A Database Approach for Soil Salinity Mapping and Generalization from Remotely Sensed Data and Geographic Information System

Assistant Prof. Seyed Kazem ALAVI PANAH and Associated Prof. Gholam Reza ZEHTABIAN, Iran

Key words: Soil Salinity, Salt Accumulation, Image Classification, Soluble Sodium, Soluble Chloride, Soil Reflectance.

ABSTRACT

The understanding of the energy interaction with soil surface is crucial to the successful interpretation of remote sensing data as well as vegetation in the planted areas, therefore a better understanding of some physico-chemical characteristics of saline soils may be important to improve the study of soil salinity in arid region using remotely sensed data. Deserts with different surface conditions and weathered materials may show a great variability in soil surface reflectance. These heterogenity and simillarities between the surface condition and land cover / land use types may prevent a very high classification accuracy. The spectral reflectance characteristics of the plants in arid region may be a good indicator of salinity. Because the plant leaves may affected by various kinds of stresses as well as by the nutrient and salinity, due to change of leaf internal and external structure under these conditions. Spectral reflectance characteristics of non healthy vegetation is different from healthy vegetation. When leaves are senescent, their light reflectance usually increases markedly in the green visible light wavelength region, because of the chlorophyll degradation.

The decrease in near infrared light reflectance, however is not nearly as great as the increase in the reflectance of the visible. The salt precipitation on the leaves of some halophytic plants may increase plant reflectance. Plants are sometimes good indicators of conditions that occur below the soil surface, therefore salinity and its severity may be apparent from some plant species. Townshend et al. (1989), used Landsat TM data to formulate a dynamic process-based model to delimit processes in the Chott el. Djerid, in which the contributions of dissolved salts, surface run-off and aeolian processes, and their changes over time are evaluated.

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 with Cl- and Na+ may have a practical value for salinity estimation. Because Cl- and Na+ are predominant, the dominant soluble salts are sodium chloride (NaCl). Sodium sulphate is of second importance and magnesium and calcium chloride are of the third importance which is dark in color and has a high content of hygroscopic salts. Cooke et al. (1993) stated that,

because of the great solubility of NaCl it is taken further down slope, and it characterizes the soil nearest to a playa, while the other salts are deposited to higher altitudes. There is no foolproof 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.

CONTACT

Assistant Prof. Seyed Kazem Alavi Panah
Iran Desert Research Center
University of Tehran
Tehran
IRAN
Tel. + 98 21 896 6760
Fax + 98 21 896 5287
E-mail: salavipa@chamran.ut.ac.ir.

Associated Prof. Gholam Reza Zehtabian
Iran Desert Research Center
University of Tehran
Tehran
IRAN
Tel. + 98 21 896 6760
Fax: + 98 21 896 5287
E-mail: salavipa@chamran.ut.ac.ir.

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1 INTRODUCTION

The understanding of the energy interaction with soil surface is crucial to the successful interpretation of remote sensing data as well as vegetation in the planted areas, therefore a better understanding of some physico-chemical characteristics of saline soils may be important to improve the study of soil salinity in arid region using remotely sensed data. surface conditions and weathered materials may show a great variability in soil surface reflectance. These heterogenity and similarities between the surface condition and land cover / land use types may prevent a very high classification accuracy. The spectral reflectance characteristics of the plants in arid region may be a good indicator of salinity. Because the plant leaves may affected by various kinds of stresses as well as by the nutrient and salinity, due to change of leaf internal and external structure under these conditions. Spectral reflectance characteristics of non healthy vegetation is different from healthy vegetation.

When leaves are senescent, their light reflectance usually increases markedly in the green visible light wavelength region, because of the chlorophyll degradation. The decrease in near infrared light reflectance, however is not nearly as great as the increase in the reflectance of the visible. The salt precipitation on the leaves of some halophytic plants may increase plant reflectance. Plants are sometimes good indicators of conditions that occur below the soil surface, therefore salinity and its severity may be apparent from some plant species. Townshend et al. (1989), used Landsat TM data to formulate a dynamic process-based model to delimit processes in the Chott el. Djerid, in which the contributions of dissolved salts, surface run-off and aeolian processes, and their changes over time are evaluated.

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 with Cl- and Na+ may have a practical value for salinity estimation. Because Cl- and Na+ are predominant, the dominant soluble salts are sodium chloride (NaCl). Sodium sulphate is of second importance and magnesium and calcium chloride are of the third importance which is dark in color and has a high content of hygroscopic salts. Cooke et al. (1993) stated that, because of the great solubility of NaCl it is taken further down slope, and it characterizes the soil nearest to a playa, while the other salts are deposited to higher altitudes. There is no foolproof 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.

2 MATERIALS AND METHODS

In this study, some important aspects of soil salinity in arid lands 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 and sodium ions (Na^+) with soil depth. The field work as one of the most important steps was carried out . 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, relationship between some soil salinity parameters and soil salinity type. 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 1:00,000 . All the samples were crushed, air-dried, passed through a 2.0 mm sieve thoroughly mixed and then they were analyzed and the following attempts were made (12).

1) The EC(1:5) of 302 soil samples (55 soil profiles) from different soil depths is plotted over 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.

3 RESULTS AND DISCUSSION

3.1 Relationships between soil depth and EC, 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 can be useful to estimate roughly the EC(1:5), Cl- and Na+ from soil depth in the Ardakan playa margin. The correlation coefficients between EC with Cl- and Na+ are 0.972 and 0.969 respectively. These three models show a very rapid decreasing rate at top soil (<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 in the marginal part of the Ardakan playa, salt distribution is mainly a function of soil depth.

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^+ = m.e/L, Cl^- = m.e/L

3.2 Relationship between EC 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 Table 2. Tanji and Biggar (10) 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 SO_4^{2-} than with Na^+ and HCO_3^- (3). The relationship between the 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.

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

Name of the area	code*	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

Code= See figure4, EC = dS m^{-1} , Na^+ = m.e/L, Cl^- = m.e/L

3.3 Measurement of Soil Salinity

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 4. It is important to note that some soil properties such 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 to the soil surface and it is succeeded down by CaSO4 and CaCO3 (4). It should be noted that the relationship between ECe, ECp and EC (1:5) at top layer has more practical value in the study of soil salinity when a high accuracy is not expected. The strongest relationship (R2) in Table 4 was found between Ece and EC (1:5) at the top layer (less than 165 cm) (Eq.3). The comparison between the equations obtained for soil surface and subsurface samples shows that they yield different results (Table 4). For example, as table 4 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 can 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 can be estimated by EC (1:5) and ECp. However , the obtained relationships can 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 soil surface texture, or soils with high gypsum content) can be useful.

Table 4. The equation for estimating ECe by EC (1:5) and ECp.

Soil depth	No.	Equations	R2
Soil depth less than 20 cm	1	ECe = 6.92 EC(1:5)	0.776
	2	ECe = 2.76 ECp	0.789
Top layer less than 165 cm	3	ECe = 8.79 EC (1:5)	0.955
	4	ECe = 3.09 ECp	0.821

No. = Number of equation

3.4 Sampling Techniques

In this study the training samples were taken on the conventional FCC where field observations were made. A large enough sample is often needed because the distribution of the sample mean approaches normality as the size of the sample increases. The sampling was performed by displaying the conventional FCC on the colour monitor and then the training samples were carefully assigned. As a result, the land cover types having inherently similar spectral pattern were detected. Finally the classes were determined not only by the occurrence in the field but also by their separability and their spectral signature evaluation.

3.5 Spectral Signatures Evaluation

The validity of the training data was evaluated both from visual examination and from quantitative characterisation. In order to improve the classification accuracy, two possibilities may examined: a) merging some training samples (before the classification performance), and b) regrouping some classes after the classification performance. A careful examination of the merging of the confused training classes showed that the confused classes could be merged in a meaningful way. When some confused classes were merged, the separability of the new obtained classes was again evaluated in order to assess the enhancement of the separability of the new spectral classes.

3.6 Image Classification and Accuracy Assessment

The training samples which are used to estimate the statistical characteristics of the spectral classes should be typical and represents the norm for each class. The maximum likelihood classifier was applied using four bands: a) the classification based on the training samples (before merging), and b) the classification based on the training samples (after merging). To evaluate the classification accuracy, the test areas were sampled for the assessment of the classification accuracy.

3.7 Regrouping

Although, many spectral classes were necessary to be trained for TM classification image, the regrouping of these classes is more meaningful and it has a better overview. The classes, mainly can be regrouped on the purpose of the user.

4. CONCLUSION

From the above we may conclude that salinity at the top layer is highly different from the salinity of the subsoil in Playa mqrgin. The upward movement of the soluble salts can be mainly responsible for accumulation of salt in the top surface in the bare soil of desert saline soil. 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 arid region. 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 (more than>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. The TM satellite images and GIS are offering a valuable contribution to fulfilling the information need in the natural resources management in the desert regions. Based on the obtained results from TM image classification, we may generally conclude that the main soil salinity classes might be classified based on Landsat satellite images. From the above result we concluded that merging of some training classes is necessary to improve the accuracy of the MSS classification. In other words, for improving the result of classification accuracy, the land cover and soil salinity classes must be defined more broadly.

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