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Determination of leaching efficiency coefficient in some saline and sodic soil in Khozestan province by using different leaching methods

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Abstract

Salinization of arable lands is one important factor in decreasing crop yield and the osmotic potential of the soil. Recently, it is one of the big problems in developing countries. There are some various techniques to increase crop yield in saline soils such as amendment of soil area for plants. Leaching of soluble salts from soil profiles can be performed to solve this problem. In this study, three different leaching methods have been performed to estimate utilized leaching water in Veis region, Khoozestan, Iran. These methods are permanent flooding method, intermittent method and sprinkler method which were performed in mint soil culms with 1 meter height inside apolyethylene area with 15 cm diameter. The depth of utilized leaching were 25, 50, 75 and 100 cm, also estimated soil layers were 0-25, 25-50, 50-75 and 75-100 cm. After performing leaching and collecting results, an experimental model was defined for each leaching method. Exponential model in permanent flooding method was the best model based on better correlation coefficient and lower standard error. However, intermittent method showed lower utilized water for soil desalinization and better leaching efficiency coefficient corresponding with soil texture. It is necessary to notice that leaching process in intermittent method needs longer time compare to permanent flooding method, but according to water shortage and good advantages of this model compare to two other methods this problem (time) can be excused.

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Introduction

Soil is one part of natural resources which contains solid materials (organic and mineral), liquid and gas and it covers earth surface, also is one important part of ecosystem. Soil ability for especial utilization shows the meaning of soil quality in ecosystem (Islam and Weil, 2000). Salinization and spread in agricultural lands is assorted at different times and depends on rainfall, irrigation, evaporation and transpiration, leaching, drainage and mutual effects among these actors. Salinity generally decreases germination, leaf area and dry matter accumulation, the rate of net CO_2 assimilation and relative growth. Rendering salinity is related to natural factors or human factors, utilization of leaching method beside construction of drainage system are one of the best solutions for amendment of saline and sodic soils. Until today many studies reported about desalinization.

Increase of population caused increase of agricultural production. Increase of yield in possible by increasing of arable land area or increasing of yield per unit. The total land surface is 13.2 billion hectares on earth where 7 billion hectares can be cultivated and 1.5 billion hectares are under cultivation. Soil destruction, fertility reduction, soil and surface and underground water pollution, deduction of pasture and soil salinization are some example of unrepairable toll which caused by wrong applications used by human power and sodic lands contain 13% of total arable land in the world (Rajabzadeh *et al.*, 2009). The main reasons of Salinization are, using saline water, acute evaporation, inadequate leaching, more evaporation and less rain, shortage of appropriate irrigation system and improper drainage system (Rajabzadeh *et al.*, 2009). Some studies showed that chemical characteristic of parent materials cause salinization which define as primary salinization (Pazira and Homaee, 2010).

The global extent of primary salt-affected soils is about 955 M ha, while secondary salinization affects some 77 M ha, with 58% of these in irrigated areas (Metternicht and Zinck, 2003).

In Iran, about 14.2% (23.5 million hectare) from total arable land (165 million hectare) faced to salinization, sodification and everglade problems (Dewan and Famouri, 1964). Whereas most regions in Iran have dry and semi-dry climates, rainfall is not steady and average of rain in Iran is 1/3 of average of annual earth rain. Due to improper of drainage condition in Khoozestan plain, added water remains in soil profile and because of more evaporation than rain in this area, slats concentration increase in soil profile and cause salinization and sodification (Asadi *et al.*, 2001). The first evidence of destruction is increasing of exchangeable Sodium percentage and extension of soil particles which by destruction of aggregations and filling big apertures, soil hydraulic conductivity will be decreased (Soe and Aylmore, 1993). Salinization and spread in agricultural lands is assorted at different times and depends on rainfall, irrigation, evaporation and transpiration, leaching, drainage and mutual effects among these actors (Corwin *et al.*, 2007). Salinity generally decreases germination, leaf area and dry matter accumulation, the rate of net CO_2 assimilation and relative growth (Bernardo *et al.*, 2000). Rendering salinity is related to natural factors or human factors, utilization of leaching method beside construction of drainage system are one of the best solutions for amendment of saline and sodic soils (Noroozi *et al.*, 2012). Until today many studies reported about desalinization. Two key factors concerning sodic soil reclamation are: (1) supplying sufficient available Ca2+ and (2) maintaining appropriate soil permeability by providing sufficiently high electrolyte concentration in soil solution (Li and Keren, 2009). Another study in Bejestan, Iran showed that by using 1 m water, soil salinity decreases from 39 ds/m to 10 ds/m and exchangeable Sodium decreases from 61% to 25% (Rahimi and Ahmad-nejad, 2005).

Depth of leaching also plays an important role in desalinization and desodification programs. Suitable depth for leaching depends on the initial salinity, soil texture and plant species (Konuku *et al.*, 2005; Corwin *et al.*, 2007).

Whereas leaching process follows displacement theory, according to Nilsen and Bigger findings in 1961, for one unit of bulk porosity 50% and for two unit of bulk porosity 80% of primary salts should remove.

By determination of utilized water to transfer soil soluble salts and increasing of their hydraulic conductivity cultivation can be possible. Further time for leaching and necessity of amending material can be estimated (Rahimi and Ahmad-nejad, 2005). Leaching of primary salts can be performed by different methods such as permanent flooding, intermittent and showery, but the most important is which methods needs less time for leaching and which one is efficient. Some researchers reported that capital leaching will be occurred when soil moisture is less than saturated moisture (Gardner and Fireman, 1958). Further, decreasing of ASR and ESP to 25% in different depth of soil by using intermittent leaching has been reported (Mostafazadeh-fard *et al.*, 2008).

There are two physical and theoretical methods to determine leaching utilized water. Due to high cost of experiments in the field, model utilization will be suitable for soil amendment programs by examination of approximate and exploratory estimates (Asensiona *et al.*, 2007). The results indicated that by using one unit water, 80% of salts were removed from soil profile.

Generally, experimental models introduced by many researchers classified in different ways. Mathematical models indrduced by Leffeloar and Sharma (1977), Hoffman (1980), and Pazira and Kawachi (1981) are reverse equations, those models introduced by Verma and Gupta (1989), and Pazira and Keshavarz (1988) are power equations and Dieleman model introduced by Dieleman (1961) is semi-logarithmic function.

Leaching efficiency coefficient (f) is the most effective and important factor to determine soil reaction to leaching process and existence of solved salts from soil profile.

This parameter is one of the main parts but undefined of equations, correlation between soil and water and experimental equations. Another role of this parameter is utilization in plans for salts leaching, preventing from secondary salinization and balance conservation of salt in irrigated lands ((Van Hoorn and Van Alphen, 1987).

Considering that there was no precise study on preparation of leaching curve in the mentioned region, this study follows these objectives: determination of leaching efficiency coefficient in Veis region saline and sodic soils by using mint soil culms in laboratory, evaluation of soil amendment process by leaching methods, determination of soil amend program to introduce in Veis region and also comparison of Leaching efficiency coefficient by performing three different leaching methods including permanent flooding, intermittent and sprinkler.

Material and methods

Leaching experiments

Leaching experiments have been performed on mint culms which were extracted from 0 to 100 cm soil depth at Islamic Azad University of Ahvaz in 6000 m^2 of Veis in Khoozestan province. This area is located in north east of Ahvaz city, lies at 31 degrees, 28 minutes, 41 seconds north latitude by 48 Degrees, 52 minutes, 49 seconds east longitude and 20 meters above sea level. This region has Typic Tempustic moisture regime and Hyperthermic Temperature regime. Most of this region soil contain clay moisture which salinization and sodification is clear. The soil in this region has been categorized in Entisols group, Typic Torrifluventssub-group, fine, Loamy mixed, Carbonutic Hyperthermic family, according to Soil Taxonomy classification. Karoon River passes this region which its water quality concerning Wilkaks diagram (Richards, 1954) classifies in C_2S_1 class.

Soil desalinization

For soil desalinization, leaching of solved salts from soil profile were performed.

The purpose of using culms in this study were control experiment levels at laboratory condition easier than field's and save cost and time. Utilized culms were made from Polyethylene (PVC) with 15 cm diameter and 125 cm height. The electrical conductivity of water which provided from University field was 2.86 ds/m.

Leaching has been done by three different methods including Permanent flooding, Intermittent and Sprinkler and water depth in all methods was 100 cm. Four culms were used to leach water inside 25, 50, 75 and 100 cm^3 respectively. It allow us to estimate drainage water and soil in each depth of leaching separately. In permanent flooding method 25, 50, 75 and 100 cm water were used at once for each culm. In fact, irrigation system has been designed to keep culms in flooding mode, also equal water could add from above by exiting drainage water from bottom of culms.

Intermittent leaching method

In intermittent leaching method, entered water to each culm was 25 cm. In this case, first 25 cm water added to each culm and then, after exiting full water within 48 hours next leaching started. These steps repeated for second, third and fourth culms which should leach with 50, 75 and 100 cm of water in a 25cm alternation.

After drain water exited, 25 cm alternation conducted for 75 and 100 cm culms and finally implemented for 100 cm culms. Leaching steps in Sprinkler method were performed the same as intermittent method. However, in intermittent method some water used to stay on the soil surface at the beginning of leaching that disappeared after exit. In Sprinkler method leaching was done by the shower connected to water input, that let us control discharge or inflow of entered water to the culms which prevent staying water on soil surface during leaching steps.

Please notice that in each step in these three methods, after leaching finished in each culm, culms were removed according to depth of slightly leaching water and total exited drain water. Then, Polyethylene culms were cut vertically to sample from depth of 0-25, 25-50, 50-75 and 75-100 cm. These samples along with analogous samples which obtain before leaching and exited drain water from culms transferred to laboratory to estimate soil physical and chemical characteristics. Electrical conductivity, PH reaction, Calcium, Magnesium and Sodium, T.N.V%, O.C%, $CaSo_4$, SP%, percentage of soil particles dimension and bulk density have been estimated to calculate SAR, $adjR_{Na}$, ESP, porosity and volumetric water content. Further, PH, EC, Calcium, Magnesium and Sodium has been measured for leaching and exited water samples; In continue SAR, $adjR_{Na}$, ESP were estimated (Tables 1, 2, 3).

Table 1. Physical characteristics of Veis soil before leaching.

Sampling depth (Cm)	Saturation water content (%)	bulk density(gr/Cm^3)	Total porosity (%)	Permeability (mm/hr)	Relative frequency (%)			Soil texture
					Sand	Silt	Clay	
0-25	43.9	1.58	40	0.73	21.9	48.9	29.2	Clay loam
25-50	43.5	1.59	36	2.5	25.5	48.9	25.6	Loam
50-75	43.8	1.54	42	1.3	27.3	50.7	22	Silt loam
75-100	47.7	1.55	42	1.3	21.9	52.5	25.6	Silt loam

Table 2. Chemical characteristics of Veis soil before leaching.

Sampling depth (Cm)	Electrical conductivity (ds/m)	pH	T.N.V (%)	O.C (%)	$CaSo_4$ (%)	SAR $(meq/lit)^{0.5}$	$adjR_{Na}$ $(meq/lit)^{0.5}$	ESP (%)
0-25	34.50	8	33	0.4	1.53	21.5	22.10	24.90
25-50	8.97	7.9	41	0.3	0.41	10.57	10.92	14.65
50-75	7.34	8.2	39	0.2	0.07	6.30	6.51	9.77
75-100	5.71	8	39	0.2	0.03	4.65	4.82	8.90
Average	14.13	8.02	38	0.27	0.51	10.75	11.08	14.55

Table 3. Characterization of utilized water quality during leaching process.

Sampling date	Water class	EC (dS/m)	pH	SAR $(meq/lit)^{0.5}$	$adjR_{Na}$ $(meq/lit)^{0.5}$
1394/12/4	C_2S_1	2.86	7.55	6.0	6.20

Primary moisture were determination

To evaluate this depletion in each method, primary moisture were determined; then, after leaching with 25 cm water and reaching to F.C, obtained amount from field were deducted. Concerning above declaration, soil moisture depletion were contemplated 8.95, 10.35 and 9.24 in permanent flooding, intermittent and sprinkler methods respectively.

According to tables 2 and 3, also by using electrical conductivity of saturated soil solution and exchangeable Sodium percentage which obtained from experimental equation G1GR (1999), weight average of EC_e and ESP were determined for 0-25, 25-50, 50-75 and 75-100 cm soil layers. In this case electrical conductivity were contemplated 2.85 ds/m. Based on amount of EC_e and ESP for different layers concerning obtained results in tables 3 and 5 some equations were defined as below:

$$\text{and} X = \frac{Dlw}{Ds} y = \frac{ECf-ECeq}{ECi-ECeq} \quad (1)$$

Where EC_i and EC_f are electrical conductivity soil before and after leaching respectively (ds/m), D_{lw} is depth of leaching water (cm) and D_s is depth of soil layer (cm).

All obtained results has been analyzed by SPSS software, Curve Expert and Excel. Thus, four mathematical models including power model, reverse model, logarithm model and exponential model were fitted on electrical conductivity of saturated soil solution and best experimental model has been selected for each leaching method. Finally, the best desalinization model and best leaching method were determined.

Another objective of this study was determination of leaching efficiency coefficient According to results in tables 1, 2 and 3 beside equations 2 and 3 variable were obtained for each soil profile.

$$\text{and} f = \frac{r.ECw}{ECeq} r = \frac{Dw}{Dp} \quad (2)$$

$$[Ln \frac{ECi-ECeq}{ECf-ECeq}] \times \theta v f = \frac{Ds}{Dlw} \quad (3)$$

In equation 2, EC_w, electrical conductivity of leaching water ds/m, EC_{eq}, equilibrium electrical conductivity of layer after leaching ds/m, D_w, depth of water cm, D_p, depth of leaching water or deep percolation (D_p = D_{lw}) cm, were estimated.

In equation 3, θ_v, is volumetric moisture content (cm^3/cm^3) and f is leaching efficiency coefficient which is dimensionless parameter and other parameters define same as equation 1.

Finally, best results were selected and based on amount of physical parameters including percentage of soil particles dimension, porosity and bulk density of soil, and linear equation and higher leaching efficiency coefficient were obtained. By entering parameters in obtained equation, new leaching efficiency coefficient evaluated for each soil layer and best equation for estimation of leaching efficiency coefficient in Veis region defined.

Results and discussion

Electrical conductivity is directly related to total anions and cations. Hence, this can be include as a suitable index to determine total amount of solved salts in irrigated water and saturated moisture (Alizade *et al.*, 2001). Based on results in table 2, Soil EC has been decreased after using leaching water.

Please notice that this distribution is apposite of salts distribution before leaching, because salts were eroded from surface to depth of soil. It has been shown in table 4. After leaching, clear reduction were seen in EC and ESP of soil layers. Reduction of salinization were higher in external layers especially 0-25 cm. Mohsenifar *et al.*, (2006) showed that highest electrical conductivity before leaching were seen on 0-25 depth, about 78.20 ds/m and it was decreased to 4 ds/m after leaching. This trend were observed for ESP for soil layers. Kolahchi and Jalali (2007) reported that leaching was very effective on reduction of salinization and helped increase of crop yield in mentioned soils. The average of EC and ESP reduction in permanent flooding, intermittent and sprinkler methods were 4.85, 8.01 and 9.19 ds/m respectively and it showed 0.38%, 4.42% and 6.82% reduction after leaching. Decreasing of 3.34 ds/m on soil salinization and decreasing of 0.5% of ESP in permanent flooding method (Behzad and Akhoond-Ali, 2002) also reduction of 6.53 ds/m and reduction of 4.58% on exchangeable Sodium percentage in intermittent method after using 100 cm water until 100 cm depth of soil have been reported by other researchers (Asadi *et al.*, 2011).

Obtained results indicated that electrical conductivity has been decreased in these three methods compared to before leaching and this reduction for amount of correspondent aperture water was higher in intermittent and sprinkler method than permanent flooding method.

However, there was no significant difference of EC reduction in three different methods, even among these methods. This process has been occurred for soil ESP reduction of different layers in three leaching methods, also for soil ESP before and after leaching. In this case, a significant difference in soil ESP reduction were observed in comparison between intermittent and sprinkler and in comparison of averages soil ESP reduction showed a significant difference (95%) before and after leaching. Considering similarity of reduction process of exchangeable Sodium percentage determination of desalinization, equations and observed models will be described. Some results indicated that there was a reduction of salinization and exchangeable Sodium percentage in soil layers and a similarity of this reduction in all similar soil layers (Rajabzadeh *et al.*, 2009), (Asadi *et al.*, 2011).

According to the significant effect of leaching in reducing electrical conductivity and ESP of sodic and alkaline soils can be stated that intermittent leaching is more suitable. Intermittent leaching is capable to reduce more soluble salts. In this study, leaching of soluble salts from sediment and fine texture soil has been evaluated and results revealed that intermittent leaching was effective on reduction of salts. Further, other results showed that due to alternative changes of soil moisture, this reduction was more effective (Rajabzade *et al.*, 2009).

Table 4. Chemical characteristic of different soil profile layers after leaching using permanent flooding, intermittent and sprinkler methods.

Leching method	Soil depth (Cm)	EC (dS/m)	pH	T.N.V (%)	O.C (%)	$CaSo_4$ (%)	SAR $(meq/lit)^{0.5}$	$adjR_{Na}$ $(meq/lit)^{0.5}$	ESP (%)
Permanent flooding leaching	0-25	4.93	7.8	32.8	0.3	_	13.86	13.37	13.95
	25-50	13.10	8	41	0.4	_	8.50	12.04	14.25
	50-75	11.45	7.7	39	0.2	_	9.43	11.07	14.55
	75-100	8.70	8	39	0.2	_	9.39	10.93	13.94

Leching method	Soil depth (Cm)	EC (dS/m)	pH	T.N.V (%)	O.C (%)	$CaSo_4$ (%)	SAR $(meq/lit)^{0.5}$	$adjR_{Na}$ $(meq/lit)^{0.5}$	ESP (%)
	Average	9.55	7.87	37.95	0.27	_	10.29	11.75	14.17
	Difference	-4.85	-0.15	-0.05	0.0	_	-0.46	0.67	-0.38
Intermittent leachig	0-25	5.17	8	32.3	0.2	_	8.56	11.00	11.55
	25-50	5.36	8.1	40.5	0.5	_	4.92	5.75	7.09
	50-75	5.55	7.7	38.5	0.2	_	4.40	5.26	6.33
	75-100	8.38	7.9	38.5	0.2	_	8.37	8.80	11.56
	Average	6.12	7.92	37.45	0.27	_	6.56	7.70	9.13
	Difference	-8.01	-0.1	-0.55	0.0	_	-4.19	-3.37	-4.42
Sprinkler leaching	0-25	6.87	8.4	33	0.3	_	6.31	7.09	8.84
	25-50	5.97	7.6	41	0.4	_	4.36	5.62	6.32
	50-75	3.98	7.9	38.5	0.2	_	4.52	5.25	6.58
	75-100	2.92	7.8	39	0.2	_	4.21	4.83	6.16
	Average	4.94	7.92	37.5	0.27	_	4.58	5.69	6.98
	Difference	-9.19	-0.1	-0.50	0.0	_	-5.9	-5.38	-6.57

Decrease - Increase +

Table 5. Weight average of primary and final salinization of saturated soil concentration before and after leaching by using different methods.

Leaching method	Soil depth(Cm)	salinization of saturated soil concentration before leaching (dS/m)	salinization of saturated soil concentration after using different amount of leaching (dS/m)				
		(EC_i)	$D_w(25)$	$D_w(50)$	$D_w(75)$	$D_w(100)$	Average
			$EC_f(25)$	$EC_f(50)$	$EC_f(75)$	$EC_f(100)$	EC_f
Permanent flooding	0-25	34.50	21.87	15.74	13.46	11.33	15.60
	0-50	21.74	19.73	10.23	11.55	9.02	12.63
	0-75	16.94	17.60	9.78	12.07	9.83	12.32
	0-100	14.13	17.30	8.26	10.83	9.55	11.48
Intermittent	0-25	34.50	21.90	19.30	15.77	13.12	17.52
	0-50	21.74	18.67	14.40	8.51	5.27	11.71
	0-75	16.94	17.18	11.97	8.57	5.36	10.77
	0-100	14.13	15.19	10.60	8.69	6.12	10.15
Sprinkler	0-25	34.50	29.23	22.92	18.59	15.66	21.60
	0-50	21.74	21.20	16.18	9.02	6.42	13.20
	0-75	16.94	18.31	15.75	8.09	5.61	11.94
	0-100	14.13	16.64	15.91	8.29	4.94	11.45

By using weight average of salinization before and after leaching, percentage of eroded and remnant salts has been evaluated and compared with those salts before leaching. The results indicated that utilization of 100 cm water in permanent flooding method could erode 67.17%, 58.52%, 41.98% and 32.45% of soil primary salts and these are equal to 11.03, 5.39, 3.79 and 2.29 unit of aperture water for 0-25, 0-50, 0-75 and 0-100 cm soil depth respectively. Researchers reported that in 100 cm of silty clay loam Soil profile, about 35% salts from 2 unit of aperture bulk, transfer for 98 cm leaching water which corresponded with salinization results (Behzad and Akhoond-Ali, 2002).

By using 100 cm water in intermittent method, eroded primary salts for mentioned depths were 61.97%, 75.78%, 68.35% and 56.72% for aperture porosity of 11.87, 5.35, 3.54 and 2.65 respectively. Researchers have reported that using 100 cm leaching water caused 73.35% reduction of primary salinity in 50 cm depth where permeable water was about 4.9 unit of aperture water.

Obtained results indicated that by using 100 cm water in sprinkler method could reduce 54.60%, 70.46%, 66.90% and 65.07% leaching of deep primary salts. These amounts are equal to 8.49, 5.03, 3.57 and 2.75 unit of soil layers aperture porosity.

Leaching is impossible by using inadequate water, albeit extra water can make difficulties for water storage and drainage system. In this study needful water for soil desalinization in the studied region has been evaluated by using three different leaching method (Permanent flooding, intermittent and sprinkler). For this objective first experimental model was define for leaching method. Hence, by using moisture fraction and quantities in table 5, two variables (x,y) which defined in equation 1 were estimated.

Based on obtained x and y variables, four mathematical models were evaluated: revers model, power model, logarithmic model and exponential model. Table 6 shows the best model for higher correlation index and lower standard error in each leaching method. Soil desalinization curve also has characterized (Fig. 1, a,b,c). For better understanding and better comparison in these methods, desalinization curve of three points were shown based on related experimental equation and defining adequate number for (x) variable to estimate (y) variable (Fig. 2).

According to fig. 2(a, b, c), leaching process were quicker, moderate and slower in intermittent, shows that in permanent flooding method more water needs for leaching compared to intermittent and sprinkler methods.

The reason is constitution of saturated condition in permanent flooding method which reduce leaching efficiency (Cote *et al.*, 2000).

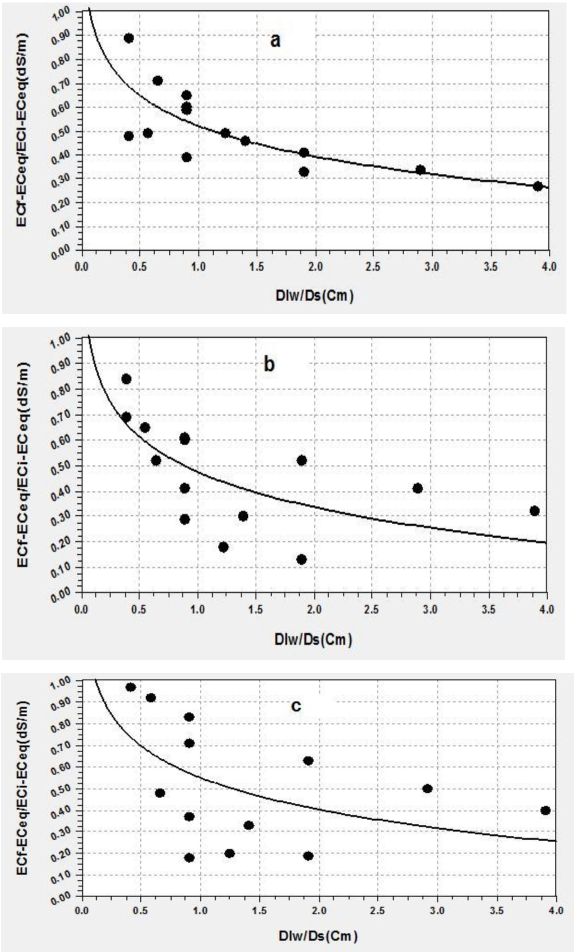

Fig. 1. Soil desalinization curves of studied region in three different leaching method. a: Permanent flooding, b: Intermittent, c: Sprinkler.

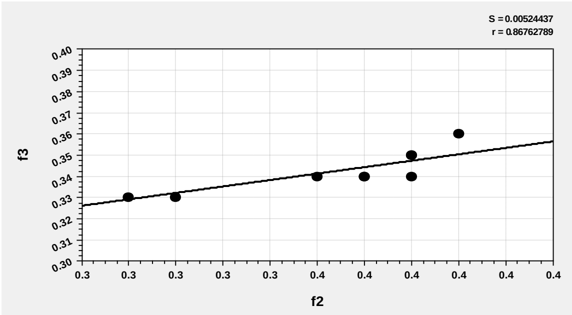

Fig. 2. Linear correlation between leaching efficiency coefficient obtained from equations 3 and 7 (f_2, f_3).

By using obtained desalinization curve based on the equations in table 6, final electrical conductivity (EC_f) and depth of applied water for leaching (D_{LW}) can be evaluated.

Estimation of time and applied water can prevent frittering extra water (Oad *et al.*, 2001). For calculation of applied water for leaching in each method it needs to put equation 1 to experimental theorem. By doing this, depth of water for leaching can be calculated from equations 4, 5 and 6 for permanent flooding, intermittent and sprinkler methods respectively.

Permanent flooding method

$$(4) Dlw = Ds * 3.27 \ln\left[0.737\left(\frac{ECi-ECeq}{ECf-ECeq}\right)\right]$$

$$ECf = \left[0.737 * \left(\frac{Dlw}{Ds}\right)^{-0.305} * (ECi - ECeq)\right] - ECeq$$

Intermittent method

$$(5) Dlw = Ds * e^{\left[\frac{\left(\frac{ECf-ECeq}{ECi-ECeq}\right)-0.476}{-0.201}\right]}$$

$$ECf = \left[\left(0.476 - 0.201\, Ln\left(\frac{Dlw}{Ds}\right)\right) * (ECi - ECeq)\right] - ECeq$$

Sprinkler method

$$(6) Dlw = Ds * e^{\left[\frac{\left(\frac{ECf-ECeq}{ECi-ECeq}\right)-0.549}{-0.213}\right]}$$

$$ECf = \left[\left(0.549 - 0.213\, Ln\left(\frac{Dlw}{Ds}\right)\right) * (ECi - ECeq)\right] - ECeq$$

Based on above equations, applied water for different depth of soil leaching has been calculated. In this evaluations, primary salinization were contemplated from 36 to 8 ds/m and final salinization were contemplated about 4 ds/m. Further, balanced salinization was 2.85 ds/m. The results showed that soil amendment for desalinization from 36 to 4 ds/m needs huge amount of water, however, soil amendment for mentioned salinization in step by step method needs less water and it is an advantage of intermittent method. Gupta (1992) reported that to emend 1 cm scale of soil under field condition needs 0.3 – 2.58 cm water using permanent flooding method. Other researchers also showed that applied water for leaching under step by step condition for 18908 m^3/ha was less than direct desalinization from 36 to 4 ds/m (Mohammadzadeh *et al.*, 2013).

Table 6. Best experimental models for three different leaching methods.

Alignment	Leaching method	Model name	Mathematical equation of model	Fixed index		Calculated statistical criteria	
				a	b	Correlation index	Standard error
1	Permanent flooding	Exponential	$Y=a.e^{bx}$	0.737	-0.305	0.743	0.1168
2	Intermittent	logaritmic	Y=a+blnx	0.476	-0.201	0.672	0.1584
3	Sprinker	logaritmic	Y=a+blnx	0.549	-0.213	0.6207	0.2253

For precise consideration, leaching efficiency coefficient has been estimated in different depth of soils and has been shown in table 9 with symbols f_1 and f_2. Evaluation of significance of obtained quantities showed that two leaching efficiency coefficients have significant difference at 5% level. Obtained quantities from analytical equation (equation 3) corresponded with soil texture of region (Pazira, 2006).

Mohammadzadeh and his research team (2013) reported that reduction or failure of leaching efficiency coefficient caused by fine texture soils, because in this kind of soils, permeability of water is lower. Further, number of soil void and their correlation are the most effective factor on water permeability which it is lower in fine texture soils. Some variables such as bulk density and soil porosity as soil texture parameters can effect on water aperture speed and increase of leaching efficiency coefficient (Pazira, 2006). According to table 10 and excess of soil particle size distribution and porosity in different soil layers, linear equation has been obtained as below:

$$Y=9.78x_1+9.42x_2+9.87x_3+6.86x_4+17.15x_5-27.12 \quad (7)$$

In equation 7 parameter ($y=f_3$) is leaching efficiency coefficient which has no dimension.

In this equation (x_1) shows clay, (x_2) shows silt, and (x_3) is sand of soil in decimal. Also (x_4) is bulk density in gr/ cm^3 and (x_5) is porosity in decimal.

Gutpa and Pandy (1980) did some research on estimation of soil leaching efficiency coefficient and theoretical models. Other researchers determined leaching efficiency coefficient by calculation concentration of Chlorine ion in exited drainage water and soil amendment in Bardenas area in Spain, by using series of reservoir theoretical model and introducing another model (Bardenas and Martinez, 1978).

According to the results in table 9 and new equation (equation 7), another leaching efficiency coefficient has been calculated for soil layers.

It has been shown as f_3 in the mentioned table. There was a similarity between quantities obtained from new equation and quantities obtained from equation 3 and based on statistical analysis differences between them were not significant. However, differences between f_3 and quantities obtained from experimental equation (equation 2) were significant. The linear equation of these two coefficients, high correlation coefficient (0.86) and low standard error (0.005) have been shown in fig. 2. The results indicated that leaching efficiency coefficient was acceptable and adequate. Furthermore, beside soil texture, other physical characters such as bulk density, porosity and leaching method are effective on leaching efficiency coefficient. When the soil texture is heavier and percentage of silt, clay and sand were lower, leaching efficiency coefficient is smaller, and it is related to difficulty of transferring leaching water from small apertures. Another finding showed that leaching efficiency coefficient in intermittent method in different soil layers was higher or bigger than in permanent flooding and sprinkler methods; but this difference was not significant among leaching methods.

Table 7. Estimation of leaching efficiency coefficient based on soil physical characteristic and comparison with f_1 and f_2 in soil by using three leaching methods.

Soil physical characteristic and leaching efficiency coefficients	Leaching method											
	Permanent flooding				Intermittent				Sprinkler			
	Different depth of soil											
	0-25	0-50	0-75	0-100	0-25	0-50	0-75	0-100	0-25	0-50	0-75	0-100
Clay	0.27	0.27	0.27	0.26	0.27	0.27	0.27	0.26	0.26	0.26	0.27	0.25
Silt	0.49	0.50	0.51	0.51	0.47	0.48	0.49	0.49	0.45	0.45	0.47	0.47

Sand	0.24	0.23	0.21	0.23	0.26	0.25	0.24	0.25	0.29	0.29	0.26	0.28
Bulk density	1.71	1.71	1.78	1.60	1.78	1.73	1.73	1.75	1.43	1.65	1.73	1.75
Porosity	0.35	0.35	0.33	0.40	0.33	0.35	0.35	0.34	0.46	0.38	0.35	0.33
f_1	0.38	0.40	0.43	0.45	0.29	0.41	0.54	0.56	0.23	0.37	0.42	0.48
f_2	0.32	0.34	0.35	0.35	0.33	0.36	0.37	0.37	0.31	0.34	0.36	0.38
f_3	0.31	0.33	0.33	0.34	0.33	0.34	0.34	0.35	0.33	0.33	0.34	0.36

Carter and funning (1964) showed that combination of intermittent method and using of cover for improvement of soil physical condition, increased leaching efficiency in a 5 month period. Another research showed that leaching efficiency in intermittent method is higher than permanent flooding method due to constitution of saturated moisture and eroding of salts will be easier and better (Cote *et al.*, 2000).

Conclusion

The soils which studied in this research have changed to arid or undesirable quality soils. High concentration of salts has reduced crop yield and soil permeability especially in clay and fine texture soils. Leaching methods used in this study, cleared that desalinization and desodification is possible in these soils. In this case, salinization of soil profile has been reduced from salinization and sodificationcalss (S_2A_2) be for leaching to salinization and sodification class (S_1A_1) after leaching in intermittent method and class (S_1A_0) in sprinkler method. In permanent flooding method reduction in salinization and sodification were observed but it was not that much to change salinization and were stayed at the same class (S_2A_2). Among evaluated methods, intermittent method gave better results than two others. This results also confirm and verity for higher leaching efficiency and lower depth of water in soil amendment.

Considering that soils has heavier texture in dry and semi-dry regions, it is better to use analytical equations for determination of leaching efficiency coefficient. Because physical characters in these soils effect on leaching efficiency and it is available in mentioned equation. The new equation has scientific value and is usable at similar conditions.

It is suggested that examination of soil amendment by using chemicals should be necessary to do in next researches and effect of these chemicals on leaching efficiency should be examined.

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