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SOIL, NUTRIENTS AND WATER CONSERVATION PRACTICES IN OIL PALM PLANTATIONS ON SLOPING AND STEEP LANDS IN MALAYSIA

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Abstract
Proper soil and water conservation practices are needed to maintain and improve soil physical and chemical properties linked to soil fertility and productivity for oil palm growth on sloping lands. This article is a review in terracing, organic mulches (EFB, Eco-mat and pruned oil palm frond) and silt pits as soil and water conservation practices on oil palm plantations, their advantages and disadvantages.

Keywords: Oil Palm, Soil and Water Conservation, Terracing, EFB, Eco-mat, pruned oil palm frond, Silt Pit

Introduction
The lack of agricultural lands in Malaysia has caused oil palm plantations to inevitably expand into marginal lands such as steep lands. The main problems of steep lands are soil erosion, loss of fertilizers and poor soil water storage. Agricultural activities and cultivation on steep slopes can severely increase soil erosion. Soil erosion in association with heavy rains could cause barren lands only after few years (Pratt and Gwynne, 1978; Pomeroy and Service, 1986; Kjekshus, 1997).
Hartemink (2006) reported that the erosion under natural forests is less than1 t ha^{-1} yr^{-1} while the Soil erosion under oil palm plantations was shown to be between 13 to 78 t ha^{-1} y^{-1} for Oxisols and 1 to 28 t ha^{-1} y^{-1} for Ultisols, both of which are dominant soil orders in Malaysia. Lim (1989) reported that soil erosion under mature oil palm trees planted on sloping lands with slopes of 6 to 8 % was more than 25 t ha^{-1} y^{-1}. However, lower soil erosion values (7-21 t ha^{-1} y^{-1}) from oil palm plantations were reported by (Maene et al., 1979). Lower values of 1.5 to 7.1 t ha^{-1} y^{-1} soil erosion were also reported from sloping oil palm plantations (Kee and Chew, 1996).

Removing the soil erosion, nutrients and water deficits of oil palm plantations through agricultural practices such as soil and water conservation practices and mulches can increase the oil palm production immediately through increasing the bunch weight and oil content of fruits (Goh et al., 1994; Donough et al., 2006). Application of soil and water conservation practices (terracing and silt pits) and organic mulches (empty fruit bunches, pruned oil palm fronds and Eco-mat) are the most common methods of oil palm yield intensification which have been practiced for several decades in Malaysia.

Terracing
Terraces are constructed with the purpose of reducing run-off and soil erosion across the hill slopes (Morgan, 2005; Troeh et al., 2004). Despite significant effects of terracing to reduce run-off and erosion for slopes of 6-20^{o} (Abo Hammad et al., 2006), on gentler slopes, terracing loses its efficiency and should be replaced by other conservation practices (Corley and Thinker, 2003). Despite of advantages of terracing, soil compaction and removing of fertile layer of top soil during construction of terraces reduce soil productivity (Hamdan et al., 2000). Compaction and removing of soil layers across terraces cause negative effects on soil physical properties such as: reduction of hydraulic conductivity, aggregate stability and water retention capacity (Ramos et al., 2007). Hill terracing is not recommended on sandy, shallow soil or soil with high fraction of stones (Troeh et al., 2004). Negative effects of terracing on soil productivity have forced some oil palm plantations to employ organic mulches and silt pits on non-terraced slopes.

Organic Mulches
Among the organic mulches, crop residues are the most commonly used in agriculture and favorable effects of these residues on soil fertility have long been recognized. These materials contain C and other plant essential nutrients which are released during the decomposition process (Wagner and Wolf, 1998). As one of the largest palm oil producer in the world, Malaysia produces a huge amount of oil palm by-products such as pruned fronds, empty fruit bunches (EFB), palm oil mill effluent (POME), shells and fibers. Some of these waste materials are produced in the field, viz pruned oil palm fronds during harvesting to facilitate the harvest of fresh fruit bunches, and felled trunk and fronds are replanting. Others such as EFB, shells, mesocarp fibers, POME and Eco-mat (a carpet-like fiber material made from compressed EFB) are by-products from milling process in the palm oil mill.

Empty fruit bunches (EFB) have been applied as a mulch and fertilizer because of their high nutrient concentration and ability to conserve high soil water content in top soil. One tonne of EFB has been estimated to supply an equivalent of 7.0, 2.8, 19.3 and 4.4 kg of urea, phosphate, rock, muriate of potash and kieserite, respectively (Singh et al., 1999). Application of different rates of EFB has been frequently studied. Zin and Tarmizi (1983) recommended 30-50 and 50-100 t ha^{-1} y^{-1} of EFB. 37, 35 and 40-60 t ha^{-1} yr^{-1} have been reported as suitable rates by Loong et al. (1987), Jantaraniyom et al. (2001) and Etta et al. (2007), respectively. Along with the ability of EFB to increase soil nutrient and soil water content, it has a fast decomposition rate. Zaharah and Lim (2000) found that EFB lost 50 and 70% of its dry matter due to decomposition in 3 and 8 months after application, respectively. However, application of EFB could only be implemented on field that are near oil palm mills because of difficulties of storage and high expenses of transportation and field application of the bulky EFB (Teh et al., 2011).

Difficulties of application of EFB motivated the development of Eco-mat. Eco-mat is a compressed EFB in the form of carpet-like material (Yeo, 2007). Therefore, field application, transportation and storage of Eco-mat are easier and cheaper than EFB. According to Wan Asma (2006) Eco-mat contains 33.85, 0.55, 0.39, 2.59 0.22 and 0.21 % of C, N, P, K Ca and Mg, respectively. Moradi et al. (2012) reported that EFB and pruned palm fronds had higher nutrient concentration and water than Eco-mat which is due to loss of nutrients and water during manufacturing process of EFB fibers into Eco-mat. However, there were no significant differences in decomposition and nutrient release rates between EFB and Eco-mat and also between the Eco-mat and oil palm fronds during their decomposition.

Pruned oil palm frond is another oil palm residue which is commonly used as mulch in oil palm plantations. Stacking the pruned fronds on the soil surface will reduce soil erosion and run-off. The decomposed fronds is a source of nutrients release into the soil. Husin et al. (1987) determined that one tonne of applied pruned frond on soil surface released 7.5, 1.0, 9.8 and 2.8 kg of N, P, K and Mg, respectively. Although pruned oil palm fronds provide high amount of nutrients (Chan et al., 1980), they are less effective to reduce run-off and soil erosion and to increase soil water content compared with other soil and water conservation practices in non-terraced oil palm plantations (Moradi et al., 2012).

Silt Pit

Silt pit is one of the recommended soil-water conservation methods in Malaysia (Teh et al., 2011). Silt pits function by reducing soil erosion, controlling run-off and sedimentation, increasing oil palm yield through supplying more water specially during dry weather, protecting and increasing soil fertility through reduction of nutrient loss and redistribution of eroded nutrients back into the soil. Silt pit redistributes collected water and nutrients into the oil palm root zone rather than being lost through deep percolation (Bohluli et al., 2012).

Murtilaksono et al (2007) examined the influences of contour ridge and silt pit on soil water content in oil palm plantations. They collected the daily and monthly required data to run the water balance equation. Outcome of study showed that silt pit was effectively able to delay the soil dryness by 3.5 months more than contour ridge (2.5 months) compared with the control (no conservation practices). Atmaja and Hendra (2007) also surveyed the effectiveness of ridge terraces and silt pits on soil moisture content on oil palm plantations. Results showed that the soil water content was highest in silt pit treatment, followed by ridge terrace and control. The planted oil palms in control showed earlier water deficit compared with other treatments. Soil moisture content indicated that silt pit was able to keep the soil water content for longer time compared with other treatments. They concluded that silt pit makes higher and more stable soil water moisture content compared with ridge terrace and control, so that, the oil palm's water demand would be fulfilled better and the production would increase significantly. In other research Bohluli et al. (2014) simulated the silt pit efficiency on conserving soil water by HYDRUS 2D model. They simulated four silt pits with different dimensions of depth and floor area. Their results showed that a narrow silt pit with a bigger tbotal wall to floor area presents better performance to return collected water into oil palm root zone. They also found that the smaller the floor area (or opening area) of silt pits, the longer it takes for pits to dry out their stored water.

Conclusion

Maximum oil palm yield production in Malaysia can be increased by yield intensification through land management practices. Yield intensification through application the soil, nutrients and water conservation practices in oil palm plantations would be cheaper, faster and more beneficial than developing new oil palm plantations. However, choosing specific or combination of conservation practices needs proper knowledge about the practices, their abilities, advantages and limitations.

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