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ORIGINAL ARTICLE

Studying Different Type of Leaching Models in Two Pilots Located at South East of Khoozestan Province of Iran.

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Forough Allahyari Pour, Kamran Mohsenifar, Ebrahim Pazira, Mohammad Azmi; Studying different type of leaching models in two pilots located at South East of Khoozestan province of Iran.

ABSTRACT

In dry areas, such as IRAN, where have low precipitation and high evaporation, salt accumulation on soil surface is unavoidable. Therefore it is necessary to use an applicable method to estimate the water requirement for agricultural soil improvement. This study aims to draw desalinization and dealkalization curves and apply the best type of empirical leaching models for leaching salt and sodium of south east Khoozestan province. This study has conducted in two areas of Khuzestan state. For this propose, two experimental areas were selected and four treatments with three replications, were designed. The treatments were included 25cm, 50cm, 75cm and 100cm water application. In addition of above treatments, in second area about mentioned treatments were repeated by amendment matter (sulfuric acid). Eleven empirical models were compared using initial and final values of EC and Na. the results showed that manner model was the best model with 83 and 85 percent coefficient correlation in pilot No.1. Meanwhile, in pilot No.2 the cubic model was the best model with 94 and 88 percent coefficient correlation. In this pilot when it was used acid, the exponential growth, logistic, compound and inverse models with 88% coefficient correlation, had shown maximum correlation.

Key words: Leaching, empirical models, amendment matter, Khoozestan State.

Introduction

Soil salinity is a process during which the soluble minerals in the surface soil may be attained to the extent that by which surface layer will lose the potential for growing and developing the plants [1] 3.0. Anyway, in the agriculture, as a sustainable development basis through the country, water accounted as the main limiting factor for it and due to more evaporation, accumulation of minerals and salinity is a natural act and inevitable.

In 1970, about 50% of whole irrigating lands encountered with different ranges of salinity problems, alkalinization, drainage, and bilge conditions, and it is now expected that it has more increasingly been developed [2]. In any conditions, increased performance in the surface unit of Faryab lands and or development of current cultured area is accompanying with functions like correct management, exploitation and scientific and reliable usage of physical resources for (water and soil) production. Applying such management in the agriculture and irrigation can be practical by following up for objectives like water economy, decreasing the water shortage losses by proper distribution, developing central exploitation

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instruments for more suitable irrigation and finally reducing the soil and lands salinity and drainage [4] in super saline soils, one can use 30 cm of good quality water to leach the depth of 30 cm of the soil and provide a proper medium for plant development. Based on studies conducted on clay - silt soils and average electric conductivity of saturated extraction with more than 40 dS/m, he obtained following experimental formula for estimating the water needed for leaching. This formula applies for conditions where the water content calculated is applied to the soil by deep water method [8].

$$\frac{Dw}{Ds} = \frac{1}{5(\frac{C}{C_o})} + 0.15 \quad (1)$$

Where, Dw is applied water depth, Ds, soil depth (both, based on cm) C and C_o (dS/m) are mean of salts concentration in the same depths of soil before and after leaching [9]. After some studies, Making some changes in the Ryo equation as following and put $\frac{Dw}{Ds}$ on x axis and $\frac{EC_f}{EC_i}$ on y axis and presented the first model [10,11]:

$$\frac{Dw}{Ds} = \frac{1}{5(\frac{EC_f}{EC_i})} + 0.15 \quad (2)$$

Equations (1) and (2) have been presented for soil and water conditions and might not be applied for different conditions and places and need a correction index. Water height required for leaching depends on the physical and chemical properties of soil, leaching water and leaching method. According to Dregne, the water content required for leaching is related to the analysis of soil, leaching and drainage water [3].

Applying equation (2) on the same soil texture (Sandy Lume to Silty Lume), Van Horn reported different results. The drawback of this model is ignoring the equilibrium salinity (EC_e) and soil's initial moisture [5]. following experimental formula for calculating the leaching water required for Solonchak soils is presented [11,12]:

$$R^* = W_{fc} - W_t + nW_{fc} \quad (3)$$

Where, R^* is leaching water, W_{fc} is the soil moisture at the farm capacity, W_t is water reserved in the soil before leaching (all based on m^3 per ha) and n is index, which can be changed between 0.5 and 2 according to Rozorph's suggestion. The more increased soil salinity and its improper mechanical properties, the more is n index, and the more increased water content required for leaching. V.R> Volobuev gives leaching process by following equation [5]:

$$\varphi = \varphi_1 + \varphi_2 + \varphi_3 \quad (4)$$

Where, j is depth of water required for leaching; j_1 is water content required for attaining the soil moisture to the farm capacity limit; j_2 is the water content required for attaining the soil moisture from the arable capacity to the saturated limit; j_3 is the water content passing the soil after attaining the soil to its saturated limit. Covoda suggested following relation for water content required for leaching [5]:

$$Y = n_1.n_2.n_3.400X \pm 100 \quad (5)$$

Where y is the leaching depth (mm), x is mean of soluble salts in the soil profile to the depth of 3 m (based on w%), n_1 is an index depending on the mechanical conditions of the soil and for sandy, loomy and clay soils it is 0.5, 1 and 2 respectively and n_2 is the index related to the depth of groundwater (m) and for groundwater depths about 1.5-2, 2-5 and 7-10 it is 3, 1.5 and 1 respectively. The salinity of groundwater in the limit of low to average, high and very high, the n_3 index is 1, 2 and 3 respectively (Heydari, 1994). Lafler and Sharma believed Ryo model and calculated the equation indexes for their soils considering the equilibrium electric conductivity (EC_e) and initial moisture of soil as well [11]. This equation is as following:

$$\frac{EC_f - EC_e}{EC_i - EC_e} = \frac{0.062}{\frac{D_{lw}}{D_s}} + 0.034 \quad (6)$$

Where: D_{lw} is the water gross depth (irrigation water based on cm)

Pazira and Kavachi [9] presented a model for Iran's soils, particularly is applicable for central parts of Khouzestan and is like Ryo's [11]:

$$\frac{EC_f - EC_e}{EC_i - EC_e} = \frac{0.070}{\frac{D_{lw}}{D_s}} + 0.023 \quad (7)$$

[11] presented two models for permanent drowned conditions and alternative drowned conditions

1. Permanent Drowned Conditions:

$$\frac{EC_f - EC_e}{EC_i - EC_e} = 0.099 * \frac{D_{lw}}{D_s}^{-1.27} \quad (8)$$

2. Alternative Drowned Conditions:

$$\frac{EC_f - EC_e}{EC_i - EC_e} = 0.09 * \frac{D_{lw}}{D_s}^{-1.63} \quad (9)$$

Water and Soil Institute determined the electrical conductivity (EC) in different locations and climates and obtained following formula [11]:

$$\frac{EC_f - EC_e}{Ec_i - EC_e} = 0.47 - \ln(\frac{D_w}{D_s}) \quad (10)$$

Pazira and Keshavarz model [11]:

$$\frac{EC_f - EC_e}{Ec_i - EC_e} = 0.0764 \times (\frac{D_{lw}}{D_s} - 0.864 \quad (11)$$

Materials and Methods

Studied region by the area of 17632 ha with chemical salty and alkali quality has been located at the eastern south of Khouzestan between 49º, 36' to 49º, 45' longitudinal and 30º, 15' to 30º, 30' latitudinal. Four plots by the dimensions of 1×1m and three replications have been created in this region (Figure 1 indicates plots' arrangement). In order to determining the salts content before leaching, there was sampled from one plot without adding water. Chemical properties of water and soil of two regions before test have been indicated in tables 1, 2 and 3. At the first period we added 25 cm or 250 lit water to each of plots and then chosen a plot of replications and sampled from it by pedology Ogher of the 25 cm depth after going the water out gravitationally. Sampled plots removed from the test and additional 250 liter of water was added to the remaining plots and after going the water out gravitationally, we sampled from the depth of 50 cm. we repeated this test for the depth of 100 cm and adding 100 cm water for leaching and then sampling.

Let samples to remain in the ambient to be dried and then sent them to the lab for calculating the electrical conductivity of soil saturated extract, its acidity, lime content, cationic exchange capacity, its exchangeable sodium content, cations and anions solved in the soil saturated extract, sodium and finally the exchange sodium percentage. Acid is added to prevent alkalization of soil and sodium washing such that in the second region in a treatment, Concentrated sulfuric acid was added about five tons per ha.

In order to obtain different mathematical models, there was used SPSS software. Net depth of irrigation water to the soil depth was entered as x (independent variable) and difference between final electrical conductivity difference with equilibrium electrical conductivity to the initial electrical conductivity difference with equilibrium electrical conductivity ($\frac{EC_f - EC_{eq}}{EC_i - EC_{eq}}$) was entered as y (dependent variable). Then, there was extracted eleven experimental models by the program. Table 4 indicates 11 models used in this test.

Results and Discussion

Results for different depths and leaching water alternatives have been indicated in table 5. According to table 5, before leaching most electrical conductivity is for depth of 0-25 cm, i.e. 78.20 dS per meter which after leaching in the mentioned depth the soil salinity has been averagely reduced to 4 dS/m. in the depth of 100 cm of soil, by adding 100 cm of irrigation water it has been reduced from 53.5 to 13.35 dS/m.

For exchangeable Na%, to the depth of 100 cm, the exchangeable Na % has averagely been reduced from 53.35 to 14.63 (table 2). Figure 2 indicates that for electrical conductivity, the amount of 86.67% of salt have been leached to the depth of 100 cm with only 13.32% of them remained in the surface soil and for exchangeable Na%, the rate of 84.96% has been leached and 15.04% remained in the soil.

Figure 2 also indicates that increasing the depth of leaching will decrease the percentage of salt and sodium remained in the soil and so depth range of 0-25 cm has been placed under other curves and so other depths have been place under each other by such arrangement. Uniformity of soil texture or soil homogeneity is the reason why curves have been reduced orderly without contacting to each other.

As figure 2 indicated, in depth of 0-25 cm, adding 25 cm of water has leached 90% of initial salts and adding the water in next orders there may not be seen high intensity of salt leaching. For depth of 0-100, adding 25 cm of water has leached less than 50% of initial salts while adding 75 cm of water has leached 90% of these salts. So for leaching the salts, it is necessary to determine the modifying depth and add water to it by the same amount, otherwise if we add water less than modifying depth, the leaching is less and we may have salinity problem and if we add more than modifying depth, it may not be economic and cannot considerably reduce the salts.

Figure 2 shows this fact that applying 75 cm of irrigation water for leaching the salts will leach the sodium as well and so we may not need to adding modifiers. According to table 8, of 100 cm of water added to the soil and irrigation water, due to deficit

Table 1: Soil chemical quality before of leaching in pilot No.1.

ESP(2) **	ESP(1) *	SAR	ESP $(\frac{meq}{100gsoil})$	C.E.C $(\frac{meq}{100gsoil})$	Gypsum $(\frac{meq}{100gsoil})$ $CaSO_4 2H_2O$	T.N.V	Soil pH	ECe	%SP	Sampling depth
41.29	77.36	48.54	7.62	9.85	7.34	70.1	6.85	78.2	41.2	0-25
44.07	72.26	54.27	5.6	7.75	3.87	68.07	6.9	49.1	42.6	25-50
41.5	31	48.59	5.05	16.29	36.24	63.5	6.85	44.2	48.8	50-75
41.5	32.77	46.93	4.62	14.1	59.09	67.56	7.1	42.5	45.6	75-100

Table 2: Soil chemical quality before of leaching in pilot No.2.

ESP(2) **	ESP(1) *	SAR	ESP $(\frac{meq}{100gsoil})$	C.E.C $(\frac{meq}{100gsoil})$	Gypsum $(\frac{meq}{100gsoil})$ $CaSO_4 2H_2O$	T.N.V	Soil pH	ECe	%SP	Sampling depth
34.51	25.18	36.58	5.01	19.9	6.24	36	7.1	46.5	33	0-25
30.41	45.62	30.48	6.25	13.7	6.86	36	6.95	36.6	32	25-50
30.12	44.49	30.07	5.25	11.71	7.41	67	7.1	38.2	30	50-75
29.88	36.58	29.74	6.01	16.43	24.88	69	7.2	36.4	30	75-100

$* \; ESP = \frac{Ex \cdot Na}{C \cdot E \cdot C} \times 100$ $\quad ** \; ESP = \frac{100(-0.0126 + 0.01475SAR)}{1 + (-0.0126 + 0.01475SAR)}$

Table 3: Quality of water irrigation

SAR	$\frac{meq}{l}$		pH	EC $(\frac{dS}{m})$	Date sampling		
	Na^{1+}	$Ca^{2+} + Mg^{2+}$			Year	Moon	Day
5.60	10.90	7.38	7.60	2.025	67	12	18

Table 4: Eleven empirical models in this assessment.

Formula	Models	Row
$Y = a.X + b$	Linear	1
$Y = a.\ln X + b$	Logarithmic	2
$Y = a.\frac{1}{X} + b$	Inverse	3
$Y = ax^2 + bX + c$	Quadratic	4
$Y = ax^3 + bX^2 + cX + d$	Cubic	5
$Y = bX^a$	Power	6
$Y = b.a^X$	Compound	7
$Y = e^{(\frac{a}{X} + b)}$	S	8
$Y = 1/(1/u + (b.a^X))$	Logistic	9
$Y = e^{aX+b}$	Growth	10
$Y = b.e^{a.X}$	Exponential	11

Table 5: Exchangeable Sodium Percentage in different depth with irrigation alternations before and after of doing irrigation in pilot No.1.

ESP soil saturation extract after application different alternation apply water					ESP before of leaching	Depth of Sampling	Row
Average ESP_f	D_w = 100 ESP_f (100)	D_w = 75 ESP_f(75)	D_w = 50 ESP_f(50)	D_w = 25 ESP_f(25)	ESP_i	(cm)	
4.52	3.23	3.59	6.25	4.65	77.36	0-25	1
8.41	3.03	4.4	12.41	13.81	72.26	25-50	2
20.05	1.94	5.46	20.49	52.32	31	50-75	3
25.53	4.3	3.26	47.67	46.89	32.77	75-100	4
14.63	3.12	4.27	27.70	29.42	53.35		Average

moisture, this amount has practically leached the salts to the depth of 92 cm because 8 cm of that water provided moisture for the soil and couldn't be attained to the related depth. So it is necessary to reduce the moisture loss from the water added to the soil to determine the water content needed for leaching the salts in our calculations.

$$d = \frac{(\theta_{mc} - \theta_{mFC}) \times \rho_d \times D}{100} \quad (11)$$

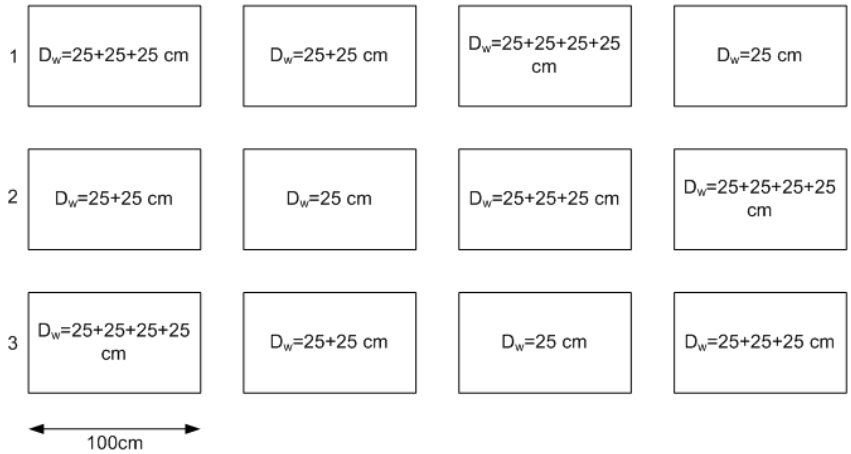

Fig. 1: Figure of plate.

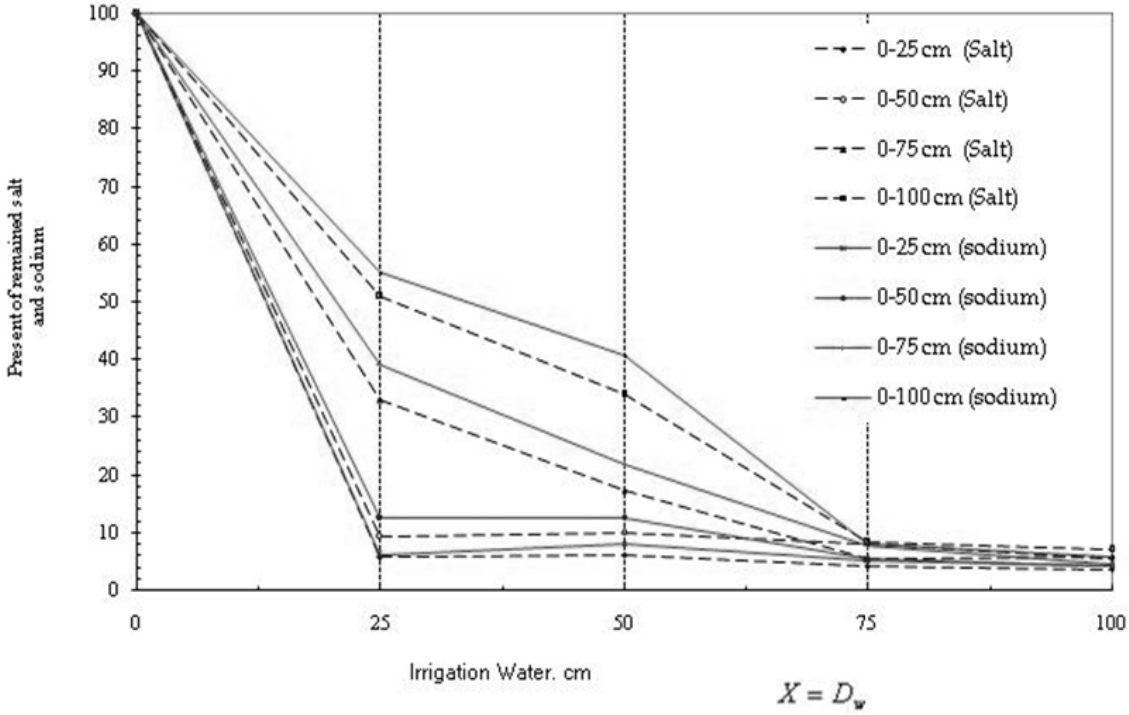

Fig. 2: Comparison of applied irrigation water in washing salt and sodium in pilot No1.

Soil's equilibrium electrical conductivity equaled with 3.1 dS/m, i.e. regarding to the electrical conductivity of irrigation water (2.025) one cannot reduce the soil salinity less than this rate (equilibrium electrical conductivity of soil is 1.5 to 2 times of electrical conductivity of irrigation water).

Reducing the equilibrium electric conductivity of each related data and obtaining the net water depth to gross water depth ratio is for generalizing it to the obtained model and separating the ambient conditions and initial moisture of test. The final electrical conductivity to initial electrical conductivity ratio to the depth of 100 cm is 0.012 for soil and 0.023 for exchangeable sodium. The net depth of leaching water (leaching water) to gross depth of leaching water (irrigation water) ratio in the depth of 100 cm after applying 100 cm of irrigation water was 0.92. as indicated in table 9, after testing the eleven experimental models with SPSS, about electrical conductivity the indices of equations have been calculated, inverse model with correlation coefficient of 92% had maximum correlation and linear model with correlation coefficient of 54% had minimum correlation. Inverse equation with calculated coefficients is as following:

$$Y = 0.086\frac{1}{X} - 0.048 \qquad (12)$$

For percentage of exchangeable sodium, after testing the eleven experimental models with SPSS, like electrical conductivity, inverse model with correlation coefficient of 83% had maximum correlation and linear model with correlation coefficient of 5430 had minimum correlation.

Inverse equation for exchangeable sodium percentage, with calculated coefficient is as following:

$$Y = 0.095\frac{1}{X} - 0.030 \quad (13)$$

For plot No.2, without adding acid as well as adding acid like what mentioned in the plot No.1, the calculations were conducted and its results are as follows. Figure 3 indicates that in the plot No.2, without adding acid, for electrical conductivity, about 92.25% of salts leached to the depth of 100 cm with only 7.75% of initial salts remained in the soil and about percentage of exchangeable sodium, 83.42% of it leaches and only 16.57% remained in the soil. In depth of 0-25 cm, adding 25 cm of water has leached 90% of initial salts and adding the water in next orders there may not be seen high intensity of salt leaching. For depth of 0-100, adding 25 cm of water has leached less than 40% of initial salts while adding 100 cm of water has leached 90% of these salts.

Dashed lines in figure 3 indicate changes in sodium percentage and continuous lines indicate salinity.

According to this chart, it can be indicated that when applying the leaching by adding 25 cm of water, there is glaring difference between leaching curves of salts and sodium, but in next alterations, particularly when adding 100 cm of water, there is more conformity between those curves. Generally speaking, adding 100 cm of water for modifying 100 cm of soil, salts may be leached accompanying with sodium and so there may not be danger of increased sodium in the soil.

As indicated in table 10, after testing the eleven experimental models with SPSS, about electrical conductivity the indices of equations have been calculated, and inverse model with regression coefficient of 80% had maximum correlation and linear model with regression coefficient of 54% had minimum correlation. Inverse equation with calculated coefficients is as following:

$$Y = 0.095\frac{1}{X} + 0.036 \quad (14)$$

According to table 11, about percentage of exchangeable sodium, from eleven models tested, the cubic model has maximum correlation coefficient (94%).

Equation for exchangeable sodium percentage is as following:

$$Y = -0.079X^3 + 0.590X^2 - 1.314X + 0.937 \quad (15)$$

In summary, results for plot No. 2 with applying the acid are as follows:

For electrical conductivity, the coefficients have been calculated and compound, inverse, growth and exponential models with regression coefficient of 76% maximum highest correlation and S model with correlation coefficient of 45% had minimum correlation. Equations with calculated coefficients are as follows:

$$Y = 0.050\frac{1}{X} + 0.004 \quad \text{Inverse} \quad (16)$$

$$Y = 0.487 \times 0.040^X \quad \text{Compound} \quad (17)$$

$$Y = \frac{1}{\frac{1}{u} + (1.88026.718^X)} \quad u = 3.78 \quad \text{logistic} \quad (18)$$

$$Y = e^{-3.218X - 0.72} \quad \text{Growth} \quad (19)$$

$$Y = 0.487e^{-03.218X} \quad \text{Exponential} \quad (20)$$

For the percentage of exchangeable sodium, from eleven models tested, cubic model had maximum correlation (88%). Related equation is as following:

$$Y = -0.090X^3 + 0.770X^2 - 1.850X + 1.302 \quad (21)$$

Table 11 indicates the test results.

Conclusion:

To leach the salts, it is necessary to determine the modifying depth and add water to the soil by the same amount. Otherwise, if we add water less than modifying depth, leaching is not enough and we will encounter with salinity and if add water more than modifying depth, it may not be economic while may not considerably reduce the salts. Applying 100 cm of water for leaching the salts will leach sodium as well, so it is not necessary to add modifiers. In the test conducted in the studied pilot, although the inverse model had often maximum correlation and its coefficients have been calculated with related chart has been drawn, but that because chemical properties of soil is dynamic in different times, places and climates, it is recommended to conduct such tests in other points for executive projects and draw related diagrams so decisions made using coefficients and models related to that pilot.

Table 6: Result kinds of empirical models to calculate EC in pilot No1.

Accounting statistic			Firm Coefficient				Formula	Model	Row
	R	R²	d	C	b	a			
0.045	0.542	0.294	-	-	0.19	-0.075	$Y = a.X + b$	Linear	1
0.0007	0.791	0.626	-	-	0.077	-0.13	$Y = a.\ln X + b$	Logarithmic	2
0	0.92	0.847	-	-	-0.048	0.086	$Y = a.\frac{1}{X} + b$	Inverse	3
0.0086	0.761	0.579	-	0.33	-0.337	0.069	$Y = ax^2 + bX + c$	Quadratic	4
0.0019	0.872	0.761	0.493	0.84	0.41	-0.059	$Y = ax^3 + bX^2 + cX + d$	Cubic	5
0	0.883	0.779	-	-	0.023	-1.622	$Y = bX^a$	Power	6
0.0028	0.733	0.538	-	-	0.121	0.322	$Y = b.a^X$	Compound	7
0.0002	0.842	0.71	-	-	-4.979	0.88	$Y = e^{(\frac{a}{X}+b)}$	S	8
0.003	0.731	0.534	-	-	7.815	3.174	$Y = 1/(1/u + (b.a^X))*$	Logistic	9
0.0028	0.733	0.538	-	-	-2.107	-1.135	$Y = e^{aX+b}$	Growth	10
0.0028	0.733	0.537	-	-	0.121	-1.135	$Y = b.e^{a.X}$	Exponential	11

Table 7: Empirical leaching models for pilot 1 and 2.

Model	Variation	Model Name	EC / ESP	Use acid	Area	Row
$Y = \frac{0.086}{X} - 0.048$	0.847	Inverse	*EC*	Don't use acid	1	1
$Y = \frac{0.095}{X} - 0.030$	0.832	Inverse				
$Y = \frac{0.059}{X} + 0.036$	0.8	Inverse	*EC*	Don't use acid	2	2
$Y = -0.079x^3 + 0.590X^2 + -1.314X + 0.937$	0.936	Cubic	*ESP*			
$Y = 0.487e^{-3.218X}$	0.758	Exponential	*EC*	Used acid	2	3
$Y = e^{-3.218X - 0.720}$	0.758	Growth				
$Y = 1/\{1/3.788 + (1.888 \times 26.718^X)\}$	0.757	Logistic				
$Y = 0.487 \times 0.040^X$	0.758	Compound				
$Y = \frac{0.050}{X} + 0.004$	0.756	Inverse				
$Y = -0.090x^3 + 0.770X^2 - 1.850X + 1.302$	0.822	Cubic	ESP			

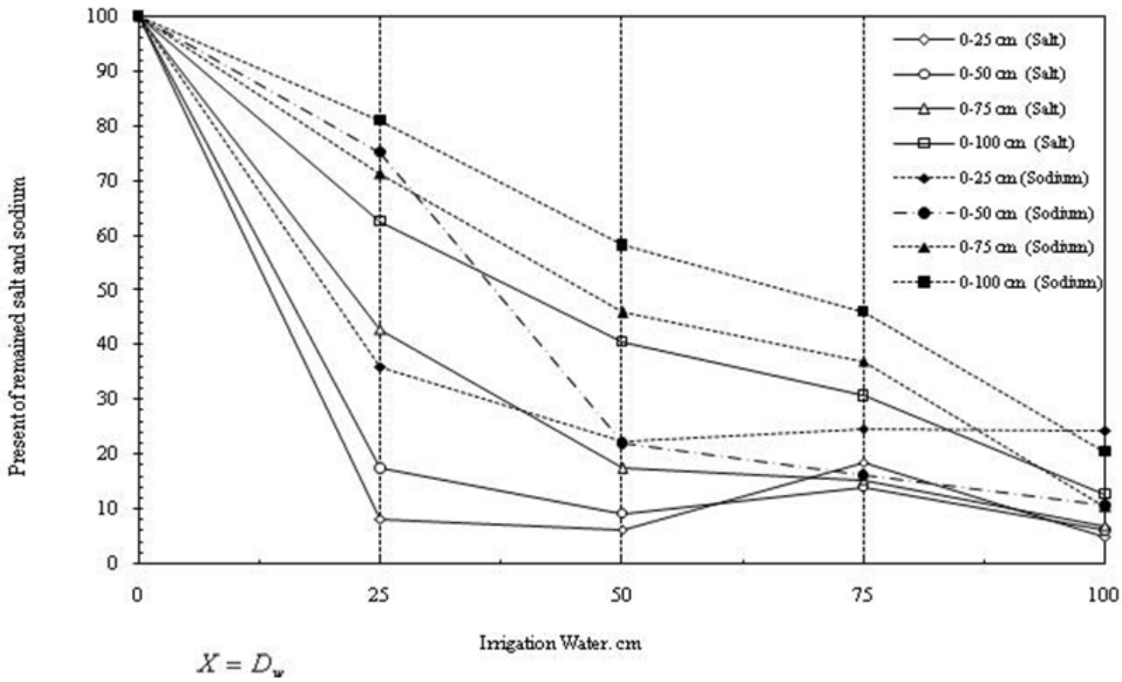

Fig.3: Comparison of applied irrigation water in washing salt and sodium in second area in pilot No2.

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