THE EFFECT OF DIFFERENT CROPPING SYSTEMS OF BANANA-PINEAPPLE ON SOIL PHYSICAL PROPERTIES, ROOT BIOMASS, AND SOIL EROSION

(Pengaruh perbedaan sistem penanaman pisang-nenas terhadap sifat fisika tanah, biomas akar, dan erosi tanah)

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ABSTRAK

Suatu penelitian tentang pengaruh perbedaan sistem intercropping di tanah tinggi terhadap perubahan sifat fisika tanah yang dipengaruhi oleh biomas akar telah dilakukan di kebun percobaan Universiti Putra Malaysia di Puchong selama periode 18 bulan. Tiga plot erosi telah ditanami dengan sistem yang berbeda-beda dan satu plot tidak ditanami (kontrol). Penelitian difokuskan terhadap beberapa sifat tanah yang berkaitan dengan struktur tanah seperti kerapatan isi, kandungan air tersedia, kemantapan agregat, kandungan bahan organik, dan dinamika biomas akar. Jumlah aliran permukaan dan kehilangan tanah juga diukur dengan menggunakan tangki-tangki sedimen yang ditempatkan di ujung bahagian bawah lereng. Hasil penelitian menunjukkan bahwa kondisi tanah yang ditanami jauh lebih baik dibandingkan dengan tanpa tanaman. Kehilangan tanah yang hebat ditemukan pada plot tanpa tanaman. Secara umum dapat disimpulkan bahwa kondisi fisika tanah pada tanah yang ditanami pisang lebih baik dibandingkan dengan yang lainnya, tetapi dalam konteks pengurangan erosi tanah, ternyata penanaman nenas memberikan sumbangan yang paling baik.

Keywords : cropping systems, soil physical properties, root biomass, soil erosion

INTRODUCTION

Malaysia is situated in the humid tropic with annual rainfall ranging from 1500 to 3000 mm of which a large portion falls in storm of high intensity causing severe and wide spread erosion. The high rain intensity and erosivity enhance the severity of the soil loss problem. As pressure on land increases, more area of rainforest is being cleared, more upland is cultivated and high quality croplands are being intensively used. These activities have aggravated the problem of soil erosion (Jamal *et al.* 1985). It is estimated that 400,000 hectares of agricultural land are subjected to erosion and require urgent soil conservation attention (Jamil, 1987). Another factor that could bring out soil degradation in Malaysia is unchecked loss of topsoil. This could happen on hilly and steep terrain where proper conservation practices are not effectively carried out, to check or reduce erosion (Jamil, 2000). Due to these conditions, erosion control is indispensable in the development of upland for agricultural purpose. Excessive soil loss can lead to soil structure deterioration, organic matter depletion, decrease in soil fertility and hence reduced crop yield (Lal, 1984, 1988).

Resistance of soil to erosion (detachment and transport) is determined by soil properties such as texture, aggregate stability, infiltrability, shear strength, organic matter content and chemical status (Wan Sulaiman *et al.* 1983). The structure of surface soil is usually given most attention in relation to soil erosion because of its vulnerability to raindrop impact and agricultural practices. Truski *et al.* (1992) and Lowery *et al.* (1995) found that as clay fraction and bulk density increases, water stable aggregate and pore size distribution decreases slightly and moderately in eroded soil as compared to non-eroded soil. Various measures have been taken to control erosion and conserve fertile topsoil. They include various crop and soil management practice on sloping land (Wan Sulaiman *et al.* 1983). Proper crop selection and good soil management practice is an important factor in controlling and reducing soil erosion. The root systems of plant contribute a significant factor in the formation of stable aggregate. Its effectiveness for stabilizing soil structure depends on the extent to which movement of particle or aggregates under the erosive influence of water can be restricted (Goss, 1991). In addition, the effectiveness of plant cover and root in reducing erosion also depend on the growth stages of crop, the extent of their foliage development, the density of ground cover, the root density and plant height (Morgan, 1979; Benwale, 1986; Hashim and Wong, 1987).

Thus the study is conducted to evaluate changes in selected soil properties due to the different cropping system of banana and pineapple, to observe the relationship of some soil properties and root of banana and pineapple

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to soil aggregate stability and to observe the relationship of some soil properties and root of banana and pineapple to soil loss.

MATERIALS AND METHODS

The study was conducted in an undulating area at Puchong (UPM experimental farm). Four erosion plots were established on 9% slope. One plot was planted with banana, second with pineapple, and third with intercropping of banana and pineapple and one plot was left bare with regular cultivation every fortnight. Sizes of plot for banana and intercropping is 22.1 x 5.0 m, and for bare and pineapple is 22.1 m x 2.5 m.

Soil Properties namely bulk density, available water content, aggregate stabilty (%WSA.0.5), organic matter content, and root biomass was observed. For sampling purpose each plot was divided into three sub-plots along the slope namely, upper slope, middle slope and lower slope. Soil samples were taken at depths of 0-15 and 15-30 cm every three months during the second year of plant growth and analyzed for the above soil properties. Root samples were collected using root auger from 0-15 and 15-30 cm depth at a distance of. 30 cm from mother plant of banana and from center of two pineapple plants, whereas sample for intercropping plot was collected from the center of banana and pineapple rows. In laboratory, roots were separated from soil using water and sodium phyrophospate (10 g l^{-1} H_2O).

Runoff and soil loss was collected after every erosive rainfall during sampling period using sediment tank that was placed at the end of the slope. Representative samples were taken for laboratory analysis. A 100ml aliqnot was taken for each sample, evaporated to dryness on a steam bath, cooled in desiccators and weighed. Runoff and soil loss then was calculated on per hectare basis.

RESULT AND DISCUSSION

Soil Physical Properties

The measured soil properties namely bulk density, available water, aggregate stability and organic matter content under cropped plots differed significantly ($P<0.05$) from the bare ones. The changes in bulk density are shown in Figure 1a and 1b. The bulk densities of the cropped plots were significantly lower than those ($P<0.05$) of bare plots. At the depths of 0-15 and 15-30 cm, bulk densities for bare plot varied from 1.27 to 1.31 g cm^{-3} and 1.26 to 1.41 g cm^{-3} respectively. The lowest bulk density (0-15 cm) was recorded in pineapple plot (1.12 g cm^{-3}) followed by banana (1.15 g cm^{-3}) and the plot intercropped with banana and pineapple (1.20 g cm^{-3}).

In terms of water holding capacity, the average available water content (AWC, at 33-1500 kPa) for bare, pineapple cultivation, plot intercropped with banana and pineapple, and plot cropped with banana ranged from 5.82 to 7.93%, 7.01 to 8.52%, 6.02 to 8.39%, 6.35 to 8.27% respectively (Figure 2 (a) and (b)).

The aggregate stability (%WSA>0.5) for cropped plots improved significantly compared to the bare plot (Figure 3a and 3b). This was in line with the changes in organic matter content with time. The organic matter content (0-15 cm) for the bare plot decreased with time from 2.23 to 1.96% whereas increase from 2.17 to 2.46%, 2.03 to 2.44%, and 1.89 to 2.38% were observed for banana, intercrop, and pineapple respectively (Figure 4a and 4b). Decrease in organic matter in the bare plot might be due to disruption of aggregate stability (through rapid wetting and impact of raindrop) resulting in the exposition and inaccessible organic matter to microbial attack and stimulation of oxidation. Aggregate stability increased by 11.63%, 17.41% and 20.26% for intercropped, pineapple and banana respectively. Thus, banana crop seemed to have contributed the most to aggregate stability of the soil.

Root Biomass

The highest root biomass was recorded in banana plots for both depths. Dry weights of root biomass at depths of 0 –15 cm increased from 2.73 to 3.17 g, 1.99 to 3.24 g, and 2.85 to 3.33 g for pineapple, intercropped, and banana respectively. At depth of 15 – 30 cm the root biomass increased from 0.15 to 1.40 g, 0.49 to 0.89 g, and 1.32 to 2.07 g for intercropped, pineapple, and banana respectively. The dynamic of root biomass under different cropping systems are shown in Figure 5a and 5b. Irrespective of cropping system, root biomass production was statistically not different for the different treatment. However there was a significant relation between organic matter content and root biomass for all treatments (Figure 6) indicating that root biomass as an important component of the organic matter content of the soil.

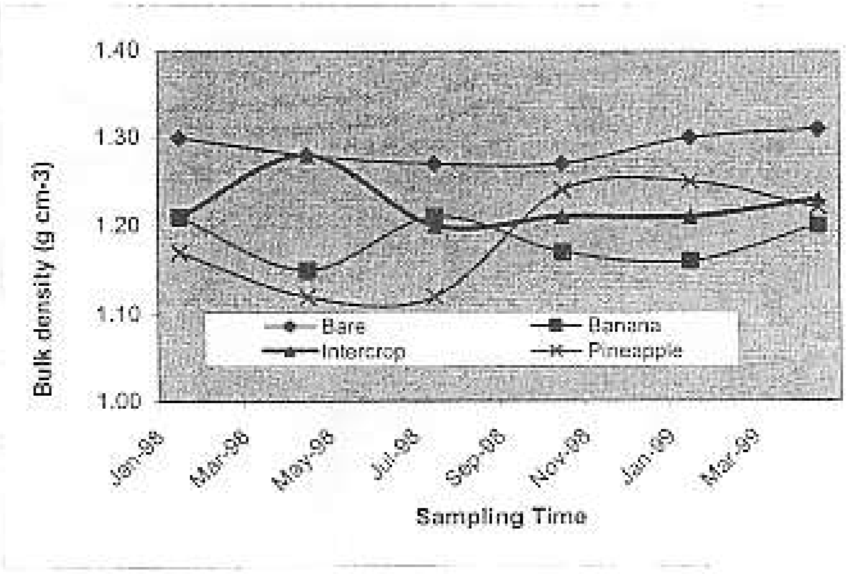

Figure 1a. Changes in bulk density under different cropping system for 0 – 15 cm depth.

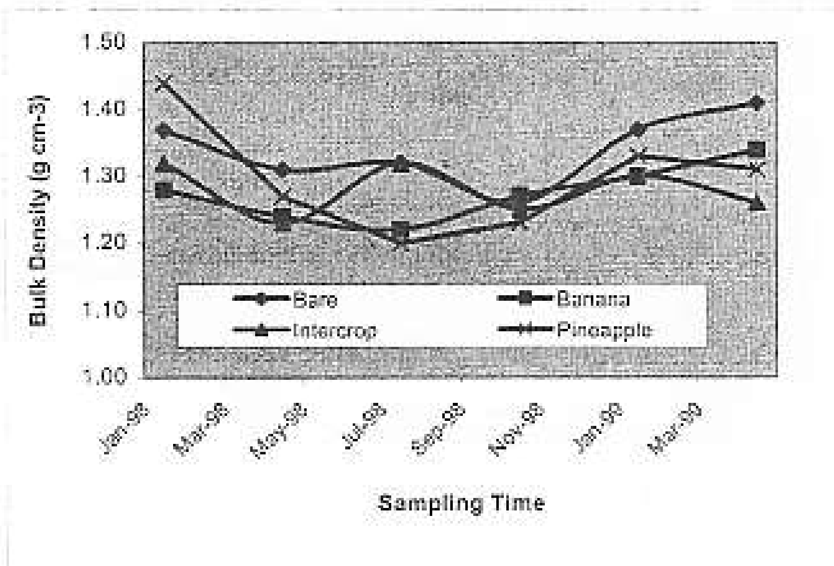

Figure 1b. Changes in bulk density under different cropping system for 15 – 30 cm depth.

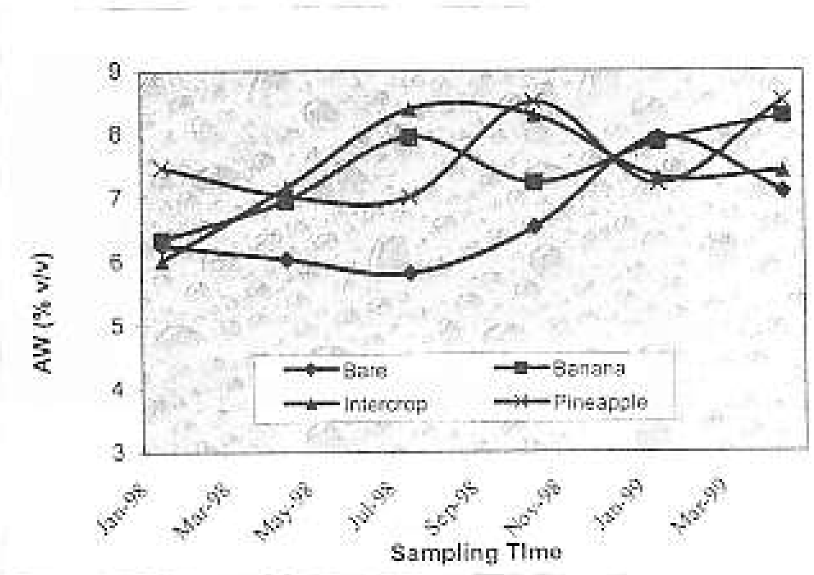

Figure 2a. Available water content under different cropping system for 0 – 15 cm depth.

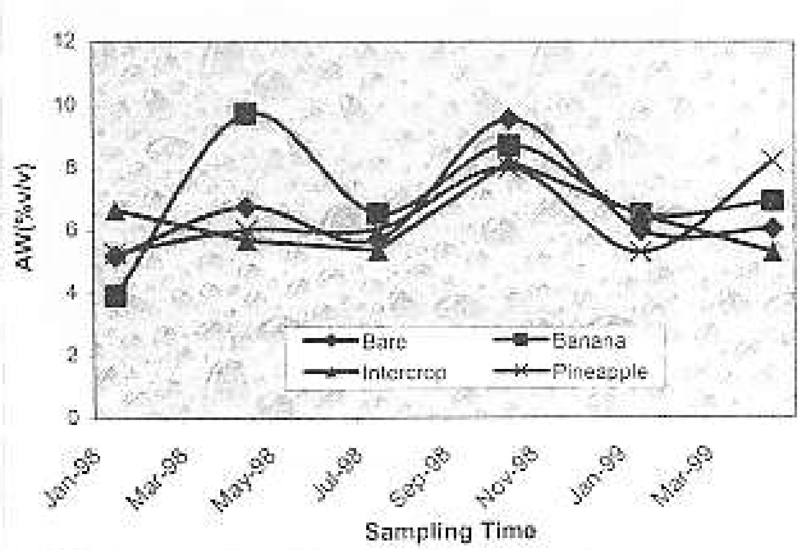

Figure 2b. Available water content under different cropping system for 15 – 30 cm depth.

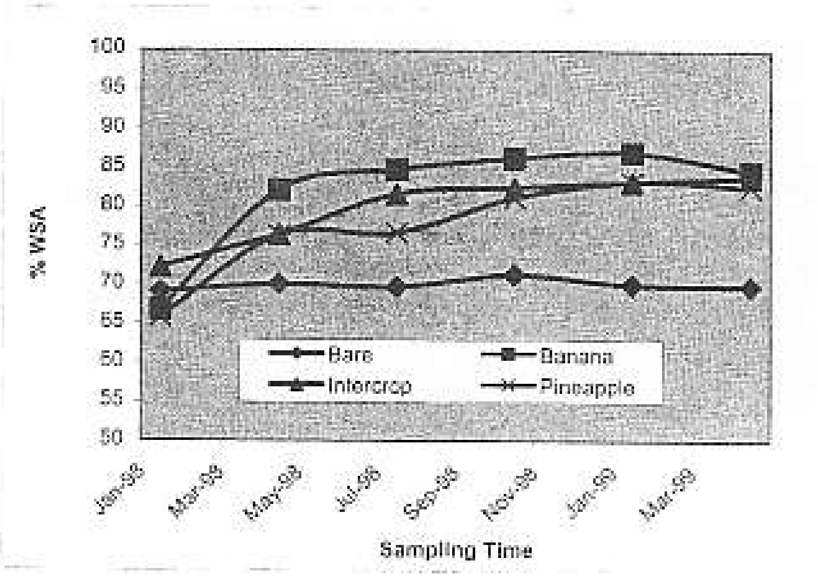

Figure 3a. Changes in water stable aggregates under different cropping system for 0 – 15 cm.

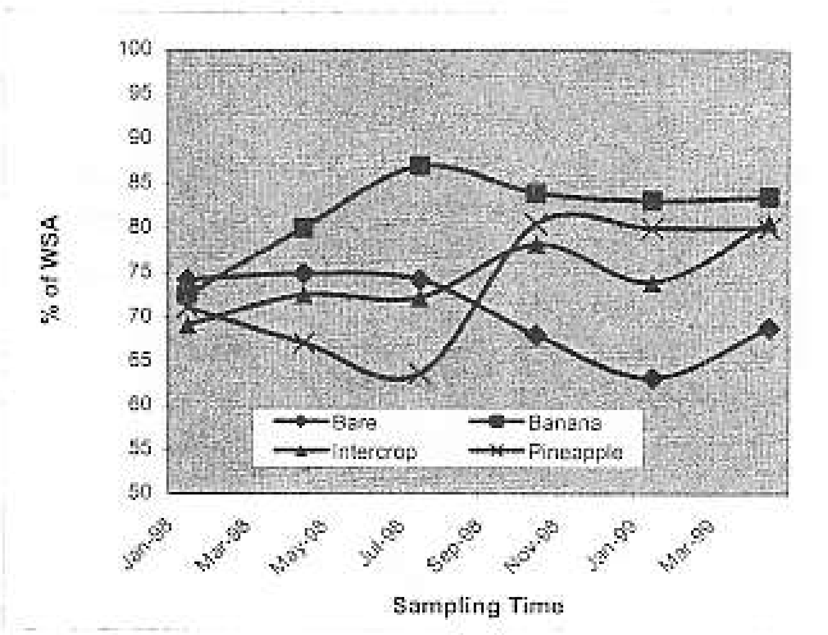

Figure 3b. Changes in water stable aggregates under different cropping system for 15 – 30 cm.

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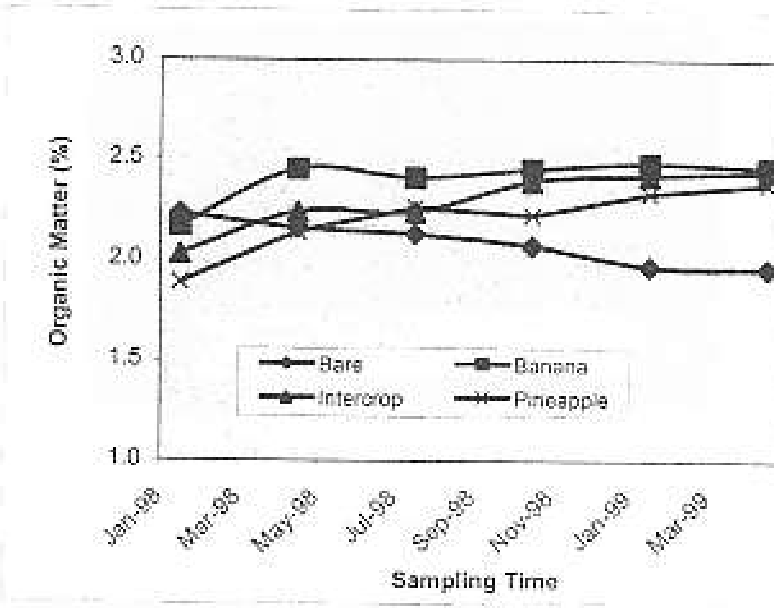

Figure 4a. Dynamic of organic matter under different cropping system for 0 – 15 cm depth.

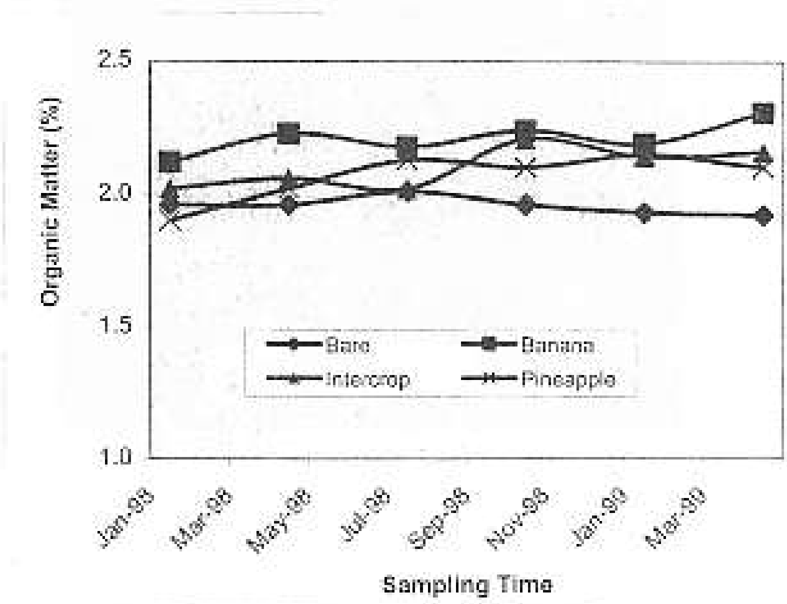

Figure 4b. Dynamic of organic matter under different cropping system for 15 – 30 cm depth.

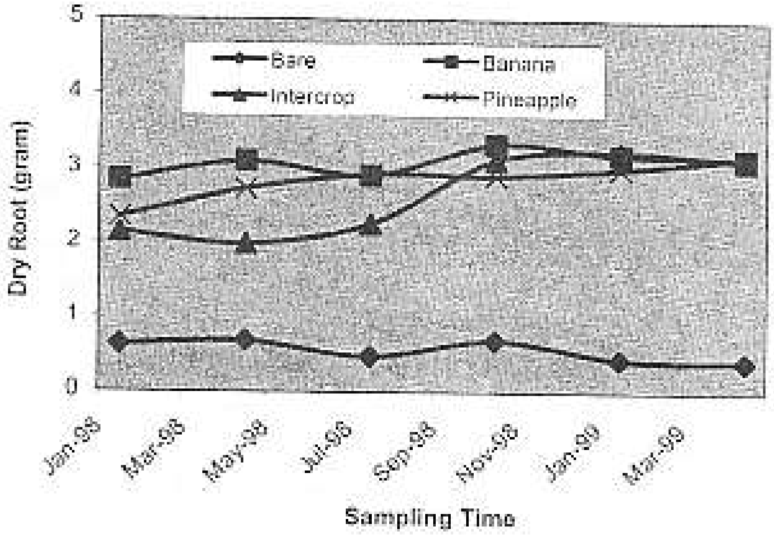

Figure 5a. Dynamic of root biomass under different cropping system for 0 – 15 cm depth.

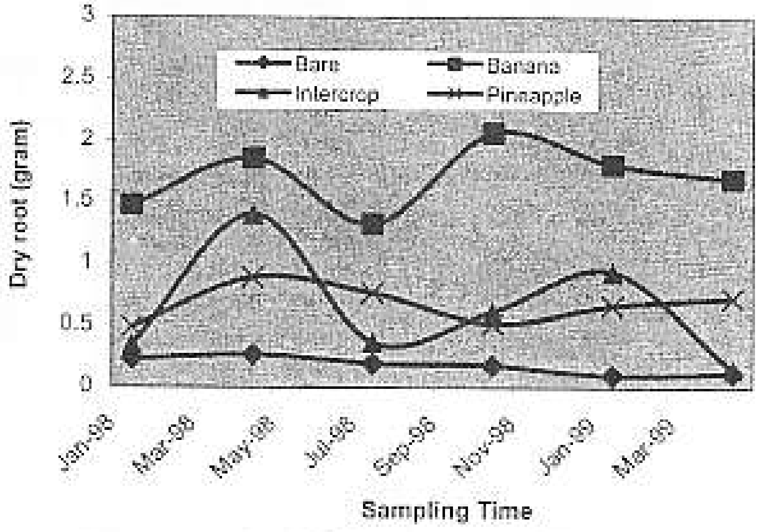

Figure 5b. Dynamic of root biomass under different cropping system for 15 – 30 cm depth.

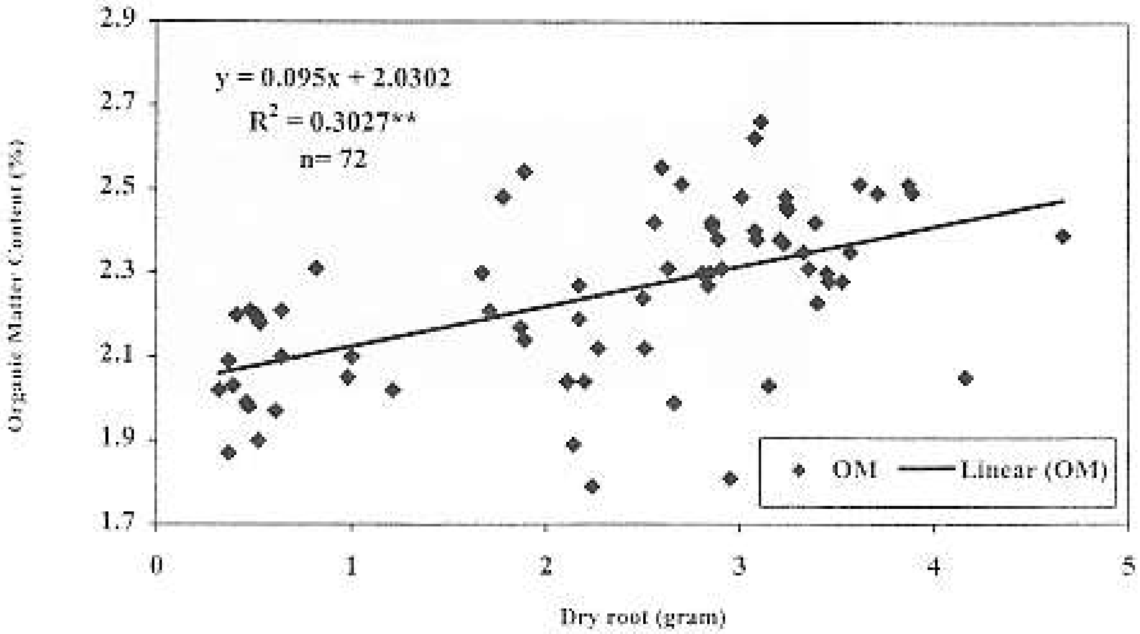

Figure 6. Relationship between root biomass and soil organic content

Relationship between soil properties, root biomass and aggregates stability

Relationship between the various soil properties, root biomass and aggregates stability (WSA>0.5) was established using stepwise multiple linear regression. These analyses indicated that aggregate stability of soil under banana and pineapple were affected by organic matter and for intercrop by organic matter and bulk density. The relationships are shown below:

Banana : WSA = 20.36 − 25.58 OM (r^2 = 0.41*)
Pineapple : WSA = 10.38 − 31.52 OM (r^2 = 0.63**)
Intercrop : WSA = 52.08 + 13.47 OM − 0.86 BD
(R^2 = 0.98**)

Where, WSA represents water stable aggregates, OM represents organic matter and BD represents bulk density.

Runoff and Soil loss

Total runoff during the stipulated study were 873 mm, 505 mm, 162 mm, and 55 mm for bare, banana, intercopped and pineapple plots respectively and these were 30.45%; 17.61%, 5.65%, and 1.92% of total rainfall (Table 1). The amount of soil loss were as follows: bare plot = 79.95 tons ha^{-1}, banana = 32.44 tons ha^{-1}, intercropped = 19.41 tons ha^{-1} and pineapple = 14.28 tons ha^{-1} (Figure 7) indicating a reduction of two and half, four, and five times that of bare plots respectively (Table 2).

Table 1. Amount of runoff for different cropping systems

Treatment	Soil loss tons/ha	Effectiveness* (%)
Bare	79,95	100
Banana	32,44	246
Intercrop	19,41	412
Pineapple	14,28	557

*compared to bare plot

Table 2. Amount of soil loss and effectiveness of different cropping systems in reducing soil loss

Treatment	Runoff		
	(x1000 l/ha)	mm	% of rainfall*
Bare	8729	873	30,45
Banana	5049	505	17,61
Intercrop	1620	162	5,65
Pineapple	553	55	1,92

*)Total Rainfall = 2867 mm

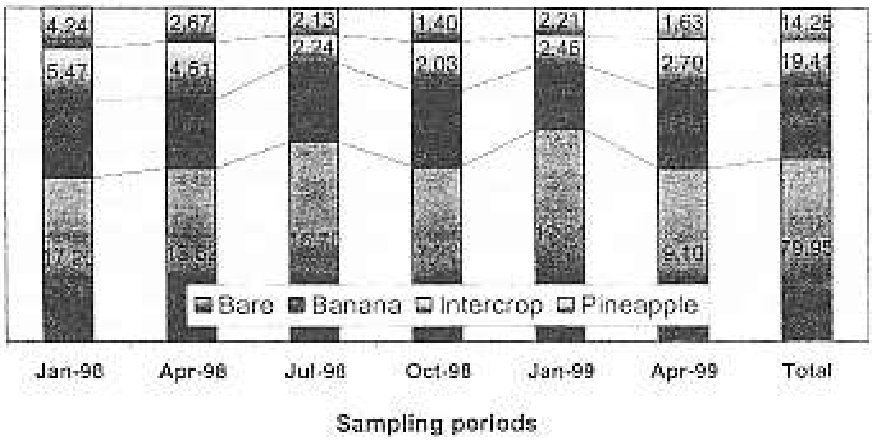

Figure 7. Soil loss under different cropping system (ton ha^{-1})

Relationship between various soil properties and root biomass with soil loss

The relationship between various soil properties and root biomass with soil loss was examined using multiple linear regression analysis. Soil loss was significantly affected by water stable aggregate for all cropped plot, whereas the decreasing in the organic matter was found to be a dominant factor in increasing soil loss under uncropped plot. The effect of root biomass on soil loss was significant only in pineapple plot. The relationships are shown below:

Bare : $SL = 1153.11 - 453.48\ OM$ ($r^2 = 0.59^{**}$)
Banana : $SL = 873.11 - 9.47\ WSA$ ($r^2 = 0.68^{**}$)
Intercrop : $SL = 95.37 - 1.03\ WSA$ ($r^2 = 0.43^{**}$)
Pineapple : $SL = 370.26 - 13.01\ Ro - 3.92\ WSA$ ($R^2 = 0.88^{*}$)

Where, SL=Soil Loss, OM=Organic Matter, Ro=Root Biomass, WSA = Water Stable Aggregates.

CONCLUSIONS

Several conclusions can be drawn from the above results. There is a tendency for better improvement in the soil properties under banana especially in aggregate stability and organic matter content compared to intercrop and pineapple cropping systems. However, pineapple contributed most in lowering the bulk density and thus allowed better water infiltrability. Aggregate stability of the soil was found to be a predominant factor in reducing soil loss in upland cropping system due to its strong dependence on the organic matter content and the root biomass in the soil.

Planting banana alone without intercropping with pineapple crop catalyzes the erosion process in sloping area. The shape of banana leaves tends to concentrate the intercepted rainwater into the flow channels with consequent drastic effect upon impact on the soil surface. Furthermore, banana does not have the capacity to hold runoff water and trap soil sediments as good as the pineapple hedgerow. This explains the fact that although banana improves aggregate stability of the soil, it is still not able to reduce soil loss. Based on the above facts, a combination of banana and pineapple optimizes both soil and economic sustainability.

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