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THE EFFECTIVENESS OF SILT PIT AS A SOIL, NUTRIENT AND WATER CONSERVATION METHOD IN NON-TERRACED OIL PALM PLANTATIONS

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INTRODUCTION

Demand for edible vegetable oils is expected to double from 2009 consumption of around 120 to 240 million ton yr^{-1} by 2050. Among the major vegetable oils, palm oil has the lowest production cost, and therefore, it will cause the increase of oil palm plantation area up to 12 million ha (or about 300,000 ha yr^{-1}) over the next 40 years (Corley 2009). If all land expansion takes place in Malaysia and Indonesia, this would increase 140% from 8.4 (2007) to 20.4 million ha (2050) in the area under harvest (FAO 2008). Inevitably, oil palm plantation activities have expanded to include marginal lands such as steep land areas. About one-third of the area in Peninsula Malaysia is covered by hill and mountain ranges. The problems of steep lands are soil erosion, loss of fertilizers and poor soil water storage. The longer and steeper the slope, the higher the erosion because runoff can easily occur.

In Malaysia, optimum yield production can be increased by a combination of land area expansion and yield intensification. Management is said to be often more important than soil type in determining the yield potential of oil palm at a given site (Goh *et al.* 1994). One of the best management ways is the application of soil, nutrient and water conservation methods. However, there are few studies about the soil and water improvement through silt pits practice. These few studies usually compare silt pit practice with other conservation practices to determine silt pit's efficiency for nutrients and water conservation. For example, Soon and Hoong (2001) have studied the overland flow and erosion reduction. On the other hand, some other researchers evaluated the effectiveness of silt pit in terms of soil fertility improvement and increased in oil palm yield (Seah 2006; Mutilaksono *et al.* 2008, 2011; Moraidalini *et al.* 2010).

The main objective of this study was to evaluate the effectiveness of various dimensions of silt pit to conserve soil, water and nutrients in a non-terraced oil palm plantation. It was also compared against control which had no conservation practices.

MATERIALS AND METHODS

Two field experiments were set up in oil palm sites at Tuan Mee estate (03° 16' N and 101° 28' E) located in Sg. Buloh, Selangor (December 2009) and Felda Tekam (03° 90' N and 102° 54' E) in Pahang (Jun 2010). Each experimental field had five treatments with three blocks (replications). The treatments were control (no silt pit) and four silt pit sizes with different volume and opening areas as shown in Table 1. The silt pit's length was perpendicular to the hill slope direction and width was parallel with the slope direction.

For all silt pit treatments the length was fixed at 3 m and the depth was 1 m except for H3 which had a 0.5 m depth.

Soil samples were taken once every two months for a year at each site. Each sampling set included the soil outside of silt pits (0-15 cm and 15-30cm from soil surface denoted as OS 0-15 and OS 15-30 respectively), sediments and 0-15 cm and 15-30 cm below the sediment depth inside the silt pit (denoted Sed, IS 0-15 and IS 15-30 respectively) . For control, soil sampling was done only from 0-15 cm and 15-30 cm from soil surface because there was no silt pit for the control treatment.

After the soil samples have been air dried for a week, the soils were analyzed for their chemical and physical properties: soil pH (1:2.5 soil to water ratio, pH meter; Walsh and Beaton, 1973), cation exchange capacity (CEC) (leaching method, Walsh and Beaton 1973). The leachate was collected to determine the concentration of cations by atomic absorption spectrometry (Ca, Mg and K), total N by Kjeldahl method (Walsh and Beaton 1973), Bray and Krut No.II was used for determining available P and total C by combustion method (CR-412 Leco Machine). Soil physical properties analysed include bulk density (core ring method, Blake and Hartge 1986), aggregate stability (wet sieving method, Kemper and Rosenau 1986), dry aggregation (dry sieving method) and soil water retention (pressure plate and membrane technique, Richards 1947). Soil water content was measured by using AP moisture probe (AquaPro Sensors).

Analysis of variance (ANOVA) was used with split-split block in RCBD experimental design, with three replications and three factors (treatments as main plot, soil depth and time as sub plot).

Table 1. Treatments includes different silt pit sizes and opening area

Treatment	Silt pit size (m) Width x Length x Depth	Volume (m^3)	Opening Area (m^2)
H0	Control (no silt pit)	-	-
H1	1.0×3.0×1.0	3.0	3.0
H2	1.5×3.0×1.0	4.5	4.5
H3	2.0×3.0×0.5	3.0	6.0
H4	2.0×3.0×1.0	6.0	6.0

RESULTS AND DISCUSSION

Soil Water Content

In Tuan Mee, H1 and H2 treatments (Table 1) were able to significantly increase the soil water content 19.22% and 16.5%, respectively compared to the control. H3 and H4 (Figure 1a) increased soil water content by 2.6% and 1.46%, respectively, and they were insignificantly different from control. The effectiveness of the silt pit treatments to conserve soil water content was in the ascending order of silt pit's opening. This study showed that silt pits with the smaller opening area (H1 and H2) helped to conserve more water than pits with large opening area (H3 and H4) because pits with smaller opening area had lower total water loss via evaporation. This is the reason why the Department of Agriculture of Australia (2005) suggested a shape with smallest surface area (opening area) and greatest depth for designing excavated tanks and hillside dams to reduce evaporation loss.

Another reason can be explained by the differences in the amount of lateral water movement. Take the two silt pits with different dimensions (H1 and H4 treatments). If both pits contained the same volume of water, the height of water in the H1 pit would be higher than that in the H4 pit. Consequently, there would be more lateral water movement in H1 than in H4, making the soil water content in the surrounding lateral area of the H1 pit to be higher than the lateral surrounding area of the H4 pit. Accordingly, a narrow silt pit has the ability to increase lateral water movement and reduce vertical water movement from the pit's floor compared to a wide pit.

In Tekam, silt pits did not increase soil water content compared to the control because there was not available runoff to be trapped inside silt pit (Figure 1b). It also had a lower slope and was covered with higher density of vegetation.

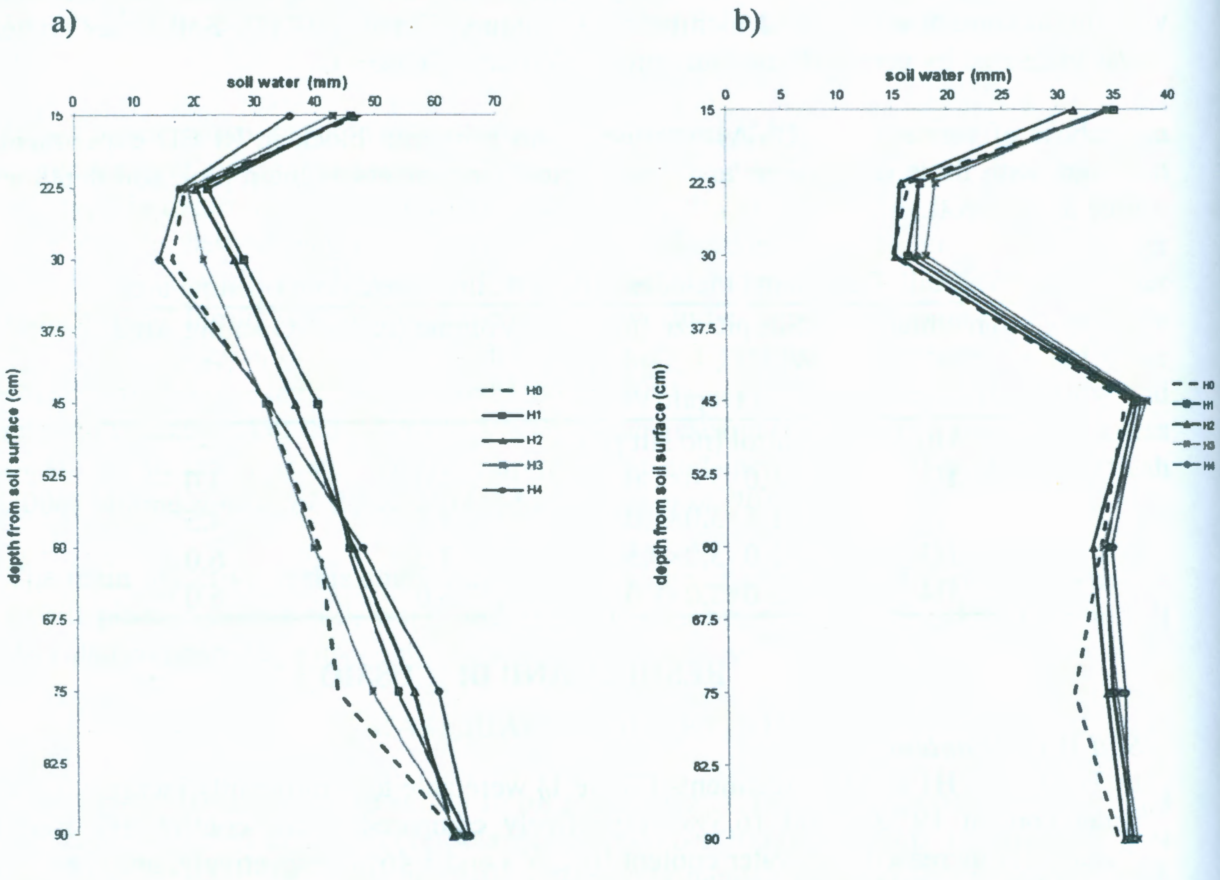

Figure 1. Changes of the soil moisture from the soil surface up to 90 cm depth in a)Tuan Mee and b)Tekam site.

Sediments trapping

There was no significant difference between silt pits for the volume of sediments trapped in Tuan Mee, except for H3 which was different from other treatments. The most important parameter for runoff and sediment input to silt pits is the length of the pit (perpendicular to the hill slope) which was equal for all treatments. So the catchment for all treatments was the same and consequently all pits had been fed with the same amount of runoff and sediments. H3 was the shallowest pit (0.5 m) compared to 1.0 m depth of other treatments (H1, H2 and H4). H3 had also the smallest volume (same as H1). Therefore, H3 would easily become full in period of high rainfall and runoff, having little time for runoff sediments to settle in the pit. There were no collected sediments inside of silt pits in Tekam. As stated earlier, this was due to the lack of runoff, as well as higher ground cover against soil erosion and sedimentation.

Soil Chemical Properties

Among the silt pits, the narrowest pit showed the best effect in improving the soil chemical properties inside (Table 2) and outside (Table 3) of the pit. The silt pit with smallest opening area (H1) trapped the same amount of sediments and water compared with the biggest silt pit (H4). Trapped sediments and water are the source of nutrients inside of the silt pit. These nutrients leach downward via the silt pit's floor or redistribute laterally into soil profile via the silt pit's walls. However, different leaching and redistribution proportion caused different effectiveness of silt pits. For the same amount of trapped nutrients, silt pits with the smaller opening area would give the highest nutrient concentrations in soil compared to the silt pits with wider opening area. This is because for the smaller opening area, trapped nutrients inside the pit would be leached downwards over a smaller floor area. Hence, the nutrients are concentrated over a smaller soil area.

Another reason is the silt pit with narrower opening area helps the water head to be higher than other wider pits and feed top soil with more nutrients. Hence, more C in top soil increases carboxyl and phenolic groups, which improves soil CEC (Allison 1973). Noble *et al* (2003) noted that soil organic carbon improvement can affect several soil properties which are related with the increasing of soil surface charge that causes preservation and preparation of nutrients. Significant part of the CEC in soils is dependent on soil organic matter. Consequently, Duxbury et al (1989) mentioned that high soil organic matter level is particularly important in tropical and sandy soils, which was properly maintained by narrower silt pits in Tuan Mee.

As it was already explained, there were no trapped water and sediments as nutrient sources inside silt pits in Tekam. Therefore, no significant changes in soil chemical properties were observed in Tekam.

Table 2. Significant soil chemical changes outside of silt pits (Tuan Mee)

	Treatments compared to the control (%)			
	H1	H2	H3	H4
CEC	24.41b	8.17b	2.63a	1.11a
C	21.60c	8.60b	6.70ab	7.30a
N	27.46b	8.63a	7.00a	2.50a
K	46.33c	18.00b	22.10b	9.40a

Means with the same letters are not significant at 95% probability level.

Table 3. Significant soil chemical changes inside of silt pits (Tuan Mee)

	Treatments			
	H1	H2	H3	H4
CEC	31.88b	26.00b	3.85a	11.20a
C	28.12c	22.06b	9.08a	10.12a
N	39.48c	24.17b	6.51a	17.31a
Ca	42.80c	31.21b	15.75a	14.30a
Mg	55.01d	47.43c	19.53b	23.15a
K	58.50c	44.62b	22.78a	35.68a
P	21.02b	14.80a	7.85a	13.10a

Means with the same letters are not significant at 95% probability level.

Soil Physical Properties

Silt pits were not able to affect soil physical characteristics outside of silt pit in two studied sites. That was because soil physical parameters change slower than soil chemical characteristics and it will take more time to see significant changes on soil physical properties furthermore of this study that was only one year.

CONCLUSION AND RECOMMENDATIONS

This study shows silt pits were able to effectively improve soil water content and chemical properties as well as control soil erosion by runoff reduction and sediment trapping. However the silt pit volume should be calculated based on rain intensity and amount of runoff, the narrowest pit is recommended as it was able to redistribute more water and nutrient in top soil layers than other pits. In terms of sites, this method has better performance in steeper slopes with lesser ground cover where severe erosion causes washing away of applied fertilizers.

More studies are recommended to determine silt pit application on various field conditions and limitations.

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