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Research Article
Soil Fertility and Diversity of Microorganism under Rubber Plantation

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Abstract

Background and Objective: To develop socio-economic in Northeast Thailand, growing of rubber trees are occur instead some cassava and sugarcane plantations. The environmental consideration respected for rubber plantation according to chemical fertilizer application for increasing of latex yield in the long-term. Soil fertility and variations of microorganism were investigated under rubber plantations in Northeast Thailand. **Materials and Methods:** A voronoi sampling method was used to collect soil samples from different ages (5, 11 and 22 years) of rubber in 3 areas. For each plot, 4 surface (0-10 cm) soil samples were randomly collected and composited. The soil samples were analyzed for chemical and physical properties and microorganisms. An analysis of variance was performed on data for each parameter with each treatment. **Results:** The study showed the soil pH, total N, exchangeable K and Ca, OM, NO_3^-, soil moisture and soil microorganisms tended to increase with the increasing age of the rubber trees, while the soil bulk density tended to decrease. **Conclusion:** Growing rubber trees as a monoculture in long-term resulted an improvement of some chemical and physical properties of soil and microorganisms. To conserve soil fertility under rubber plantations, the use of organic fertilizer combined with chemical fertilizers is recommended.

Key words: Latex yield, cassava, ecosystem, mineralization, rubber plantation, bulk density

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

In Northeast Thailand, rubber plantations have developed rapidly. Conversion of natural forest to rubber plantations affected the species and density of soil macrofauna[1] including growth of rubber tree at the beginning after plantation. Moreover, the rubber trees plantation also replaced cassava and sugar cane, in Laos the rubber plantations are often established to the detriment of natural spaces. The introduction of *Hevea brasiliensis* leads to significant changes in land use, environment and ecological processes, including soil condition, biodiversity and carbon sequestration[2-4]. Many researchers predicted that soil fertility in a rubber plantation decreases with the age of the rubber trees, especially with crop removal and soil erosion in sloping areas. Fertilizer application, legume crop cover and the use of suitable cropping systems can maintain soil fertility. However, gas emissions from rubber plantations are slightly low. Moreover, rubber plantations can mitigate global warming by carbon sequestration[4].

With the development of rubber plantations, the purposes of latex extraction and rubber trees have a natural life of 30 years. Due to the extraction of latex and removal of biomass from rubber plantations and nutrient loss from the soil of rubber plantations in relation to substituted natural forests are obvious, even though long-term or life-time quantified research of these effects was not available before this study. Many studies have been carried out to improve rubber production, including studies of soil and water loss, soil fertility and growth characteristics[5-7]. However the long-term environmental changes in soil fertility and biodiversity may cause by rubber trees planting has not been studied. The objectives of this study were to assess variations in soil fertility and microorganism diversity after other types of vegetation were replaced by rubber plantations in Northeast Thailand. Also, further to provide fundamental data that could be use for the sustainable management of rubber plantations.

MATERIALS AND METHODS

Soil sampling: The experiment was conducted in Kranuan district, Khon Kaen province, Northeast Thailand. According to 2015-2016 data, this area is characterized by a tropical climate with an acid sandy soil. Four soil samples at a depth of 0-10 cm were collected from each plot twice a year for 2 years (Voronoi method) from rubber plantations of different ages (5, 11 and 22 years), each in a different area. Soil samples were stored in plastic bags at 4°C awaiting analysis of chemical and physical properties and microbial biomass. Prior to the establishment of rubber plantations, farmlands and secondary forest were the predominant land uses in the area. At present, with the establishment of a rubber estate in the area, slashing without burning is the main weed and grass control practice in the plots.

Soil chemical and physical analysis: Soil samples were air-dried, ground and passed through a 2 mm sieve and then analyzed for the following chemical properties: total N (kjeldahl method), available P (Bray II and molybdenum-blue method), exchangeable K (1 N NH_4OAc, pH 7 and flame photometry method), exchangeable Ca (1 N NH_4OAc, pH 7 and flame photometry method), organic matter (Walkley and Black method), soil pH (pH meter), electrical conductivity[8-10], NH_4^+ and NO_3^- (Kjeldahl method). Physical properties, such as soil moisture content and soil bulk density, were also determined.

Soil moisture content and soil bulk density: Soil moisture content was measured using a gravimetric method (micro-auger) at 0-5 cm depth below the soil surface every 6 months (at the beginning and end of the rainy season) for 2 years. Soil wet weight (WW) was determined. Soil was dried at 105°C for 24 h or until a constant dry weight was achieved and then weighed (DW). Percentage soil moisture content and soil bulk density (g cm^{-2}) were then determined.

Determination of microbial population (dilution plate count by selective media): To determine microbial population from soil sample, pour plate technique is a method used for isolation and purification. The initial samples were diluted to various concentrations by serial dilution technique in order to make bacteria diluted enough for single colonies. The sample at a suitable concentration was raised on the petri dishes and then agar medium was poured into petri dishes. The agar medium incubation temperature is approximately 48-50°C, bacteria and yeast was not killing by the culture. The mixture was mixed to distribute evenly by turning on agar plates. The petri dishes were incubated at room temperature for 48 h. The microbial colony will be occurring. Microbial cells are glued to the inside of the culture and will be a single colony infection up[11].

Statistical analysis: An analysis of variance was performed on data for each parameter with each treatment. All analysis were carried out using Statistical software version 8.0. Least significant differences (LSD) were calculated at a significance level of $p<0.05$. Standard deviation was also calculated for the variance.

RESULTS AND DISCUSSION

Soil fertility: The extraction of latex and weed control from rubber plantations are key factors in the decrease in soil nutrients and changes in diversity of microorganism. With increasing age of the rubber plantation stand, soil organic matter, NO_3^- and soil moisture were significantly increased. The exact time-period was 2015-2016 (24 months), soil pH, total N, exchangeable K and Ca, OM, NO_3^-, soil moisture and soil microorganisms tended to increase (Table 1) with the increasing age of rubber trees, while the soil bulk density tended to decrease (1.48 g cm^{-2}). Similar results of decreases in available P from 12.88-6.50 ppm were reported in a rubber plantation over a 17 year period[12]. The P is easily absorbed onto the surface of oxides of F, Al, Mg and hydroxides and becomes a nutrient, which is difficult to be utilized by plants, often causing the shortage of P.

Biodiversity of microorganism: The leaf coverage provided by rubber trees and their root system regulates the microclimate, allowing a range of secondary plants to flourish and providing protection of soil against dehydration and the erosive effect of rain[13]. In addition, rubber trees also provide a habitat for a great variety of fauna. It has also been reported that biodiversity remains remarkably high in rubber plantations, in marked contrast to most other forms of monoculture[14]. The research found that soil microorganisms were at highest levels in the 11 and 22 year-old rubber tree plantations and the community of actinomycetes, bacteria and fungi varied between the different aged rubber tree plantations (Table 2). Actinomycetes were found to be more prevalent than either bacteria or fungi. Variation of soil microorganisms is related to the succession of vegetation at different stages growth of rubber tree.

Previous researchers reported that diversity of soil microbial communities affected the bi-directional exchanges between above-and below-ground communities[15-19]. Many more microorganisms exist in top soil, where food sources are plentiful, than in the subsoil. The change in the soil microbial community was not directly affected by vegetation, although vegetation can drive soil microbial community changes through indirect mechanisms, such as altering pH, litter chemistry, root density and carbon secretions[11,20]. Soil pH, organic matter, NO_3^- and soil moisture were important factors affecting the soil bacterial community. The results found that the composition of the soil microbial community was closely related to soil properties and vegetation at different stages growth of rubber tree. Vegetation and soil characteristics of rubber tree plantations were more complex and changeable compared to tropical rain forests. Furthermore, the microbial community could provide an indicator of soil health and quality. Actinomycetes, bacteria and fungi are the most abundant and diverse groups of soil microorganisms[21]. They play vital roles in terrestrial ecosystems through mineralization of dead organic matter, incorporation of humic compounds into the soil mineral layers, cycling of carbon and nitrogen and the provision of nutrients for plant growth[22-25]. These factors contribute to healthy soil which supports the growth of rubber trees.

Table 1: Soil properties in different aged rubber tree plantations in the Kranuan district, Khon Kaen province, Thailand

	Rubber tree age (year)			
Soil properties	5	11	22	F-test
pH (1:1 H_2O)	5.28	5.55	5.43	ns
Total N (%) (micro-kjeldahl)	0.34	0.39	0.51	ns
Available P (mg kg^{-1}) (Bray II method)	12.88	11.35	6.50	ns
Exchangeable K (ppm)	45.66	59.65	64.66	ns
Exchangeable Ca (ppm)	163.26	211.60	176.84	ns
OM (%)	0.48^b	0.60^b	0.90^a	*
EC (µS cm^{-1})	19.81	18.52	22.30	ns
NH_4^+ (mg kg^{-1})	7.16	5.91	7.81	ns
NO_3^- (mg kg^{-1})	8.96^b	9.36^b	14.88^a	*
Moisture (%)	6.02^b	7.79^{ab}	9.12^a	*
Soil bulk density (g cm^{-2})	1.53	1.53	1.48	*

ns: No significant difference, *Significant difference at $p \leq 0.05$, different letters indicate a significant difference at $p \leq 0.05$

Table 2: Soil microbial population in different aged rubber tree plantations in the Kranuan district, Khon Kaen province, Thailand

	Microbial population ($\times 10^4$/g dry soil)		
Rubber tree age (year)	Actinomycetes	Bacteria	Fungi
5	293.38	44.84^b	9.52
11	350.94	26.57^b	4.96
22	326.88	337.09^a	14.93
F-test	ns	*	ns

Means in the same column with different letters are significantly different at $p \leq 0.05$ by LSD, *Significantly different at $p \leq 0.05$, ns: No significant difference

CONCLUSION

This study discovered the changes in soil properties with increasing age of rubber tree plantation that can be beneficial for crop growth, ecosystem service and soil degradation. The vegetation and soil characteristics of rubber tree plantations were more complex. Thus an actinomycetes, bacteria and fungi are the most abundant and diverse groups that play a vital roles in terrestrial ecosystems through mineralization of dead organic matter, incorporation of humic compounds into the soil mineral layers, cycling of carbon and nitrogen and the provision of nutrients for soil and rubber trees growth.

SIGNIFICANCE STATEMENT

This study discovers the increasing age of rubber tree plantation and the possible synergistic effect of soil organic matter, NO_3^-, soil moisture content, the soil bulk density and biodiversity, especially bacteria community that can be beneficial for ecosystem service, soil physical and soil chemical properties. This study will help the researcher to uncover the critical period of nutrients loss under rubber tree plantation that many researchers were not able to explore. Thus, a new theory on these macronutrients combination and possibly other combinations, may be arrived at.

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