Research article

Chemical Properties of Soils in Reforested and Bare Areas in Salt Affected Area of Khon Kaen Province, Thailand

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Abstract Salt affected soil is a severe environmental problem in northeast of Thailand. About 16.82 percent of the total land area in the region is accounted for the salt affected area. In the study area of Phra Yun district, Khon Khaen province, there were many studies since 1990 and 18 governmental projects of Thailand have been conducted for rehabilitating salt affected soil since 1999. However, attention has been paid to the current condition of salt accumulation in Phra Yun district, after many studies and projects have been implemented. So in this study, soil survey was conducted in four areas, Eucalyptus (*Eucalyptus camaldulensis*) reforested area and adjacent bare area, Acacia (*Acacia ampliceps*) reforested area and adjacent bare area. Disturbed and undisturbed soil samples were collected for analyzing physical and chemical properties of soils. The differences in chemical properties of soils were analyzed by *t*-test statistical method. The results showed that $EC_{1:5}$ values of soils in reforested and adjacent bare areas were significantly different at 99%. The sodium and calcium concentration of soils at the same depth in reforested and adjacent bare areas also showed significant different at 95% and 99%. Moreover, there was a tendency that $EC_{1:5}$ values, sodium and calcium concentration decreased with soil depth due to accumulation of salts at the surface layers. Although many studies and projects have been implemented in Phra Yun district, salt accumulation has been still severe, especially in bare areas. In addition, it was clearly observed that reforested areas of Eucalyptus and Acacia tended to be lower in electrical conductivity, sodium and calcium concentration than that of adjacent bare areas. Thus, it was concluded that reforestation is an effective approach to rehabilitate salt affected soil.

Keywords salt affected soil, reforested areas, chemical properties of soil

INTRODUCTION

Salt affected soil is a severe environmental problem in northeast of Thailand. Total area of this region is 16.928 million hectares while the salt affected land covers 2.848 million hectares or about 16.82%. From the rock salt stratum, called Mahasarakam formation, laid under soil surface at 100 m to 200 m deep, salt components are rising associated with soil water to ground surface. Salt affected soil is not only an environmental problem but also economic and social problems in rural areas.

Capillary rise of saline groundwater is one of the main causes of salinization (Kohyama and Subhasaram, 1993). One of the practices to prevent salinization is interrupting capillary rise of saline groundwater (Mihara et al., 2009) and to control the saline groundwater level (Dissataporn et al., 2002). Among several practices for controlling saline groundwater level, reforestation is also recommended to lower saline groundwater and mitigate salt accumulation (Yamklee et al., 1995 and Yuwaniyama, 2011).

Khon Kaen province is one of the provinces in northeast of Thailand that faces salt affected soil problem. The salt affected area covers around 10.85 percent of total area. Salt affected soil problem is severe in Phra Yun district, Muang district, Ban Fang district and Ban Phai district (Khon Kaen province, 2005; Topark-ngarm, 2006).

Phra Yun district is one of the salt affected areas of Khon Kaen province. Agriculture is the main occupation of villagers in the district, paddy rice and sugarcane are the main agricultural products. Topography of this area ranges from flat land to rolling hills, elevation varies from 175 to 190 m above sea level. Paddy rice was cultivated in lowland areas while in the hill areas villagers grown sugarcane, cassava and Eucalyptus trees. Average income of population in Phra Yun district is 58,673 Baht or around 1,884 USD per year (Phra Yun Community Development Office, 2012).

In the study area, there were many studies about causes, effects and distribution of salt affected soil since 1991 (JICA, 1991). Besides that, 18 governmental projects of Thailand have been conducted for rehabilitating salt affected soil since 1999 (Land Development Department, 1999, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, Land Development Office of Region 5 (Khon Kaen), 2000, 2010, 2011a and 2011b).

Main activities of government projects for suppressing and/or ameliorating salt affected soil problem in the study area included; introducing salt tolerant rice species to farmers, increasing rice productivity by organic fertilizer and green manure application. Making groundwater drainage system, promoting salt tolerant tree included *Eucalyptus camaldulensis* and *Acacia ampliceps* and halophyte grass, *Sporobolus virginicus* in severely salt affected areas as well as planting fast growing trees in recharge areas to prevent salinization.

Moreover, in 1985, Agricultural Development Research Center (ADRC) has established in cooperated with Japan International Cooperation Agency (JICA), Thai Government and Khon Kaen University (JADES, 1997). The aims of the center are: 1) classification of agro-ecological zones and land use planning, 2) development of farm management system and 3) development of low-input technology. One of the activities of ADRC was to suppress salinization and ameliorate the salt affected areas.

However, attention has been paid to the current condition of salt accumulation in Phra Yun district, after many studies and several projects have been implemented. Therefore, the objective of this study is to investigate chemical properties of soils in reforested and bare areas in salt affected area of Khon Kaen Province, Thailand.

METHODOLOGY

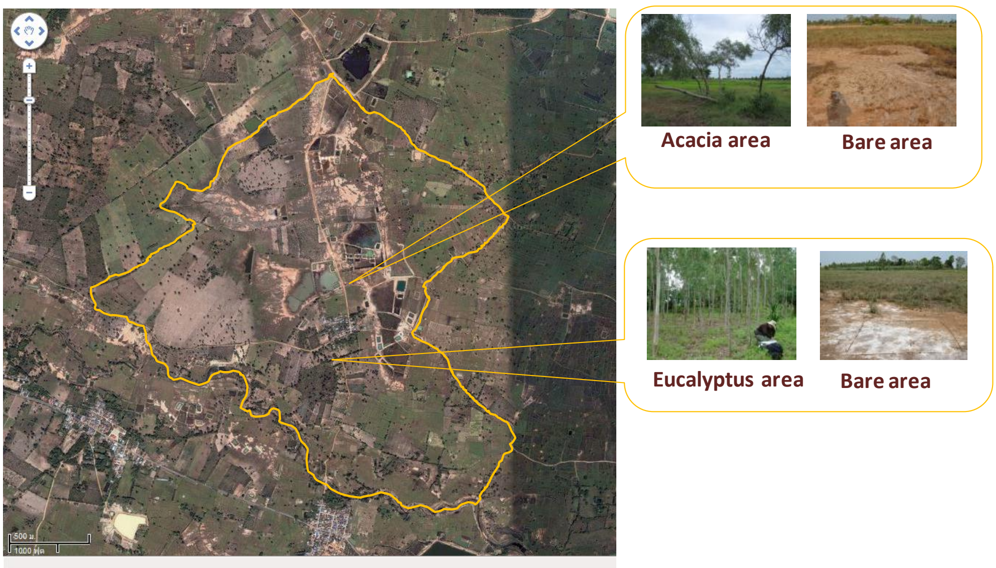


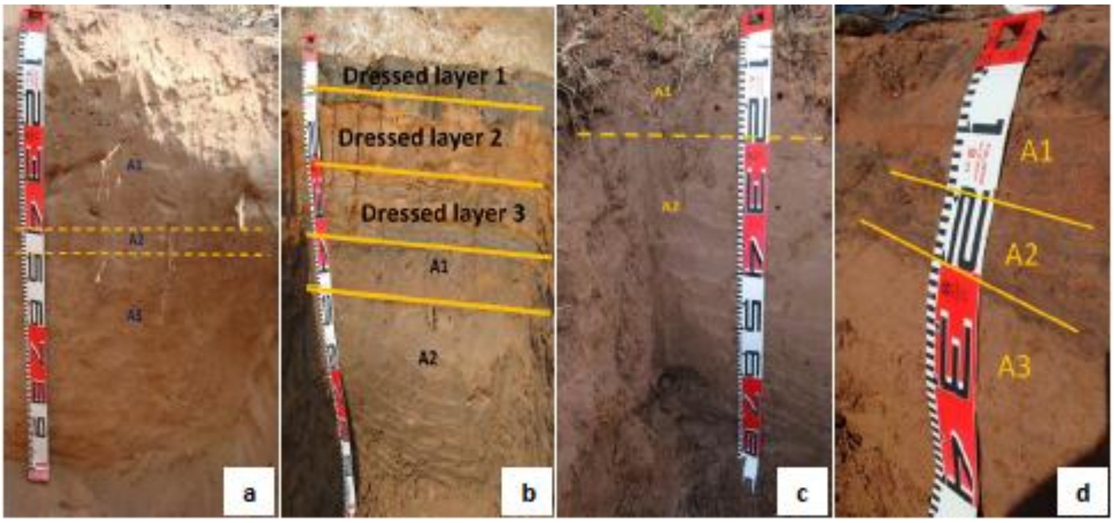
Fig. 1 Areas of conducted soil profile survey and collected soil samples

In January 2012, soil profile survey was conducted in 4 areas, Eucalyptus (*Eucalyptus camaldulensis*) reforested area and adjacent bare area, Acacia (*Acacia ampliceps*) reforested area and adjacent bare area. According to soil profile in Eucalyptus reforested area, 3 disturbed and 9 undisturbed soil samples were collected while from the adjacent bare area of Eucalyptus, 5 disturbed and 15 undisturbed soil samples were collected. In Acacia reforested area, 2 disturbed and 6 undisturbed soil samples were collected while from the adjacent bare area of Acacia, 3 disturbed and 9 undisturbed soil samples were collected. Soil samples were analyzed for physical and chemical properties. The physical properties of soils including soil texture, dry density, specific gravity and soil permeability were analyzed. In addition, soil chemical properties including pH, electrical conductivity ($EC_{1:5}$) value, sodium, calcium, total nitrogen and total phosphorus concentration were analyzed. The differences in chemical properties of soils were analyzed by *t*-test statistical method.

RESULTS AND DISCUSSION

Physical properties of soils in reforested and bare areas

The soil textural classes of soils from 4 study sites were sand, sandy loam and loamy sand. Soils specific gravity ranges between 2.62 to 2.66. Dry density of soils in 4 study sites ranges from 1.54 to 1.80 g/cm^3. The highest percentage of loss on ignition was found in topsoil of Acacia reforested area 3.63% (Tables 1 and 2).



a Eucalyptus reforested area **b** bare area adjacent to Eucalyptus **c** Acacia reforested area **d** bare area adjacent to Acacia

Fig. 2 Soil profiles in 4 areas

Table 1 Physical properties of soils in Eucalyptus reforested area and adjacent bare area

Depth from soil surface (cm)	Horizon	Soil texture	Specific gravity	Dry density (g/cm^3)	Ignition loss (%)	Saturated permeability (x10^{-3} cm/s)
Soil in Eucalyptus area						
0 – 40	A1	S	2.62	1.80	0.89	125.90
40 – 45	A2	LS	2.65	1.79	0.67	145.10
45 – 100	A3	LS	2.64	1.78	0.47	127.60
Soil in bare area adjacent to Eucalyptus area						
0 – 10	Dress layer 1	L	2.64	1.54	3.59	0.10
10 – 25	Dress layer 2	S	2.64	1.67	0.68	133.70
25 – 34	Dress layer 3	LS	2.62	1.56	1.24	0.50
34 – 44	A1	LS	2.65	1.62	1.2	140.10
44 – 100	A2	SL	2.66	1.62	1.37	125.40

Table 2 Physical properties of soils in Acacia reforested area and adjacent bare area

Depth from soil surface (cm)	Horizon	Soil texture	Specific gravity	Dry density (g/cm^3)	Ignition loss (%)	Saturated permeability ($x10^{-3}$ cm/s)
Soil in Acacia area						
0 – 10	A1	S	2.64	1.58	1.04	134.20
21 – 80	A2	S	2.65	1.62	1.35	51.20
Soil in bare area adjacent to Acacia area						
0 – 15	A1	LS	2.64	1.63	3.63	41.90
15 – 22	A2	LS	2.66	1.64	1.33	122.40
22 – 70	A3	LS	2.63	1.63	1.02	95.90

Chemical properties of soils in reforested and bare areas

As shown in Fig 3, the $EC_{1:5}$ values of soils in 4 areas were significantly different at 99%. The $EC_{1:5}$ value in topsoil of Eucalyptus reforested area was the lowest at 0.01985 mS/cm and the highest value was topsoil of bare area adjacent to Eucalyptus at 20.00 mS/cm.

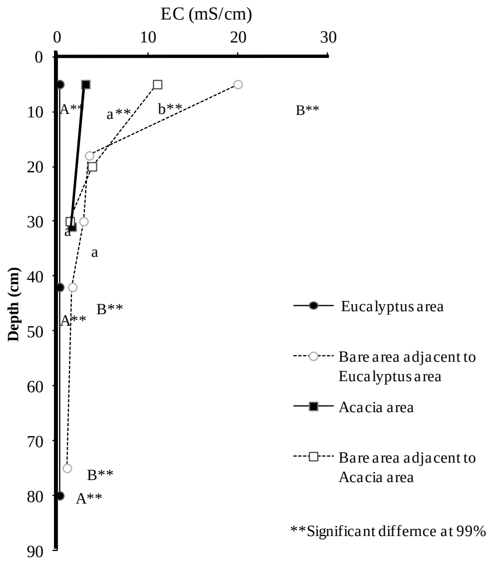


Fig. 3 Electrical conductivity values ($EC_{1:5}$) of soils in 4 areas

The sodium and calcium concentration of soils at same depth in 4 areas showed significant difference at 95% and 99%. It was observed that sodium concentration was the lowest in topsoil of Eucalyptus reforested area at 1.84 mg/kg and the highest concentration was topsoil of bare area adjacent to Eucalyptus at 21,447.86 mg/kg (Fig. 4, left side).

Calcium concentration was the lowest in topsoil of Eucalyptus reforested area at 10.10 mg/kg and the highest concentration was topsoil of bare area adjacent to Acacia at 1,926.84 mg/kg (Fig 4, right side). Moreover, there was a tendency that the $EC_{1:5}$ values, sodium and calcium concentration decreased with depth due to accumulation of salts at the surface layers.

As shown in Fig. 5 (left side), the total nitrogen concentration of soils in 4 areas was significantly different at either 95% or 99%. A significant difference at 95% in the total nitrogen concentration were found in soil of 2nd layer and 3rd layer of Eucalyptus area and adjacent bare area, while a significant difference at 99% were found in topsoil of Acacia area and bare area adjacent to Acacia. The highest total nitrogen concentration at 522.89 mg/kg was found in Acacia reforested area due to high amount of nitrogen in Acacia leaf litter. Low total nitrogen concentration in topsoil of Eucalyptus plantation might be due to allelopathic affect of Eucalyptus trees to soil macronutrients (Tilashwork, 2009).

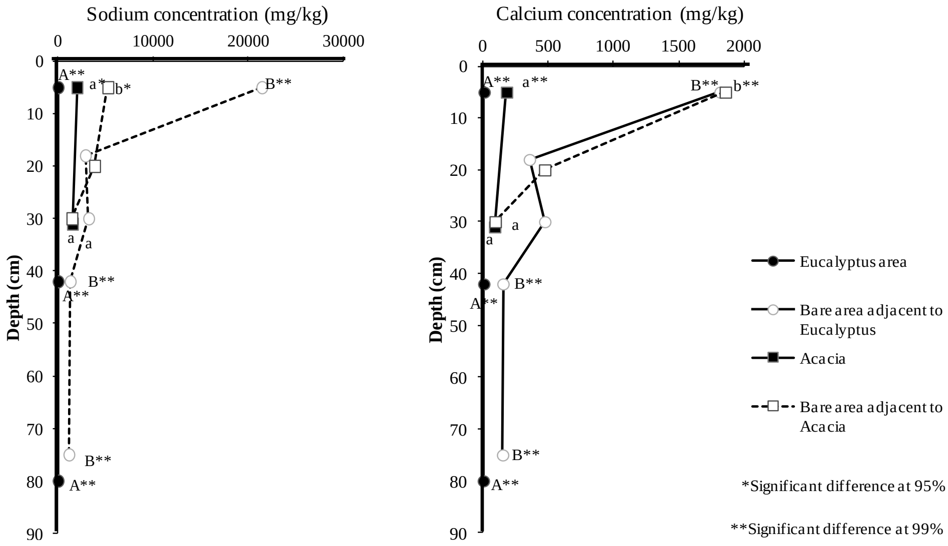


Fig. 4 Sodium concentration (left) and calcium concentration of soils (right) in 4 areas

The total phosphorus concentration of topsoil of Acacia area was significantly different at 95% from that of adjacent bare area. The total phosphorus concentration found in 4 areas was relatively low ranging from 0.67 to 6.64 (Fig.5, right side). From the result, the highest value of total phosphorus was found in the bare area adjacent to Eucalyptus area, the possibility is frequently burning residues in bare area might be increase total phosphorus in soil (Li et al., 2012).

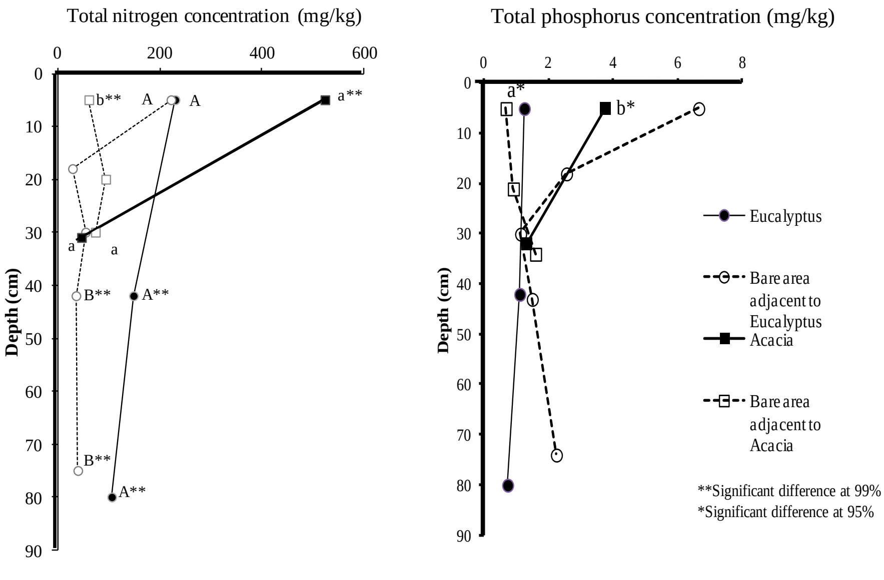


Fig. 5 Total nitrogen concentration (left) and total phosphorus concentration (right) of soils in 4 areas

Table 3 Changes in salt affected areas in Phra Yun district, Khon Kaen province

Year	Severely affected area (salt crust cover more than 50%) (ha)	Strongly affected area (salt crust cover 10- 50%) (ha)	Moderately affected area (salt crust cover 1- 10%) (ha)	Total salt affected area (ha)	% of total area (17,200 ha)
1991	310	1,480	3,550	5,340	31
2003	441.6	1,404	4,250	6,095	35

Source; JICA (1991); REO 10 (2003)

Although 18 development projects of Thai government has been conducting in the study area since 1991, the results of this chapter revealed that the soil salinity still severe, especially in bare area. Moreover, the salt affected areas are increasing from 31 percent of total district area in 1991 to 35 percent in 2003 (Table 3-3).

Strategy for promoting reforestation in salt affected area

Based on the results of this study, it was supported that reforestation is an efficient way to rehabilitate salt affected soil. However, low economic benefit with reforestation became the constraint for the locals to grow more trees in salt affected area of Khon Kaen province, Thailand (Sakkhamduang et al., 2012).

In 2001, Sakkhamduang et al. report that agro-forestry system in Salt affected area in Khon Kaen Province had a lower practice than that of in non-salt affected area according to the salt affected soil condition. Agro-forestry practices on salt affected area can be categorized into five types; patch forests, trees on paddy bunds, tree plantations associated with animal husbandry, home gardens and trees in vegetable gardens. Moreover, Im-Erb et al. (2004) reported that an agro-forestry system being promoted on 2003 in recharge area of Nakhon Ratchasima province was well accepted by farmers according to their additional income.

Thus, agro-forestry system that combined salt tolerant tree with salt tolerant or halophyte vegetables or field crops should be introduced to farmers in the study area for increasing their income as well as rehabilitating salt affected soil.

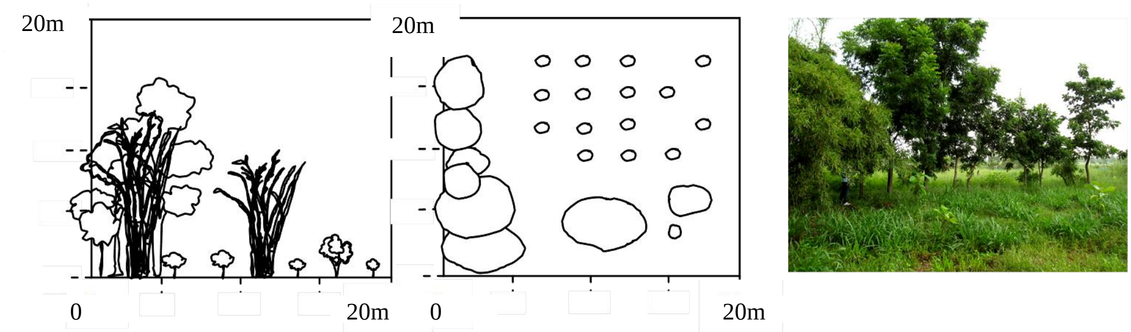


Fig. 6 Cross section and top views of home garden, one of agro-forestry systems existing in salt affected area

CONCLUSION

Many government projects have been implemented in Phra Yun district since 1991. The activity of those projects included; introducing salt tolerant rice species to farmers, increasing rice productivity by organic fertilizer and green manure application. Making groundwater drainage system, promoting salt tolerant tree included *Eucalyptus camaldulensis* and *Acacia amplicep* and halophyte grass, *Sporobolus virginicus* in severely salt affected areas as well as to planting fast growing trees in recharge areas for preventing salinization.

Although several projects were implemented, salt accumulation is still severe; especially in bare areas that has EC value of 20 mS/cm. In addition, it was clearly observed that reforested areas of Eucalyptus and Acacia tended to be lower in electrical conductivity, sodium and calcium concentration than that of adjacent bare areas. Moreover, Thaweethavornsawat (1999) reported that the decreasing of forest area in Phra Yun district increases the distribution of salt patches in the area. Thus, it was concluded that reforestation is an effective approach to rehabilitate salt affected soil.

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