A Note on the Alluvial Soils of Iraq, their Salinity, Sodicity and Reclaimability

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The Lower Rafidain (Mesopotamian) Plain is located in Central and Southern Iraq. It is the alluvial plain of the Tigris and Euphrates rivers and it covers an area of about 120,000 square kilometres i.e. one quarter of the total area of Iraq. The prevailing climate is continental and arid (rainfall range 0 to 150 mm) with dry hot summers (mean 35 °C) and cool winters (mean 10 °C).

The general characteristics of the soils in the Lower Rafidain Plain are the following:

1. Stratification with horizontal and vertical differentiation in texture, mineral composition, clay minerals, structure, consistence and permeability.
2. Flat topography with a mesorelief having a few metres' range.
3. Deep soils with active sedimentation as a result of the annual flooding regime of the Tigris and Euphrates rivers.
4. The inherent fertility varies depending upon the soil texture and the pattern of sedimentation.
5. Pedocalcic conditions prevail with a range of 20 to 30% $CaCO_3$ and $MgCO_3$ content.
6. Salinization is active due to the geosynclinal geologic origin of the Plain whereupon inland lakes were formed. There is predominence of Na and Cl ions in the soil solution since the Ca, Mg and HCO_3 ions precipitate preferentially due to the low solubility product constants of $CaCO_3$ and $MgCO_3$.
7. Gypsum is a common constituent, usually not exceeding 5%. It acts as a soil ameliorant preventing the formation of sodic conditions. Thus the differentiation in the physical, chemical and pedological characteristics of the soils in the Lower Rafidain Plain is determined by the physiography of the terrain. Eight physiographic major soil mapping units have been recognised namely:

1. The Older Fluviatile Terraces.
2. The Flood Plain.
3. The Delta Plain.
4. The Marsh Region.
5. The Estuary Region.
6. The Eastern Section of the Plain.
7. The Fan Region.
8. The Coastal Region.

Figure 1 shows a block diagram of the physiographic location of these major mapping units. Within each of the physiographic units the mesorelief determines the minor soil mapping units which are formed in response to the meandering of the rivers and their flood pattern of sedimentation.

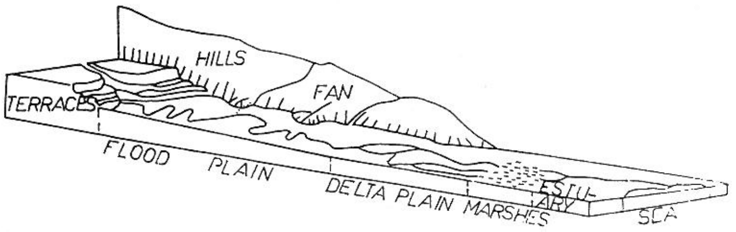

Fig. 1
Block diagram of the physiographic units of the Lower Mesopotamian Plain

Figure 2 represents an example of the meandering pattern of the Euphrates River.

Fig. 2
Map of the meander belt of a former Euphrates course, south of Hindiya Barrage

Figure 3 shows a cross-section of a hypothetical river basin with a topographic sequence of the minor soil mapping units in terms of their depositional pattern.

Figure 4 shows a hypothetical case of a three dimensional deep cross-section through a flood plain where the river levees and basins are formed during the different stages of sedimentation.

Salinity

The principal process in the soils of the Lower Rafidain Plain is salinization. More than 50% of the arable areas in this region have had a pronounced decline in yield as a result to salinization. Saline, saline-sodic and, to a very limited extent, sodic soils do occur throughout these arable areas. According to the (U.S. Salinity Laboratory 1954) definition of saline soils they are characterised by an Electric Conductivity (E.C.) of their soil solution of higher, than 4 mmhos, an Exchangeable Sodium Percentage (E.S.P.) of less than

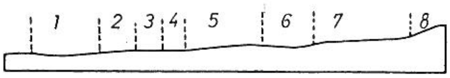

Fig. 3

Sketch of the various units of a river basin. 1. Lake, 2. Lake bottom. 3. Low basin. 4. Haur. 5. High basin. 6. Basin depression. 7. High basin. 8. River levee

15 per cent and a pH of less than 8.5; saline-sodic soils are characterised by an E.C. of higher than 4 mmhos, an E.S.P. of higher than 15% and a pH less than 8.5; sodic soils are characterised by an E.C. of less than 4 mmhos, an E.S.P. of more than 15% and a pH of more than 8.5. The saline soils in the Lower Rafidain Plain have a predominance of Sodium Chloride (NaCl) with varying levels and mixtures of Calcium Chloride ($CaCl_2$), Magnesium Chloride ($MgCl_2$), Potassium Chloride (KCl), Gypsum ($CaSO_4 \cdot 2\ H_2O$), Sodium Sulphate ($Na_2SO_4 \cdot 10\ H_2O$) and Magnesium Sulphate ($MgSO_4$).

Several pedogenetic groups of saline (Solonchak) soils exist, namely: Internal Solonchak, External Solonchak, Flooded Solonchak and Puffed Solonchak.

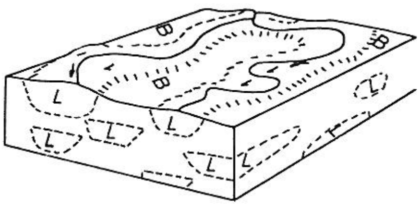

Fig. 4

Deep cross-section through a flood plain showing various river levees and basins which were formed during different stages of sedimentation]

Apart from the Solonchak soils, there occurs a form of hygroscopic saline soils locally known as Sabakh soils. These Sabakh soils exist in patchy dark patterns in extensive areas of the Lower Rafidain Plain. Table 1 presents the chemical composition of these soils (HANNA [4]). It can be noted from the table that the deliquescent salt constituents $CaCl_2$ and $MgCl_2$ predominate.

Figure 5 shows the usual distribution pattern of the Solonchak and Sabakh soils in a hypothetical cross-section of an irrigated area.

Table 1

Chemical composition of soluble salts in meq/l of three Sabakh soils (after Hanna, 1956)

Salt	Soil 1.	Soil 2.	Soil 3.
$CaCl_2$	115	187	197
$MgCl_2$	91	53	83
NaCl	12	—	14
$MgSO_4$	—	16	—
Na_2SO_4	24	1	22
$NaHCO_3$	0.4	0.4	0.4
Total	246	275	333

The general differentiation in the soil salinity levels and the pattern of its distribution as presented in the table 2 can be attributed to the outcome of interactions between several factors namely:

1. The mesorelief of the terrain in terms of the levels, basins and depressions and the transitional sites therein.
2. The ground water level, e.g. on an average this level is lower in the flood plain area than in the delta plain area.
3. The intensity of irrigated agriculture being practised.
4. The interaction between soil texture, soil structure, the differential stratification of the soil profile, and the ground water level and salinity status.
5. The seasonal range in the salinity concentration (in ppm) of the Tigris and Euphrates rivers varies between 190 and 500 hence, a differentiation in the salinization of the soils due to this factor is not expected to occur.

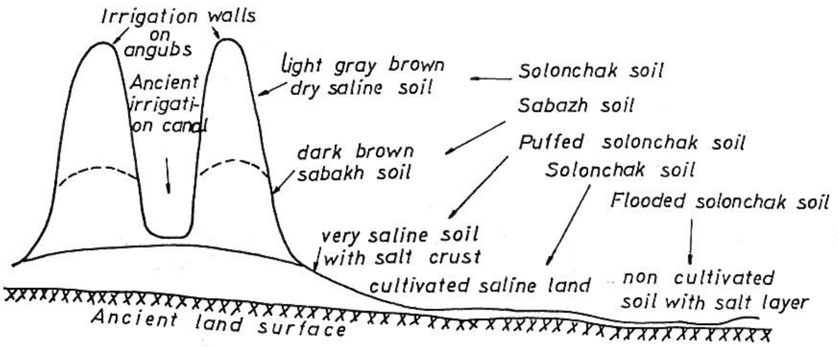

Fig. 5
Diagram showing the relative location of the various soil salinity types

The quantitative vertical and horizontal distribution of soil salinity is accompanied by a marked qualitative differentiation in the salt composition.

Table 2

Salinity classes in the investigated areas (in percentage)

Location	ECe in mmhos at 25°C in the 0—30 cm topsoil						
	0—2	2—4	4—8	8—16	16—32	32—64	64
Middle Tigris L.B.	27	24	10	12	9	13	5
Yousifiah	9	33	20	19	15	3	1
Rumaitha	1	10	21	16	14	25	13
Shattra	0	13	25	27	22	11	2
East-Gharraf	16	16	17	16	16	11	8

This is attributed to the variation in the salt composition of the ground water and the temperature and moisture gradients in the profile. A differential precipitation of the constituent salts occurs in the soil profile. No direct correspondence occurs between the distribution of the saline ions in the river waters and the soil solution in the adjacent soils. This is attributed to the

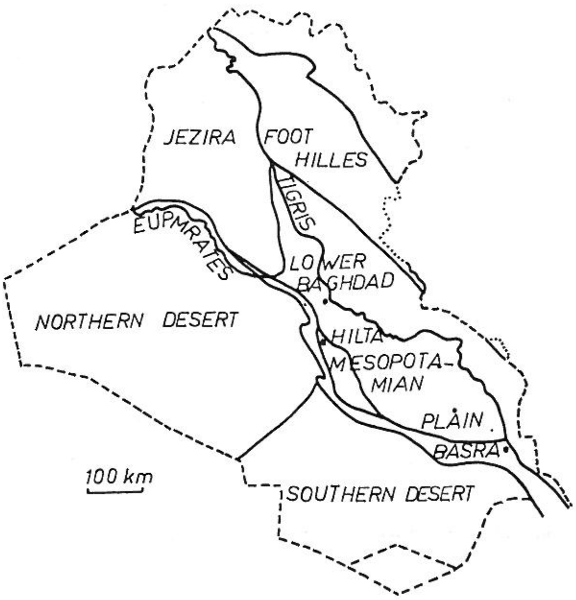

Fig. 6
Map of physiographic units of Iraq

prevalence of the gypsum deposits in the soils which contribute to the preferential precipitation of $CaSO_4$ in the soil profile.

The specific differentiation of the salt composition in the soils in terms of their cation and anion constituents is accounted for by the interaction between the following factors:

1. The physical properties of the soil layers which determine the pattern and rate of capillary rise and its distribution.

2. The differential rates of solubilities and precipitation of the constituent salt compounds.

3. The temperature, moisture and vapour gradients.

4. The variations in salinity concentrations correspond to variations in the ion-ratios. In the top soil the Na cations predominate over the Ca cations. In the subsoil where the Ca cations precipitate in the form of gypsum a high correlation exists between total salinity (ECe) and the $\frac{Na}{Ca + Mg}$ ratio. Leaching induces a more marked decrease in the cation concentration than the Ca cation concentration since the latter is released from the gypsum constituent especially in the subsoil.

Sodicity and land reclamation

The salinity in the soils of the Lower Rafidain Plain is commonly associated with sodicity. As the sodium cation constitutes a high fraction of the saline composition of the soils, a high fraction of the cation exchange capacity upon the surfaces of the clay complex is taken up by exchangeable sodium percentage. However, in view of the fact that the gypsum and lime constituents of these soils occur on an average in relatively high concentrations with ranges of 1 to 5 per cent and 20 to 30 per cent respectively, the sodicity

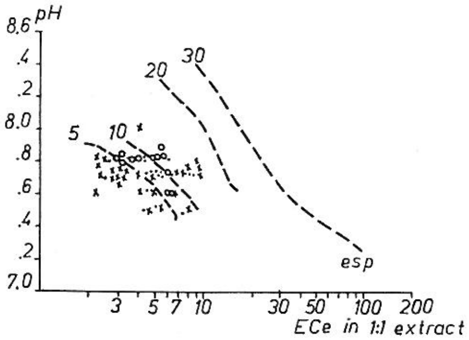

Fig. 7

Relationship between soil salinity (1 : 1 extract), pH and exchangeable sodium

does not cause dispersibility of the clay fraction. Hence, stable soil structure is maintained and the permeability of the soil to water is not impaired. Land reclaimability, therefore, is not expected to require soil ameliorants apart from the usual soil fertility building management practices. The field investigations on the reclaimability of the saline and saline-sodic soils of the Mussayib, Dujeilab, Amarah and Tweirig projects have in effect demonstrated that the reclamation of the saline and saline-sodic soils can be achieved by leaching coupled with the growing of relatively salt tolerant leguminous and grain crops in combination with fertilizer applications and the associated judicious cultural and water management practices.

Tables 3—7 below show that the gypsum constituent has a marked

Table 3

Average gypsum content (in percentage) in relation to the salinity degree of the top soil (0—30 çm)

Area	ECe					
	0—4	4—8	8—16	16—32	32—64	64
Middle Tigris L.B.	0.20	0.30	0.63	0.82	1.11	2.26
Yousifiah	0.22	0.38	0.46	0.83	1.47	no data
Rumaitha	0.16	0.30	0.96	1.41	1.82	2.74
Shattra	0.18	0.26	0.40	0.65	1.29	1.81
East Gharraf	0.21	0.40	0.50	0.83	1.97	1.70

effect upon reducing the Exchangeable Sodium Percentage levels in soils after the processes of leaching and land reclamation are applied.

Figure 5 demonstrates that salinity and sodicity vary from area to area. At ECe 50 mmhos the average ESP in Yousifiah is estimated at 31%, in Rumaitha on the other hand the ESP is 50%. Thus the difference in the ESP levels could not be attributable to the southerly location of the area in the Rafidain Plain but follow rather the inherent level of salinity in the area in question. Tables 2 and 8 show this phenomenon.

Rumaitha, the most saline area shows the highest level of sodicity at

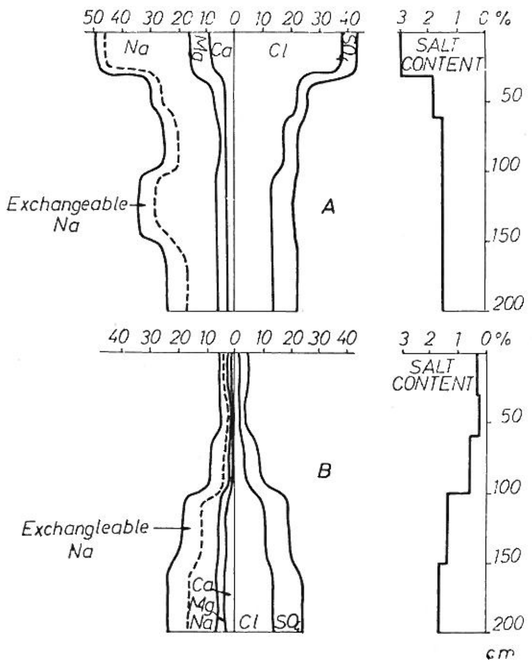

Fig. 8

Distribution of cations and anions (in meq/100 g) in a soil before (A) and after (B) leaching (data from Boumans, 1956). Almost all the salts are removed from the upper metre in one season of washing

Table 4

Average ESP per area as related to salinity degree

Area	ECe					
	0—4	4—8	8—16	16—32	32—64	64
Middle Tigris L.B.	1.5	6	12	24	38	53
Yousifiah	1.5	5	11	20	27	no data
Rumaitha	2.0	8	15	29	44	61
Shattra	1.5	5	11	20	30	43
East Gharraf	1.5	6	12	23	32	44

Table 5

Milliequivalents exch. Na/100 g. soil to be removed per area and salinity class if ESP has to be reduced to 10; estimation of average C.E.C. values

Area	ECe						estim. C.E.C. meq/100 g
	0—4	4—8	8—16	16—32	42—64	64	
Middle Tigris L.B.	0	0	0.35	2.45	4.90	7.53	17.5
Yousifiah	0	0	0.18	1.78	3.03	no data	17.8
Rumaitha	0	0	0.90	3.42	6.12	9.18	18
Shattra	0	0	0.18	1.80	3.60	5.94	18
East Gharraf	0	0	0.38	2.47	4.18	6.46	19

Table 6

Required gypsum percentage in 30 cm on top soil in relation to salinity level if by leaching ESP has to decrease to 10

Areas	ECe — classes — mmhos					
	0—4	4—8	8—16	16—32	32—64	64
Middle Tigris L.B.	0	0	0.47	0.29	0.58	0.78
Yousifiah	0	0	0.04	0.21	0.36	no data
Rumaitha	0	0	0.17	0.40	0.72	0.95
Shattra	0	0	0.04	0.21	0.43	0.61
East Gharraf	0	0	0.07	0.29	0.49	0.67

Table 7

Relative occurrence in % of gypsum in topsoil according to area

Areas	% gypsum				
	0.3	0.3—0.5	0.5—1	1—5	5
Middle Tigris L.B.	63	12	8	14	3
Yousifiah	58	14	16	11	1
Rumaitha	42	7	8	34	9
Shattra	38	26	17	19	0
East Gharraf	51	19	10	18	2

Table 8

Relative occurrence of different $\frac{Na}{Ca + Mg}$-ratios in 1 : 1 — extracts

Area	$\frac{Na}{Ca + Mg}$					
	0	0.5	1	2	4	8
Yousifiah	39	39	16	4	2	0
Rumaitha	13	33	27	22	5	0
Shattra	15	41	36	7	1	0

a certain ECe level. Yousifiah, the area with the lowest salinity level shows the lowest sodicity degree.

In the Dujailah project area the correspondence of the decrease in the gypsum content with the decrease in the ESP level during the leaching process is expressed in Tables 9 and 10.

Figure 7 for Dujailah soils demonstrates the interrelationship between the pH, salinity and ESP.

Figure 9 shows the leaching curves based on field drainage and leaching infiltration tests in both the Dujailah and the Ananah project areas as compared to an area in Utah in the USA.

Figure 8 taken from the Dujailah project's land reclamation experimental

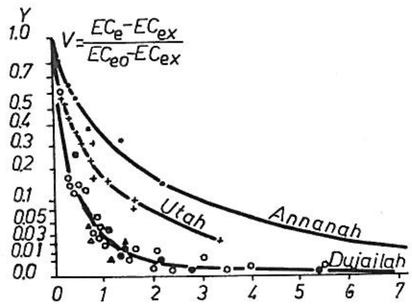

Fig. 9

Leaching curves. Absc.: depth of leaching water per unit depth of soil EC_e = Actual EC of leachee soil; ECeo = Initial EC of soil; EC_{ex} = Equlibrium level of EC in soil for areas concerned

Table 9

Average gypsum content of Dujailah soils

Depth cm	Plot T (before leaching)			Plot I (after leaching)		
	meq/100 g	%	No. of samples	meq/100 g	%	No. of samples
0— 30	11	0.95	9	0	0	9
30— 60	3	0.26	15	0	0	9
60—100	19	1.64	15	12	1.03	7
100—150	29	2.50	15	19	1.64	7
150—200	12	1.03	15	8	0.69	7

Table 10

Decrease of exchangeable sodium and salt during leaching

Treatments	Depth soil layer, cm							
	0—30		30—60		60—100		100—150	
	ECe	ESP	ECe	ESP	ECe	ESP	ECe	ESP
Before leaching	106	34	37	38	34	44	36	44
After 12 days leaching; 15 cm drainage*	6.5	15	13.5	33	—	—	—	—
After 42 days leaching; 52 cm drainage	3.0	8	2.6	23	—	—	—	—
After 69 days leaching and 84 days cropping	2.6	7	2.2	21	7.5	38	24	43
After 69 days leaching and 93 days cropping	3.8	5.5	2.0	20	—	—	—	—
After 69 days leaching and 3 cropping seasons	3.6	4.2	3.9	10	8.1	19	16	21

*15 cm drainage indicates that during the period specified a water depth of 15 cm was discharged by the field drains

area, shows the distribution of cations and anions in the local soil before and after leaching. It can be noted that all the salts were removed from the upper metre in one season of washing.

Summary

1. The alluvial soils of the Lower Rafidain (Mesopotamian) Plain of Iraq account for one quarter of the country's total land area.

2. The general characteristics of the soils are determined by the physiographic location, the mesorelief and the lithological origin which is mainly calcareous, gypsiferous and of varying soil textural composition.

3. Salinization is an active process in the terrain whereupon different pedogenetic forms of solonchak and sabakh soils are formed depending upon the groundwater regime and its saline composition.

4. The general and specific factors that determine the differentiation in soil salinity and sodicity levels, their pattern of distribution and composition have been described.

5. A correspondence exists between the behaviour of the gypsum constituent and sodicity during the leaching process which precedes soil reclamation.

6. Land reclamation can be achieved through leaching coupled with the application of soil fertility building practices.

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