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Effect of Texture and Organic Matter on Soil Water Retention Parameters

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ABSTRACT. *Soil water retention parameters such as field capacity, permanent wilting point (PWP) and available water are used in irrigation planning and management, soil water conservation, modelling of soil water and solute flow and in drought tolerance studies. The objective of this study was to characterize the soil water retention parameters for the soils of the Intermediate Zone (IZ) of Sri Lanka and to determine their relationship with texture and organic matter content. Field capacity, PWP, soil texture and organic matter contents were measured for 20 benchmark soil series from the IZ of Sri Lanka. The results indicated that the soils of the up and low country IZ showed moderate amounts of available water (180-120 mm/m) while soils of the mid country IZ showed low amounts of available water (<120 mm/m) to crops. The field capacity and PWP increased with the increase of clay content but the rate of increase was not similar in all soil series. The organic matter content was positively related to field capacity and PWP only in the topsoil. Therefore, increase in clay and organic matter content improved soil water retention thereby increasing soil and water conservation, but not necessarily the available water to plants.*

INTRODUCTION

Agriculture is the single largest consumer of water amounting to 70% of the global freshwater resource. The water scarcity directly affects the rainfed and irrigated agriculture forcing millions of farmers to search for suitable lands and adequate water supplies for crop production. The high water requirement per unit of dry matter produced applies not only for crops but also to all plants for their transpiration (Kuruppuarachchi, 2001). Plants and soil micro-organisms depend on the water, which is retained in the soil. Knowledge in soil water retention is necessary for irrigation planing and management as well as for many soil related investigations such as, water conservation, modelling water and solute flow and evaluation of plant water stress (Saxton *et al.*, 1985).

When considering soil water retention, the field capacity (FC) and permanent wilting point (PWP) are the most important parameters. The field capacity is defined as the water retained after the drainage rate of a completely saturated soil becomes negligible (Hillel, 1971). The permanent wilting point is the soil moisture content at which plants wilt permanently. The water held between these two upper and lower limits is the water available to crops. This is used when estimating available water for irrigation requirements and soil aeration indexes as field air porosity (Bodinayake and Mapa, 1989). Field capacity depends on several factors such as soil texture, structure, type of clay present and organic matter content (Hillel, 1971). Many researchers have documented that the field capacity shows a positive relationship with clay content, clay mineralogy and organic matter contents (Uehara and Gilman, 1981). Sandy soils can quickly be recharged with soil moisture but is unable to hold as much water compared with soils of heavier textures. As texture becomes heavier, the wilting point increases because fine soils with narrow pore space hold water more tightly than soils with wide pore spacing. In soil classification studies, the PWP is estimated by dividing the clay content by 2.5 when such data is not available (Soil Survey Staff, 1992) indicating the close relationship between these two.

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Sri Lanka experience diverse agro-ecological conditions throughout the country. Based on the amount of rainfall received, the country is divided in to three major zones called the Dry Zone, Intermediate Zone and Wet Zone. The Intermediate Zone of Sri Lanka is the area receiving a mean annual rainfall of 1750-2500 mm which covers approximately 13.2% of the total land area amounting to 0.87 million ha. This zone is sub divided on the basis of elevation namely up country Intermediate (> 900 m), mid country Intermediate (900-300 m) and low country Intermediate Zone (< 300 m). The soil water retention parameters of the Intermediate Zone soils have not been studied in detail. Therefore, the objective of this study was to characterize the water retention parameters of the soils in the Intermediate Zone (IZ) of Sri Lanka and to determine its relationship with soil texture and organic matter content.

MATERIALS AND METHODS

This study was conducted using 20 benchmark soil series from the up-country, mid-country and low-country areas of intermediate zone of Sri Lanka (Nayakekorala and Mapa, 2002). The names of the soil series, their great soil groups according to De Alwis and Panabokke (1972) and the soil taxonomic equivalents are given in Table 1. Benchmark sites of these soil series where the soil samples were collected are shown in Fig. 1. The soil profiles were characterized according to the FAO system (1990) and the major horizons were identified. Soil samples were collected for measuring the soil water retention parameters, clay and organic matter contents from the surface and sub surface horizons from each of these benchmark sites.

Table 1. Names of the soil series of the Intermediate Zone of Sri Lanka used for the study.

Agro Ecological Zone	Soil Series	Great Soil Group	Soil Taxonomic Equivalents
Up Country Intermediate Zone	Welimada	Immature Brown Loams	Typic Dystrochrepts
	Ragala	Red Yellow Podzolic	Typic Hapludults
Mid Country Intermediate Zone	Mahawalathanna	Red Yellow Podzolic Soils derived from Quartzite	Typic Troporthents
	Kundasale	Immature Brown Loams	Typic Eutropepts
	Ukuwela	Reddish Brown Latasolic	Typic Rhodusalfs
	Badulla	Red Yellow Podsolic	Typic Haplohumulfs
	Waligepola	Immature Brown Loams	Typic Dystrochrepts
Low Country Intermediate Zone	Kuliyapitiya	Red Yellow Podzolic	Typic Troporthents
	Maho	Reddish Brown Earth	Pasmmentic Hapludults
	Kuda Oya	Low Humic Glay	Aqualfs
	Hembarawa	Alluvils	Typic Ustorthens
	Ulhitiya (Rolling)	Reddish Brown Earth	Typic Rhodudalfs
	Kurunagala	Red Yellow Podzolic with soft and hard latarites	Plinthudults
	Ranugalla	Immature Brown Loams	Typic Dystropepts
	Ulhitiya	Reddish Brown Earths	Typic Haplustalfs
	Wariyapola	Non Calcic Brown	Typic Dystrochrepts
	Andigama	Red Yellow Podzolic with soft and hard latarites	Typic Troporthents
	Dombagahawela	Immature Brown Loams	Typic Dystropepts
	Mutukandiya	Alluvial	Typic Ustorthens
	Bibile	Immature Brown Loams	Typic Dystropepts

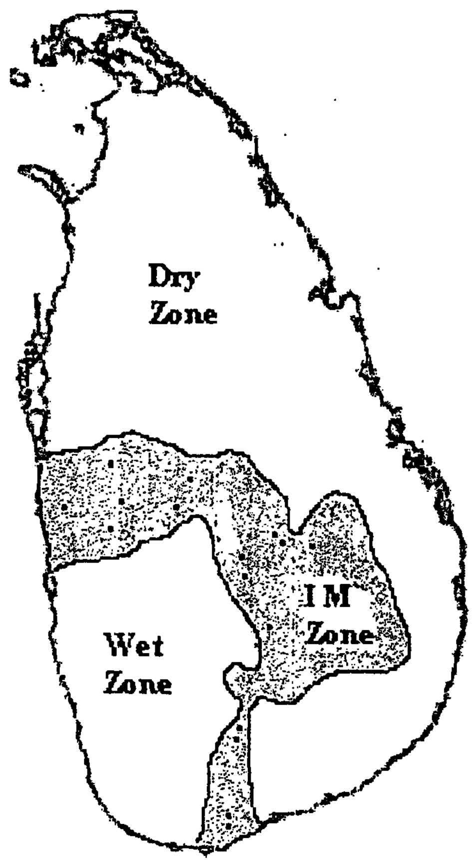

Fig. 1. Sampling sites of the soil series in the Intermediate Zone of Sri Lanka.
[Note: Each square represents sampling locations].

Soil core samples of 6 cm in diameter and 3 cm in height were obtained for measuring the FC and PWP. Four replicates were obtained from each horizon. The core samples were saturated with water in the laboratory and the FC and PWP were measured using a pressure plate apparatus as described by Klute (1986). The field capacity was estimated as the water content at 10 kPa (Joshua, 1985) and the PWP as the water content at 1500 kPa (Cassel and Nielsen, 1986). The bulk density obtained from the same core sample was used to convert the gravimetric water to volumetric water content.

Soil texture and organic matter content were determined using air-dried and sieved samples. Fifty grams of soil was used to determine the clay, silt and sand content using the Pipette method as described by Gee and Bauder (1986). Pipefitting times were calculated for clay and silt particles according to the USDA classification. Aliquots were removed from the soil suspension at calculated times and oven dried to obtain the clay and silt contents. Soil organic matter was determined using the dichromate method (Hesse, 1971). Clay and soil organic matter contents were determined for the three replicates from each surface and sub surface horizon from all the benchmark sites.

RESULTS AND DISCUSSION

The soil water retention parameters including field capacity, and PWP, for the top and sub soil and the available water for the Intermediate Zone soils are shown in Table 2. Clay and organic matter contents of these soil series are shown in Table 3.

Table 2. Soil water retention parameters obtained for soil series of the Intermediate Zone of Sri Lanka.

Soil Series	Top soil		Sub soil		Available water of the profile (mm)
	FC (%)	PWP (%)	FC (%)	PWP (%)	
Up Country IZ					
Walimada	27	11	24	11	80 /m
Ragala	34	24	35	21	132 /m
Mid Country IZ					
Mahawalathanna	15	10	17	9	69 /m
Kundasale	24	18	24	17	76 /m
Ukuwela	31	22	34	28	66 /m
Badulla	22	14	28	17	99 /m
Waligepola	32	22	31	23	91/50 cm
Low Country IZ					
Kuliyapitiya	28	15	18	12	85 /m
Maho	23	16	18	13	65 /m
Kuda Oya	23	10	27	14	132/50 cm
Hembarawa	25	13	27	15	119 /m
Ulhitiya (Rolling)	23	14	26	17	81 /m
Kurunagala	27	14	30	19	119/60 cm
Ranugalla	23	13	25	15	96/50 cm
Ulhitiya	21	11	23	17	106 /m
Wariyapola	13	5	10	4	83 /m
Andigama	20	14	18	13	73/65 cm
Dombagahawela	20	10	25	14	97 /m
Mutukandiya	23	12	22	14	90/40 cm
Bibile	22	8	28	16	67/50 cm

The available water is shown in the standard form of mm per meter depth of soil. When the soil profile was shallow with less than one-meter depth, the available water is shown for the depths of measurements only. According to Landon (1984), when the available water is higher than 180 mm/m it is classified high available water. When the available is 180-120 mm/m and less than 120 mm/m it is classified as moderate and low available water, respectively.

Table 3. **Clay and organic matter contents of top and sub soils for soil series of the Intermediate Zone of Sri Lanka.**

Soil Series	Top soil		Sub soil	
	Clay (%)	Organic matter (%)	Clay (%)	Organic matter (%)
Up Country IZ				
Walimada	14	2.1	14	1.2
Ragal	15	4.8	46	0.5
Mid Country IZ				
Mahawalathanna	26	2.1	26	2.1
Kundasale	15	2.0	14	0.9
Ukuwela	47	1.7	37	1.5
Badulla	21	3.1	33	2.5
Waligepola	16	3.3	18	1.5
Low Country IZ				
Kuliyapitiya	16	2.2	33	2.1
Maho	11	1.9	20	0.7
Kuda Oya	8	1.6	11	0.3
Hembarawa	7.5	0.9	8	0.3
Ulhitiya (Rolling)	17	0.7	14	0.2
Kurunegala	8	1.1	8	0.7
Ranugalla	11	0.9	17	0.2
Ulhitiya	6	1.9	6	0.5
Wariyapola	4	0.1	7	0.03
Andigama	9	2.2	9	2.0
Dombagahawela	5	1.7	20	0.6
Mutukandiya	3	0.1	3	0.03
Bibile	10	1.6	9	0.2

The soils of the mid country Intermediate Zone showed low available water while some of the soils of the low country and up country Intermediate Zone soils showed moderate amounts of available water. The soils holding moderate amounts of available water are more suitable for rainfed and irrigated agriculture than soils with low available water, as they can hold more water after a rainfall event or irrigation.

Effect of clay content on field capacity

From the textural separates analyzed, only the clay content showed a relationship with soil water retention parameters. The relationship between the volumetric water content at field capacity and clay content for the top and sub soils are shown in Figs. 2 and 3. According to these results the field capacity of these soils increased with increasing clay content. This positive relationship was significant at 95% probability level. The regression equations and correlation coefficients (R^2) for top and sub soils are given in Fig. 2 and 3. As shown from this table the increase of the field capacity with the clay content was higher in sub soil than the topsoil. There are several soil physical characters that could affect the water held at field capacity. Among those, water retention is strongly affected by soil texture. Hillel (1971) documented that the greater the clay content, in general, greater the water content at any given suction. The results show that this phenomenon is true for some soil series of the Intermediate zone of Sri Lanka. Furthermore, specific surface of soil particles also greatly influence the water retention. When specific surface is high the water held at any given suction is high. Clay is the finest particle in the textural component of the soil, and therefore, water holding capacity is much greater in clay than other particles (Marshar, 1959). In addition to clay and organic matter content, soil structure also influence the field capacity. In general, soils structure mainly influences the water held at low suctions by modifying the macro-porosity (Salter and Williams, 1965). Certain soils of the low country intermediate zone showed a high field capacity even with low clay content due to the influence of soil structure, which can only be characterized qualitatively.

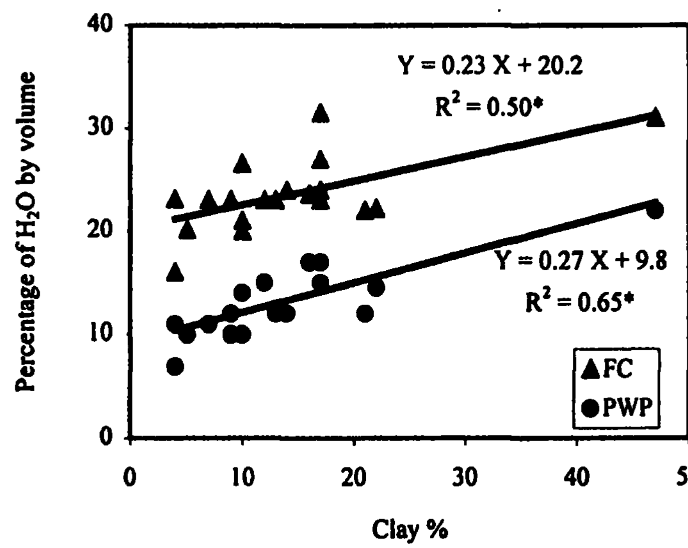

Fig. 2. Relationship between field capacity (FC) and permanent wilting point (PWP) with clay content of top soil.

Effect of clay content on PWP

The relationship between the clay content and the volumetric water content at PWP for the top and sub soils are shown in Fig. 2 and 3, respectively. Permanent wilting point increased with the increasing clay content, which was significant at the 95% probability level for top and subsoil. As shown in Fig. 2 and 3, the increase of PWP with increasing clay content was higher in the topsoil than the sub soil. As documented by Marshar (1959), increasing clay content from 38-58% increased PWP only by 20-25%. He also showed that PWP is not affected very greatly by structure and therefore does not require any special precaution during soil sampling in the field.

As shown in Fig. 2 and 3 the water held at field capacity in top soil increased at a slightly lower rate (slope = 0.23) with increase in clay content than that held at PWP (slope = 0.27). According to Fig. 2 and 3 there is no parallel increase of available water held between FC and PWP with the increase of clay content. Therefore, no significant relationship was found with the available water and clay content. Salter and Williams

(1966) also showed that the increase in FC with clay content was not parallel to the increase in PWP and the difference in moisture content between these upper and lower limits did not increase in a constant manner for a sandy loam soil.

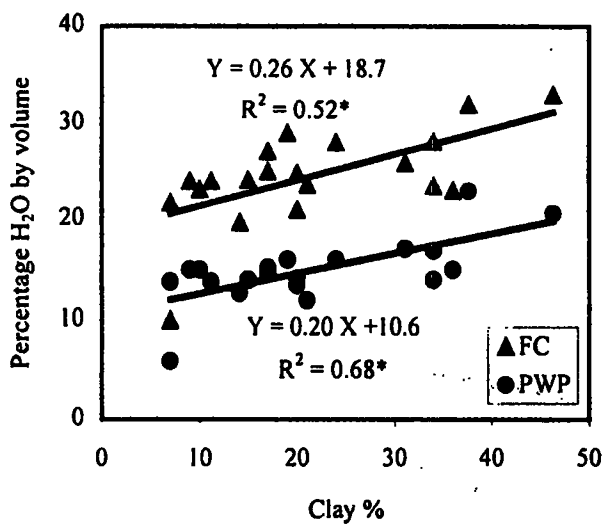

Fig. 3. Relationship between field capacity (FC) and permanent wilting point (PWP) with clay content of sub soil.

Effect of organic matter content on field capacity

Fig. 4 shows the relationship between organic matter and volumetric water content at field capacity for the topsoils. The field capacity showed a significant positive relationship with organic matter content only for the topsoil. The relationship, between organic matter and volumetric water content at field capacity for the sub soils, is not significant at 95% probability level and showed a very low correlation coefficient value (R^2), which was 0.03.

The organic matter content of the sub soil did not show any relationship with field capacity, as it was low in organic matter. Hudson (1994) showed how the organic matter content increased the field capacity in three textural classes of soils, namely sandy, silt loam and silty loam textures. According to Hillel (1971), soil organic matter can help to retain more water, though the amount of the organic matter normally present in mineral soils are too low to have a significant effect.

Effect of organic matter on PWP

The positive relationship of soil organic matter content with volumetric water content at PWP for the top soils is shown in Fig. 4. As for the relationship with field capacity, the sub soil did not show any significant relationship with organic matter and PWP. Correlation coefficient of this relationship is 0.14, which is not significant value. According to Table 3 most of the sub soils contains low amounts of organic matter content when compared to topsoil.

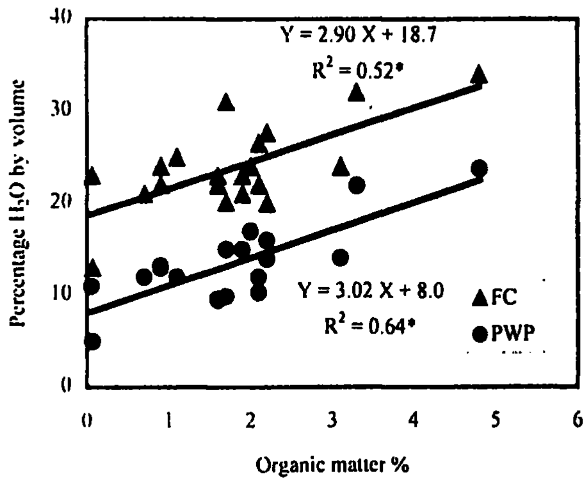

Fig. 4. Relationship between field capacity (FC) and permanent wilting point (PWP) with organic matter content of top soil.

Fig. 4 shows the regression equations with soil organic matter content and soil water retention parameters and correlation coefficients (R^2) for the topsoil. According to these data the PWP increased at a higher rate than the field capacity with the increase of organic matter content. This is mainly due to the high affinity of water molecules to organic matter. Therefore, even the increase of organic matter content increased the water held at field capacity and permanent wilting point, it may not necessarily increase the available water content. In a review article Macrae and Mehuys (1985) stated that organic matter increased available water content in soils only under specific circumstances, and that such increases are the exception rather than the rule. The increase of organic matter is still beneficial as the higher amount of water retained decrease the runoff, increase water conservation and thereby reduce soil erosion.

CONCLUSIONS

In this study the soil water retention parameters, namely field capacity and permanent wilting point, were determined for 20 benchmark soil series of the Intermediate Zone of Sri Lanka. The results showed that the available water was moderate in majority of soils in the low and up country Intermediate Zone soils while the soils from the mid country Intermediate Zone showed low available water. This study demonstrated that the field capacity and PWP increases with increasing clay content, but this increase was not parallel and therefore did not increase the available water at all times. The increase of soil organic matter content increased the field capacity and PWP for the topsoil. These increases were also not similar. Therefore, increase in clay and soil organic matter content may increase water retention and contribute to soil and water conservation while it may not necessarily contribute to the increase in available water as commonly believed.

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