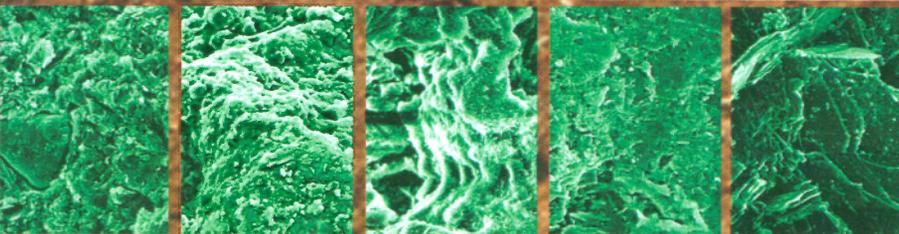
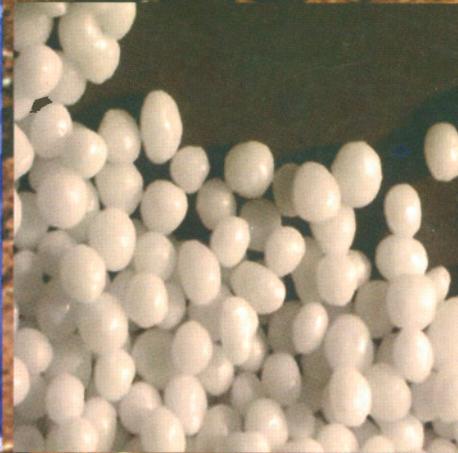


Volume 3

Advances in

# Tropical Soil Science



EDITORS

Hamdan Jol • Shamshuddin Jusop

Volume 3  
Advances in  
**Tropical  
Soil Science**

EDITORS

Hamdan Jol • Shamshuddin Jusop



Universiti Putra Malaysia Press  
Serdang • 2015

© **Universiti Putra Malaysia Press 2015**

First Print 2015

All rights reserved. No part of this book may be reproduced in any form without permission in writing from the publisher, except by a reviewer who wishes to quote brief passages in a review written for inclusion in a magazine or newspaper.

UPM Press is a member of the Malaysian Book Publishers Association (MABOPA) and a member of Majlis Penerbitan Ilmiah Malaysia (MAPIM)

Perpustakaan Negara Malaysia      Cataloguing-in-Publication Data

Advances in Tropical Soil Science. Volume 3 / Editors Hamdan Jol,  
Shamshuddin Jusop.

ISBN 978-967-344-515-8

1. Soil science. 2. Soil productivity.

I. Hamdan Jol. II. Shamshuddin Jusop.

631.4

Cover design: Mohd Ghazali Razak

Typesetting: Noor Sholihah Mohamed Daud

Type face : Baskerville

Font size : 11/13

*Direct orders to*

Universiti Putra Malaysia Press

43400 UPM, Serdang

Selangor Darul Ehsan

Tel: 03-89468851/89468854

Fax: 03-89416172

E-mail: [penerbit@upm.edu.my](mailto:penerbit@upm.edu.my)

*Printed by*

Sepantas Kurnia (M) Sdn. Bhd.

No 52A, Jalan Seri Aman, Taman Seri Aman

Batu 8, 43200 Cheras, Selangor

Land is an indispensable resource for the survival and prosperity of mankind as well as for the maintenance of all terrestrial ecosystems. In agriculture, potential production of arable land and its susceptibility to degradation are dependent on the management strategies employed and on inherent soil and other characteristics. Over the years, increased demand and pressure on land resources results in competition for land use, declining crop production and degradation of land quality in agriculture areas.

In the tropics, it is known that agricultural intensification of an area for cropping causes decline in soil quality. Transforming the natural ecosystem to an agro-ecosystem can involve significant changes in organic matter input and turnover rates. These changes alter the infiltration, water retention, bulk density, soil strength, mineralization of nutrients and their availability to plants, cation exchange capacity, soil fertility and accumulation of heavy metals and toxic chemicals.

This book embodies the results of the on-going research on tropical soils as well as those completed in the last several years by the academic staff of the Department of Land Management, Faculty of Agriculture, Universiti Putra Malaysia and collaborative research works with other research agencies in Malaysia. Fifteen articles were submitted and published, covering wide range of topics in the area of soil genesis, soil physic, soil chemistry, soil microbiology and strategic soil fertility management in the tropics, particularly Malaysia.



Penerbit Universiti Putra Malaysia  
43400 UPM Serdang  
Selangor Darul Ehsan

Tel: 03-89468851/ 89468854  
Fax: 03-89416172  
Web: <http://penerbit.upm.edu.my>  
E-mail: [penerbit@putra.upm.edu.my](mailto:penerbit@putra.upm.edu.my)



# 4

## Review on the Use of Silt Pits (Contour Trenches) as a Soil and Water Conservation

*Mohsen Bohluli, Christopher Teh Boon Sung, Ahmad Husni Mohd Hanif and  
Zaharah A. Rahman*

### INTRODUCTION

In Malaysia, 47% of oil palm expansion up to 2002 (an area of about 1,450,393 ha) involved deforestation (Wakker and Gelder, 2003) and in Indonesia, an estimation of 18 mil ha of rainforests were destroyed for oil palm (Wakker, 2006) making an approximate total of 3.3 mil ha deforested for oil palm in Malaysia and Indonesia together. Converting undisturbed natural tropical forests to agricultural lands reduces the total soil organic carbon, total N and P, as well as the reduction of soil water holding capacity from 66.48% in undisturbed forests to 38.18% in disturbed agroforest lands such as oil palm, which results danger of run-off and soil erosion. Reduction in water holding capacity also cause less soil water storage and more water deficit for crops during dry seasons. Surface run-off from the sloping lands in oil palm plantations in Malaysia was reported to be between 10 and 50% of total rainfall (Maena *et al.*, 1979; Lim *et al.*, 1994; Soon and Hoong, 2002). In an experiment carried out in three different sites with various slopes ranging from 3.5 to 8 degrees, Kee and Chew (1996) showed that surface run-off under matured oil palm trees increased with slope and amount of rainfall and ranged from 22.9 to 28.4% of annual rainfall. Lim *et al.* (1995) indicated that surface run-off from sloping land oil palm plantations with gentle slopes of 6-8 degrees and mean annual rainfall of 1645 mm was 14.3 %. This value increased to 32 % when mean annual rainfall increased to 2150 mm. Maena *et al.* (1979) reported that surface run-off from clayey soil with a slope of 4 % and 1426 mm rainfall was 18.5 %.

Hashim *et al.* (2008) highlighted that converting 1464 ha of primary forests of Pasoh forest region (Malaysia) to oil palm plantation increased the total soil erosion from 59 to 69 million t ha<sup>-1</sup> yr<sup>-1</sup>. In oil palm plantations, especially on steep slopes, the surplus of non-infiltrated precipitations forms run-off during high intensity rainfall (Banabas *et al.*, 2008). Run-off initially begins from oil palm rows, harvesting paths and other compacted field areas because of lower soil water infiltration in these areas (Bruijnzeel, 1990).

Silt pit is one of the recommended soil-water conservation methods in Malaysia (Teh *et al.*, 2011). Goh *et al.* (1994) mentioned that maximum oil palm yield production in Malaysia can be increased by yield intensification through land management practices such as silt pits. Silt pits are long, narrow and deep close-ended trenches which are dug between oil palm planting rows to hold surface run-off during rainy days (Roslan and Haniff, 2004).

Silt pit, pit (or pitting), irrigation pit, water harvesting pit and planting pit are various terms to mean straggled contour trenches to collect run-off, trap and settle down the sediments, increase the soil moisture or improve the groundwater, break the slope length, and to reduce soil erosion and fertilizers loss.

## CONTOUR TRENCHES

Trenches are any kind of excavated depression along the land's surface with purpose of preventing soil erosion via trapping and absorbing sediments and run-off. Trenches are made on slopes (steepness >15%) along contour lines for forestry and horticultural use. Commonly, contour trenches are dug with cross section size of 0.3×0.3 m and 1 to 2 m vertical distances. Contour trenches without gap and 100 to 200 m long are called *continuous contour trenches*. Continuity of contour trenches may be interrupted into several scattered parts with length of 2 to 4 m. These trenches are named *staggered contour trenches*. Both continuous and staggered contour trenches can be constructed with trapezoidal or rectangular cross section (Singh *et al.*, 2006).

Contour trenches are dug along the same hill elevation. The excavated soil may be compacted in the lower side to form bunds. Contour trenches divide the slope to smaller catchments and reduce the length of slope which results in the decrease of the amount and velocity of run-off and in

turn soil erosion reduction. Contour trenches collect rainwater and run-off and redistribute the trapped water into the soil profile. Trenches must be constructed along the contour lines to contain the water in trenches for longer periods. Construction of trenches could increase the run-off velocity by acting as askew slope channels that result in higher soil erosion risk if the trenches are not made parallel with the contour lines (Baba Amte Centre, 2007). The main objectives of contour trenches are to reduce the velocity of run-off, soil erosion and sediments and increase soil moisture content.

Singh *et al.* (2006) reported that using trenches was effective in improving the soil moisture content and reducing run-off to  $7.81 \text{ mm hr}^{-1}$ . The highest peak of run-off ( $86.10 \text{ mm hr}^{-1}$ ) was recorded from shifting cultivation with highest range of run-off ( $19.89$  to  $54.99 \text{ mm hr}^{-1}$ ). Their data showed that contour trenches combined with grassed water ways retained 98.68% of annual rainfall. Trenches in a clay loam soil with 2554 mm annual rainfall had  $0.16 \text{ t ha}^{-1}\text{yr}^{-1}$  of soil erosion which was lower than contour bunds + bench terrace ( $0.33 \text{ t ha}^{-1}\text{yr}^{-1}$ ), agroforestry ( $0.38 \text{ t ha}^{-1}\text{yr}^{-1}$ ), contour bunds + bench terrace + half-moon terrace ( $1.22 \text{ t ha}^{-1}\text{yr}^{-1}$ ) and half-moon terrace + grassed water ways ( $4.37 \text{ t ha}^{-1}\text{yr}^{-1}$ ). Half-moon terraces are semicircular bunds with various radiuses from 2 to up to 30 m. Half-moon terraces let the water to infiltrate into the soil and therefore reduce run-off and increase soil water content which can be used for cultivation of different type of crops in arid and semiarid regions.

Virendra *et al.* (2007) studied the suitable soil and water conservation measures for small watersheds through remote sensing and GIS. They found that V-shape ditch, continuous and staggered contour trenches were the best soil and water conservation methods for non-arable lands. These methods can be adopted in small watersheds to reduce run-off and sediment yield.

There is no consensus on the proper or correct dimension and distances between trenches. However, the size and distances of trenches are depend on the rain amount and intensity, soil water infiltration, soil depth, slope steepness and crop cover (MANAGE, 2010). In high rainfall, high slope, heavy and shallow soil and less crop cover, the size of trenches as well as the number of trenches per unit area must increase. For example, trenches with 4.6 m length, 0.45 m width and 0.45 m depth were dug on hilly slopes of Bihar (India) with less than 10% slope steepness. The horizontal and vertical distances of trenches were 4.6 m and 0.9 m, respectively.

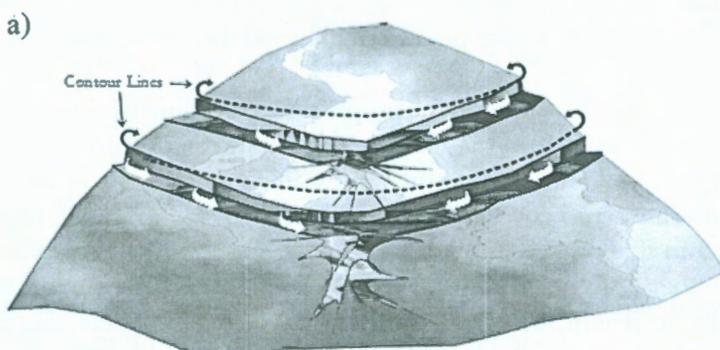
The size of trenches was increased to 0.6×0.6 m (width and depth) where the slope steepness exceeds 10% (Luna, 1989). Baba Amte Center (2007) recommended contour trenches on slopes with steepness between 10 to 25%. However, the risk of erosion would increase with increasing steepness because of water over flow from countour downstreams and embankments. Table 4.1 shows the interval spacing between trenches based on steepness of slop for trenches with 0.6 m width and 0.3 m depth (MANAGE, 2010).

**Table 4.1** Interval trench spacing for various hillslope steepness

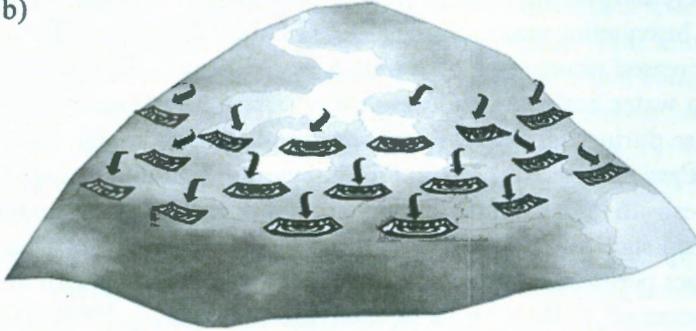
Hillslope (%)	Distance between trenches (m)
0-4	10-12
4-8	8
8-10	6
15-33	4

(Source: Manage, 2010)

Dalvi *et al.* (2009) studied the contour trenches as a rain water harvesting method for non-arable lands in agrohorticultural (MW-I treatment) and silvipastural systems (MW-II treatment) in India. They applied trenches with 0.6 m width and 0.3 m depth and 5 m horizontal distances between trenches. The spaces between trenches were planted. The results of this study. They concluded that contour trenches increased the vegetative growth and reduced run-off by 97% which resulted in a negligible soil erosion.



b)



- a. In continuous contour trenches, there is a possibility run-off will flow along this sloping channel and spill out, creating gullies.
- b. Staggered trenches minimise the risk of run-off flowing out of the trenches and are therefore safer.

(Source: Baba Amte Centre, 2007)

**Figure 4.1** Continuous vs. staggered trenches

Staggered contour trenches are better than continuous trenches on steep and hilly areas because the continuous contour trenches may cause formation of water channels and ultimately gullies (Bharad, 1991). Digging long contour trenches along the slopes also increases the excavation error on going off the correct contour lines. If the water flows inside the continuous trenches, the water would over flow and erosion would occur. In contrast, the staggered contour trenches are flexible and can easily be placed in order to correct the placement of contour lines. Figure 4.1 illustrates that how wrongly levelled continuous trenches increased erosion along the slope and staggered trenches can correct the error (Baba Amte Centre, 2007).

Filho (2012) used staggered contour trenches with  $1.0 \times 0.5 \times 0.5$  m (length, depth and width, respectively) and with 12.5 m distances between trenches. They effectively reduced the run-off and increased the discharge of the spring immediately in recharge zone of natural water springs. Trenches with 0.4 m depth of trapezoid shape with 0.6 m width in top and 0.4 m in floor on slopes with more than 8% steepness were suggested by Rajshekar (2009). He contended that staggered contour trenches with 2 m length and 2 m vertical and horizontal distances in combination of planted trees and grasses on downstream embankment of trenches can reduce run-off by 80%.

Increasing of the trench's cross section size was suggested in dry areas with a heavy rainy season (Luna, 1989; MANAGE, 2007). This is because the increased dimensions of a trench would help capture more amounts of rain water and run-off during rainy season and reserve the water for crop use during the dry season. For example, in moderately arid areas of Uttar Pradesh and Rajasthan of India, various lengths staggered contour trenches with 0.45 m width and 0.45 m depth and 3 to 5 m distances were practiced successfully in order to support the plantation of *Acacia niltica*. Trenches performed better when trenches cross section (width and depth) was increased to 0.6×0.6 m in drier locations (Joshi, 1983). In another location of India (Maharashtra), staggered contour trenches with various distances of 9 to 12 m and a cross section of 0.6×0.3 m (width and depth, respectively) were dug. Construction of trenches with 3.7 m length and 3.7 m apart from trees ensured reduction of soil erosion and run-off (Joshi, 1983).

## PITS AND SILT PITS

Pits can be constructed in an arc or rectangular shape. This process of pit excavation is called *pitting*. Heady (1975) noted that pitting in range lands increased the grass cover through increasing water infiltration, breaking the soil surface crusts and reducing run-off. The effectiveness of pitting was compared with root-plowing and control (no practices) in Arizona. Three year of run-off measurements showed that pitting significantly reduced run-off compared with other treatments. Pits can be also used for horticultural crops (Tromble, 1976).

Pradeepkumar *et al.* (2008) described that in hilly horticultural areas construction of pits with 0.9×0.9×0.45 m (length, width and depth, respectively) was useful for soil loss protection. He added that crops can be planted at 1 to 1.5 m spacing from pits with 0.75 m width and 0.3 m depth in low rainfall areas and in moderate slopes, excavation of 1.8×0.5×0.6 m (length, width and depth, respectively) pit between four trees was helpful in conserving soil and water conservation.

Mishra *et al.* (2002) studied the effect of contour trenches and pits in combination with *Vesicular arbuscular mycorrhizas* (VAM) fungi on the growth of trees in degraded areas. They set up two experimental sites with slopes of 15 to 20% and 3 to 5%. Although the two sites had different slope steepness, both sites had similar soil erosion. They constructed pits

with volumes of 45 m<sup>3</sup> with 2 m horizontal and 2 m vertical spacing and staggered trenches with size of 3×0.5×0.5 m (length, width and depth, respectively) between the rows of crops. They concluded that construction of pits and staggered trenches rehabilitated severely eroded soil. This was because staggered trenches and pits provided higher soil moisture and higher nutrient uptake which resulted in more activity of VAM and consequently, better growth of plants.

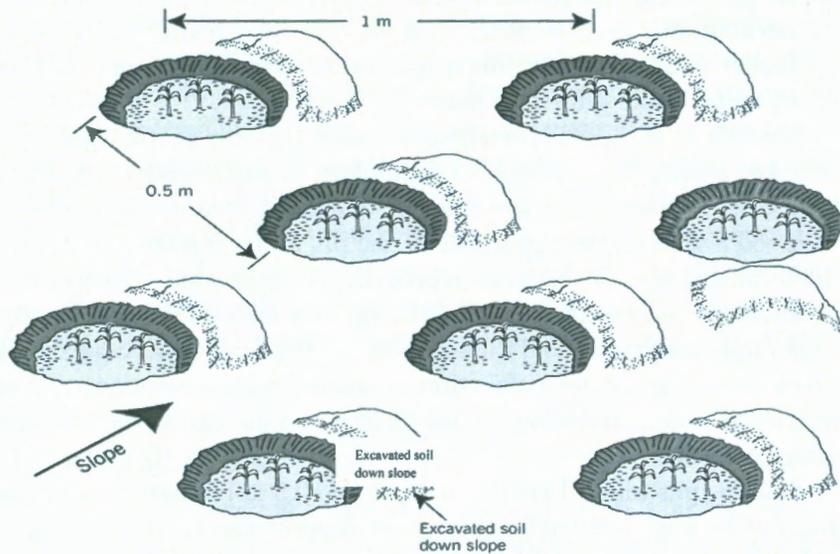
Sharma *et al.* (1986) presented another concept of pit application named *pit planting*. Pit planting is a technology in arid sloping lands. In this method, the required pit's size must be dug along contour lines. The top fertile soil is kept on the upper side of the pit, and it is refilled into the pit with fertilizers after the excavation process. The excavated sub-surface soil is compacted on the down-side of the pit in a form of half-circle ridge. Ridges store water and hold the soil erosion. Application of staggered pits makes enough space for cultivation compared with continuous contour trenches as well as reducing of run-off line and increasing the soil water storage capacity.

Planting pits with 0.15 to 0.5 m depth and 0.5 to 1 m part away of each other can be implemented for cultivation of annual and perennial crops in arid and semi-arid areas with low permeable soils (WOCAT, 2007). Figure 4.2 illustrates the basic design of planting pits adopted by Malesu *et al.* (2007). Planting pits have been named differently in literatures such as *Zay*, *Chololo*, *Mantengro*, *Ngoro* and *Tassa* (ADB, 2008; UNEP, 2012).

Matengo people, living in highlands of Southern Tanzania, created a unique soil conservation system which is called *Matengo Farming System* (Willis, 1966; Shillington, 1989; Basehart, 1972).

Matengo Farming System contains a large number of pits (Allan, 1965). This method has also been referenced as *Ngolo Farming System* because "Ngolo" means pit in Matengo language (Itani, 1998). This indigenous soil and water conservation method enables plantation on slopes with 10 to 60% steepness. In this farming system, pits collect the run-off during the wet season and allow the rain water to stay inside for longer time. The spaces between pits are planted with crops. Then the pits release the collected water slowly and conserve the soil water moisture to be used by crops during dry season. Malley *et al.* (2004) studied the effects of different pit sizes in the Ngoro system for maize cultivation. They found out that the total soil erosion was negligible and the biggest pit size was the best. However, there were insignificant differences between treatments in term

of soil moisture regime. Increasing the pit size would increase the soil water infiltration amount and increase the maize yield because of higher amount of supplied water.



(Source: Malesu *et al.*, 2007)

**Figure 4.2** Basic design of planting pits in arid and semi-arid areas

Silt pits are long, narrow and deep close-ended trenches which are dug between oil palm planting rows to hold surface runoff during of rainy days (Roslan and Haniff, 2004). Silt pit is one of the recommended soil-water conservation methods in Malaysia (Teh *et al.*, 2011). Goh *et al.* (1994) mentioned that maximum oil palm yield production in Malaysia can be increased by yield intensification through land management practices such as silt pits.

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.

Soon and Hoong (2002) examined the effect of silt pit size of  $4 \times 0.5 \times 0.5$  m (length, width and depth, respectively) in association with contour stacked fronds, compared with pruned fronds stacked down the slope following the planting row and contour stacked fronds. The experimental site was an oil palm plantation in Sabah (Malaysia) with density of 136 palms  $\text{ha}^{-1}$ , sandy loam to loamy sand soil and deep well drained steepness below  $15^\circ$  and total of 2437.30 mm rainfall during the year of the experiment. The annual run-off loss in this site was 19.79% of the rainfall while the silt pit + contour stacked fronds reduced the run-off by 10.68% of rainfall followed by contour stacked fronds (17.88%) and pruned fronds stacked down the slope (30.83%). Table 4.2 shows the effect of treatments on run-off loss. Silt pit + contour stacked fronds reduced the soil loss more effectively than other treatments by  $4.39 \text{ t ha}^{-1}$  followed by  $4.91 \text{ t ha}^{-1}$  in contour stacked fronds plots and  $21.73 \text{ t ha}^{-1}$  in pruned fronds stacked down the slope (Table 4.3).

Murtalaksono *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). The effects of silt pit and bund terrace in combination with retarded-water hole on oil palm production was studied by Murtalaksono *et al.* (2009). They measured total number of oil palm fronds, number of new fronds and bunches as vegetative growth parameters, fresh fruit bunches (TBS) and average weight of bunches (RBT) as yield parameters. They observed that both soil and water conservation practices were able to improve the growth and yield parameters of oil palm more effectively compared with control. However, bund terrace increased the TBS and RBT ( $25.2 \text{ t ha}^{-1}$  and 21 kg, respectively) higher than silt pit and control. Silt pit performed better TBS and RBT production by  $23.6 \text{ t ha}^{-1}$  and 20 kg, respectively, compared with control by  $20.8 \text{ t ha}^{-1}$  TBS and 19 kg RBT. Murtalaksono *et al.* (2011) studied the profitability and feasibility of bund terraces and silt pits in oil palm plantations compared with control (no practices). Bund terraces performed higher full fruit bunch production ( $4.761 \text{ t ha}^{-1}$ ) than silt pits ( $3.046 \text{ t ha}^{-1}$ ). Both terraces and silt pits significantly increased the oil palm production by 21.5 and 13.4%, respectively, compared with control. They concluded that both methods were profitable.

**Table 4.2** Surface run-off losses under different conservation practices

Month	Rainfall (mm)	Rain days	Run-off (L ha <sup>-1</sup> )		
			No contour frond stacking	Contour frond stacking	Silt pit + contour frond stacking
May	271	11	348.6	281.0	136.5
June	126	7	462.4	212.3	70.4
July	163	7	398.8	356.1	121.0
Aug	85	6	223.2	139.4	55.9
Sep	321	18	258.4	170.4	401.0
Oct	355	11	767.1	725.5	461.0
Jan	96	5	173.5	143.9	106.9
Total	2032	93	5636.1	3268.1	1953.0
Mean			626.2	363.1	217.0
Annual run-off			7514.8	4357.4	2604.0
Run-off/ha (% of total rainfall)			30.8	17.9	10.7

(Source: Soon and Hoong, 2002)

**Table 4.3** Total mean soil losses under different treatments

Month	Rainfall (mm)	Rain days	Soil loss (t ha <sup>-1</sup> )		
			No contour frond stacking	Contour frond stacking	Silt pit + contour frond stacking
May	271	11	1.3	0.6	0.4
June	126	7	1.6	0.3	0.1
July	163	7	1.2	0.4	0.3
Aug	85	6	0.7	0.1	0.2
Sep	321	18	0.5	0.2	0.7
Oct	355	11	2.2	0.4	0.6
Jan	96	5	4.3	0.9	0.6
Total	2032	93	16.3	3.7	3.3
Mean			1.8	0.4	0.4
Annual soil loss/ha			21.7	4.9	4.4

(Source: Soon and Hoong, 2002).

Muslim *et al* (2008) studied the effectiveness of bund terraces and silt pits in association with vertical mulches on overland flow and soil erosion in oil palm plantations. Silt pits reduced the overland flow and soil erosion (94.9 and 98.1 %, respectively) much more effectively than bund terraces (50.8 and 67.5%, respectively) and control (Table 4.4).

Atmaja and Hendra (2007) surveyed the effectiveness of ridge terraces and silt pits on soil moisture content on oil palm plantations. They applied three treatments including control (T0, without any soil-water conservation measure), ridge terrace (T1) and silt pits (T2). 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 compare with ridge terrace and control, so that, the oil palm's water demand would be fulfilled better and the production would increase significantly.

**Table 4.4** Effectiveness of bund terraces and silt pits on overland flow and sediment load

Treatment	Overland flow (mm)	Sediment load (kg ha <sup>-1</sup> )	Total soil erosion (kg ha <sup>-1</sup> )
Control	60.7	15.0	729.3
Bund terraces	26.2	4.8	238.7
Silt pits	2.0	0.1	13.9

(Source: Muslim *et al.*, 2008)

Moradi *et al.* (2012) evaluated the effectiveness of silt pit and three other soil water conservations (EFB, Ecomat and pruned oil palm fronds) in improving soil chemical properties and oil palm nutrients. They reported the application of EFB as the best practice in non-terraced oil palm plantations. Silt pit was not as effective as EFB. This was because EFB is a source of high amount of nutrients by itself whereas, silt pit redistributes the eroded nutrients contained in the collected water or trapped sediments.

Bohluli *et al.* (2012) evaluated the effectiveness of various dimensions of silt pit (Table 4.5) to conserve soil, water and nutrients in a non-terraced oil palm plantation. They reported that silt pits with the smaller opening area helped to conserve more water than silt pits with the larger opening area.

This is because lower evaporation from smaller opening area of narrow silt pit. Moreover, lateral water flow through the walls of narrow silt pit was more than silt pits with bigger wall to floor area ratio (W:F). Therefore, upper layers of the soil received more water from the pit. Narrowest pit showed the highest increase in the soil chemical properties outside and inside of the pit. The narrowest silt pit infiltrated laterally more water and conserved more amounts of dissolved nutrients of trapped run-off into oil palm active root zone area than other silt pit. Silt pits with the smaller floor area had higher concentration of nutrients in soil of the pit's floor because, for the smaller floor area, trapped nutrients inside the pit were leached downwards through a smaller area. Hence, the nutrients were concentrated over a smaller soil area below the silt pit's floor.

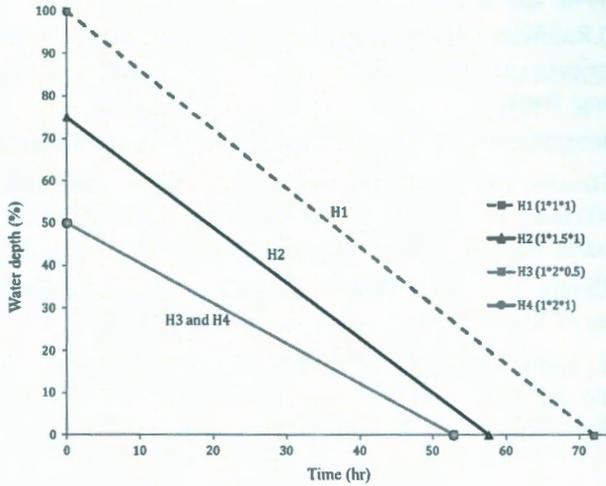
**Table 4.5** Treatments including different sizes, opening area and wall to floor area ratio

Treatment	Silt pit size (m) Width x Length x Depth	Volume (m <sup>3</sup> )	Opening or floor area (m <sup>2</sup> )	W:F
H <sub>0</sub>	Control (no pit)	-	-	-
H <sub>1</sub>	1.0×3.0×1.0	3.0	3.0	2.66
H <sub>2</sub>	1.5×3.0×1.0	4.5	4.5	2.00
H <sub>3</sub>	2.0×3.0×0.5	3.0	6.0	0.83
H <sub>4</sub>	2.0×3.0×1.0	6.0	6.0	1.66

(Source: Bohluli *et al.*, 2012)

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 (Table 4.5). Their results showed that a narrow silt pit with a bigger total 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 (Figure 4.3).

Increasing of W:F results more water flux out of the silt pit through walls than the floor. This is an important implication because the oil palm roots are located around the walls rather than below the silt pit's floor. Therefore, the silt pit with larger W:F would be able to redistribute the trapped water to the root zone rather than being lost through percolation via the silt pit floor.



(Source: Bohluli *et al.*, 2014)

**Figure 4.3** Temporal changes to water depth in the silt pit  
(Note: lines for H3 and H4 overlap each other)

## CONCLUSION

Expansion of oil palm plantations on sloping lands can potentially cause large amount of run-off and soil erosion, and consequently, lowering soil fertility and soil physico-chemical conditions. Silt pit is one of the recommended soil, water and nutrients conservation practice in oil palm plantations. Although silt pits have been practiced for several decades, their practices have not always been successful. This is because of the absence of instructions on how to build silt pits. This review shows that the number and the dimensions of silt pits are related to the hill slope steepness, soil physical conditions, amount of run-offs and soil erosion. The total volume of constructed silt pits must be able to contain the total volume of run-off and yet not to have too large an opening which would encourage large evaporative losses. Silt pits should not be deeper than 1 m or shallower than 0.5 m to release trapped water into oil palm active root zone and to avoid overflow of trapped runoff and sediments. Increasing of the wall-to-floor area ratio (W:F) results in more water flux into oil palm root zone through the pit walls than deep percolation through the pit floor.

## REFERENCES

- ADB. (2008). Rainwater Harvesting Handbook. Assessment of Best Practices and Experience in Water Harvesting. Tunis-Belvedere, Tunisia: African Development Bank.
- Allan, W. (1965). *The African Husbandman*. Oliver & Boyd, Edinburgh.
- Atmaja and Hendra. 2007. Soil Moisture Content in Soil Conservation Technique of Ridge Terrace and Silt Pit in Oil Palm Plantation PTPN VII Rejosari, Lampung. *IPB, Bogor Agricultural University*.
- Baba Amte Centre. (2007). For People's Empowerment. Samaj Pragati Sahayog for Ministry of Rural Development, Government of India.
- Bharad, G.M., Bathkal, B.G., Nagdeve, M.B., Kohale, S.K., Ingle, S.N., Gawande, R.L., Mahorkar, V.K., and Kayande, K.S. (1991). Watershed Approach in Rainfed Agriculture. Res. Bulletin, Dr. Punjabrao Deshmukh Vidyapeeth, Akola.
- Banabas, M., Turner, M. A., Scotter, D. R. and Nelson, P. N. (2008). Losses of nitrogen fertiliser under oil palm in Papua New Guinea: 1. Water balance, and nitrogen in soil solution and runoff. *Aust. J. Soil Res*, 46, 332-339.
- Barbhuiya A.R., Arunachalam A., Pandey H.N., Khan M.L. and Arunachalam K. (2008). Effects of disturbance on fine roots and soil microbial biomass C, N and P in a tropical rainforest ecosystem of Northeast India, *Current Science* 94(5), 31-44.
- Basehart, H. W. (1972). Traditional history and political change among the Matengo of Tanzania. *Journal of the International African Institute*, Vol.XIII, 4, 87-97.
- Bohluli, M., Teh, C.B.S., Husni, A.M.H. and Zaharah A.R. (2012). The Effectiveness of Silt Pit as a Soil, Nutrient and Water Conservation Method In Non-Terraced Oil Palm Plantations. In *Proceedings of Malaysian Society of Soil Science*.
- Bohluli, M., Teh, C.B.S., Husni, A.M.H. and Zaharah A.R. (2014). Silt Pit Efficiency in Conserving Soil Water as Simulated by HYDRUS 2D Model. *Pertanica Journal*, 37(1), (in press).
- Bruijnzeel, L.A. (1990). Hydrology of Moist Tropical and Effects of Conversion: A State of Knowledge Review, UNESCO IHP, Amsterdam.
- Dalvi V.B., Nagdeve M.B., and Sethi L.N. 2009. Rain Water Harvesting to Develop Non-arable Lands using Continuous Contour Trench (CCT). *Assam University Journal of Science and Technology: Physical Sciences and Technology*, 4, pp. 54-57.

- Filho W. L. (2012). *Climate Change and the Sustainable Use of Water*. Springer Heidelberg Dordrecht London New York. ISSN 1610-2010.
- Goh, K.J., Chew, P.S. and Teo, C.B. (1994). Maximising and maintaining oil palm yields on commercial scale in Malaysia. In: Chee, K.H. (ed.) *International Planters Conference on Management for Enhanced Profitability in Plantations*. Kuala Lumpur, 24–26 October 1994. ISP, 121–141.
- Goh, K.J., Teo, C.B., Chew, P.S. and Chiu, S. B. (1999). Fertiliser management in oil palm: Agronomic principles and field practices. In: *Fertiliser management for oil palm plantations*, 20-21, September 1999, ISP North-east Branch, Sandakan, Malaysia.
- Hashim M., Ibrahim A.L., Marghany M., Ahmad S., and Okuda T. (2008). Assessment of Impact on Landscape Development to Ecological Service Values and Goods in Malaysia Lowland Tropical Rainforest Using Integrated Remote Sensing and GIS Techniques. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*. Vol. XXXVII (B7), 1403-1414.
- Heady H.F. (1975). *Rangeland Management*. McGraw-Hill Book Company. New York.
- Itani, J. (1998). Evaluation of an Indigenous Farming System in the Matengo Highlands, Tanzania, and its Sustainability. *African Study Monographs*, 19(2), pp.55-68.
- Joshi H.B. (1983). *Troup's Silviculture of Indian Trees*. Controller of Publications, Delhi, 4, p. 345.
- Kee, K.K. and Chew. P.S. (1996). Nutrient losses through surface runoff and soil erosion-implications for improved fertiliser efficiency in mature oil palms. In *Proceedings of the 1996 PORIM International Palm Oil Congress: Agriculture*, Sept 23-28, 1996, Kuala Lumpur: Palm Oil Research Institute of Malaysia, Ariffin, D., Wahid, M.B., Rajanaidu, N., Tayeb, D., Paranjothey, K., Chean, S.C., Chang, K.C. and Ravigadevi, S. (eds.), 133-169.
- Lim, K.H., Chuah, J.H. and Ho, C.Y. (1994). Management of soil water retention through use of organic materials for enhancing performance of oil palms on inland soils. In *Proceedings of Soil Science Conference of Malaysia*, Petaling Jaya, Apr 18-19, 1994, Aziz, A. and Hawa, J. (Eds.), 20-29.
- Lim, K.H., Chuah, J.H. and Ho, C.Y. (1995). Sustainable soil and water management practices under oil palms on slopes. In *Proceedings of International Conference on Soil Resources and Sustainable Agriculture*, Kuala Lumpur, Aziz, B. (Ed.), 71-80.
- Luna, R.K. (1989). *Plantation and Practice os Silviculture*. Khanna Bandhu, Dehradun, 371-372.

- Madhu, M. and Tripthai, K.P. (1997). Soil-and water-conservation practices in tea at Nilgiris: some facts. *Indian Farming*, 47(1), 33-38.
- Madhu M., Raghunath B., Tripathi K.P., Sam M.J., Chandran B., Mohanraj R., and Haldoria B. (2011). Vegetative Barrier with Contour Staggered Trenches for Resource Conservation in New Tea Plantations of the Nilgiris, India. *Indian Journal of Soil Conservation*. 39 (1), 33-36.
- Maena, L.M., Thong, K.C., Ong, T.S. and Mokhtaruddin, A.M. (1979). Surface wash under mature oil palm. In *Proceedings of the Symposium on 'Water in Agriculture in Malaysia'*, Kuala Lumpur: Malaysian Society of Soil Science, E. Pushparajah (ed.), 204-216.
- Malesu, M.M., Oduor, A.R., Odhiambo, O.J. (2007). Green water management handbook. Rainwater harvesting for agricultural production and ecological sustainability. Nairobi: The World Agroforestry Center.
- Malley, Z. J. U., Kayombo, B. Willcocks, T. J. and P. W. Mtakwa, (2004). Ngoro: an indigenous, sustainable and profitable soil, water and nutrient conservation system in Tanzania for sloping land. *Soil Tillage Res.*, 77, 47 – 58.
- MANAGE – National Institute of Agricultural Extension Management, Ministry Agriculture, Government of India. [www.manage.gov.in](http://www.manage.gov.in), Last accessed 2010.
- Manivanna S., Rajendran V. and Ranghaswami M.V. (2010). Effect of In-situ Moisture Conservation Measures on Fruit and Nut Quality of Cashew (*Anacardium Occidentale*) in Lateritic Soils of Goa. *Indian Journal of Soil Conservation*, 38 (2), 116-120.
- Mishra T.k., singh A.K., and Banerjee S.K. (2002). Response of Conservation Measures on the Growth of Planted Species and Improvement in Soil Properties in a Degraded Area. 12<sup>th</sup> ISCO conference. Beijing.
- Moradi A., Christopher T.B.S., Goh K.J., Hanif A.H.M., and Fuziah C.I. (2012). Evaluation of Four Soil Conservation Practices in a Non-Terraced Oil Palm Plantation. *Agronomy Journal*, 104 (6), 27-40.
- Murtillaksono K., Siregar H.H., and Darmosarkoro W. (2007). Water Balance Model in Oil Palm Plantation. *Jurnal Penelitian Kelapa Sawit*, 15 (1), 21-35.
- Murtillaksono K., Darmosarkoro W., Sutara E.S., Siregar H.H., and Hidayat Y. (2009). Effort to Increase Oil Palm Production through Application Technique of Soil and Water Conservation. *Jurnal Tanah*, 14(2), 135-140.
- Murtillaksono K., Siregar H.H., and Darmosarkoro W. (2011). Water Balance Model in Oil Palm Plantation. *Jurnal Penelitian Kelapa Sawit*, 15 (1), 21-35.
- Muslim A.S., Hidayat Y., and Sutarta E.S. (2008). Bund Terraces and Silt Pits Effectiveness to Reduce Overland Flow and Soil Erosion in Oil Palm Plantation Area in Rejosari Management Unit. Institut Pertanian Bogor.

*Review on the Use of Silt Pits (Contour Trenches) as a Soil and Water Conservation*

- Netherlands Water Partnership. (2007). Smart Water Harvesting Solutions. Examples of innovative, low-cost technologies for rain, fog, runoff water and groundwater.
- Pradeepkumar T., Suma J. and Satheesan K.N. (2008). Management of Horticultural Crops. New India Publishing Agency.
- Rajshekar. (2009). Techniques for Steeply Sloping Land. Rain Water Harvesting in the Landscape. India Water Portal.
- Roslan, M.N. and Haniff, M. (2004). Water Deficit and Irrigation in Oil Palm: A Review of Recent Studies and Findings. *Oil Palm Bulletin*, 49, 1-6.
- Sharma K.D., Pareek O.P. and Singh H.P. (1986). Microcatchment water harvesting for raising Jujube orchards in an arid climate. In: Transactions of ASEA, 29 (1), 112-118.
- Shillington, K. (1989). History of Africa. Macmillan Press Ltd., London.
- Singh R.K., Lama T.D., and Satapahy K.K. (2006). Treatment Technologies for Watershed Development and Management in North East.
- Soon, B.B.F. and Hoong, H.W. (2002). Agronomic practices to alleviate soil and surface runoff and soil losses in an oil palm estate. *Malaysian Journal of Soil Science*, 6, 53-64.
- Tambe S., Kharel Ghanashyam., Arrawatia M.L., Kulkarni H., Mahamuni K., and Ganeriwala A.K. (2012). Reviving Dying Springs: Climate Change adaptation Experiments From the Sikkim Himalaya. *Mountain Research and Development*, 32 (1), 62-72.
- Teh C.B.S., Goh K.J., Law C.C. and Seah T.S. (2011). Short-term Changes in the Soil Physical and Chemical Properties due to Different Soil and Water Conservation Practices in a Sloping Land Oil Palm Estate. *Pertanika J. Trop. Agric. Sci.*, 34 (1), 41-62.
- Tromble J.M. (1976). Semiarid Rangeland Treatment and Surface runoff. *J. Range Manage.*, 29, 251-255.
- UNEP (Editor) (2012) Sourcebook of Alternative Technologies for Freshwater Augmentation in Africa. Planting Pits. Geneva: United Nations Environmental Program.
- Virendra K., Singh R.S., Singh P.K., and Singhvi B.S.M. (2007). Standardization of Suitable Soil and Water Conservation Measures Using Remote Sensing and GIS for Small Watersheds. *Journal of Agricultural Engineering*, 44 (2), 67-73.
- Wakker, E. (2006). The Kalimantan Border Oil Palm Mega-Project. Commissioned by Milieudefensie-Friends of the Earth Netherlands and the Swedish Society for Nature Conservation (SSNC).

- Wakker, E., Gelder, J.W. (2003). PT Gunung Mas Raya: Assessment of Investment Risks Associated with Environmental and Social Issues related to an Indofood Sukses Makmur Subsidiary in Rokan Hilir, Riau (Indonesia). Report for WWF International. AIDEnvironment and Profundo.
- Wan Sulaiman, W.H. and Jamal, T. (1981). Influence of crop and soil management practices on soil erosion. In *Proceeding of Seminar on Management of Tropical Soils*, Kuala Lumpur, Mar 30-31, 1981, Ghazalli, Z.K. and Huan, L.K. (Eds.), 14-24.
- Willis, R. G. (1966). The Fipa and related peoples of south-west Tanzania and north-east Zambia. In (D. Dorde ed.) *Ethnographic Survey of Africa*, p. 79. International African Institute, London.
- WOCAT. (2007). *Planting Pits and Stone Lines. Niger - Tassa avec cordon pierreux*. Oak Brook, IL: SWC Technology.