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Land Suitability and Characterization Study of Soils, Natural Vegetation Cover in Wahat Elnukhila area, Northern Darfur State, Sudan

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ABSTRACT

This study was conducted in the Wahat Elnukhila area, about 600 km northeast of El-fashier town, northern Darfur State, to produce broad–base data on the geographical distribution of soils, characterization of soils using some soil indicators (ECe, pH and SAR), explore the natural land cover and evaluate the soil suitability for agricultural activities in the study area. The study area covers (20000 feddans). This research was based on the data and information extracted from the soil survey, remote sensed landsat, Enhanced Thematic Mapper (ETM+) images dated 2018, in addition to field observation aided by GPS receivers and geographic information system were used to generate soil map in the study area. By using the American soil classification system (FAO, 1990 and 2006) study area may be classified into three units, the total area of the three units and natural vegetation cover decreased in the following order: unit1 (12734 feddans) > unit 2 (3994 feddans) > unit 3 (3272 feddans), green covers as a result of the availability of quantities of ground and surface water, which distinguishes it from the rest of the surrounding desert lands. The predominant vegetation cover is Imperata cylindrical (halfa), Tamarix (Tarfa), phragmites (communist)" Alboes", Citrullus Colocynthis (Hanzal), Ischaemum muticum and p. dactylifera (date palm). Regarding soil texture, drainage, soil depth, and fertility status for units 1, unit 2, and unit 3, can be described as follows: sandy to loamy sand, well-drained, shallow and low fertile, coarse texture to moderate, moderately drained, shallow to moderate and low fertile, gravelly surface, moderatly drained, shallow to moderate and very low fertile respectively. Soil analysis reveled that there was high inherent risk of soil salinity and sodicity especially unit 1. In general, the result showed that there were clear aspects of wind erosion represented as large areas affected by the sand encroachment form of crescent dunes and rocks interspersed with hills and plateaus. Furthermore, soils of the targeted area were formed from the accumulation of creeping and portable aeolian sands. The research site lies in the southeastern part of the border triangle between Sudan, Egypt, Libya and Chad, which is severely affected by wind erosion because the site was bare, open with no wind barriers or shelter belts, also this area falls under the sand moving winds of the Sahara. These are the northerly winds that prevail in Northern Darfur State. Furthermore, the prevalent climatic conditions including high temperature, rainless area and relatively high wind speed are conducive to high wind erosion. The area in danger unless serious measures carried out to reduce wind erosion. The area has very low potential suitability for agriculture. The study area was rich in wild life such as deer, rabbits, birds, many insects and snakes.

Keywords: Land evaluations, natural vegetation, soil characterization, saline–sodic soils and wind erosion.

Introduction:

As a matter of fact, remote sensing turned out to be a powerful modern technique for assessing, mapping, and monitoring of terrestrial natural resources worldwide. Numerous research were conducted on the Spatio-temporal of degraded natural resources in Sudan e.g., (Ali *et al*. *2012;* Biro *et al*. *2013*; Adam *et al. 2014;* Abdelwahab, *et al. 2014*; Fadl *et al. 2014*; Mohammedzain, *et al. 2015*; Elhaja, *et al. 2017;* Abuzied, *et al. 2017)*. The cost of remote sensing is effective compared to old field survey methods, particularly for large areas 3,600 to 324,000 km^2 (Abdelwahab *et al., 2014*). The technique is mainly based on the physical interaction between solar radiation, atmosphere and the main features of the land surface, so this technique can be used for assessing and monitoring all types of degradation processes by estimation biophysical soil properties such as salinity and sodicity problems because of take place among the major factors which limit crop production. They are primarily appearing in heavy soils associated with arid and semi-arid regions, where conditions are conducive to the salt formation, namely, insufficient rain to leach soluble salts besides the prevailing high temperatures. Such harsh climates prevail, reflected in presence of marginal and fragile ecosystem with highly susceptibility to all degradation processes. Thus, there is impressing needs to rational use of these lands. Salinity and sodicity are widely spread and have a series of adverse impacts on the productive capacity of agricultural lands, forestlands, and rangelands (Dregne et al.,1991; Mustafa, 2007). Salt-affected soils in the Sudan occur in the desert and semidesert climatic zones, e.g. the high terrace of the River Nile and its tributaries, and in the arid regions. Secondary salinization occurs when the concentration of dissolved salts in water and soil increased by anthropogenic processes, particularly via poorly managed irrigation schemes. Salt-affected soils in Sudan fall under three soil orders: Vertisols, Aridisols and Entisols (USDA, 1999). They extend along vast areas at latitudes 14-22^{o} N, including the White Nile, North Gezira, Khartoum state, crossing the River Nile and the Northern states. Mohammed and Mustafa (2000) found a very significant increase according to the second degree polynomial equation in the size of the soil shrinkage by increasing the sodium exchangeable ratio at several fixed values of the total concentration of salts. The direction of these equations explained more than 90% of the variation in shrinkage size. Consideration to these studies, still there is tremendous gap in salt-affected soils studies in Sudan, including surveying and reclamation. Sodicity represents the relative predominance of exchangeable sodium compared to other exchangeable cations, chiefly calcium, magnesium, potassium, hydrogen and aluminium and is expressed as ESP (Exchangeable Sodium Percentage). The sodium adsorption ratio, (SAR), is another expression of sodicity that refers to the ratio of adsorbed sodium and the sum of calcium and magnesium. Soil salinity is a characteristic of soils relating to their content of water-soluble salts and expressed mostly as ECe (electrical conductivity of paste extract) and is measured as dS/m (Charman and Murphy, 2000). In Sudan, some research conducted in salt affected soils showed the impact of salts on the physiochemical properties of soil (Mohammed and Mustafa 2001; Ishaq and Mustafa 2005; Saeed and Aissa 2002; Mustafa and Abdelmajid 1981, 1982; Dahab, *et al. 1988*). In addition to the beneficial effects of land preparation, irrigation frequency, organic amendments on management and production of some crop production (forage, sorghum, lucerne…etc) in salt affected soils (Elaagib, 1999; Elaagib, 2003; Elaagib and Babiker, 2004; Elkhazin and Khalid, 2013; *Elmahi et al.*, 2002; Karouri,1977; Mahagoub,1979; Karouri *et al*.,1980; Sokrab, 1983; Gabir,1984; and Mustafa, 2007). Despite all research that has been conducted, still there is tremendous gap in the assessment of biophysical indicators of land degradation as well as salt-affected soils studies in Sudan (survey, extent, severity, and reclamation). Assessment and mapping of land degradation and salt-affected soils is an urgent need to determine the inherent risk in the affected areas in order to determine the land capability and suitability of the country. In addition to production potential, the conservation of soil and water resources for use by future generations requires consideration in planning land development. Undoubtedly, a proper land management decreases soil erosion and increases agricultural yield. Land evaluation is an important step in the process of land use planning where the resources are limited. Land use programming for optimum use causes the maximum profitability so that, the land will be protected for the future land users. The present study was undertaken to achieve the following objectives:

1. To generate a preliminary database in the study area, especially since it is not investigated before.
2. To investigate the geographical distribution of soils that occurs in the study area.
3. To explore the land cover nature and type beside, wildlife in the study area.
4. To evaluate and determine the soil suitability for agricultural activities.

1. Materials and Methods

1.1. Materials

1.1.1. Study area

North Darfur State occupies more than half of the Darfur territory. Bordering Chad and Libya, it includes parts of the mountainous Jabal Marrah region in the south. There are around 1.9 million internally displaced persons (IDPs), returnees, refugees and vulnerable residents who need assistance in the state, according to the 2022 Humanitarian Needs Overview (HNO) (Reliefweb, 2022). Elnuhkila project is an agricultural investment located 600 Km north-east Alfashier City; the area is about 20000 feddan (Fig. 1). The area is approximately bounded by longitudes and latitudes given below (Fig. 2). Detailed survey was conducted and covered area about 3000 feddan out 20000 feddan (Fig. 2), and 7650 feddan out of the total area was studied in semi-details. The remaining area was surveyed and observed to illustrate the morphological feature which is considered the main topographical limiting factor.

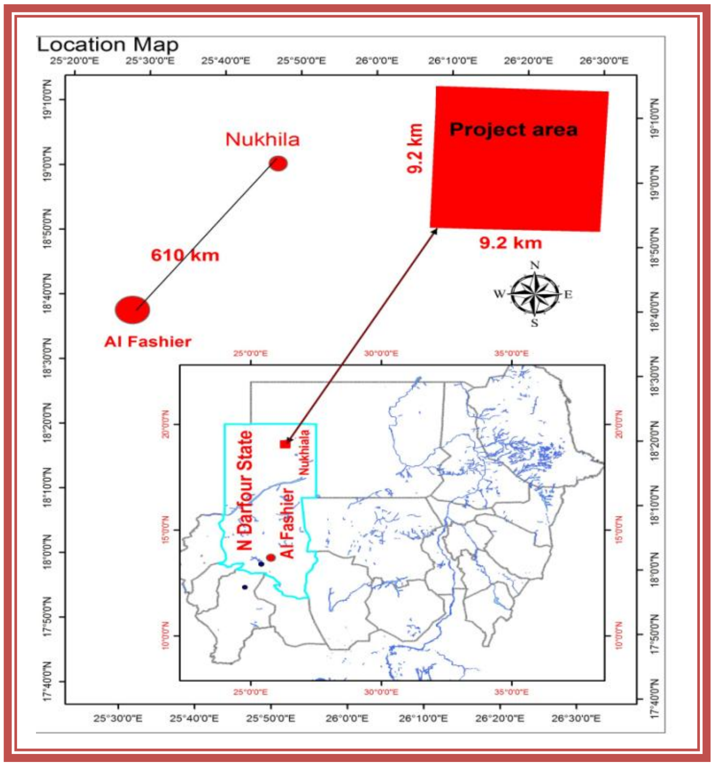


Fig.1. Location map of the study area

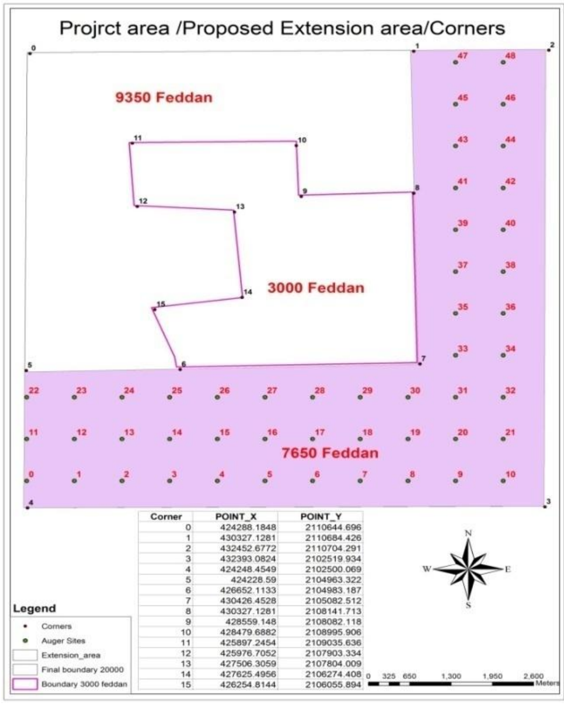
1.1.2. Remote sensing imagery

Land sat false colour composite (FCC) subsets images Enhance Thematic Mapper (ETM) dated (2018) covering the study area (20000 Feddan), were used in this study. The fieldwork was conducted during the period 25 March to 08th April 2022 aided by GPS receivers (Garmin 60C).

1.2. Methods

1.2.1. Office methods include:

i. Collection of previous studies on the study area.
ii. Preparation of location maps and other topographic maps.
iii. Preparation and interpretation of satellite images.



Corner	POINT_X	POINT_Y
0	424288.1848	2110644.696
1	430327.1281	2110684.426
2	432452.6772	2110704.291
3	432393.0824	2102519.934
4	424248.4549	2102500.069
5	424228.59	2104963.322
6	426652.1133	2104983.187
7	430426.4528	2105082.512
8	430327.1281	2108141.713
9	428559.148	2108082.118
10	428479.6882	2108995.906
11	425897.2454	2109035.636
12	425976.7052	2107903.334
13	427506.3059	2107804.009
14	427625.4956	2106274.408
15	426254.8144	2106055.894

Fig.2. the project areas and corners

1.2.2. Fieldwork and soil sampling

Soil samples were collected from different selected locations to cover the variability observed from satellite image analysis. Global Positioning System (GPS) was used to locate the position of soil samples. Two types of soil surveys have been done as follows:

1.2.2.1. Semi-detail survey (7650 and 9350 feddan)

Grid survey of observation points for auger and profile applied in order to confirm the delineation between different soil units. the intensity of observations will be one auger for 127 feddans about to have = 120 auger sites for two depths (0-30cm, 30-60cm and, the vertical and horizontal distance between the auger sites is 750 meters (Figure 3). Digging and description of soil profiles for the soil units indicated by the interpretation of satellite images and Sudan Land Cover maps. Sixteen profiles cover all the soil units and the horizontal distance between the Auger sites is 2500 meters (Figure 4). Soil analysis information (Evaluation Classification & Land Suitability) based on the USDA (2010) system of classification was carried out.

2.2.2.1. Detailed soil survey (3000 feddan)

The soil grid system of observation auger and profile sites will be applied for verification of the delineation of different soil units, the intensity of observations will be one auger for (73 feddans) about to have = 36 auger sites for two depths (0-30cm, 30-60cm and, vertical and horizontal distance between the Auger sites is 250 meters (Figurer 5 and 6). Digging and description of soil profiles for the soil units indicated by the interpretation of satellite images and Sudan Land Cover maps. Three profiles cover all the soil units, and the horizontal distance between the auger sites is 650 meters (Figures 5 and 6).

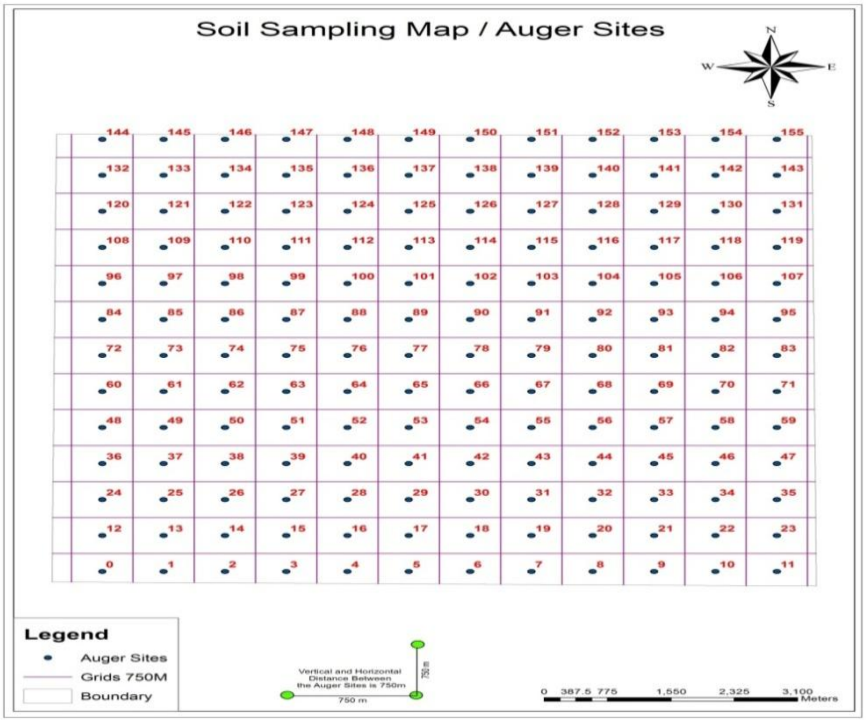


Fig.3. Sites of soil sampling taken by auger (20000 feddan).

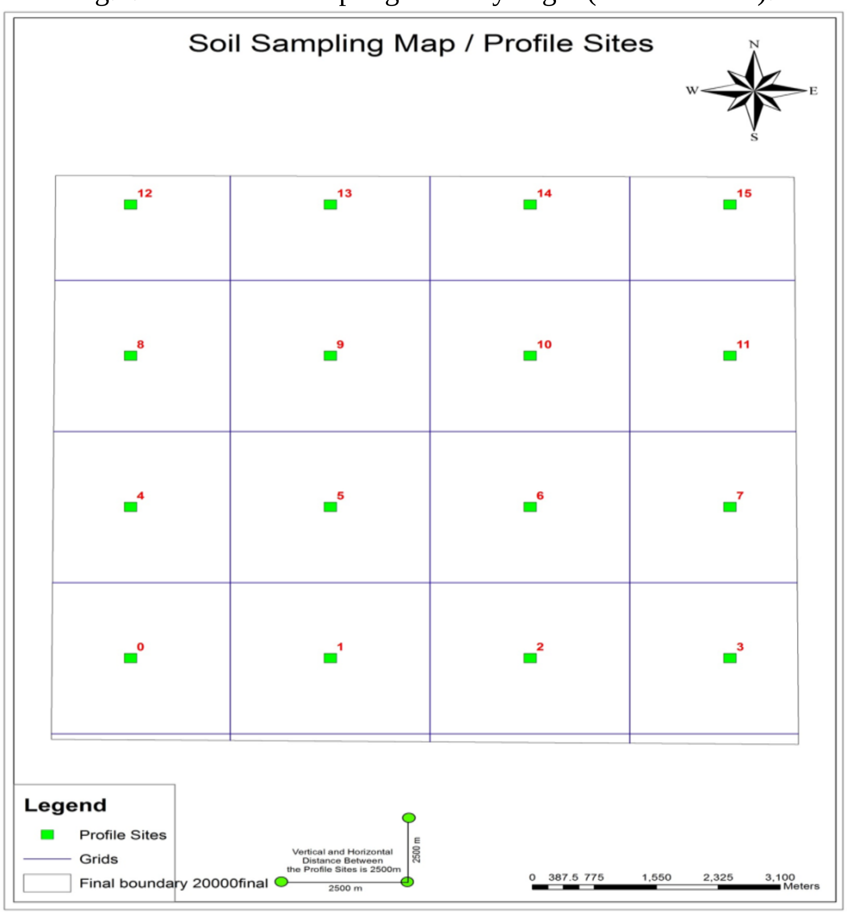


Fig.4. Sites of soil sampling taken from profile (20000 feddan).

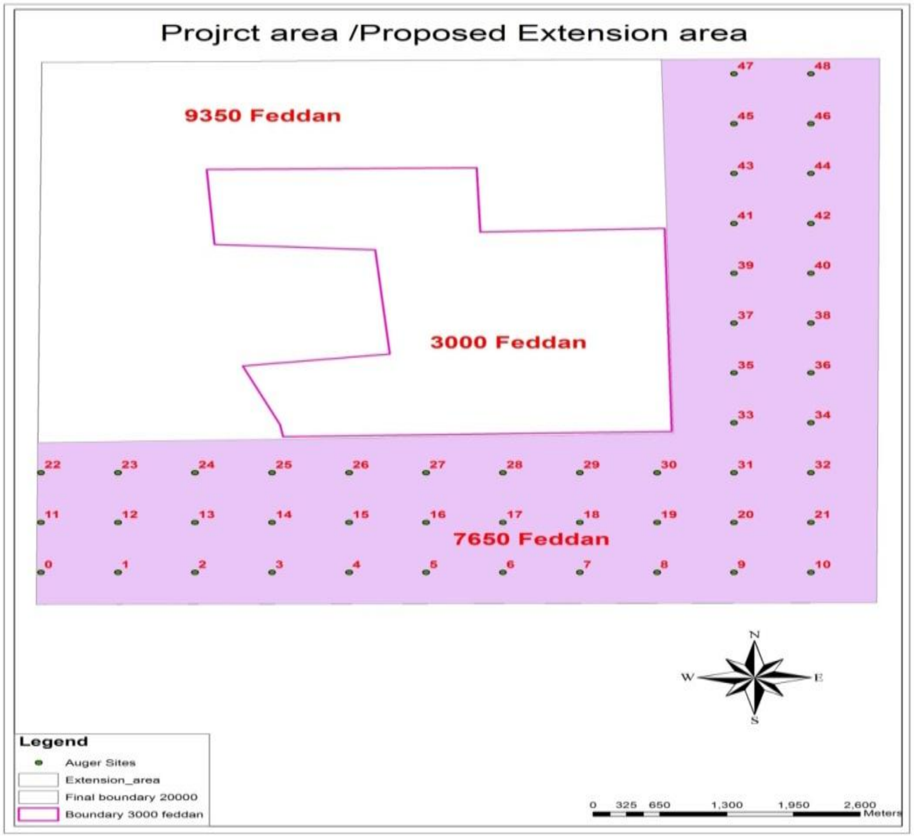


Fig.5. Sites of soil sampling taken from profile (17000 feddan).

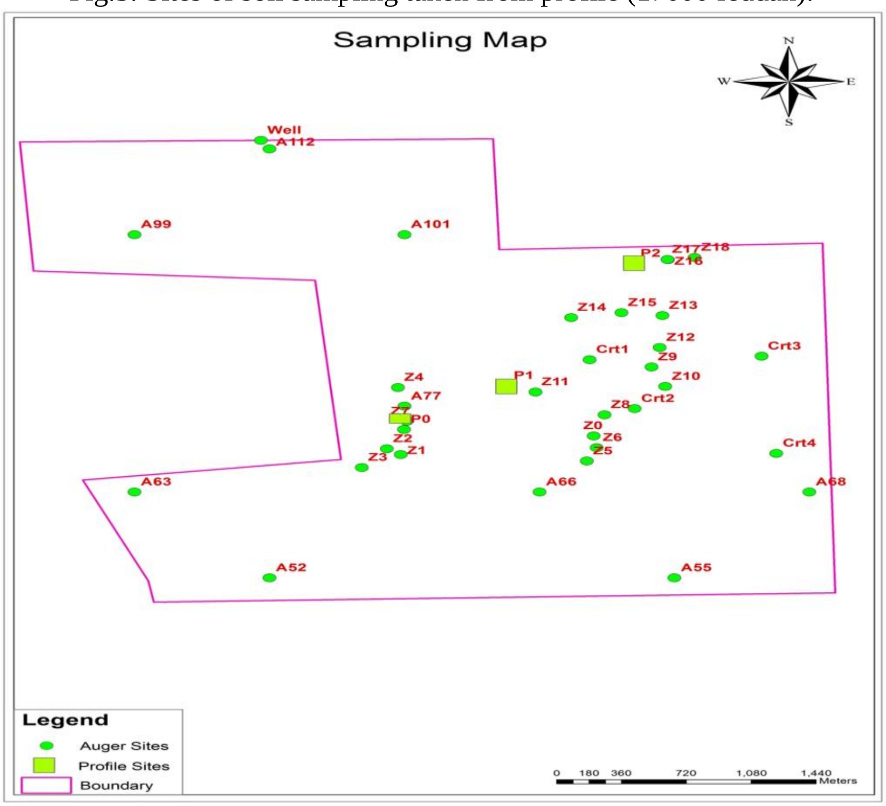


Fig.6. Sites of soil sampling for sub area 3000 feddan.

2.2.3. Laboratory work.

The chemical analysis was carried out to investigate the following parameters:

1. The Electrical conductivity (Ec) to investigate the soil salinity.
2. Soil reaction (pH) to investigate soil alkalinity and acidity.
3. The Sodium Adsorption Ratio (SAR) to investigate soil sodicity.

2.2.4. GIS Analysis and mapping.

Geographical Information System (GIS) was used for data capture, input, manipulation, transformation, visualization, combination, query, analysis, modelling and output; an intersection was performed between the classified image and the soil map of the study area in order to improve the classification results, are shown in Figures 7 to 12 a & b.

3. Results and discussion

3.1. Soil mapping units

The basis of soil mapping is plotting into a base map of every auger soil pit and profile site, each with its soil unit designation. Lines are then drawn enclosing all (or as many as possible) points of the same soil unit. The main objective of the soil survey is to keep each map unit as pure as possible. In reality, because soils are spatially variable, a soil mapping unit usually contains a dominant soil unit (soil consociation) after which the map unit is labelled and inclusions of one or more other soil units in a small number (soil inclusions). At this scale of survey and mapping (1:50,000), the accuracy or the purity of the mapping units is expected to be about 75% (between 65% and 85%; Soil Taxonomy USDA, 2010). If the soil units cannot be mapped separately the concept of the soil complex units has been used. Three soil mapping units were identified and mapped in the survey area. The following is a brief description of each of them:

3.1.1. Unit 1 (soil of flat desert plains).

These soils occupy flat to slightly sloping plains. The surface soil is sandy and sandy loams the sub soil is fine loamy sand >60 cm depth, excessively drained with clay content <10%. These soils are non saline-slightly saline non sodic and moderately – high alkaline, they are generally low fertile. (Figs.7 to 12, table 1and appendix 1 a to g). There is an appreciable amount of surface water in a depth of (30-70 cm), these waters are low salinity and sodicity, so it is suitable for agricultural uses, whereas water at a one-meter depth is highly saline and sodic. The dominant natural vegetations are Imperata cylindrica (halfa), tamarix (Tarfa), phragnites (communist)“ Alboes”, Citrullus colocynthis (Hanzal), Ischaemum muticum and p. dactylifera (date palm).with shallow roots system grown on sandy soils. These condition making the natural vegetation threaten by wind erosion. High temperature, evaporation, and rainless promoted accumulation of salts in the surface forming hard layers (plate 1,2 and 3). Inspite of the tolerance of trees and grass to salinity and sodicity, the climate can be described as drastic climate and major determinative factor leading to the spreading of trees and grass.

3.1.2. Unit 2 (deep coarse loamy soils).

These soils occupy only the elevated soil positions and represent scattered units. These soils are characterizes by heterogeneous and complex soil patterns. Where the soil depth is ranging from moderately deep (90 cm depth), they are moderately drained. The soil textures are varied from coarse texture to medium textured (sands, loamy sands and sandy loam), they are low in fertility. (Figs.7 to 12, table 1and appendix 1 a to g). All types of natural vegetation in unit one are present in unit two, but with low density. In addition to the scarcity of surface water and absence of salt layers on the soil surface.

3.1.3. Unit 3 (skeletal loamy soil).

These soils occupy gently undulating sloping desert plains and the soil surface is covered by many types of gravel, stones and some boulders and rock out crops. These soils are characterized by heterogeneous and complex soil patterns; however, the soil depth is ranging from very shallow (20 cm depth to moderately deep, i.e. 60 cm depth). The soil texture is varied from coarse texture (loamy sands) to medium textured (sandy loams).the volume of coarse fragments are ranging from 50%-90%. They are very low in fertility and moderately in drain ability (Figs.7 to 12, table 1 and appendix 1 a to h).

3.2. Soil characteristics

The role of any soil is to support a plant, whether it is a tree, vegetable, large –scale arable crop, or pasture. The soil has to be a physical support for the plant roots and above ground parts, but it also needs to act as a supporting store and supply air, nutrients and water for growth. As a result, we aim to explain the most soil growth limiting factors and their influence in production of different crops in the study area, Although there is no such thing as an ideal soil, there are plenty of measures that the agronomist and farmer can do to improve this basic growing media; therefore we aim to interpret the analytical data obtained to overcome the most problematic growth factors.

The high creep of sand and degradation of vegetation cover, despite its scarcity, The high temperature led to the accumulation of salts on the soil surface and the formation of thick salt layers (plate 1) that threaten the plant growth in the study area, resulting increase in sand encroachment (plate 2 and 3) and a decrease in vegetation cover.

Plate 1. Represent the relatively flat area covered by the white crusted salts

Plate 2. Highly saline and highly Sodic surface water/Some vegetation covers

Plate 3 a and b. Shows the sand dunes on the vegetation covered

Table1. Soil characteristics

Soil pH				
Soil depths	Ranges	Average	Guideline	Comments
Surface soil (0 - 30 cm)	6.40 – 10.60	9.27	6.5- 7.5	highly alkaline
Sub–surface soil (30-60 cm)	5.50 – 10.1	8.57	6.5- 7.5	moderately alkaline
Soil Ece				
Soil depths	Ranges	Average	Guideline	Comments
Surface soil (0 - 30 cm)	0.75 – 109.9	40.92	<4.0ds/m	strongly saline
Sub- surface soil (30-60cm)	0.40 – 110.5	14.85	<4.0ds/m	highly saline
SAR				
Soil depths	Ranges	Average	Guideline	Comments
Surface soil (0 - 30 cm)	3.10 – 98.07	56.31	<13.0	strongly sodic
Sub-surface soil (30-60cm)	0.103 – 97.53	39.54	<13.0	strongly sodic

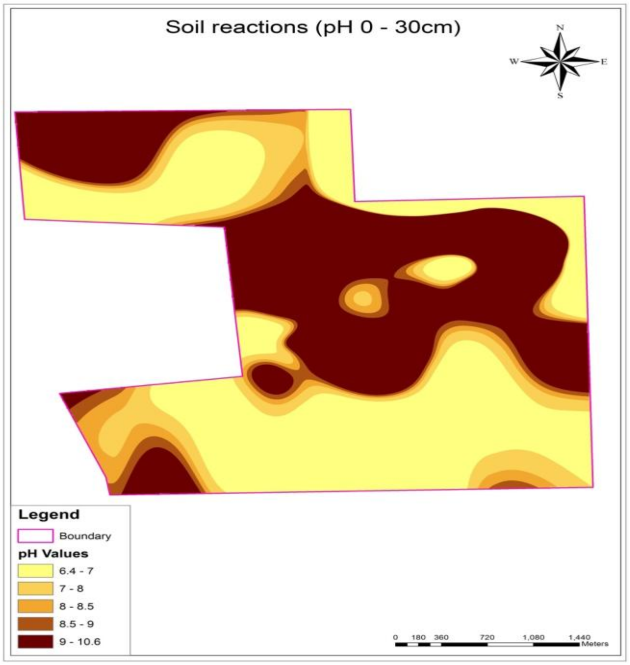


Fig.7a. Soil pH (0- 30 cm) 3000 feddan

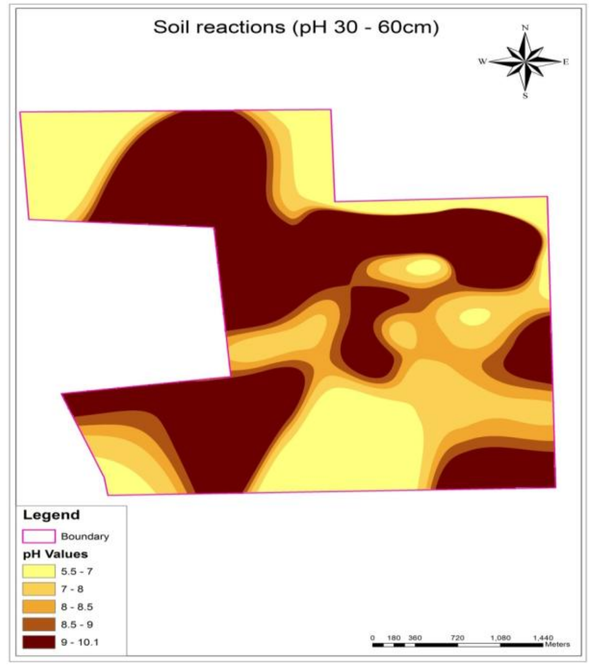


Fig.7b. Soil pH (30- 60 cm) 3000 feddan

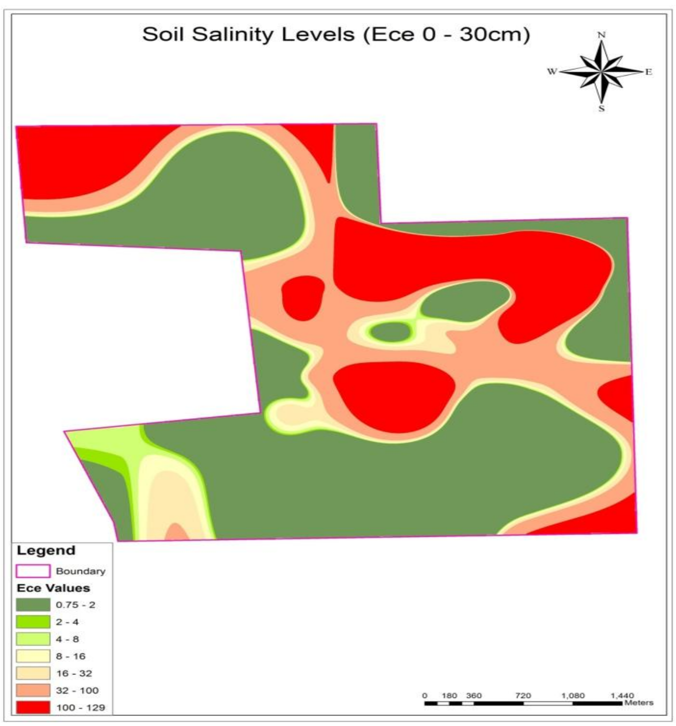


Fig.8a. Salinity (0-30 cm) 3000 feddan

Fig.8b. Salinity (0-60 cm) 3000 feddan

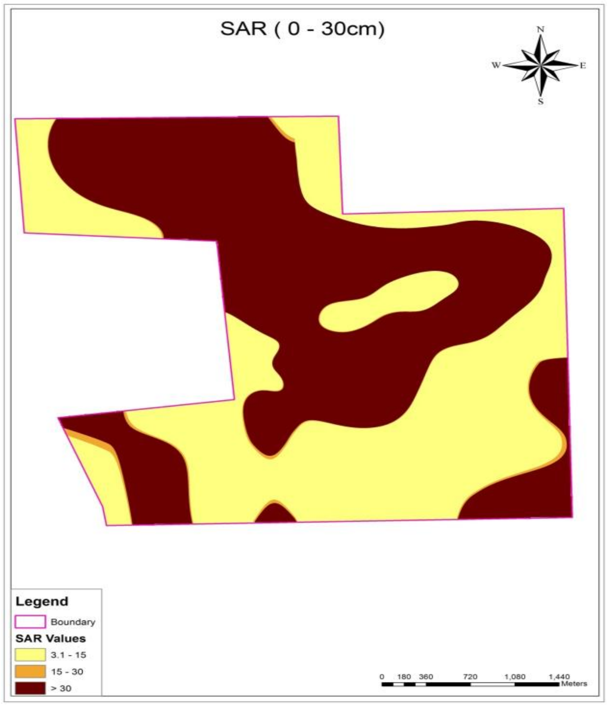


Fig.9 a. SAR in the surface (3000 feddan)

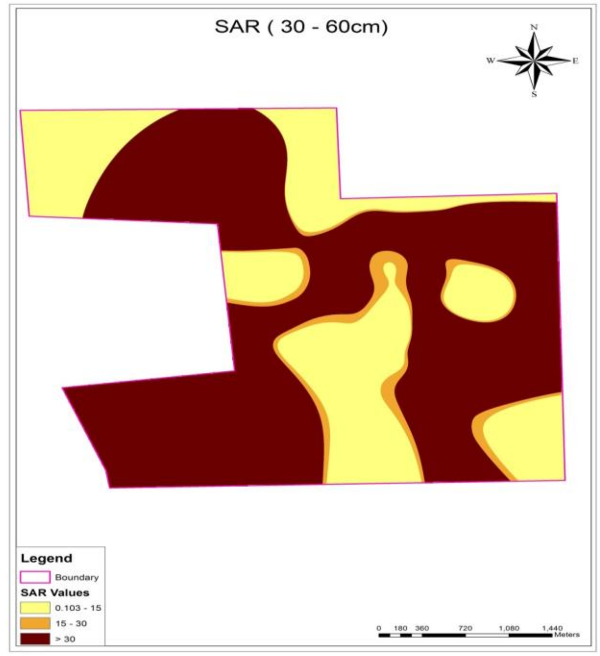


Fig.9 b.SAR in the sub Surface (3000 feddan)

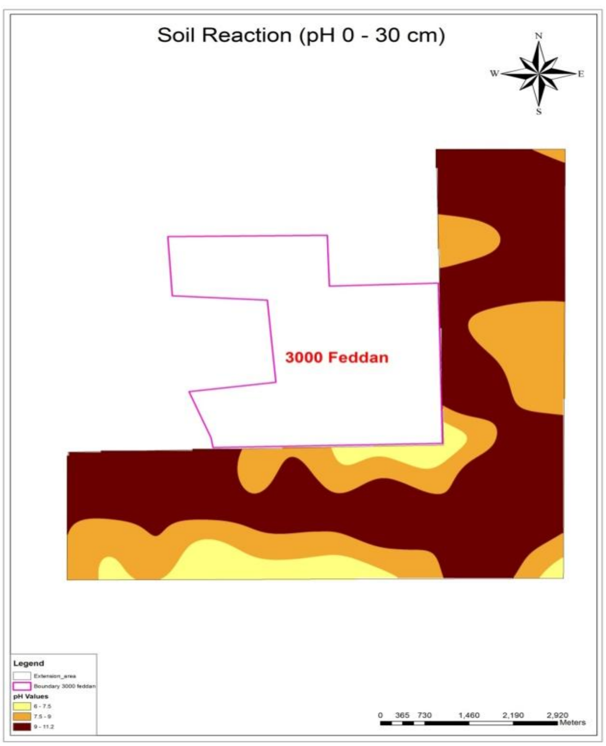


Fig.10a. Soil pH (0-30 cm) 17000 feddan

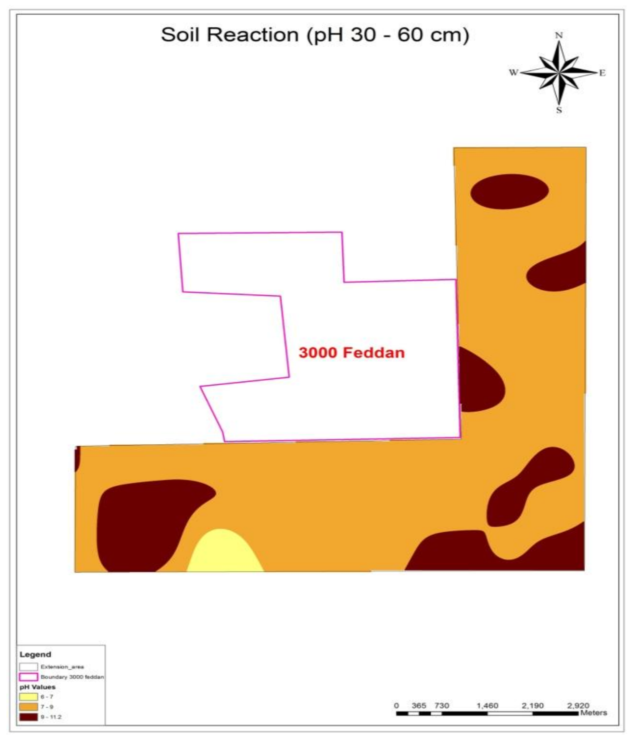


Fig.10b. Soil pH (30-60 cm) 17000 feddan

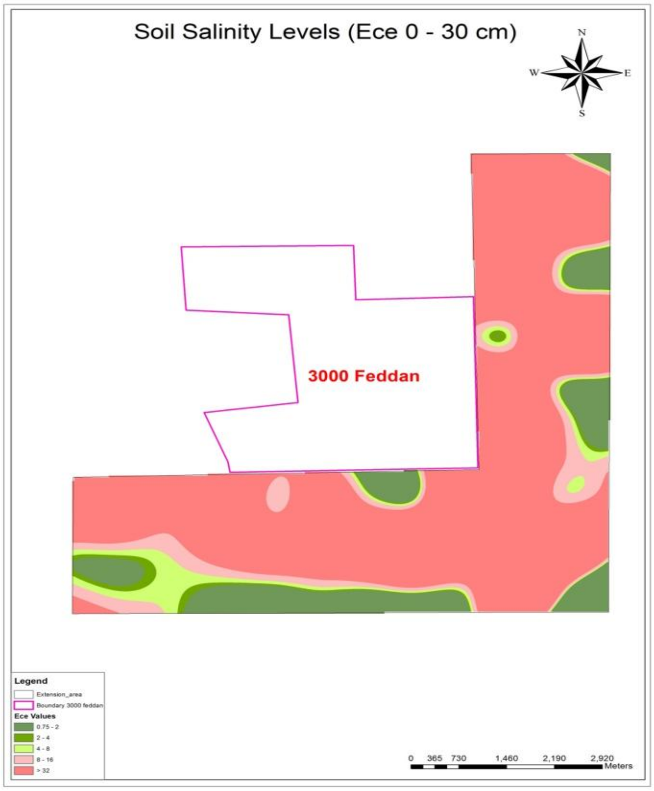


Fig.11a. Salinity (0-30 cm) 17000 feddan

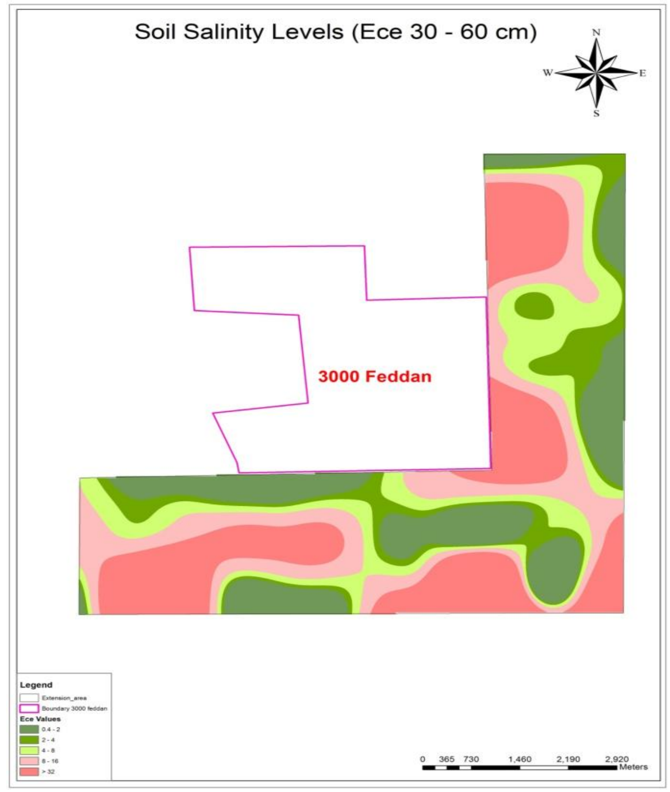


Fig.11 b. Salinity (30-60 cm) 17000 feddan

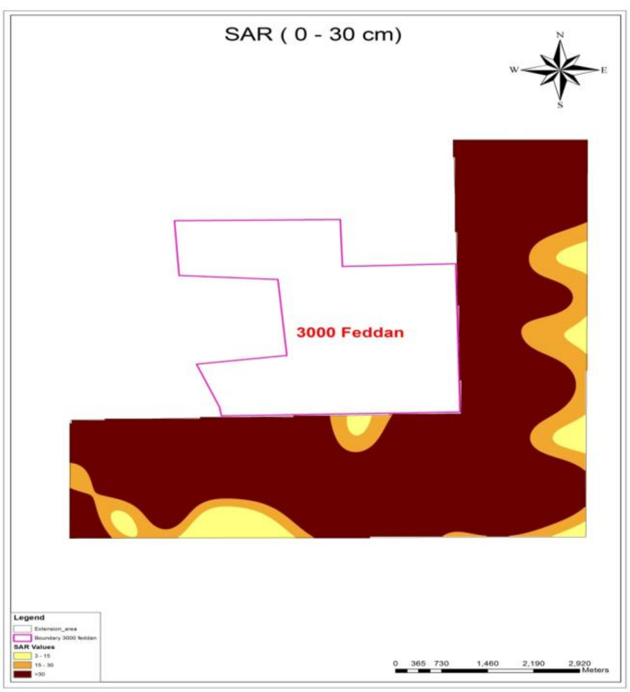


Fig. 12 a SAR in the surface (17000 feddan)

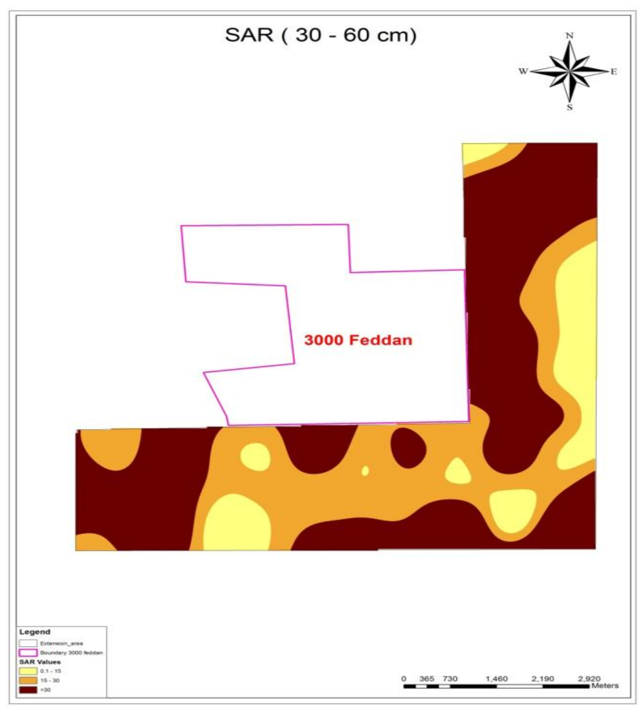


Fig.12 b. SAR in the sub surface (17000 feddan)

4. Conclusion and recommendations

The study revealed different signs of land degradation in the study area as judged by change in soil chemical properties. The high creep of sand and degradation in vegetation cover, despite its scarcity. The high temperature led to the accumulation of salts on the soil surface and the formation of thick salt layers that threaten the plant growth in the study area, resulting increase in sand encroachment and a decrease in vegetation cover.

These changes indicated decrease in vegetations cover yield and productivity; the saline and sodic soils cover most of the areas. These signs could be revised with the use of agricultural indicators. Land degradation as reduction in biological productivity can be interpreted from vegetations yields. Soil analysis indicated that the chemical properties of the soil had revealed different changes; most of the study area was affected by salinity and sodicity that had negative impact on the soil productivity. Based on these findings, the following recommendation can be stated:

1. Encouraging the establishment of windbreaks by planting endemic plants in the study area.
2. Establishment of a natural reserve in the study area.
3. Preserving the existing vegetation cover.

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Appendix 1 a, Analytical results

Auger sites: Depth (0 – 30). 3000 feddan.

Augers 0-30	pH(s)	Ece ds/m	SAR
A52	8.80	9.08	3.100
A55	7.60	2.07	54.750
A63	8.60	5.47	12.860
A66	6.40	1.02	90.000
A68	7.60	0.75	44.297
A77	7.80	8.71	46.418
A99	7.60	9.57	19.484
A101	8.60	18.59	34.195
A112	9.00	17.15	34.195
Z0	10.5	109.9	34.195
Z1	9.20	16.94	34.195
Z2	9.30	13.51	68.290
Z3	9.20	13.67	68.290
Z4	9.20	12.87	68.290
Z5	9.30	40.6	68.290
Z6	9.30	40.6	97.220
Z7	9.60	40.6	52.154
Z8	9.60	57.0	52.154
Z9	10.5	91.8	46.835
Z10	9.60	91.8	98.074
Z11	9.30	39.7	73.468
Z12	10.5	91.8	52.154
Z13	10.6	104.1	96.391
Z14	10.5	91.8	58.496
Z15	9.70	41.9	39.845
Z16	10.5	91.8	48.555
Z17	8.50	11.0	93.445
Z18	9.5	52.4	94.142
Well	10.3	64.7	21.108
Crt1	10.5	15.17	81.793
Crt2	8.00	64.7	66.256
Crt3	10.3	15.17	93.540
Crt4	10.5	64.7	11.813

Augers 30-60	SP%	pH(s)	Ece ds/m	SAR
A52	25.128	8.8	3.26	0.103
A55	25.128	9.6	41.4	7.400
A63	18.974	9.5	43.5	14.200
A66	30.872	5.5	0.4	15.062
A68	31.692	7.9	0.52	15.632
A77	29.231	8.1	3.25	17.700
A99	25.538	7.8	12.45	17.777
A101	26.359	8.5	34.6	18.593
A112	27.590	10.1	110.5	18.593
Z0	25.949	8.8	1.88	18.593
Z1	29.231	9.3	10.91	18.593
Z2	28.821	8.6	13.09	22.978
Z3	25.949	9.7	11.18	22.978
Z4	23.897	9.8	18.21	22.978
Z5	28.821	8.6	20.06	22.978
Z6	28.821	8.6	20.06	24.324
Z7	27.179	7.6	20.06	24.324
Z8	23.077	7.6	1.87	24.324
Z9	25.128	8.5	2.52	35.395
Z10	27.179	7.6	2.52	36.027
Z11	29.641	9.3	3.52	46.220
Z12	25.128	8.5	2.52	46.253
Z13	30.872	9.0	9.39	49.104
Z14	25.128	8.5	2.52	52.154
Z15	14.872	8.6	4.52	53.188
Z16	25.128	8.5	2.52	59.310
Z17	28.000	7.7	1.70	68.875
Z18	24.718	8.6	5.58	77.994
Well	27.590	8.6	3.82	83.592
Crt1	28.000	9.2	8.79	85.200
Crt2	24.308	8.3	32.2	91.455
Crt3	27.590	8.6	8.79	95.548
Crt4	28.000	9.2	32.2	97.538

Appendices (1 b) Auger sites: 3000 feddan. Depth (30 - 60 cm).

Appendices (1 c) Auger sites: 17000 feddan. Depth 0 -30cm and 30-60cm.

Site	pH30	pH60	Ece30	Ece60	SAR30	SAR60
0	8.8	8.8	9.08	3.26	81.793	35.00
1	7.6	9.6	2.07	41.4	11.813	42.00
2	8.6	9.5	5.47	43.5	46.835	52.00
3	6.4	5.5	1.02	0.4	3.100	0.10
4	7.6	7.9	0.75	0.52	12.860	14.20
5	7.8	8.1	8.71	3.25	48.555	32.00
6	7.6	7.8	9.57	12.45	66.256	36.00
7	8.6	8.5	18.59	34.6	55.000	40.00
8	9	10.1	17.15	110.5	40.000	70.00
9	10.5	8.8	109.9	1.88	52.000	7.40
10	9.2	9.3	16.94	10.91	45.000	68.87
11	9.3	8.6	13.51	13.09	21.108	52.00
12	9.2	9.7	13.67	11.18	61.000	40.00
13	9.2	9.8	12.87	18.21	60.000	49.10
14	9.3	8.6	40.6	20.06	60.000	18.59
15	9.3	8.6	40.6	20.06	60.000	18.59
16	9.6	7.6	40.6	20.06	60.000	18.59
17	9.6	7.6	57	1.87	60.000	17.70
18	10.5	8.5	91.8	2.52	60.000	22.98
19	9.6	7.6	91.8	2.52	60.000	18.59
20	9.3	9.3	39.7	3.52	60.000	15.63
21	10.5	8.5	91.8	2.52	61.000	22.98
22	10.6	9	104.1	9.39	61.000	36.00
23	10.5	8.5	91.8	2.52	61.000	22.98
24	9.7	8.6	41.9	4.52	54.000	53.19
25	10.5	8.5	91.8	2.52	56.000	22.98
26	8.5	7.7	11	1.7	58.000	15.06
27	9.5	8.6	52.4	5.58	58.000	52.15
28	8	7.7	13.13	3.5	19.484	17.78
29	8.8	8.5	16.25	6.54	51.000	36.03
30	8	8.4	129.1	3.36	51.000	15.81
31	10.3	8.6	64.7	3.82	52.154	46.00
32	10.5	9.2	15.17	8.79	19.484	17.78
33	8	8.3	64.7	32.2	52.154	37.00
34	10.3	8.6	15.17	8.79	41.000	36.03
35	10.5	9.2	64.7	32.2	52.154	54.00
36	8.5	7.7	11	1.7	41.000	15.06
37	9.5	8.6	52.4	5.58	41.000	52.15
38	8	7.7	13.13	3.5	19.484	17.78
39	8.8	8.5	16.25	6.54	41.000	36.03
40	8	8.4	129.1	3.36	42.000	15.81
41	10.3	8.6	64.7	3.82	52.154	46.25
42	10.5	9.2	15.17	8.79	19.484	17.78
43	8	8.3	64.7	32.2	52.154	51.00
44	10.3	8.6	15.17	8.79	41.000	36.03
45	10.5	9.2	64.7	32.2	52.154	52.00
46	10.6	9	104.1	9.39	61.000	46.22
47	10.5	8.5	91.8	2.52	61.000	22.98
48	9.7	8.6	41.9	4.52	58.000	53.19

Appendices (1 d) Profiles sites/ 3000 feddan/ unit 1.

Profile No & Layer cm	p H (s)	E.Ceds/m	SAR
P0			
(0 – 30)	8.0	13.13	19.48
(30 – 60)	7.7	3.5	17.77
P1			
(0 – 30)	8.8	16.25	98.07
(30 – 60)	8.5	6.54	36.027
P2			
(0 – 5)	10.6	129.1	100.16
(5 – 30)	8.0	3.36	15.811
(30 – 60)	8.4	9.08	1.8246

Appendices (1 e) Profile analytical results/ unit2.

P19	p H (s)	E.Ce ds/m	SAR
(0 – 12)	7.1	0.35	0.25
(12 – 31)	7.1	0.21	0.25
(31 – 70)	7.4	0.21	0.219
P21			
(0 – 10)	7.8	0.62	0.60
(10 – 37)	8.1	1.06	1.74
(37 – 80)	9.5	11.95	0.90

Appendices (1 f) Profile analytical results/ unit3.

Profile No & Layer cm	p H (s)	E.Ce ds/m	SAR
P0			
(0 -8)	6.8	0.31	0.32
(8 – 30)	7.2	0.53	0.54
(30 – 70)	8.0	1.42	0.43
P8			
(0 – 9)	7.2	0.32	0.23
(9 – 29)	7.6	0.84	0.53
(29 – 57)	8.0	1.42	0.68
(57 – 80)	8.0	1.68	0.52

	p H	E.Ce mmhos/cm	TDS PPm	Na mq/l	Ca+Mg mq/l	SAR	Comment
Non saline area	7.5	2180	1395.2	17.8	4.0	8.9	C4S2
Strongly saline area	10.0	111200	11168.0	107.4	3.8	53.7	Not recommended for drinking or irrigation

Appendices (1 g) Surface water analyses result/ 3000 feddan/ unit 1.