Original Research Article

Aggregate stability: an indicator of quality and resistivity of arable soil

Abstract

Soil aggregate stability is a key indicator of soil quality. Changes in aggregate stability may serve as early indicators of recovery or degradation of soils. We have applied laboratory based aggregate fractions method where fine and coarse soil aggregatesfixed by set of sieves for two typesof soil to estimate aggregate stability. Co-efficient of vulnerability and mean weight diameter was calculated for each aggregate size fractions. Stability index (SI) and aggregate size distribution was determined to conclude on soil erodibility and compaction. Mean weighted diameter (MWD) of the Nurkerke and Hesteert soil after wet sieving is 2.03 mm and 1.56 mm respectively. The instability index of the Nurkerke soil is 2.41 and of Hesteert soil is 2.89. The aggregate stability index of the Nukerke is 0.41 and Hesteertsoil is 0.35. The coefficient of vulnerability (Kv) of Nukerke soil is 2.18 while the Hesteert has 2.81; hence the Nukerke soil seems more stable than the Hesteert soil of Belgium. Results revealed that the Nukerke soil is less vulnerable for erodibility and compaction than the Hesteert soil under investigation.

Key Words: Aggregate sizedistribution, Aggregate stability, Sieve and Soil erodibility.

Introduction

Soil aggregate stability is widely recognized as a key indicator of soil quality (Herrick et al. 2001). Soil aggregate stability is a key factor of soil resistivity to mechanical stresses, including the impacts of rainfall and surface runoff, and thus to water erosion (Canasveras et al. 2010). Soil aggregates can be defined as groups of soil particles that bind to each other more strongly than to adjacent particles, while space between the aggregates provide pore space for retention and exchange of air and water in the system concerned. It refers to the ability of soil aggregates to resist disruption when outside forces such as rain drops but it differed from dry aggregate stability which is used for wind erosion prediction. Aggregate stability is an important soil quality parameter, i. e., it affects erosion, movement of water and plant root growth.Aggregate stability is an indicator of organic matter content, biological activity and nutrient cycling in soil (Arshad et al., 1996; Kemper and Rosenau, 1986). Generally, the particles in small aggregates (<0.25 mm) are bound by older and more stable forms of organic matter. Microbial decomposition of fresh organic matter releases products (that are less stable) that bind small aggregates into large aggregates (>2-5 mm). These large aggregates are more sensitive to management effects on organic matter, serving as a better indicator of changes in soil quality. Greater amounts of stable aggregates suggest better soil quality (Arshad et al., 1996; Kemper and Rosenau, 1986). When the proportion of large to small aggregates increases, soil quality generally increases.Thus aggregate stability is crucial for sustainability of soils and crop production. Conservation practices that in are resulting aggregate stability favorable to soil function and or quality include conservation crop rotation, cover crop, pest management, prescribed grazing, residue and tillage management, salinity and sodic soil management and surface roughening. Desirable aggregates are stable against mechanical stress such as inversion tillage, rainfall and water movement. Aggregates that break down in water or fall apart when struck by raindrops release individual soil particles that can seal the soil surface and clog pores. This breakdown creates crusts that close pores and other pathways for water and air entry into a soil and also restrict emergence of seedlings from a soil (Anon. 1996).Several authors reported aggregate size and moisture retention for agricultural soils (Tamboli and Tamhane, 1955; Amemiya et al. 1964; Tamboli, 1961). However, quantification and interpretation of aggregate stability might be difficult because numerous methods have been used to determine aggregate stability with varying success (Amézketa, 2008).Aggregate stability varies widely across a variety of scales (Pearson et. al., 1994) and soil texture. Correlation between aggregate stability and other soil properties (erodibility, compaction, crusting status) is not always consistent but at times difficult to establish.There are several methods to assess aggregate stability. But a unified methodological framework based on existing methods mightbe implemented for aggregate evaluation and aggregate stability data that canbe used for an estimation of soil erodibility and compaction.Laboratory based methods include soil aggregates fractions method where aggregates manually passed through a set of sieves of a particular mesh size (ASTM International, 2006; AASHTO, 2006; Yoder 1936).This sieve-based methodcontains some limitations (few sieve sizes, particle size distribution of sub sample material, labour) but these limitations could be overcome by undertaking aggregate stability measurements with a laser granulometer instrument, but this technology has not been widely applied to the quantification of aggregate stability (Rawlins, 2013).While Schomakers et al. (2011) reported that a more comprehensive analysis of aggregate stability can be obtained when using both, the wet-sieving SAS method and ultrasonic dispersion at low energy levels.The stability of aggregates is affected by several factors such organic matter content, soil water content, chemical constituent of the soil.Changes in aggregate stability may serve as early indicators of recovery or degradation of soils, thus aggregate stability estimation is significant to comment on soil health.For this study, the soil aggregate fractions method through a set of sievesinto particular fine and coarse soil particles was used to estimate erodibility and soil compaction of two different soils of Nukerke and Heestret, Gent, Belgium.

Materials and Methods

The aggregate stability was determined from spatially collected arable land top soil (0-30 cm)samples of two different soils, namely Nukerke and Heestret soil, Gent, Belgium, during the year 2010 by using adapted aggregate fractions method through set of sieves. 250 grams of aggregates less than 8mm were put on a set of sieves of the following sizes: 4.76, 2.83, 2, 1, 0.5 and 0.3 mm respectively. A closed bottom was put underneath the sieves. The set of sieves was then gently shaken five times by hand to obtain aggregates of different diameters. For the fixed aggregate fraction method, the distribution is 40, 32 and 28 grams for aggregate size between 8 – 4.76, 4.76 – 2.83 and 2.83 -2 mm respectively for Belgian soils. The aggregates were moistened to field capacity by large drops falling from a height of about 50 cm. The amount of drops to be added to each sample was determined by catching 30 drops in a nickel cup and weighing them. The average weight of the drop was calculated and the amount of drops was determined to moisten the soil to field capacity. The nickel cups with different aggregate size fraction were placed on the incubator for 24 hour (20°C and 98 -100% relative humidity). After incubation each aggregate size fraction was placed on its corresponding sieve for the wet sieving. The bottom was not closed in this procedure. The sieves were then gently shaken up and down under water at a constant speed for 5 minutes.After sieving the wet aggregates remaining on each sieve were removed by washing them into nickel cups. The cups were then placed on heating plate to evaporate the remaining water. After drying each aggregate size fraction is weighed again to determine the dry mass.

Figure 01. Set of sieves for soil aggregates determination

Measurements and calculations: The co-effiecient of vulnerability was calculated by the following formula (Rohoskova and Valla (2004):

$$K_v = \frac{x}{mwd}$$

Where,

K_v = Co-efficient of vulnerability

x = Mean weight diameter of aggregate taken to analysis

$mwd =$ Mean weighted diameter

Co-effiecient of vulnerability (Kv) for Nukerke and Hesteert soil was found 2.18 and 2.81 respectively.

a) Mean weighted diameter

$$MWD = \frac{\sum_{i=1}^{1=n} m_i d_i}{\sum_{i=1}^{i=n} m_i}$$

Table 01. Mean weighted diameter of soil samples

Soil Type	Wet	Dry
Heestert	1.562	4.48
Nukerke	2.035	4.48

Where, MWD is the mean weight diameter (mm) of the aggregates after their disintegration, 'i' is the sieve size class, mi is the soil aggregate amount above the 'ith' sieve size (g) and d is the sieve diameter for the ith sieve (mm).

b). Instability Index (IS)

$$\mathrm{IS} = \mathrm{MWD_{dz}} - \mathrm{MWD_{nz}}$$

$\mathrm{IS(Heestert)} = 2.841$

$\mathrm{IS(Nukerke)} = 2.295$

c) Stability index (SI)

$$SI = \frac{1}{SI}$$

SI(Heestert) = 0.347
SI(Nukerke) = 0.415

Results and Discussion

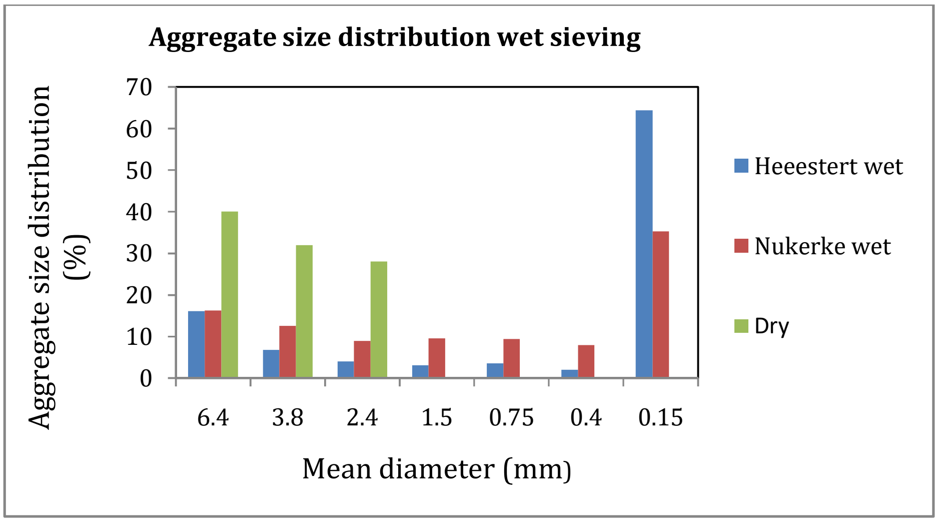

Figure 02.Aggregate distribution (wet sieving) of soil samples.

Aggregate distribution of soil samples were shown in Figure 02. Laboratory data of tested samples and aggregate indexes were shown in Table 02 and 03 respectively. Mean weighted diameter (MWD) of the Nurkerke and Hesteertsoil after wet sieving is 2.03 mm and 1.56 mm respectively but the MWD of the dry sieving is 4.48 mm (Table 01). During hydration, disruption of aggregates occurs through swelling and explosion of entrapped air. Hence, the moist soil is more stable than the dry one. The instability index of the Nurkerke soil is 2.41 and Hesteert soil is 2.89. The aggregate stability index of the Nukerke is 0.41 and Hesteert is 0.35. According to the Leenheer and De Boodt (1959) this value falls under bad aggregate stability category since the value is smaller than 0.5. Thecoefficient of vulnerability (Kv) of Nukerke soil is 2.18 while the Hesteert has 2.81. The Nukerke soil seems more stable than the Hesteert. The Nukerke soil has high amount of $CaCO_3$ and clay content. These both are responsible for the formation of the stable aggregate. In addition, calcium ions associated with clay generally promote aggregation, whereas sodium ions promote dispersion. While the sand content decreases aggregate stability because the sand doesn't have charge,this is crucial for aggregate stability.Soils that have a high content of organic matter usually have greater aggregate stability. Organic matter content also play vital role in aggregate stability because the organic matter works not only binding agents but also brings negatively charged clay matrix together for flocculation. Moreover, the organic matter also increases the biological activity in the soil resulting to the stable aggregates. Soil microorganisms produce many different kinds of organic compounds, some of which help to hold the aggregates together. On the other hand, the ionic concentration of the ions and their respective valence determine the compression of the double layer. The monovalent like sodium increases the zeta potential form the critical value results in deflocculating the soil aggregates.

However, Fe and Al in solution act as flocculants, sesquioxides bind clay particles to the organic molecules, and they precipitate as gels on clay surfaces.The soil aggregate stability measurement is a compound value for textural, chemical and physical properties of the soil. The aggregate stability is the ability of the bonds of the aggregates to resist when exposed to stresses causing their disintegration (tillage, swelling and shrinking processes, kinetic energy of raindrops etc.). Thus highly stable aggregate soil can withstand the raindrop impact as well as the disturbance due to tillage operation.

Table 02. Laboratory data of tested soil samples

Nr. Can	Empty weight	Dry can + mass soil	Mass soil (g)	Mean diameter (di)
1	77.98	93.62	15.64	6.4
2	75.39	80.73	5.34	3.8
3	76.84	81.35	4.51	2.4
4	77.22	81.17	3.95	1.5
5	77.47	82.42	4.95	0.75
6	74.89	78.5	3.61	0.4
		(>0.3mm)	62	0.15
7	76.8	93.29	16.49	6.4
8	76.94	85.17	8.23	3.8
9	77.34	80.97	3.63	2.4
10	77	79.24	2.24	1.5
11	75.13	77.27	2.14	0.75
12	71.06	71.48	0.42	0.4
		(>0.3mm)	66.85	0.15
13	73.16	88.66	15.5	6.4
14	74.11	86.24	12.13	3.8
15	76.24	85.21	8.97	2.4
16	77.11	84.22	7.11	1.5
17	78.14	85.65	7.51	0.75
18	74.93	80.02	5.09	0.4
		(>0.3mm)	43.69	0.15
19	73.08	90.17	17.09	6.4
20	76.6	89.63	13.03	3.8
21	76.15	85.14	8.99	2.4
22	73.28	85.21	11.93	1.5
23	77.11	88.44	11.33	0.75
24	74.9	85.74	10.84	0.4
		(>0.3mm)	26.79	0.15

Table 03. Soil aggregate stability and instability index

mi.di (wet)	MWD (wet)	Dry soil (g)	mi.di (dry)	MWD (dry)	Instability index (IS)	Stability index (SI)
100.1		40	256			
20.3		32	121.6			
10.8		28	67.2			
5.9		0	0			
3.7		0	0			
1.4		0	0			

9.3		0	0			
151.6	1.515935		444.8	4.448	2.932065	0.341057
105.5		40	256			
31.3		32	121.6			
8.7		28	67.2			
3.4		0	0			
1.6		0	0			
0.2		0	0			
10.0		0	0			
160.7	1.606825		444.8	4.448	2.841175	0.351967
99.2		40	256			
46.1		32	121.6			
21.5		28	67.2			
10.7		0	0			
5.6		0	0			
2.0		0	0			
6.6		0	0			
191.7	1.91709		444.8	4.448	2.53091	0.395115
109.4		40	256			
49.5		32	121.6			
21.6		28	67.2			
17.9		0	0			
8.5		0	0			
4.3		0	0			
4.0		0	0			
215.2	2.15213		444.8	4.448	2.29587	0.435565

Conclusion

The aggregate stability is very important for soil compaction and soil erodibility. However, tillage, texture, organic matter content, mechanical stress, sesquioxides may play important role in the aggregate stability of arable soils. The Nukerke soil is less vulnerable for erodibility and compaction than the Hesteert as evidenced from findings of the study based on stability index. In essence, increasing of organic matter and conservative management of land is very important measure to increase the aggregate stability of arable soil.

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