer					Matrix Color		Texture	Structure	Consistence				Mottles
	Obser. Method	Depth (cm)	Horizon	Horizon Boundary	Dry	Moist		Grade Size Type	Dry	Moist	Wet		
											Stickiness	Plasticity	
1	SP	0-14	A	CW Clear Wavy	10 YR 5/4 Yellowish Brown	10 YR 4/4 Dark Yellowish Brown	SL	2 CO SBK Moderate Coarse Sub-angular Blocky	H Hard	FI Firm	SS Slightly Sticky	MP Moderately Plastic	No
2	SP	14-48	Ck	CW Clear Wavy	10 YR 7/3 Very Pale Brown	10 YR 4/4 Dark Yellowish Brown	L	2 CO SBK Moderate Coarse Sub-angular Blocky	H Hard	FR Friable	SS Slightly Sticky	MP Moderately Plastic	No

* SL: Sandy Loam, L: Loam

الخلاصة

أجريت الدراسة لتقيم حالة التصحر و جودة التربة و ملائمة الأرض و تصنيف قابلية الأرض للأراضي الجافة في بعض مناطق العراق و أقليم كوردستان العراق.

تضمنت منطقة الدراسة الأراضي الجافة و شبه الجافة التي تقع بين خطي الطول ٤٣° ٢٥' ٤"- ٤٦° ٢٨' ١" شرقاً و دائرتي العرض ٣٤° ١٨' ٣٣"- ٣٦° ٢٠' ٥٦" شمالاً و التي تضمنت أجزاء في محافظات السليمانية و ديالى و كركوك و أربيل في العراق و بمساحة أجمالية بلغت ٢٦٤٥٦٠٠ هكتار.

تم حفر٢٠ مقد تربة و وصفت مورفولوجياً. و بالإضافة الى ذلك تم أخذ ٨٩ نموذجاً للترب السطحية للمناطق المجاورة لهذه المقدات. أخذت نماذج التربة للمختبر و تم تجفيفها هوائياً و مررت بمناخل قطرها ٢ملم بغية تهيئتها للتحاليل الكيميائية و الفيزيائية.

تم تقييم حالة التصحر بأستخدام طريقة نموذج MEDALUS المقترحة من قبل (Kosmas et al., 1999b) و بأستخدام برنامج GIS لرسم الخرائط.

بناءاً على معدل سقوط الأمطار السنوية تبين بأن منطقة الدراسة تقع ضمن ثلاثة أحزمة مناخية تضمنت حزام ٢ ﴿المنطقة الجافة (١٠٠-٣٠٠) ملم﴾ و حزام ٣ ﴿شبه جافة (٣٠٠-٥٠٠) ملم﴾ و حزام ٤ ﴿المنطقة الجافة تحت الرطبة (>٥٠٠) ملم﴾ و ذلك بناءاً على التصنبف المقترح من قبل (FAO،١٩٩٨)، و بعدها تم تقدير جودة التربة في كل حزام مناخي.

و من ثم تم تصنيف ملائمة الأرض حسب ما جاء في Sys و آخرون ١٩٩٣، و تصنيف قابلية الأراضي حسب ما جاء في دليل مسح التربة الأمريكي، ١٩٧١.

النتائج التي تم الحصول عليها في هذه الدراسة كانت كالآتي:-

١- تقييم حالة التصحر

أ- دليل جودة التربة (SQI)

- تراوحت نسجة التربة بين الصنف الثاني (المتوسط) و الصنف الثالث (الفقير) و بمساحة بلغت (٧٣٧١٠٠ و ١٩٠٨٥٠٠) هكتار و التي غطت بنسبة ٢٧,٨٦٪ و ٧٢,١٤٪ من مساحة منطقة الدراسة على التوالي.
- إن مادة الأصل لترب منطقة الدراسة تقع ضمن الصنف الثاني (متوسط).
- دليل إنتشار الحصى و الصخور يقع ضمن الصنف الثالث (عارية للصخور- قليلة الصخرية) و التي شملت ٩٩,٢٥٪ من المساحة الكلية لمنطقة الدراسة.
- دليل إنحدار التربة في معظم أجزاء منطقة الدراسة كان ضمن الصنف الثاني (مستوي) و بمساحة بلغت ٢٥٦١٠٠٠ هكتار و التي غطت مساحة نسبتها ٩٦,٨٠٪ من منطقة الدراسة. و بقية المساحة كانت ضمن الأصناف الأولى و الثالثة و الرابعة التي غطت جميعها مساحة ٣,٢٠٪ من منطقة الدراسة.
- دليل عمق التربة يقع ضمن الصنف الأول (عميق).
- دليل حالة بزل التربة يقع ضمن الصنفين الثاني (بزل ناقص) و الصنف الثالث (بزل فقير) و بمساحة بلغت (٢١٥٠٦٠٠ و ٤٩٥٠٠٠) هكتار و بنسبة بلغت ٨١,٢٩٪ و ١٨,٧١٪ على التوالي.
- دليل المادة العضوية انتمت الى الأصناف الثاني (جيد) و الثالث (فقير) و الرابع (فقير جداً). بلغت مساحة الصنف الثالث ٢١٤٤٣٠٠ هكتار و بنسبة بلغت ٨١٪ و الذي تفوق على الصنف الثاني و الرابع اللذان بلغا مساحتها (٢٢٤٨٠٠ و ٢٧٦٥٠٠) هكتار و بنسبة بلغت (٨,٥ و ١٠,٥)٪ من المساحة الكلية لكل منهما على التوالي.
- دليل كاربونات الكالسيوم يقع ضمن الصنف الثالث (فقير) في الأغلب، حيث غطت مساحة ٢٦٠٨٢٠٠ هكتار و بنسبة ٩٨,٥٩٪ من منطقة الدراسة.

لدى حساب أوزان دليل جودة التربة تبين بأن تربة منطقة الدراسة يمكن تقسيمها الى صنفين و هما الصنف الثاني ٢٥١٤٧٠٠ هكتار و بنسبة بلغت ٩٥٪، و الصنف الثالث (جودة منخفضة) الذي بلغ مساحتها ١٣٠٩٠٠ هكتار و بنسبة ٥٪ من مساحة منطقة الدراسة.

ب- دليل جودة الغطاء النباتي (VQI)

- تبين من النتائج إن الغطاء النباتي كان من الصنف الثاني (منخفض)، مما يدل على ان منطقة الدراسة ليست محمية من التصحر.
- خطورة الحرائق كانت ضمن الصنف الثاني (متوسط).
- مقاومة الجفاف كانت ضمن الصنف الخامس (فقير جداً).
- تقسم منطقة الدراسة الى صنفين من حيث دليل الحماية من التعرية و هما الصنف الثالث (منخفض) و مساحتها ٨٠٣٧٠٠ هكتار و الصنف الرابع (منخفض جداً) بمساحة ١٨٤١٩٠٠ هكتار اللذان غطيا نسبة (٣٠,٣٨ و ٦٩,٦٢)٪ من المساحة الكلية لمنطقة الدراسة على التوالي.

دليل جودة الغطاء النباتي تقع ضمن الصنف الثاني (جودة متوسطة) و مساحته ٧٦٠١٠٠ هكتار و الصنف الثالث (جودة منخفضة) و مساحته ١٨٨٥٥٠٠ هكتار و بنسبة ٢٨,٧٣٪ و ٧١,٢٧٪ لكل منهما على التوالي.

ج- دليل جودة المناخ (CQI)

- تقسم منطقة الدراسة الى صنفين من حيث جودة التساقط و هما الصنف الأول (جودة عالية) و مساحتها ٢٨٩٨٠٠ هكتار و نسبتها ١٠,٩٥٪ من المساحة الكلية، أما الصنف الآخر فهو الصنف الثاني (جودة متوسطة) الذي يشغل مساحة قدرها ٢٣٥٥٨٠٠ هكتار و بنسبة بلغت ٨٩,٠٥٪ من المساحة الكلية.
- دليل القحولة لمنطقة الدراسة كان ضمن الصنفين الرابع و الخامس اللذان شغلا (٧٠٦٥٠٠ و ١٩٣٩١٠٠) هكتار و بنسبة بلغت ٢٦,٧٠٪ و ٧٣,٣٠٪ لكل منهما على التوالي.
- جودة المناخ لمنطقة الدراسة تقع ضمن الصنف الثاني (متوسط).

ء- دليل جودة الأدارة (MQI)

- أراضي المحاصيل لمنطقة الدراسة تقع ضمن الصنف الثاني (شدة أستعمال الأراضي متوسطة).

- دليل معايير الخطط قسمت الى ثلاثة أصناف رئيسية و هي الصنف الأول (عالي) و الصنف الثاني (متوسط) و الصنف الثالث (منخفض) و بمساحة بلغت ٤٨٦٥٠٠ هكتار ، (١٨,٣٩٪) و ٧١٥٠٠٠ هكتار (٢٧,٠٣٪) و١٤٤٤١٠٠ هكتار (٥٤,٥٨٪) لكل منهم على التوالي.

دليل جودة الأدارة لمنطقة الدراسة قسمت الى ثلاثة أصناف و يتضمن الصنف الأول (عالي) و مساحتها ٤٥٦٢٠٠ هكتار و الصنف الثاني (متوسط) و مساحتها ٧٤٧١٠٠ هكتار و الصنف الثالث (منخفض) ومساحتها ١٤٤٢٣٠٠ هكتار و الذين يشغلون (١٧,٢٤ و ٢٨,٢٤ و ٥٤,٥٢)٪ من مساحة منطقة الدراسة على التوالي.

هـ- الحساسية البيئية للتصحر ESAs

المساحة الأكثر شيوعاً الخاصة بالحساسية البيئية كانت ضمن الصنف الثالث (حرج) و مساحتها ١١١٢٧٠٠ هكتار و بنسبة بلغت ٤٢,٠٦٪ من منطقة الدراسة، و يليها الصنفين الثاني والأول و مساحتها (٧٥٩٧٠٠ و ٣٦٤٠٠٠) هكتار و اللذان شغلا (٢٨,٧١ و ١٣,٧٦)٪ من منطقة الدراسة على التوالي. أما أصناف الهش (F2, F3) شغلا مساحة قدرها (٣٠٩٣٠٠ و ٩٩٩٠٠) هكتار و بنسبة بلغت (١١,٦٩ و ٣,٧٨)٪ على التوالي.

٢- جودة التربة لمنطقة الدراسة

أ- إن نسبة الطين في الحزام الرابع و الثالث بلغت (٣٨,٦ و ٣٧,٥)٪ على التوالي و بفارق معنوي مع الحزام الثاني الذي بلغ ٢٠,٧٪ في حين لم يلاحظ أي فرق معنوي بين الحزامين الثالث و الرابع.

ب- ظهر فرق غير معنوي (P=0.163) في الأحزمة الجافة بالنسبة للكثافة الظاهرية. تفوق الحزام الرابع على الحزام الثالث و الذي بدوره تفوق على الحزام الثاني بقيم بلغت (١,٦٦ و ١,٦٢ و ١,٥٩) ميغاغرام م$^{-٣}$ على التوالي.

ت- ظهرت اختلافات معنوية بين الحزام الثالث و الرابع في محتوى الكاربون العضوي و بنسب بلغت ٠,٩٠٪ و ٠,٨١٪ على التوالي. في حين إن الحزام الثالث تفوق على الحزام الرابع و كليهما تفوقا على الحزام المناخي الثاني معنوياً و الذي بلغت نسبته ٠,٤٦٪.

ث- لم يظهر الأحزمة المناخية أية إختلافات معنوية في درجة تفاعل التربة حيث بلغت معدل القيمة ٧,٨٩ و ٧,٨٦ و ٧,٧٧ للأحزمة المناخية الثانية و الثالثة و الرابعة على التوالي ($P>0.05$)، على الرغم من وجود إختلافات قليلة في القيم حيث أن قيمته في الحزام الثاني كانت أعلى من الحزام الثالث و تفوقا على الحزام الرابع.

ج- جميع ترب الدراسة لم تكن مالحة حيث بلغت معدل قيم التوصيل الكهربائي (٠,٤٨ و ٠,٣٨ و ٠,٢٠) دسسمنز م$^{-1}$ للأحزمة المناخية الثانية و الثالثة و الرابعة على التوالي و بفروقات غير معنوية.

ح- لم يكن هناك فروقات معنوية بين الأحزمة المناخية في كمية البوتاسيوم الجاهز ($P>0.05$) و لكن اختلفوا في القيم، حيث كانت كمية البوتاسيوم الجاهز أعلاها في الحزام الرابع ٠,٦١٤ سنتمول كغم$^{-1}$ و تلاها الحزام الثالث ٠,٥٦٤ سنتمول.كغم$^{-1}$ ثم الحزام الثاني ٠,٤٥١ سنتمول كغم$^{-1}$.

خ- هناك اختلاف معنوي في الناتروجين الجاهز بين الحزام الثاني من جهة و الحزامين الثالث و الرابع من جهة أخرى. و بقيم بلغت (١,٥٦٧ و ٢,٣٣٤ و ٢,٢٢٢) غم كغم$^{-1}$ للأحزمة المناخية الثانية و الثالثة و الرابعة على التوالي، مع عدم وجود فروقات معنوية بين الحزامين الثالث و الرابع.

د- لم يلاحظ فروقات معنوية بين الأحزمة المناخية من حيث كمية الفسفور الجاهز و بلغت القيم (٤,٣٢ و ٥,٦٥ و ٤,٧٨) مايكروغرام كغم$^{-1}$ للأحزمة المناخية الرابعة و الثالثة و الثانية على التوالي.

ذ- لم يلاحظ فروقات معنوية بين الأحزمة المناخية في تركيز الكالسيوم المتبادل، حيث تفوق الحزام الرابع تلاها الحزامين الثالث و الثاني و بقيم بلغت (٢٢,٥ و ٢٢,٣ و ١٨,٢) سنتمول كغم$^{-1}$ على التوالي.

ر- لم يظهر فروقات معنوية في تركيز مغنسيوم المتبادل بين الحزامين الثالث و الرابع و لكنهما إختلفتا عن الحزام الثاني معنوياً و بقيم بلغت (٥,١ و ٧,٤ و ١,٦) سنتمول كغم$^{-1}$ للأحزمة المناخية الرابعة و الثالثة و الثانية على التوالي.

١- بلغت قيم الصوديوم المتبادل (٠,٢١٥، ٠,٢٢١ و ٠,١٩٣) سنتمول كغم$^{-1}$ للأحزمة المناخية الرابعة و الثالثة و الثانية على التوالي. و أختلف الحزام الثاني معنوياً مع الحزام الثالث و لم يختلف معنوياً مع الحزام الرابع.

٢- بلغت قيم البوتاسيوم المتبادل (٠,٤٠ و ٠,٥٣ و ٠,٥٩) سنتمول كغم$^{-1}$ للأحزمة المناخية الثانية و الثالثة والرابعة على التوالي. كما أختلف الحزام المناخي الثاني إختلافاً معنوياً مع الحزام الرابع، و لكن ظهر اختلاف غير معنوي بين الحزامين الثاني و الثالث، و أيضاً بين الحزام الثالث و الرابع. و كان نمط توزيع البوتاسيوم المتبادل متماثلة مع البوتاسيوم الجاهز.

٣- اختلفت الأحزمة المناخية في قيمة السعة التبادلية الكاتيونية معنوياً. أعلى القيم ظهرت في الحزام الرابع (٢٦,١ سنتمول كغم$^{-1}$)، تلاها الحزام الثالث (٢١,٩ سنتمول كغم$^{-1}$) ثم الحزام الثاني (١٥,٧ سنتمول كغم$^{-1}$).

٤- ظهرت إختلافات معنوية في كمية معدن الكاربونات بين الأحزمة المناخية، أقل قيمة ظهرت في الحزام الثاني (٣١٦,٤ غم.كغم$^{-1}$) تلاها الحزامين الثالث (٢٠٤,٠ غم كغم$^{-1}$) و من ثم الحزام الرابع (١٧١,٠ غم كغم$^{-1}$).

٣- ملائمة الأرض لزراعة محصول الحنطة

أ- أراضي منطقة الدراسة كانت عميقة و لا يوجد محددات بالنسبة للعمق و تراوحت معدل القيم ٩٠ و ٩٥ و ١٠٠ لمعظم البيدونات.

ب- تراوحت معدل قيمة النسجة بين ٩٨ و ١٠٠ لترب منطقة الدراسة مما يدل على عدم وجود محددات بالنسبة لهذه الصفة.

ت- القيمة المقدرة للكاربونات بلغت ٤٠-١٠٠ و هذا يدل على إن معادن الكاربونات قد يكون عامل محدد في نمو الحنطة.

ث- بلغت قيم ملوحة التربة ٩٥,٢ و ٩٥,٣ لمعظم إجزاء منطقة الدراسة مما يدل على وجود محدد بسيط لهذه الصفة.

ج- تراوحت قيم درجة تفاعل التربة ٨٧-١٠٠. و لم تصل درجة تفاعل التربة الى الحد الذي يؤثر في نمو الحنطة.

ح- قيمة السعة التبادلية الكاتيونية لها تأثير مختلف في ملائمة الأرض. ففي بعض المناطق بلغت درجة الملائمة ٦٠ الأمر الذي يدل على تأثير واضح في ملائمة الأرض، ولكن في معظم المناطق الأخرى كانت ١٠٠ مما يدل على عدم تأثيره.

خ- أختلفت قيم درجة الكاربون العضوي بين مناطق الدراسة. في أغلب المناطق كان ١٠٠ مما يدل على عدم وجود محددات و انخفضت في مناطق أخرى الى ٧٣.

د- لم يظهر تأثير لخصائص الفيضانات على ملائمة الأرض لزراعة الحنطة، حيث بلغت الدرجة ١٠٠ لجميعها.

ذ- لم يؤثر حالة البزل على ملائمة الأرض بشكل ملحوظ حيث تراوحت الدرجة ٩٥ و ١٠٠ لمعظم المواقع.

ر- بلغت درجة نسبة التشبع بالقواعد ١٠٠ درجة لجميع مناطق الدراسة مما يدل على عدم وجود تأثير لهذه الصفة على الملائمة.

ز- بلغت درجة الكاتيونات الكلية ١٠٠ و يدل هذا على عدم وجود تأثير على الملائمة.

س- تبين من النتائج شيوع ثلاثة أصناف رئيسية تتعلق بملائمة الأرض لزراعة الحنطة. و كالآتي:-

- صنف S2 (متوسط الملائمة): إن أراضي هذا الصنف متوسطة الملائمة لزراعة الحنطة. و بلغت مساحتها ٢٦٠٨٠٠ هكتار و بنسبة مئوية بلغت ١٠٪ من المساحة الكلية.
- صنف S3 (هامشية الملائمة): و هي أراضي هامشية بلغت مساحتها ١٨٤٤٧٠٠ هكتار و يشغل ٦٩,٧٢٪ من منطقة الدراسة.
- صنف N1 (غير ملائمة في الوقت الحاضر): يبلغ مساحة هذا الصنف ٥٣٩١٠٠ هكتار الذي يشغل ٢٠,٣٧٪ من المساحة الكلية.

٤- تصنيف قابلية الأراضي

صنف قابلية الأراضي إلى خمسة أصناف رئيسية التي شملت:-

- صنف II: بلغت مساحة هذا الصنف ٤٢٥٠٠ هكتار و بنسبة ١,٦٪ من المساحة الكلية لمنطقة الدراسة. و تضمنت تحت الصنف كل من IIe1 و IIs1e1.

- صنف III: بلغت مساحة الصنف الثالث ٧٧٠٠٠ هكتار و بنسبة ٢,٩٪ من المساحة الكلية لمنطقة الدراسة. و تضمنت تحت الصنف كل من IIIe و IIIs و IIIew و IIIc و IIIce.
- صنف IV: بلغت مساحة هذا الصنف ٢٠٩٠٦٠٠ هكتار (٧٩٪). و تضمنت تحت الصنف كل من IVe و IVs و IVc.
- صنف V: بلغت مساحة هذا الصنف ٤٢٠٠٠٠ هكتار و بنسبة ١٥,٩٪ من المساحة الكلية.
- صنف VI: بلغت مساحة هذا الصنف ١٥٥٠٠ هكتار و بنسبة ٠,٦٪ من المساحة الكلية لمنطقة الدراسة.

حكومة أقليم كوردستان

وزارة التعليم العالي و البحث العلمي

جامعة السليمانية

كلية علوم الهندسة الزراعية

تصنيف و حالة تدهور الأراضي و تصحر الأراضي الجافة في أقليم كوردستان – العراق

رسالة

مقدمة الى مجلس كلية علوم الهندسة الزراعية في جامعة السليمانية

كجزء من متطلبات نيل شهادة دكتوراه في

(مسح و تصنيف التربة)

من قبل

مهتاب حمه صالح فقى قادر

بكالوريوس في الزراعة- علوم التربة- جامعة السليمانية - ٢٠٠٠

ماجستر في الزراعة- علوم التربة و المياه- جامعة السليمانية ٢٠٠٧

باشراف

د. دلشاد رسول عزيز

مساعد بروفيسور

٢٧١٩ ك ١٤٤١ هـ ٢٠٢٠ م

پوختە

ئەم لێکۆڵینەوەیە ئەنجامدراوە بە مەبەستی هەڵسەنگاندنی دیاردەی بە بیابانبوون و جۆرایەتی و گونجاندنی خاك، هەروەها پۆلێن کردنی توانایی زەوی بۆ هەندێك زەوییە وشکەکانی ناوچەکانی عیراق و هەرێمی کوردستان.

لێکۆڵینەوەکە ئەو ناوچە وشك و نیمچە وشکانەی لەخۆگرتبوو کە دە کەویتە نیوان هێڵی درێژی ٤٣° ٢٥' ٤"-٤٦° ٢٨' ١" ڕوەو ڕۆژهەڵات و هێڵی پانی ٣٤° ١٨' ٣٣"- ٣٦° ٢٠' ٥٦" ڕوەو باکور کە هەندێك ناوچە لە پارێزگاکانی(سلیمانی، دیالی، کەرکوك، هەولێر) لە عیراق لە خۆگرتووە بە ڕووبەری گشتی (٢٦٤٥٦٠٠ هێکتار) .

هەستاین بە هەڵکەندنی(٢٠) لابڕی خاك (pedon) و ئەنجامدانی وەسفی مۆرفۆلۆجی بۆ هەر لابڕێك. سەرەڕای ئەوەش (٨٩) نموونەمان وەرگرت لە بەشی سەرەوەی خاکی دەوروبەری لابڕەکان. نمونە وەرگیراوەکان لە هەوا وشککراونەتەوە لە تاقیگەدا و بە هێڵەکی تیرە (٢ملم) تێپەڕ کراون تاوەکو ئامادە بکرێن بۆ شیکارە کیمیایی و فیزیاییەکان،

بە بەکار هێنانی شێوازی (MEDALUS) کە لە لایەن (Kosmas et al., 1999b) پێشنیارکراوە هەستاین بە هەڵسەنگاندنی دیاردەی بە بیابانبوون خاکەکە لەگەڵ بەکارهێنانی بەرنامەی (GIS) بۆ وینەکێشانی نەخشە.

بە پشتبەستن بە تێکڕای ڕێژەی باران بارینی ساڵانە دەردەکەوێت کە ناوچەی لێکۆڵینەوەکە لە سێ پشتێنەی کەشوهەوایی پێکدێت بەمجۆرە (پشتێنە ٢) پێکدێت لە {ناوچەی وشك (١٠٠-٣٠٠) ملم} و (پشتێنەی٣) {نیمچە وشك (٣٠٠-٥٠٠) ملم} و (پشتێنەیٚ ٤) {ناوچەی وشکی ژێر تەڕی (<٥٠٠) ملم} وەك ئەوەی ڕێکخراوی فاو لە ساڵی (١٩٩٨) دیاری کردووە، هەروەها خەملاندنی جۆرایەتی خاك بۆ هەریەك لە پشتێنە کەش و هەواییەکان کرا.

پۆلێنکردنی گونجاندنی زەویەکە ئەنجامدرا هەروەك لە (Sys, 1993) ئاماژەی پێدراوە ، وە هەروەها پۆلێنکردنی شیاوی زەوییەکان وەك ئەوەی لە پێوەری ڕوپێوی خاکی ئەمریکی کراوەو (١٩٧١).

ئەوەی لە خوارەوە ئاماژەی پێکراوە بریتیە لەو ئەنجامانەی کە لە توێژینەوەکەدا دەرکەوت:-

١- هەڵسەنگاندنی دیاردەی بەبیابانبوون

أ- پێوەری جۆرایەتی خاك (SQI)

- پێكهاتەی خاك دەكەوێتە نیوان پلەی دووەم (مامناوەندی) و پلەی سێیەم (لاواز)ە و پانتاییەكەی بە ڕووبەری (٧٣٧١٠٠ و ١٩٠٨٥٠٠) هێكتار وە ڕێژەی (٢٧,٨٦٪ و ٧٢,١٤٪) لەڕووبەری پانتایی ناوچەی لێكۆڵینەوەكە پێكدەهێنێت یەكبەدوای یەك.
- مادە بنەڕەتیەكەی خاكی ناوچەكە دەكەوێتە نێو پلەی دووەم (مامناوەندە).
- پێوەری بوونی چەو و بەردی ناوچەكە دەكەوێتە نێو پلەی سێیەم (نەبونی بەرد – بەردەڵانی كەم) كە ئەمەش (٩٩,٢٥٪)ی كۆی گشتی ڕووبەری ناوچەكە پێكدەهێنێ.
- پێوەری لێژی خاك لە زۆربەی بەشەكانی زەوی ناوچەكە دەكەوێتە نێو پلەی دووەم (تەخت) وە بە ڕووبەری (٢٥٦١٠٠٠ هێكتار) و ڕێژەی (٩٦,٨٠٪)ی ناوچەی لێكۆلینەوەكەی دادەپۆشێت. ئەو ڕووبەرەی كە دەمێنێتەوە لە ناوچەی لێكۆڵینەوەكە بریتیە لە پلەی یەكەم و سێیەم و چوارەم كە سەرجەمیان (٣,٢٠٪)ی ڕێژەی ڕووبەری گشتی ناوچەكە پێكدەهێنن.
- پێوەری قوڵی خاك لە پلەی یەكەمە (قوڵ).
- پێوەری دیاردەی شۆردنەوەی خاكەكە دەكەوێتە پلەی دووەم (شۆردنەوەی نیوەچڵ) و پلەی سێیەم (شۆردنەوەی لاواز) بە ڕووبەری (٢١٥٠٦٠٠ و ٤٩٥٠٠٠) هێكتار كە ڕێژەی (٨١,٢٩٪ و ١٨,٧١٪)٪ی ڕووبەرەكە پیكدەهێنن بۆ هەردووكیان یەكبەدوای یەك.
- پێوەری ماددەی ئەندامی دابەشدەكرێت بۆ پلەی دووەم (باش) و پلەی سێیەم (لاواز) و پلەی چوارەم (زۆر لاواز). ڕووبەری پلەی سێیەم (٢١٤٤٣٠٠ هێكتار)ە كە ڕێژەكەی (٨١٪)ە كە ئەمەش زیاترە لە هەریەك لە پلەی دووەم و چوارەم كە ڕووبەرەكەیان بریتین لە (٢٢٤٨٠٠ و ٢٧٦٥٠٠) هێكتار كە دەكاتە ڕێژەی (٨,٥ و ١٠,٥)٪ ڕووبەری گشتی ناوچەكە بۆ هەردووكیان یەكبەدوای یەك.
- پێوەری بوونی كاربۆناتی كالسیۆمی خاكەكە زۆربەی لە پلەی سێیەم (لاواز)ە. كە ڕووبەرەكەی دەگاتە (٢٦٠٨٢٠٠ هێكتار) بە ڕێژەی (٩٨,٥٩٪)ی لە ڕووبەری ناوچەی لێكۆڵینەوەكە.

كاتێك پێوەری كێشی جۆرایەتی خاكەكە پێوانەكرا دەركەوت كە ناوچەكە دابەشدەبێت بۆ دوو پلە كە ئەویش پلەی دووەم كە ڕووبەرەكەی (٢٥١٤٧٠٠ هێكتار) و بە ڕێژەی (٩٥ ٪)، وە پلەی سێیەم كە ڕووبەرەكەی (١٣٠٩٠٠ هێكتار) بە ڕێژەی(٥٪)ی ڕووبەری ناوچەی لێكۆڵینەوەكە.

ب- پێوەری جۆرایەتی ڕووپۆشی ڕوەکی (VQI)

- لە ئەنجامەکاندا دەرکەوت کە ناوچەکە لە ڕووی ڕووپۆشی ڕوەکیەوە لە پلەی دووەم (نزم)ە، وە ئەمەش دەریدەخات ناوچەی لێکۆلینەوەکە پارێزراونیە لە بە بیابانبوون.
- مەترسی ڕوودانی ئاگرکەوتنەوە دەکەوێتە پلەی دووەم (مامناوەند)ەوە.
- بەرگری وشکی لە پلەی پێنجەم (زۆر لاواز)ە.
- ناوچەی لێکۆڵینەوەکە دابەش دەکرێت بە دوو پلەوە لە ڕووی دیاردەی پاراستن لە ڕامالّین ئەویش هەردوو پلەی سێیەم (لاواز) کە ڕووبەرەکەی(٨٠٣٧٠٠ هێکتار) وە پلەی چوارەم (زۆر لاواز) بە ڕووبەری (١٨٤١٩٠٠ هێکتار) کە ڕێژەی (٣٠,٣٨ و ٦٩,٦٢)٪ی ڕووبەری گشتی ناوچەی لێکۆڵینەوە کە پێکدەهێنن بۆ هەردووکیان یەکبەدوای یەك.

پێوەری جۆرایەتی ڕووپۆشی ڕوەکی ناوچەکە دەکەوێتە پلەی دووەم (جۆرایەتی مامناوەند)ە و (٧٦٠١٠٠ هێکتار)یە وە پلەی سێیەم(جۆرایەتی لاواز)ە کە ڕووبەری (١٨٨٥٥٠٠ هێکتار)یە و ڕێژەکەی (٢٨,٧٣٪ و ٧١,٢٧٪)یە بۆ هەریەکەیان یەکبەدوای یەك .

ج- پێوەری جۆرایەتی کەش و هەوا (CQI)

- ناوچەکە دابەشدەبێت بۆ دوو پلە لە ڕووی جۆرایەتی بارینەوە کە ئەوانیش پلەی یەکەم (جۆرایەتی بەرز)ە کە ڕووبەری (٢٨٩٨٠٠ هێکتار)یە و ڕێژەی (١٠,٩٥٪)ی لە کۆی گشتی ڕوبەری ناوچەکە پێکدەهێنێت، بەلاّم پلەکەی تر دووەمە (جۆرایەتی مامناوەند)ە ڕووبەرەکەی (٢٣٥٥٨٠٠ هێکتار)یە ڕێژەکەی بریتی بوو لە (٨٩,٠٥٪) لە ڕووبەری گشتی.
- پێوەری وشکێتی ناوچەکە لە پلەی چوارەم و پێنجەمدایە کە ڕووبەرەکەیان (٧٠٦٥٠٠ و ١٩٣٩١٠٠) هێکتار و بە ڕێژەی (٢٦,٧٠ و ٧٣,٣٠)٪ بۆ هەردووکیان یەکبەدوای یەك.
- جۆرایەتی کەش و هەوای ناوچەکە لە پلەی دووەمە (مامناوەند).

د- پێوەری جۆرایەتی بەڕێوەبردن (MQI)

- زەویە کێڵگەییەکانی ناوچەکە دەکەوێتە پلەی دوو (توندی بەکارهێنانی زەوی مامناوەند)ە.
- پێوەری پلاندانان دابەش دەبێت بۆ پلەی یەکەم (بەرز) وە پلەی دووەم (مامناوەند) وە پلەی سێیەم (نزم) کە ڕووبەری (٤٨٦٥٠٠ هێکتار)ە بە ڕێژەی (١٨,٣٩٪) وە (٧١٥٠٠٠ هێکتار) و ڕێژەی (٢٧,٠٣٪) و (١٤٤٤١٠٠ هێکتار) و ڕێژەی (٥٤,٥٨٪)ە ، بۆ هەر پلەیەکیان یەکبەدوای یەك.

دیاردەی جۆرایەتی بەڕێوەبردنی ناوچەکە دابەش دەبێت بۆ سێ پلە، پلەی یەکەم (بەرز) ڕووبەری (٤٥٦٢٠٠ هێکتار)، وە پلەی دووەم (مامناوەند) بە ڕووبەری (٧٤٧١٠٠ هێکتار) وە پلەی سێیەم (نزم) بە ڕووبەری (١٤٤٢٣٠٠ هێکتار) بە ڕێژەی (١٧,٢٤ و ٢٨,٢٤ و ٥٤,٥٢)٪ی ڕووبەری ناوچەی لێکۆڵینەوەکە ، بۆ هەر پلەیەکیان یەکبەدوای یەك.

هـ - هەستیاری ژینگەیی بۆ بە بیابانبوون ESAS

ئەو ڕووبەرەی زیاتر بڵاوە و تایبەتە بە هەستیاری ژینگەیی دەکەوێتە جۆری سێیەم (شلۆق)ە کە ڕووبەرەکەی (١١١٢٧٠٠ هێکتار) کە دەکاتە ڕێژەی (٤٢,٠٦٪)ی ناوچەی تویژینەوەکە، دوای ئەویش پلەی دووەم و یەکەم دێت کە ڕووبەرەکەیان (٧٥٩٧٠٠ هێکتار) و (٣٦٤٠٠٠ هێکتار)ە کە ڕێژەی (٢٨,٧١ و ١٣,٧٦)٪ی ناوچەی لێکۆڵینەوەکە پێکدەهێنن یەکبەدوای یەك. بەڵام پلەکانی فشەڵ (F3 و F2) ڕووبەری هەریەکێکیان (٣٠٩٣٠٠ و ٩٩٩٠٠) هێکتار بەرێژەی (١١,٦٩و ٣,٧٨)٪ یەکبەدوای یەك.

٢- جۆرایەتی خاکی ناوچەی لێکۆڵینەوەکە:

أ- ڕێژەی قوڕ لە پشتێنەی چوارەم و سێیەم گەیشتە (٣٨,٦ و ٣٧,٥)٪ یەکبەدوای یەك بە بوونی جیاوزییەکی بایەخدار بە ڕێژەی (٢٠,٧٪) لەگەڵ پشتێنەی دووەمدا لە کاتێکدا جیاوازییەکی ئەوتۆ بە دی نەکرا لە نیوان هەردوو پشتێنەی سێیەم و چوارەمدا .

ب- جیاوازییەکی بێبایەخ دەرکەوت (P=0.163) لە پشتێنە وشکەکاندا سەبارەت بە چڕییە ڕوکەشەکان. پشتێنەی چوارەم زیاترە لە پشتێنەی سێیەم وە ئەمەش زیاترە لە پشتێنەی دووەم بە بڕی (١,٦٦ و ١,٦٢ و ١,٥٩) میگاگرام م$^{-٣}$ یەکبەدوای یەك.

ت- دەرکەوتنی بوونی جیاوزییەکی بایەخدار لە نێوان پشتێنەی سێیەم و چوارەم لە هەبوونی پێکهاتەی کاربونی ئەندامی بەرێژەی (٩٠٪ و ٨١٪) یەکبەدوای یەك. لە کاتیکدا پشتێنەی سێیەم زیاترە لە پشتێنەی چوارەم و هەردووکیشیان زیاترن لە پشتێنەی دووەم کە بایەخدارە وە بە ڕێژەی (٠,٤٦٪).

پ- لە هیچ کام لە پشتێنەکان جیاوازییەکی بایەخدار بەدی نەکرا لە ڕووی پلەی کارلێك لەگەڵ خاکدا لە کاتێکدا تێکڕای بەهاکانیان بریتی بوون لە (٧,٨٩ و ٧,٨٦ و ٧,٧٧) بۆ هەرسێ پشتێنە کەش و هەواییەکان واتە (دووەم و سێیەم و چوارەم) یەکبەدوای یەك (P>0.05)، لەگەڵ بوونی جیاوازیەکی کەم لە بەهاکانیان، بەهای پشتێنەی دووەم زیاترە لە پشتێنەی سێیەم و هەردوکیشیان زیاترن لە پشتێنەی چوارەم.

ج- هەموو خاکی ناوچەی لێکۆڵینەوەکە سوێر نیە بە جۆرێك بەهای گەیاندنی تەزووی کارەبا (٠,٤٨ و ٠,٣٨ و ٠,٢٠) دسسمنز م$^{-١}$ بوو لە پشتێنەی دووەم و سێیەم و چوارەمدا لە گەڵ هەبوونی جیاوازییەکی بێبایەخ.

ح- جیاوازییەکی بایەخدار نەبوو لە بڕی پۆتاسیۆمی ئامادە لە نیوان پشتێنەکاندا (P>0.05) بەڵام جیاواز بوو لە بەهاکاندا، لە کاتێکدا بوونی بڕی پوتاسیۆمی ئامادە لە پشتێنەی چوارەمدا بەرزترین بوو کە بریتی بوو لە (٠,٦١٤) سنتمۆل کگم$^{-1}$ بەدوایدا پشتێنەی سێیەم (٠,٥٦٤) سنتمۆل کگم$^{-1}$ وە پشتێنە دووەم (٠,٤٥١) سنتمۆل کگم$^{-1}$ بووە.

خ- جیاوازییەکی بایەخدار هەبوو لە بوونی نایترۆجینی ئامادە لە نێوان پشتێنەی دووەم لە لایەك وە هەردوو پشتێنەی سێیەم و چوارەم لەلایەکی تر، کە بەهاکانی گەیشتە (١,٥٦٧ و ٢,٣٣٤ و ٢,٢٢٢) گم کگم$^{-1}$ بوو بۆ پشتێنەی دووەم و سێیەم و چوارەم بەدوایەکدا. لەگەڵ نەبوونی جیاوازی بایەخدار لە نیوان هەردوو پشتێنەی سێیەم و چوارەم.

د- جیاوازییەکی بایەخدار نەبوو لە نیوان پشتێنەکاندا لە ڕووی ڕێژەی فۆسفۆری ئامادە کە بەهاکانی دەگەشتنە (٤,٣٢ و ٥,٦٥ و ٤,٧٨) مایکرۆگرام کگم$^{-1}$ بۆ پشتێنەی چوارەم و سێیەم و دووەم بەدوایەکدا.

ژ- هیچ تێبینیەکی جیاوازی بایەخدار بە دی نەکرا لە نێوان پشتێنە کەش و هەواییە کاندا لەڕووی خەستی کالیسیۆمی ئاڵوگۆڕکراو لە نیوانیاندا، بەجۆرێك بڕی پشتێنەی چوارەم زیاترە لە هەردوو پشتێنەی سێیەم و دووەم بە بەهای (٢٢,٥ و ٢٢,٣ و ١٨,٢) سنتمۆل کگم$^{-1}$ بەدوای یەکدا.

ر- جیاوازییەکی بایەخدار بەدی نەکرا لە خەستی مەگنسیۆمی ئاڵوگۆڕکراو لە نیوان پشتێنەی سێیەم و چوارەمدا بەڵام هەردوکیان جیاوازیەکی بایەخداریان هەبوو لە گەڵ پشتێنەی دووەم کە بەهاکەیان دەگەیشتنە (٥,١ و ٧,٤ و ١,٦) سنتمۆل کگم$^{-1}$ بۆ پشتێنەکانی چوارەم و سێیەم و دووەم یەکبەدوای یەکدا.

ز- بەهاکانی صودیۆمی ئاڵوگۆڕکراو گەیشتە (٠,٢١٥ و ٠,٢٢١ و ٠,١٩٣) سنتمۆل کگم$^{-1}$، بۆ پشتینەی چوارەم و سێیەم و دووەم بە دوای یەکدا. پشتێنەی دووەم جیاوازیەکی بایەخداری هەبوو لە گەڵ پشتێنەی سێیەم بەڵام جیاوازیەکی بێبایەخی هەبوو لە گەڵ پشتێنەی چوارەم.

س-بەهاکانی پۆتاسیۆمی ئاڵوگۆڕکراو گەیشتە (٠,٤٠ و ٠,٥٣ و ٠,٥٩) سنتمۆل کگم$^{-1}$ بۆ پشتێنەی دووەم و سێیەم و چوارەم بە دوای یەکدا. جیاوازیەکی بایەخدار هەبوو لە نێوان پشتێنەی دووەم و چوارەمدا ، بەڵام جیاوازیەکی بێبایەخ دەرکەوت لە نیوان پشتێنەی دووەم و سێیەمدا هەروەها لە نیوان پشتێنەی سێیەم و چوارەمدا. دابەشبوونی پۆتاسیۆمی ئاڵوگۆڕکراو و پۆتاسیۆمی ئامادە وەك یەك وابوون.

ش-پشتێنەکان جیاواز بوون لە بەهای توانای ئاڵوگۆڕی کاتیۆنی. بەرزترین بەها لە پشتێنەی چوارەمدا دەرکەوت کە (٢٦,١) سنتمۆل کگم$^{-1}$، بوو دوای ئەو پشتینەی سێیەم (٢١,٩) سنتمۆل.کگم$^{-1}$ وە پشتێنەی دووەمیش بریتی بوو لە (١٥,٧) سنتمۆل کگم$^{-1}$.

ص- جیاوازیەکی بایەخدار دەرکەوت لە بڕی کانزا کاربۆنیەکان، کەمترین بەهایان لە پشتێنەی دووەمدا دەرکەوت کە (٣١٦,٤) گم کگم$^{-1}$ ، بوو بە دوایدا هەردوو پشتێنەی سێیەم (٢٠٤,٠) گم کگم$^{-1}$ و چوارەم (١٧١,٠) گم کگم$^{-1}$ بوو.

٣- **گونجاندنی زەویەکە بۆ چاندنی گەنم:**

أ- زەویەکانی ناوچەی لێکۆڵینەوەکە قوڵن و هیچ ڕێگریەکی سنوردارکراو نیە سەبارەت بە قوڵیەکەی وە تێکڕای بەهاکانی (٩٠ و ٩٥ و ١٠٠)ن بۆ زۆربەی بیدۆنەکان .

ب- تێکڕای بەهای پێکهاتەکان لە نێوان (٩٨ و ١٠٠)ن بۆ خاکی ناوچەی لێکۆڵینەوەکە ئەمەش ئەوە دەگەیەنێ کە هیچ ڕێگریەکی سنوردارکراوی تایبەت نیە بۆ ئەو سیفەتە.

ت- بەهای خەملێنراوی کاربۆنات گەشتە (٤٠ – ١٠٠) ئەمەش ئەوە دەگەیەنێ کە کانزای کاربۆنات هۆکارێکی سنوردارکراو بێت بۆ گەشەی گەنم.

پ- بەهای سوێری خاکەکە بریتیی بوو لە (٩٥,٣-٩٥,٢) لە زۆربەی ناوچەی لێکۆڵینەوەکە کە ئەمەش سنورداریەکی کەمی ئەم سیفەتە دەگەیەنێ.

ج- بەهاکانی کارلێکی خاك دەکەوێتە نێوان (٨٧- ١٠٠). وە پلەی کارلێکی خاك نەگەشتۆتە ڕادەیەك کاربکاتە سەر گەشەی گەنم.

ح- بەهاکانی توانای ئاڵوگۆڕی کاتیۆنەکان کاریگەری جیاوازیان هەیە لە گونجاندنی زەویەکان. لە هەندی ناوچە پلەی گونجاندن (٦٠)ە ئەمەش واتای ئەوەیە کە کاریگەری ئاشکرا لە گونجانی زەوی هەیە. بەڵام لە زۆربەی شوێنەکانی تر (١٠٠)بووە ئەمەش ئەوە دەگەیەنی کە کاریگەری نیە.

خ- جیاوازی هەیە لە بەهاکانی پلەی کاربونی ئەندامی ناوچەی لێکۆڵینەوەکە. لەنێوان زۆربەی شوێنە جیاوازەکان(١٠٠) بووە و لە شوێنەکانی تر نزم بوەتەوە بۆ (٧٣).

د- هیچ کاریگەریەك لەسەر تایبەتمەندیی لافاو لەسەر گونجانی زەوی بۆ چاندنی گەنم دەرنەکەوتووە چونکە پلەکەی (١٠٠) بۆ سەرجەم ناوچەکان.

ژ- دیاردەی شۆردنەوە کاریگەری ئەوتۆی نەبووە لە سەر گونجاندنی زەوی. بەجۆرێك زۆربەیان (٩٥ و ١٠٠) بووە لە زۆربەی ناوچەکاندا.

ر- پلەی تیربوون بە تفتەکان (١٠٠) بووە لە سەرجەم ناوچەی لێکۆڵینەوەکە ئەمەش ئەوە دەگەیەنێ ئەم سیفەتە هیچ کاریگەریەکی لەسەر گونجاندن نیە.

ز- پلەی کاتیوناتی گشی گەیشتۆتە (١٠٠) ئەمەش ئەوە ئەگەیەنێ کە کاریگەری لەسەر گونجاندن نیە.

س- دەرئەنجامەکان دەریدەخەن کە سێ جۆری سەرەکی هەن پەیوەستن بە گونجاندنی زەویەوە بۆ چاندنی گەنم ئەویش ئەمانەن:-

- جۆری S2 (گونجاندنی مامناوەند): ئەو زەوییانەی ئەمجۆرە لەخودەگرن گونجاندنەکانیان مامناوەندن بۆ چاندنی گەنم. کە ڕوبەرەکەی گەیشتوەتە (٢٦٠٨٠٠ هێکتار) وە ڕێژەی سەدی (١٠٪) لە کۆی گشتی ڕووبەرەکە پێکدەهێنێت.

- جۆری S3 (گونجاندنی لاوەکی): ئەویش ئەو زەویە لاوەکیانەن کە ڕوبەرەکەیان دەگاتە (١٨٤٤٧٠٠ هێکتار) کە یەکسانە بە ڕێژەی (٦٩,٧٢٪) لە ناوچەی لێکۆڵینەوەکە.
- جۆری N1 (لە ئێستادا نەگونجاوە): ڕووبەری ئەم جۆرە دەگاتە (٥٣٩١٠٠ هێکتار) وە ڕێژەی (٢٠,٣٧٪) ڕووبەری گشتی پێکدەهێنێت.

٤- پۆلێنکردنی توانایی زەوی

پۆلێنکردنی توانایی زەوی دابەشکرا بۆ پێنج جۆری سەرەکی کە ئەمانەن:-

- پۆلی II: تێکڕای ڕووبەری ئەم پۆلە (٤٢٥٠٠ هکتار)ە کە دەکاتە (١,٦٪)ی سەرجەم ڕووبەری ناوچەی توێژینەوەکە. ژێر پۆلی ئەم پۆلە بریتیە لە IIe1 و IIs1e1.
- پۆلی III: تێکڕای ڕووبەری ئەم پۆلە (٧٧٠٠٠ هکتار)ە کە دەکاتە (٢,٩٪)ی سەرجەم ڕووبەری ناوچەی توێژینەوەکە. ژێر پۆلی ئەم پۆلە بریتیە لە IIIe و IIIs و IIIew و IIIc و IIIce.
- پۆلی IV: تێکڕای ڕووبەری ئەم پۆلە (٢٠٩٠٦٠٠ هکتار)ە (٧٩٪). ژێر پۆلی ئەم پۆلە بریتیە لە IVe و IVs و IVc.
- پۆلی V: تێکڕای ڕووبەری ئەم پۆلە (٤٢٠٠٠٠ هکتار)ە وە بە ڕێژەی (١٥,٩٪)ی سەرجەم ڕووبەرەکە.
- پۆلی VI: تێکڕای ڕووبەری ئەم پۆلە (١٥٥٠٠ هکتار)ە وە بە ڕێژەی (٠,٦٪)ی سەرجەم ڕووبەری ناوچەی توێژینەوەکە.

حکومەتی هەرێمی کوردستان

وەزارەتی خوێندنی باڵا و توێژینەوەی زانستی

زانکۆی سلێمانی

کۆلێجی زانستە ئەندازیاریە کشتوکاڵیەکان

پۆلێن کردن و دیاردەی تێکچونی زەوی و بە بیابانبونی زەوییە وشکەکانی هەرێمی کوردستان - عیراق

نامەیەکە

پێشکەش کراوە بە ئەنجومەنی کۆلێجی زانستە ئەندازیاریە کشتوکاڵیەکان لە زانکۆی سلێمانی وەك بەشێك لە پێداویستیەکانی بە دەستهێنانی بڕوانامەی دکتۆرا لە

(ڕوپێوی و دابەشکردنی خاك)

لە لایەن

مەهتاب حمەصالح فقی قادر

بکالۆریۆس لە کشتوکاڵ- زانستی خاك- زانکۆی سلێمانی- ٢٠٠٠

ماستەر لە کشتوکاڵ- زانستی خاك و ئاو- زانکۆی سلێمانی- ٢٠٠٧

بە سەرپەرشتی

د.دڵشاد رسول عزیز

پرۆفیسۆری یاریدەدەر

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