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CAUSES, ORIGIN, GENESIS AND EXTENT OF SOIL SALINITY IN THE SULTANATE OF OMAN

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Soil salinity is very huge problem of the world. Sultanate of Oman being a part of arid regions is also very badly hit by this problem. The survey data indicated that 1.56 m ha were affected from salinity within suitable agricultural land that was calculated to be 70.25% of the total cultural land. Salt affected area within unsuitable agriculture is 12.32 m ha that is 39.21 % of the total geographical area of the country. Thus, total salt affected area (13.88 m ha) was 44.18 of the total geographical area of the country. The losses from crops due to salinity have been estimated as 49.04 m$ while that from abandoning of date palm orchards are 4.47 m$ which would make the total as 53.51 m$. The main causes of salinity are the climatic conditions (Scanty rainfall and high temperature), nearness to sea, salty parent material and development of secondary salinity due to consistent usage of very saline water. Many soils have a surface accumulation of secondary lime, which may also be Aeolian. The salinization of irrigated soils by groundwater has become a major process of soil formation in many areas of the Sultanate, particularly, in coastal areas. Salt pans in many soils can be attributed to Aeolian addition originating from the nearby sea through wind flows towards the inland. The genesis and classification studies indicted that salt affected soils in Oman belong to only two orders, the Aridisols and Entisols. The suborder are; Salids, Psamments, Fluvents and Orthents while great group is Typic. The subgroups are mostly Typic Aquisalids, Typic Haplogypsids, Typic Calcigypsids, Typic Haplocalcids and Typic Torrifluvents.

Key words: Causes, origin, genesis, extent, soil salinity, Oman

INTRODUCTION

Salinity is worldwide problem that spreads in all the continents except Antarctica. Adequate world resources of good quality irrigation water have become limited due to extensive usage and soil and ground water resources are becoming extremely saline after over utilization and development of secondary salinity. Soil salinity has emerged as a major crop production problem (http://www.fao.org/landandwater/agll/spush/table 1.htm). Based on the FAO/UNESCO Soil Map of the World, the total area of saline soils is 397 million hectare and that of sodic soils is 434 million ha, which are not necessarily arable but cover all salt-affected lands at global level. Out of the current 230 million ha of irrigated land, 45 million ha are salt-affected soils (19.5 percent) and of the almost 1,500 million ha of dry land agriculture, 32 million ha are salt-affected (2.1 percent), to varying degrees by human-induced processes (Oldeman *et al.*, 1991).

The Sultanate of Oman is located in arid zone of the world where annual mean temperature is high and rainfall is extremely low (MAF, 1990 & MWR, 1991). Moreover, major part of agriculture is concentrated in the coastal belt called Batina. Hence, most of the agricultural lands originated from parent material coming from the Gulf of Oman. Naturally, this coastal strip is irrigated with a huge aquifer having low gradient and flowing from south to the north. This aquifer was recharged by the percolation of water from the heavy rainfalls on mountains and plains in the north. Rather, excess water was bringing floods and land erosion in and around natural water ways called Wadies (MAF, 1993; Qureshi, 1995 & MAF, 1997).

The ground water use (through wells of animal traction) was in very good equilibrium with the annual recharge in the past. Therefore, groundwater was not so saline up to the end of seventies of twentieth century. The salts deposited by irrigation were being leached and washed by surface irrigations while residual groundwater flow moving the salts out of the cropped area. The groundwater resource was not fully used. However, during eighties and nineties, there has been a great expansion of agriculture and the ground water use was extended a lot either by wells equipped with motors and pumps in the traditional area or drilling of deep wells (power driven) and heavy pumping to irrigate new farms in the upstream areas. As a result, the aquifer became deficit because the recharge was lower than withdrawals. There was no salt control and

salinization process (secondary salinity) became very active and persistent. There was also some poorly drained depression areas near coast called Sebkha where salt and water accumulated. The excessive water either evaporated or fell in the sea increasing salt content of these areas gradually. Salt affected lands and abandoning of farms has become a permanent feature and ever-increasing phenomenon of the landscape in Batina plain. Gradual but consistent increase in salt concentration of groundwater is another outcome of the present development.

Hence, sustainability of agricultural system in the country is at a great threat. Agricultural development would not be possible. Thus, soil and water salinity has emerged as an extreme problem of Oman agriculture (Hussain, 2005). The objectives of the present review efforts was to understand the basis and processes of development of soil and water salinity in Sultanate of Oman and document its extent and losses so that this giant problem can be controlled effectively.

MATERIAL AND METHODS

The major part of present study consisted of review from different component surveys (MAF, 1990; MWR, 1991; MAF, 1993; Qureshi, 1995; MAF, 1997; Anonymous, 2005 & Hussain, 2005). The required data were collected from different sources and processed for making various calculations. A lot of basic data regarding extent of salt affected soils and categorization were collected mainly from Integrated Study of South Batinah (1993) and North Batinah (1997). All the 12 printed volumes were consulted in this regard. Present land use data were collected from 2004 Census of Agriculture and Fisheries (Ministry of Agriculture and Fisheries, 2004). The extent of soil salinity problem was not presented in the General Soil Survey Map of the Sultanate of Oman (MAF 1990), as the problem was not dealt separately. Tables (2 & 3) have been compiled by collecting information presented at different pages of the original source. Nature of problem in different mapping units of the suitable agricultural land, correctable limitations coupled with salinity and correctable measures are presented in Table 2. The extent of salt affected lands of different mapping units within unsuitable lands and the permanent limitations along with salinity are presented in compiled Table 3.

Data for whole of the country were not available for various aspects of salinity. Hence, Batinah Region was taken as an example because it is also the major agricultural area of Oman. Long and detailed calculations were made using primary data to construct the tables that are being presented here to analyze the prevailing situation in the country. Some secondary parameters were also calculated to adjudge the prevailing conditions. Gross margins were calculated taking into consideration the mean yield of the crop, average value of the output and mean total variable cost. Losses of salinity were calculated based upon certain assumption e.g. 25 & 50 % yield losses and the gross margins coming from crops/trees which could be grown on the abandoned lands due to salinity.

RESULTS AND DISCUSSION

A) Causes of salinity in Oman

1) Climatic conditions

High temperature and a little rainfall are always conducive for accumulation of salts in the surface and sub-surface of the soil because the salts cannot be leached down completely. Moreover, the net water movement in the soil remains upwards. The water brings dissolved salts with it, evaporates and leaves these salts on the surface or nearer underneath. Thus, this process slowly and gradually builds up the saline soils. The process is always active, especially in dry seasons in arid and semi-arid climates. Unluckily, high temperature and low rainfall (50 mm) prevails in Oman also (MAF, 1990). Soil genesis of centuries long caused salt accumulation from salty rocks and minerals. Hence, the chances of development of saline soils remained always very high.

2) Nearness to sea

The places nearer to sea always face salinity threat due to soil formation from minerals high in soluble salt content, saline water intrusion, saline water floods and salty water sprays. A major part of Oman soils was built up from the deposited coastal material. Therefore, salt content are naturally high in these soils. During the integrated study of the soils, this fact was confirmed and the soils were classified naturally having salty minerals in them (MAF, 1993 & MAF, 1997). The saline water intrusions can also be found underneath.

3) Secondary Salinity

This is the type of salinity induced due to man's activity during different cultural practices, irrigation operations and crop sequences in the agriculture field and wasting saline and polluted effluent into the soils and waterways by the industry and sewage from residential areas. The secondary salinity is very much pronounced in Oman. With the extension of agriculture in Oman during the last decade, groundwater was pumped indiscriminately and blindly without knowing that it is saline or fresh. Farmers were also unaware about the

quality changes that could occur because of very high pumping compared with annual recharge. They bother neither about the quality changes in well water nor bad effects of saline water when used on soils without any precautionary measure. Gradually the soils were salinized, the groundwater became more concentrated in salts and there were seawater intrusions as well (MWR, 1991 & Qureshi, 1995).

4) Fallowing

Leaving the soil uncultivated for longer periods invites salinity build up because the net water movement becomes upwards which results in salt accumulation. On the other hand keeping the soils under crop cover is useful because irrigation for crops divert the water cycle and salt movement downwards. Nevertheless, the water resources in Oman are very limited and the annual recharge is far behind the actual requirements. Therefore, crop intensity cannot be increased and farmers are forced to keep their lands fallow for some part of the year, especially during summer. They cannot grow two crops a year in the same land. Hence, accumulated salts remain recycling in sub-surface and cannot be pushed into the very deep depths or drained off.

B) Origin and genesis of soil salinity

Sultanate of Oman is located in the southeastern part of Arab Peninsula. It extends along the Gulf of Oman and the Arabian Sea. Most part of the country is a sub-tropical desert. The coastal areas are hot and humid in summer that extends over major part of the year. Mean annual rainfall is less than 50 mm in the two thirds of the country and is around 100 mm in rest of the areas. However, in southern mountains the rainfall ranges from 200 to 300 mm. Calcareous sedimentary rocks is the main source of parent materials in the major part of the country. Parent material in the mountainous parts developed from sedimentary rocks. The soils remain dry for most of the year. Therefore, the influence of the desert environment is visible and the soils are very low in organic matter. Shallow accumulation of calcium carbonate, gypsum and salts that are more soluble is evidence of the low leaching power of the prevailing climate. Salt pans in many soils can be attributed to Aeolian addition originating from the nearby sea through wind flows towards the inland. Many soils have a surface accumulation of secondary lime, which may also be Aeolian. The salinization of irrigated soils by groundwater has become a major process of soil formation in many areas of the Sultanate, particularly, in coastal areas (MAF, 1990).

C) Losses due to salinity

In spite of the severity of soil and water salinity in the country, needed necessary steps were not taken to tackle this menace. Resultantly, the problem has emerged in the shape of a giant ready to eat the whole agriculture of Oman, that of Batinah region in particular. Desertification can be seen everywhere. Many farms, especially the date palms have been abandoned. Thus, the earning source and the livelihood of the farmers were snatched by salinity. Many people have become jobless. Yields have gradually decreased on the farms, which could yet remain under cultivation. This problem has now become so acute that farming became very uneconomical. No direct data were available on this aspect. However, some estimates of losses have been made by Hussain (2005) and are presented in Table 1. Thus, it is very clear from the data of this table that estimated annual losses occurring from soil salinity to the country are 49.04 m$ (20.66 million Omani Rials). The loss from abandoned date palm farms has been estimated as 4.47 m$. If these losses are included in the estimates then total would become 53.51 m$. Clearly, this is very big annual loss to agriculture and economy of the country.

D) Extent of soil salinity

a) Soil salinity problem within suitable agricultural land

On the basis of information collected from General Soil Survey Map of the Sultanate of Oman (MAF 1990) the salinity problem appeared to be very extensive. The impact of problem would have been intensified but no fresh survey was conducted that would indicted the exact extent of problem at present. The old data indicated that 1.56 m ha were affected from salinity within suitable agricultural land that was calculated to be 70.25% of the total cultural land (Hussain 2005). It can clearly be realized that how much was the severity of salinity problem in suitable agricultural land that was already very limited (Table 2).

b) Soil salinity problem within unsuitable agricultural land

According to estimates, salt affected area within unsuitable agriculture is 12.32 m ha that is 39.21 % of the total geographical area of the country. This area is permanently unsuitable for agriculture due to salinity coupled with other permanent constraints, which cannot be corrected. Therefore, this area is not of great significance. Further detail can be seen in Table 3.

Table 1. Estimated losses of salinity in Oman

Crops	Area (ha)	Gross Margins Per ha (OR)	Total Gross Income (m OR)	Loss (m OR) due to salinity (25% decrease on 50 % area)	Loss (m OR) due to salinity (50% decrease on 50 % area)	Loss (m $) due to salinity (50% decrease on 50 % area)
Tomato	991	2315	2.29	0.29	0.58	1.38
Pepper	623	5545	3.45	0.43	0.86	2.05
Cabbage	320	160	0.05	0.01	0.02	0.05
Egg plant	274	419	0.15	0.02	0.04	0.10
Potato	560	681	0.38	0.01	0.02	0.05
Onion	881	445	0.39	0.05	0.10	0.24
Alfalfa	11273	4174	47.05	5.88	11.76	27.99
Rhodes Grass	6470	2077	13.44	1.68	3.36	8.00
Date palm	41975	307	12.89	1.61	3.22	7.66
Mango	1470	295	0.43	0.05	0.10	0.24
Lime	1210	526	0.64	0.08	0.16	0.38
Banana	2857	538	1.54	0.19	0.38	0.90
Total	68904	-	82.7	10.33	20.66	49.04

Abandoned date palm farms = 4.47 m$

Table 2. Soil salinity problem in suitable agricultural lands (S1 & S2)

Map unit No.	Extent (ha)	Land suitability Class	Correctable Limitation	Correctable Measures
1	286494	S1	Excess salts	Leaching
2	87449	S2	Excess salts & Slope	Leaching Leveling
3	21688	S2	Excess salts Slope Stoniness	Leaching Leveling Removal of stones
4	70533	S2	Excess salts	Leaching
6	51421	S2	Excess salts Slope	Leaching Leveling
7	334084	S2	Excess salts Slope	Leaching Leveling
32	6810	S2	Excess salts Sand blowing	Leaching Wind breaks
36	65905	S1	Excess salts Flooding	Leaching Diking
37	130410	S1	Excess salts Flooding	Leaching Diking
40	18436	S2	Excess salts Flooding	Leaching Diking
41	6854	S2	Excess salts	Leaching
42	454617	S2	Excess salts Flooding	Leaching Diking
52	27141	S2	Excess salts Slope	Leaching Leveling

Total 1561842 ha

Table 3. Extent of soil salinity in unsuitable (N) area

Map unit No.	Extent (ha)	Suitability class	Permanent limitations
8	35884	N	Excess salts and gypsum, depth to rock & Drainage
9	22799	N	Excess salts and gypsum, depth to rock & Drainage
16	836267	N	Excess salts and gypsum, depth to gypsum pan
20	38501	N	Excess salts and gypsum, depth to gypsum pan, high gravel content
22	257999	N	Excess salts and gypsum, depth to rocks and gypsum pan, slope
23	33166	N	Excess salts and gypsum, flooding, high gravel content
24	251091	N	Excess salts and gypsum, depth to rocks and gypsum pan, slope
25	112967	N	Excess salts and gypsum, slope, droughtiness, sand blowing
27	785795	N	Excess salts and gypsum, depth to gypsum pan, rockiness, slope
28	4974025	N	Excess salts and gypsum, depth to rocks and gypsum pan, slope
31	2202434	N	Excess salts and gypsum, slope, sand blowing, depth to gypsum pan
33	1452817	N	Excess salts, slope, sand blowing, poor drainage
34	7046	N	Excess salts, slope, sand blowing, poor drainage, rockiness
49	362102	N	Excess salts and gypsum, depth to rock, rockiness
56	37900	N	Excess salts, droughtiness, sand blowing
57	497628	N	Excess salts, poor drainage
58	126737	N	Excess salts, poor drainage, flooding
59	287658	N	Excess salts, sand blowing, slope, Poor drainage

Total 12322816 ha

Table 4. Classification of salt affected soils of Batina

Orders	Suborder	Great group and subgroup	Family	Key Features
Aridisols	Salids	Typic Aquisalids	Fine loamy dominant, mixed, hyperthermic	Salic horizon with gleying features
		Typic haplosalids	Clayey dominant, mixed, hyperthermic	Salic horizon fine Textured soils
			Fine loamy dominant, mixed, hyperthermic	Salic horizon, Moderately fine Textured soils
			Coarse loamy dominant, mixed, hyperthermic	Salic horizon, Medium textured soils
Entisols	Psamments	Typic Torripsamments	Mixed, hyperthermic	Sandy throughout, Coastal marine and aoelin deposits
	Fluvents	Typic Torrifluvents	Fine loamy dominant mixed, hyperthermic	Stratified material, salinized
			Coarse loamy over or satisfied with fine loamy, coarse loamy dominant, mixed, hyperthermic	Stratified material, Salinized, Somewhat restricted Drainage
			Coarse loamy over or stratified with sandy, Coarse loamy dominant, mixed, hyperthermic	Stratified material deposited near coast
			Sandy dominant, mixed, hyperthermic	Sandy top soil
			Sandy dominant, mixed, hyperthermic	Low salinity material
	Orthents	Typic Torriorthents	Sandy dominant, mixed, hyperthermic	Stratified material
			Sandy skeletal dominant, mixed, Hyperthermic	Stratified material

Table 5. Salt affected soil series and area (ha) of Batina

Locality	Total No. of soil series	Salt affected soil series	Slightly saline (4-8 dS/m)	Moderately saline (8-16 dS/m)	Strongly saline (16-32 dS/m)	Very strongly saline (32-64 dS/m)	Extremely saline (>64 dS/m)	Total affected/survey area (ha)
Liwa	16 (LW1 to LW16)	LW8 LW9 LW11 to LW14	765.8	1135.2	390.8	-	-	2292/4714 **(49%)**
Sohar	15 (SH1 to SH15)	SH5 SH7 to SH12	2187.9	1153.6	1486.2	568.1	-	5396/10760 **(50%)**
Shinas	21 (SN1 to SN21)	SN5 to SN10 SN12 to SN21	3168.7	1280.5	764.8	48.0	-	5262 /8657 **(61%)**
South Batinah	35	Sumayrat Suwayaq Wudam Kubbah Sawadi Hayal, Seeb Basit Manumah	3023.0	2242.0	2105.0	2285.0	4100.0	13755/27527 **(50 %)**
Total			9145.4 **17.7**	5811.3 **11.3**	4746.8 **9.2**	2901.1 **5.6**	4100.0 **7.9**	26705/51603 **52 %**

Notes:

1. Bold values in parentheses in the last column indicate percent area affected in the locality.
2. Bold values in the last line of the table indicate percent area of each category of salinity in the whole Batinah.

Salt affected area of Oman

Using the information detailed in Table 3 & 4 above the salt affected area under different categories of soil can be calculated.

1. Salt affected area within suitable lands (1.56 m ha) as %age of the total area of Oman = 4.97
2. Salt affected area within suitable agricultural land as percentage of total suitable agricultural Land = 70.25
3. Salt affected area within unsuitable lands (12.32 m ha) as percentage of the total area of Oman = 39.21
4. Total salt affected area (13.88 m ha) as %age of the total geographical area of Oman = 44.18

E) Categorization of salt affected soils

The genesis and classification studies indicted that salt affected soils in Oman belong to only two orders, the Aridisols and Entisols. The suborder are; Salids, Psamments, Fluvents and Orthents while great group is Typic. The subgroups are mostly Typic Aquisalids, Typic Haplogypsids, Typic Calcigypsids, Typic Haplocalcids and Typic Torrifluvents. For more details Table 4 can be seen. The detailed soil classification into series was separately done for each locality (Willaya). The numbers of salt affected soil series identified in each area, the designated names of these series as well as salt affected area of different categories are presented in compiled Table 5.

In broad classification, these soils are overwhelmingly saline with very little problem of sodicity that is in low-lying pockets. Hence, there are very less saline sodic soils whereas sodic soils are found nowhere. The texture of the soils is mainly sandy loam or loamy sand. However, at certain places in smaller areas, medium and heavy textured soils can also be found.

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