Iran Agricultural Research 20:189-200(2001)

NOTE

CHARACTERIZATION OF SOME SOIL SALINITY PARAMETERS IN THE PLAYA MARGIN (CASE STUDY: YAZD PROVINCE)

S. K. ALAVI PANAH AND M. DE DAPPER[1]

Iran Desert Research Center, University of Tehran, I.R. Iran and Department of Regional Geography and Landscape Study, University of Gent, Belgium.

(Received: May 15, 2000)

ABSTRACT

A better understanding of some physico-chemical characteristics of saline soils, developed in playa margins, may be important to improve the study of soil salinity in playas using remotely sensed data. In this study, some important aspects of soil salinity in the Ardakan and Abarkooh playa margins in the central part of Iranian deserts were investigated. For this study, 115 soil profiles were excavated and soil samples from different intervals/horizons were analyzed for some physico-chemical properties. It was also attempted to study the accumulation of soluble salts in the soil profile, and relationship between some soil salinity parameters such as electrical conductivity (EC), soluble chloride (Cl^-) and sodium ions (Na^+) with soil depth. The results obtained from the relationship between soil salinity parameters showed that the estimation of soluble Cl^- and Na^+ from EC(1:5) and electrical conductivity of soil paste (ECp) of surface samples has the advantage of saving time when high accuracy is not

1. Assistant Professor and Professor, respectively.

intended. The result also showed that EC and soluble Cl^- and Na^+ decreases rapidly at about 20 cm and that below this depth, soil salinity decreases gradually. Based on the results obtained, we generally concluded that the relationship between soil salinity parameters might be useful to design a sampling plan more efficiently.

Key words: Playa margin, Salt accumulation, Soil salinity, Soil variability, Soluble chloride, Soluble sodium.

تحقیقات کشاورزی ایران

(۱۳۸۰) ۲۰۰-۱۸۹:۲۰

ویژگی های برخی پارامترهای شوری خاک در حاشیه پلایا (مطالعه موردی: استان یزد)

سید کاظم علوی پناه و مورگان دداپر

به ترتیب استادیار دانشگاه تهران، مرکزتحقیقات مناطق کویری و بیابانی ایران، تهران، جمهوری اسلامی ایران و استاد بخش ژئومرفولوژی دانشگاه گنت، بلژیک.

چکیده

درک بهتر برخی مشخصات فیزیکی و شیمیایی خاک های شور حاشیه پلایا به انجام بهتر مطالعه آن ها با استفاده از داده های دورسنجی کمک می نماید. در این مطالعه، مهمترین ویژگی های شوری خاک حاشیه پلایا های اردکان و ابرکوه، در بخش مرکزی بیابان های ایران، مورد مطالعه قرار گرفت. بدین منظور ۱۱۵ نیمرخ خاک حفر گردید و نمونه های افق ها ویا اعماق خاک جهت بررسی برخی خواص

فیزیکو- شیمیایی مورد تجزیه و تحلیل قرار گرفت. تجمع املاح محلول در نیمرخ خاک و رابطه برخی پارامترهای شوری مانند قابلیت هدایت الکتریکی (EC) و کلرید سدیم محلول با عمق خاک مورد مطالعه قرار گرفت. براساس نتایج حاصله از روابط پارامترهای شوری خاک نتیجه گیری شد که Na^+ و Cl^- محلول از روی EC و قابلیت هدایت الکتریکی گل اشباع (ECp) نمونه های سطح الارض قابل تخمین بوده و این امر برای مواردی که دقت زیاد مورد نظر نیست موجب صرفه جویی در وقت می گردد. بر اساس نتایج حاصله Cl^-, EC و Na^+ قابل حل تا عمق ۲۰ سانتی متری سطح الارض روند کاهش سریعی را نشان می دهد ولی پایین تر از این عمق، شوری به آرامی کاهش می یابد. براساس این نتایج معلوم گردید که رابطه بین پارامترهای شوری خاک ممکن است در طراحی نمونه برداری مؤثرتر، مفید واقع شود.

INTRODUCTION

Playa can be defined as the lowest areas within enclosed desert drainage basins with almost horizontal, mostly vegetation-free and fine-grained sediments (4). Many investigations have shown that the playas in Iran can be valuable as sources of some non-metallic compounds such as chloride, sulphate, nitrate, and borate. All of the 60 Iranian playas with different surface characteristics exist in areas where the annual evaporation is considerably greater than annual precipitation. Estimated land area affected by salinity varies between 16 to 23 Mha (8, 9). Electrical conductivity and concentration of the chloride anion (Cl^-) are two important criteria in the evaluation of soil salinity. Because the laboratory analysis of soluble Cl^- and Na^+ is more expensive and time consuming than that of EC, the relationship between EC and Cl^- and Na^+ may have a practical value for salinity estimation. Alavi Panah (2) studied some physico-chemical properties of the soils in the Abarkooh playa margin, and found a very strong relationship between the ECe and soluble Cl^- data. He also showed that the soluble salts that accumulate in soil surfaces in the Ardakan playa margin are mainly composed of Cl anion and Na cation. Because Cl^- and

Na^+ are predominant, the dominant soluble salts are sodium chloride (NaCl). Sodium sulphate is of second any importance followed by magnesium and calcium chloride. Cooke *et al.* (4) stated that, because of the high solubility, NaCl is taken further down slope, and it characterizes the soil nearest to a playa, while the other salts are deposited at higher altitudes. There is no conversion factor that can be used to compare EC at different soil water ratios. The solubility of salts may vary with increasing dilution. However, the relationship between ECp, EC (1:5) and ECe is useful to estimate ECe as a conventional method of soil salinity measurement from EC (1:5) and ECp.

MATERIALS AND METHODS

In this study, the areas of the Chah Afzal and Abarkooh in the playa margins in the Yazd province were selected to characterize soil salinity parameters. We attempted to study some important aspects of the soil salinity in the Iranian playa margins such as accumulation of soluble salts at the surface, soil variability, relationship between some soil salinity parameters and soil salinity type. In this study, the main attention was focused on the Chah Afzal area located between latitudes, 32° 5' and 32° 34' N and longitudes, 53° 45' and 54° 14' E. This area is situated in the Ardakan-Yazd watershed in the north of Yazd city and in the south of Ardakan playa (Fig. 1). The Ardakan playa with the area of 1250 km^2 comprises 525 km^2 salt crust. It has been estimated that about 20% of the total amount of run off water of the Ardakan Yazd watershed reaches the Ardakan playa (11). In order to study some soil salinity characteristics of the playa margins, once a sampling strategy was chosen (1), 115 soil profiles (55 soil profiles in the Chah Afzal area, 30 in the Ardakan area near the Chah Afzal and 30 in the Abarkooh area) were dug and about one kilogram soil samples were taken from different intervals to maximum depth of 165 cm. The sample sites are mainly selected according to the photomorphic units (PMU) (5) delineated on the Landsat TM false color composite (FCC) at a scale of 1:100,000. All the samples were crushed, air-dried, passed through a

2.0 mm sieve thoroughly mixed and then analyzed. The following attempts were made:

1) The EC (1:5) of 302 soil samples (55 soil profiles) from different soil depths were plotted vs. soil depth and the best model was fitted for the relationships between EC (1:5), soluble Cl^- and Na^+ with soil depth.
2) The soil salinity parameters (EC, Cl^-, Na^+) as a single dependent variable and soil depth as an independent variable were used to study the equations from the fitted models that might be useful to roughly estimate the EC, Cl^- and Na^+ in study area.

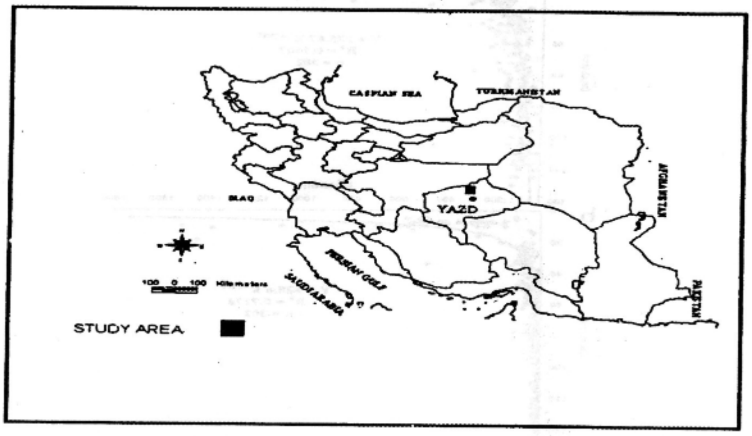

Fig. 1. Location of the study area.

RESULTS AND DISCUSSION

Relationships between Soil Depth and Electrical Conductivity, Soluble Chloride and Sodium Ions

The obtained equations from the fitted models of the soil salinity parameters and depth of soil are shown in Table 1. These models are useful in estimating roughly the EC (1:5), Cl^- and Na^+ from soil depth in the Ardakan playa margin. The trend of the three curves are comparable to each other (Fig. 2), because of a very high correlation between EC, Na^+ and Cl^-. The correlation coefficients between EC with Cl^- and Na^+ are 0.972 and 0.969, respectively.

Table 1. The equations for estimating EC, Na^+ and Cl^- from soil depth in summer.

Equations	R^2
EC 1:5 = 235.87 $(Depth)^{-0.9051}$	0.740
Na^+ = 533.23 $(Depth)^{-0.626}$	0.718
Cl^- = 328.60 $Depth)^{-0.566}$	0.717

Depth = cm, Na^+ = meq. l^{-1}, Cl^- = meq. l^{-1}

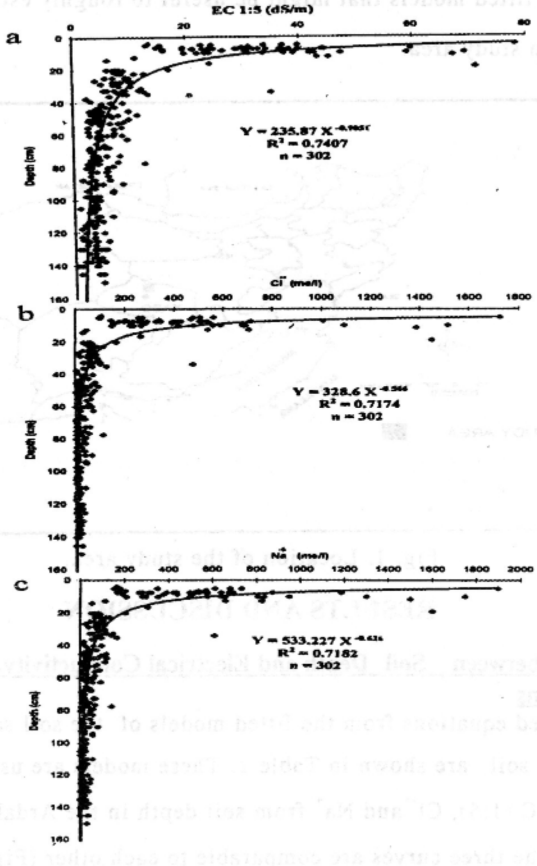

Fig. 2. Relationship between soil depth and: (a) electrical conductivity, (b) soluble chloride, and (c) soluble sodium.

These three models show a very rapid decreasing rate at topsoil (<50 cm depth) which can be due to a great accumulation of salts in the top horizon, and then the curve decreases very gradually with increasing depth. From the above results we may conclude that in the bare land of the marginal part of the Ardakan playa, salt distribution is mainly a function of soil depth.

Relationship between Electrical Conductivity and Soluble Chloride and Sodium Ions

The results of the fitted models (polynomial) between the soluble Cl^- and Na^+ (as dependent variables) and EC (as independent variable) are shown in Fig. 4. Fig. 2 shows that the relationships are not completely linear. Tanji and Biggar (9) stated that the relationship between EC and ion concentration is not completely linear, because the amount of salts is directly related to the total charge and ion mobility, and as the concentration increases, there is a concomitant decrease in both these parameters due to relaxation and formation of ion pairs. More ion pairs are formed with Ca^{2+}, Mg^{2+} and $SO4^{2-}$ than with Na^+ and HCO_3^- (3). The relationship between Cl^- and EC (1:5) at the soil profiles in the Chah Afzal area suggests that 99.1% of the variation in soluble Cl^- may be explained by EC (1:5), but relationship between Cl^- with EC (1:5) at the soil surface in the Chah Afzal area shows that 98% of the variation in soluble Cl^- may be described by EC (1:5). The result shows that 98.2% of the variation in the ECe in the soil profile in the Abarkooh area can be explained by ECe. A careful examination of Fig. 3 or the related equation (Table 2) indicates some differences between the Fig. 3 and related equations of the Chah Afzal area.

It means that the coefficient of X^2 and X in the equations of the Chah Afzal and Abarkooh areas are not completely comparable. The reason may be attributed to a) difference in the method of soil salinity measurement, and b) low salinity values in the Abarkooh area which could not be found in the Chah

Table 2. The equations for estimating soil salinity parameters by ECe.

Name of the area	Code of Equation	Soil depth	Equations	R^2
Chah Afzal	a	Soil profile	$Cl^- = 0.217\,(EC\ 1{:}5)^2 + 5.516\,(EC\ 1{:}5)$	0.991
	c	Soil surface	$Cl^- = 0.213\,(EC\ 1{:}5)^2 + 5.778\,(EC\ 1{:}5)$	0.980
Abarkooh	e	Soil profile	$Cl^- = 0.085\,(ECe)^2 + 6.531\,(ECe)$	0.982
Chah Afzal	b	Soil profile	$Na^+ = 0.206\,(EC\ 1{:}5)^2 + 8.937\,(EC\ 1{:}5)$	0.985
	d	Soil surface	$Na^+ = 0.195\,(EC\ 1{:}5)^2 + 9.661\,(EC\ 1{:}5)$	0.963

$EC = dS\ m^{-1}$, $Na^+ = m.e.\ l^{-1}$, $Cl^- = m.e.\ l^{-1}$

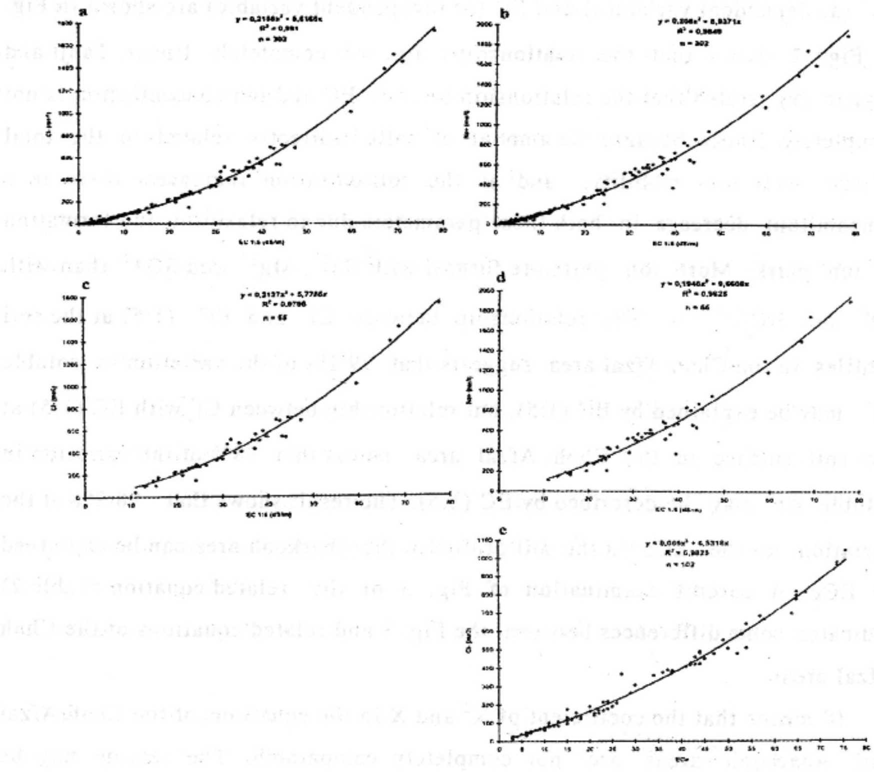

Fig. 3. Relationship between electrical conductivity and: (a) soluble chloride of the soil profile depth, (b) soluble sodium of the soil profile depth, (c) soluble chloride at surface horizon, (d) soluble sodium at surface horizon, and (e) soluble chloride at the soil profile in the Abarkooh.

Afzal area. From this result we may conclude that the equation "e" is preferred to be applied in places where none to very severe saline soil occurs and equation "c" is preferred in places where soil surfaces are under high salinity conditions. This equation is in agreement with those obtained by Haj Rasuliha (7). He found a strong correlation coefficient (0.93) between chloride and ECe for 640 soil samples collected from different regions of Iran.

Measurement of Soil Salinity

Fig. 4 indicates the relationship between the ECe, EC(1:5) and ECp for 69 soil salinity samples with ECe lower than 200 dSm^{-1} A relatively high correlation of 0.776 and 0.789 was found between ECe with EC(1:5) and ECp respectively. Therefore, the application of these models largely depends on how close (accurate) an approximation is needed. The obtained equations for estimating the ECe by EC (1:5) and ECp are indicated in Table 3. It is important to note that some soil properties such as soil texture and the presence of gypsum at top layer are different from those of subsurface soil. Due to high solubility of NaCl, usually it reaches the soil surface and is succeeded down by $CaSO_4$ and $CaCO_3$ (4, 6). It should be noted that the relationship between ECe, ECp and EC (1:5) of top layer have more practical value in the study of soil salinity when a high accuracy is not expected. The strongest relationship (R^2) in Table 3 was found between ECe and EC (1:5) of the top layer (less than 165 cm) ([Eq.3]). Fig. 4 shows the relationship between ECe with EC (1:5) and ECp at the top layer (20 cm). These figures shows that the soil salinity values at the points of M, N and P are far from the fitted line. The comparison between the equations obtained for soil surface and subsurface samples shows that they yield different results (Table 3). For example, as Table 3 shows the conversion factor of 2.76 for soil depth less than 165 cm (Eq. [2]) is less than the conversion factor 3.09 for top layer (Eq. [4]).

The reason may be attributed to the total quantity of dissolved salts (concentration) and type of ions present. Based on the obtained results we may generally conclude that ECe may be estimated by EC (1:5) and ECp. However, the obtained relationships may be useful as a guide in the study of soil salinity in the playa margin. In order to obtain a more reliable estimation of ECe by EC (1:5) and ECp more soil salinity data of specific soil types (for example, soils with sandy surface texture, or soils with high gypsum content) may be useful.

Table 3. Equations for estimating ECe by EC (1:5) and ECp.

Soil depth	No.	Equations	R^2
Sõil depth	1	ECe = 6.92 EC (1:5)	0.776
less than 20 cm	2	ECe = 2.76 ECp	0.789
Top layer	3	ECe = 8.79 EC (1:5)	0.955
less than 165 cm	4	ECe = 3.09 ECp	0.821

No. = Number of equation.

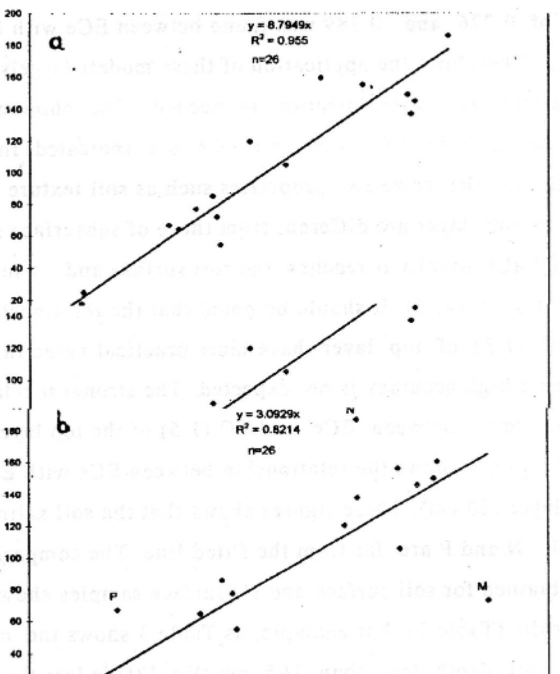

Fig. 4. Relationship between electrical conductivity of the soil extract (including surface and subsurface horizons) with (a) electrical conductivity of soil water: ratio (EC 1:5), and (b) soil saturation paste.

CONCLUSION

The obtained results confirm that salinity at the top layer is highly different from the salinity of the subsoil. The upward movement of the soluble salts can be mainly responsible for accumulation of salt in the top surface in the bare soil of the Chah Afzal area. Based on the obtained results we may conclude that salt distribution in the soil profiles are usually due to circumstances of a long arid history and strong salt enrichment in the bare land in the Ardakan playa margin. A very close relationship between EC and soluble Na^+ and Cl- in the study area suggests that soil salinity map can be a good indicator of soluble Na^+ and Cl^-. Electrical conductivity and concentration of Cl^- and Na^+ are important criteria in the soil salinity. From the obtained results we may generally conclude that the estimation of ECe by EC (1:5) and ECp at the soil surface has the advantage of saving time. We may suggest that for estimating ECe by EC (1:5) and ECp with a higher accuracy, a more detailed research is needed. Therefore the application of these models largely depends on how accurate an approximation is needed. The results confirm that salinity at the top layer (<20 cm) is highly different from the salinity of the subsoil (>20 cm). The upward movement of the soluble salt is mainly responsible for accumulation of salt in the top surface in the bare soil in the studied playa margin.

LITERATURE CITED

1. Alavi Panah, S.K. 1997. Study of soil salinity in the Ardakan area (Iran) based upon field observations, remote sensing and a GIS. Ph.D. thesis, University of Gent, Belgium. 292 p.
2. Alavi Panah, S.K. 1990. Effect of some physico chemical properties of salt affected soils on the yield of Atriplex lentiformis in the Abarkooh playa. M.S. thesis, Tarbiat Moddares University, Tehran, Iran. 165 p.
3. Alzubaidi, A., and G.R. Webster. 1983. Ion pairs in a Solonetzic soil. Canad. J. Soil Sci. 63:479-484.

4. Cooke, R.U., A. Warren and A.S. Goudie. 1993. Desert geomorphology. University College, London Press Limited, London, England.
5. Daels, L. and M. Antrop. 1977. The extraction of soil information from remote sensing documents. Pedologie, 27: 123-190.
6. Hoffman, G.J. 1990. Leaching fraction and root zone salinity central. In: K.K. Tanji (ed.), Diagnosis of Salt Problems, American Society of Civil Engineers 237-261.
7. Haj Rasuliha, S. 1992. Estimation of chloride ion concentration in saline soils by electrical conductivity of soil saturation. Proc. 3rd Symposium of Soil Science Congress of Iran. Karaj, Iran. 90-91.
8. Siadat, H, M. Bybordi and M.J. Malakouti. 1997. Salt-affected soil of Iran: A Country Report. International Symposium on Sustainable Management of Salt Affected Soil in the Arid Ecosystem. Cairo. Egypt.
9. Tanji, K.K. and J.W. Biggar. 1972. Specific conductance model for natural waters and soil solutions of limited salinity level. Water Resour. Res. 8-153.
10. Yazd Water Organization. 1990. Climatological data of the Siah Kooh playa in the Yazd Province, Yazd, Iran.
11. Yazd Soil and Water Institute. 1983. Soil and salinity map and data, Yazd, Iran.