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Soil Acidity Ranking, Soil Sensitivity and Vulnerability to Acid Deposition in the Northeast Region of Thailand

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***Abstract*— The soil sensitivity to acidification depends on a number of factors, the most significant of which include cation exchange capacity, base saturation, texture, organic matter content, anion mobility, thickness, precipitation rate and vegetative cover of the area. This study assesses the acidity rankings and sensitivity and vulnerability of agricultural soils to acid deposition in Northeast region of Thailand. Three representative soil types were selected from the region. Cation exchange capacity and base saturation were used to assess the soil sensitivity and vulnerability of the agricultural soils in the region. Results showed that all the investigated soils belong to same sensitivity and vulnerability class i.e. very low. Korat soil was found to be moderately acidic in nature, while Pak Chong and Phon Pisai soils were found to be slightly acidic to neutral soils. GIS software (ArcMap) was used to develop soil maps showing the acidity ranking and sensitivity and vulnerability classes of the agricultural soils in the region.**

Keywords- soil sensitivity; soil vulnerability; soil acidity; acid deposition; Northeast Thailand

I. INTRODUCTION

Soil sensitivity can be defined as "*the degree to which a soil may respond to acid deposition is known as soil sensitivity. Thus, soil sensitivity stresses the risk of an increase in the rate of change of the soil chemistry (the acidification rate)*". While, soil vulnerability is defined as "*it is the extent to which acid deposition may harm or damage the soil". Thus, Soil vulnerability stresses the risk of damage to a soil system (the acidification state).* The relative sensitivity and vulnerability of soils can be assessed on the basis of cation exchange capacity and soil base saturation [1]. Cation exchange capacity (CEC) is the number of negatively charged sites on soil particles' and the proportion of these negative sites occupied by base cations, as opposed to aluminum or hydrogen ions, is known as the base saturation (BS). In general, soil CEC is a measure of the soil's capacity to buffer pH and BS is a measure of the degree to which pedogenic processes have advanced.

Acidic deposition is a serious environmental problem that adversely affects soil quality, surface water, aquatic animals and plants, forests, crops, human health, building materials, etc. Sulfur dioxide (SO_2) and oxides of nitrogen (NO_x) are the major pollutants in industrial areas, principally as causative agents of acid rain. Due to increased combustion of fossil fuels in heavy industry for the rapid economic growth, there is an increased emission of SO_2 and NO_x in the developing countries. Such emissions of SO_2 (mainly from stationary sources) and NO_x (mainly from mobile sources, industries) cause the formation of H_2SO_4 and HNO_3 in precipitation [2]. The long range transport of acidic precursors depends on the life time of the compounds. In European condition, NO_x and SO_2 with lifetimes of 1 to 3 days can be transported about 1000 to 1500 Km. While nitrate and sulfate can be transported up to 2000 Km for their life time of 1 week. Thus depending on the composition and meteorological conditions, the acidic precursors can travel long range [3].

Rainwater in equilibrium with CO_2 in the atmosphere is acidic in nature (pH > 5.6). But H_2SO_4 and HNO_3 formed further decrease the pH of rain. Any rain having pH below 5.6 can be termed as acid rain, also known as acid deposition. Acid deposition can occur in two forms, namely wet and dry deposition. Wet deposition includes acidic species falling with snow, dew, rain, fog drip, and sleet, while dry deposition includes large particles e.g. fly ash, sea salt, suspended compounds ($(NH_4)_2SO_4$ and NH_4NO_3), etc [4]. The acid deposition causes a number of adverse effects on almost all the ecosystems. It intensifies the leaching losses of essential nutrient cations (K, NH_4). These leaching losses, in addition with immobilization of phosphate caused by soil acidification, reduce the soil fertility leading to forest decline

[5]. Leaching of soil base cations by acid rain also induces soil acidification, which negatively affects the availability of other plants nutrients (N, P, Mo, S, etc.) [6]. Due to depletion of base cations from soils, soil acidification will develop which in turn would induce unfavorable agricultural consequences. In addition, acid deposition also enhances the damaging of building materials and paints, including statues, sculptures, irreplaceable buildings, and our cultural heritage [7]. Its other important effects include increased mobility of potentially toxic elements such as aluminum that can cause toxicity to roots and create chemical stress in plants [8] and enhanced mobility and bioavailability of heavy metals in contaminated soils which cause plant injuries [9].

The soils of Southeast Asian countries are sensitive to acid deposition depending on climatic conditions and weathered parent material [10]. It is also important to note that problem of acid rain has been observed in this region in recent years due to rapid industrialization and urbanization. The main objective of this paper was to assess the acidity, sensitivity and vulnerability to acidic deposition in different agricultural soils in the Northeast (NE) region of Thailand.

II. Methodology

A. *Selection of agricultural soils for assessment*

Three soils were selected in three different areas of the Northeast region as representative of those areas. The selected soils have different properties and are being used for agricultural production in Thailand. These soils cover large area and are very important from agricultural point of view. The selected soil series are as under;

- Korat soil series
- Pak Chong soil series
- Phon Pisai soil series

B. *Soil sampling and sample preparation*

Soil samples were collected from the undisturbed agricultural fields at the depth of 30 cm from the surface. The sampling locations are shown in Fig. 1. Coordinates were recorded using GPS at all the sampling locations to indicate soil sampling sites on maps using GIS software (ArcMap). The collected soil samples were kept in plastic bags and brought to the laboratory for basic soil analysis. These samples were prepared for analysis by drying, grinding and sieving (2 mm). Finally, samples were mixed thoroughly to make homogeneous before the physical and chemical analysis.

C. *Soil analysis*

Representative samples of all the three soils were taken and analyzed in the laboratory for some basic properties. Soil pH was measured in distilled water with a soil: water ratio of 1:1 using pH meter [11]. Wet oxidation method [12] was employed to determine the organic carbon content in the soils, which was converted to soil organic carbon by multiplying with a factor (1.724). Cation exchange capacity (CEC) was determined by extraction method, using 1 *N* ammonium acetate (NH_4OAc) [13].

D. *Soil acidity ranking in the study area*

Soil pH was measured to determine the soil acidity rankings [14] of the selected soils of Northeast region of Thailand. Soil rankings are given below;

- Extremely acidic soils (I)
- Very strongly acidic soils (II)
- Strongly acidic soils (III)
- Moderately acidic soils (IV)
- Slightly acidic to neutral soils (V)
- Slightly alkaline soils (VI)

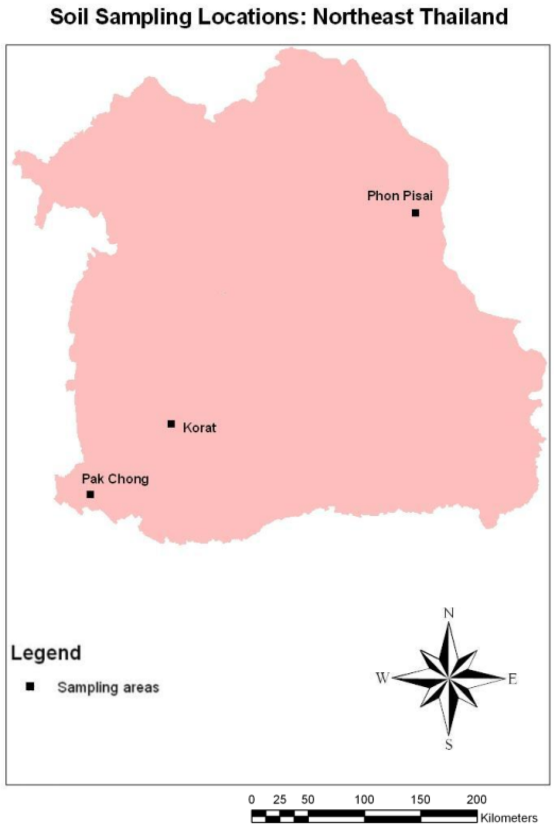

Figure 1. Selected soil series and sampling locations

E. *Soil sensitivity and vulnerability to acid deposition*

Important soil properties that can be useful in assessing the sensitivity and vulnerability of agricultural soil include cation exchange capacity and base saturation. These properties were used for determination of sensitivity and vulnerability of the selected soils of Northeast region of Thailand. Soil sensitivity and vulnerability to acid deposition [1, 15] can be categorized into the following four classes with sensitivity or vulnerability ranging from very high (I) to very low (V);

- Very high sensitivity or vulnerability (I)
- High sensitivity or vulnerability (II)
- Moderate sensitivity or vulnerability (III)
- Low sensitivity or vulnerability (IV)
- Very low sensitivity or vulnerability (V)

F. *Soil maps preparation using GIS software*

Different soil maps were developed using GIS software (ArcMap). Soil maps depict the soil acidity ranking and sensitivity and vulnerability of the agricultural soils to acid deposition in the Northeast region of Thailand. Soil maps developed are given as under;

- Soil acidity ranking map
- Soil sensitivity classification map
- Soil Vulnerability classification map

III. RESULTS AND DISCUSSION

A. *Soil characterization*

The basic properties of the studied soils are given in Table I. Sandy soil is slightly acidic with very small cation exchange capacity (CEC). One clayey soil is slightly alkaline and other clayey soil is slightly acidic with higher cation exchange capacity. In general, all the three soils have very high base saturation (BS).

TABLE I. BASIC PROPERTIES OF THE INVESTIGATED SOILS

Properties	Units	Korat	Pak Chong	Phon Pisai
Soil Texture	-	Loamy sand	Clay	Clay
Soil pH (1:1)	-	5.8	6.3	7.1
SOM	%	0.18	2.9	0.7
CEC	$cmol_{(+)}/kg$	2.8	17.7	17.6
BS	%	80.94	97.27	99.53

SOM = soil organic matter, CEC = cation exchange capacity

B. *Soil acidity ranking and buffering mechanisms*

Soils have different buffering mechanisms depending on soil pH ranges in order to minimize the effects of soil acidification caused by depletion of base cations. Such proposed mechanisms [14] are presented in Table II.

TABLE II. SOIL ACIDITY RANKING AND BUFFERING MECHANISMS

Descriptive Terms	Soil pH Range	Buffering Mechanism
Extremely acid (I)	<4.5	Iron range (pH 2.4–3.8)
Very strongly acid (II)	4.5–5.0	Aluminum/iron range (pH 3.0–4.8)
Strongly acid (III)	5.1–5.5	Aluminum range (pH 3.0–4.8)
Moderately acid (IV)	5.6–6.0	Cation exchange (pH 4.2–5.0)
Slightly acid to neutral (V)	6.1–7.3	Silicate buffers (all pH values typically >5)
Slightly alkaline (VI)	7.4–7.8	Silicate buffers (all pH values typically >5)

The pH values of two soils (Pak Chong and Phon Pisai) fall in the range of 6.1-7.3 (V class) with silicate buffering mechanism. So the kaolinite (silicate clays), which is common in these soils, might be mainly involved in neutralization of acidic deposition. The pH value of third soil (Korat) falls in the range of 5.6–6.0 (moderately acidic, IV class) with cation exchange buffering mechanism. It indicates that base cations including plant nutrients (K^+ and Mg^{2+}) would suffer leaching losses due to acid deposition. The soil acidity ranking in the Northeast region of Thailand is shown in Fig. 2.

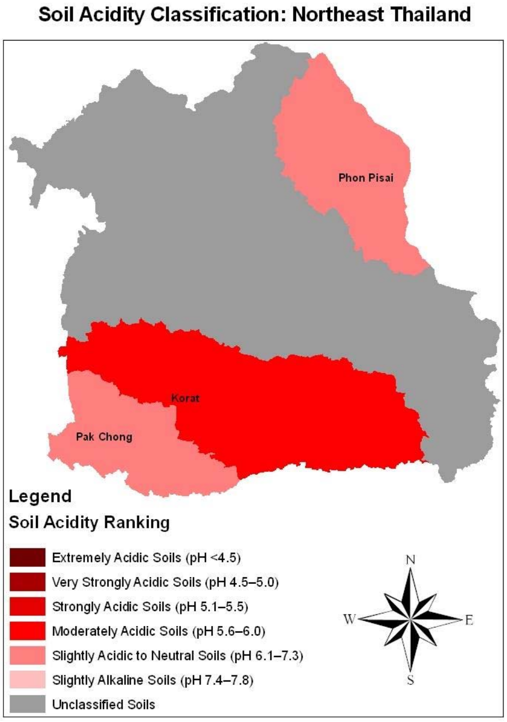

Figure 2. Soil acidity ranking in the NE region of Thailand

C. *Soil sensivity to acid deposition*

CEC and BS are very important soil properties which play a key role in the process of acidic neutralization. Sensitivity of selected soil series was assessed by using 3 CEC levels and 5 base saturation ranges [15], as given in Table III.

TABLE III. RELATIVE SENSITIVITY CLASSES

		CEC (meq /100 g) at field pH		
		< 10	10 – 25	> 25
Base Saturation (%)	0 – 20	I	I	II
	20 – 40	I	II	III
	40 – 60	II	III	IV
	60 – 80	III	IV	V
	80 – 100	V	V	V

Soils with high cation exchange capacity and base saturation will be insensitive to base cation depletion, while soils having low cation exchange capacity and moderate base saturation will be sensitive to base cation depletion. However base cations may not be depleted in soils which have very low BS independent of CEC.

According to this classification system (Table III), all the investigated soils have very low sensitivity (V). This is because of high base saturation, although these soils have low cation exchange capacity. Soil sensitivity classification in the Northeast region is given in Fig. 3.

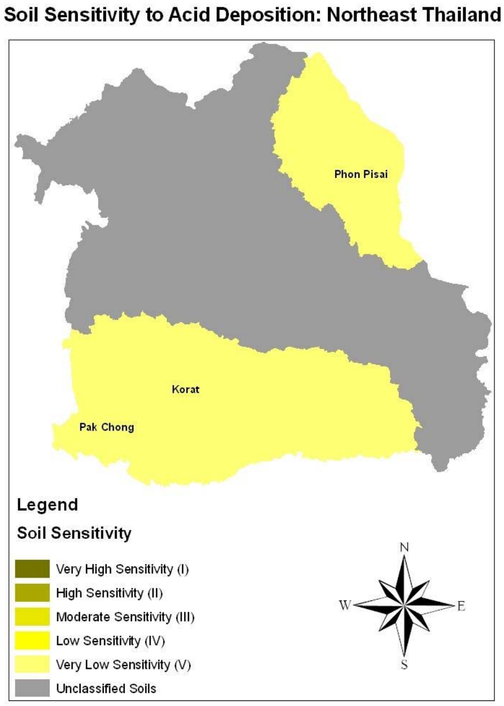

Figure 3. Soil sensitivity in the NE region of Thailand

D. *Soil vlnerability to acid deposition*

CEC and BS can also be used to determine the vulnerability of soils to acid deposition. Vulnerability of selected soil series was assessed using 3 CEC levels and 4 base saturation ranges [9], as given in Table IV.

TABLE IV. RELATIVE VULNERABILITY CLASSES

		CEC (meq /100 g) at field pH		
		< 10	10 – 25	> 25
Base Saturation (%)	0 – 20	I	I	II
	20 – 60	II	III	IV
	60 – 80	III	IV	V
	80 – 100	V	V	V

Similar to sensitivity, all the investigated soils have low vulnerability (V). But it is important to note that Korat soil series has lower base saturation (80.94%) than those of Pak Chong (97.27%) and Phon Pisai soil series (99.53%). Acidic deposition can adversely affect the Korat soil series.

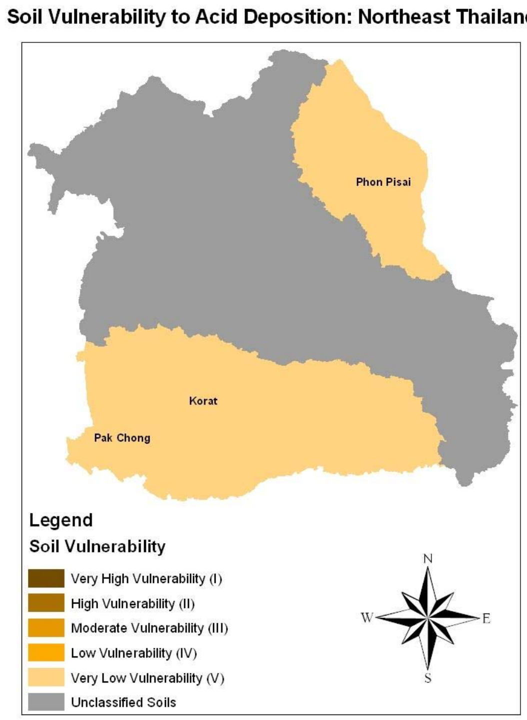

Figure 4. Soil vulnerability in the NE region of Thailand

IV. CONCLUSIONS

An assessment study was conducted to determine the acidity and sensitivity and vulnerability of different agricultural soils to acid deposition in the Northeast region of Thailand. All the investigated soils were found to have low sensitivity and vulnerability to acidic deposition due to high base saturation of the soils. But the leaching of base cations can increase their vulnerability to acid deposition due to low weatherable minerals. Thin and highly weathered soils are common in some highland, non-volcanic portions of southeast region of Asia. The weathering process of these soils is close to end having few soil base cations remaining. The anthropogenic acidification causing activities are ever-increasing due to urbanization and industrialization in the region, which can cause enormous soil acidification in such highly weathered soils. Therefore, possible measures should be taken to control the emission of acidifying gases.

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