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Aggregate Stability of Major Soils in the Wet Zone of Sri Lanka

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ABSTRACT. *Aggregate stability is an index of the resistance of a soil to erosion, crusting and the ability to maintain a favourable pore size distribution, which determines proper soil–water–air relationships. The dry and wet aggregate stabilities were measured for major soil profiles of wet zone of Sri Lanka, namely, Red Yellow Podzolic soils, Immature Brown Loam soils, Reddish Brown Latasolic soils and Alluvial soils. Dry and wet aggregate stabilities are indicators of the resistance to wind and water erosion of soils, respectively. Multiple sieving technique with a nest of sieves was used to evaluate dry aggregate stability. Wet aggregate stability was evaluated using a single sieve technique and measuring the aggregates remaining after sieving for different time intervals in water. Soil clay and organic matter contents of the test soils were determined. The mean weight diameter, log mean weight diameter and geometric mean diameter determined were consistent showing their suitability as aggregate indices to measure dry aggregate stability. The surface horizons of the Reddish Brown Latasolic soils showed the highest dry and wet aggregate stability compared to that of other soils of the Wet Zone of Sri Lanka indicating a higher resistance to erosion by wind and water.*

INTRODUCTION

A soil aggregate is a group of primary particles which cohere to each other more strongly than to surrounding particles (Kemper and Rosenau, 1986). Aggregation is a favourable property of agricultural soils as it reduces erosion and improve the pore size distribution, thereby, resulting in better soil–water–air relationships. Many investigators have preferred the use of the stability of aggregates as an index of soil structure instead of aggregate size distribution in the field (Kemper, 1965). The ability of soil aggregates to resist

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disruptive forces of water and wind are indicated by the soil physical parameters, wet and the dry aggregate stability, respectively. It is an excellent accessory property of soil which indicate its susceptibility and resistance to erosion by water or wind, to surface crusting and swelling and shrinking. Stable aggregates resist raindrop impact for a much longer time and maintain a soil in a more permeable condition reducing run–off and erosion (Thompson and Troeh, 1973). Aggregate stability is usually related to the amount and the type of clay, the organic matter content, the content of cementing agents such as iron and aluminum oxides and to the drainage conditions (Landon, 1984).

The Wet Zone of Sri Lanka is a region receiving a mean annual rainfall higher than 2000 mm, covering approximately 1.35 million ha. These soils support planation agriculture that earns valuable foreign exchange to the country. Area of arable lands are known to decrease annually within this region consequent to the increasing population. Land use planning become essential where unproductive lands should be given for non–agricultural purposes. The major soils found in the wet zone of Sri Lanka as described by De Alwis and Panabokke (1972) include Red Yellow Podzolic soils (Rhodudults), Reddish Brown Latosolic soils (Tropudults), Immature Brown Loams (Dystropepts) and Alluvial soils (Tropaquents). Aggregate stability also is a major variable that is well correlated with soil erodibility. Aggregate stability, therefore, has special concern for the Wet Zone region due to high annual rainfall and topography. Erosion washes away the most productive surface soil from the agricultural lands, thereby decreasing the fertility of the residual soils thus creating other environmental problems such as siltation of the reservoirs. Studies characterizing aggregate stability of soils is scanty for the wet zone soils.

The objective of this study was to determine the wet and dry aggregate stability of major soils in the Wet Zone of Sri Lanka to evaluate their susceptibility or resistance to erosion by water or wind.

MATERIALS AND METHODS

Samples were collected from the representative profiles of four major soils of the Wet Zone. These consist of Red Yellow Podzolic soil from Galigamuwa, Immature Brown Loam soil from Aranayaka, Reddish Brown Latasolic soil from Wathurakumbura and Alluvial soil from Kiribathkumbura. The soil profiles were described in detail and major horizons were identified. Samples were removed from each horizon using a round edge spade so as to minimize aggregate breakdown (Kemper and Rosenau, 1986). These were collected in large aluminum trays, to avoid any crushing of the sample by bagging or any other procedure.

Samples were air dried and sieved using a rotary sieve shaker consisting of a nest of sieves with openings of 5, 3, 2, 1, 0.5 and 0.25 mm for 15 minutes at an oscillation of 150 cycles per minute (Lyles *et al.*, 1970). The aggregates remaining on each sieve was weighed and expressed in dry weight basis. Three replicates were used for each horizon. These data were used to calculate four aggregate indices, namely, mean weight diameter, log mean weight diameter, geometric mean weight diameter and log standard deviation.

Mean weight diameter (MWD) was obtained as proposed by Van Bavel (1949) using the following equation:

$$MWD = \sum_{i=1}^{n} XiWi$$

Where;

Xi is the mean diameter of i^{th} size fraction
*Wi*s the aggregates retained on i^{th} sieve as a fraction of total sample and the summation is carried out to cover all *n* fractions.

Geometric mean diameter (GMD) was calculated as proposed by Mazurak (1950).

$$GMD = \exp\left[\sum_{i=1}^{n} Wi \log Xi \sum_{i=1}^{n} Wi\right]$$

Where;

Wi is the weight of aggregates in i^{th} size class,
Xi is the average diameter of i^{th} class

Gardner (1956) suggested that if the aggregate size distribution could be approximated by a log normal distribution than a normal distribution, the geometric mean diameter (GMD) and log standard deviation (LogSD) are better parameters in describing aggregate size distribution after disintegration by sieving. The GMD was obtained as the diameter at 50% oversize and LogSD as the ratio of diameters at 50% and 15.7% obtained from the log normal distribution (Gardner, 1955).

The wet aggregate stability was determined using a single sieve technique. Kemper and Rosenau (1986) documented that wet aggregate stability determined by single sieve method was well related with the stability of aggregates in the field. The sieves used had an opening of 0.26 mm in diameter. Ten grams of 1 to 2 mm soil aggregates were pre–wetted using a wetting chamber and a vaporizer to prevent any pre–treatment effects (Kemper and Rosenau, 1986). These samples were then sieved in water at a frequency of 35 cycles per minute with a stroke length of 1.3 cm. Sieves were removed at different time intervals up to 16 min and the amount remaining on the sieve was expressed as a percentage of initial sample on dry weight basis.

Soil organic matter was determined using the dichromate method (Hesse, 1971). Soil clay content was determined using the pipette method as described by Gee and Bauder (1986).

RESULTS AND DISCUSSION

Red Yellow Podzolic soils

The dry aggregate indices of mean weight diameter (MWD), log geometric mean diameter (LGMD), geometric mean diameter (GMD) and log standard deviation (Log SD) with the associate clay and organic matter contents for the Red Yellow Podzolic (RYP) soils obtained from Galigamuwa is shown in Table 1. The mean values and the least significant differences (LSD) were obtained using the ANOVA procedure of SAS (1988) for all the four major horizons identified.

As shown from Table 1 the first three aggregate indices, MWD, GMD and LGMD which are indicators of the mean aggregate size showed the same trend. After dry sieving the largest aggregates were observed in the BA and B21t horizons, indicating a higher resistance to aggregate breakdown. Baver *et al.* (1972) showed how clay particles and organic matter act as cementing agents in stabilizing the soil structure formation. They also showed that when the clay content is low organic matter becomes more important in stabilizing the soil structure. Such a relationship was not evident for the RYP soils.

Table 1. **Dry aggregate stability indices, organic matter and clay contents for major horizons of RYP soils.**

Depth Horizon (cm)	Dry Aggregate Indices				Organic matter %	Clay %
	MWD	LGMD	GMD	LogSD		
0–15 Ap	2.27b	1.05b	1.28c	0.75a	2.96	13.8
15–35 BA	2.48a	1.35a	2.28a	0.37b	1.85	18.0
35–85 B21t	2.29b	1.31a	1.03b	0.81a	0.62	31.0
85–130 B22	2.29b	1.28c	0.99b	0.78a	0.20	24.0
LSD ($p<0.05$)	0.098	0.027	0.317	0.069		

Means followed by the same letter in each column is not significantly different at $p<0.05$.

The log standard deviation (LogSD) which is an indication of the presence of different size of aggregates was high in Ap, B21t and B22 horizons. As shown by Tsuji *et al.* (1975) this helps in forming of inter aggregate pores of various sizes resulting in favourable water retention and aeration. As shown from these results the BA horizon of RYP shows highest resistance to dry aggregate breakdown.

The results obtained for the wet aggregate stability for all four horizons of RYP soils are shown in Figure 1a. This show the extent of disintegration of aggregates by wet sieving up to 16 minutes. The results are expressed as the percentage of initial sample remaining on the sieve at different time intervals.

According to Figure 1a the wet stability of aggregates is highest for the BA horizon with 99% of the original sample remaining after 16 min of sieving. Therefore in the RYP soil profile the AB horizon shows the highest dry and wet aggregate stabilities.

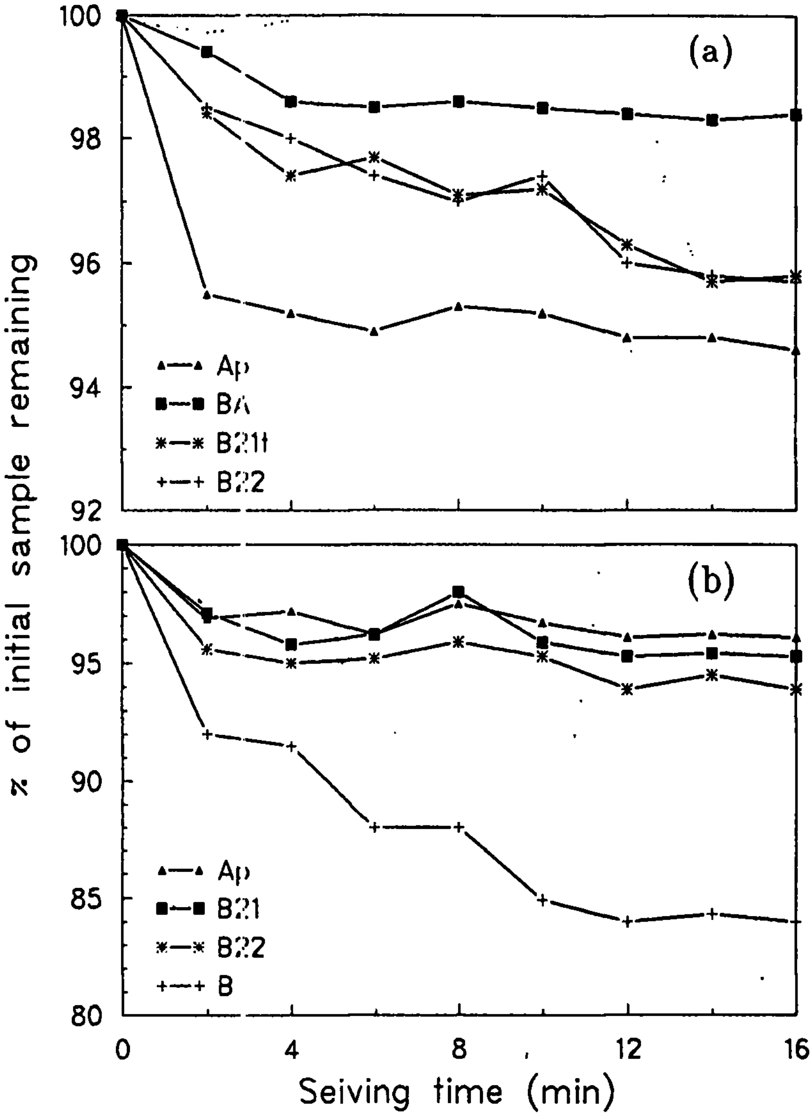

Figure 1. Wet aggregate stability for major horizons of (a) Red Yellow Podzolic and (b) Reddish Brown Latasolic soils.

Reddish Brown Latasolic soils

The aggregate indices obtained for the four major horizons of Reddish Brown Latasolic (RBL) soils collected from the Wathurakumbura area is given in Table 2. The results given in Table 2 show that the highest sizes of aggregates after dry sieving were from the Ap horizon. This is attributed to the high organic matter content and considerable amounts of clay in this horizon The log standard deviations were highest in the Ap and B horizons.

The wet aggregate stability for the four horizons of RBL soils shown graphically in Figure 1b indicate that the highest aggregate stability in the wet state is in the Ap horizon. The results indicate that both wet and dry aggregate stability are highest in the Ap horizon.

Table 2. Dry aggregate stability indices, organic matter and clay contents for major horizons of RBL soils.

Depth Horizon (cm)	Dry Aggregate Indices				Organic matter %	Clay %
	MWD	LGMD	GMD	LogSD		
0–5 Ap	2.23a	1.24a	0.98a	0.62a	2.25	11.6
5–40 B21	1.60c	1.08b	0.89c	0.50c	1.55	28.0
40–85 B22	1.75b	1.13b	0.92b	0.57b	0.52	25.0
85–18 B	1.58c	1.09c	0.90c	0.64a	0.13	27.8
LSD ($p<0.05$)	0.135	0.035	0.021	0.018		

Means followed by the same letter in each column is not significantly different at $p<0.05$.

Immature Brown Loam soils

The dry aggregate indices of mean weight diameter (MWD), log geometric mean diameter (LGMD) geometric mean diameter (GMD) and log standard deviation (LogSD) with the associate clay and organic matter contents for the Immature Brown Loam (IBL) soils obtained from Mawanalla is shown in Table 3. The largest mean aggregate size after dry sieving was obtained from the Ap horizon. The mean diameters obtained from different methods consistently showed a similar trend indicating that any of these indices are valid for comparisons. The highest dry aggregate stability of the Ap horizon is probably due to the high organic matter and considerable amount of clay in the top layer.

Table 3. **Dry aggregate stability indices, organic matter and clay contents for major horizons of IBL soils.**

Depth Horizon (cm)	Dry Aggregate Indices				Organic matter %	Clay %
	MWD	LGMD	GMD	LogSD		
0–15 Ap	2.09a	1.24a	0.97a	0.72a	1.29	7.6
15–33 AB	1.36b	1.01b	0.85b	0.49b	0.57	20.8
33–58 Bw	1.06c	0.92c	0.79c	0.40b	0.31	13.6
58–120 C	0.83d	0.84d	0.65d	0.15c	0.16	9.1
LSD ($p<0.05$)	0.111	0.043	0.047	0.136		

Means followed by the same letter in each column is not significantly different at $p<0.05$.

The LogSD of aggregates were also highest in the Ap horizon showing that it consists of different sizes of aggregates. This helps in maintaining a balance between the macro and micro pores which is useful in water and air retention.

The results of wet sieving analysis for IBL soils are shown in Figure 2a. As shown from these results the wet aggregate stability was highest in the Ap horizon. The IBL soils are immature soils and even though the clay fraction is dominated by kaolinitic clays a certain amount of smectite and vermiculites are also found in the clay fraction (Mapa, 1992). As these clay minerals swell and shrink with wetting and drying, their effect in stabilizing the aggregates is less pronounced than that of organic matter.

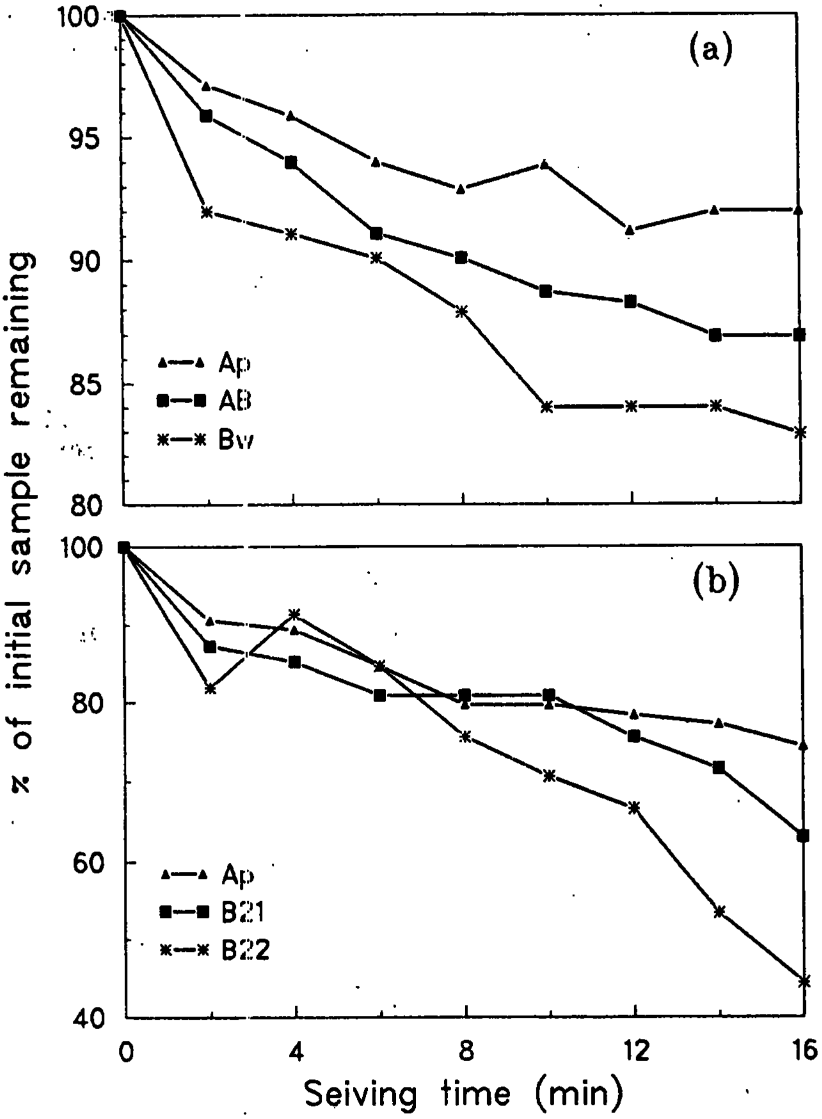

Figure 2. Wet aggregate stability for major horizons of (a) Immature Brown Loams and (b) Alluvial soils.

Alluvial soils

The aggregate indices, clay and organic matter contents for the three major horizons of Alluvial soils collected from Kiribathkumbura are shown in Table 4. According to these results the highest dry aggregate stability is shown in B21 and B22 horizons. These two horizons showed higher clay contents than the surface horizon and which contributed to larger stable aggregates as suggested by Baver *et al.* (1972). The Log standard deviation indicating the presence of different size aggregates were higher in B21 and B22 horizons. As a results these horizons exhibit a range of pore sizes creating a favourable soil water–air relationship.

The wet aggregate stability of the three horizons of Alluvial soils is given in Figure 2b. As shown from these results the wet aggregate stability was higher in Ap horizon than in other two horizons.

Table 4. **Dry aggregate stability indices, organic matter and clay contents for major horizons of Alluvial soils.**

Depth Horizon (cm)	Dry Aggregate Indices				Organic matter %	Clay %
	MWD	LGMD	GMD	LogSD		
0–25 Ap	1.86b	1.11b	0.67b	0.85a	2.59	7.6
25–100 B21	2.34a	1.26a	0.85a	1.03a	1.94	24.5
100–165 B22	2.30a	1.24a	0.83a	1.02a	1.42	24.2
LSD ($p<0.05$)	0.180	0.060	0.080	0.011		

Means followed by the same letter in each column is not significantly different at $p<0.05$.

As the surface soil horizons are more susceptible for erosion by wind and water it is more appropriate to compare stability of such horizons of the four soils studied. When the surface horizons were considered RYP and RBL soils showed comparable mean weight diameters after dry sieving than IBL and Alluvial soils. Therefore, RYP and RBL which are the major soils in the wet zone of Sri Lanka showed the highest resistant to wind erosion. The IBL soils showed slightly less resistance while the Alluvial soil showed the least resistance to wind erosion.

Alluvial soil showed the highest Log standard deviation which indicated the presence of different aggregate classes resulting in favourable soil water and air relationships. The IBL soils showed the least LogSD.

When the wet aggregate stability of surface horizons were considered the RBL soils appear to have a higher aggregate stability than that of RYP. Joshua (1988) measuring the wet aggregate stability of RYP showed an aggregate stability index of 86% for the RYP soils. The Alluvial soil showed the least resistance to erosion by water.

CONCLUSIONS

The surface horizon of the Reddish Brown Latasolic soils showed the highest dry and wet aggregate stability compared to Red Yellow Podsolic soils, Immature Brown Loam Soils and Alluvial Soils. This indicates that Reddish Brown Latasolic soils have a higher resistance against erosion by wind and water than other major soils of the Wet Zone of Sri Lanka.

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