Research article

Ecological Management in Salt-affected Area of Northeast Thailand: Monitoring Soil Quality

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Received 10 December 2010 Accepted 20 January 2011

Abstract Soil salinity has become one of the major determinants of crop productivity in Northeast Thailand, and has an adverse impact on the physical, chemical and biological properties of soil, as well as plant growth and yield. Ecological management of soil is essential to sustainable production. Soil microorganism may fulfill many important ecological roles including decomposition and nutrient cycling in salt-affected area. This study aimed to monitor the impact of salinity on soil properties under tree plantation at Amphur Borabue, Mahasarakam Province, Northeast Thailand. The study area was divided into 3 zones followed by the plant community found in each area which correlated with the flooding situation and soil salinity. Soil samples were collected from three different zones at the same depth (0-20cm) with three replications during the rainy seasons of 2008 and 2010 in order to analyze soil physical, chemical and biological properties. The results showed that biodiversity of soil biota and soil microbial activity in terms of soil microbial carbon, soil microbial nitrogen and soil respiration after tree plantation was higher than before. The EC, Na and K values were decreased, whereas pH, OM and N were increased after tree plantation. It could be concluded that soil physical, chemical and biological properties were improved after tree plantation. Therefore, this result would be valuable for sustainable land resources improvement and rehabilitation.

Keywords salinity, ecological management, soil quality

INTRODUCTION

Awareness of the ecological and environmental health of ecosystems around the world has been increasing in recent years. As a result, there has been a growing interest in sustainable agricultural alternative practices. In Thailand, the agricultural society has been criticized for problems with soil salinity, soil degradation, greenhouse gas release into the atmosphere, water pollution and a loss of wildlife habitat. Tree plantation has been associated with an increasing quantity of environmental and ecological benefits such as enhancement of microclimatic conditions, improved utilizing and cycling of soil nutrients, improved soil and water quality, creation of suitable habitats for insect and animal species, protection from erosion, and protection from wind (Jose et al., 2004). Ecological management such as tree plantation in salt-affected areas has the potential to alleviate salinity stress on farms for sustainable production.

Soils in Northeast Thailand are salt-affected due to salt bearing rocks (Department of Land Development, 1991), particularly in Nakhon Ratchasima, Khon Kean, Roi Et and Mahasarakham provinces (Department of Mineral Resources, 1982). Soil salinity has become one of the major determinants of crop productivity in those areas, and might have an adverse impact on soil physical properties (Boivin et al., 2004), chemical properties (Sumner, 2000) and soil microbial communities and activities (Zahran, 1997; Sardinha et al., 2003) and also influence on plant growth and yield (Marschner, 1995). Among them, changes in mineralization of C and N with increasing salinity have been observed (Nelson et al., 1996; Pathak and Rao, 1998).

Salt-affected soils may be reclaimed by growing salt-tolerant tree species, which improve the physical and chemical properties as well as biological activity in the soil (Garg, 1998). Investigations carried out at various research locations in India have shown that salt-affected soil can be improved by trees plantation. For example, incorporation of trees in the land can help in maintaining the nutrient pool and enhance soil fertility (Young, 1997; Rao et al., 1998). Tejwani (1994) also reported that tree plantation is an excellent strategy for reclamation of salt-affected soils. Tree litter improves soil fertility not only through the release of nutrients in the soil by mineralization but by also adding soil organic matter. Thevathasan and Gordon (2004) also reported that tree intercropping under temperate significantly enhanced the diversity of birds, insects, and earthworms; increased soil organic carbon content and N cycling; and improved soil quality. The objective of this study was to monitor the impact of salinity on soil quality under tree plantation in salt-affected area of Northeast Thailand.

MATERIALS AND METHODS

Study area

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 3 zones followed by 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 (2710 plants of 17 species). Woody plants such as common ironwood (*Casuarina equisetifalia* J.R. & C. Forst) and fruit plants such as manila tamarind (*Pithecolobium dulce*) in salt-affected area were grown covering with native grasses and weeds, i.e., torpedograss (*Panicum repens* L.).

Soil sampling and analysis

Soil was sampled from three random locations of each zone and unplanted soil near experimental site (control) at the depth of 0–20 cm during the rainy seasons of 2008 and 2010. The soils were analyzed to determine soil physical and chemical properties according to routine methods of the Land Resources and Environment section, Faculty of Agriculture, Khon Kaen University. Soil texture was determined by hydrometer method. Soil pH and electrical conductivity (EC) were determined in a 1:2.5 and 1:5 soil to water solution by pH meter and EC meter, respectively. Cation exchange capacity (CEC) was determined by 1 N ammonium acetate method. Total nitrogen (N) was measured by Kjeldahl method; available phosphorus (P) by the Olsen method, exchangeable potassium (K) by 1 N ammonium acetate and flame photometry; and total organic matter (OM) by using Walkley and Black method.

Microbial biomass C and N were determined in field moist subsamples immediately after sampling by the chloroform fumigation extraction method. For microbial biomass C (MBC), 20 g of fumigated and unfumigated soil were extracted with 100 ml of 0.5 M K_2SO_4. MBC in the extracts was determined after oxidation with $K_2Cr_2O_7$. For microbial biomass N (MBN), 20 g of soil was extracted with 100 ml of 1 M KCl. Besides, non-fumigated samples were extracted immediately after sampling. MBN was determined by the ninhydrin-reactive N method (Amato and Ladd, 1988). MBC and MBN were calculated as the difference between fumigated and unfumigated values and employing k_{EC} and k_{EN} factors of 0.33 (Sparling and West, 1988) and 3.1 (Amato and Ladd, 1988) to convert extracted organic C and N to microbial C and N, respectively. Microbial activity was studied by soil respiration using titrimetric method (Zuberer, 1991). This method was based on the determination of CO_2 evolved from the soils. Field moist soil (200g) was placed and incubated at 28°C in an airtight jar containing a vial with 15 ml of 1.0 M NaOH. After incubation of a day, the NaOH solution was removed and the trapped CO_2 titrated with 0.5 M HCl after precipitating the carbonate with excess 0.5 M $BaCl_2$. Soil respiration, i.e., evolved CO_2-C, was computed according to the equation (1) described by Anderson (1982) as shown below:

$$CO_2\text{-C (mg)} = (B-V)\ NE \quad (1)$$

where B is the volume (ml) of acid (HCl) used to titrate the alkali (NaOH) of blank (no soil), V is the volume (ml) of acid used to titrate the soil sample, N is the normality of acid (HCl), and E is equivalent weight of CO_2-C. The metabolic quotient qCO_2 (Anderson and Domsch, 1986) of each sampling period was calculated by using equation (2).

$$qCO_2 = CO_2\text{-C} / \text{MBC} \quad (2)$$

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

Statistical analysis: The data recorded was analyzed statistically using Statistix 8.0 software and Microsoft Excel software (2007) to compare each zone at 5% probability level.

RESULTS AND DISCUSSION

Soil physical and chemical properties

In this study, tree plantation covered with native grasses had a significant impact on soil physical properties of salt-affected soil. Soil texture of study area was sandy soil. Bulk density decreased from 1.72 g cm^{-1} to 1.55 g cm^{-1} under tree plantation, whereas soil moisture content increased from 9.3% to 13.5%.

Several soil chemical properties of salt-affected area were influenced by tree plantation and time (Fig. 1). Three years after planting (in 2010), decreases in the values of EC, Na, and K in the soil became apparent in growing trees when compared with the first year after planting (in 2008). Soil organic matter (OM) and total nitrogen (N) content in all zones by tree plantation increased with time since 2008, which were from 0.53 % and 0.057% in the first year after planting to 0.73% and 0.086 % in three years after planting, respectively. The increases in CEC, OM and N content could be attributed to the addition of leaf litter and root decay, which improved microbial activity in soil. The results confirm the findings of Mishra et al. (2004). Although there were no significant differences in pH and available P between tree plantation and unplanted soil, there were slight increases in all zones in year 2010.

Soil biological properties

The MBC and MBN values in 2008 and 2010 were significantly higher in tree plantation than in unplanted soil, with the highest value being with zone 3 (Fig. 2). It might be due to the accumulation of humus from decomposition of leaf litter and root decay, which increased soil organic C. Soil respiration, as a good index of the activity of microorganisms, was consistently lower in the unplanted soil when compared to tree plantation zones in both years 2008 and 2010. These results are in accordance to other findings, which showed decreased soil respiration (Sardinha et al., 2003; Tripathi et al., 2006) in natural saline soils. The metabolic quotient (qCO_2) was higher in 2008, probably as a result of stress by salinity on soil microflora (Anderson and Domsch, 1993; Rasul et al., 2006), whereas it tended to lower in 2010. A low metabolic quotient implies that the microbial populations were energetically efficient, i.e., allocating proportionally more carbon to growth (biosynthesis) than to maintenance (Zak et al., 1994).

There was a significant negative relationship between EC and microbial biomass C, microbial biomass N, basal soil respiration and metabolic quotient (Fig. 3). This relationship revealed the detrimental effect that soil salinity had on the soil microbial activity. These results are in line with the findings of Yuan et al. (2007). Increased soil microbial activity might be due to the ameliorative effects of trees and consequently organic matter inputs. According to Rao and Pathak (1996), carbon is an important factor influencing microbial activity in salt-affected soils.

Biodiversity index (H′) of soil biota in zone 1, zone 2 and zone 3 were 0.11, 0.63 and 0.71 in the first year after planting and 0.23, 0.95 and 0.75 in three years after planting, respectively. The results observed that biodiversity of soil biota after tree plantation was higher than before.

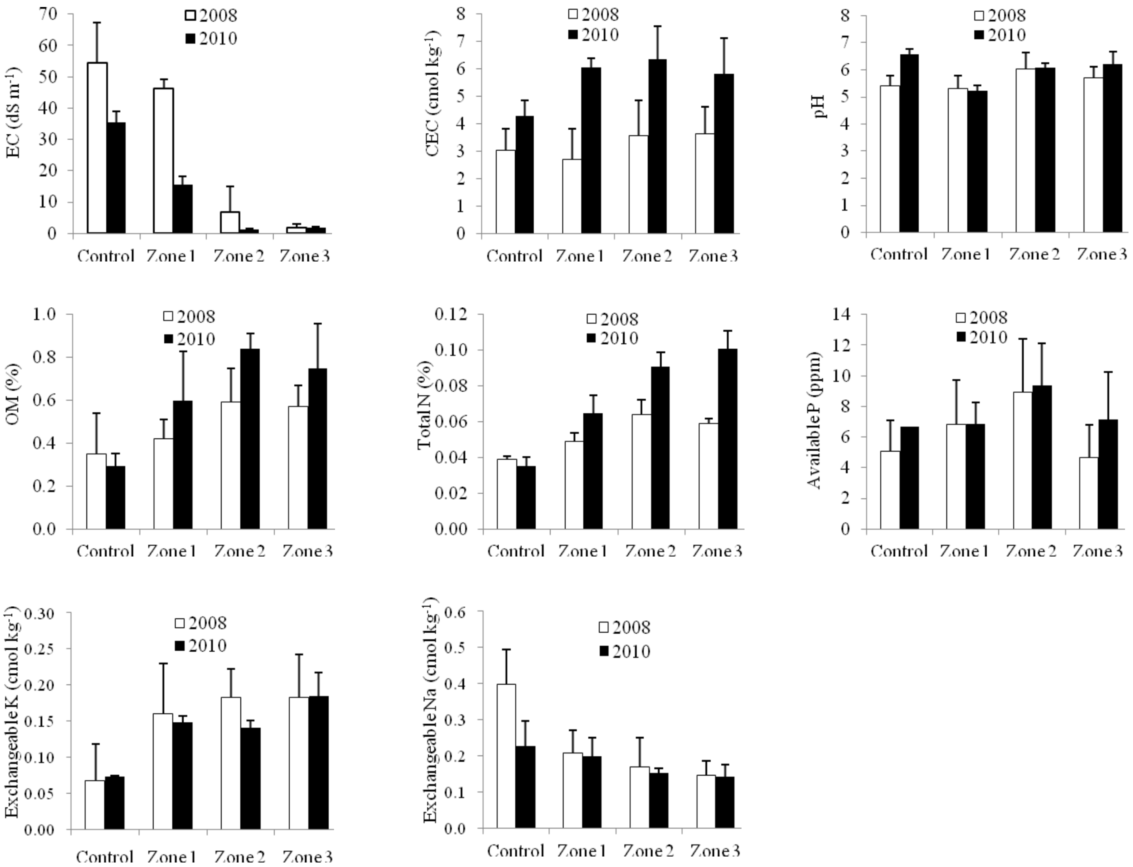

Fig. 1 Soil chemical properties of salt-affected soils after tree plantation
(2008 is the first year after plantation and 2010 is three years after plantation; Bars represent standard deviation)

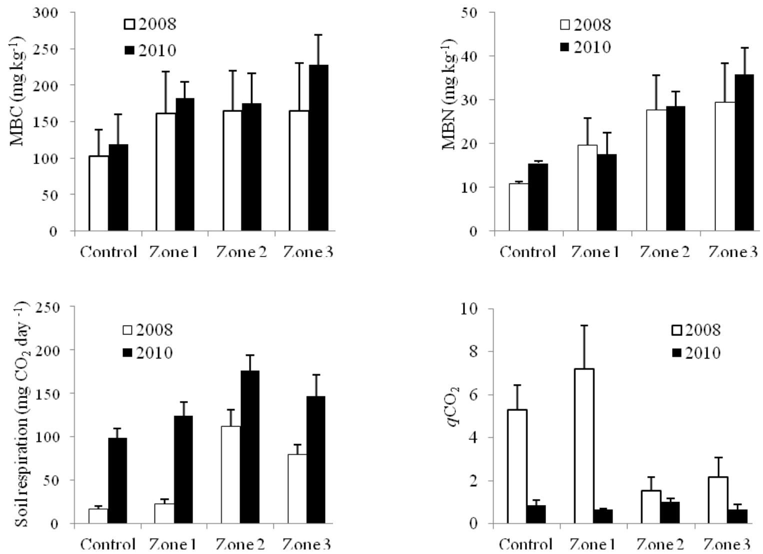

Fig. 2 Soil microbial parameters of salt-affected soils after tree plantation
(2008 is the first year after plantation and 2010 is three years after plantation; Bars represent standard deviation)

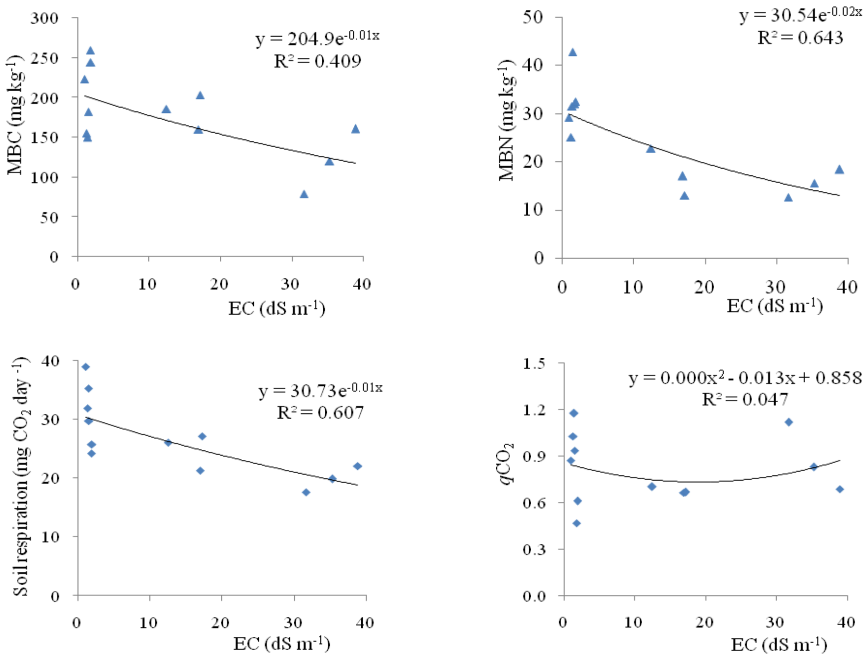

Fig. 3 Relationship of microbial parameters with electrical conductivity of salt-affected soils
(Regression equation, line of best fit and R^2 were shown)

CONCLUSION

Monitoring in salt-affected soil grown with tree species indicated more efficient changes in terms of dropping EC and decreasing Na^+ levels in the soil. In contrast, evidence of increased organic matter and total nitrogen showed after tree plantation. Likewise, there was greater microbial activity in salt-affected soil under tree plantation. It could be concluded that soil physical, chemical and biological properties were improved after tree plantation covered with native grasses in salt-affected soil. Therefore, it is pertinent that tree plantation has a great scope and potential in terms of ecologically sustainable land resources improvement and rehabilitation.

ACKNOWLEDGEMENT

This study was supported by the Research Project: “Problem Soils in Northeast Thailand”, Khon Kaen University, Thailand and the KKU Research Project “Improvement of Soil Fertility and Biodiversity in the Salt-Affected Lowland Area by Various Species Trees Pantation”.

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