



# Effect of Intercropping Coconut Lands on Soil Water Retention

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## ABSTRACT

This study was conducted to evaluate the effect of intercropping coconut lands on soil water retention, available water, porosity and their relationship with organic matter contents. The results showed that the water holding capacity and available water increased significantly at both depths (0-20 and 20-40 cm) investigated. The increase in available water was mainly due to increase in field capacity which can be attributed to better soil structural development and stability related to higher organic matter and root activity in intercropping treatments. Bulk density in coconut monoculture plots was as high as  $1.72 \text{ g cm}^{-3}$  which is restrictive to root growth in these sandy loam soils and decreased in intercropped plots to  $1.49 \text{ g cm}^{-3}$  facilitating better root penetration and soil aeration. The total porosity and macro-porosity increased significantly with intercropping. The intercropped treatments did not show a significantly higher organic matter content but showed an increasing trend. Clay content of this soil was as low as 8% in the top soil and increased to 17% in the sub soil. At such low clay contents, even a slight increase of organic matter will have a significant effect on soil aggregation and thereby on water retention. The coconut yields of intercropped treatments increased by 5% to 34% over monoculture indicating sustainability of such farming systems under rainfed conditions.

## INTRODUCTION

Coconut (*Cocos nucifera* L.) is an important plantation crop occupying about 326,000 ha accounting for 23% of the land area in Sri Lanka (Dimantha, 1994). This crop contributed approximately 2.1% to the gross national product with foreign exchange earnings of US \$70 million in 1991 (Central Bank Report, 1992). Traditionally, a spacing of  $8 \times 8$  metres has been used between coconut palms. The fibrous coconut root system uses only about 25% of the soil volume and there is

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sufficient light penetration through the canopy for intercropping to be feasible. Coconut is mainly a smallholder crop in Sri Lanka where 86% of coconut land consisting of less than 2 ha holdings (Agricultural Census, 1991) which is subjected to decrease with further land fragmentation. Intercropping will bring an additional income for the smallholder with limited land resources while minimizing the risk of over dependence on coconut. This will also provide a minimum income from the land during replanting periods which is a must for such plantation crops as coconut. The potential for coconut based cropping systems are high in areas where the soils are comparatively deep and fertile. Intercropping is recommended when coconut palms are of 0 to 5 years and above 20 years of age. The heavy shading during the 5 to 20 years period makes it unsuitable for intercropping (Liyanage, 1992).

Liyanage & Dassanayake (1991) reported that if the coconut and intercrop are adequately fertilized there are more complementary effects than competitive effects by intercropping. Long term experiments conducted by Coconut Research Institute (CRI) of Sri Lanka show significant increases in coconut and copra (dried kernel) yields when intercropped with annuals, semi-perennials, perennials (Anon, 1988) as well as with livestock (Santhirasegaram, 1966). Coffee, black pepper, cocoa and cinnamon are some of the intercrops popular with the smallholder sector. Liyanage & Dassanayake (1991) showed how soil physical, chemical and biological properties improved with intercropping. The organic carbon content, total nitrogen, available phosphorous, exchangeable potassium and earthworm activity increased and bulk density decreased with intercropping coconut with cocoa, coffee and pepper. Mapa *et al.* (1993) documented how intercropping improves soil structure by increasing aggregate mean diameter and stability.

Coconut is a multipurpose tree where other than nuts, leaves, trunk, and husks are used for industrial purposes. Most other parts are used as domestic fuel. There is no addition of organic matter to soil and plant nutrient recycling is minimal in a monoculture plantation. In such cases, intercropping is most beneficial due to addition of organic matter to the soil. While contributing to plant nutrients, the organic matter increases the soil water retention and thereby the available water for plant growth. This is due to the direct hydrophilic nature of organic matter combined with the formation of well aggregated soil structure. Soil water retention is primarily dependent on soil texture, structure and organic matter content (Salter & Williams, 1965). With intercropping the organic matter content and structure undergo major changes affecting water retention. Tsuji *et al.* (1975) showed how soil microstructure development influenced water retention characteristics in the Oxisols of Hawaii. An increase in water retention will increase

the available water for plant growth and reduce the competition for soil moisture between the intercrop and the main crop, making such farming systems sustainable under rainfed conditions.

Water retention relationship is a major soil hydraulic property used to estimate available water, to evaluate pore size distribution (Danielson & Sutherland, 1986), to predict hydraulic conductivity (Green & Corey, 1971) and for calculating water movement in unsaturated soils (Mehta *et al.* 1994). This is also being used as a factor in land suitability classification (Landon, 1984).

The objective of this study was to evaluate the effect of intercropping coconut land on soil water retention, available water and porosity, and their relationships to organic matter content.

## MATERIALS AND METHODS

Water retention was evaluated using undisturbed soil core samples obtained from an ongoing intercropping experiment conducted by the Coconut Research Institute at Walpita Estate in the low country wet zone of Sri Lanka. Coconut was planted in the year 1948 and the intercropping systems were established in 1981 and maintained to the present time. The sampling was done in August 1992 which was 11 years after intercropping. The soil belongs to the great soil group Red Yellow Podzolic soils (de Alwis & Panabokke, 1972) which is classified as Udults according to the Soil Taxonomy (Soil Survey Staff, 1992). The treatments included coconut monocrop and intercrops of coffee, pepper, cocoa, and both pepper and cocoa together. The coconut monocrop was planted at a spacing of 8 × 8 m. Coffee (*Coffea robusta*) was intercropped at a spacing of 8 × 8 m, each coffee plant being at the middle of four coconut trees. Pepper (*Piper nigrum*) was intercropped using gliricidia stakes planted at a spacing of 2.2 × 2.5 m. Cocoa (*Theobroma cacao*) was intercropped with coconut at a spacing of 2.4 × 2.4 m. Pepper and cocoa both were intercropped at a spacing of 2.4 × 2.4 m in a rotational manner where pepper was trained on gliricidia stakes. The coconut and intercrops were fertilized according to standard recommendations (Liyanage & Dassanayake, 1991). Soil core samples of 5.2 cm in diameter and 3 cm in height were removed with minimum disturbance to the soil structure from two depth increments, 0 to 20 cm (top soil) and 20 to 40 cm (sub soil) from the coconut monocrop and intercropped treatments for measurement of soil water retention. Six replicates were obtained from each depth of all five treatments. These samples were transported to the laboratory and carefully trimmed to provide surfaces which were level with the end of

the brass ring prior to measurement. A cheese cloth was wrapped at one end to facilitate repeated weighing and better contact with the pressure plates. These were saturated under vacuum and water retention was measured using a tension table at low suction (0 to 10 kPa) and a standard pressure plate apparatus at higher suction (10 to 1500 kPa) as described by Klute (1986). Samples were equilibrated at 15 suction increments from 5 to 1500 kPa. Soil cores were weighed after each step to allow calculation of water loss between suction increments. The soil cores were oven dried and weighed after the final suction step. The volumetric water content was estimated using the gravimetric water and bulk density from the same soil sample.

Other than for moisture retention, soil samples were removed for bulk density, organic matter and textural characterization. Bulk density was measured using undisturbed soil core samples of 5.2 cm diameter and 6 cm height. Six replicates were obtained for each depth from all treatments. Samples were oven dried and the dry soil weight was divided by the core volume to obtain the bulk density. The porosity was calculated using the bulk density and particle density which was assumed as  $2.65 \text{ g cm}^{-3}$  (Danielson & Sutherland, 1986). Particle size distribution was determined using the sieve and pipette method as described by Gee & Bauder (1986), using three replicates. Soil organic matter was determined using calorimetric methods as described by Nelson & Sommers (1982). Six replicates from the two depths of each treatment were air dried and sieved using a 2mm sieve and used for organic matter analysis.

## RESULTS AND DISCUSSION

The soil water parameters obtained using the water retention characteristics for 0–20 and 20–40 cm depths are shown in Tables 1 and 2 respectively. The particle size distribution of the soils showed that the soil texture varied from sandy loamy to loamy sand according to USDA classification (USDA, 1975). The clay content of the 0–20 cm depth was as low as 8% and increased to 17% at 20–40 cm depth.

### Water Holding Capacity

As shown from the results the volumetric water contents at saturation in intercropped treatments were always higher than in coconut monocrop in both depths investigated. The bulk densities of the intercropped treatments showed a significantly lower value as shown in

TABLE 1

Mean soil water parameters obtained from the water retention characteristics for 0-20 cm depth

Parameter	Treatment					LSD (P<0.05)
	Coconut	Coconut Inter-cropped with				
	Monocrop	Cocoa	Pepper	Coffee	Cocoa & Pepper	
Saturated water Content %	35.12a	41.13b	10.38b	42.26b	43.77b	2.39
Field capacity (10 kPa) %	11.79a	14.98b	13.76b	14.60b	17.00c	1.68
Wilting Point (1500 kPa) %	6.47a	8.02b	7.47b	7.75b	8.05b	1.13
Available Water (mm/m)	53.20a	69.60b	62.90b	68.50b	89.50c	7.30
Readily Av. Water (mm/m)	26.40a	34.80b	31.50b	34.30b	44.80c	3.65
Macroporosity (cm <sup>3</sup> /cm <sup>3</sup> )	23.33a	26.15b	26.62b	27.66b	26.77b	1.93

(Means followed by the same letter in each row are not significantly different at 5% probability level. LSD = Least Significant Difference).

TABLE 2

Mean soil water parameters obtained from the water retention characteristics for 20-40 cm depth

Parameter	Treatment					LSD (P<0.05)
	Coconut	Coconut Inter-cropped with				
	Monocrop	Cocoa	Pepper	Coffee	Cocoa & Pepper	
Saturated water Content %	33.21a	38.49b	39.25b	40.03b	40.38b	3.51
Field capacity (10 kPa) %	9.12a	12.85b	12.73b	12.47b	14.72c	2.13
Wilting Point (1500 kPa) %	4.21a	7.17b	7.09b	6.71b	8.11b	1.93
Available Water (mm/m)	49.10a	56.80b	56.40b	57.70b	66.10c	6.60
Readily Av. Water (mm/m)	24.60a	28.40b	28.90b	33.10b	44.80c	3.30
Macroporosity (cm <sup>3</sup> /cm <sup>3</sup> )	21.42a	25.64b	26.52b	27.56b	25.66b	2.11

(Means followed by the same letter in each row are not significantly different at 5% probability level. LSD = Least Significant Difference).

Table 3. This is an indication of higher soil porosities associated with intercropping. Intercropping added more organic matter to soil than the monocrop system, which improves aggregate development and contributes to an increase in porosity. Many workers have documented the improvement of soil structure due to addition of organic matter and root activity (Juma, 1993; Wambeke, 1991). Mapa *et al.* (1993) showed that aggregates obtained from intercropped treatments showed a higher mean diameter and higher stability than the coconut monocrop treatment. Large aggregates will form more macro-pores and increase the water holding capacity. Table 4 shows the increases in soil organic matter content with intercropping. Even though these were not significant at a 95% probability level it showed an increasing trend. Soil temperatures were about 35°C during the sampling season and thus most of the organic matter would have already decomposed. The organic matter content was lower in the subsoil as there was no mixing or tillage in these types of cropping systems. Liyanage & Dassanayake (1991) documented how the organic matter content showed a significant increase from 0.86% in a coconut monocrop to 1.42% in coconut intercropped with cocoa. Coconut intercropped with cocoa together with pepper showed the highest water holding capacity and also showed the highest organic matter content. This increase in water holding capacity will help to reduce the surface runoff and increase water holding during the rainfall periods, thus increasing the water economy of the plants.

TABLE 3

Mean soil bulk density values for coconut mono-crop and inter-cropping systems

Treatment	Bulk Density (g/cm <sup>3</sup> )	
	Depth 1	Depth 2
Coconut Mono-crop	1.72a	1.77a
Coconut inter-cropped with Cocoa	1.56b	1.63b
Coconut inter-cropped with Pepper	1.58b	1.54b
Coconut inter-cropped with Coffee	1.53b	1.59b
Coconut inter-cropped with Cocoa & Coffee	1.49b	1.58b
LSD (P<0.05)	0.10	0.14

(Means followed by the same letter in each column are not significantly different at 5% probability level. LSD = Least Significant Difference).

TABLE 4

Mean soil organic matter content at two depths for coconut mono-crop and inter-cropping systems

Treatment	Soil Organic Matter %	
	Depth 1	Depth 2
Coconut Mono-crop	0.64a	0.63b
Coconut inter-cropped with Cocoa	0.80a	0.58b
Coconut inter-cropped with Pepper	0.78a	0.62b
Coconut inter-cropped with Coffee	0.71a	0.61b
Coconut inter-cropped with Cocoa & Coffee	0.81a	0.64b
LSD (P<0.05)	0.12	0.08

(Means followed by the same letter in each column are not significantly different at 5% probability level. LSD = Least Significant Difference).

### Available Water Capacity

The available water capacity was estimated as the volume of water held between field capacity and permanent wilting point. Field capacity was estimated as the water held at 10 kPa matric potential as suggested by Joshua (1984) for sandy soils. Permanent wilting point was estimated as water content at 1500 kPa (Cassell & Nielson, 1986). All the intercropped plots showed significantly higher available water than the coconut monocrop treatment at both depths. This was mainly due to increases in field capacity. Even though the permanent wilting points of intercropped plots were significantly different to those of the coconut monocrop, they did not show any parallel increases in field capacity, indicating the beneficial effect was more due to soil aggregation than due to the hydrophilic nature of organic matter itself. At permanent wilting point soil moisture is mostly held in micro-pores and as adsorbed water on soil particle surfaces which is less dependent on soil structural conditions (Landon, 1984). Salter & Williams (1965) showed that addition of organic matter will not increase available water in clay soils due to parallel increases in moisture retention at field capacity and permanent wilting point. As shown by the textural analysis, this soil contained only 8% to 17% clay and therefore the benefits of increase in organic matter on water retention is greater than for a clayey soil. Baver *et al.* (1972) documented that when soils are grouped according to the clay content, the effect of organic matter on water retention is more pronounced in soils with low amounts of clay. Therefore even the slight increase in organic matter in intercropped treatments increased the available water significantly.

Coconut intercropped with cocoa together with pepper showed the highest available water among the treatments in both depths investigated. This may be due to high litter fall from the two intercrops and greater root activity in promoting development of soil structure. Cocoa which is a seedling plant has a deep tap root system compared with the fibrous root system of pepper propagated through cuttings. This helped to keep both top and subsoil well aggregated, resulting in higher water retention than in other treatments.

The readily available water is the amount available before the plant suffers from any yield reduction due to moisture stress. As all these intercrops and coconut are moderately drought tolerant, readily available water was estimated at 66% of the total available water as suggested by Landon (1984) and are given for both depths in Tables 1 and 2.

### Macro-Porosity

The macro-porosity was determined as the porosity drained from saturation to field capacity as suggested by Green *et al.* (1986). It should be noted that there are many classifications used when defining macro-porosity in the literature (Bouma *et al.*, 1977; Germann & Beven, 1981; Skopp, 1981) and the limits used here are the same as those chosen in many agricultural studies. The main functions of macro-pores are drainage by gravity flow, thereby aerating the soil and facilitating root proliferation. Pores which are not filled with water are filled with air. The amount of air-filled porosity at field capacity is a soil parameter commonly referred to as aeration porosity but more specifically as field-air capacity (Hillel, 1982). Greenwood (1975) suggested a limiting field air capacity value of 10%, above which anaerobic conditions are unlikely to occur. As shown in Tables 1 and 2 the aeration porosity in the coconut monocrop treatment was higher than this limit and therefore had adequate aeration. The intercropped plots showed significantly higher aeration porosities due to better aggregation. This will help increase water intake during high rainfall periods, improve root penetration and also make conditions better for associated soil flora and fauna.

The soil bulk densities and organic matter contents for the coconut monocrop and intercrop treatments are shown in Tables 3 and 4. The bulk densities of 0–20 cm depth were significantly lower in intercropped treatments. This was due to better aggregation and higher root activity in intercropped treatments. Taylor & Gardner (1963) showed that bulk density values of 1.6 to 1.8 g cm<sup>-3</sup> in sands and loams

will show resistance to root growth. Bulk densities of topsoil and sub-soil of coconut monocrop plots were within this range. By intercropping, the bulk density decreased below this critical value reducing restrictions to root penetration and growth in these soils.

Liyange & Dessanayake (1991) analysed the yield data of coconut in the same experiment and reported that the nut yield of intercropped plots increased by 3 to 34 per cent while the copra yields (dried kernels) increased by 13 to 33 per cent when compared with monoculture. This is an indication of complementary effects of intercropping where the nutrient recycling was beneficial while decreasing the competition for soil moisture due to increased water retention.

## CONCLUSIONS

This study shows the complementary effects of intercropping on major crop and intercrop if both are managed in a proper manner. Intercropping decreased soil bulk density, increased porosity as well as macro-porosity at both depths investigated. Available water increased in intercropping treatments mainly due to the increase in field capacity. This could be attributed to increases in soil aggregation and root activity. The soil organic matter content showed an increasing trend. As this was a sandy loam soil with low clay content, even a slight increase in organic matter showed beneficial effects on soil water retention. Increases in available water will decrease the competition between the coconut and the intercrop for soil moisture in these cropping systems.

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