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RESEARCH REGARDING THE ESTIMATED RELATIONSHIP BETWEEN SOIL SALINITY INDICES

BY

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Abstract. Despite salinization is one of the most widespread soil degradation processes and affects between 1 and 3 million hectares in the European Union, the measurement of exchangeable cations concentration of soil generates some problems related to the intensity and duration of these laboratory tests for determination. In these context it is desirable to determine relationships between certain models of soil salinity indices.

One of these indicators is soil Exchangeable Sodium Percentage (ESP), which is determined using laborious and time consuming laboratory tests. Therefore it may be more appropriate and economical to develop a relationship which uses a more simple soil salinity indicator. Therefore, the main objective of this study is to propose a pattern ESP-SAR for salinized soils from investigated perimeter of Osoi-Moreni, Iaşi County, Romania.

The research required the use of pairs of samples, which were collected and processed as the indicated above, to compare ESP values measured by laboratory tests with data from the application of the linear regression equation SAR-ESP.

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The Bland-Altman method (Bland and Altman, 1999) was used to compare the results from laboratory tests with the results of SAR-ESP model. Statistical analyzes were performed using Microsoft Excel (version 2010).

Keywords: Sodium absorption ratio; Exchangeable sodium percentage; Soil.

1. Introduction

Land degradation, which can be considered as a decline in land quality or reduction in its productivity, is receiving increasing concern among global issues because of its impact on world food security and the quality of the environment (Qadir and Oster, 2004). Land degradation is a composite term and includes various physical and chemical processes. Soil salinity has remained one of the major and most widespread land-degradation problems for long time that substantially limits crop productivity

Salinity is a process where we have accumulation in soil with excessive quantities of sodium salts, calcium, magnesium, potassium, particularly accumulations of chlorides, sulphates, carbonates and bicarbonates, which give us a negative fertility soil (Eckelman *et al.*, 2006). Excess of salts in a soil can bring drastic changes in some of the soils physical and chemical properties resulting in the development of an environment unsuitable for growth of most crops. Soils having salts in the solution phase and/or sodium ions (Na^+) on the cation exchange sites exceeding the specified limits are called salt-affected soils. Major captions in salt-affected soils are sodium (Na^+), calcium (Ca^{2+}), magnesium (Mg^{2+}) and to a lesser extent potassium (K^+). The major anions are chloride (Cl^-), sulphate (SO_4^{2-}), bicarbonate (HCO_3^-), carbonate (CO_3^{2-}) and nitrate (NO_3^-). These soils are generally divided into three broad categories: saline, sodic and saline-sodic.

One of these indicators is soil Exchangeable Sodium Percentage (ESP), which is determined using laborious and time consuming laboratory tests. Therefore it may be more appropriate and economical to develop a relationship which uses a more simple soil salinity indicator.

Two different criteria are recognized in the scientific literature as indices of salinity. One of this two is Sodium Absorption Ratio (SAR) with a reported threshold is accepted as 12 $(cmol/kg^{-1})^{0.5}$ and second one as noted above, is the Exchangeable Sodium Percentage (ESP), with a reported threshold of 15% of the Cation Exchange Capacity (CEC).

The two indicators are defined by Eqs. (1) and (2):

$$SAR = \frac{Na^+}{\sqrt{\left(Ca^{2+} + Mg^{2+}\right)/2}} \tag{1}$$

where: SAR − Sodium Absorption Ratio, [cmol $kg^{-1}]^{0,5}$; Na^+, Ca^{2+}, Mg^{2+} − Mesured exchangeable Na^+, Ca^{2+}, Mg^{2+}, respectively, [cmol kg^{-1}].

$$ESP = (Na^+/CEC)100 \quad (2)$$

where: ESP − Exchangeable Sodium Percentage, [%]; Na^+ − Measured exchangeable Na^+, [cmol kg^{-1}]; CEC - Cation Exchange Capacity, [cmol kg^{-1}].

According to the Eq. (2) it can be seen that in order to determining soil Exchangeable Sodium Percentage (ESP), it is necessary to have soil CEC.

Since for determining soil Cation Exchange Capacity, is necessary laborious and time consuming laboratory tests, it is more appropriate to develop a relationship which calculates soil ESP indirectly, based on another index of soil salinity.

Previous research has revealed a strong connection between the soil ESP and soil SAR, so that the soil Sodium Absorption Ratio may be used to estimate soil Exchangeable Sodium Percentage.

The United States Salinity Laboratory (USSL) has been the first to propose a pattern (equation) to predict the soil ESP using soil SAR, according to the Eq. (3):

$$ESP = -0.0126 + 0.01475\ SAR \quad (3)$$

the equation applies to the United States soils, model developed from 1954.

Since then, the model developed by USSL has been applied from 59 arid areas soils, finding that in the most cases, this model has been assumed to be veridical. The changes have been occurred to specific soils features, such as the solution ionic strength and the dominant clay mineral present in the soil.

Research of Soil and Water Department of Iran, have recommended for the studied soils a linear regression equation for predicting soli ESP from soil SAR (Eq. (4)):

$$ESP = 1.95 + 1.03\ SAR \quad (4)$$

Therefore, the main objective of this study is to propose a pattern ESP-SAR for salinized soils from investigated perimeter of Osoi-Moreni, Iaşi County, Romania and to verify the developed model by comparing its results with those of the laboratory tests.

The research required the use of pairs of samples, which were collected and processed as the indicated above, to compare ESP values measured by laboratory tests with data from the application of the linear regression equation SAR-ESP. The Bland-Altman method was used to compare the results from laboratory tests with the results of SAR-ESP model. Statistical analyzes were performed using Microsoft Excel (version 2010).

2. Experimental

Study area

The area in which the research took place and the soil samples were taken, (Fig. 1) is part of Iaşi County, Prisăcani village, common meadow Prut and Jijia. The village is located in the eastern part of the county.

Common meadow and Prut rivers Jijia consists of alluvial deposits with sandy-clayey facies or sandy loam, tens of meters thick argillized surface, instead of the old river bed or lake bottoms, these layers are deposited on a bed of marl.

Plain climate Moldova is continental with cold winters and mild summers moderately warm, with maximum rainfall in late spring and minimum in autumn and winter. Annual rainfall varies between 500-600 mm.

The most important affluent of the Prut River on the right part is Jijia, in this area has a deep riverbed, with single meandering, Jijia waters are discharged into the Prut, in Oprişeni village area upstream of the experimental field.

According to the literature (Niţu *et al.*, 1985), the soils from the common meadow Jijia and Prut rivers, occur as alluvial, calcareous and saline marshy grounds. Alluvial soils are clayey, fallow, or becoming fallow, some evolved, other less developed, with morphological differentiation and clear texture. In the formation of these soils an important role has been the influence of groundwater, located at depths of 1-2 m and its mineralization till 5 g/L (Fig. 2).

Fig. 1 − Locating the research base perimeter of Osoi-Moreni, Prisacani village.

Fig. 2 − Silted soil profile with the presence of groundwater to the surface.

Soil sampling and analysis

Forty soil sampling was carried out from 25 to 25 cm to a depth of 100 cm, in disturbed sample and undisturbed sample from of experimental site. Soil sampling in the undisturbed sample was performed with the metal cylinder, defined volume (100 cm^3), made of stainless steel, having the walls with a thickness of about 1 mm. Preparation of soil samples, taken in a modified settlement, for laboratory analysis, consisted in organic debris removed and skeleton, followed by grinding and the sifting through a sieve of 2 mm Ø (except soil samples collected in natural settlement).

To describe some soil physical and chemical properties *i.e*. grain size and texture, pH, electrical conductivity and measurements on the ion content of Na^{+}, $Mg^{2}+$, Ca^{2+}, SAR (Sodium Absorption Ratio) and soil ESP (Exchangeable Sodium Percentage) of the soil samples were using laboratory tests (Table 1) as described by Chemical and microbiological analysis methods of National Institute of Research - Development for Soil Science, Agrochemical and Environmental Protection, and Geotehnica - laboratory tests.

Table 1
Mean Values, Standard Deviation (S.D.) and Coefficient of Variation (C.V) of Soil Physical and Chemical Proprieties of Forty Soil Samples Used to Determine Soil ESP-SAR Model

Parameter	Minimum	Maximum	Mean	S.D	C.V
Sand (%)	2.6	4.25	3.83	0.73	19.22
Silt (%)	26.23	63.34	39.70	14.91	37.55
Clay (%)	34.06	69.52	56.46	14.21	25.17
pH	6.83	6.99	6.91	0.05	0.85
EC (dS/m^{-1})	8.54	11.07	9.81	0.99	0.10
Na^{+} (m.e/100g)	23.98	25.96	25.34	0.81	3.22
$Ca^{2+}+Mg^{2+}$ (m.e/100g)	3.37	4.08	3.83	0.29	7.57
SAR (m.e/100g)	11.44	13.57	12.44	0.86	6.92
ESP (%)	59.66	63.92	61.90	1.74	2.81

Also, in order to verify the soil ESP-SAR model by comparing its results with those of the laboratory tests, forty soil samples were taken from different fields of the experimental site (Table 2). Sand, silt and clay content (% by weight) and pH, EC, Na^{+}, Ca^{2+}, Mg^{2+}, SAR and ESP of the soil samples were measured using laboratory tests as described by the Chemical and microbiological analysis methods of National Institute of Research - Development for Soil Science, Agrochemical and Environmental Protection, and Geotehnica- laboratory tests.

Statistical analysis

The relationship between ESP and SAR is described by the following logarithmic equation:

$$y = a + b \cdot \ln x \tag{5}$$

where: y is dependent variable (soil ESP); x − independent variable (soil SAR); a and b − regression coefficients.

Table 2
Mean Values, Standard Deviation (S.D.) and Coefficient of Variation (C.V) of Soil Physical and Chemical Proprieties of Forty Soil Samples Used to Verify Soil ESP-SAR Model

Parameter	Minimum	Maximum	Mean	S.D	C.V
Sand (%)	2.0	4.0	3.50	0.73	14.22
Silt (%)	36.23	63.34	41.70	15.01	37.50
Clay (%)	44.06	69.52	62.16	14.41	23.17
pH	6.83	7.0	6.70	0.15	1.65
EC (dS/m^{-1})	8.64	11.07	10.02	1.99	1.10
Na^+ (m.e/100g)	23.98	23.98	23.30	1.21	2.72
Ca^{2+} +Mg^{2+} (m.e/100g)	3.77	3.40	3.5	0.99	8.4
SAR (m.e/100g)	11.84	11.47	12.6	1.2	7.42
ESP (%)	59.62	59.92	62.5	2.2	3.21

A paired samples T-test and the mean difference confidence interval approach were used to compare the soil ESP values predicted using the soil ESP-SAR model with the soil ESP values measured by laboratory tests. The Bland-Altman approach (Bland and Altman, 1999) was also used to plot the agreement between the soil ESP values measured by laboratory tests with the soil ESP values predicted using the soil ESP-SAR model. The statistical analyses were performed using Microsoft Excel (Version 2010).

3. Results and Discussions

The p-value of the independent variable, Coefficient of Determination (R^2) and Coefficient of Variation (C.V.) of the soil ESP-SAR model is based on the statistical result, the soil ESP-SAR model was judged acceptable due to statistical results. The R^2 value and C.V. of the model were 0.92 and 12.6%, respectively. The linear regression soil ESP-SAR model is given in Eq. (6).

$$ESP = 39.76 + 1.78\ SAR \qquad (6)$$

A paired samples T-test and the mean difference confidence interval approach were used to compare the soil ESP values predicted using the soil ESP-SAR model with the soil ESP values measured by laboratory tests.

The Bland-Altman approach was also used to plot the agreement between the soil ESP values measured by laboratory tests with the soil ESP values predicted using the soil ESP-SAR model. The mean soil ESP difference between two methods was 0.28% (95% confidence interval: -1.91 and 2.47%; P = 0.63). The standard deviation of the soil ESP differences was 1.3%. The paired samples T-test results showed that the soil ESP values predicted with the soil ESP-SAR model were not significantly different than the soil ESP measured with laboratory tests. Soil ESP differences between these two methods were normally distributed and 95% of the soil ESP differences were expected to lie between μ+1.96 and μ-1.96, known as 95% limits of agreement (Bland & Altman, 1999). The 95% limits of agreement for comparison of soil ESP determined with laboratory test and the soil ESP-SAR model were calculated at -1.30 and 1.62%. Thus, soil ESP predicted by the soil ESP-SAR model may be 1.30% lower or 1.62% higher than soil ESP measured by laboratory test. The average percentage differences for soil ESP prediction using the soil ESP-SAR model and laboratory test was 9.64%.

4. Conclusions

The linear regression model based on soil Sodium Adsorption Ratio (SAR) was used to predict Exchangeable Sodium Percentage (ESP). The values of ESP soil predicted using the model was compared to the soil ESP values measured by laboratory tests. The paired samples T-test results, indicated that the difference between the ESP soil values predicted by the model and measured by laboratory tests, were not significant ($P > 0.05$). Therefore, the soil ESP-SAR model can provide an easy, economic and brief methodology to estimate soil ESP.

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CERCETĂRI PRIVIND ESTIMAREA RELAŢIEI DINTRE INDICII DE SALINITATE AI SOLULUI

(Rezumat)

Deşi salinizarea este unul dintre cele mai răspândite procese de degradare a solului şi afectează între 1 şi 3 milioane de hectare în Uniunea Europeană, măsurarea concentraţiei cationilor de schimb ai solului generează anumite probleme legate de

minuţiozitatea şi durata acestor teste pentru determinarea acestora în laborator. În acest context, este de dorit să se stabilească anumite modele între relaţiile indicilor de salinitate ai solului.

Unul dintre aceşti indicatori ai salinităţii solului este ESP (procentul interschimbabil de sodiu), care se determină în laborator în urma unor teste laborioase şi care sunt consumatoare de timp. De aceea se doreşte dezvoltarea unei relaţii (model), mai simple de determinare a acestui indicator de salinitate a solului.

Prin urmare, obiectivul principal al acestui studiu este de a propune un model ESP-SAR pentru solurile salinizate din perimetrul investigat din comuna Osoi, sat Moreni, judeţul Iaşi, România.

Cercetarea a necesitat utilizarea unor perechi de probe, care au fost colectate şi prelucrate conform metodologiilor în vigoare de lucru, pentru a compara valorile ESP măsurate prin teste de laborator cu date din aplicarea ecuaţiei de regresie liniară SAR-ESP. Metoda Bland-Altman a fost folosită pentru a compara rezultatele de la testele de laborator cu rezultatele modelului SAR-ESP. Analizele statistice au fost realizate folosind Microsoft Excel (versiunea 2010).