USING GIS AND MAP DATA FOR THE ANALYSIS OF THE EXPANSION OF SALINIZED SOILS

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ABSTRACT:

One of the most serious limitations of the agricultural activities in the Northeast of Thailand is the problem of the soil sources, which are infrastructural factors of agriculture. Nowadays the problems of soil salinity are becoming increasingly severe because of the fact that the salt-affected areas are extensively spreading, bringing about the agricultural produces to decline. Soil salinity is one of the most harmful and comprehensive phenomena among the hazardous effects on the soils and the environment as a result of human activities. The salt source for the saline water in the Northeast of Thailand is primarily derived from rock salt of the Maha Sarakham Formation. As a result, to improve the problems of soil salinity and to prevent the salinity from spreading, it is necessary that the soils should be divided into different categories so that the solution and the improvement will be carried out effectively. The data analysis by using Geographic Information Systems (GIS) in correlation with the ground data such as geology, soil drainage, deep ground water, chlorides, EM-slope and the data about water and salt farms derived from the satellite image Landsat 5TM with the visual interpretation have been used for analyzing the salt-affected areas and to be a guideline in developing the stability of the land in an effective way. GIS is a powerful technique for storing, manipulating and retrieving data into useful information. The data can be interactively transformed, updated and manipulated in GIS. The mapping of the salt-affected areas by using the derived data is divided into five stages based on the criteria of the Land Development Department as follows: (1) Salt crusts covering more than 50% around 9.89%; (2) Salt crusts covering 10-50% around 6.82 %; (3) Salt crusts covering 1-10% around 3.97%; (4) Salt crusts covering less than 1% around 22.85%; (5) Non-saline covers 56.48% of this classification. The classification result was found to indicate more details. The conclusion of the study is that the integration of GIS with mapping data used for analysis of data base was very effective in classifying and monitoring the saline soils.

1. INTRODUCTION

Since historic times, salt has been regarded as one of the most valuable resources of all Asian regions especially in the areas which are so distant from the sea. Salt has been produced by drawing salt water from underground or ground level wells. This kind of salt is known as rock salt (Suyasith, 1973). The people in the Northeast of Thailand have given credit to salt as significant resources in making consuming products and manufacturing things such as ice, paper, detergent, steel, etc. Therefore, salt has been playing a great role in the economic and social development of the country (Arunin, 1984; Department of Environmental Quality Promotion, 2002).

The collection of the salt in the Northeast of Thailand comes from the transpiration of saline groundwater (Khpyama et al., 1993). When underground salt water evaporates to the soil surface, especially in the dry season by capillary movement, it will crystallize on the ground (Srisuk, 1994). Then, it will be sieved and filtered until salt is deposited. This water will be boiled until it becomes salt crystallite (Sattayarak, 1990). It has recently been reported that about 17% of the present arable land is affected by salinity (Weda et al., 1984; Arunin, 1992).

A modern technological method has been used to pump saline water from underground. However, because of the high expansion of salt farms, the problems of saline transpiration into the agricultural areas are becoming more serious, causing a lot of damages to cultivated areas of other crops. About 90% of the Thai population is farmers and two-thirds of them are affected by the saline efflorescence into their agricultural areas. Moreover, agriculture is culturally and socially important for Thai people. The saline efflorescence also has a great impact on the environment causing a lot of ecological problems (Arunin, 1992). For example, some natural resources of water become saline and the water cannot be used for drinking or manufacturing things. It also causes aquatic animals to die. Moreover, pumping a lot of salt water from the ground causes some hollows in the ground resulting in the subsidence of the soil layers (Charasdamrong, 1991; Setthabuthra, 1990).

The reason for the spread of salinity is primarily the removal of forest cover leading to increasing groundwater recharges. This factor has been exacerbated by anthropogenic activities including dam constructions, low technology satellite extractions and irrigations. The source of the salt is primarily the dissolution of the rock salt in the Maha Sarakham Formation, which underlies most of the Khorat Plateau in Northeastern Thailand (Arunin, 1987).

Nowadays, the problems caused by the production of rock salt are becoming more critical and in some areas the crisis of ground subsidence is more evident and the dispersion of saline water is expanding widely (Charasdamrong, 1991), so it is necessary that there should be a study by using geographic information systems and map data for the analysis of data bases related to the expansion of saline soils to learn of the location, the size of the salt-affected areas and the areas at risk of being saline so that it will be easier to prevent the expansion of the soil salinity (Battle-Sales and Abad-Franch, 1992).

2. OVERVIEW OF STUDY SITE

The study site covers 413.29 km^2 in the district of Kantarawichai, the province of Maha Sarakham, which is one of the 19 provinces in the northeast of Thailand (Figure 1).

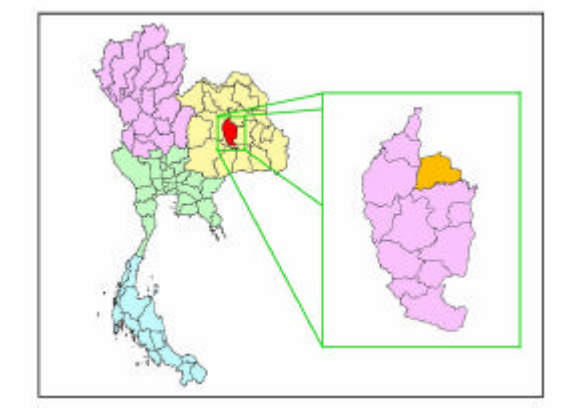

Figure 1. Study site

The climate of northeastern Thailand is that of the tropical savanna and is hot all year round. The rainy season is from May to October and the dry season is from November to April. The mean annual rainfall in Maha Sarakham is about 1,200 mm. However, yearly differences are significant and the fluctuation of the rainfall makes the agriculture in the region unstable. The mean annual temperature is 27.5° C, the monthly lowest temperature is 23.5° C in December, and the highest temperature is 30.1° C in March. In the region, there are four types of soil problems which are widely distributed; namely, sandy, skeletal, saline and vertical kinds of soil. (Mitsuchi et al., 1986). These kinds of soils have caused serious degradation problems, e.g., erosion and salinity (Imaizumi et al., 1999). The areas seriously affected by salt accumulation are located in the study site. This study is more concentrated on technical accessibility for mapping salt-affected soils rather than social issues. The conclusion drawn from the study will be applicable in mapping such soils.

3. HISTORICAL BACKGROUND

The Northeast of Thailand is mainly composed of Mesozoic sediments called the Khorat group and Quaternary deposits; it has long been famous for its wealth of salt deposits (La Moreaux et al., 1958; Sundharovat, 1978; and Suwanich, 1986). Rock salt including halite NaCl, gypsum ($CaSo_4$ $2H_2O$), anhydrite ($CaSO_4$), tachyhydrite ($CaMg_2Cl_6$ $2H_2O$), sylvite (KCl) and camallite ($KMgCl_3$ $6H_2O$) are associated within the Upper Cretaceous Maha Sarakham formation. The occurrence of these salts as marine deposit was earlier proposed (La Moreauz et al., 1958; Sundharovat, 1978; Utha-Aroon, 1993)

In fact, the local people have been familiarized with the sign of the saline deposits. Since the ancient times, salt efflorescence has been widely dispersed throughout the region, especially during the dry season. At present, the areas of salt sources are approximately 15 kilometers wide, 35 kilometers long and the salt layer is 500 feet thick. It covers the area of the province of Maha Sarakham.

Nowadays, in the district of Kantharawichai, province of Maha Sarakham, people produce a large quantity of underground salt and market it nationwide as well as in neighboring countries. This business is run by at least 375 salt producers. The salt produced here is boiled, not dried in the sun like sea salt. Workers pump salty water from underground and boil it in big pans for 24 hours until it gets dry. Then they put it in big baskets and leave it dry again. After that, salt is packed and sent to buyers (Charasdamrong, 1991).

The salinity of the natural bodies of water which are affected by the production of rock salt in the province of Maha Sarakham is measured by the Water Checker Model U10. The measurement result is composed of the alkalinity, the turbidity, the salinity and the conductivity. It is found that salt is produced in the district of Kantharawichai, and the only method of producing it is by boiling. The production sites are situated a long way from the natural sources of water. However, the result of the water quality measurement of the streams nearby is found to range from lowest to high salinity levels, and the most apparent effect is on the paddy fields and the fresh water sources near the salt producing sites because the salt water from the salt wells has been seeping through the soil into the lower paddy fields, and the saline residues are clearly seen (Department of Environmental Quality Promotion, 2002).

4. METHODOLOGY

The mapping regulation of the salt-affected areas was carried out by using the major factors which are associated with the generation of salinity. Then the analytical model was evaluated by using a geographic information system in the following procedures.

4.1 Main Factors

The regulation of the main factors which are related to the generation of salinity was based on the study guideline of the Land Development Department as follows.

4.1.1 Geology: Salt is believed to originate from the Maha Sarakham Formation, where there are a few strata of rock salt and classic rock salt because the salt-affected areas always underlie the Maha Sarakham Formation (Haworth el al., 1996). The Maha Sarakham Formation is composed of rock salt formation which is considered as the cause of soil salinity in the Northeast of Thailand as mentioned above (Mistsuchi et al., 1989) and (Kohyama et al., 1993).

4.1.2 Deep ground water: At first, rock salt is considered as the source of salt, but several researchers doubted the hypothesis of the origin of rock salt because the strata of rock salt were too deep, more than 60 meters below the surface (Sinanuwong et al., 1974). It is about 18-32 meters deep below the Maha Sarakham Formation that salinity can appear. It was reported that besides the rock salt strata, the “salt-bearing beds” are also the major source of salt.

4.1.3 Water: The regular rainfall to an area has been generally found to increase the salinity of the soil. After the water evaporates, salt is left behind. Therefore, this factor is also included in this study to generate the water buffers to figure out at what distance salt will appear.

4.1.4 Salt Farms: Similarly, salt-making farms may be the main cause of enhancing the salinity in the areas where there are salt strata in the soil profile (Abrol et al., 1988). Although the sources of salt in the northeast region are based on the geological strata of rock salt, causing the land to be moderately and strongly-affected areas, human activities have also aggravated the rapidly-expanding salinity causing a big problem in agricultural development (Arunin, 1987). The salt-affected areas are extensively found near and around the salt domes other than in the places where these domes do not exist. This indicates that the source of salt has a close relationship with salt domes (Hattori, 1990).

4.1.5 Soil Drainage: In general, the poorer the soil drainage is, the greater the possibility of the increase of the level of perched ground groundwater, especially in the low-lying areas. This has become a more concerning factor for the salinity if such an area has worse groundwater quality. Therefore, three types of soil drainage found in the areas were classified as poor, poorer, and worst or vice versa (Staff, 1951)

4.1.6 Chlorides (Cl): The neutrally soluble salt associated with the saline soils is chloride and sulfate of sodium, calcium and magnesium (excluding gypsum). Among them, sodium salt is the main component (Bhargrava, 1989).

4.1.7 EM-slope: Using the EM 34 to measure the soil salinity at the depth of 7.5, 15 and 30 meters (V7.5, V15, V30) from the surface is based on the principles that the water-receiving areas are liable to cause the soil to be highly- cleansed, making the soil at a deeper level more saline than that of the shallower level, but around the water-receiving areas, there is a movement of saline water up to the soil surface and when the water evaporates, salt is left over. Therefore, the salinity of the soil at a deeper level is less than that at a shallower level. Yet the comparison of the mean salinity of each area will become more distinct than looking at the proportion of the soil salinity at a deeper level compared with that at a shallower level (V30/V15+V30/V7.5+V15/V7.5/3). This mean is called EM slope, so if EM slope is 1, it indicates that the salinity of the soil is the same at every level. If the EM slope is more than 1, it means that the salinity of the soil at a deeper level is higher than that at a shallower level, which is in the water-receiving areas. If the EM slope is less than 1, the salinity of the soil at the shallower level is higher than that at a deeper level, which is in the water-giving areas. The result of the study shows that the data of the water-receiving areas obtained by using EM 34 are nearly the same as those obtained by specifying the spot and by studying the movement of the underground water by setting a piezometer. These data can be used to produce a soil salinity map and prevent soil salinity from spreading (Land Development Department, 1994).

4.2 Data Capture

Data capture is the step of accumulating and classifying different types of spatial and attribute data. The sources of the data are shown in the Table 1 displaying factors and the sources of data used in the study.

No	Name of Map	Issued by	Scale
1	Topography	Royal Survey Department	1:50,000
2	Geology	Department of Land Development	1:50,000
3	Depth ground water	Department of Land Development	1:50,000
4	Chlorides	Department of Land Development	1:50,000
5	Soil drainage	Department of Land Development	1:50,000
6	EM-slope	Department of Land Development	1:50,000
7	Visual Interpretation from Landsat 5 TM Land use 2004 Water Salt farm	Geo-Informatics and Space Technology Department Agency (Public Organization)	1:50,000

Table 1. List of existing maps used

4.3 Data Input

The input of the data into the GIS is conducted as follows:

4.3.1 Spatial Data Input: The input of the spatial data into the GIS is done with ArcGIS 9 using the digitally-adapted calculation of the visible land use satellite data of Landsat 5 TM.

4.3.2 Attribute Data Input: The input of the attribute data which are digital or descriptive is used to give details of the relevant mapping data such as soil texture and is done via the keyboard.

4.3.3 Data Accuracy Checking: A visual check was conducted to compare the digitized data with the original maps in order to ensure data quality.

4.3.4 Data Manipulation and Analysis: There were two types of data manipulation and analysis. One is the weighting of the factors and the other is the rating of the classification data of each factor as follows:

Various factors which were related to the generation of the soil salinity were put in the GIS and if they range from 1 to7, they were equally weighted.

The class of each factor will have a respective rating according to the importance of the data class. This study has regulated the rating of the factor weighting and the data class based on the precedent studies of the Land Development Department and the experience in the study site. After that the data overlay procedures were calculated to find the weight linear total as follows (Figure 2):

$$S = W_1R_1 + W_2R_2 + W_3R_3 + \cdots + W_nR_n \quad (1)$$

Note: The quantity of chlorides in the study site.

$W_1 \cdots W_n$: The weighting mean of the first factor to n

$R_1 \cdots R_n$: The rating of the data class of the first factor to n

4.4 Classification of Salt Affected Soil

The calculation by the equation brings about the weighted linear total, which was grouped to find out the possibility of the generation of the salinity by using the mean of the rating. Then the standard deviation is used to regulate the range of each rating, which is divided into five ranges based on Table 2 accumulated by the Land Development Department (1991).

Class	Definition
Class1	Very severely salt affected area where salt patches cover more than 50% of the area
Class 2	Severely salt affected area where salt patches cover 10-50% of the area
Class 3	Moderately salt affected area where salt patches cover 1-10% of the area
Class 4	Slightly salt affected area where salt patches cover less than 1% of the area
Class 5	None saline area

Table 2. Classification of salt sffected soil

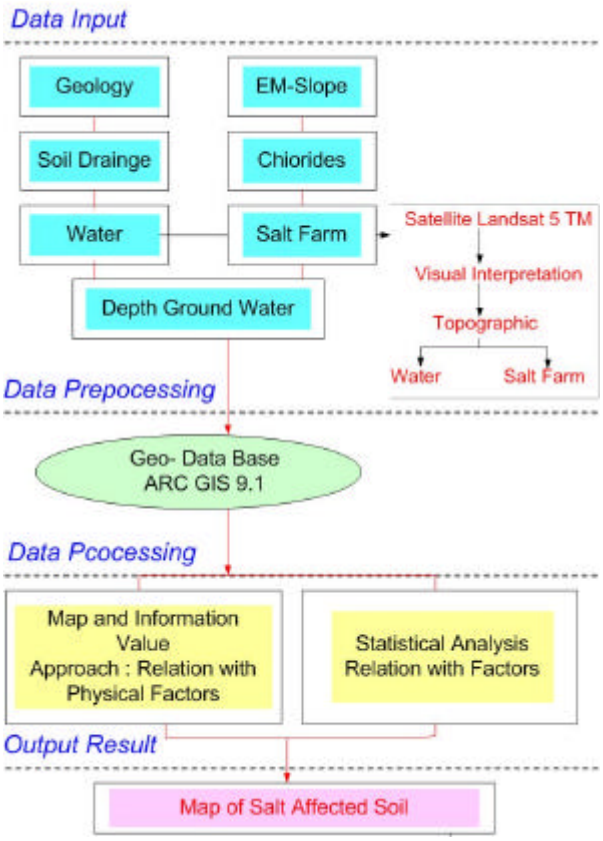

Figure 2. Flow hart of creating and integrating GIS coverage with data map

5. RESULTS AND DISCUSSION

According to the studies on the study site, it is found that the characteristics of the saline soils are easily seen because of the salt patches covering the areas which are barren and uncultivated or if the salt patches are not noticeable, the areas are totally barren except for some weeds which are compatible with salinity or those which can stand the saline condition of the soils.The characteristics and intensity of salinity are different in the same area, and the salinity will accumulate in the layers of the soils differently in different seasons. For example, in the rainy season, salt is washed away and accumulates in the low layers of soils. However, in the dry season, salt can evaporate more quickly because it is mixed with the underground water and moves upward through the capillary movement to the soil surface. Most of the land is characterized as sandy soil or loam, so salt can move up or down very rapidly between the layers of soils, compared with clay.

The expansion of the saline soils can be mapped in order to show the site and the size of the saline soil expansion in correlation with the land use. The result of the study showed that there are five different stages of saline soil expansion (Figure 3).

- *Very severely salt-affected areas* where salt patches cover more than 50% of the area. The land in total is about 9.89% covering the study site which is used as salt farms or orchard and crop fields. In some areas, the land is barren and covered with shrubs and small bushes.
- *Severely salt-affected areas* where salt patches cover about 10-50% of the area. This land is found in the northwest and the south of the study site near the Chi River covering 6.82%. This characteristic of soil salinity is found in the place where the land is used for growing field crops, range land and rivers.
- *Moderately salt-affected areas* where salt patches cover only 1-10% of the area which is mostly composed of large bodies of water, rice fields and crop fields in the northeast of the study site. However, this kind of saline soil is not found in the western part of the study site. In total, this kind of land covers 3.97%.
- *Slightly salt-affected areas* where salt patches cover less than 1% of the areas which are composed of the large area in the middle of the study site. The areas mostly consist of rice fields and in the east of the study site there are crop fields intermingling with various kinds of trees covering 22.85% of the areas.
- *Non-saline areas* cover 56.48% of the land and is found in the place where the land is used for the rice fields.

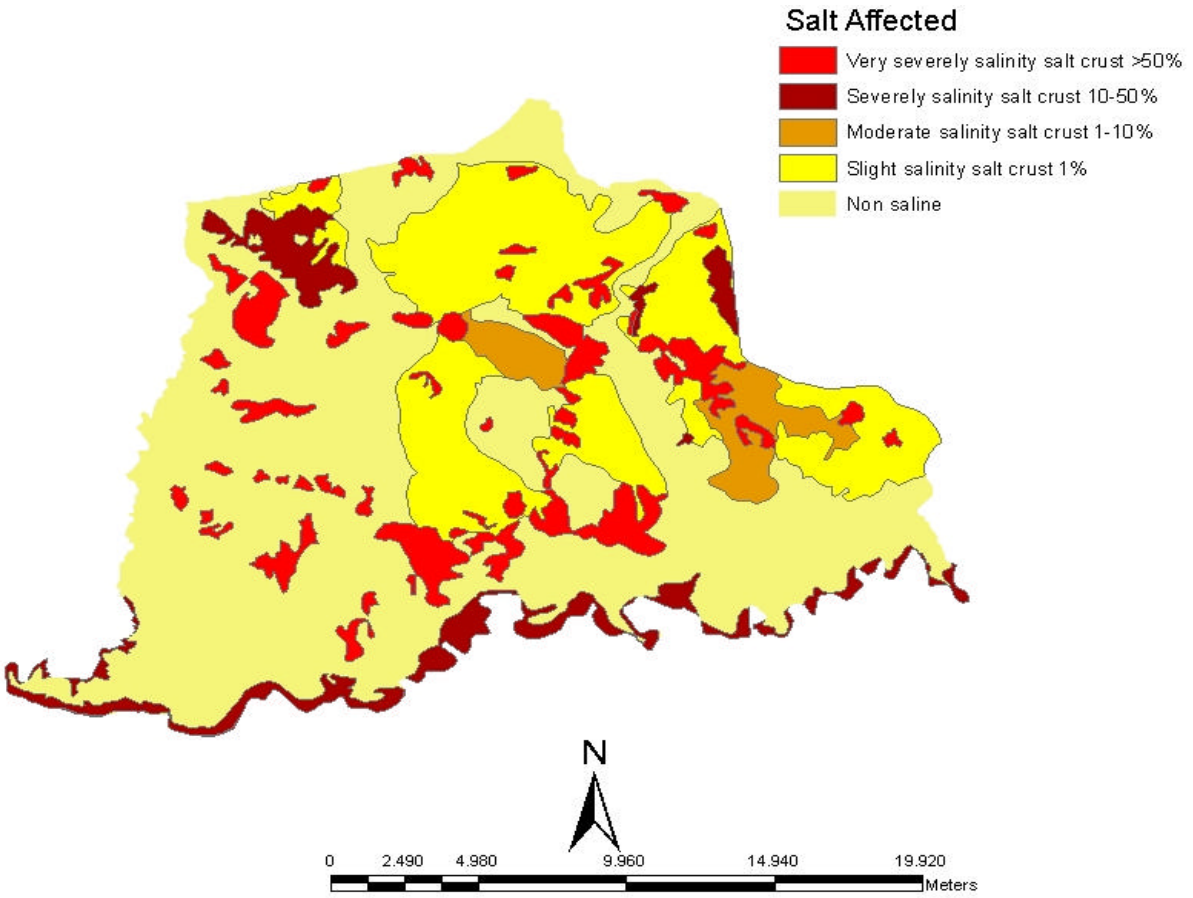

Figure 3. Salinity map of study area resulting from GIS analysis.

The study shows that the salinity expansion has a great impact on the areas where there are salt-boiling factories. Especially during November and December, the rice fields turn yellow and the level of the salinity is extremely high, contributing to the plants to be undersized and their ears turn reddish black. Their grains are parched, emaciated and lightweight. The harvest area has severely decreased, and later the areas have become absolutely barren. The salinity has also seriously affected the buildings and houses because the humidity from the salt crusts has permeated the house walls and concrete columns causing them to be friable and porous. Moreover, pumping too much underground water has caused a big problem because the water cannot be replenished in due time causing the subsidence of the soils and the buildings. Besides this, the electrical appliances which are made of metal can easily turn rusty causing a lot of damages to human residence and properties.

The soil salinity also has a bad effect on water sources and health. It is found out that the water sources on which the villagers have been dependent for the agricultural irrigation have been reduced especially from April to May. The water becomes very salty and it cannot be used for drinking and for watering field crops, so they cannot grow enough to become food. The number of aquatic animals such as fish, prawns, crabs and shells has been steadily decreasing while there are a lot of salt crusts appearing on both cement walls of the irrigation canals. In addition, some villagers have been affected by the particles of the black paddy husks blown about the residence in great number causing them to have respiratory diseases.

These problems have become serious crises for the villagers' way of life like a link of chain. They have earned less money, and they are deprived of working areas, while the cost of living is increasingly rising causing them to be completely in debt. Some of them have had to move out from the area, and look for another job in other places, bringing about a lot of various social problems.

6. CONCLUSION

Saline soils are located in the Khorat Plateau areas where the rock salt has imbedded in Maha Sarakham Formation. The salt which is made by boiling the saline water is obtained from the crystallized salt on the surface of the Khorat Plateau. In the dry season, salt patches can be seen over the soil surface in the salt-affected areas. The main cause of this phenomenon is that the evaporation rate of salt water is high and exceeds precipitation inducing dissolved salt in the underground water to move upward through capillary movement to the ground surface. The soils with high accumulation of salt are hazardous for plant growth and cropping plants on the soils is fruitless. This research shows that using GIS can be successful in mapping saline soils. GIS is very useful in classifying the soils into five stages; namely, very severely, severely, moderately, slightly and non-salt affected areas.

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