PREDICTING SALINIZATION IN ITS EARLY STAGE, USING ELECTRO MAGNETIC DATA AND GEOSTATISTICAL TECHNIQUES: A CASE STUDY OF NONG SUANG DISTRICT, NAKHON RATCHASIMA, THAILAND

Aiman S. Soliman*, Abbas Farshad**, Rob Sporry**, and Dhruba P. Shrestha**
*Faculty of Agriculture Ain-Shams University, Cairo, Egypt
**International Institute for Geo-information Science and Earth Observation (ITC)
P. O. Box 6, 7500 AA Enschede, The Netherlands
Fax: +31 53 4874 336, E-mail: Shrestha@itc.nl

KEY WORDS: salinity prediction, electro-magnetic survey, sub-surface variability

ABSTRACT: Salinization is the process of accumulation of soluble salts in the soils. Depending on the environmental conditions and causes, the following factors: parent material, depth and quality of groundwater, capillary rise and evaporation play a significant role for the process. To track down the process in its early stage is a great challenge, as the phenomenon usually initiates in the subsoil and optical remote sensing cannot detect it in time. In the present study electromagnetic survey, using EM-38 sensor, in combination with some geostatistical techniques have been applied under various conditions. Assessment of the accuracy of the electromagnetic measurement at various depths was also carried out. In addition, the variability of soil salinity representing horizontal and vertical distribution of salts in discrete and continuous models was mapped.

The study shows that it is possible to map soil salinity variability in both discrete and continuous models, using geopedologic map and an appropriate interpolation technique. The study also shows that it is possible to assess and map soil salinity distribution using electromagnetic survey, with a maximum reliability of 64%.

1. INTRODUCTION

The world's demand for food is increasing at such a rate that the ability to meet anticipated needs in the next several decades is becoming questionable (FAO, 1999). This is a very threatening warning emphasizing the need for detection of soil salinization in its early stage, i.e, before the soil is destructed. Detecting and mapping salinity has been subject of many researches, but none has claimed to have detected the degradation at its early stage. Remote sensing can detect the surface salinity when the degradation is already exhibited at the soil surface (Farifteh and Farshad, 2002). Geostatistical techniques need uneconomic number of samples to model the variability. Electromagnetic survey combined with multivariate geostatistics is declared to be an efficient method to detect the salinity distribution in subsurface soil, and at early stages of the process (Wentz and van der Pluym, 1998).

The objective of this study is to establish a method for subsoil salinity detection, the application of which should help track down an ongoing salinization process in its early stage and to check on it's accuracy and the resolution of visualizing subsurface salinity variation over the surveyed ground, for combating land degradation. The part of the study, as reported here, includes reconstructing the spatial variability of subsoil salinity; and evaluating the accuracy of electromagnetic measurement to predict subsoil electrical conductivity at various depths.

2. THE STUDY AREA

The Nong Sung district, Nakhon Ratchasima province, of Thailand lies between 101° 45′ and 102° E and between 15° and 15° 15′ N, with a surface area of 7400 ha. The area is relatively dry, with the rainy season during the months May through October, with the highest rainfall of about 450 mm in the month of September. The dominant soil moisture regime is Ustic in higher parts and Aquic in the extensive low-lying part.

The massif base-rock, called "Korat group" plays an important role in the geopedologic setting of the region. The Korat group comprises of several formations, of which "MahaSarakham" is composed of clay stone, shale, inter-bedded with two or three layers of evaporites (halite, gypsum, anhydrite).
The five main soil orders of Ultisols, Alfisols (Ustalfs and Aqualfs), Inceptisols, Vertisols, and Entisols occur in the different units of the two landscapes, namely ridge, glacis, depression, and vales in the extensive peneplain, terraces and floodplain in the narrow valley (Fig. 1).

The distribution of salinity in the study area shows a clear relationship with the geopedologic setting (Soliman, 2004). The process can be related to the occurrence of a salt rock layer, at 80 m depth (Imazumi et al., 2002), and its effect on groundwater. Saline ground water reaches the surface through natural channels (faults, fractures) or through the openings created by salt mining activities. Salt also moves upwards through bio-climatic factors, which influences the evapotranspiration rate. Salt spreading mechanism at the surface of paddy fields has been related to the occurrence of a densipan at around 50-70 cm depth, which can be broken in some parts letting the saline groundwater reaching the surface, forming saline spots and in the next stage spreading laterally to form surface crusts (IRD, 2004). This latter process is also affected by capillary rise of groundwater through natural pores (Pishkar, 2003).

The native land cover in the Korat region is 'Dipterocarps' forest. A major part of the area has been deforested and converted into agricultural land (Suckchan, 2003). Maize and kenaf were introduced to the local farmers in the 1960's, Cassava in the 1970's, and sugarcane in the 1980's, while the dominant crops at the time of the fieldwork was the cassava, and sugarcane.

3. METHODS AND TECHNIQUES APPLIED

3.1 Mapping sub surface variability

Two models: discrete and continuous, were applied to study the distribution pattern of salinity. The area of figure 1 (of about 270 km²), that is geo-pedologically surveyed, was selected wherein 42 observations (1/ 6 km²) were made in a roughly designed grid (Fig. 2). The purpose was to check on the reliability of discrete (geopedologic survey) and continuous (by means of interpolation) models in representing soil salinity distribution. Altogether 126 soil samples, collected from three depths (0-30, 30-60 and 60-90 cm) from all the 42 points, were analyzed for electrical conductivity measurements.

3.1.1 Discrete model: Two salinity maps for representing horizontal and vertical distribution were prepared, horizontal maps were produced by averaging the salinity value in each delineation after converting the EC1:5 to ECe values using Talsma equation (ECe=6.4x EC1:5). In order to derive vertical distribution of salinity, the 'Threshold mapping technique' was applied which enables the visualization of the third dimension. Each layer was classified, applying a subjectively selected threshold (0.8 microS/cm), to obtain two classes, namely A: above the threshold, and B: below the threshold. In this way the sequential threshold map was produced through the intersection operation of the three layers.

3.1.2 Continuous model: The inverse distance interpolator was used to interpolate ECe values at the three depths,. The interpolated layers of logEC1: 5 were stretched linearly to fit the image range (0-255), and a RGB colour-composite was formed with stretched log EC0.6-0.9m assigned to the R, logEC0.3-0.6m, assigned to Green and logEC0-0.3m assigned to Blue, respectively.

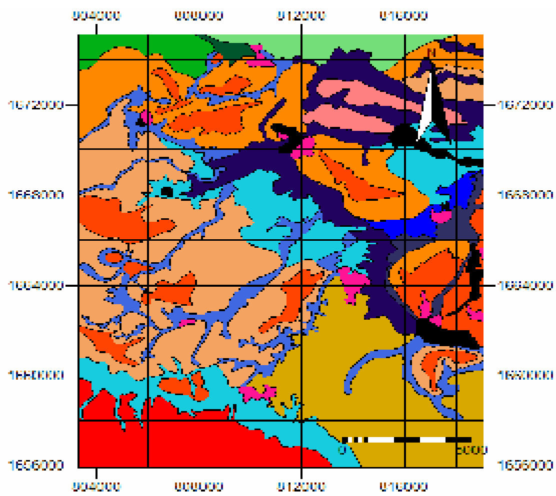

Fig. 1: Geopedologic map

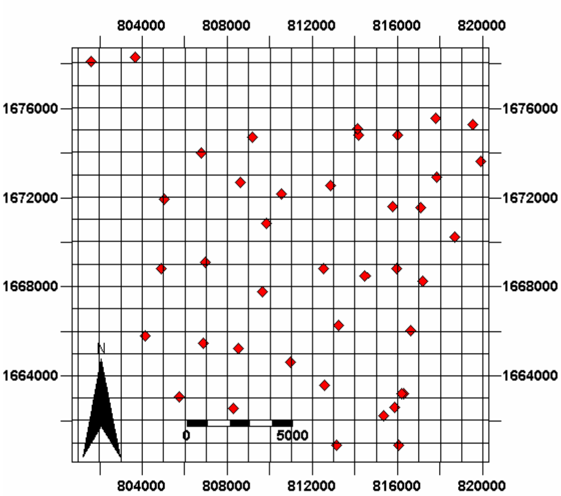

Fig. 2: The grid survey area

3.2 Evaluating the accuracy of the EM measurement to predict salinity

The experiment was carried out in two plots (3 ha each), of sandy and clayey soils to examine the robustness of the prediction model by Electromagnetic survey to texture variability in predicting soil salinity. EM data on both modes was collected systematically from 3000 points, 75 of which were selected systematically to be sampled at three depths 0-30, 30-60 and 60-90 cm to measure soil ECe for regression model fitting and validation. In addition, average Cation Exchange Capacity of soil (CEC) for each plot was measured in two random compound samples.

A preliminary linear regression model for each depth was fitted using Ordinary Least Square (OLS) method between ECe values and ECa at both vertical and horizontal modes in order to select the mode which best explains the ECe variability as a predictor, and to drop the collinear one. Randomly fitting set of 50 points was used to train the linear model using OLS fitting for each depth separately. Remaining 25 points were used as validation set to calculate the Root Mean Square Error (RMSE) of the estimate.

4. RESULTS AND DISCUSSIONS

Results of discrete and continuous models are shown in Fig. 3. Figures 3a and 3b show the horizontal and vertical maps in the discrete model while figures 3c and 3d show them in the continuous model. Interpretations of the colours in the composites are shown in table 1.

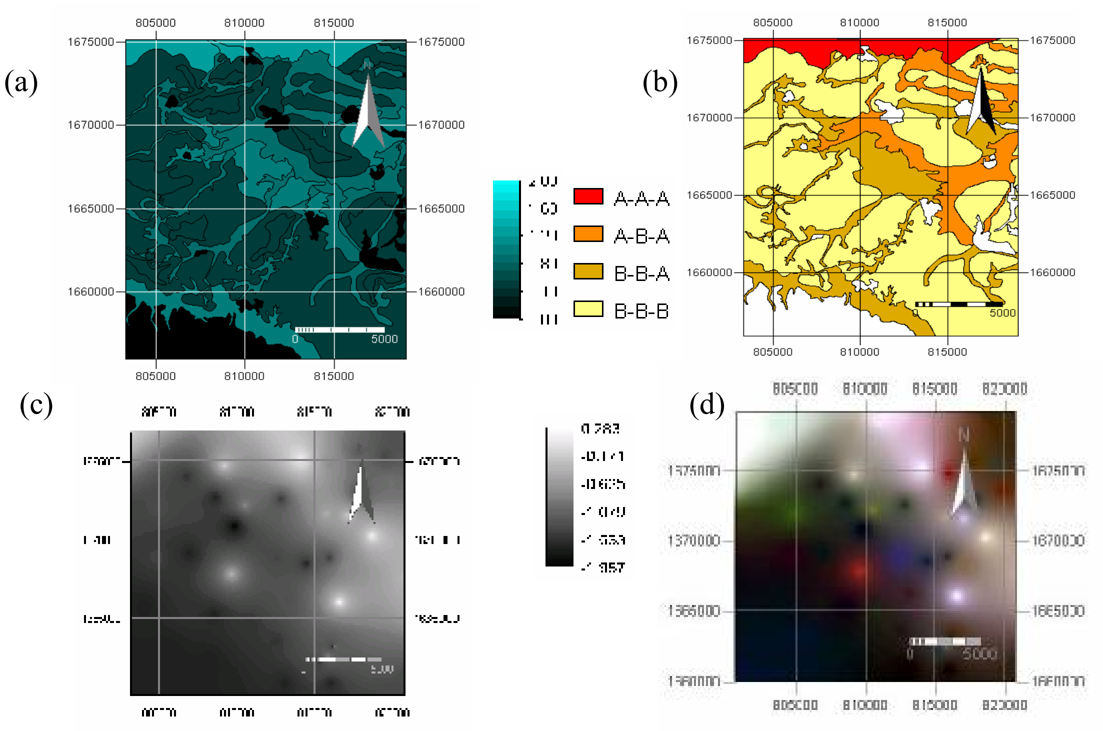

Figure 3: (a) Discrete map of ECe 0.6-0.9m. (b) Sequential threshold map of salts vertical distribution A: above threshold, and B: below threshold (c) Ordinary Kriging interpolation of LogEC1:5 of 0.6-0.9m, (d) Color composite of vertical salt distribution R: LogEC3, G: LogEC2, B: LogEC1

Table 1: Interpretation of colors in the color composite

Color	Red: LogEC0.6-0.9	Green: LogEC0.3-0.6	Blue: LogEC0-0.3
Red	High	Low	Low
Green	Low	High	Low
Blue	Low	Low	High
Pink	High	Medium	Medium
Brown	Medium	Low	Low
Black	Low	Low	Low
White	High	High	High

The study shows that both discrete and continuous models were successful in modelling soil salinity variation, each with advantages as well as disadvantages (Table 2). Choice should be made depending on the availability of inputs and the objective of the survey.

It also shows that salt vertical distribution maps can be produced using any of the models, using interpolation and making colour composite technique in the case of continuous model, and sequential threshold maps in the case of a discrete model. Stratification of the study area using aerial photo-interpretation was successful because the gap between acquisition time of aerial photographs and salinity sampling is small according to speed of degradation (eg. four years).

Table 2: Comparison between the discrete and continuous models

Model	Advantages	Disadvantages
Discrete	- Availability of aerial photos with different scales. - A widespread technique, and applied in all soil survey institutes	- Time consuming technique. - The photo interpreter needs to be experienced.
Continuous	- A fast technique - Highly consistence even when it is applied to large areas. - Shows soil variation with high spatial resolution.	- Needs high number of samples - In some cases the discrete model is more representative of soil variation

Three linear models for each plot were fitted to predict ECe at the three depths (Figure 4 and Table 3). Their accuracy as indicated by RMSE is represented in Figure 5. The comparison between the plots shows that the EM data better explains the ECe variability in sandy soils, as indicated by R^2. The data also shows higher model accuracy. Results reveal that relation between ECe and ECa is not linear after 100 µS/m (high saline land).

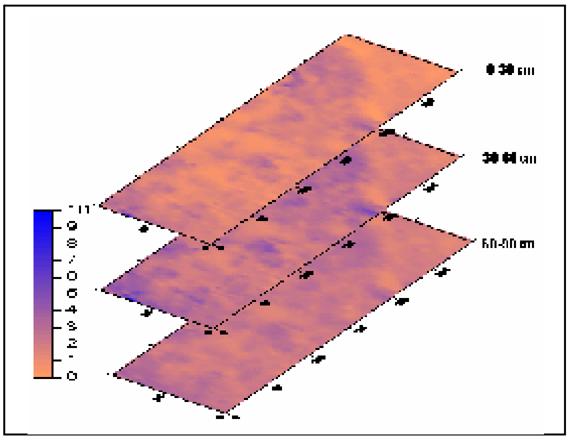

Figure 4: ECe statistical model using ECa as predictor

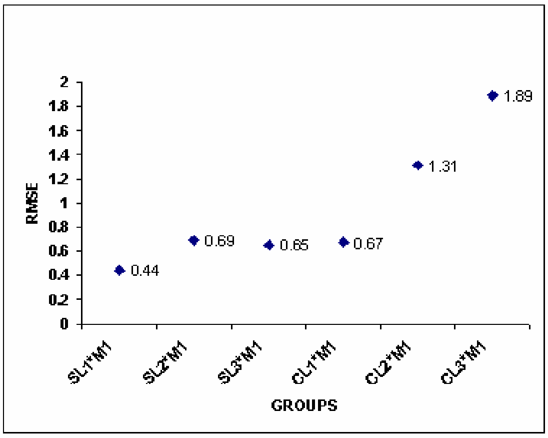

Figure 5: Difference in prediction accuracy (RMSE) between the sand and the clay plot models

Table (3): summary of linear models

Sandy soils			Clayey soils		
Predicted ECe Depth (cm)	Predictor	Adj.R^2	Predicted ECe Depth (cm)	Predictor	Adj.R^2
0-30	EM_H	0.533	0-30	EM_H	0.321
30-60	EM_H	0.647	30-60	EM_H	0.426
60-90	EM_V	0.449	60-90	EM_H	0.376

5. CONCLUSION

The study shows that it is possible to assess and map soil salinity distribution efficiently using electromagnetic surveying. It is especially useful if sub-surface salinity mapping is important to understand salt movement in the soil profile. The ECe-ECa prediction models are not robust for soil texture variation. To overcome this either CEC should be entered as co-predictor in the statistical model or the area must be stratified using texture and mineralogical classes before the survey. With regards to the reliability of EM-38, it can be said that the maximum salinity variation that EM data can explain is 64% (at 30-60 cm of the sand plot), using a linear regression model. This is much less in the clay plot, only 42%. The relation between measured EM conductivity data and ECe is not linear; the relation begins to deviate from linearity in high saline conditions. This is in line with the description of Mc Neil (1980a, 1980b) of true versus observed conductivities. Investigating the first 60 cm of the profile can be done using only EM H-dipole mode, but for deeper investigations the V-mode is also required. Finally techniques such as 'Threshold mapping technique' and colour composites are valuable to reconstruct the sub surface soil variability.

REFERENCES

FAO, 1999. Soil salinity assessment: methods and interpretation of electrical conductivity measurement. FAO: Rome. p. 150.

Farifteh, J. and A. Farshad. 2002. Remote sensing and modelling of topsoil properties, a clue for assessing land degradation. IUSS Congress, BKK, Thailand

Geonics, 1992. EM38 operating manual, Geonics, Ontario. p. 29.

IRD, 2004. Improving the management of salt-affected soils: a case study of saline patches in rainfed paddy fields in Northeast Thailand. LDD, BKK. Thailand

Talsema, 1968. Environmental studies of the Coleambally irrigation area and the surrounding districts, Part III, Soil salinity. Water conservation and Irrigation commission NSW Bull No. 2 (Land Use Series).

Mc NEILL, J.D., 1980a. Electrical conductivity of Soils and Rocks. Geonics: Ontario. p. 22.

Mc NEILL, J.D., 1980b. Electromagnetic Terrain Conductivity measurement at low induction numbers. Geonics: Ontario. p. 15.

Pishkar, A. R. 2003. Analysis of the reclamation between soil salinity dynamics and geopedologic properties. A case study of the Goorband area, Iran. Unpublished MSc thesis, ITC, Enschede, The Netherlands.

Soliman, S. A. 2004. Detecting salinity in early stages using electromagnetic survey and multivariate geostatistical techniques. A case study of Nong Suang district, Nakhon Ratchasima, Thailand Unpublished MSc thesis, ITC, Enschede, The Netherlands.

Wentz, D. and H. Van der Pluym, 1998. Trends in Dryland Salinity.