AGGREGATE BREAKDOWN MECHANISMS BY WATER IN TILLAGE HORIZONS IN NW SPAIN

M.M. Taboada-Castro[A], *Y. Le Bissonnais*[B], *and O. Duval*[B]
[A] University of A Coruña. Faculty of Sciences. A Zapateira, s/n. 15071. A Coruña. Spain.
[B] Institut National de la Recherche Agronomique (INRA). Science du Sol. Centre de Recherche d´Orleans. 45160, Ardon, France.

Abstract
In this work the disintegration mechanisms during wetting are analyzed in surface horizons of tillage formed on schist in NW Spain. The samples contained different organic matter contents and medium soil texture. Aggregate stability was determined under three treatments: fast wetting, mechanical breakdown and slow wetting, each treatment repeated three times. These three treatments enabled differentiation of the main disintegration mechanisms of aggregates using mean weight diameter (MWD) values. A laser granulometer was used to determine the distribution of fragments formed by aggregate breakdown after the each treatment. Seven diameter classes were obtained, which were used to calculate MWD. The MWD for the fragment distribution obtained after fast wetting was lower than that measured after mechanical breakdown and slow wetting. This suggests that in these soils the slaking produced from the effect of entrapped air is more important than that by mechanical breakdown. On the other hand, a significant correlation was observed between MWD values after fast wetting and slow wetting. In contrast, no correlation was obtained between MWD values after fast or slow wetting and mechanical breakdown. These results show that fragmentation mechanisms, such as the action of slaking due to entrapped air during fast wetting and mechanical breakdown, are independent.

Additional Keywords: aggregate stability, cultivated soils, fast and slow wetting, mechanical breakdown.

Introduction

Soil structure is an essential soil property that largely determines ecological soil functions. It controls the behavior at the soil-air interface with regard to infiltration, runoff, aeration, erosion, and the local environment of plant roots and edaphon, especially in the topsoil. Cultivated soils tend to lose their original structure as a result of the breaking up of bigger aggregates into smaller units, with the consequent reduction in macropores and increase in micropores and density (Carpenedo and Mielniczuck, 1990; Tisdall and Oades, 1980a). The magnitude with which such alterations occur depends on the soil type and on the soil management systems used. Conventional tillage systems and the small contribution of organic residues and periods of fallow, as is the case of corn cultivation in Galicia (NW, Spain), generally have negative effects on the aggregation of the soil, unlike plurianual grassland that are more efficient in soil aggregation (Bradfiel, 1973; Tisdall and Oades, 1979; 1980b).

The formation of stable aggregates requires that the primary particles be held strongly together, and not break up in water. Several authors (Emerson, 1967; Boiffin, 1984; Le Bissonnais, 1988) have identified four main mechanisms of disintegration: (i) by the compression of entrapped air during wetting; (ii) breakdown by differential swelling; (iii) breakdown by raindrop impact; (iv) physicochemical dispersion caused by osmotic stress**.** These mechanisms differ mainly in the nature of interparticles bonds are broken and the energy involved in their disruption, in the physicochemical conditions required for disaggregation, in the kinetics of the breakdown process and in the type of soil properties influencing the mechanism.

Materials and Methods

The study was carried out in two agricultural areas (Mabegondo and Liñares) in the province of A Coruña (NW Spain). The soils studied were formed over schists and are relatively deep and of loam and silt-loam texture, according to the USDA criteria. Five fallow plots (M1, M4, M13, M14, Li) were chosen. Samples of the surface horizon were taken from areas of different color (suffix c and c´) or from adjacent areas, of plurianual grassland (suffix p). The determination of the size and stability of the aggregates in water was achieved following the method described by Le Bissonnais (1996). This experiment simulates the behavior of the aggregates under three possible hydric conditions where disintegration under field conditions can occur: fast wetting by immersion, mechanical breakdown by agitation after rewetting and slow wetting by capillary action.

A laser granulometer was used to determine the fragment distribution, with three replicates for each treatment. This instrument differentiates 44 diameter classes that were grouped into seven intervals: 50 µm, 50-100 µm, 100-

200 µm, 200-500 µm, 500-1000 µm, 1000-2000 µm and > 2000 µm, from which the mean weight diameter (MWD) was calculated for each treatment and for the mean of three treatments.

Results and Discussion

The analysis performed of organic matter content in aliquots of each sample showed a wide range of values, varying between sample pairs and for different uses (Table 1). Moreover, the soils studied were characterized as being of medium texture. The results of the MWD averaged for three treatments and for each individual treatment (fast wetting, mechanical disintegration and slow wetting) of the 11 soil samples analyzed are presented in Table 2. The MWD values obtained for each treatment showed big differences in stability, these being less apparent after the treatments of fast wetting and slow wetting, unlike those of mechanical breakdown after immersion in ethanol that showed greater fluctuations.

Table 1. Soil uses, organic matter content and texture

	M1c	M1p	M4c	M4c'	M13c	M13c'	M13p	M14c	M14c'	Lic	Lip
OM (%)	3.58	5.18	0.94	2.98	1.46	3.36	6.34	2.49	3.42	2.60	4.33
Texture	S-L	S-L	S-L	S-L	S-L	S-L	S-L	S-L	S-L	L	L
Soil use	F	G	F	F	F	F	G	F	F	F	G

SL: Silt- loam; L: Loam; F: Fallow; Gr: Grassland

Greater stability differences between treatments suggest different fragmentation processes; yet, differences between the processes are not as evident when similar stability values are obtained (Le Bissonnais and Le Souder, 1995). Sample M4c, presenting the lowest organic matter content (0.97%), is always the most unstable, showing MWD values of 0.210 mm, 0.316 mm and 0.232 mm after the treatments of fast wetting, mechanical breakdown and slow wetting, respectively. In contrast, the sample taken from the area adjacent to this plot (M4c'), richer in organic matter, presents relatively low MWD values after fast wetting (0.279 mm) and slow wetting (0.536 mm), which is quite different from a MWD of 2.255 mm after mechanical disintegration. In the same way, the soil sample taken from a grassland (Lip) presents a higher MWD average (2.514 mm) obtained from the individual MWD values in each treatment, that were relatively similar, 2.363 mm after fast wetting, 2.646 mm after mechanical breakdown, and 2.534 mm after slow wetting. However, the cultivated sample adjacent to the previous one (Lic) showed MWD values that were much lower after fast wetting (0.343 mm) and slow wetting (0.411 mm) than those obtained after mechanical disintegration (2.646 mm), making the average MWD 0.937 mm.

Samples Mc4 and Lip, whose mean MWD values were in the soil groups of highest instability and highest stability, respectively, despite their differences, have in common the fact that the three treatments of stability analysis gave similar MWD results. This result indicates that the structural behavior of these samples is practically independent of the external conditions and confirms the observations of Amézketa *et al*. (1996), in the sense that the soils located at both ends of the stability scale, whether very stable or very unstable, present fragmentation characteristics that are similar for different treatments.

In the 11 samples, the MWD obtained by fast wetting is lower than that measured after mechanical breakdown and slow wetting. Moreover, the MWD after mechanical disintegration is always higher than that after slow wetting. Therefore, in these soils, the MWD is in the following order: mechanical breakdown > slow wetting > fast wetting.

The correlation coefficient of the MWD after fast wetting and slow wetting was very high ($r^2 = 0.961$) and significant ($p < 0.01$); in contrast, between the MWD after fast or slow wetting and mechanical disintegration, no significant correlation was found. This shows that the slaking produced from the effect of entrapped air and mechanical breakdown are destabilization mechanisms that fragment the aggregates according to different patterns or mechanisms of action. However, fast wetting and slow wetting in these samples would break the union points between the particles of the aggregates of similar nature, yet the intensity by which the disintegration takes place would vary.

Different works in the literature report that frequently treatment by fast wetting is the most destructive, although mechanical breakdown can predominate in some soils. Le Bissonnais and Arrouays (1997) in a study of 12 soils of loam texture showed that the breakdown by slaking predominates over mechanical breakdown, the MWD obtained after fast wetting always being higher than that after mechanical disintegration.

Table 2. Mean weight diameter (MWD) for each treatment and average MWD of three treatments

	MWD (mm)			
Plot	**Fast wetting**	**Mechanical breakdown**	**Slow wetting**	**Mean of the three treatments**
M1c	0.346	0.953	0.404	0.568
M1p	0.416	2.206	0.604	1.075
M4c	0.210	0.316	0.232	0.253
M4c’	0.279	2.255	0.536	1.023
M13c	0.411	2.391	0.521	1.108
M13c’	0.462	1.930	0.580	0.991
M13p	1.289	3.061	1.885	2.078
M14c	0.410	1.947	0.540	0.966
M14c’	0.476	1.816	0.575	0.956
Lic	0.343	2.056	0.411	0.937
Lip	2.363	2.646	2.534	2.514

From the MWD values averaged for three treatments, different degrees or classes of stability are considered in agreement with the criteria established by Le Bissonnais (1996). According to these criteria, of the 11 samples, one (M4c) was very unstable (MWD < 0.4 mm), another (M1c) was unstable (MWD between 0.4 and 0.8 mm), seven (M1p, M4c´, M13c, M13c´, M14c, M14c´, and Lic) were fairly stable (MWD between 0.8 and 1.3 mm) and two (M13 and Lip) were very stable (MWD > 2.0 mm), but none was classified as being stable (MWD between 1.3 and 2.0 mm). Therefore, the conclusion is that although the range of variation of organic material content is broad, most of these soils are classified as being moderately stable, so the number of samples, found at both ends of the scale, the very unstable or the very stable, is very limited.

Conclusions

The different contents of organic matter can be translated as differences in stability between pairs of samples. The mean weight diameter (MWD) after fast wetting was lower than that measured after slow wetting and mechanical breakdown, the latter being higher. These differences between treatments indicate that the slaking produced from the effect of entrapped air would be the principal breakdown mechanism in these soils and the mechanical action produced from the impact of raindrops would contribute in a lesser degree to the reduction of the mean diameter.

A significant correlation was observed between the mean weight diameter (MWD) after fast wetting and slow wetting; in contrast, correlation was absent between the MWD after fast or slow wetting and mechanical disintegration. These results indicate that the fragmentation mechanisms and the slaking produced from the effect of entrapped air during fast wetting of the soil and the mechanical breakdown by the impact of raindrops are independent.

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