

DRY AGGREGATE STABILITY OF NON-CALCIC BROWN SOILS UNDER FIVE LAND USE PATTERNS

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ABSTRACT

Aggregation improves soil structure, reduces erosion and makes the pore size distribution of soil favourable for sustainable agriculture. The objective of this study was to evaluate the effect of five land use patterns in aggregate formation and stability of Non-calcic brown soils. A rotary sieving equipment was used to evaluate soil aggregation and dry stability under natural forest, reforested areas with *acacia* and *leucaena*, grassland and in continuously cultivated land. The aggregate size distribution fitted best to a log normal distribution pattern. Log Mean Geometric Diameter (LGMD) and Log Standard Deviation (LSD) were used as aggregate indices to compare the distributions. Forest soil showed the highest LGMD indicating higher amount of macro-aggregates after dry-sieving than for other treatments and therefore the highest resistance to wind erosion. Reforested soils showed higher LGMD than grassland and cultivated soils. Higher soil organic matter, Ca and Fe contents combined with intensive root systems in natural forest, and reforested areas seemed to be beneficial for the formation of macro-aggregates (> 1 mm). The grassland soil showed the highest amount of micro-aggregates (> 1 mm) due to the effect of fibrous root systems. Therefore, leaving stripes of natural forest in land clearings or having stripes of reforested land would help in soil structure development and stability than lands with annual crops or grasses.

KEY WORDS: Aggregation, Land use patterns, Non-calcic brown soils

INTRODUCTION

Soil aggregation is a favourable property that affects the behaviour of soil with respect to erosion, water retention and flow, aeration and root growth. Clay and organic molecules derived from plants and organisms in soils are considered as the main aggregating agents that cement the primary particles together to form secondary particles or aggregates (Emerson, 1959). The size, distribution and stability of the soil aggregates depend on the amount and type of binding materials present in the soil.

A prerequisite for soil aggregate formation is that clay particles flocculate to form clay domains. Flocculation is necessary but not sufficient for stable aggregate formation (Emerson, 1959). Iron and aluminum as well as CaCO_3 can improve aggregate stability considerably by cementing the flocculated clay (Baver *et al.*, 1972; Greenc *et al.*, 1979; Hillel, 1982). Iron oxides and some transitional iron forms bonded to the soil organic matter are crucial in stabilizing soil aggregates in tropical soils (Giovannini and Sequi, 1976).

Rapidly decomposable materials such as microbial and plant derived polysaccharides, mycorrhizal exudate and materials in association with amorphous Fe and Al compounds are responsible for soil aggregation (Greenland, 1965; Tisdall and Oades, 1982). The types and amounts of organic compounds present in a certain soil is influenced by the type of vegetation (Baver *et al.*, 1972). Long term annual cropping systems result in loss of labile organic matter which binds micro-aggregates together. Their ability to replenish organic materials is low and cause a reduction in macro - aggregation (Elliott, 1986; Gupta and Germidith, 1988). Active humus is accumulated and soil aggregation is stabilized most effectively under perennial clod forming herbage better than most of the annual crops (Oades, 1984). The cropping systems also influence soil aggregation by pressures exerted from roots depending on the nature of the crops used. Many investigators have clearly demonstrated that grasslands promoted stable aggregate formation (Marshall and Holmes, 1979).

The stability of aggregates as well as aggregate size distribution are used to assess soil structure. The dry stability of soil aggregates is a good indication of resistance of a soil to wind erosion (Baver *et al.*, 1972).

Non-calcic brown soils (NCB) is an important great soil group covering about 200,000 ha in the dry zone of Sri Lanka (De Alwis and Panabokke, 1972). As these soils have low clay content (sandy to loamy sand textures) organic matter play a dominant role in aggregate formation. These soils are extensively used for agriculture and their susceptibility to wind erosion is high. Cropping systems which add organic matter to soil could improve soil structure formation and stability to overcome these problems.

The objective of this study was to investigate the effect of different land use patterns on aggregate distribution and dry stability of NCB soil.

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MATERIALS AND METHODS

Soil samples for the evaluation of dry aggregate distribution and stability were obtained from different land use patterns from the Regional Agricultural Research Centre at Aralaganwila in the Mahaweli System B. The soils of the area are classified as Non-calcic brown soils (De Alwis and Panabokke, 1972) and as Halplustalfs according to Soil Taxonomy (Soil Survey Staff, 1992). A natural forest, two reforested areas with two-year old *acacia* and *leucaena* (underground completely devoid of grasses and herbs), fallow land with grasses and cultivated land (with chilli and corn rotation under ridge and furrow irrigation for about 4 years) adjacent to one another were selected for the sampling.

Undisturbed soil clods were obtained using a round edge spade from a 15 cm by 15 cm area to a depth of 10 cm at five randomly selected locations for each treatment. They were transported after packing in polythene bags to the laboratory and allowed to air-dry to about 5% gravimetric moisture content under greenhouse conditions.

A rotary sieve set as proposed by Chepil (1962) was used to determine the dry aggregate distribution and the stability of aggregates. A set of six square hole sieves with openings of 3, 2, 1, 0.5, 0.25 and 0.106 mm diameter was used. A 750 g sample was sieved for six minutes at an oscillation rate of 22 cycles per minute. At the end of sieving, the gravel particles were removed and each fraction retained on the sieves was weighed and expressed on a dry weight basis.

The over size percentage for each aggregate size category was obtained using the amount retained on each sieve. The Log Geometric Mean Diameter (LGMD) and Log Standard Deviation (LSD) were obtained by plotting the diameter versus over size percentage of aggregates in log probability graph paper as suggested by Gardner (1956). The LGMD was obtained as the diameter at 50% over size percentage and LSD as the ratio of diameters at 50% to 15.87% over sizes.

Particle size analysis of the soil was obtained using the pipette method as suggested by Gee and Bauder (1986). Organic matter content of samples was determined by wet combustion method (Nelson and Sommers, 1982). The soluble Ca and Fe were extracted by NH_4OAc solution and determined using an atomic absorption spectrophotometer (Lanyon and Heald, 1982; Olson And Roscoe, 1982).

RESULTS AND DISCUSSION

The distribution of soil aggregates as percentage over size among the various size classes for the five different land use patterns is given in Table 1.

Table 1. Mean soil aggregate size distribution of five land use patterns of NCB soils

Aggregate diameter (mm)	Percent over size				
	Forest	Acacia	Leucaena	Grassland	Cultivated
> 3	2.17	5.53	4.94	0.48	1.43
> 2	4.10	7.40	7.04	0.95	2.06
> 1	17.68	18.00	18.74	8.19	9.57
> 0.5	46.41	45.08	45.01	39.15	36.41
> 0.25	86.48	80.74	81.18	83.23	83.46
> 0.106	93.61	93.49	93.70	92.99	91.83
> 0.00	100	100	100	100	100

The distribution of soil aggregates fitted well to a log normal distribution. Since the aggregate size distribution of five land use patterns were log normally distributed their LGMD and LSD were calculated as suggested by Gardner (1956). These aggregate indices for the five land use patterns in NCB soils are given in Table 2.

Table 2. Summarized mean aggregate indices for five land use patterns of NCB soils

Land use pattern	LGMD (mm)	LSD
Forest	0.476 a	0.424 b
Acacia	0.445 b	0.340 b
Leucaena	0.466 ab	0.364 c
Grassland	0.356 c	0.480 a
Cultivated	0.374 c	0.474 a

Means followed by the same letter in each column are not significantly different at $p < 0.05$ according to the Duncan's multiple range test (DMRT)

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The highest LGMD was obtained for forest soils and lowest for the grassland soils. This is an indication that the aggregates of forest soil were well-distributed towards larger sizes and they were more stable than others. As discussed by Browning and Milam (1941) and Oades (1984) the significantly high organic matter content of forest soils may be the major reason for its large aggregate sizes. As shown in Table 3, natural forest soils had the highest organic matter content compared to other land use patterns. The high amount of Ca found in forest soils (Table 3) also contributed to soil aggregation. Ilaco (1981) documented that better developed

Table 3. Physical and chemical properties contributing to soil aggregation in five land use patterns of NCB soil

<i>Land use pattern</i>	<i>Sand (%)</i>	<i>Silt (%)</i>	<i>Clay (%)</i>	<i>Organic matter (%)</i>	<i>Ca (ppm)</i>	<i>Fe (ppm)</i>
Forest	94.30	3.71 b	1.99 d	1.80 a	55.35 a	1.55 bc
<i>Acacia</i>	90.59	4.83 a	4.55 a	0.77 b	36.27 c	1.50 a
<i>Leucaena</i>	90.45	4.83 a	4.72 a	0.81 b	25.39 d	0.82 c
Grassland	95.22	2.95 c	1.83 c	0.52 c	44.05 b	1.70 a
Cultivated	94.90	2.70 c	2.40 b	0.82 b	15.32 e	1.06 bc

Means followed by the same letter in each column are not significantly different at $p < 0.05$ according to the Duncan's multiple range test (DMRT)

more favourable soil structures are often associated with CaCO_3 or gypsum. This indicates the beneficial effects of organic matter as an aggregate agent specially for soils such as NCB whose clay content is low.

The LSD of aggregate size distribution of grassland soil was higher than in land use patterns other than cultivated soils. When the LSD high, it shows the presence of different range of aggregate sizes in the soil. This will lead to formation of various pore sizes improving water and air relationships of soil. A similar trend was observed by Van Bravel (1949) in Clarion silt loam soil under blue grass and corn cultivation.

As indicated from percent over size in Table 1, the effects of land use patterns were more pronounced on macro-aggregates (>1 mm) than on smaller ones. Cultivated and grassland soils showed lower amounts of aggregates over 2 and 3 mm in diameter

than other treatments. Since there had been only minimum land disturbance, the fibrous root systems of grasses were responsible for high amounts of smaller aggregates. As shown from Table 3 the low aggregation of the cultivated soil may be attributed to the loss of labile organic materials as observed by Elliott (1986). In contrast, the higher amounts of larger aggregates in reforested areas of *acacia* and *leucaena* may be due to the presence of high amounts of clay, silt and the relatively high amounts of organic matter (except forest) in those soils (Table 3). As shown in Table 1 the differences in aggregate sizes between the reforested treatments were low. This may be due to the similarities of the organic matter and clay contents of these soils. In the case of forest soil, even with the highest organic matter content of all soils considered, macro-aggregate formation was retarded due to low levels of clay and silt.

A contrasting trend emerged when aggregates smaller than 1 mm (micro-aggregates) were considered. The percentage over size than 1 mm is reported in Table 3. When the percentage under size is calculated by subtracting these values from 100, the highest value of 91.81 is obtained for grassland soils. The percentage of aggregates less than 1 mm in the different land use patterns followed the order: grassland > cultivated land > natural forest > reforested lands with *leucaena* and *acacia*. Even though clay, silt and organic matter contents were low, grassland soils showed the highest amount of micro-aggregates. As shown in Table 3, grassland soils had high contents of Fe and Ca. Besides their positive effects on micro-aggregation the fibrous root system of grasses also favour micro-aggregate formation.

The adverse effects of cultivation on stable aggregate formation was more pronounced in aggregate size > 0.5 mm. These results are in agreement with the findings of Guptha and Germidh (1988) for an Orthic Brown Chernozemic soil under continuous cultivation for a period of 67 years. The rest of land use patterns consisted of tap root systems and the formation of micro-aggregates appeared to be dispersed. The highest LSD in grassland soil indicates the presence of many different size aggregates making the pore size distribution favourable for soil water and air relationship.

CONCLUSIONS

Lands under natural forests and reforested with *acacia* and *leucaena* showed higher LGMD and therefore greater formation of macro-aggregates (> 1 mm) compared to grassland and cultivated soils, indicating the importance of organic

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matter and root systems on soil aggregation. The most stable dry aggregates which were more resistant to wind erosion were formed in forest soils than in the other soils evaluated. The reforested areas produced stable aggregates than areas under grassland or annual crops. Formation of micro-aggregates (< 1 mm) due to breakdown of larger aggregates was promoted by grasses and annual crops than by perennial plantations. Irrespective of the land use it was shown that soil aggregate distribution fitted well to a logarithmic distribution for all five soils. Although the aggregates of forest soils were more stable, grassland and cultivated soils showed aggregates of many different sizes as indicated by the LSD. Clay, organic matter, Ca and Fe seemed to be equally important for aggregate formation in NCB soils. This indicates that leaving stripes of natural forest when land is cleared for agriculture or having stripes of reforested land would help in soil structure development and stability than lands with annual crops and grasses.

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REFERENCES

- Baver, L.D., W.H. Gardner and W.R. Gardner. 1972. Soil Physics. John Wiley and Sons, New York, USA. 493p.
- Browning, G.N. and F.M. Milam. 1941. Rate of application of organic matter in relation to soil aggregates. Soil Sci. Soc. Am. Proc. 6:96-97.
- Chepil, W.S. 1962. A compact rotary sieve and the importance of dry sieving in physical soil analysis. Soil Sci. Soc. Am. Proc. 26:4-6.
- De Alwis, K.A. and C.R. Panabokke. 1972. Handbook of soils of Sri Lanka (Ceylon). J. Soil Sci. Ceylon 2:1-97.
- Elliott, R.F. 1986. Aggregate structure and carbon, nitrogen and phosphorous in native and cultivated soils. Soil Sci. Soc. Am. Proc. 50: 627-633.
- Emerson, E.W. 1959. The structure of soil crumbs. J. Soil Sci. 10:223-235

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- Gardner, W.R. 1956. Representation of soil aggregate size distribution by a logarithmic normal distribution. *Soil Sci. Am. Proc.* 20:151-153.
- Gee, G.W. and J.W. Bauder. 1986. Particle size analysis. *In Methods of Soil Analysis*. Part 1, 2nd ed. Ed A.Klute. pp 283-409. American Society of Agronomy, USA.
- Giovannini, G and P. Sequi. 1976. Iron and aluminium as cementing substances of soil aggregates. II. Changes in stability in soil aggregates following extraction of iron and aluminum by acetyl acetone in a non-polar solvent. *J. Soil Sci.* 27:148-153.
- Greene, R.S.B., A.M. Posner and J.P.Quirk. 1979. A study of the coagulation of montmorillonite and illite suspensions by calcium chloride using the electron microscope. *In Modification of Soil Structure*. Eds. W.W. Emerson, H.D. Bond and A.A. Dexter. pp 35-41. John Wiley and Sons, New York, USA.
- Greenland, D.J. 1965. Interactions between clays and organic compounds in soils. Part 1. Mechanisms of interaction between clays and defined organic compounds. *Soils & Fert.* 28:415-425.
- Guptha, V.V.S.R. and J.J. Germidh. 1988. Distribution of microbial biomass and its activity in different soil aggregate size classes as affected by cultivation. *Soil Biol. Biochem.* 20:777-786.
- Hillel, D. 1982. *Introduction to Soil Physics*. Academic Press, New York, USA. 319p.
- Ilaco, B.V. 1981. *Agricultural compendium for rural development in the tropics and sub tropics*. Elsevier Publications, Netherlands. 345 p.
- Lanyon, E.L. and W.R. Heald. 1982. Magnesium, Calcium, Strontium and Barium. *In Methods of Soil Analysis*. Part II, 2nd ed. Eds. A.L. Page *et al.* pp 247-260. American Society of Agronomy, USA.
- Marshall, T.J. and J.W. Holmes. 1979. *Soil Physics*. Cambridge University Press, Cambridge, UK. 189p.
- Nelson, D.W. and L.E. Sommers. 1982. Total Carbon, Organic Carbon and Organic Matter. *In Methods of Soil Analysis*, Part II, 2nd ed. Eds. A.L. Page *et al.* pp 539-554. American Society of Agronomy, USA.
- Oades, J.M. 1984. Soil Organic matter and structural stability. Mechanisms and implications for management. *Plant and Soil* 76:319-337.

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Olson, R.V. and E. Roscoe Jr. 1982. Iron. *In* Methods of Soil Analysis, Part II, 2nd ed. Eds. A.L. Page *et al.* pp 141-163. American Society of Agronomy, USA.

Soil Survey Staff. 1992. Keys to Soil Taxonomy. Soil Management Support Services, Technical Monograph 19 (5th Edition). Pocahontas Press, Blacksburg, Virginia, USA. 232p.

Tisdall, J.M. and J.M. Oades. 1982. Organic matter and water stable aggregates in soils. *J. Soil Sci.* 33:141-162.

*Van Bavel, C.H.M. 1949. Mean weight diameter of soil aggregates as a statistical index of aggregation. *Soil. Sci. Am. Proc.* 14:20-23.