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SOIL STRUCTURE ATTRIBUTES AND SOIL ERODIBILITY UNDER INTERCROPPING SYSTEM OF IMMATURE RUBBER WITH BANANA AND PINEAPPLE PLANTED ON SLOPING LAND

(Struktur dan erodibiliti tanah pada sistem intercropping karet muda dengan pisang dan nenas pada tanah lereng)

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ABSTRAK

Suatu penelitian yang bertujuan untuk mengkaji pengaruh sistem intercropping antara karet dengan pisang dan nenas serta pengaruh posisi lereng terhadap struktur dan erodibiliti tanah telah dilaksanakan pada tahun kedua dan ketiga setelah penanaman. Hasil penelitian menunjukkan bahwa kondisi struktur tanah di bawah tanaman yang berbeda setelah tahun kedua cenderung menjadi lebih baik dengan kondisi struktur tanah serta ketahanan terhadap erosi pada tanah di bawah penanaman nenas dan *intercropping* antara pisang dan nenas lebih baik dibanding dengan yang lain. Walau bagaimanapun, keadaan struktur tanah mulai mengalami degradasi setelah memasuki tahun ke tiga. Posisi lereng juga mempengaruhi kondisi struktur dan erodibiliti tanah, dimana strukur tanah jauh lebih baik di bahagian tengah dan bawah lereng dengan erodibiliti yang rendah dibandingkan pada bahagian atas lereng.

Keywords : intercropping, sloping land, soil structure, soil erodibility

INTRODUCTION

Accelerated soil erosion as a dominant type of soil degradation is driven by the interactive effects of decline in soil structure and harsh climate. Soil erosion affects soil physical quality due to decline in soil structure and imbalance in soil-water regime (Lal, 1999). Its impact on productivity is due to loss of available water capacity, decline in soil fertility and deterioration of soil structure. An important factor affecting soil erosion is erodibility, which expresses the susceptibility of the soil to erosion. According to Lal (1988), erodibility of the soil depends on the inherent soil properties such as bulk density, porosity, permeability, texture, aggregation, sesquioxide, and organic matter. The relationships between soil physical properties and soil erodibility have been reported by some authors such as Egashire *et al.*, (1983), Elwell (1986) and Datta *et al.*, (1990). They observed that there was a significant relationship between soil erodibility and aggregates stability of the soil. Beside those soil properties, in humid tropic condition soil erosion is also greatly affected by slope steepness and vegetation cover. Several studies have confirmed the influence of slope steepness on soil loss (Roose, 1977; Hudson, 1984; and El-Swaify *et al.*, 1987). They showed that erosion generally increased exponentially with increase of slope. Whilst, El Hassanain *et al.*, (1993) in their study on Burundi soils found that the relationship between runoff and soil loss was linear and significant under various conditions of slope and vegetation covers. They also stated that, steep slopes and inappropriate management practices would enhance the erosiveness of running water and soil erodibility. For Malaysian soils, Zainol and Mokhtaruddin (1993) found that intercropping activities affected the nature of soil aggregate and stability of the soil. Three year after establishing rubber and intercropping component, they found that the finer aggregates were greatly reduced and the larger one was increased. It is reflected that intercropping activity improved resistance of soil to erosive effect of raindrops and runoff because it enhances soil aggregation as indicated by formation of more large aggregates. Based on the above aspects the purpose of the study is to evaluate the effect of intercropping of immature rubber-banana-pineapple and slope position on some soil structure attributes and soil erodibility.

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MATERIALS AND METHODS

Study Site.

One on–farm research was conducted for a period of 24 months at small holding area Tanam Semula Berkelompok (TSB) at Bukit Nering Village. It is situated at the village of Kampung Gudang at approximately Longitude 100° 49 E and latitude 5° 01'N. It lies in the sub-district of Batu Kurau, within the district of Larut matang in the state of Perak. The site is about 35 km from the major town of Taiping and 300 km north of Kuala Lumpur. Land preparation, contour lining, holing, and rubber planting was conducted on October 1997 whereas planting of banana and pineapple took place in May 1998.

Soil Sampling and analysis

Soil samplings were done four times with the first sampling conducted one year after planting of banana and pineapple and then repeated every six months. Soil characteristics observed in this experiment included the followings: particle size distribution, bulk density, available water holding capacity, soil aggregation, soil aggregate stability, and soil organic matter.

Measurement of Soil Erodibility

A rainfall simulator used in the field is a portable rainfall simulator (Figure. 1) as described by Kamphorst (1987). This equipment was chosen since it is a small unit that can be easily transported and hence very suitable for *in situ* measurements. On the other hand, it can also be operated easily in a very short time. The suitability of the equipment for Malaysian soil was evaluated by Wan Sulaiman *et al.*, (1990) and Tajuddin (1992). This method was adopted due to its high sensitivity that is able to detect variation in erodibility due to small differences in organic matter content, which is quite common in Malaysian soil. The simulator produces 18mm rain shower in three minutes trough 49 capillaries, giving intensity equivalent to 36 cm/hour. The raindrop fall from average height of 0.40m onto 0.0625m^2 surface areas of the tested plot having 20% slope. The amount of soil loss is dependent on kinetic energy of the falling raindrops. Since the average height of fall is 0.40 m (too small for raindrops to attain terminal velocity) and the plot size is small a high intensity shower is used i.e. 36 cm/hour. With this intensity and height, the rainfall simulator will produce the total kinetic energy of 35.4 Jmm^{-1} adequate to produce measurable erosion loss within a short duration.

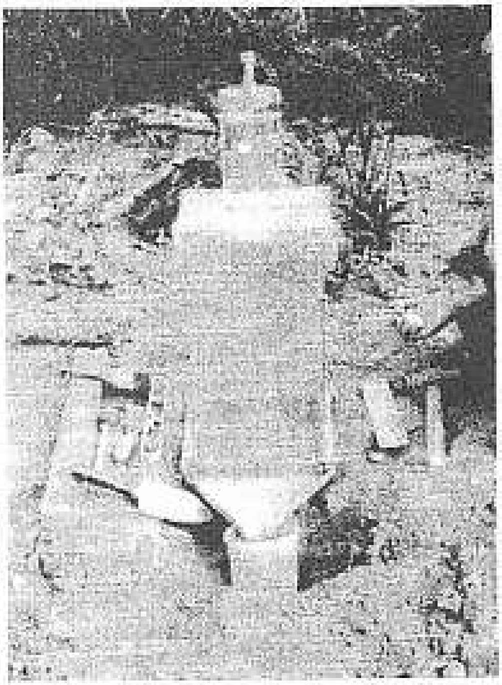


Figure 1. The set up of portable rainfall simulator in the field

RESULTS AND DISCUSSIONS

The site is situated in an undulating country with an average slope of 8-15%. Some portions, which are adjacent to the valleys, have slopes of 15 – 22%. The altitude is around 45 m above mean sea level. The geology of the area is composed of meta sediment, which is derived from contact metamorphism of the shale and sandstone by the younger granite. The site lies in the 'West-Coast' type rainfall distribution. The annual distribution of rainfall is characterized by maximum rate occuring during April and October/November. The nearest station where long-term rainfall recorded is in Taiping, which has an average annual rainfall of 4002 mm. The number of rain-days (>0.2 mm per day) is close to 200 in one year. The maximum rainfall intensity is about 21 mm per rain-day in the month of October while the minimum is 15 mm per rain-day in June. The maximum intensity coincides with the high rainfall period during the northeast monsoon. June and July are the drier months. The temperature remains uniformly high and is between 25-28°C. The mean relative humidity is about 85%. The soil belongs to Batu Kurau series. It is deep and has a sandy clay loam to sandy clay topsoil texture. The sub soil is generally sandy clay. In The foot slopes, colluvial materials of loamy sand texture are frequently encountered. The soil is acidic with low base saturation. The organic matter content is relatively high, giving rise to favorable levels of nitrogen. The soil is classified, as *Typic Kandiudult* according to Soil Taxonomy and its FAO equivalent is *Haplic Acrisol*.

Table 1. Particle size distribution of the soil of experimental site before and 30 months after planting

Position	Depth(cm)	Particle size distribution (microns)						Soil Textural class
		Clay (0 – 2)	Silt (2-50)	Very fine sand (50-100)	Fine sand (100-250)	Medium sand (250-500)	Coarse sand (>500)	
Before Planting								
Upper slope	0 - 15	50.45	2.48	3.10	8.12	14.78	21.07	Sandy Clay
	15 - 30	45.65	4.44	2.87	6.75	12.38	27.91	Sandy Clay
Middle slope	0 - 15	47.10	2.79	3.27	7.68	13.40	25.76	Sandy Clay
	15 - 30	47.07	2.81	3.01	6.84	13.24	27.03	Sandy Clay
Lower slope	0 - 15	40.65	7.48	3.67	7.68	12.49	28.03	Sandy Clay
	15 - 30	45.02	5.18	3.70	7.92	12.58	25.60	Sandy Clay
30 months after	**planting**							
Upper slope	0 - 15	42.26	2.06	3.10	7.11	12.59	32.87	Sandy Clay
	15 - 30	45.91	4.44	2.67	6.67	11.56	29.11	Sandy Clay
Middle slope	0 - 15	43.38	3.02	2.94	6.67	13.64	30.32	Sandy Clay
	15 - 30	48.57	5.02	3.08	7.20	13.04	22.98	Sandy Clay
Lower slope	0 - 15	42.13	3.47	3.19	7.47	14.82	28.51	Sandy Clay
	15 - 30	42.38	1.62	3.25	7.14	13.97	31.52	Sandy Clay

Table 2. The mean bulk density under different cropping systems planted on sloping land

Depth (cm)	Treatments	Bulk Density (g cm^{-3})			
		12 MAP	18 MAP	24 MAP	30 MAP
0-15	Pineapple	1.14 ^{aA}	1.15 ^{aA}	1.11 ^{aA}	1.06 ^{aA}
	Rubber	1.14 ^{aA}	1.14 ^{aA}	1.16 ^{aA}	1.24 ^{aA}
	Banana	1.11 ^{aA}	1.14 ^{aA}	1.12 ^{aA}	1.12 ^{aA}
	Banana-Pineapple	1.14 ^{aA}	1.13 ^{aA}	1.08 ^{aA}	1.16 ^{aA}
	Rubber-Pineapple	1.16 ^{aA}	1.12 ^{aA}	1.14 ^{aA}	1.16 ^{aA}
15-30	Pineapple	1.20 ^{aAB}	1.06 ^{aB}	1.18 ^{aA}	1.29 ^{aA}
	Rubber	1.21 ^{aA}	1.15 ^{aA}	1.25 ^{aA}	1.22 ^{aA}
	Banana	1.25 ^{aA}	1.24 ^{aA}	1.23 ^{aA}	1.24 ^{aA}
	Banana-Pineapple	1.21 ^{aA}	1.12 ^{aA}	1.16 ^{aA}	1.26 ^{aA}
	Rubber-Pineapple	1.25 ^{aA}	1.12 ^{aA}	1.22 ^{aA}	1.25 ^{aA}

Means within column bearing same small letter (s) and within row(s) bearing capital letter (s) are not significantly different at P<0.05 DMRT.

Table 3. The mean of percent aggregation and macro aggregate stability under different crops on sloping land

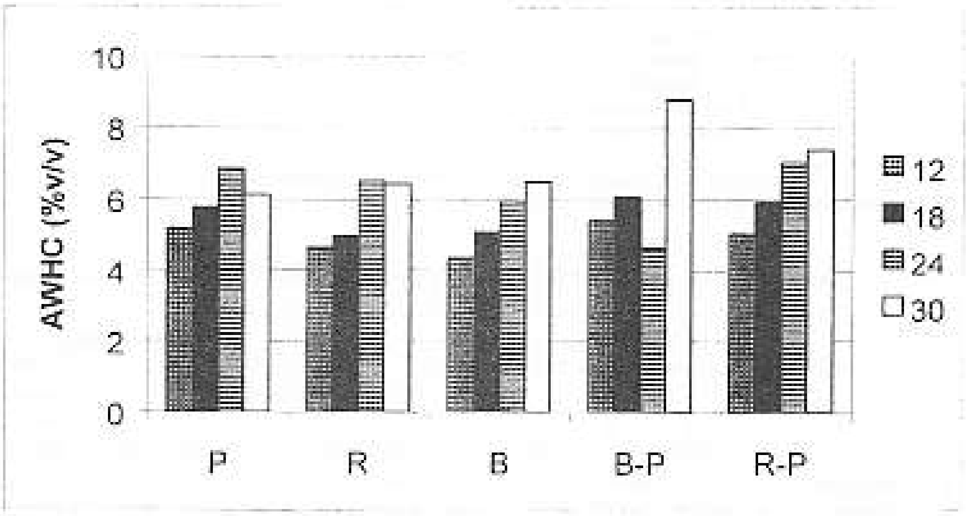
Depth (cm)	Treatment	Percent of Aggregation > 2 mm (De Leenheer and De Boodt, 1959)				Aggregate Stability: Stability Index (De Leenheer & De Boodt, 1959)				Aggregate Stability: %WSA>0.5 (Brian, 1968)			
		12 MAP	18 MAP	24 MAP	30 MAP	12 MAP	18 MAP	24 MAP	30 MAP	12 MAP	18 MAP	24 MAP	30 MAP
0 -15	Pineapple	21.19 ^{aB}	34.34 ^{aA}	39.57 ^{aA}	41.76 ^{aA}	0.64 ^{aB}	0.85 ^{aA}	0.87 ^{aA}	0.79 ^{aAB}	73.03 ^{aB}	81.56 ^{aAB}	84.23 ^{aA}	85.34 ^{aA}
	Rubber	29.79 ^{aB}	33.17 ^{aAB}	29.70 ^{aB}	42.26 ^{aA}	0.53 ^{aAB}	0.69 ^{aAB}	0.80 ^{aA}	0.58 ^{aB}	73.37 ^{aA}	83.02 ^{aA}	80.49 ^{aA}	74.79 ^{aA}
	Banana	15.38 ^{aC}	29.15 ^{aB}	41.19 ^{aA}	47.77 ^{aA}	0.59 ^{aA}	0.70 ^{aA}	0.75 ^{aA}	0.72 ^{aA}	71.12 ^{aA}	77.48 ^{aA}	81.13 ^{aA}	75.73 ^{aA}
	Banana-Pineapple	22.30 ^{aB}	31.71 ^{aAB}	41.79 ^{aAB}	46.50 ^{aA}	0.66 ^{aA}	0.72 ^{aA}	0.83 ^{aA}	0.80 ^{aA}	76.56 ^{aA}	78.52 ^{aA}	82.34 ^{aA}	82.23 ^{aA}
	Rubber-Pineapple	25.85 ^{aB}	31.44 ^{aAB}	35.35 ^{abAB}	44.33 ^{aA}	0.64 ^{aA}	0.82 ^{aA}	0.89 ^{aA}	0.72 ^{aA}	71.78 ^{aA}	80.10 ^{aA}	83.28 ^{aA}	79.56 ^{aA}
15 - 30	Pineapple	40.44 ^{aB}	45.49 ^{aAB}	44.01 ^{aAB}	50.48 ^{aA}	0.46 ^{aA}	0.59 ^{aA}	0.62 ^{aA}	0.71 ^{aA}	68.65 ^{aA}	74.78 ^{aA}	80.48 ^{aA}	84.46 ^{aA}
	Rubber	41.95 ^{aB}	39.63 ^{aB}	42.19 ^{aB}	51.50 ^{aA}	0.47 ^{aA}	0.67 ^{aA}	0.82 ^{aA}	0.46 ^{bA}	72.67 ^{aA}	76.79 ^{aA}	80.27 ^{aA}	73.43 ^{abA}
	Banana	40.65 ^{aAB}	39.26 ^{aB}	42.75 ^{aAB}	49.80 ^{aA}	0.52 ^{aA}	0.50 ^{aA}	0.84 ^{aB}	0.45 ^{bA}	70.40 ^{aB}	71.44 ^{aAB}	82.00 ^{aA}	65.55 ^{bB}
	Banana-Pineapple	42.97 ^{aAB}	40.74 ^{aB}	44.77 ^{aAB}	53.42 ^{aA}	0.49 ^{aA}	0.60 ^{aA}	0.60 ^{aA}	0.53 ^{abA}	73.39 ^{aA}	75.72 ^{aA}	76.96 ^{aA}	73.98 ^{abA}
	Rubber-Pineapple	41.75 ^{aB}	41.53 ^{aB}	43.44 ^{aB}	53.52 ^{aA}	0.45 ^{aA}	0.58 ^{aA}	0.65 ^{aA}	0.54 ^{abA}	72.99 ^{aA}	73.80 ^{aA}	81.71 ^{aA}	77.44 ^{abA}

Means within column bearing same small letter (s) and within row(s) bearing capital letter (s) are not significantly different at P<0.05 DMRT

MAP = Months after planting

Measurement of some physical properties except particle size analysis was carried out every six months, starting one year after planting of banana and pineapple. Particle size analysis for determining soil textural class of experimental site was done at upper, middle and lower slope. Based on textural classification released by USDA, the soil of experimental site at the depth of 0–15 cm and 15-30 cm is categorized as sandy clay. Clay was dominant on both depth, and it decreased with depth while the sand content increased. Silt content was the least compared to other soil fractions for both depth and did not show any discernible trend (Table 1). The bulk densities of the soil under different crops tend to decrease over time. The mean values varied from 1.11 to 1.16 g cm at first depth and 1.18 to 1.24 for second depth with the lowest value for both depths occurring under pineapple plot but not significantly different ($P<0.05$) from four others (Table 2). The percent of aggregation generally increased significantly ($P<0.05$) over time (Table 3). The highest increment of soil aggregation at 0-15cm depth after 30 months planting occurred on soil under banana, followed by banana-pineapple intercropping (B-P), pineapple, rubber-pineapple intercropping (R-P), and rubber. The increments in percent of aggregation were 32.39, 24.20, 20.57, 18.48, and 12.47 % respectively. Whilst for 15-30 cm depth the increment in percent of aggregation were 11.77, 10.45, 10.05, 9.23, and 9.55% for R-P, B-P, pineapple, banana, and rubber respectively. Aggregate stability (stability index and %WSA>0.5) and available water holding capacity (AWHC) was also found increasing gradually during experimental period (Figure 2a and 2b). Improvement of soil structural stability as indicated by some soil structure attributes may be due to the increase of soil organic matter. During the period of 30 months, organic matter at first depth increased with time until 24 months after planting and then tended to decrease slightly after that for all crops (Figure 3a and 3b). The highest increment of soil organic matter appeared on banana-pineapple followed by rubber-pineapple, banana, pineapple, and rubber, and the increment were 0.76, 0.68, 0.66, 0.45, and 0.07% respectively. In case of slope position effect, generally it was found that soil properties under middle slope and lower slope were much better than upper slope showing significant differences ($P<0.05$) in bulk density, organic matter, and percent of aggregation (Figure 4 a, b, and c).

(a)



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(b)

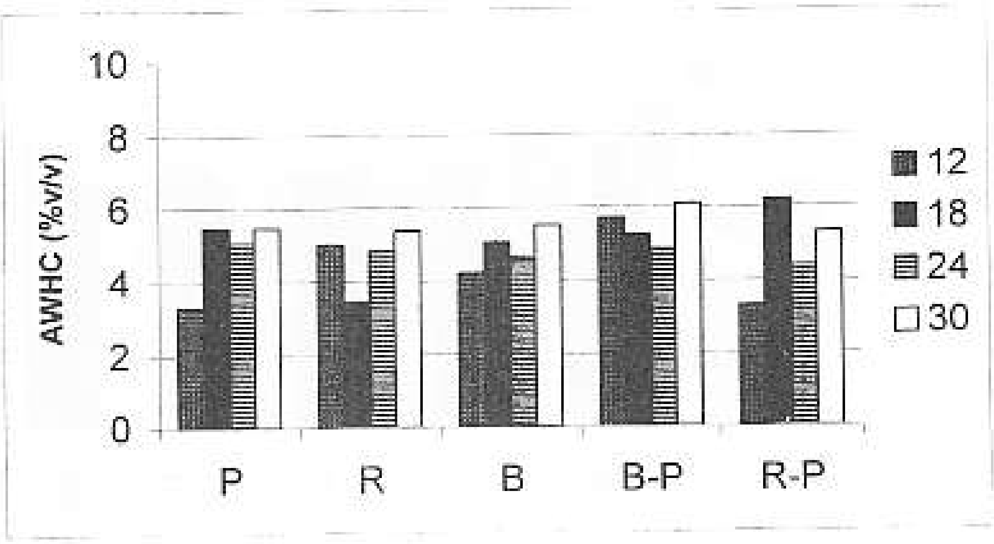
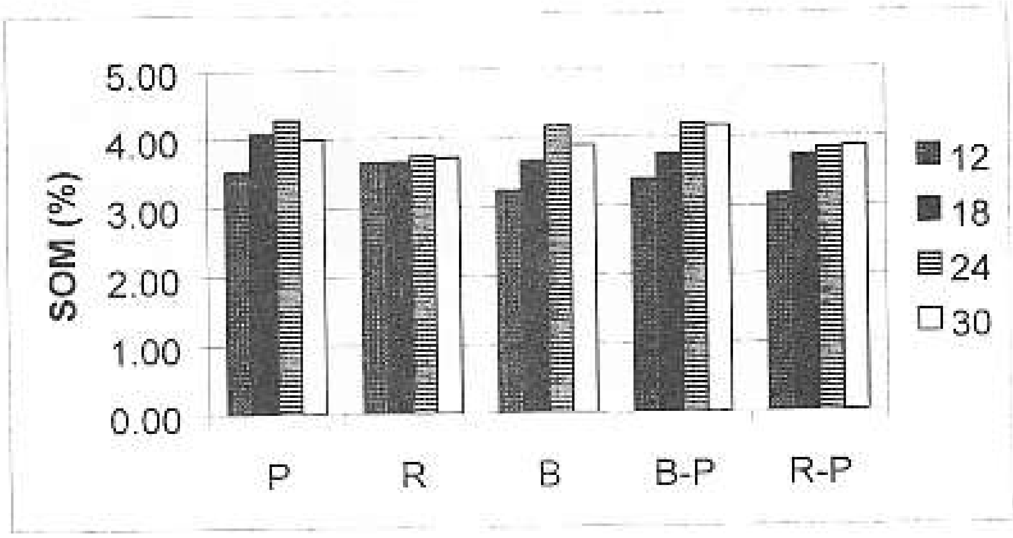


Figure 2. Available water holding capacity as affected by different cropping system at 0-15 cm depth (a) and 15-30 cm depth (b)

(a)



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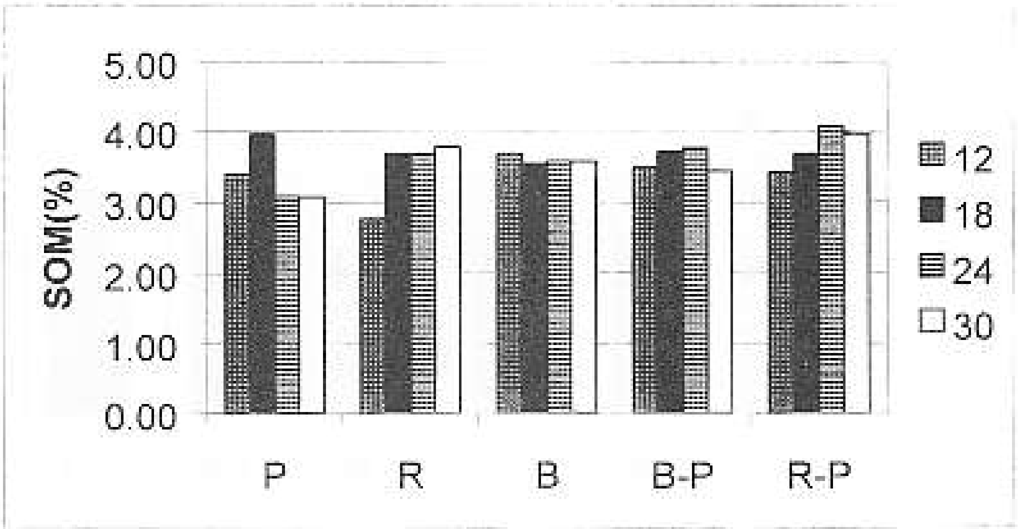
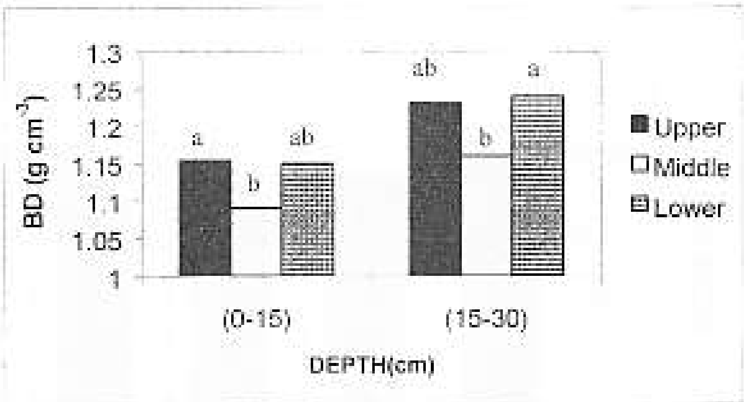
(b)



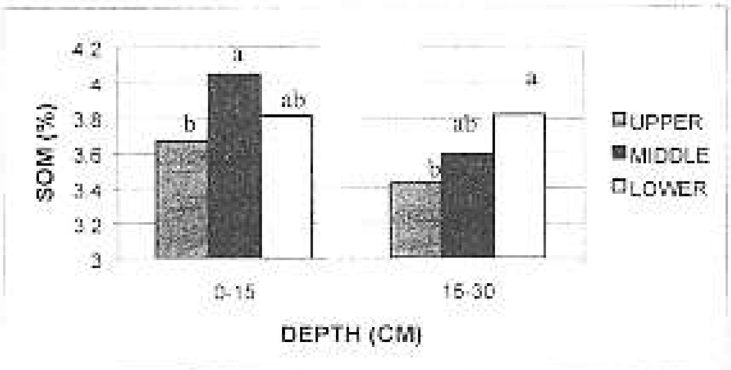
(b)

Figure 3. Dynamic of soil organic matter as affected by different cropping system 0-15 cm depth (a) and 15-30 cm depth (b)

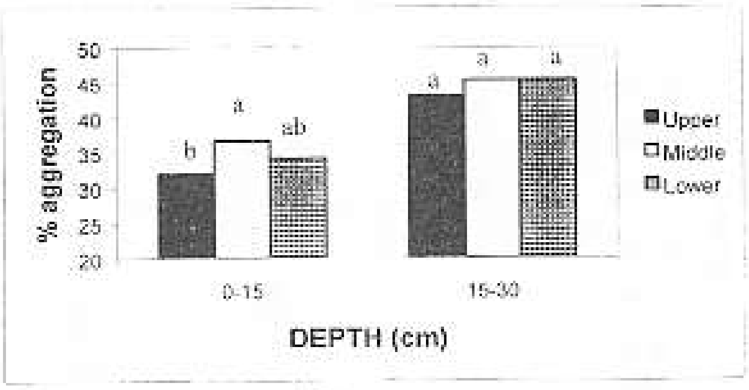
(a)



(b)



(c)



(c)

Figure 4. The effect of slope position on bulk densities (a), soil organic matter (b), and percent of soil aggregation (c).

The relative soil erodibility is expressed by the amount soil loss for each measuring period (12, 18, and 24 months after planting). The results showed that soil loss were reduced over time and varied highly among crops. The highest soil loss occurred under rubber for whole periods and then followed by banana, R-P, B-P, and pineapple. In terms of soil erosion after 24 months of planting, soil loss under pineapple and banana-pineapple intercropping was reduced about two times compared to soil loss at 12 months (Figure 5), with the middle slope found as the least erodible position (Figure 6).

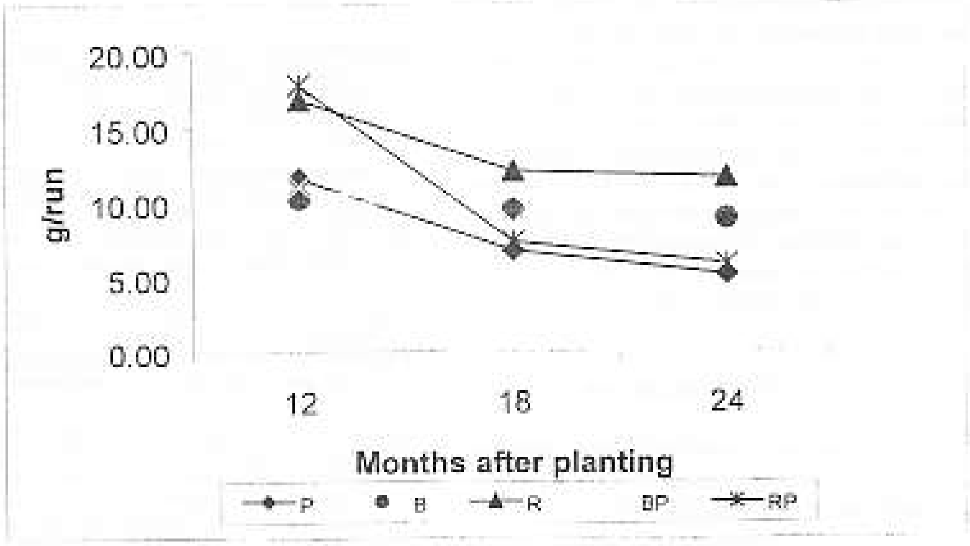


Figure 5. Amount of soil loss under different crops in intercropping system

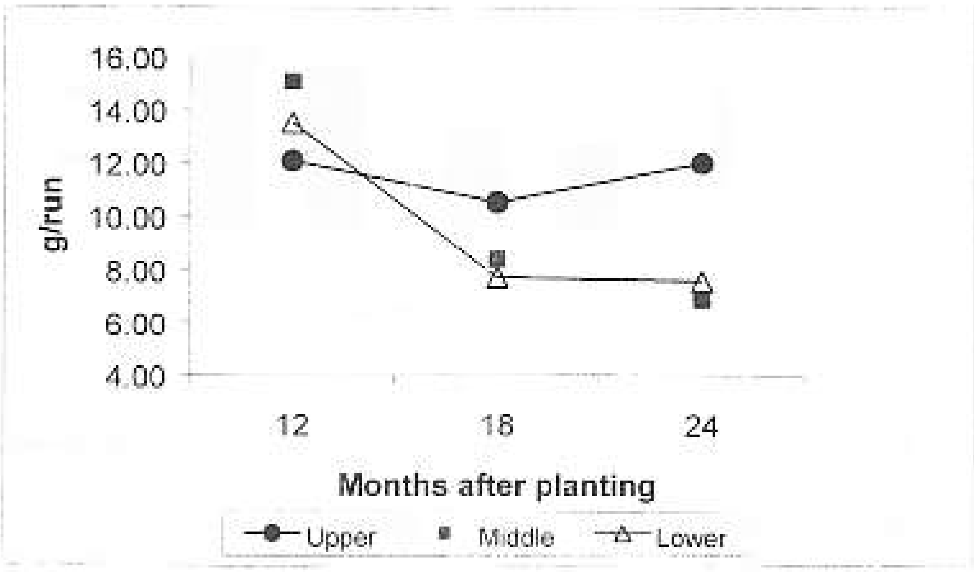


Figure 6. Amount of soil loss under different slope position

CONCLUSION

Results indicate that intercropping system improves soil structure up to 24 months after planting after which most of soil structure attributes tend to decline. The highest improvement in soil structure occurs on soil under pineapple followed by banana-pineapple intercropping, and banana. Looking at the slope position, better soil structure occurs on middle slope compared to lower and upper slope. Finally, it can be concluded that the soil under pineapple and banana-pineapple intercropping is less erodible compared to rubber-pineapple intercropping, and banana, whereas soil under rubber is most erodible.

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