INNSPUB

International Journal of Biosciences | IJB |
ISSN: 2220-6655 (Print) 2222-5234 (Online)
http://www.innspub.net
Vol. 5, No. 1, p. 389-396, 2014

RESEARCH PAPER OPEN ACCESS

Study on prediction of the final soil salinity for soil desalinization and the amount of reclamation water requirement for salt leaching of saline and sodic soils using empirical simulation models (case study: Khuzestan Province, Iran)

Amirpouya Sarraf*

Department of Soil Sciences, Roudehen Branch, Islamic Azad University, Roudehen, Iran

Key words: Land reclamation, saline and sodic soils, reclamation water requirement, empirical simulation models, desalinization and desodification.

http://dx.doi.org/10.12692/ijb/5.1.389-396 Article published on July 12, 2014

Abstract

The study area was located at central part of Khuzestan province, Iran. Soil survey and land classification of the area showed that from total surveyed area of about 41,855 hectares, an area of about 14,100 hectares (33.7%) were saline / saline - sodic soils, in different extents. Also about 36,430 hectares (87.0 % of the total area) was subjected to water logging and poor internal drainage conditions. To study the possibilities of Desalinization and Desodification, six different sites were selected in the most Saline – Sodic parts of the study area for which eight treatments (Six for leaching water applications and two with gypsum as soil amendment) by means of 1.0 meter depth of leaching water application in four 0.25 meter intervals. Soil samples were taken before, during and after each leaching water application interval. The collected soil and water samples were then analyzed in the laboratory. Based on the collected data from salt leaching experiments, the Desalinization and Desodification leaching curves were obtained. Different theoretical models were also tested by comparing the calculated and experimental Desalinization and Desodification data. Reasonable agreements between theoretical and typical experimental leaching curves were observed. Some empirical exponential relationships were then obtained, enabling users to insert leaching efficiency coefficient and volumetric soil water content and depths to predict both final soil salinity and sodicity along with required depth of leaching water application. Also, application of any amendment materials such as gypsum was not needed for the reclamation of these soils.

* **Corresponding Author:** Amirpouya Sarraf ✉ amirpooya@hotmail.com

Introduction

The most important effective factor in regeneration of the Saline or Saline and Sodic soils is the determination of the proper leaching method as well as, estimation the required water for leaching soluble salts from the soil profile (Pazira *et al.*, 1999). Due to the limited range and the time consuming and costly nature of tests on the field, computer based simulation models can be used with the results of the field tests to estimate the required water volume for leaching soluble salts with an acceptable accuracy (Nogués *et al.*, 2000; Pazira *et al.*, 1981). In this regard, scholars have completed a series of models to determine the required water volume for leaching of the Saline and Sodic soils.

Saline and Sodic soils make up 13% of the total arable lands of the world. One of the main problems in the field of agriculture is land salinity. Various Studies show that using salty water, severe evaporation, insufficient leaching and deficit irrigation are the main causes of land salinity. In the salty soils due to the increase in the soluble salts, the water absorption via osmotic processes is disrupted. This In turn, results in growing disorders (Lal *et al.*, 2003).

Reclamation of salt affected soils is accomplished by either an addition of chemical amendment commonly mixed with the upper parts of the soil or directly dissolved in water, or recently by planting crops capable of accumulating salts (phytoremediation) in their parts (Qadir *et al.*, 2002).

In Jordan, it is estimated that more than 30% of agricultural land in the Jordan valley is salt affected soils (Mashali, 1989). Salinity and sodicity problems are expected to be enlarged in future as a result of using poor quality irrigation water (Gharaibeh *et al.*, 2009).

Moreover, little work has been done to evaluate the efficiency of moderate saline-sodic water in soil reclamation. It is reported that such water contains adequate calcium and magnesium ions that can potentially prevent destruction of soil structure and improve water penetration (Mace, 2001).

The objectives of this study were: (1) to determine the most appropriate experimental models for predicting the final salinity and exchangeable sodium percentage (ESP) of regional soils in response to water applications to achieve desalinization and desodification of the soils, (2) Survey and comparison the desalinization and desodification cases of the tested soils using the application of leaching water and leaching water plus soil chemical amendment (Gypsum).

Materials and Methods

The region under study is located in Khuzestan plains and in southern of Shoushtar city, between 32° 3' N and 48° 50' E. Lands in the studied region has an average elevation of 67 m above sea level, and the total area of the respective region is 41,855 hectares. The climate of region is arid and semi-arid with long and hot summers and short and relatively temperate winters. The average annual rainfall of this region reaches 322 mm, and average annual temperature of the region is 26.3 degrees Celsius, while the hottest and coolest months of the year are July and January, with 32.9 and 20.2 degrees Celsius, respectively. Additionally, the annual evaporation from the class (A) evaporation pan in this region is 3721 mm/year (Sarraf, 2008).

Soils in the study area vary from moderate to heavy and very heavy clays, and the land classes before implementation of leaching tests, have ranged from S_3A_3 to S_4A_3, with respect to the sodic and saline features. Six tests were conducted with the intermittent leaching method using 1.0 m water depth (in four 0.25 m alternations). The required water for leaching was supplied from Shotait and Gargar rivers. Before implementation of the tests, soil samples were collected to a depth of 1.5m using a sampling drill. Soil samples were tested for soil texture, field moisture content, existence of mottle and grey stains and other parameters. The soil samples then were sent to the laboratory to perform the full chemical and physical analyses (Sarraf, 2008). For each of the tests, four empirical models were developed for the Desalinization and Desodification relationships. The relationships were compared with correlation coefficient (R) and standard error (S.E) at the 1% of significance level. To determine the equilibrium salinity values (EC_{eq}), and the equilibrium exchangeable sodium percentage (ESP_{eq}) after the leaching tests, soil samples from 0-5cm depth were collected and sent to the laboratory. Samples from the applied water were also collected and analyzed for full chemical components. The respective classification based on Wilcox diagram was C_3S_1, with salinity (EC_w) and sodium absorption ratio (adj RNa) of 2.65 dS/m and 4.56 Millie Equivalent / (liters)1/2, respectively. The resulting figures and values were refined, unreasonable and abnormal figures (which were not significant) were omitted. Results of the field tests from six chosen sites were combined and merged to present practical recommendations, and scientific and reasonable solutions. The salinity figures (Soil saturation extract Electrical Conductivity) and the exchangeable sodium percentage associated with before, during and after the leaching tests were inspected, and the weighted average for the different water depth applications were calculated for the respective horizons in the soil profile (i.e. 0-25, 0-50, 0-75, 0-100, 0-125, and 0-150cm). It should be noted that a part of the applied leaching water could be used to compensate for the lack of soil moisture at the sampled depths. This part of the leaching water, therefore, had no effect on the leaching process. Also, full chemical equilibrium with the leaching water quality may not occur in the surface layers of soil profile in the short term, which may affect the reduction in salinity due to the leaching water application. In order to remove such moisture defect, based on weight averages data of the salinity and exchangeable sodium percentage, by making use of physical and chemical features obtained before, during and after leaching operations from different layers of soil profile in the studied region, it was preceded with preparing the Desalinization and Desodification figures as:

$$X = [Dl_w / D_s] \quad , \quad Y = [(EC_f - EC_{eq})/(EC_i - EC_{eq})]$$

$$X = [Dl_w / D_s] \quad , \quad Y = [(ESP_f - ESP_{eq})/(ESP_i - ESP_{eq})]$$

EC_i and EC_f are the soil saturated extract electrical conductivity before and after utilization of leaching water, respectively (Based on dS/m), EC_{eq} is the soil saturated extract electrical conductivity, which is under chemical equilibrium with the irrigation or leaching water quality (Based on dS/m), ESP_i and ESPf are the soil exchangeable sodium percentage before and after leaching water application, ESP_{eq}, is the exchangeable sodium percentage which is under chemical equilibrium with the irrigation or leaching water quality, Dl_w is the net amount of leaching water which is exiting the respective soil layer after provision for the respective soil layer moisture deficit (meters), D_s is the soil layer depth or thickness which shall be modified (meters with respect to the ground surface).

The Desalinization and Desodification curves of the tested soils were prepared using the SPSS Software, Four mathematical models (Power, Exponential, Inverse and Logarithmic) for the desalinization and desodification figures were calculated (X,Y) and interpolated. The models were analyzed with the statistical criteria, correlation coefficient (R) and standard error (S.E) at the 1% significance level. The most proper desalinization and desodification models of the tested soils were determined.

Results and discussion

The desalinization and desodification relationships of the soils were studied to provide the best experimental (Compositional) model of soils desalinization and desodification based on the field tests.

Soil Desalinization

Based on the results of the statistical analysis and interpolation of the different experimental models to the desalinization figures of the tested soils, the exponential model was the most proper desalinization experimental model for the soils of studied region (Bahçecİ, 2009). The exponential model had the highest correlation coefficient (R) equals 0/6808 and standard error (S.E) equals to 0.1764, at the 1% significance level, the exponential model was:

$$Y = 0.6227 \times e^{-1.5152X} \quad (1)$$

Replacing X and Y in relation (1), we have:

$$\left(\frac{EC_f - EC_{eq}}{EC_i - EC_{eq}}\right) = 0.6227 \times e^{-1.5152(Dlw/Ds)} \quad (2)$$

Then, in order to clarification the results of the experimental model simulation, the required factors, i.e. the leaching efficiency coefficient of the soluble salts from the soil profile (f = 0.3) and the soil volumetric moisture content during the process of the salt leaching from the soil profile θv = 0.32 (cm^3/cm^3) to be considered in the same and finally the studied region soils desalinization experimental relation was completed and used as follows:

$$\left(\frac{EC_f - EC_{eq}}{EC_i - EC_{eq}}\right) = 0.6227 \times \exp\left[-1.5152 \cdot \left(f/\theta_v\right)/\left(Dl_w/D_s\right)\right] \quad (3)$$

Table 1. Summary of the Results of Application the Saline Soils Leaching Experimental Models in Southeast of Khuzestan Province.

No.	Applied experimental model features		Soil leaching required water, (m)				Soil leaching required {Water averages (m)}		Practical model appropriation
			Respective soil improvement horizons, Ds, (m)						
	Name	Mathematical Formation	0.25	0.5	0.5	0.5	Weighted	Geometric	
1	Dieleman	Exponential	0.49	0.97	0.97	0.97	1.46	1.08	6
2	Leffelaar and Sharma	Hyperbolic	0.14	0.28	0.28	0.28	0.43	0.31	4
3	Hoffman	Hyperbolic	0.17	0.35	0.35	0.35	0.52	0.39	2
4	Pazira and Kawachi	Hyperbolic	0.16	0.32	0.32	0.32	0.47	0.35	3
5	Pazira and Keshavarz	Power	0.12	0.24	0.24	0.24	0.36	0.27	5
6	New	Exponential	0.24	0.48	0.48	0.48	0.73	0.54	1

Knowing the other variables, the net leaching water depth required for soil improvement (Dl_w) may be calculated using the following relation:

$$Dl_w = 1.5152 \times D_s \times \left(f/\theta_v\right) \times \left[\ln\left(0.6227\left(\frac{EC_i - EC_{eq}}{EC_f - EC_{eq}}\right)\right)\right]^{-1} \quad (4)$$

Also, to predict the final salinity of soil saturated extract (EC_f), using the relation (3) we have:

$$EC_f = \left(EC_i - EC_{eq}\right)\left[0.6227 \times \exp\left(-1.5152\left(\left(f/\theta_v\right)/\left(Dl_w/D_s\right)\right)\right)\right] + EC_{eq} \quad (5)$$

It should be noted that using the relations (4) and (5) for the range of soil types (heavy to very heavy) in the region and the initial salinity and exchangeable sodium percentage of the tested soils may have practical reliability (Anonymous, 2006), while the range of these changes have been 7.12 to 30.8 dS/m, and 9.41 to 31.80 percent, respectively.

Soil Desodification

The mathematical model for soil desodification may be given as follows:

$$Y = 0.7184 \times e^{-0.5015X} \quad (6)$$

The correlation coefficient (R) equals 0.5129 and the standard error (S.E) equals 0.2543 at the 1% significance level. Replacing the X and Y values in relation (6), we have:

$$\left(\frac{ESP_f - ESP_{eq}}{ESP_i - ESP_{eq}}\right) = 0.7184 \times e^{-0.5015(Dlw/Ds)} \quad (7)$$

Regarding estimation the net leaching water required of soil exchangeable sodium percentage; the following relation is resulted using relation (7):

$$Dl_w = 2 \times D_s \times \ln\left[0.7184\left(\frac{ESP_i - ESP_{eq}}{ESP_f - ESP_{eq}}\right)\right] \quad (8)$$

Also in order to predict the final exchangeable sodium percentage (ESP_f), using relation (7) we have:

$$ESP_f = \left(ESP_i - ESP_{eq}\right)\left[0.7184 \times e^{-0.5015\left(Dl_w/D_s\right)}\right] + ESP_{eq} \qquad (9)$$

The Desalinization and Desodification Curves of Studied Region Soils

(Dieleman, 1963; Gardner *et al.*, 1957; Rajabzadeh, 2009). Applying the relations (3) and (7) which are the best experimental models for the studied region soil's desalinization and desodification, desalinization and desodification curves for the tested soils were drawn (Figures 1 and 2).

Table 2. Soil Profile Different Salinity Classes in the Respective Depths (Unit, 1000 M3 / Hectare).

Soil salinity classes after leaching operation EC_f (dS/m)	Soil Salinity Classes Before Leaching Operation (EC_i)															
	S_1				S_2				S_3				S_4			
	Soil layer thickness from ground surface (m))				Soil layer thickness from ground surface (m)				Soil layer thickness from ground surface (m)				Soil layer thickness from ground surface (m)			
	0.25	0.5	1.0	1.5	0.25	0.5	1.0	1.5	0.25	0.5	1.0	1.5	0.25	0.5	1.0	1.5
S_0	0.15	0.3	0.45	0.6	0.3	0.6	0.9	1.2	0.42	0.84	1.26	1.68	0.55	1.1	1.65	2.2
S_1	-	-	-	-	0.07	0.14	0.21	0.28	0.2	0.4	0.6	0.8	0.32	0.64	0.96	1.28
S_2	-	-	-	-	-	-	-	-	0.05	0.1	0.15	0.20	0.17	0.34	0.51	0.68
S_3	-	-	-	-	-	-	-	-	-	-	-	-	0.04	0.08	0.12	0.16

It is possible to estimate the net water depth (Dl_w) to reduce the salinity or exchangeable sodium percentage of the soil to desirable levels using these curves. The extracted values from the aforementioned curves are the net needed water depth for leaching the soluble salts. In order to estimate the total (gross) required water for leaching (D_w), the lack of moisture of the respective soil layer (up to the field capacity), evaporation (from water and soil surfaces) and the rainfall shall be considered and applied in calculations and planning for leaching and improving the soil and lands (Pazira *et al.*, 1998 and 1999).

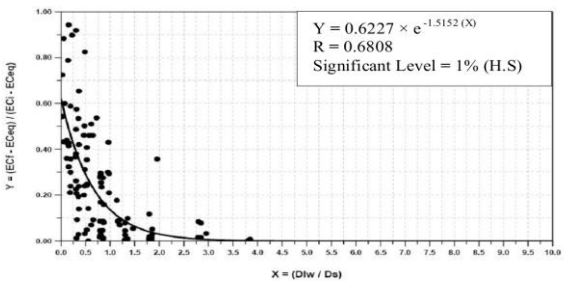

Fig. 1. Compositional Curve of the Tested Soils Desalinization Studies Results (Desalinization leaching curve).

A comparison between the newly developed model and some of the other leaching experimental models reported in the literature also was done. The required water for leaching soluble salts is compared in table (1). In this comparison, the initial salinity up to 1.50 m depth of the soil, the final salinity and level of equilibrium salinity were considered as 40.0, 8.0 and 2.65 dS/m, respectively. The results showed that the Hoffman (1980), Pazira and Kawachi (1981), Leffelaar and Sharma (1997), Pazira and Keshavarz (1998) models estimated the required water for the soils leaching as 33% to 50% less than the new model (experimental relation in this study), while Dieleman (1963) estimates the required water for leaching as double of the experimental relation of this study. The reasons for these differences are changes in the physical features (texture and structure), the chemical features (initial salinity and exchangeable sodium percentage) of the tested soils and the leaching method in determination such relations. Similar results have also been reported in other studies (Pazira *et al.*, 1997 and 1999).

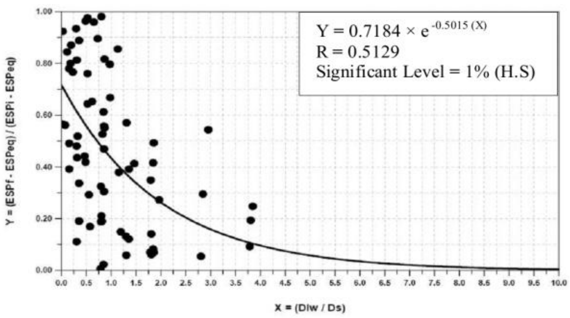

Fig. 2. Compositional Curve of the Tested Soils Desodification Studies Results (Desodification Leaching Curve).

Also in order to facilitate in estimating the required water volume (net or Dlw), table (2) has been provided and given as the guide for reducing the soil different classes of salinity in different soil profile horizons.

It should be mentioned that the tested soils desodification cases are very similar to the soils desalinization with respect to the method of analysis and conclusion, and only the latter has been mentioned here for brevity.

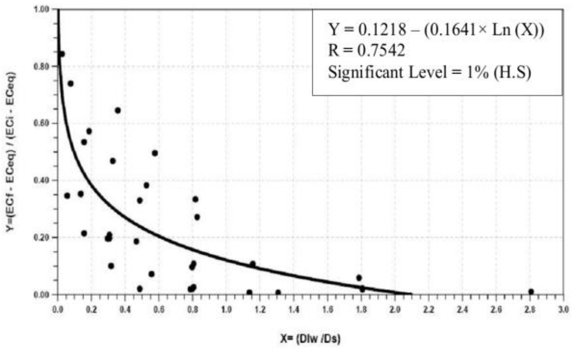

Fig. 3. Compositional Curves of the Chosen two Locations Combined Tests Desalinization Studies Results.

Survey and Comparison the Desalinization and Desodification Cases of the Tested Soils Using the Application of Leaching Water and Leaching Water + Soil Chemical Amendment (Gypsum)

This series of the tests were completed at two out of six chosen stations at which the sodicity and salinity problems were more intense in comparison with other regions. In order to improve the soil 6 tons of 62% pure gypsum was used as the soil amendment accompanied with 100 cm (effective) leaching water, to be applied in four 0.25m alternations. Tests evaluated whether adding the chemical amendment to applied water will improved the trend of leaching or not. In order to evaluate desalinization and desodification of the two chosen sites, the figures and valuesfrom the tests were combined for the field tests from the two chosen locations.

Desalinization and Desodification of the Tested Soils Using Leaching

Water + Chemical Amendment

Tested Soil Desalinization Issues

The statistical analysis results and interpolation of the different experimental models to the tested soils desalinization values were analyzed using the SPSS Software, Version 17. Four models were fit to the values resulted from the test implementation. The logarithmic model had the highest correlation coefficient (R) equals 0.7542 and the standard error (S.E) equal to 0.1558, at the 1% significance level and was selected as the proper desalinization experimental model (Bahçecİ, 2009). Hence, the better following relation may be given:

$$Y = 0.1218 - (0.1641 \cdot \ln X) \qquad (10)$$

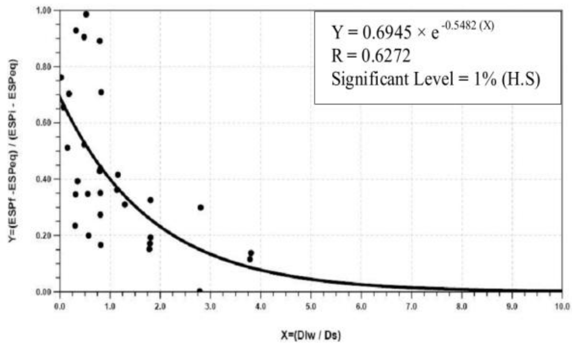

Fig. 4. Compositional Curves of the Chosen two Locations Combined Tests Desodification Studies Results.

By replacing X and Y by the respective variables we have:

$$\left(\frac{EC_f - EC_{eq}}{EC_i - EC_{eq}}\right) = 0.1218 - \left[0.1641 \cdot \ln\left(Dl_w / D_S\right)\right] \qquad (11)$$

Where the applied symbols have the foregoing meanings.

Having the soil layer thickness (Ds), for which leaching is desired, and by choosing or measuring the initial soil salinity (ECi) of this layer, having the equilibrium salinity (ECeq), and choosing the final salinity (ECf), it is possible to calculate the required leaching net water depth for soil improvement using the following relation:

$$Dl_w = D_S \cdot \exp\left[0.7422 - 6.0938\left(\frac{EC_f - EC_{eq}}{EC_i - EC_{eq}}\right)\right] \qquad (12)$$

Similarly, it is possible to estimate the soil saturated extract final salinity (EC_f) using the following relation, provided that the other variables are known:

$$EC_f = (EC_i - EC_{eq})[0.1218 - (0.1641.\ln(Dl_W / D_S))] + EC_{eq} \quad (13)$$

Tested Soil Desodification Issues

The statistical analysis results and interpolation of the different experimental models to the tested soils desodification values were analyzed using the SPSS Software, Version 17. Four models were fit to the values resulted from the test implementation. The exponential model had the highest correlation coefficient (*R*) equals 0.6272 and the (S.E) equals to 0.2118; at the 1% significance level was selected as the most proper desodification experimental model (Bahçeci̇, 2009). Hence, the better following relation may be given:

$$Y = 0.6945 \cdot e^{-0.5482X} \quad (14)$$

By replacing X and Y by the respective variables we have:

$$\left(\frac{ESP_f - ESP_{eq}}{ESP_i - ESP_{eq}}\right) = 0.6945 \cdot e^{-0.5482\left(\frac{Dl_w}{D_S}\right)} \quad (15)$$

Where the applied symbols have the foregoing meanings.

Having the soil layer thickness (D_s), for which leaching is desired, and by choosing or measuring the initial exchangeable sodium percentage (ESP_i) of such layer, having the equilibrium exchangeable sodium percentage (ESP_{eq}), and choosing the final exchangeable sodium percentage (ESP_f), it is possible to calculate the required leaching net water depth for soil improvement using the following relation:

$$Dl_w = 1.8241 \cdot D_S \cdot \ln\left[0.6945\left(\frac{ESP_i - ESP_{eq}}{ESP_f - ESP_{eq}}\right)\right] \quad (16)$$

Similarly, it is possible to estimate the final exchangeable sodium percentage (ESP_f) using the following relation, provided the other variables are known:

$$ESP_f = (ESP_i - ESP_{eq})\left[0.6945 \cdot e^{-0.5482\left(\frac{Dl_w}{Ds}\right)}\right] + ESP_{eq} \quad (17)$$

Conclusion

Solved salts leaching from the alluvial, heavy textured, saline and sodic soils of the region using the intermittent water application (intermittent salt leaching method) has been effective in reducing the soluble salts, especially in the soil profile shallow layers. Also, The salinity and sodicity classes of the lands before implementation of leaching operations was ranging from S_3A_3 to S_4A_3 while after implementation of the test it changed to S_2A_2 .This indicates the possibility of soil profile leaching soluble salts using the leaching water application and without any need for chemical soil improving amendments. Moreover, as it was also reported by the other researchers (Pazira *et al.*, 1997, 1998 and 1999), comparing with the other studies completed in Khuzestan Province using continues ponding method and with approximately similar conditions, it may be stated that the method and way of soluble salts decrease (Leaching) is of the same trend, while with respect to the time period of field tests implementation, the intermittent ponding method takes longer time in comparison with the other mentioned soil salt leaching method.

References

Anonymous. 2006. Guideline for Application of the Empirical and Theoretical Soil Desalinization Models, Publication No. **359**, Water Resources Management Organization, Ministry of Energy (in Farsi).

Dieleman PJEd. 1963. Reclamation of Salt Affected Soils in Iraq. I.L.R.L. Wageningen, the Netherlands.

Gardner WR, Brooks RH. 1957. A Descriptive Theory on Leaching. Soil Science, **83**, 295-304.

Gharaibeh MA, Eltaif NI, Shunnar OF. 2009. Leaching and reclamation of calcareous saline-sodic soil by moderately saline and moderate-SAR water using gypsum and calcium chloride, J. Plant Nutr. Soil Science **175(5),** 713-719. http://dx.doi.org/10.1002/jpln.200700327

İdris Bahçeci̇. 2009. Determination of salt leaching and gypsum requirements with field tests of saline – sodic soils in central Turkey, Irrigation and Drainage **58(3),** 332–345. http://dx.doi.org/10.1002/ird.406

Lal P, Chippa BR, Arvind, K. 2003. Salt affected soils and crop production, a modern synthesis, AGROBIS (India).

Mace JE, Amrhein C. 2001. Leaching and reclamation of a soil irrigated with moderate SAR waters, Soil Science Journal **65,** 199-204. http://dx.doi.org/10.2136/sssaj2001.651199x

Mashali AM. 1989. Salinization as a Major Process of Soil Degradation in the Near East, Land and Water Development Div., FAO-AGL/RNEA--LWU/89/9, FAO: Rome (Italy), 1989, 1-9.

Nogués J, Herrero J, Rodríguez-Ochoa R, Boixadera J. 2000. Land Evaluation in a Salt-Affected Irrigated District Using an Index of Productive Potential **25(2),** 143-152. http://dx.doi.org/10.1007/s002679910011

Pazira E, Kawachi T. 1981. Studies on Appropriate Depths of Leaching Water Iran, A Case Study. Jour. Integ. Agr. Water Use and Fresh. Reservoir **6,** 39-49. Faculty of Agriculture, Kyoto University. Japan.

Pazira E. 1997. Study on Appropriate Depth of Leaching Water for Soil Salt Removal from Saline and Sodic Soils of Middle Part of Khuzestan Providence, Journal of Iranian Agricultural Engineering Research Institute **2(7),** (in Farsi).

Pazira E, Keshavarz A, Torii K. 1998. Studies on Appropriate Depth of Leaching Water, International Workshop on the Use of Saline and Brackish – Water for Irrigation, Indonesia.

Pazira E, Keshavarz A. 1999. Studies on Appropriate Depth of Leaching Water, A Case Study for Reclamation of Saline and Sodic Soils of Southeastern Part of the Khuzestan Province, Journal of Iranian Agricultural Engineering Research Institute **4(16)** (in Farsi).

Pazira E. 1999. Land Reclamation Research on Soil Physico – Chemical Improvement by Salt Leaching in South – Western part of Iran, Innovation of Agricultural Engineering Technologies for The 21st Century, P.R. China.

Qadir M, Oster JD. 2002. Vegetative Bioremediation of Calcareous Sodic Soils: History, Mechanisms and Evaluation, Irrigation Science journal **21,** 91–101. http://dx.doi.org/10.1007/s00271-001-0055-6

Rajabzadeh F, Pazira E, Mahdian MH. 2009. Leaching Saline and sodic soils along with reclamation-rotation program in the mid-Part of khuzestan, Iran, Applied Sciences journal **9(22),** 4020-4025. http://dx.doi.org/10.3923/jas.2009.4020.4025

Sarraf AP. 2008. Simulation of Water Table Variations and Estimating Drainage Water Quality for Subsurface Systems under Unsteady Inflows, Science and Research Branch, Islamic Azad University, Tehran - Iran.