Experimental Study on Relation between Whole-salt Quantity and Electric Conductivity

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Abstract: *Through different water-soil ratio, oscillation time, ion contents and soil salt quantity, the correlation and regression between the whole soil salinity in oasis-desert ecotones in Tarim basin and electro conductivity of soil soak-out-liquid have been studied by electric conductivity methods. The results indicated: when water-soil ratio was 1:1-6:1, there was significantly correlation between electro conductibility and whole-salt quantity. But the 5:1 water-soil ratio is better according to the soil characteristic in this locality. After the oscillation time of soil samples was 10 minutes under the 5:1 water-soil ratio, the electro conductibility of soak-out-liquid there was not marked difference. The correlation between ion of comparative large contents and the electro conductibility soak-out liquid was very marked. When soil salinity is large, linear functions can be used to better measure the whole salt quantity of this local by subsection analysis.*

Keywords: *Soak-out liquid, Electrical conductivity, Whole-salt quantity, Oasis-desert ecotones.*

Introduction

The soil salt content is a physical parameter of soil, which is significant for the growth of plants. Meanwhile, the soil salinity has an important influence on the soil environment. Monitoring the change of the soil salinity is the basic work in the study of agriculture and environment. There are many methods for measuring the soil salinity, but at present, the main methods still are the gravimetric method and the conductivity method, which also are the basis of other methods.

Conductivity method is an electrochemical analysis method that analyzes the conductivity of a solution to analyze the content of the substance to be tested [9]. The method for determining the soluble salt content of soil by the conductivity method is simple and accurate, and the basic principle of the determination is the conductivity of the electrolyte in the extract. It is convenient and fast to measure the total amount of water-soluble salt in the soil with the conductivity method [4], and this method is also suitable for the dynamic located monitoring of the salinity of the undisturbed soil in the field. The conductance characteristics of the soil in different regions have been studied and discussed both at home and abroad [5, 6, 8, 14]. For a long time, it is common to use the conductivity to directly express the soil salinity in foreign publications [10], and there have been some domestic people suggesting using the conductivity under 25 ℃ to express the salinity directly. However, due to the water-soil ratio, oscillation time, salt composition and other factors, the application indicator has not yet been determined [7], and customarily the mass fraction of the soil salt content is still used to express the salinity. In China's Soil Taxonomy established in the late 1980s, the classification and diagnostic indicator of the salty soil also was the mass fraction of salt. In different regions, the relations used to convert the conductivity into the mass fraction of soil salt content are different [1]. At present and in a long time in the future, it is still necessary to study on measuring the conductivity of soil soak-out liquid and converting it into the mass fraction of soil salt content.

In this experiment, we studied the correlation and regression between the soil conductivity and the total soil salinity (‰) in the oasis-desert ecotone of Tarim Basin from 4 aspects: different water-soil ratios, soil processing time, salt composition and salt content.

Materials and methods

The source of soil sample

The source of soil sample was from Aksu Water Balance Experiment Station, Chinese Academy of Sciences, which is located in the plain oasis in the northwest of Tarim Basin and about 60 km away from Taklimakan Desert, and belongs to a typical continental desert climatic zone. In this region, the soil is the desert meadow solonchak, the texture is sandy loam [13]; in the desert meadow area adjacent to the north, the soil is the desert solonchak, there a layer of salt shell with a thickness of 10-15 cm within the surface layer with a thickness of 0-15 cm, and its salt content is up to 50-70% [12]. In September, 2017, we selected 6 sampling spots in the uncultivated land and the cotton fields with different planting years, and the sampling depth was 0-140 cm.

Soil sample processing and analytical method

After drying the soil samples, grind and sift (1mm) the soil according to the experiment requirements, weight 30 g of the soil samples and mix the soil and water according to different ratios from 1:1-10:1 respectively, and then oscillate them with an oscillator (HY-4 speed-governing multipurpose oscillator manufactured by Jiangsu JintanHuafeng Instrument Co., Ltd.) and extract and filter them. The total salt content was measured with the gravimetric method and the conductivity method respectively. The conductivity meter and the conductance electrodes were DDS-302 type and DJS-1C type respectively manufactured by Shanghai Precision and Scientific Instrument Corporation. The soil ions were measured with the conventional method [2].

Result analysis

The influence of the water-soil ratio on the conductivity

Select 7 soil samples with different depth, concoct the soak-out liquid in the water-soil ratios from 1:1-10:1, and then measure the total salt content and conductivity respectively. The analysis results are shown in Table 1 and Fig. 1.

In Table 1, when the water-soil ratios are l:1, 2:1, 3:1, 4:1 and 6:1, the correlation coefficients between the conductivity of the soak-out liquid and the total salt content are less than that when the water-soil ratio is 5:1, but all their regression equations are significant, which indicates that the conductivities of the soil soak-out liquid can be used to express the soil salt content in the sampling region when the water-soil ratios are 1:1-6:1.

Table 1. The statistical analysis results of the conductivity and total salt content with different water-soil ratios

Water-soil ratio	Regression equation	R^2
1:1	$y = 4.7540x - 2.3545$	0.8980
2:1	$y = 0.7004x - 1.8519$	0.9589
3:1	$y = 0.4179x - 0.6889$	0.9738
4:1	$y = 0.2100x - 0.1221$	0.9791
5:1	$y = 0.1545x - 0.0957$	0.9944
6:1	$y = 0.1261x - 0.1193$	0.9914

The regression equations between the conductivity of the soil soak-out liquid and the total salt content of soil with different water-soil ratios are different, which is mainly due to the different solubility of the salt in soil with the change of the soil-water ratio. By studying, the quantity of Ca^{2+} and SO_4^{2-} in the soak-out liquid with 5:1 of water-soil ratio is 5 times that with 1:1 of water-soil, the quantity of Na^+ is 2 times, and quantity of Cl^- is almost the same [3]. The content of SO_4^{2-} and K^+ Na^+ is large in the sampling region (as shown in Table 2), and the correlation between the SO_4^{2-} and K^+ Na^+ and the conductivity of the soil soak-out liquid is significant (as shown in Table 3). Therefore, when the conductivity is used to measure the total salt content in the local soil, the appropriate water-soil ratio is 5:1, in order to reflect the total salt content of soil more precisely.

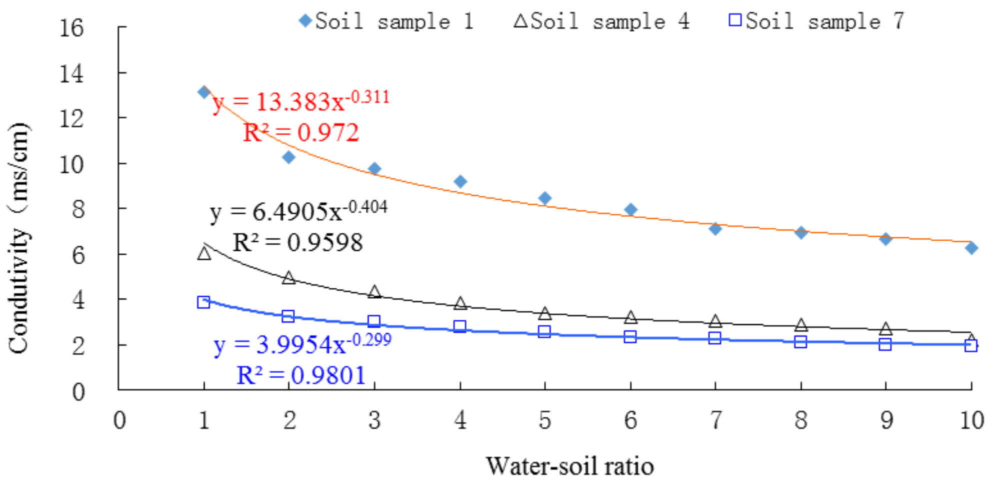

Fig. 1 The relation between the water-soil ratio and the conductivity

Fig. 1 shows the relations of the conductivities of the soak-out liquid of three different soil samples with different salt content and the water-soil ratios, in which, we can see that the conductivity of the soak-out liquid of each soil sample decreases with the increase of the water-soil ratio in a power relation, and the correlation is significant. However, when the decreasing value of the conductivity is less than the dilution ratio, the conductivity with 1:1 of water-soil ratio is 1.56 times that with 5:1 of water-soil ratio, which is less than the result researched by Wu and Wang [11]. It is related to the type of soil salinity possibly.

The influence of oscillation time on the conductivity

Select soil samples from two sampling locations with different depth to prepare the soak-out liquid with 5:1 of ware-soil ratio, oscillate sample 1-7 with 1Hz of frequency, and oscillate sample 8-15 with 3 Hz of frequency. The oscillation time is 0, 1, 2, 3, 4, 5, 10, 30 and 60 min respectively. The conductivities measured are shown in Fig. 2. The results show that, when the water-soil ratio is 5:1, the conductivity of the soak-out liquid increases correspondingly with the increase of oscillation time. However, the relation between the oscillation time and the conductivity with two different oscillation frequencies shows that, when the oscillation time is increased to 10 min, the numerical value of the conductivity is not remarkable, which means the oscillation time after 10 min has little influence on the conductivity of the soak-out liquid with 5:1 of ware-soil ratio. Therefore, the appropriate oscillation time is 10 min in the conductivity measurement experiment.

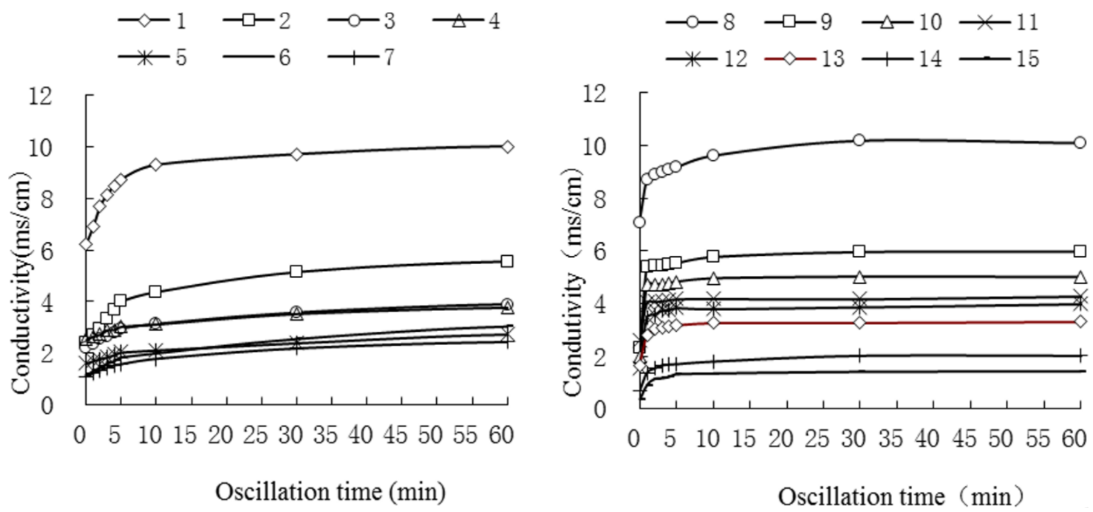

Fig. 2 The influence of the water-soluble salt ions in the soil on the conductivity

Table 2. The soil salinity conditions in the farmland of Aksu Water Balance Experiment Station

Location	Sampling depth, (cm)	Conductivity, (ms/cm)	Gravimetric method	HCO_3^-	Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+K^+
Cotton filed	5	2.80	14.22	0.12	0.21	9.186	2.83	0.61	0.18
	10	2.57	13.52	0.17	0.12	9.123	2.94	0.45	0.30
	20	2.47	12.82	0.15	0.10	8.557	3.04	0.32	0.12
	30	2.41	12.48	0.12	0.04	8.431	2.94	0.33	0.12
	40	2.22	11.00	0.10	0.05	7.865	2.73	0.26	0.22
	60	2.32	12.04	0.14	0.05	7.802	2.94	0.19	0.09
Paddy field	5	4.97	22.58	0.10	2.56	12.14	2.83	0.84	2.68
	20	4.06	18.80	0.14	1.43	10.89	2.83	0.45	2.09
	40	4.78	21.30	0.15	2.03	12.02	2.83	0.45	3.03
	60	5.64	24.00	0.14	3.03	12.40	2.73	0.32	4.22
	80	7.09	28.74	0.17	4.50	14.41	2.73	0.32	6.14
	100	8.57	33.79	0.15	6.77	15.79	2.57	0.29	8.51

After sorting out the salinity dada of the soil in the farmland of Aksu Water Balance Experiment Station and analyzing the correlation coefficients between ions and between each ion and the conductivity (as shown in Table 3), we can know from the results that, the correlation coefficients between the conductivity of the soak-out liquid and the ions, such as Cl^-, Na^+ K^+, SO_4^{2-} and Ca^{2+} are significant, especially the correlation coefficients of the first three ions are above 0.98, which is mainly due to the high content of these ions with great influence on the conductivity of the soak-out liquid. Therefore, the conductivity of the soak-out liquid can reflect the soil salt content objectively.

Table 3. The correlation coefficients between ions and between each ion and the conductivity

	Mg^{2+}	K^+Na^+	HCO_3^-	Cl^-	SO_4^{2-}	Conductivity
Ca^{2+}	0.0063	0.6516	0.0011	0.6441	0.5524	0.6157
Mg^{2+}		0.0057	0.1174	0.0003	0.0165	0.0006
K^+Na^+			0.1468	0.9897	0.9467	0.9875
HCO_3^-				0.1110	0.1420	0.1284
Cl^-					0.9447	0.9864
SO_4^{2-}						0.9805

The influence of soil salt content on the conductivity

Weight 30 g of 14 soil samples from different sampling locations respectively, and mix them with water in the ratio of 5:1 and oscillate them for 10 min. After filtering them, measure the conductivity and the total salt content (with the gravimetric method). The results are shown in Table 4. By the data regression analysis in Table 2 and Table 4, the equations, $y = 4.0209x + 1.5195$ and $R^2 = 0.9836$ are obtained. After that, calculate the total salt content according to the conductivities in Table 4 by the equations. We can see from Table 4 that, the relative error of the calculated value and the estimated value in the regions with low salt content is large, which is mainly due to the simplification of salt content in the regression fitting.

Table 4. The soil salt content measured with the gravimetric method and the conductivity

Conductivity, (ms/cm)	Total salt content, (g/kg)		Absolute error, (g/kg)	Relative error, (%)
	Gravimetric method	Calculated value		
1.15	5.28	6.14	-0.87	16.42
1.32	6.01	6.83	-0.82	13.67
1.35	5.94	6.95	-1.01	16.96
1.64	7.33	8.11	-0.79	10.77
1.88	8.21	9.08	-0.87	10.58
2.01	9.05	9.60	-0.55	6.09
2.10	9.46	9.96	-0.50	5.32
2.15	9.85	10.16	-0.31	3.19
2.38	10.89	11.09	-0.20	1.83
2.47	10.85	11.45	-0.60	5.54
3.84	14.42	16.96	-2.54	17.61
5.52	24.19	23.71	0.48	1.96
6.89	30.22	29.22	1.00	3.30
8.29	36.03	34.85	1.18	3.27

Analyze the regression between the conductivity and the total salt content into 3 stages (salt content <10‰, 10-20‰ and >20‰) according to the salt content. After studying the difference of the regression equations by t-test, it is discovered that, when the salt content >20‰

and between 10-20‰, the regression coefficients of the two regression equations are not different significantly, and the difference between the intercepts is not significant. Therefore, the two equations can be merged into one equation: $y = 3.7199x + 3.5026$, $R^2 = 0.9913$; when the total salt content is between 10-20‰ and <10‰, the regression coefficients of the two regression equations are not different significantly, but the difference between the intercepts is significant, so the two equations shall not be merged. Therefore, the relation between the conductivity and the total salt content shall be expressed by different equations with different total salt content of soil.

Conclusion

(1) When the water-soil ratios are l:l-6:1, the correlation between the soil soak-out liquid and the total salt content of soil is significant, and the regression equation is significant, too. According to the salt characteristics of the soil in the oasis-desert ecotone of Tarim Basin, the total salt content shall be expressed by the conductivity of the soil soak-out liquid with 5:1 of water-soil ratio appropriately.

(2) When measuring the total salt content of the local soil with the conductivity method, the numerical values of the conductivity with 5:1 of water-soil ratio and for 10 min or above of oscillation are not different significantly.

(3) In the soil soak-out liquid, the correlation between the ions with high content and the conductivity is significant.

(4) The relation between the total salt content and the conductivity shall be calculated with different equations according to different salt content. In the oasis-desert ecotone of Tarim Basin, when the total salt content is less than 10‰, the equation $y = 4.5081x - 0.0241$ is appropriate; when the total salt content is more than 10‰, the equation $y = 3.7199x + 3.5026$ is appropriate.

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