Tropical Agricultural Research Vol. 13: 134-142 (2001)

Aggregate Stability of Soils of the Intermediate Zone of Sri Lanka

K.L.N. Rajapaksha, R.B. Mapa[1] and A.R. Dassanayake[2]

Postgraduate Institute of Agriculture
University of Peradeniya
Peradeniya, Sri Lanka

ABSTRACT. Aggregate stability is an important indicator showing the susceptibility or resistance to soil erosion, which is a major problem in the sloping lands of the Intermediate Zone (IZ) of Sri Lanka. The objective of this study was to measure the wet and dry aggregate stability of the soils of the Intermediate Zone, and to use this information in planning and management of agricultural lands. The dry and wet aggregate stability, soil clay and organic matter contents were studied in the surface horizon of 17 benchmark soil series in the IZ zone. The dry aggregate stability, which is an indication of resistance to wind erosion, was higher in the soils of up country and mid country IZ with mean weight diameters (MWD) of 2.24 to 2.05 mm respectively. The low country IZ soils showed lower MWD ranging from 1.65 to 0.75 mm. The standard deviation of the aggregates showing the presence of different sizes, were also higher in up country and mid country IZ than in low country IZ soils. The wet aggregate stability was highest (98.5%) in Ragala series in up country IZ and lowest (55%) in Andigama series in low country IZ. The aggregate stability did not show any significant relationship with soil organic matter or clay content. These results indicate that most of the low country IZ soils are susceptible to wind and water erosion and soil conservation measures should be adopted when used for agriculture.

INTRODUCTION

The Intermediate Zone of Sri Lanka is the area receiving a mean annual rainfall of 2500-1750 mm which covers approximately 0.87 million ha amounting to 13.2% of the total land area. This zone is sub divided on the basis of elevation as Up Country Intermediate (> 900 m), Mid Country Intermediate (900-300 m) and Low Country Intermediate Zones (< 300 m). According to the Central Environmental Authority of Sri Lanka the major environmental problem related to land in Sri Lanka is soil erosion and the worst affected area is the mid country (Ministry of Environmental and Parliamentary Affairs, 1991). Krishnaraja (1984) reported that soil losses due to erosion measured in Ultisols in the Hanguranketha area which belongs to the mid country Intermediate Zone were 70, 38 and 18 mt/ha under tobacco, capsicum and carrot cultivations respectively with no conservation practices. These values were very much higher than the proposed soil loss tolerance limit of 9 mt/ha for this area.

---

[1] Department of Soil Science, Faculty of Agriculture, University of Peradeniya, Peradeniya, Sri Lanka.

[2] Land Use Division, Department of Irrigation, Colombo 7, Sri Lanka.

Soil loss of agricultural land could be measured using unit erosion plots as suggested by Wischmeir and Smith (1978), but it is costly and time consuming. Wischmeir *et al.* (1971) developed a nomograph to estimate soil erodibility using the silt and fine sand, sand, organic matter, soil structure and permeability. These should be used with caution as such models are only validated for temperate soils. Evaluating aggregate stability is another way of comparing the erodibility of different soils. The dry aggregate stability of a soil is an indication of resistance to wind erosion while wet aggregate stability shows the susceptibility or resistance to erosion by water (Hillel, 1982). Jayalath and Mapa (1997) evaluated the aggregate stability for the wet zone soils of Sri Lanka and showed that Reddish Brown Latasolic soils showed highest dry and wet aggregate stability. The information on soil erodibility and aggregate stability for most of the Sri Lankan soils of the Intermediate Zone is not available. Therefore, the objective of this study was to measure the dry and wet aggregate stability of soils in the Intermediate Zone of Sri Lanka to be used in planning and management of soils in the agricultural lands.

MATERIALS AND METHODS

This study was conducted using soils from the Intermediate Zone of Sri Lanka. Seventeen soil series (Nayakekorala and Mapa, 2001) were used for determining the aggregate stability. The names of the soil series, their great soil groups according to De Alwis and Panabokke (1972) and the Soil Taxonomic Equivalents (Soil Survey Staff, 1992) are given in Table 1. Benchmark sites of these soil series in the Intermediate Zone are shown in Fig. 1. Soil samples were collected for analysis of clay content and organic matter from the surface horizon from each of these benchmark sites as only the top layer is subjected to soil erosion by wind and water. Soil was air-dried and sieved using the 2 mm sieve. Fifty grams of air-dried soil were used to determine the clay content using the Pipette method (Gee and Bauder, 1986). Soil organic matter was determined using the dichromate method (Hesse, 1971). Soil clay and organic matter were determined for three replicates from each location. Samples for dry and wet aggregate stability were collected using a round edged spade to minimize aggregate breakdown as described by Kemper and Rosenau (1986) to large aluminium trays, avoiding any crushing in bagging or any other procedure.

For determining the dry aggregate stability the soils were air-dried and sieved using a rotary sieve shaker consisting of a nest of square hole sieves with openings of 5, 3, 2, 1, 0.5 and 0.25 mm for 15 min at an oscillation of 150 cycles per minute (Lyles *et al.*, 1970). The aggregates remaining on each sieve were weighed and expressed in dry weight basis. Two samples were analysed for each location. These data were used to calculate aggregate indices, namely, mean weight diameter (MWD) and log standard deviation (log SD). MWD was obtained as proposed by Van Bavel (1949) using the following equation:

$$MWD = \sum_{i=1}^{n} x_i w_i$$

Where:

x_i is the mean diameter of i^{th} size fraction, and

w_i is the aggregates retained on i^{th} sieve as a fraction of total sample.

Gardner (1956) suggested that most aggregate size distributions could be approximated by a log normal distribution. He suggested that Log SD could be used as a parameter showing the presence of different size aggregates. The Log SD was obtained as the ratio of diameter at 50 and 84.13% over size using a log probability graph paper as described by Gardner (1956).

Table 1. Names of the soil series from 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	Rikillagaskada	Reddish Brown Latasolic	Typic Rhodudults
	Bandarawela	Red Yellow Podosolic	Typic Hapludults
	Ragala	Red Yellow Podosolic	Typic Hapludults
Mid Country Intermediate Zone	Mahawalathanna	Red Yellow Podzolic soils derived from Quartzite	Typic Troporthents
	Waligepola	Immature Brown Loams	Typic Dystrochrepts
	Mahaberiyatanna	Reddish Brown Latasolic	Rhodudulfs
Low Country Intermediate Zone	Kiruwana	Red Yellow Podzolic	Typic Hapludults
	Hembarawa	Alluvail	Typic Ustorthents
	Maho	Reddish Brown Earth	Pasmmentic, Hapludults
	Beliatta	Red Yellow Podzolic with soft and latarites	Plinthudults
	Okawela	Immature Brown Loams	Typic Dystropepts
	Ulhitiya (Rolling)	Reddish Brown Earth	Typic Rhodudalfs
	Kurunegala	Red Yellow Podzolic with soft and hard latarites	Plinthudults
	Melsiripura	Reddish Brown Latasolic	Rhodudaifs
	Ulhitiya	Reddish Brown Earths	Typic Haplustalfs
	Wariyapola	Non Calcic Brown	Typic Dystrochrepts
	Andigama	Red Yellow Podzolic with soft and hard latarites	Typic Troporthents

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 stability of aggregate in the field. These single size sieves had an opening of 0.26 mm in diameter. Ten grams of 1-2 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 in 2 min time intervals up to 16 min. The amount remaining on the sieve was expressed as a percentage of initial sample on dry weight basis.

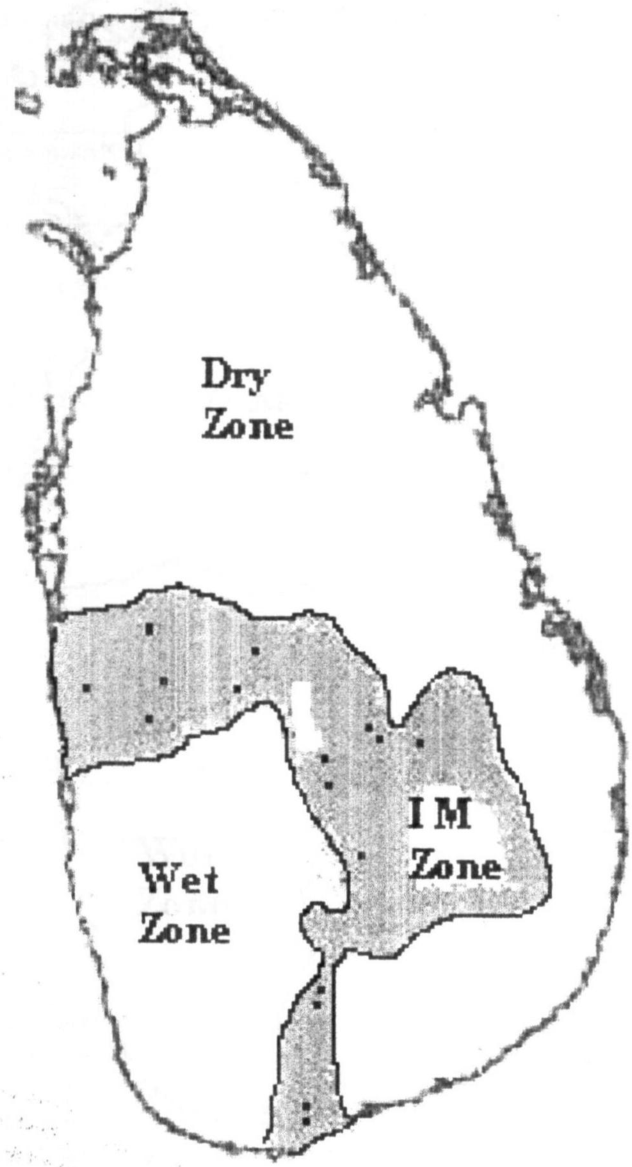

Fig. 1. Benchmark sites of the soil series in the Intermediate Zone of Sri Lanka.

RESULTS AND DISCUSSION

Dry aggregate stability

Table 2 shows the mean weight diameter (MWD), Log Standard Deviation (Log SD) with the associated organic matter and clay contents for the Intermediate Zone soils. The mean value and the least significant difference (LSD) were calculated using the ANOVA procedure of SAS (1988).

Table 2. Mean weight diameter (MWD), Log SD, organic matter and clay percentages of the Intermediate Zone soils.

Agro ecological zone	Soil series	MWD (mm)	Log SD	Organic matter %	Clay %
Up Country Intermediate Zone	Rikillagaskada	2.24^{a}	0.77	0.31	21.3
	Bandarawela	1.89^{bc}	0.75	2.1	34.7
	Ragala	1.67^{cd}	0.73	1.0	15.3
Mid Country Intermediate Zone	Mahawalathanna	2.05^{ab}	0.70	2.1	26.0
	Waligepola	1.88^{bc}	0.70	3.3	16.2
	Mahaberiyatannna	1.55^{d}	0.65	3.3	29.3
Low Country Intermediate Zone	Kiruwana	1.65^{cd}	0.60	4.7	15.2
	Hembarawa	1.46^{de}	0.71	0.9	7.5
	Maho	1.40^{de}	0.26	1.9	11.0
	Beliatta	1.26^{e}	0.66	3.1	15.4
	Okawela	1.21^{ef}	0.59	2.0	11.7
	Ulhitiya (Rolling)	1.21^{ef}	0.68	0.7	16.7
	Kurunegala	0.96^{fg}	0.19	1.1	7.6
	Melsiripua	0.99^{fg}	0.60	1.8	13.1
	Ulhitiya	0.83^{gh}	0.40	1.9	5.8
	Wariyapola	0.75^{gh}	0.17	0.06	3.6
	Andigama	0.72^{h}	0.17	2.2	9.4

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

As shown in Table 2, MWD is generally high in up country Intermediate Zone soils where Rikillagaskada showed the highest value of 2.24 mm among all the soil series. Low country Intermediate Zone soils showed the lowest MWD value, which is 0.72 mm for Andigama soil series. For the soils of the mid country Intermediate Zone MWD fall between these two values. The MWD values are related to the resistance or susceptibility to wind erosion, where high MWD values indicate high resistance to wind erosion. Therefore, up country Intermediate Zone soils have higher dry aggregate stability with high resistance to wind erosion than the low country Intermediate Zone soils Baver *et al.* (1972) documented that clay particles and organic matter act as cementing agents in stabilizing the soil structural formations. No such relationships were found in these soil series, may be as these sites are located in the cultivated lands where the topsoils are frequently mixed during tillage operations. Sometimes farmers add organic matter to the field, where natural conditions of these sites have been altered. In addition, soil aggregate stability also depends on soil mineralogy. Uhera and Gilman (1981) documented that soils with high clay activity have low soil aggregate stability as they swell and shrink with intermittent wetting and drying.

The Log SD is a parameter indicating the presence of different sizes of aggregates in the soil. Formation of different size aggregates is very useful as it leads to creation of inter-aggregate pores of various diameters resulting favourable air water relation (Tsuji *et al.*, 1975). Up country Intermediate Zone soils have high Log SD, of more than 0.7, leading to better soil air water relationships. Low country Intermediate Zone soils showed lower values of Log SD and therefore a uniform aggregate size.

Wet aggregate stability

The results obtained for the wet aggregate stability of surface soils in selected Intermediate Zone soils are shown in Fig. 2. This figure indicates how the aggregates breakdown in water up to 16 min of sieving. The final values obtained from the graph (the amount of aggregates remaining as a percentage of the initial sample after 16 min of sieving) indicate the resistance to erosion by water. These values are listed in Table 3. According to Table 3 the highest wet aggregate stability was recorded in Ragala series from the up country Intermediate Zone as 98.5% of the initial sample remaining after sieving for 16 min. Lowest wet aggregate stability was recorded in Ulhitiya (with rolling landscape) as 44% of the initial sample remaining. Generally, the wet aggregate stability of mid country Intermediate Zone soils were higher than that of the other two regions.

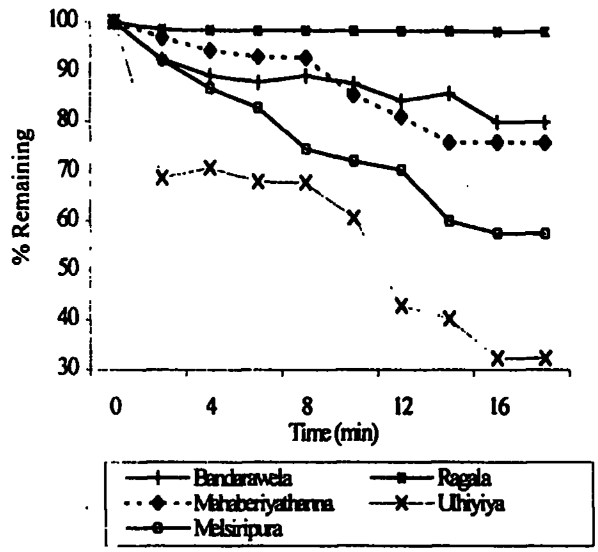

Fig. 2. Wet aggregate stability of selected soil series from the Intermediate Zone of Sri Lanka.

According to Table 1, Ragala and Ulhitiya soil series belong to Red Yellow Podsolic and Reddish Brown Earth great soil groups respectively. Joshua (1977) documented that Red Yellow Podzolic soils are more resistant to erosion than Reddish Brown Earth soils. He estimated erodibility values of 0.22 and 0.27 for Red Yellow Podzolic and Reddish Brown Earth soils respectively, which agree with the wet aggregate stability data obtained in this study.

Table 3. Wet aggregate stability of the Intermediate Zone soils.

Agro ecological zone	Soil series	% aggregates remaining after 16 min
Up Country Intermediate Zone	Rikillagaskada	60.5
	Bandarawela	81.5
	Ragala	98.5
Mid Country Intermediate Zone	Mahawalathanna	96.5
	Waligepola	89.5
	Mahaberiyatanna	80.5
Low Country Intermediate Zone	Kiruwana	68.6
	Hembarawa	94.0
	Maho	86.5
	Beliatta	94.9
	Okawela	82.5
	Ulhitiya (Rolling)	44.0
	Kurunegala	57.0
	Melsiripura	66.0
	Ulhitiya	50.5
	Wariyapola	66.0
	Andigama	55.0

CONCLUSIONS

This study shows that the surface horizons of the soils in up country and mid country Intermediate Zones are more resistant to erosion than the soils of the low country Intermediate Zone. Even though soil erosion depends on factors such as slope, gradient and rainfall, aggregate stability is a valid indicator of soil erodibility. If soil aggregate stability is high it has ability to decrease soil erosion. Therefore, more emphasis should be given to soil conservation measures when lands of the low country Intermediate Zone are used for cultivation. The aggregate stability did not show any relationship with the silt, clay or organic matter content due to differences in mineralogy or as these soils have been cultivated for long time, where mixing with the subsoils with tillage, compaction, erosion of the surface layer and management practices may have changed the soils considerably.

ACKNOWLEDGEMENTS

This study was funded by the twinning project between the Canadian Society of Soil Science (CSSS) and the Soil Science Society of Sri Lanka (SSSSL). The assistance given in soil analysis by Mr. H. Kulasiri and Mr. Jayalath Bandara is greatly appreciated.

REFERENCES

Baver, L.D., Gardner, W.H. and Gardner, W.R. (1972). Soil Physics, John Wiley and Sons, New York. Pp. 283.

De Alwis, K.A.N. and Panabokke, C.R. (1972). Handbook of the soils of Sri Lanka. J. Soil Sci. Soc. Sri Lanka. 2: 1-26.

Gardner, W.R. (1956). Representation of soil aggregate size distribution by a logarithmic-normal distribution. Soil Sci. Soc. Amer. Proc. 20: 151-153.

Gee, G.W. and Bauder, J.W. (1986). Particle size analysis. pp. 383-489. *In*: Klute, A. (Ed). Methods of Soil Analysis, Part 1-2nd Edition, American Society of Agronomy, Madison, Wisconsin.

Hesse, P.R. (1971). A Textbook of Soil Chemical Analysis. John Murray, London.

Hillel, D. (1982). Introduction to Soil Science. Academic Press, New York. Pp. 159.

Jayalath, K.D.D. and Mapa, R.B. (1997). Aggregate stability of major soils in the wet zone of Sri Lanka. Trop. Agric. Res. 9: 276-287.

Joshua, W.D. (1977). Soil erosive power of rainfall in the difference climatic zones of Sri Lanka. Proc. Sym. Erosion and Solid Matter Transport in Inland Waters, Paris, July 1977.

Kemper, W.D. and Rosenau, R.C. (1986). Aggregate stability and size distribution. pp. 425-442. *In*: Klute, A. (Ed). Part 1-2nd Edition, American Society of Agronomy, Madison, Wisconsin.

Krishnaraja, P. (1984). Erosion and degradation of the environment. Paper presented at the Annual Sessions of the Soil Science Society of Sri Lanka.

Lyles, L., Dickerson, J.D. and Disrud, A.D. (1970). Modified rotary sieves for improved accuracy. Soil Sci. 109: 201-210.

Ministry of Environmental and Parliamentary Affairs. (1991). National Environmental Action Plan, Ministry of Environmental and Parliamentary Affairs, Government of Sri Lanka.

Nayakekorala, H.B. and Mapa, R.B. (2001). Soils of the Intermediate Zone of Sri Lanka. Morphology, Characterization and Classification. Special Publication No. 3, Soil Science Society of Sri Lanka, Sarvodaya Vishvalekha Press. (In Press).

SAS. (1988). SAS/STAT User's Guide. 6th Edition, SAS Institute Inc., Cary NC, USA.

Soil Survey Staff. (1992). Keys to Soil Taxonomy. Soil Management Support Service, Technical Monograph No. 19, 5th Edition, Pochontas Press, Blacksburg VA.

Tsuji, J.Y., Watanabe, R.T. and Saka, W.S. (1975). Influence of soil microstructure on water retention characteristics of selected Hawaiian soils. Proc. Soil Sci. Soc. Amer. 29: 28-33.

Uehara, G. and Gilman, G. (1981). The Mineralogy, Physics and Chemistry of Tropical Soils with Variable Charge. Westview Press, Boulder, Colorado. Pp. 159.

Van Bavel, C.H.M. (1949). Mean weight diameter of soil aggregates as a statistical index of aggregation. Proc. Soil Sci. Soc. Amer. 17: 416-418.

Wischimeier, W.H., Johnson, C.B. and Cross, B.W. (1971). A soil erodibility homograph for farm land and construction sites. J. Soil and Water Cons. 26: 189-183.

Wishmayer, W.H. and Smith, D.D. (1978). Predicting rainfall erosion losses - A guide to conservation planning. U.S. Department of Agriculture, Agric. Handbook. 527: 56.