Soil biological activity and greenhouse gas production in salt-affected areas under tree plantation

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Abstract: Soil salinity is likely the most important abiotic factor that constrains the crop production in Northeast Thailand. This study aimed to evaluate impacts of soil salinity on the soil biological activity and greenhouse gas evolution in salt-affected areas under tree plantation, at Amphur Borabue, Mahasarakam province, Northeast Thailand. The study area was divided into two zones based on the plant community found in each area which linked with the flooding situation and soil salinity. Soil samples were collected from the two different zones at the same depth (0-20cm) with three replications during the rainy season of 2010, in order to analyze soil salinity and biological properties. The results showed that the soil biological activity in terms of soil respiration, microbial biomass carbon and microbial biomass nitrogen in the upper site were greater than in the lower site. Moreover, metabolic quotient was higher in the lower site than the upper site. Field evolution of CH_4 varied with different location. It could be concluded that tree plantation covered with native grasses in salt-affected areas increased soil biological properties and reduced the greenhouse gas production.

Key words: soil biological activity, salinity, methane

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Introduction

Soils in Northeast Thailand are salt-affected due to salt bearing rocks (Department of Land Development, 1991), particularly in Nakhon Ratchasima, Khon Kaen, Roi Et and Mahasarakham provinces (Department of Mineral Resources, 1982). Soil salinity is likely the most important abiotic factor that constrains the growth of plants and the activity of soil microorganisms in those areas. It has been reported that salinity has an adverse impact on soil physical properties (Boivin et al., 2004), chemical properties (Sumner, 2000) and soil microbial communities and activities (Sardinha et al., 2003) and also has influence on plant growth and yield (Marschner, 1995). Salt-affected soils may be reclaimed by growing salt-tolerant tree species, which improve the physical and chemical properties as well as the biological activity in the soil (Garg, 1998). Therefore, tree plantation in salt-affected area has the potential to alleviate salinity stress on farms for sustainable production.

Climate change is an important issue in the present day. Atmospheric concentrations of carbon-based greenhouse gases, namely carbon dioxide (CO_2) and methane (CH_4), have been rising because of emissions caused by industrial activities and combustion of fossil fuels for non-industrial activities, deforestation and other land-use changes (Fearnside, 2006). CH_4 is one of the most potent of the greenhouse gases, accounting for approximately 15% of the greenhouse effects at the present time. The current atmospheric concentration of methane (1.75 ppmv) is about 200 times smaller than that of carbon dioxide (365 ppmv), but its relative global warming potential (GWP) is 23 times that of CO_2 over a time horizon of 100 years (IPCC, 2001). The largest sink for methane is biological oxidation by soils and accounts for 6% of the global methane sink (Hutsh, 2001). However, there is no investigation on the effects of tree plantation on methane oxidation activity in salt-affected areas of Northeast Thailand. The objectives of this study were to evaluate impacts of soil salinity on the soil biological activity under salt-affected areas of Northeast Thailand and to monitor the impacts of soil salinity on the soil surface methane evolution in salt-affected areas under tree plantation.

Materials and Methods

Site description

This study was carried out at Ak-Kasatsuntorn water reservoir, Tumbon Borabue, Mahasarakam Province, Thailand at latitude of 16° 01' N and longitude of 103° 05' E, and at an elevation of 178 m from mean sea level. The study area was divided into two zones based on the plant community found in each area where they are correlated with the flooding situation and soil salinity. The study site has been established for three years with tree plantation such as common ironwood (*Casuarina equisetifalia* J. R. & C. Forst.) and manila tamarind (*Pithecolobium dulce*) in salt-affected areas. In addition, the studied areas were covered with native grasses and weeds, i.e., torpedograss (*Panicum repens* L.).

Soil sampling and analysis

Soil samples were taken from three random locations of each zone at the depth of 0–20 cm during the rainy season of 2010. The soils were analyzed to determine soil salinity and biological properties according to routine methods in the Land Resources and Environment section, at Faculty of Agriculture, Khon Kaen University. Electrical conductivity (EC) was determined in a 1:5 soil to water solution by using an EC meter. Exchangeable sodium percentage (ESP) was determined as the ratio of exchangeable Na^+ to the total cation exchange capacity of the soil.

Microbial biomass C (MBC) and microbial biomass N (MBN) were estimated by the chloroform fumigation extraction method using a correction factor (k_{EC}) of 0.33 (Sparling and West, 1988) and factors (k_{EN}) of 3.1 (Amato and Ladd, 1988), respectively. Microbial activity was studied by soil respiration that was determined by titrimetric method (Zuberer, 1991). The metabolic quotient (qCO_2) was calculated as follows:

$$qCO_2 = CO_2\text{-C} / MBC$$

where CO_2-C (mg kg^{-1} soil) is soil respiration and MBC (mg kg^{-1} soil) is microbial biomass C.

Greenhouse gas collection

The closed chamber technique was used to monitor the flux of methane between soil and the atmosphere. At random locations within each of the two sites, the base module (50 cm in height, 60 cm in length and 60 cm in width) was inserted 4 cm into the ground and remained in place for the duration of study with three replicates per site. The top edge of the base module was grooved so that the gas chambers fit securely. Once the gas chamber was inserted into the groove, the groove was filled with water to provide an air-tight seal. The top cover of the chamber had two 1.5 cm diameter holes where rubber caps were tightly fitted. One was used to extract the gas samples and the second to place a thermometer.

Gas samples were collected at times 0, 10, and 20 minutes using 1 ml glass syringes. After collecting, the gas was transferred to the laboratory and measured for CH_4 by using a gas chromatograph (Shimadzu GC-14B). Gas flux measurement was initiated on July 2010. Gas was sampled twice a month during the rainy season of 2010. The condition of GC and calculation were followed the procedure described by Saenjan and Sributta (2002). During the gas sampling, water table depth was recorded from the soil surface and soil moisture content was measured gravimetrically.

The data recorded was analyzed statistically using Statistics 8.0 (Analytical Software, 2003) and Microsoft Excel software.

Results and Discussion

Soil salinity and biological properties

The results showed that in salt-affected area, electrical conductivity (EC) and exchangeable sodium percentage (ESP) were smaller in the upper site when compared to the lower site (Table 1), demonstrating that the lower site was still influenced by salinity.

The average MBC and MBN of soil were greatly influenced by soil salinity (**Table 1**). The higher MBC was recorded in the upper site (223.1 mg kg^{-1}) when compared to the lower site (203.4 mg kg^{-1}). Likewise, MBN was higher in the upper site (29.2 mg kg^{-1}) than in the lower site (13.0 mg kg^{-1}). The ratio of microbial biomass C to biomass N was smaller in the upper site (7.6) than in the lower site (15.7). Moreover, the metabolic quotient (qCO_2) tended to increase with increasing salinity. Soil respiration was much greater in the upper site (128 mg CO_2 kg^{-1} d^{-1}) than in the lower site (108 mg CO_2 kg^{-1} d^{-1}) during the sampling season (**Table 1**). Sardinha et al. (2003) suggested that salinization has an adverse effect on soil microbial properties.

Greenhouse gas production

Evolution of methane (CH_4) from soils under salt-affected areas varied over a wide range from -91.2 to 63.08 mg CH_4 m^{-2} d^{-1} (**Figure 1**). The highest oxidation rate occurred from the upper site, which was twice as high as that of the lower site during July, indicating that it has the potential for CH_4 oxidation by aerobic methanotrophic bacteria. In the next month, there was a little oxidation in both sites, suggesting the increasing water table and soil moisture content (**Figure 2**). In contrast, CH_4 emission was observed in both sites during September, demonstrating that soils were saturated during the sampling period. These results are in line with the findings of Yavitt et al. (1995).

Conclusion

Investigating salt-affected soils planted with tree species indicated the changes of salinity in terms of reducing EC and declining ESP in the upper site. Consequently, there was greater soil biological activity in terms of soil respiration, MBC and MBN in the upper site. Field evolution of CH_4 varied with different location because of differences in soil moisture and water table. It could be concluded that tree plantation covered with native grasses in salt-affected areas increased soil biological properties and reduced the greenhouse gas production.

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Table 1 Soil biological properties and salinity after tree plantation

	Soil biological properties					Salinity	
	MBC ($mg\ kg^{-1}$)	MBN ($mg\ kg^{-1}$)	MBC/MBN	Soil respiration‡	qCO_2†	EC ($dS\ m^{-1}$)	ESP (%)
Upper site	223.1 (29.6)	29.2 (3.4)	7.6 (1.2)	128 (14.6)	0.75 (0.10)	1.0 (0.1)	2.10 (0.23)
Lower site	203.4 (25.5)	13.0 (2.4)	15.7 (1.4)	108 (11.9)	1.18 (0.19)	17.2 (4.2)	3.86 (0.69)

‡$mg\ CO_2\ kg^{-1}\ d^{-1}$

† metabolic quotient ($mg\ CO_2$-C g^{-1} microbial biomass C day^{-1})

Parentheses show standard deviations.

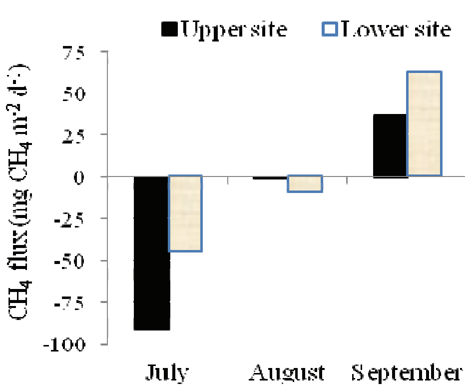

Figure 1 Average CH_4 flux measured during the rainy season of 2010

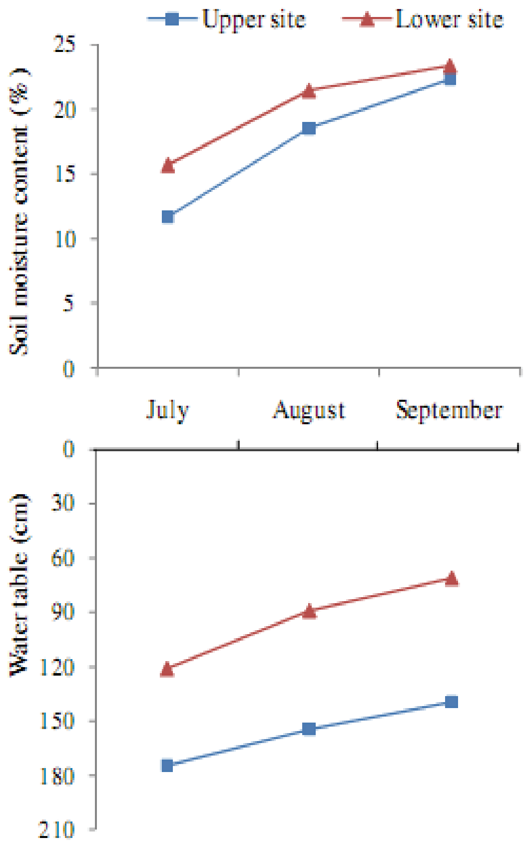

Figure 2 Average soil moisture content and water table during the rainy season of 2010