Research article

Effect of Long-Term Rubber Tree Plantation on Soil Properties Comparing to Sugarcane Plantation in Khon Kaen, Thailand

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Abstract Following extensive land conversion from other crops to rubber plantations, Southeast Asia has become the main natural rubber producer in the world. Within Southeast Asia, Thailand is a leader of rubber production. This research addresses the question of the long-term effect of land conversion to rubber tree plantations on selected soil properties. The study reported here aimed to evaluate change in soil properties after 5 and 23 years of rubber tree plantation (5 RB, 23 RB) compared to soil properties under annual cash crops such as sugarcane (SG), in Kranuan district, Khon Kaen province, Thailand. Randomized sampling was conducted at soil depth increments from 0-10 to 150-160 cm. Topsoil organic carbon, total N and total K were higher in 23 RB than in the 5 RB and in the SG system. Available phosphorus in 23 RB was also higher than in soil under the 5 RB system, but not significantly different from that in the SG system. Soil pH was identical throughout the soil profile in the three observed cropping systems. We found evidence of soil compaction under the SG system at the 30-40 cm depth. Finally, topsoil in 23 RB had higher moisture content than that under the 5 RB and SG systems. Overall, this study indicated that, relative to cash crops such as sugar cane, conversion to rubber tree plantation in Northeast Thailand did not lead to land degradation and even improved some of the soil property indicators.

Keywords rubber tree plantation, soil quality, cash crops, soil degradation

INTRODUCTION

Rubber tree (*Hevea brasiliensis*) is an important economic tree in tropical areas. In 2015, Thailand was the first world rubber producer with 4.5 million tons (Thailand Board of Investment, 2016). In the past, Northeast Thailand was considered as a marginal area for rubber trees due to climatic constraints. During the last 20 years, in relation with expected high benefits, farmers have converted many of their annual cropland (sugar cane, cassava) to rubber plantations. The environmental impact of this shift from annual to perennial crops remains unknown. Previous intensive and continuous annual cash cropping has degraded sandy soils of the Northeastern plateau. In particular, deep and repeated tillage and lack of organic restitutions resulted in compaction of deeper layers (20-40 cm) and reduced soil organic matter levels to <1%. Such degradation is sometimes so severe that near-permanent erosion gullies occur even when the slope is <5%. In rubber plantations as in many other perennial tree plantations, the absence of tillage and the continuous accumulation of organic debris on the soil surface appears to facilitate a restoration of soil physical characteristics and an increase in soil organic matter. On the other hand, the absence of fertilization in rubber plantations may result in chemical degradation, acidification and a decrease in mineral nutrients.

OBJECTIVES

The objective of our study was to compare selected physical and chemical properties of soil under sugar cane, young and old rubber plantations and assess the impact of the rubber plantations on sandy soil already degraded by continuous annual cropping systems.

METHODOLOGY

Site Description

A study site representative of rubber tree plantations of Northeast Thailand was selected at Kham Hai village, Kranuan district, 50 km north of Khon Kaen city. Parent material was alluvial sand stone and current altitude is around 250 m asl. Soil is Chum Puang series (Cpg) with coarse-loamy, siliceous, isohyperthermic Typic Kandiustults; pH is ranging from 5.5 to 7 in the top soil and from 4.5 to 5 in subsoil and it is considered as a low fertility soil (LDD, 2015). The rubber tree plantation was converted from fields where cassava and sugarcane alternated for several decades. We compared 3 land uses: sugarcane (SG), 5 and 23 year old rubber tree plantation (5 RB and 23 RB, respectively). For each land use we sampled 3 replicates, i.e. blocks A, B, C. The blocks were located within a few hundred meters from each other (Fig. 1). As each plot was located at least 100 m from each other, we assumed that they were independent from each other, which allowed the use of ANOVA.

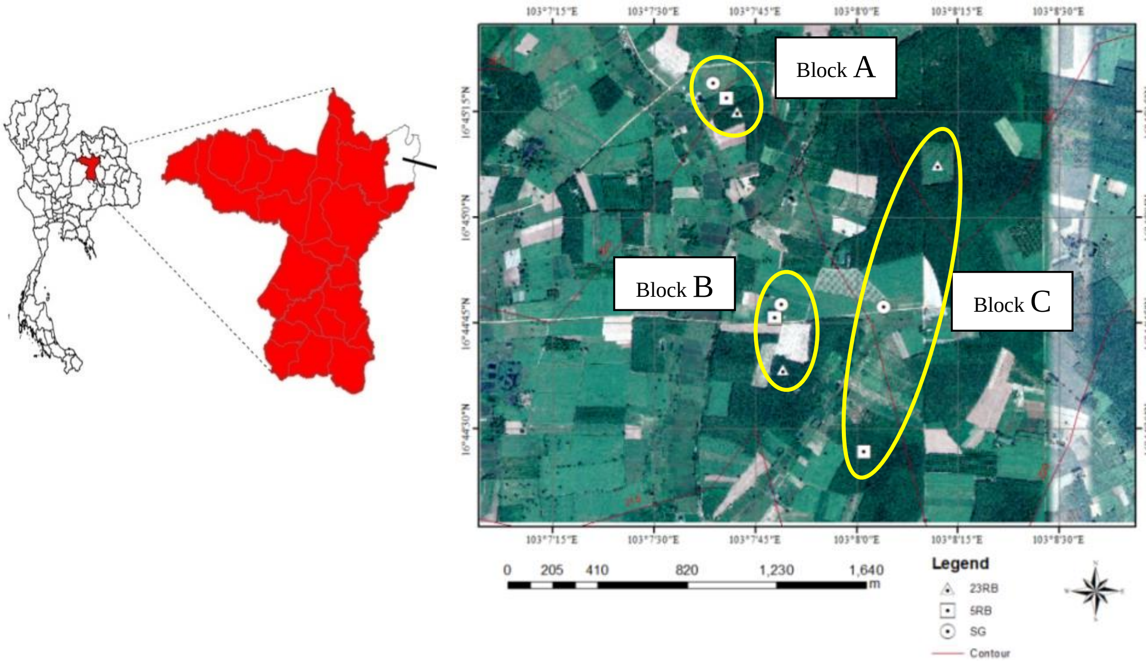

Fig. 1 The study plots in Khamhai village, Kranuan district, Khon Kaen, Thailand

○=sugarcane plantation (SG), □=5 years old rubber tree plantation (5RB),
△=23 years old rubber tree plantation (23RB) in Blocks A, B, C

Soil Sampling and Analysis

Rubber tree spacing was 2.5 x 7 m between trees and lines, respectively. Sugarcane spacing was 0.3 x 1.5 m between plant and lines. Samples were collected at 3 points per block, in which 3 points were randomized within the plot in the area of 50 x 50 m. At each point, samples were collected at 6 different depths between the plant rows: 0-10, 10-20, 30-40, 60-70, 100-110 and 150-160 cm (Haile et al., 2008, Gama-Rodrigues et al., 2010, and Monroe et al., 2016). The samples were oven dried at 105°C for 48 hours to determine the water content; after that, samples were sieved with 2 mm mesh size and stored in sealed plastic bags for laboratory analysis. Soil pH was measured in 1:2.5 soil: water suspensions with glass electrode pH meter. Organic Carbon (OC) was determined using the Walkley and Black's method, the total N was determined by Kjeldahl's method, while available phosphorus (P) was extracted by BrayII method. Exchangeable K was determined by extraction with neutral 1M NH_4OAC. Percentage of coarse sand, find sand was determined by sieving.

Statistical Analysis

Data were tested for normality; standard deviations were computed and outliers identified. Data were analysed by analysis of variance (ANOVA) as randomized complete block design (RCBD). All computations were done with the R software, and the Tukey's test was applied to identify differences between means at 5% probability level. Microsoft Office Excel was used to plot figures.

RESULTS

Soil Physical Properties

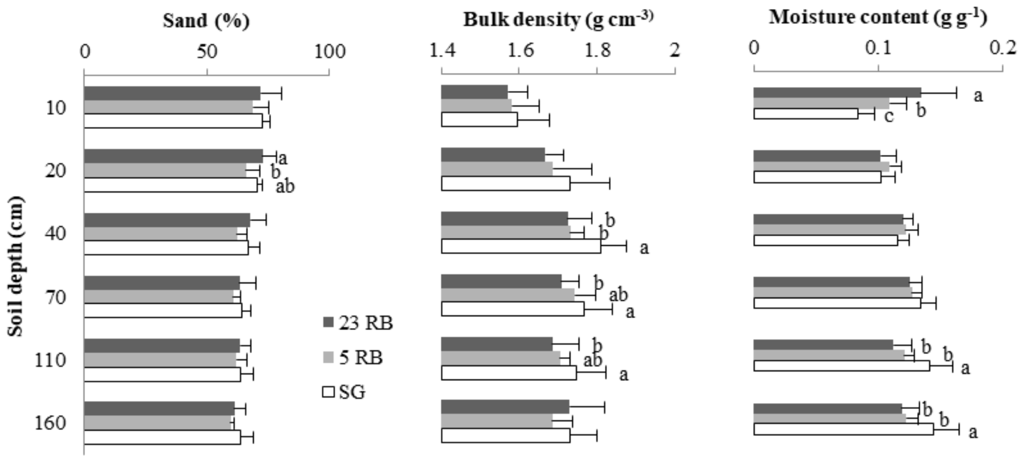

Fig. 2 Soil physical properties of three studied plantations 23RB, 5RB and SG in Khamhai village, Kranuan district, Khon Kaen, Thailand

Throughout the soil profile 0-160 cm depth, bars followed by different letters are significantly different according to Tukey HSD test n= 24, α=0.05.
Horizontal solid lines correspond to the standard deviation

Sand content in this area was > 60% on the average. The analysis revealed that three study plots were not significantly different throughout the soil profile. The high amount of sand content was consistent with low fertility and low content of plant nutrients. Soil moisture content of the three 23 RB plantations was higher ($p<0.001$) at 0-10 cm (0.13 g g^{-1}), than that of 5 RB (0.11 g g^{-1}) and SG (0.08 g g^{-1}) samples. In the 10-70 cm depth layers, there were no differences in soil moisture content between the three cropping systems (Fig. 2). Between 70 and 160 cm depths, however, soil moisture content was higher in the SG than in either the 23 RB and 5 RB systems ($p<0.001$). The bulk density of the 0-20 cm depths was not significantly different among systems.

However, at soil depths of 30 to110 cm depth, bulk density was higher in the SG than 23 RB or 5 RB systems (Fig. 2). In the SG system, the highest compaction was found at 30-40 cm depth (1.81 g cm^{-3}).

Soil Chemical Properties

The soil pH of the entire area was very low which is the case for sandy soils of this region of Thailand and for soils of this particular classification (Ultisols). We found that long term rubber tree plantation did not appear to change the soil pH in the top 10 cm of soil depth compared to 5RB and SG systems ($p>0.29$). However, the 10-20 cm layers of the SG system revealed a lower mean pH (5.3) compared to that in 5 RB system (5.6) ($p<0.01$). The pH at depths between 30 and 110 cm were not different for the 3 situations whereas a pattern similar to that observed at 10-20 cm, i.e. 5 RB > SG but 23 RB not different from either 5 RB or SG, was found at 110 and 160 cm depths (Fig. 2).

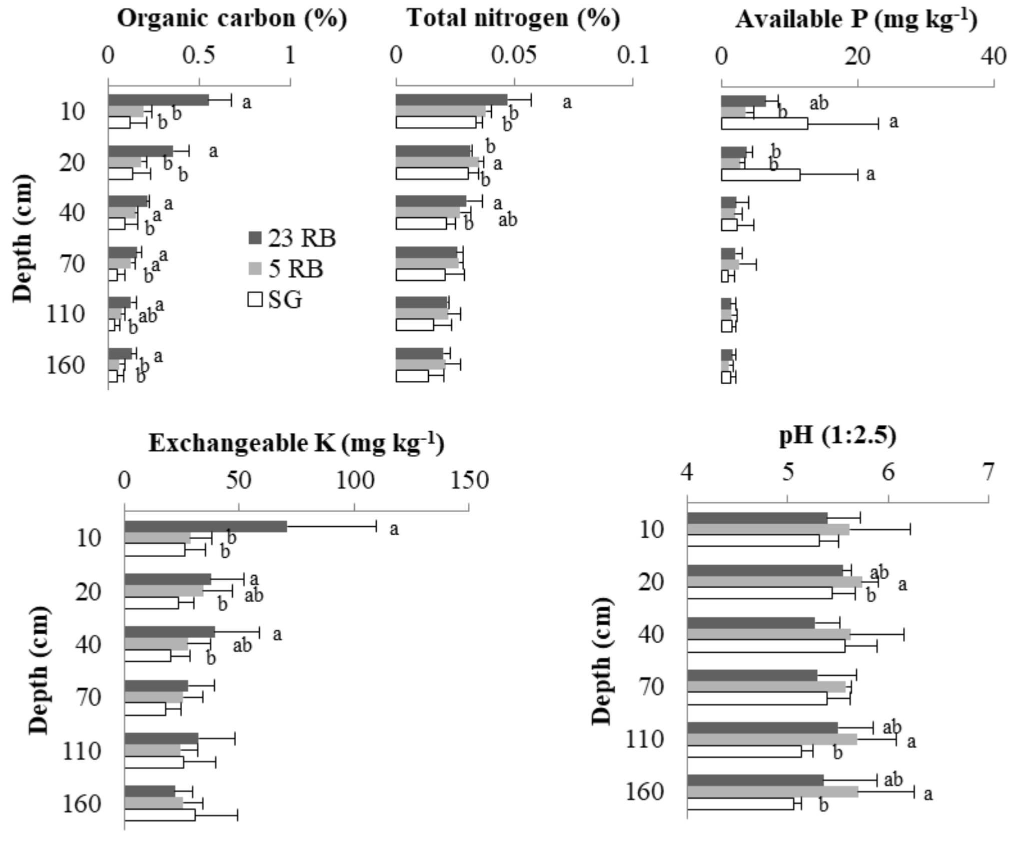

Fig. 3 Nutrient, Carbon content and pH of the three plantation systems 23 RB (23 years under rubber), 5RB (5 years under rubber) and SG (sugar cane system) in Khamhai village, Kranuan district, Khon Kaen, Thailand

Throughout the soil profile 0-160 cm depth, bars followed by different letters are significantly different according to Tukey's HSD test n= 24, α=0.05.
Horizontal solid linescorrespond to the standard deviation

Organic carbon was higher in the 23 RB system than in SG throughout the soil profile and also different from 5 RB from the surface to 30 cm (Fig.2). OC of the 23 RB system was 2.75 and 4.58 times higher compared to 5 RB and SG systems, respectively. Total N in the studied area was also very low, less than 0.05%on the average, even in the top soil of the 23 RB system (Fig. 3). The 23 RB was characterized by the highest total N at 10 cm, while 5 RB was highest at 20 cm depth. There were no major differences between the 3 systems deeper in the profile. Levels of available phosphorus of 23 RB, 5 RB and SG were also very low throughout the soil profile, again consistent with the soil classification of (Ultisol). There were, however, significantly higher amounts of P in the top10-20cm of SG. Finally, exchangeable K was higher in 23 RB than in the SG system from the surface down to 40 cm depth.

DISCUSSION

This study revealed that organic carbon levels increased slightly, but not significantly in the top soil of the 23-year-old rubber tree plantation compared to that in the 5-year-old rubber tree plantations and sugar cane plantations. This low increase in OC might be due to the low input of litter in rubber tree plantations compared to that occurring in natural forests. Naturally occurring tropical forest structure typically comprises 4 layers; namely the emergent layer, the canopy, the understory and the forest floor. Rubber tree plantations, however, only have the canopy layer with hardly any growth on either the understory or the plantation floor (Spies, 1998). The four layers of rain forest structures play an important role for ecosystem, especially soil protection and in improving soil fertility. Soil fertility accumulation also depends on tree species (Ramesh et al., 2013), with some species producing more biomass than others and/or biomass that is more readily degradable often caused by differences in lignin/nitrogen ratio, C/N, and cellulose etc) . Sang et al. (2013) reported that *A. mangium* plantations decreased soil bulk density and increased OC, total N and available P compared to secondary forest and pasture. It has been reported that the litter fall of rubber tree plantation is less than that of oil palm, jungle rubber and natural forest, amounting to an average of only 3.84 Mg ha^{-1} while that of natural forest was 9.04 Mg ha^{-1}. This clearly results in a lower nutrient return to the soil (Kotowska et al., 2016). The total nitrogen in the top soil of 23 RB was significantly higher compared to that of either the 5 RB or the SG systems, probably because of higher biomass accumulation. However, this increase in total N in 23 RB was, as in the case of OC, very small, probably due the large amounts of N needed for rubber tree growth or exported in latex production. Indeed, Iewkittayakorn et al. (2018) reported that the N content of latex is of the order of 40%. Finally, available P in the SG system was significantly higher than that in either the 23 RB or 5RB system, most likely as the result of previous chemical fertilization.

The main result of the work presented here was that OC, total N and exchangeable K in old rubber tree plantation were higher at some soil depths than in 5RB and SG systems. This is in line with results of Lakshmi et al. (2016) who reported reductions of N and K in sugarcane mono-cropping. Long term sugarcane cultivation in semi-arid regions and soils can, reportedly, increase OC and total N in 0-10 cm soil depth (Beza and Assen, 2016) which is not consistent with our results. This outlines the need for further studies to clarify the respective effects of sugar cane and rubber tree on soil fertility depending on soil type and climate. In this study, we also report that the BD of sugarcane plantation was very high, reaching 1.81 g cm^{-3} at the 40-70 cm depth, which constitutes a compacted layer. This reveals the negative impact of the use of heavy machinery to manage crops on such sandy. weathered soils (Usaborisut, 2011; Barzegar et al., 2005). Soil preparation is also a known a factor influencing SOC loss and soil degradation (Bilandžija et al., 2016). Together with improved OC levels at the surface in the 23 RB system, the higher soil moisture content illustrates the widely reported positive effect of organic matter on water retention (Brady, 1990; Robin et al., 2018; Minasny and McBratney, 2018; Ankenbauer and Loheide, 2017). Deeper in the soil however, our study indicates that soil moisture content was higher under the sugar cane system, which may reflect a lower water uptake than that of 23 and 5 year old rubber tree plantations.

CONCLUSION

In the studied plots of Khon Kaen province, Northeastern Thailand, rubber tree plantations were found to improve soil fertility, especially soil organic carbon as well as total N, and exchangeable K in comparison with a sugar cane system. Available P in sugarcane plantation was higher than in rubber tree plantation most likely because of the effect of fertilization. In this specific agroecosystem, rubber tree plantations did not appear to have a negative impact on soil fertility relative to previously established sugarcane crops. However, more extensive long-term studies should be carried out to clarify the relevance of the results of this study.

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