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Research articles

Soil characteristics pattern with the depth as affected by forest conversion to rubber plantation

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Abstract: This research was an attempt to study the impact of forest conversion to intensive rubber plantation on soil characteristics. We selected three landuses (forest, jungle rubber, and rubber plantation) in Bukit Duabelas and Harapan landscape, Jambi, and each repeated three times. Soil profiles were described and sampled at every 10 cm layer to 200 cm depth. Soil bulk density, pH, exchangeable basic cations content, and CEC were determined. The result showed that in three landuses, bulk density is relatively low in the upper 20 cm, but increased with depth. Clay content was lower in forest than other landuses, and increased with depth in forest and jungle rubber. In rubber plantation however, fine clay was accumulated at 60-140 cm depth. The CEC pattern with depth was in accordance to the clay content. There was no significant difference in soil pH between all landuses. In rubber plantation, soil pH was commonly higher in the surface, which probably due to liming activities. Sum of bases decreased with depth and tended to be generally lower in rubber plantation.

Keywords: *forest, landuse change, rubber plantation, soil development, soil depth*

Introduction

Forest land cover in Indonesia has declined since 1950 (the forest area about 162 million hectares) to 1997 (the forest area about 95 million hectares) and has continued until the period of 2000-2009 became 79.5 million hectares (Sumargo *et al.*, 2011). Indonesia is the second largest rubber producer in the world with a total production reached 3.01 million tons and more than 15 million people depend on the income of rubber (Kopp *et al.*, 2014). About 72% of national rubber production was produced from a rubber plantation in Sumatra and Kalimantan Barat (Arifin, 2005). BPS (2004) mentioned that Jambi has about 465.109 Ha rubber plantation with total production of 197.865 tons; in which about 99.6% managed by community (Kopp *et al.*, 2014).

Rubbers were originally planted in between other trees and not intensively managed, which is now known as jungle rubber or agroforestry (Arifin, 2005). As time passes and new technologies developed, people started to apply the monoculture's rubber system with intensive management.

Rubber plantations in Jambi province are generally in Ultisol (Junaedi, 2010), which normally developed in areas with high rainfall intensity. Landuse change from forest into rubber plantations affected soil properties, such as litter inputs (Hairiah *et al.*, 2004), soil bulk density, soil porosity, water movement in the soil, and content of bases in the soil (Prijono and Wahyudi, 2009; Junaedi, 2010; Deekor *et al.*, 2012; Li *et al.*, 2012). Changes in soil bulk density, soil porosity and water movement in the soil will indirectly determine the intensity and thickness of the translocation of soil particles. Clay translocation and accumulation process had been studied; such as the development of soil texture by the process of bioturbation and translocation (Phillips, 2007), lessivage as the main process of soil formation (Quénard *et al.*, 2011), the accumulation of clay and formation of argillic by aeolian deposition

(Elliott and Drohan, 2009), and the accumulation of clay and carbonate on the different precipitations (Gunal and Ransom, 2006). In Jambi itself, the studies about the effect of forest conversion were commonly focused on the characteristics in the top soil (Prasetyo and Suriadikarta, 2006; Junaedi, 2010; Refliaty and Marpaung, 2010). Unfortunately, those studies did not explain how the forest conversion into other landuses could affect the pattern of soil characteristics with depth.

Materials and Methods

Bukit Duabelas landscape of Sarolangun District and Harapan landscape of Batanghari District, Jambi Province were selected as sites of the research. In each site, we selected three landuse systems (forest, jungle rubber and rubber plantations), and repeated three times (Figure 1).

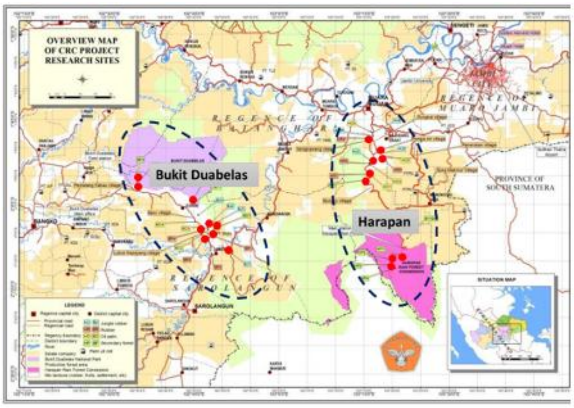

Figure 1. Research Location Map

The site locations were identified as Ultisols. Soil profiles were described and sampled at every 10 cm layer to 200 cm depth, as it is assumed that soil development is established in this depth (Soil Survey Staff, 2014). Soils were sampled in two methods, undisturbed and undisturbed soil samples. Soil samples were then analyzed for soil bulk density (gravimetric), soil particles distribution (sand, silt, and clay in coarse, medium and fine sizes (Gee and Bauder, 1986), soil pH (pH meter, pH H_2O 1:1), CEC and content of exchangeable basic cations (NH_4OAc pH 7).

Results and Discussion

Soil characteristics

The soils in Bukit Duabelas and Harapan were developed from different parent materials (Mangga, *et al.*, 1993), which would determine their characteristics. Bukit Duabelas were heavier soils (clay) than in Harapan (loamy and sandy). Soil texture in study sites vary from coarse (sandy clay) to fine texture (clay and fine clay). Allen *et al.* (2015) and Guillaume *et al.* (2015) classified soils in both locations as Acrisols (IUSS Working Group WRB, 2006), which is equivalent to Ultisols (Soil Survey Staff, 2014). Ultisols are normally characterized by acid and very acidic soil, low base saturation (<35%) and low cation exchangeable capacity (CEC <16 cmol / kg soil), due to very intensive leaching process.

Soil bulk density

The result showed that soil bulk density increased with depth in all landuses (Figure 2), which was probably due to heavier texture in the deeper layer. This results were in accordance to other studies elsewhere (Bonifacio *et al.*, 2009; Quénard *et al.*, 2011). There was no significant difference between the three landuses. However, compaction tended to occur at shallower layer (40 cm) in Harapan.

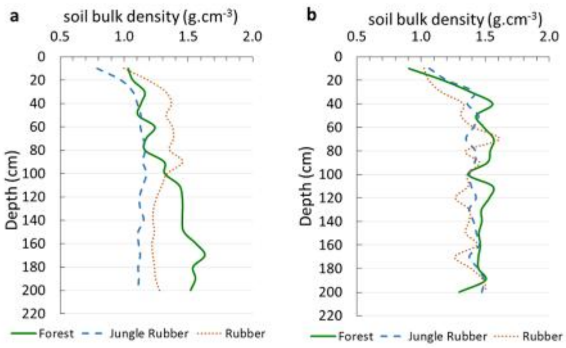

Figure 2. Soil bulk density in Bukit Duabelas (a) and Harapan (b)

Clay content

Clay content increased with depth in both locations (Figure 3). The clay content in Bukit Duabelas landscape is higher (30-61%) than in the Harapan landscape (21-49%). We also observed that fine clay content in Bukit Duabelas higher than in Harapan (Figure 4). The clay content tended to be lower in forest than other landuses. The pattern of fine clay was following total clay content. The accumulation of fine clay starting at 40 cm depth in the forest, and at 20 cm depth. in the jungle rubber and rubber plantation. Maximum illuviation of fine clay was indicated at the depth of 100-140 cm in rubber plantation. This showed that clay translocation still occurred at deeper layer in rubber plantation than other landuses. In Harapan landscape (Figure 4b), fine clay content still showed considerable increased up to 200cm depth in the forest and jungle rubber. However, a different pattern shown in rubber plantation. In both landscapes, the fine clay content was maximum at 60-140 cm depth, then decreased again to a depth of 200 cm.

Overall, forest cover did not affect of clay translocation. Rezaei et al. (2012) mentioned that it would take 50 years of landuse change from forest to other landuses before soil physico-chemical properties could change. However the distribution pattern of fine clay accumulation in both locations, indicated that the clay translocation more intense in the rubber plantation rather than forests and jungle rubber.

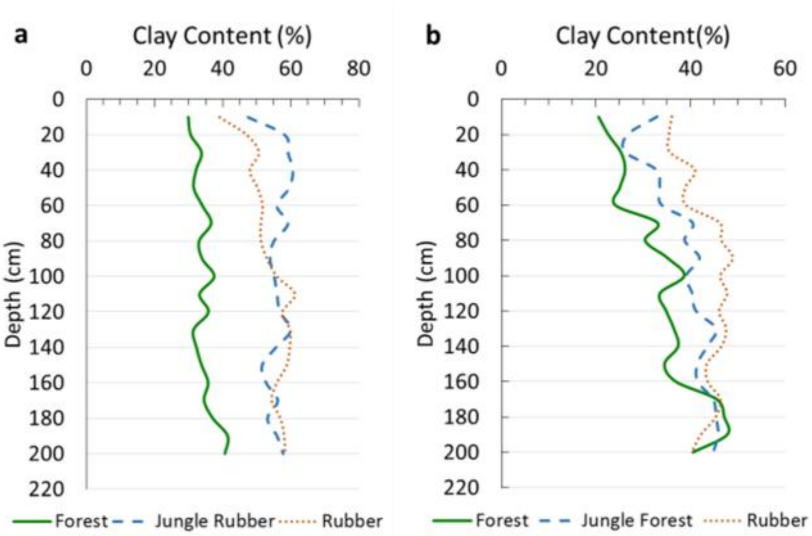

Figure 3. Clay content in Bukit Duabelas (a) and Harapan (b)

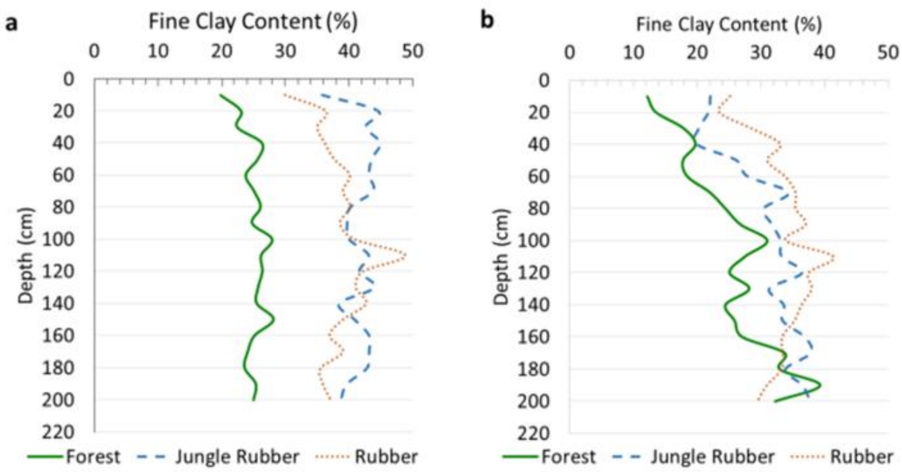

Figure 4. Fine clay distribution with depth in Bukit Duabelas (a) and Harapan (b).

Soil pH

The result showed that soil pH at study sites was ranging from 3.7 to 4.8 (very acid to acid). Figure 5 shows that soil pH increased with depth in Bukit Duabelas and decreased with the depth in Harapan. Leaching of bases was expected to be more intensive in Harapan, due to a lower clay content.

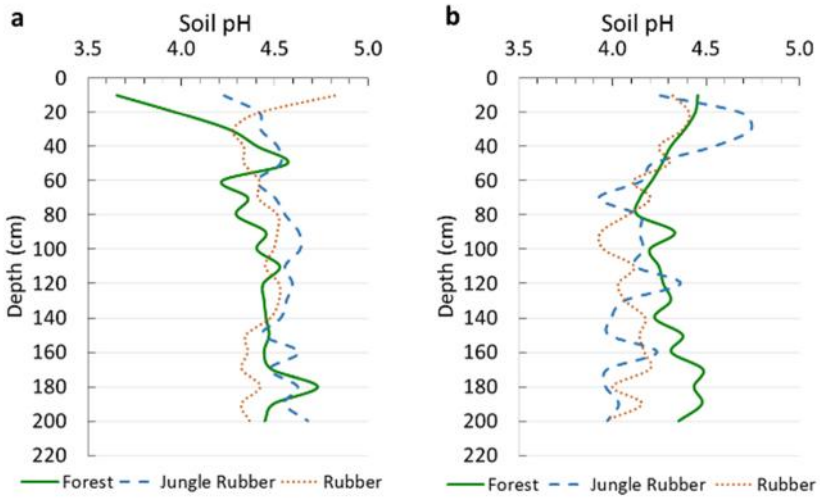

Figure 5. Soil Acidity in Bukit Duabelas (a) and Harapan (b)

Cation exchange capacity and sum of bases

Cation exchange capacity (CEC) in Bukit Harapan Duabelas and Harapan (Figure 6), generally were <10 me/100g soil, except in the jungle rubber in Bukit Duabelas. The CEC slightly increased with depth. The CEC tended to be higher in Bukit Duabelas than in Harapan, due to the higher clay content. Similarly, CEC in the forest was lower than other landuses. The pattern of the sum bases with depth was unsignificantly different between the three landuses (Figure 7a). This was probably due to: 1). the very low CEC, hence a very low capacity to retain cations, 2). in addition, the soils of study area were developed on very humid climate (total rainfall 2,902 mm /yr in Bukit Duabelas and 2,567 mm/yr in Harapan Harapan (Kotowska et al., 2015), enhance intensive leaching process in all landuses, 3). the studied forest was not primary forest, but secondary forest, which undergo rather intensive disturbance.

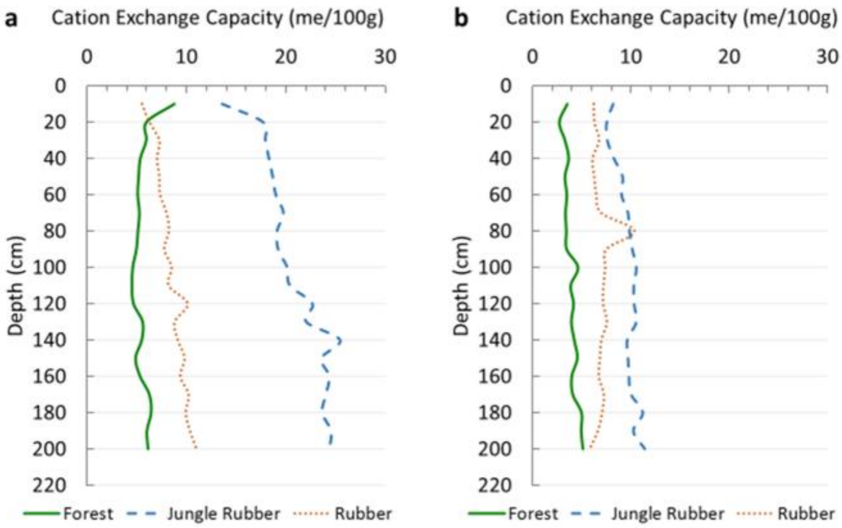

Figure 6. Depth of cation exchangable capacity in Bukit Duabelas (a) and Harapan (b)

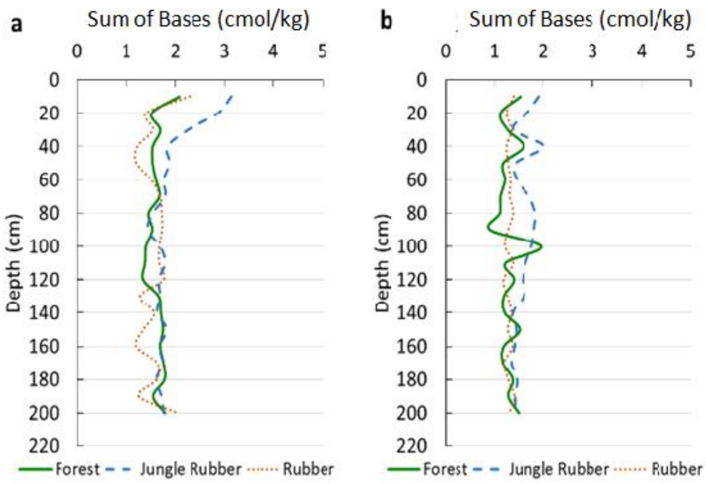

Figure 7. Depth of sum of bases in Bukit Duabelas (a) and Harapan (b)

The sum of bases in Harapan was slightly lower than in Bukit Duabelas, as a result of coarse texture in Harapan. Kurniawan (2016) mentioned that the porosity of the soil is strongly influenced by the clay content in the soil. Clayey soil can increase the number of micro pores in the soil rather than loamy soil, hence reducing water percolation and consequently reducing nutrient leaching in the soil. In the landscape of Bukit Duabelas, rubber plantation is younger (7-8 years) than in Harapan (14-17 years), hence there are still remnants of the previous landuse. Furthermore, Kotowska et al. (2015) stated that no fertilizer input in community rubber plantation in Harapan, resulting a lower basic cations content in the soil surface.

Conclusion

The result showed that in three landuses, bulk density is relatively low in the upper 20 cm, but increased with depth. Clay content was lower in forest than other landuses, and increased with depth in forest and jungle rubber. In rubber plantation however, fine clay was accumulated at 60-140 cm depth. The CEC was in accordance with clay content. There was no significant difference in soil pH and sum of bases between all landuses. In rubber plantation, soil pH was commonly higher in the surface, which probably due to liming. Sum of bases decreased with depth and tended to be generally lower in rubber plantation.

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