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## Evaluation on Soil Hardness in Riparian Forest Restoration along Kayan Ulu River, Sarawak, Malaysia

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### ABSTRACT

Soil hardness plays a vital role in evaluating the physical properties of soil structure. With regards to the impact of compaction on practical forest management issues, most report and review forms were available. Thus, the aim of this study was to evaluate the soil condition in riparian forest restoration planted with indigenous species along Kayan Ulu River with special reference to soil hardness. Soil hardness was measured by using Hasegawa-type cone penetrometer from the surface soils to 100 cm depth, with a total of 48 random points for both study sites surveyed; restoration sites planted with *Shorea macrophylla* in year 1996 and 1998 (SPD96 and SPD98, respectively) for both on and between planting lines. Our findings indicated that, soil hardness in SPD98 was harder as compared to SPD96 at shallow depth presented in one drop penetrability. Likewise, soil penetration resistance on planting line in SPD98 was significantly higher than SPD96 at surface soils (0-20 cm) and subsurface soils (20-40 cm). A high number of strikes and soil penetration resistance indicate that the soils were highly compacted. However, there was no significant difference in term of soil penetration resistance between planting line. In order to avoid effects on tree productivity, it is recommended that in future, the evaluation of soil hardness should be determined during the early establishment for future restoration of riparian ecosystem.

Keywords: Riparian forest restoration, riparian ecosystem, Sarawak, soil hardness

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### INTRODUCTION

Riparian forest provides the ecological sustainability between terrestrial and river ecosystems in regulating the interaction, stabilizing the riverbanks from erosion, maintaining the biodiversity, storing the water and sediment (National Research Council, 2002; Schultz, Isenhardt, Simpkins & Colletti, 2004). The biogeochemical, ecological and hydrological vital functions of these forests bordering waterways are widely recognized in current management strategies, particularly in the tropics. Soil hardness mostly linked to a reduction in permeability to water and air. According to Batey (2009); Usaborisut and Ampanmanee (2015), the indicator of soil hardness comprises of bulk density, porosity and moisture content. It brings negative impact to limit root growth and plant development in forest management (Batey, 2009; Hamza & Anderson, 2005). Soil penetration resistance expressed the average of soil hardness by its mechanical resistance on roots and has been found to be well correlated with root growth to sustain sufficient turgor pressure in the study sites (Hattori *et al.*, 2013). In addition, soil hardness of the artificial planting with representative points had been expressed by one drop penetrability (ODP) (Ishizuka *et al.*, 1998; Sakurai *et al.*, 1995).

Most of the heavy equipment, due to their weight and size, have the tendency to compact the soils at deeper part even after 40 years logged-over (Hattori *et al.*, 2013; Sivarajan, Maharlooei, Bajwa & Nowatzki, 2018; Usaborisut & Sukcharoenvipharat, 2011). However, compact soils also caused by natural conditions without any biotic such as human and animal disturbance involvement (Batey, 2009). The environmental impacts were an inevitable of the prolonged such as floods and heavy rains which occurred during the North East Monsoon Season between November to February in the riparian forest of Malaysia (Ng, Singh & Thiruchelvam, 2018). According to An, Cheng, Sun, Wang and Li (2002); Balian and Naiman (2005); Tiegs, Leary, Pohl and Munill (2005), the distribution of riparian forest trees along the riverbanks area has been considered important in the river management and forest restoration.

With regard to the impact of compaction on practical forest management issues, most report and review forms such as those of Batey (2009); Hattori *et al.* (2013); Ishizuka *et al.* (1998) were available. Our previous studies have been conducted in restoration sites to examine different aspects of the soil properties existing in the riparian ecosystem (Jaffar, Wasli, Perumal, Lat & Sani, 2018a, b; Perumal, Wasli, Ho, Lat & Sani, 2015; 2017; Wasli *et*