# Salinity mapping using geopedologic and soil line approach

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**Abstract:** Salinization is the process of accumulation of soluble salts in the soils which may be caused by groundwater rise due to improper land use practices in dry lands. It is well known that salt concentration in soil has negative impact on crop growth which results in reduced crop yield. Thus it is necessary to timely detect the process for monitoring and combating purposes.

In order to map soil salinity in an efficient way a step-wise approach is proposed using remote sensing and topographic data. The area is first subjected to geomorphic analysis for which a stereo-model is generated using satellite data and digital elevation model derived from interpolating contours lines. The second step is application of band rotation technique to transform near-infrared and red spectral bands to derive soil line. Soil line minimizes vegetation influence while maximizing spectral response from bare soil. Soil line values were used to map soil salinity levels. For the purpose of validation soil line values were correlated with topsoil conductivity measurements. Geopedologic modeling gave overall view of the depth wherein salinization is active. This approach is simple and can be considered very efficient in mapping soil salinity.

**Keywords:** geopedology, soil line, land degradation, salinity

## 1. Introduction

Land degradation, a decline in land quality caused by human activities, has been a major global issue since the 20th century (Eswaran et al., 2001). It is reported that more than 50 percent of the dry areas of the world are affected by land degradation (Gregne and Chou, 1994). Although water erosion is reported to be the dominant human-induced soil degradation process considerable part of our land (0.8 million $km^2$) is suffered by secondary salinization, caused by land mismanagement, with 58 percent of these in irrigated areas and nearly 20 percent of all irrigated land is salt affected (Ghassemi et al., 1995). For salinity mapping various remote sensing and GIS techniques have been applied by various researchers (Howari, 2003; Metternicht and Zinck, 1996; Metternicht and Zinck, 2003; Peng, 1998; Shrestha et al., 2005; Soliman et al., 2004). Salinity is a dynamic process and may vary seasonally. Since moisture content affects surface reflectance, especially in visible portion of spectrum mapping salinity can be a tricky business. In the present paper a step-wise approach is proposed to map saline soils using remote sensing and topographic data in a case study in Nakhon Ratchasima province in Thailand where soil salinity is a known problem which has negative impact on crop growth and production.

## 2. Methods and techniques

### 2.1 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).

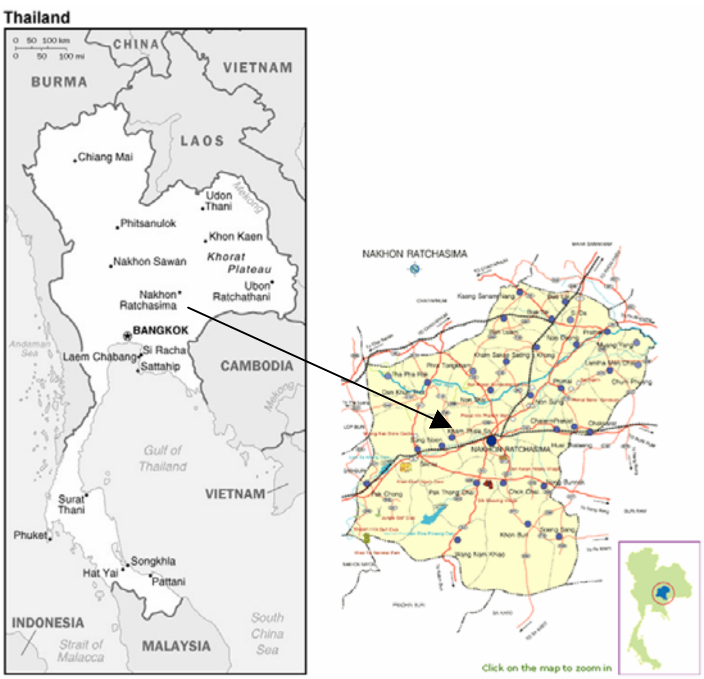


**Fig. 1: The study area**

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 (Imaizumi 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 evapo-transpiration 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 (Sukchan, 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.

### 2.2 Geopedologic analysis

Landsat TM data of the area, acquired in February 2003, was available. The data was geo-referenced to UTM coordinate system (zone 47) with Indian 1975 datum. Topographic map at scale 1:50,000 (sheet no. 5339II) was scanned and the contour lines were digitized on screen. Linear interpolation follows to get digital elevation model (DEM) of the area with 30 m. spatial resolution to fit Landsat TM data. A stereo image was generated (stereo anaglyph, Fig.2) using DEM and geomorphic interpretation was carried out using red-green glasses. Lines were delineated directly by on-screen digitizing. The resulting interpretation map for geopedological survey is shown in Fig. 3. Advantage of on-screen digitizing is that the interpretation lines are geocoded and no transformation is required to transfer the interpretation lines to base map. The area is categorized into Peneplain and Valley. Peneplain consists of isolated hills, glacis, vales and depressions whereas valley consists of flood plain and terraces.

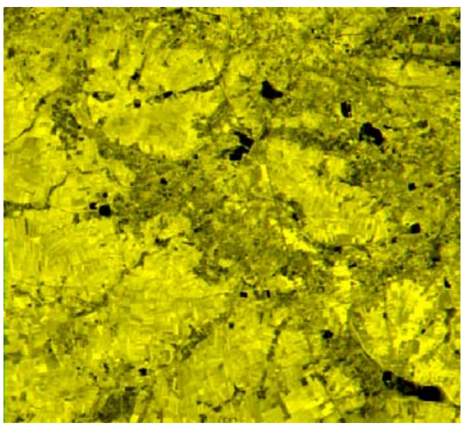

**Fig. 2: Stereo anaglyph generated using Landsat TM4 and DEM**

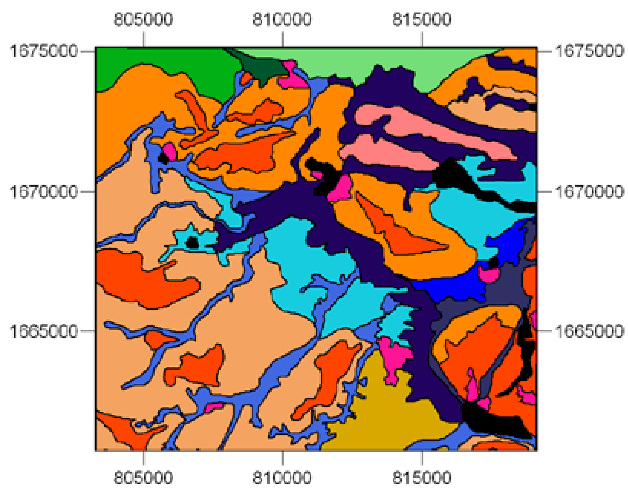


**Fig. 3: Geopedologic interpretation map**

### 2.3 Masking of geomorphic units having relation to soil salinity

It is of general understanding that soil salinity develops in the lowest part of the landscape where ground water table is closer. Rise of groundwater takes place due to capillary rise and the evaporation of saline water results in salinity development in the soil. It is also shown by study carried out in the area (Soliman, 2004). The geomorphic units which occur in the lower part of the landscape such as flood plain, terraces and vales were masked out. The resulting map shows only those areas which have potential soil salinity problems.

### 2.4 Image processing

Image transformation by means of band rotation using red and near infrared data maximizes information from soil surface features (Shrestha, 2005). Since soil salinity is shown by higher reflectance values due to formation of salt crusts on the surface, band rotation was considered useful to enhance soil features and applied in the present case study. Band rotation angle was calculated by taking training samples of bare soil surfaces in red and near infrared bands of Landsat TM data (Fig.4). A linear least square model was fitted (r = 0.95) as shown in the equation below:

$$y = 0.45x + 19.55 \tag{1}$$

As shown in Fig.4, band rotation of about 24 degrees is desirable which is calculated from the slope of the best fitting line (0.45). Arc tangent of 0.45 is 24.23 degrees. Equation for anti-cloakwise rotation of band is then given by:

$$\begin{aligned} \text{Rotation1} &= 0.91\ tm3 + 0.41\ tm4 - 19.55 \\ \text{Rotation2} &= -0.41\ tm3 + 0.91\ tm4 - 19.55 \end{aligned} \tag{2}$$

Where the coefficient 0.91 is the cosine value of 24 degrees, 0.41 is the corresponding sine value, and 19.55 is the constant to shift the line to start at the origin. Rotation1 maximizes information of soil surface features while rotation2, which is perpendicular to rotation1 captures vegetation information. Use of rotation2 is to exclude high vegetation areas from bare soil where salinity is considered not the main issue. Also sloping areas were excluded using slope map computed from digital elevation model. Level slicing was then applied to generate salinity level classes applied to the masked areas i.e. flood plain, terraces and vale and depressions.

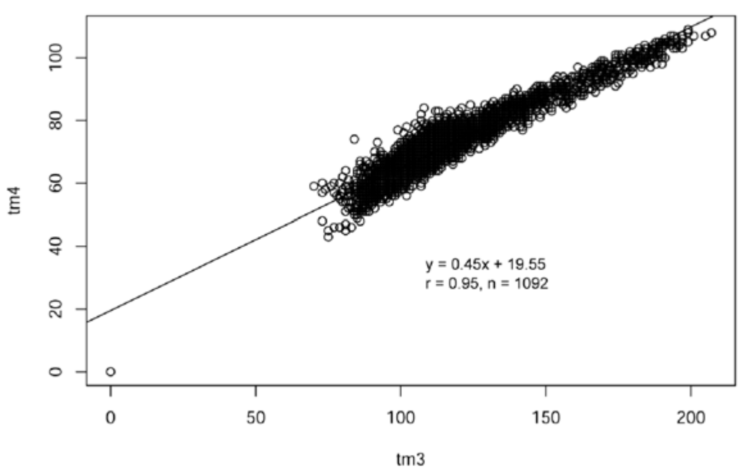


**Fig. 4: Best fitting line along the bare soil pixels (soil line)**

## 3. Result and conclusion

The results (Fig.5) show that nearly 1/3 of the area have potential soil salinity development. Moderately saline (8 – 15 mS.cm$^{-1}$ $EC_e$) and saline (> 15 mS.cm$^{-1}$ $EC_e$) soils occupy about 2524 ha (11 %) and bright saline spots cover about 64 ha. The results were verified by comparing with topsoil conductivity values. Areas presently not affected by salinity but close to saline areas are potential areas for salinity development in future especially if they are also low-lying. In this respect it is very important to take necessary measures in implementing proper land use plans and cultivation practices. Since salinity is a dynamic process it is important to monitor salinity process and map its spatial distribution regularly. Although geostatistical technique is available to see the spatial structure it takes lots of effort in collecting sufficient soil samples and their laboratory analysis. In this respect combination of geopedologic interpretation of the area and incorporation of band rotation seems to be useful in accessing salinity problem quickly.

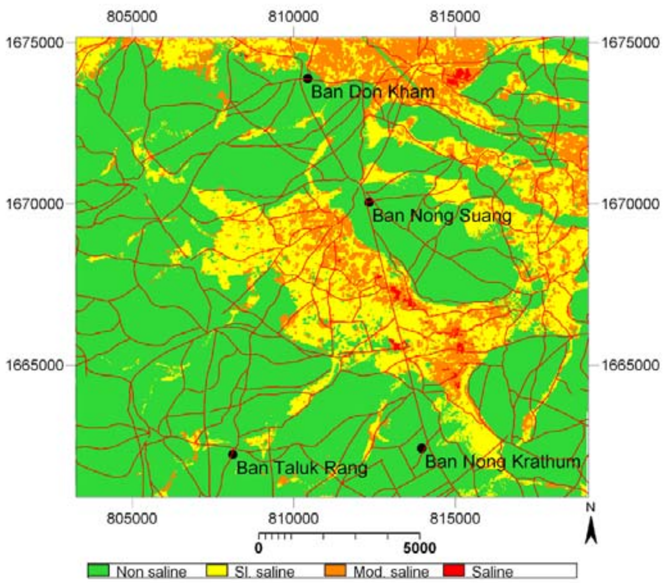


**Fig. 5: Classification of saline soils**

## References:

Eswaran, H., Lal, R. and Reich, P.F., 2001. Land degradation: an overview. In: E.M. Bridges et al. (Editors), Response to land degradation. Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi, Calcutta, pp. 20-35.

Ghassemi, F., Jakeman, A.J. and Nix, H.A., 1995. Salinisation of land and water resources:human causes, extent, management and case studies. CAB International, Wallingford, Oxon, UK, Canberra, Australia.

Gregne, H.E. and Chou, N.T., 1994. Global desertification dimensions and costs. In: H.E. Dregne (Editor), Degradation and Restoration of Arid Lands. Texas Technical University, Lubbock, USA.

Howari, F.M., 2003. The use of remote sensing data to extract information from agricultural land with emphasis on soil salinity. Australian Journal of Soil Research, 41(7): 1243-1253.

Imaizumi, K., Sukchan, S., Wichaidit, P., Srisuk, K. and Kaneko, F., 2002. Hydrological and geochemical behavior of saline groundwater in Phrayun, Northeast Thailand, Land Development Department, Khon Kaen.

Metternicht, G.I. and Zinck, J.A., 1996. Modelling salinity-alkalinity classes for mapping salt-affected topsoils in the semiarid valleys of Cochabamba (Bolivia). ITC Journal, 1996(2): 125-135.

Metternicht, G.I. and Zinck, J.A., 2003. Remote sensing of soil salinity: Potentials and constraints. Remote Sensing of Environment, 85(1): 1-20.

Peng, W., 1998. Synthetic analysis for extracting information on soil salinity using remote sensing and GIS: A case study of Yanggao Basin in China. Environmental Management, 22(1): 153-159.

Pishkar, A., 2003. Analysis of relationship between soil salinity dynamics and geopedologic properties: a case study of Goorband area, Iran. MSc. Thesis, International Institute for Geo-information Science and Earth Observation (ITC), Enschede, 145 pp.

Shrestha, D.P., 2005. Image transformation and geo-statistical techniques to assess sedimentation in southern Nepal. Asian Journal of Geoinformatics, 5(3): 24 - 31.

Shrestha, D.P., Margate, D.E., Meer, F.v.d. and Anh, H.V., 2005. Analysis and classification of hyperspectral data for mapping land degradation: An application in southern Spain. International Journal of Applied Earth Observation and Geoinformation, 7(2): 85-96.

Soliman, A.S., 2004. Detecting salinity in early stages using electromagnetic survey and multivariate geostatistical techniques. MSc. Thesis, International Institute for Geo-Information Science and Earth Observation (ITC), Enschede, 90 pp.

Soliman, A.S., Farshad, A., Sporry, R. and Shrestha, D.P., 2004. Predicting salinization in its early stage, using electro magnetic data and geostatistical techniques: a case study of Nong Suang District, Nakhon Ratchasima, Thailand, 25th Asian Conference on Remote Sensing and 1st Asian Space Conference, Chiang Mai, Thailand, pp. 847-852.

Sukchan, S., 2003. Land suitability analysis concerning water resources and soil property, Land Development Department, Khon Kaen.