GIS Application to Spatial Distribution of Soil Salinity Potential in Northeast Thailand

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KEY WORDS : Soil salinity potential, GIS, Northeast Thailand

ABSTRACT

The most extensive area of the Northeast Thailand is underlain by a thick sequence of Mesozoic rocks which contain considerable quantities of rock salts (Maha Sarakham Formation).The occurrence of this Formation leads to soil salinization scattered throughout the regions. The salinization has the profound effects on the crop production and consequently on the regional economy. The soil salinity potential in the region was then established with objective of providing a spatial distribution of severity classes of soil salinity. Based on the sources and mechanisms regarding salt-affected areas, the creation of GIS data layers was then performed to be used for overlay modeling with defined criteria. The data layers include geologic formation, ground water quality and its yield, land cover and land form. These layers consist of a set of logically related geographic features and its associate attributes. The overlay operation was then undertaken with criteria that the severity of salinity, based on the salinity model applied to the resultant polygonal layer or salinity class. The salinity classes were randomly checked against the salt crust map performed by the Land Development Department. The areas of soil salinity potential cover 0.66, 8.93, 9.81 and 88.60% of the total area for high, moderate, low and none salinity respectively.

1. BACKGROUND

Northeast region of Thailand covers an area of about 170,000 sq.km. and contains approximately 21 millions population or 1/3 of the kingdom both area and population. Over 70% of the population is engaged in rainfed agriculture. The major constraints of agriculture include insufficient water, infertile soil and salinity. Soil salinization is a crucial problem and increasingly widespread especially in the Northeast where the extensive areas are underlain by rock salts (Department of Mineral Resource, 1982). The close examination of salt crusts confirmed that the rock salt of the Maha Sarakham Formation is the source of salt (Sinanuwong et al., 1974; Phianchareon, 1973; Thai-Australia Tung Kula Ronghai (TKR) project, 1983). The Maha Sarakham Formation underlying the Northeast area, covering approximately 34.18% of the total area on which a number of activities enhance the expansion of salinization. These include misuse of land, salt mining and deforestation. The deforestation during the past three decades is the main cause in bringing the soluble salts from the lower strata up to soil surface (TKR project, 1983). The rapid expansion of salt-affected soil in the northeast has been an important issue in the national economic and social development plan in which the measures of preventing its expansion were described (NESDB, 1987). The estimation of the saline soil concluded from the soil map, for the entire northeast, is some of 1.6% of the regional area. The expectation of the salinity expansion may reach 17% of the total area (Arunin, 1992). The map of salt crust was manually established during the past two decades by LDD(1989-1991) based on Landsat data and field survey. Due to dynamic phenomena of salinization the reliable and up-to-date information in terms of salinity distribution is needed. To date, there remains inadequate information of the potential area of the expansion for the whole region. With the advent of remote sensing and GIS technology, a number of papers were conducted using the integration of the thematic layers concerned to map the salt affected soil (Mongkolsawat et al., 1990; Sah et al., 1995; Evans et al. 1995,2006).

Douaoui et al. introduced the salinity index which corresponds to exogenous information derived from remote sensing data, it is possible to establish salinity map with greater accuracy than by use of ordinary kriging or remote sensing data alone. Two different GIS-based approaches are described by Coxwin et al. (1996) for the prediction of areal distribution of salinity at a basin scale. The first approach couples a regression model of salinity development to a GIS soil salinity development factors. The second approach coupled the one dimensional transient-state solute transport model to the GIS. With the increasing capability of GIS the integration of thematic layers could be systematically performed. The results to be obtained can be used to plan for salt reclamation and to allocate the budget to the affected areas. The objective of this study is to map the soil salinity potential in the Northeastern Thailand with the integration of the thematic layers concerned using GIS.

2. STUDY AREA

Northeast Thailand, the selected study site covering an area of approximately 170,000 sq.km. lies between 14° 14´ to 18° 27´ North latitude and 101° 0´ and 105° 35´ East longitude (Figure 1.). Geologically, the most extensive area are formed by a thick sequence of Mesozoic sediment, the Korat group ranging in age from upper Triassic to Tertiary. The region is bound by the prominent topography or low hill on the west and the south. The flat to gently undulating alluvial plains are formed in the north and south of the region and is divided by the Phu Phan range into 2 basins, Sakon Nakhon in the North and Korat basin in the south. These two basins are underlain by the Maha Sarakham geologic Formation. Mean annual rainfall ranges 1200 in the south east and 1800 in the Northeast of the region. Land use is restricted to rice, field crops (cassava & sugar cane) and forest. The scattered trees and isolated patches of remnant forest can be found on the undulation topography of the alluvial plains. The dense forest, mainly Dipterocarp sp and Evergreen sp covers extensively on the mountainous area and sloping land mostly the National Parks and Wildlife Sanctuaries. Soils are inherently low in fertility and have light texture with low cation exchange capacity.

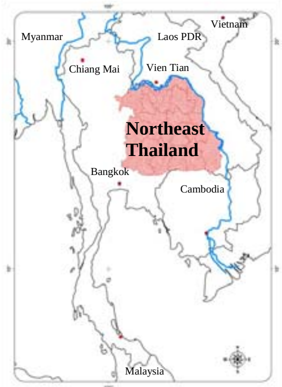

Figure 1. Study area

3. METHODOLOGY

3.1 Soil salinization model

A model of salinity development was formulated upon the interaction of the factors as earlier identified by Mongkolsawat et al. (1990). As a result to determine the spatial soil salinity potential for the northeast it can formulate by coupling a GIS to additional model relating the interaction of four thematic layers: geologic formation, ground water quality and its yield, landform and land cover.

The build up of salt in the soil surface is basically found on the land which is underlain by the Maha Sarakham Formation (Mitsuchi et al., 1983; Kohyama et al., 1993). The ground water quality and its yield greatly enhance the salinization of soil (Sattayarak et al., 1987). A shallow water table and high total dissolved solid are recognized to be influential in the development of soil salinity as a result of the high potential for upward movement of soluble salts. In addition, the areas under vegetation cover decreased salt accumulate at the soil surface while the surrounding areas with bare land are likely to result in higher salinity (TKR project, 1983). The accumulation of salt near the soil surface, due to the upward movement of salt carries by the water rising and the lateral movement is highly related to the low terrace (Soil Survey Division, 1978; Kohyama et al., 1993). The “low terrace” land form in the Northeast is characterized by light textured soil flat to gently sloping topography. As a result, the soil salinization model in the northeast is then based on the interaction of geology, ground water and its yield, land form and land cover.

3.2 The organization and GIS database establishment

This involved the development of a spatial database of geo-referenced data and its associated attribute for the Northeast. The spatial database consisted of the four thematic layers as shown in table1.

Table 1. Thematic layers and their associated attributes.

Layer	Spatial Data Source	Attribute Data				
Geology	Geology Map (1:250,000) / Dep. Of Mineral Resource (1982)	Qa =	Quaternary			
		Ms =	Maha Sarakham Formation			
		Other =	Other Formations			
Ground water and its yield	Department of Mineral Resource	TDS (mg/l of cl)	Yield (m3 / hr)			
			< 2	2-10	10-20	>20
		< 750	W1	W1	W2	W2
		750 – 1,500	W2	W2	W2	W3
		>1,500	W2	W2	W3	W3
Landform	Terrain Map (1:50,000) / Landsat TM (1992)	T1 =	Upper Terrace			
		T2 =	Lower Terrace			
Landcover	Landuse Map (1:100,000) / Landsat TM (2002)	Vegetation Cover	Landform type			
		L4 = Slight	Lower Terrace			
		L3 = Sparse	Lower Terrace			
		L2 = Moderate	Lower Terrace			
		L1 = Any	Upper Terrace			

Source: Modified from Mongkolsawat et al. (1990)

The table 1. represents GIS data layers its associate attributes and sources of data. The GIS data layers were collected from the existing databases, digitization of paper map and satellite data as follows:

- The geologic map developed by Department of Mineral Resource (1982) at 1:250,000 scale was digitally encoded in the GIS database.
- The ground water quality and its yield, acquired from the Department of Mineral Resource (1989) at 1:100,000 scale were digitally established.
- The land form maps were prepared using topographic map (1:50,000) and Landsat TM imagery. The maps were digitized. The land form databases were entered into the GIS.

The land cover maps, based on vegetation density were performed using Landsat TM data taken in 2002. The vegetation density was visually estimated by the geo-referenced Landsat TM data to establish the land cover. This was categorized into three classes of density: sparse, moderate and dense.

3.3 The development and iteration of the model

This phase involved the formulation and testing the salinization model followed by the iteration of the model to the geo-referenced ground information to create the map output. As a result of testing the combination of conditions for soil salinity potential class is presented in table 2.

Table 2. Combination of factor condition for soil salinity potential.

Condition	Salinity class
Ms + W1 + T2 + L1 (L2, L3 or L4) Ms + W1 + T2 + L1 (or L2) Ms + W3 + T2 + L1	Low Salinity Potential (LS)
Ms + W2 + T2 + L3 (or L4) Ms + W3 + T2 + L2	Moderate Salinity Potential (MS)
Ms + W3 + T2 + L3 (or L4)	High Salinity Potential (HS)
Qa (or T1)	Non Saline (NS)

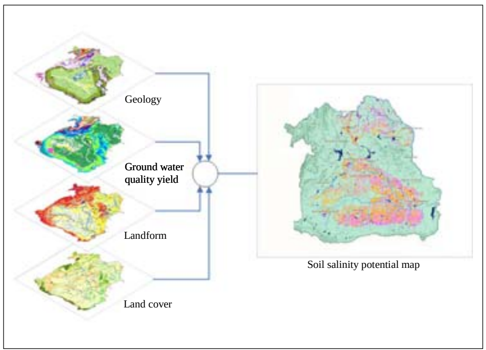

Figure 2. Schematic of map overlaying of salinization.

Applying the model to the four factor databases the overlay operation was digitally performed to create the map units that were subsequently assigned to the soil salinity potential class as defined. In the process of the formulation of the model the iterations were made to adjust the conditions being highly correlated the geo-referenced ground truth and the existing salt crust maps. The schematic of map overlaying of salinization factors as shown in figure 2 in which the soil salinity potential map was created.

4. RESULTS AND DISCUSSIONS

4.1 Salinity Model

The model of salinization in the Northeast consists of 4 factor layers:

Salinity = geology + ground water quality and yield + Landform + Land cover

The high salinity potential were found on the areas underlain by the Maha Sarakham Formation and low water quality and high yield. The low lying topography and poor vegetation cover greatly enhanced the salinization. The area occupies by each class of the salinity are shown in table 3. The high and moderate soil salinity classes cover approximately 0.66% and 9.81% of the total area respectively. The non and low salinity potential classes together accounted for over 89% of the total area. It is evident that the areas highly vulnerable to salinization greatly related to the ground water quality and yield that normally occurred on the Maha Sarahkam Formation. The combination of factor conditions for the soil salinity potential class is assigned in table 2. The salinity potentials where the specified condition as identified in the table 2 occurs together in the same area were categorized accordingly. The spatial distribution of the soil salinity potential in the Northeast was identified in figure 3.

Table 3. Area occupied by the salinity potential class.

Class	Area (%)
High	0.66
Moderate	9.81
Low	8.93
Non-saline	77.16
Other	3.44
Total area = 170,000 sq.km.	

Areas of high salinity potential: Areas of high salinity potential are defined as those places where geology, ground water quality, land form and land cover predispose a location to salinity. These conditions are similar to those occurring in areas of known salt crust. These areas are common in lower terrace and paddy field with sparse or no vegetation in conjunction with the high total dissolved solid and high ground water yield. This includes lower slopes, relatively flat and poorly drained soil.

Areas of moderate salinity potential: these areas cover the site wherever the conditions are less severe than those occurring in areas of high salinity potential. These areas are also in lower terrace, moderate ground water quality and moderately drained soil.

Areas of low salinity potential: Areas in which salinization factors do not occur together and are of minor importance. Soils are somewhat well drained and underlying strata are low in the total dissolved solid.

Areas of non-salinity potential: these areas cover the site wherever they meet one of these conditions: 1.beyond the rock salt "Maha Sarakham" Formation 2.upper terrace 3.mountain 4.dense vegetation 5.good quality of ground water.

The map information presented in this paper is available as potential zone. This provides no guarantee that the salinity will not develop. Further information collected will be used to update the map. The map should be used in conjunction the other publications and related experiments.

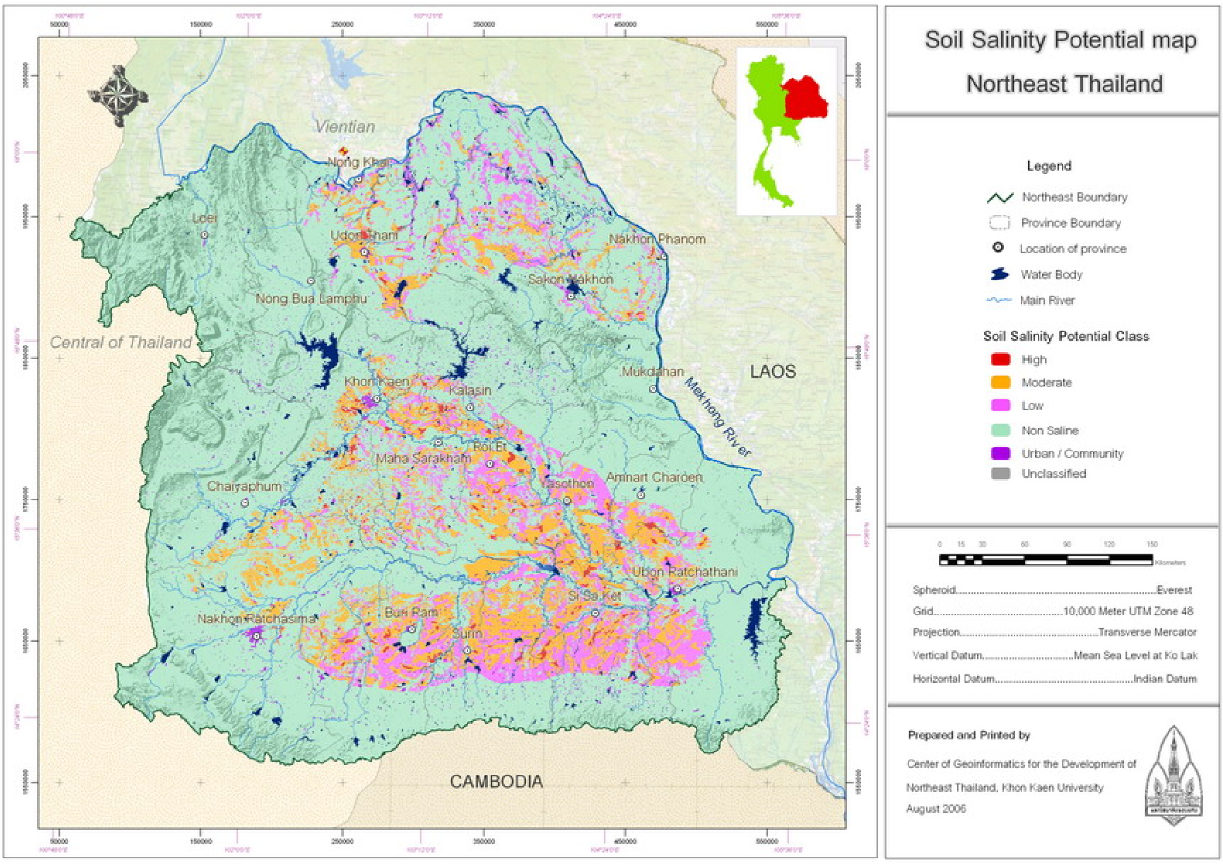

Figure 3. Soil salinity potential map Northeast Thailand

4.2 Validation of the model

The validation of the model was carried out by both the ground investigations and the existing salt crust maps with referenced to the same locations. The ground investigations included the soil salinization appearance, the component factors and their associated information.

The resultant maps were compare with the existing salt crust maps made by the Land Development Department (LDD). The LDD maps

Table 4. Comparison of the soil salinization potential with the LDD map (number of location).

LDD Map	Salinization potential			
	HS	MS	LS	NS
>50%	1	3	-	6
10-50%	1	3	-	7
1-10%	3	6	-	8
<1%	-	8	6	11

based on the salt crust were manually performed by field observation of remote sensing bases. The comparison of the results with the LDD maps is presented in table 4. The selection of 63 locations was randomly checked and compared. Of the 63 locations, mismatch of 13 locations for the 10-50% salt crust and non-salinity potential. More detailed investigation is needed for the salt crusts exist on the areas beyond the Maha Sarakham Formation. Within the Maha Sarakham Formation the reliability of the result is satisfactory. To achieve a more reliable map detailed map layers of ground water and geology should be made available preferably at the 1:50,000 scale. It may need other thematic layers i.e. ground water pumping locations and hydro-geological and geochemical data of the areas to be added for the overlay process.

5. CONCLUSIONS

The GIS-based approach for predicting the spatial distribution of soil salinization is promising method widely accepted. The ability to predict the salinazation potential provides an invaluable tool for agricultural management purposes. It can serve as a mean of monitoring the salinity and to assist in formulating the allocation of the budget plan for salt reclamation. To minimize the impact of salinity on the agricultural land, with the spatial information the testing experiment for the reclamation should be located. A very complicated and dynamic phenomena of the soil salinization in the Northeast should be a long term study and made available to publics. A watershed approach to the management of salinity should be taken particularly the reforestation in the upstream areas. This is to lower ground water in the down stream areas. On locations of salinity previously developed, consideration of the water use and balance should be undertaken to minimize the movement of the soluble salt from the lower strata to soil surface. The development of water sources should be considered carefully and avoid construction in vulnerable areas.

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