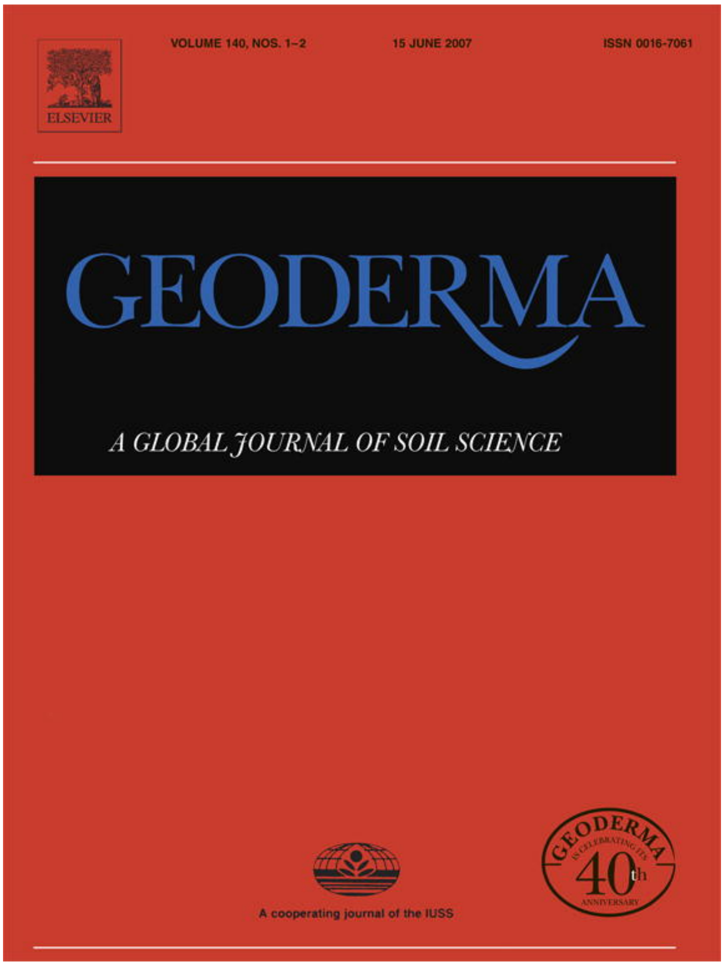
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Tillage affects soil aggregation parameters linked with wind erosion

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Abstract

Geometric mean diameter (GMD), erodible fraction (EF), and dry aggregate stability (DASt) are soil parameters deduced by dry sieving that are used to identify soil susceptibility to wind erosion. Values of GMD, EF, and DASt have been calculated for different soil types but limited information is available on the effects of tillage on these parameters. In order to asses this influence we analyzed their variation in an Entic Haplustoll of Argentina during a 2 year sampling period. This soil was submitted to three tillage systems during the 7 years prior to sampling: no-till (NT), vertical tillage (VT) and conventional tillage (CT). We also analyzed the dry stability of each aggregate size fraction coarser than 0.84 mm (DASi). Results showed that tillage produced significant differences in all analyzed parameters. Average parameter values were, by treatment: GMD (2.37 mm) and DASt (88%) the highest and EF (20%) the lowest in NT, and GMD (0.88 mm) and DASt (49%) the lowest and EF the highest (49%) in CT. VT showed intermediate values of these parameters. As a consequence of soil disturbance by tillage, variations with time in CT were higher for GMD (SD=0.42), EF (SD=8.26) and DASt (SD=16.31) than in VT (SD=0.31, 5.71 and 8.00, respectively) and NT (SD=0.31, 2.75, and 1.99, respectively). GMD calculated with a regression equation based on soil textural fractions, OM and $CaCO_3$ contents (Hagen, pers. comm.), was similar to the measured GMD in soils with low tillage disturbance (NT and VT) but it was much higher than the measured GMD in highly disturbed soils (CT). WEQ overestimated the wind erosion of the studied soil by 25 t ha^{-1} year^{-1} in NT and 9 t ha^{-1} year^{-1} in VT when the potential wind erosion (I factor) was calculated with an EF value obtained from the regression equation given by Fryrear et al. [Fryrear, D.W., Krammes C.A., Williamson D.L., Zobeck T. M. 1994. Computing the wind erosion fraction of soils. Soil Water Conserv. 49:183-188.]. NT exhibited greater quantities of aggregates coarser 19.2 and 6.4 mm than VT and CT, and lesser quantities of fine aggregates (0.84 and 2 mm) than CT on most sampling dates. The variability of the 19.2 mm sized aggregates between sampling dates was greater in NT (SD=18) than in VT (SD=6) and CT (SD=4), while the variability of the 6.4 mm sized aggregates (SD=5.5) was similar in all tillage systems. A time-dependent trend toward an increase of the 0.84 mm sized aggregates and a decrease of the 19.2 mm sized was observed in CT, indicating that tillage was degrading 19.2 mm aggregates into 0.84 mm aggregates. DASi of all sized aggregates was lower in NT (8.1%) than in VT (14.1%) and CT (23.1%), and was also less variable between sampling dates in NT (SD=1.1), than in VT (SD=4) and CT (SD=7.6). A negative relationship between aggregate size and DASi was found ($y=-1.755\times+86.46$, $R^2=0.56$, $P<0.001$). Aggregates formed in NT were 5 to 7% more stable than VT aggregates and 13 to 16% more stable than CT aggregates. We concluded that tillage practices affect the parameters deduced from dry aggregate size distribution at different rates in the studied soil. Therefore, further studies should be developed to obtain reliable correction factors for these parameters on the basis of previous management conditions.

Keywords: Aggregate size distribution; Wind erosion; Dry sieving

1. Introduction

Wind erosion is a soil degradation process frequently occurring in semiarid environments (Dregne and Willis, 1983; Lal and Stewart, 1990), including the semiarid Pampas of Argentina (Buschiazzo et al., 1999). The susceptibility of soils to wind erosion largely depends on their degree of aggregation

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(Zobeck and Popham, 1990). Dry sieving by means of a rotary sieve is the standard method for determining several parameters associated with soil aggregation and the susceptibility of the soil to erode by wind (Chepil, 1962). These parameters are derived from cumulative aggregate distribution curves and some of them are included in the soil subroutines of several wind erosion prediction models like the Wind Erosion Equation (WEQ, Woodruff and Siddoway, 1965), the Revised Wind Erosion Equation (RWEQ, Fryrear et al., 1998) or the Wind Erosion Prediction System (WEPS, Hagen, 1991). Soil aggregation parameters commonly used by some of these models that may be deduced from the cumulative aggregate size distribution curves are the geometric mean diameter (GMD), the erodible fraction (EF), and the dry aggregate stability (DASt).

EF is the percentage of aggregates with sizes smaller than 0.84 mm, and is considered the soil fraction susceptible to be transported by wind (Chepil, 1942). EF is used as an index of the potential erodability by WEQ and RWEQ. It varies as a function of soil texture (Lyles and Woodruff, 1960), organic matter contents (Chepil 1955), and free $CaCO_3$ (Chepil 1954). Long term field measurements of the first 25 mm soil layer are needed for the determination of this variable (Fryrear et al., 1998) but it can be also predicted with a multiple regression equation, where EF is a function of soil texture, organic matter contents and free $CaCO_3$ contents (Fryrear et al., 1994).

Previous tillage practices are not considered for these calculations. It is known that not only static soil properties but also management conditions can affect EF (Zobeck and Popham, 1990). Tillage operations can affect EF directly through the break down of coarse aggregates and their transformation into smaller ones (Siddoway 1963; Six et al., 1998; Gale et al., 2000; Six et al., 2000; Hevia et al. 2003), but it can also affect EF indirectly by decreasing soil organic matter contents (Six et al., 1998; Wright and Hons, 2004).

López et al. (2001) found that soil management, particularly tillage operations, affected EF more than the intrinsic soil characteristics in calcareous soils of Spain. It has been widely demonstrated that tillage operations like conventional tillage and no-till produce opposite effects on soil organic matter (SOM) contents and on soil aggregation (Six et al., 1998; Buschiazzo et al., 1999, Wright and Hons, 2004). Due to tillage systems effect on SOM, differences in EF are expected to exist in contrasting tillage systems given similar texture and $CaCO_3$.

GMD is used as an index of soil aggregation and soil erodability (Zobeck and Popham, 1990). Farres (1978) found that GMD was associated with the susceptibility of the soil to form surface crusts, but Zobeck and Popham (1992) did not found such relationship in soils of the North American High Plains.

GMD can be deduced from dry aggregate sievings but also with a multiple regression equation where soil texture, organic matter and free $CaCO_3$ contents are independent variables. Previous tillage practices are not considered in any of the calculations, but they can affect the GMD by breaking down coarse aggregates in smaller ones (Siddoway 1963). Zobeck and Popham (1990) concluded that tillage practices must be taken into account for GMD determinations, suggesting a separation of moldboard plow from both chisels and diskers.

The dry aggregate stability of the soil (DASt) can be used as an index of the breakdown susceptibility of the >0.84 mm sized aggregates, and therefore of the soil to erode by wind. DASt can be calculated as a function of clay contents (Hagen, 1991). As clay contents are not affected by tillage practices, lower effect of tillage practices on DASt than on EF and GMD are expected.

The comparison of the dry aggregate stability of each aggregate size class (DASi) has not been widely analyzed. The knowledge of DASi variations can be useful to measure the susceptibility of >0.84 mm non-erodible aggregates to transform into <0.84 mm aggregates.

The objective of this study was to analyze the effect of tillage practices on EF, GMD, DASt and DASi, important soil properties closely linked with wind erosion susceptibility.

2. Materials and methods

This study was conducted at a long-term experimental site located in the Faculty of Agronomy of the Universidad Nacional de La Pampa, Argentina (36° 46″ S latitude and 64° 16″ W longitude). This long-term experimental site has been in operation since 1996 in three 10 ha fields. Each field contained one of the following tillage systems: 1) no-till (NT), consisting of the chemical control of weeds with glyphosate and 2-4 D, and the seeding of crops with no-till seeders, 2) conventional tillage (CT) where the primary and secondary tillage practices are carried out with an offset disc, and crops are seeded with conventional systems, and 3) vertical tillage (VT) where the primary tillage practices were made with chisels, the secondary with an offset disc, and crops are seeded with conventional systems. Crops used in all tillage systems were wheat (*Triticum aestivum L.*) and oats (*Avena sativa*) as winter crops, and sunflower (*Helianthus annus*) and corn (*Zea mays*) as summer crops.

The soil at the study site is classified as a fine sandy loam (Entic Haplustoll), with an A-AC-C-C_k horizon sequence. The initial characteristics of the A horizon of the soil for each tillage practice are shown in Table 1.

Composite soil samples were taken in each tillage system from three randomly selected 10 m^2 areas. In each selected area a 1 kg weight soil sample was taken with minimum disturbance with a shovel from the first 10 cm soil layer in the following dates: October 11 2002, November 11 2002, December 16 2002, February 19 2003, April 29 2003, June 10 2003, October 6 2003, November 24 2003, December 29 2003, February 13 2004, March 19 2004, April 15 2004, May 17 2004, June 16 2004, August 2 2004, September 6 2004, and October 21 2004.

Soil samples taken on each date were air dried and sieved with a rotary sieve (Chepil, 1962). The following aggregate

Table 1
Organic matter (OM), clay, silt and sand contents of the studied soil at the experiment end in each tillage system

Tillage system	OM	Clay	Silt	Sand	CaCO3
			%		
NT	3.08	16.9	23.8	59.3	0
VT	2.72	13.7	22.1	64.2	0
CT	2.85	13.5	22.7	63.8	0

sizes were separated: <0.42 mm, 0.42 to 0.84 mm, 0.84 to 2 mm, 2 to 6.4 mm, 6.4 to 19.2 mm, and >19.2 mm. Each aggregate size coarser than 0.84 mm was independently sieved a second time. Following Zobeck et al. (2003) aggregates were classified on the basis of the sieve retained fraction. For example, the 0.84 to 2 mm sized aggregates were named the 0.84 mm aggregate size fraction.

The percentage of <0.84 mm aggregates, the erodible fraction of the soil (EF), was calculated with the following equation:

$$\mathrm{EF}(\%) = \frac{W_{<0.84}}{T} \times 100 \tag{1}$$

where EF is the erodible fraction, $W_{<0.84}$ the weight (g) of the <0.84 mm aggregates after the first sieving, and T the initial weight (g) of the total sample.

EF was also calculated with the equation given by Fryrear et al. (1994):

$$\begin{aligned}\mathrm{EF} = {} & 29.09 + 0.31\mathrm{sand} + 0.17\mathrm{silt} \\ & + 0.33(\mathrm{sand}/\mathrm{clay}) - 2.59\mathrm{OM} - 0.95\mathrm{CaCO_3}\end{aligned} \tag{2}$$

where OM is soil organic matter. Contents of all variables are expressed in percentage.

The geometric mean diameter (GMD) was estimated by means of the log–normal method described by Zobeck et al. (2003).

GMD was also calculated with the following equation (Hagen, pers. comm.):

$$\begin{aligned}\mathrm{GMD} = {} & \exp(1.343 - 2.235{*}\mathrm{sand} - 1.226{*}\mathrm{silt} - 0.0238{*}(\mathrm{silt}/\mathrm{clay}) \\ & + 33.6{*}\mathrm{OM} + 6.85{*}\mathrm{CaCO3}){*}(1.0 + 0.006{*}\mathrm{layer\ depth})\end{aligned} \tag{3}$$

in which the textural fractions and OM contents are expressed in % and the layer depth in cm (for the calculations in this case, a layer depth of 2.5 cm was considered).

The dry aggregate stability for the whole soil (DASt) was estimated using the following equation:

$$\mathrm{DASt} = \frac{(W_{>0.84})_1 - (W_{<0.84})_2}{(W_{>0.84})_1} \times 100 \tag{4}$$

where $(W_{<0.84})_2$ is the weight of the >0.84 mm aggregates that passed the 0.84 mm sieve after the second sieving, and $(W_{>0.84})_1$ is the total weight of the aggregates retained by the 0.84 mm sieve after the first sieving.

The dry aggregate stability for each aggregate size fraction coarser than 0.84 mm (DASi) was calculated with the following equation:

$$\mathrm{DASi} = \frac{A1 - A2}{A1} \times 100 \tag{5}$$

where A1 is the weight (g) of the "i" sized aggregates after the first sieving, and A2 is the weight (g) of the "i" sized aggregates passing the 0.84 mm sieve after the second sieving.

All studied parameters were compared between tillage systems and sampling dates by means of ANOVA and LSD multiple comparison tests using the 0.05 probability level. A correspondence analysis was used to relate tillage system and aggregate size. The relationships between DASi and their size as well as the relationship between EF and GMD were analyzed with simple regression analysis.

3. Results and discussion

The GMD values (Fig. 1a) varied between 0.32 mm and 3.14 mm. Mean GMD values for all sampling dates were significantly greater ($P<0.05$) in NT (2.37 mm) than in VT

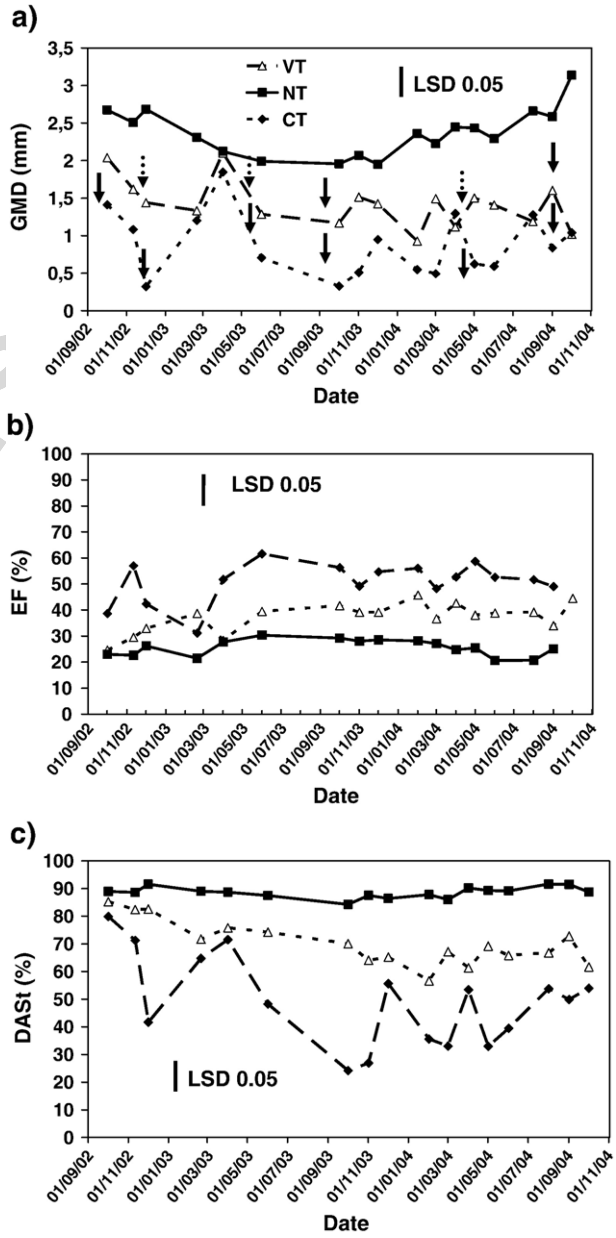

Fig. 1. a) Geometric mean diameter (GMD), b) erodible fraction (EF) and c) dry aggregate stability (DASt) of the soil in each tillage system and sampling dates. Filled arrows indicate tillage with tandem disc plow and dotted arrows indicate tillage with chisel plow.

(1.42 mm) and CT (0.88 mm). These results are affected by the destruction of coarse aggregates by frequent disc tillage in CT. The tillage related destruction of coarse aggregates and their transformation into finer and easily wind erodible aggregates has been frequently reported for different soils (Six et al., 1998; Gale et al., 2000; Six et al., 2000; Hevia et al. 2003). It has been demonstrated that the lack of tillage and the deposition of plant residues in no-till systems improve the production of particle bonding substances such as soil organic matter (Paustian et al., 2000; Six et al., 2000, Hevia et al., 2003), thus increasing aggregation (Buschiazzo et al., 1999; Wright and Hons, 2004).

The GMD values observed for VT were smaller than NT but greater than CT, probably because tillage in this system was less frequent and aggressive than in CT. Previous research has shown that GMD values decrease with increasing intensity of surface tillage operations. Zobeck and Popham (1990) reported GMD values of 4.3 mm in soils tilled with chisel and 2.3 mm in soils tilled with disc plows. Yang and Wander (1998) found GMD values of 12 mm in soils under no-till and 7.1 mm in soils under conventional tillage using moldboard and disc plows. The GMD values reported by these authors are greater than those found here for similar tillage systems. This is probably due to the intrinsically better structure of the Paleustalfs and Paleustolls studied by Zobeck and Popham (1990) and the Argiaquic Argialboll studied by Yang and Wander (1998) than the Entic Haplustoll studied here.

GMD variability among sampling dates was smaller in NT and VT (SD=0.31 in both cases) than in CT (SD=0.42). These results can be attributed to the greater and more frequent soil disturbance produced by tillage practices in CT than in VT and NT. A significant interaction between tillage and sampling date existed for GMD, ($P<0.001$). This allowed the comparison of GMD values for each sampling date by LSD. GMD was significantly greater ($P<0.05$) on most sampling dates in NT than in VT and CT.

GMD decreases were detected in CT and VT in December 2002 and October 2003, and in CT in May 2003 and September 2003. These decreases were directly related with tillage operations carried out few days before soil sampling, which crushed aggregates and decreased GMD (Six et al., 1998).

GMD was only weakly affected by the total rainfall before each sampling date in NT ($y=0.0071x+2.0403$, $R^2=0.3515$, $n=16$, $P<0.05$). This result is unexpected as it is known that rain drop impact destroys aggregates (Six et al., 2000) and thus decreases GMD (Zobeck and Popham, 1990). We believe the greater plant residue cover existing in NT protected the soil against the direct impact of rain drops. The crop residues in NT may also have increased the soil water content of the soil improving the microbial activity and the production of organic binding agents (Golchin et al., 1994, Jastrow, 1996).

Estimates of GMD based on Eq. (3) and the data presented in Table 1, gave the following GMD values: 2.02 mm in NT, 1.58 in VT and 1.46 in CT. These calculated values underestimated GMD by 14% in NT, and overestimated GMD by 11% in VT and by 66% in CT when compared with our measured field data. These results confirm that the Eq. (3) can be used for GMD calculations in soils with low disturbance by tillage practices, but considerable errors can be done when used in soils under high tillage disturbance.

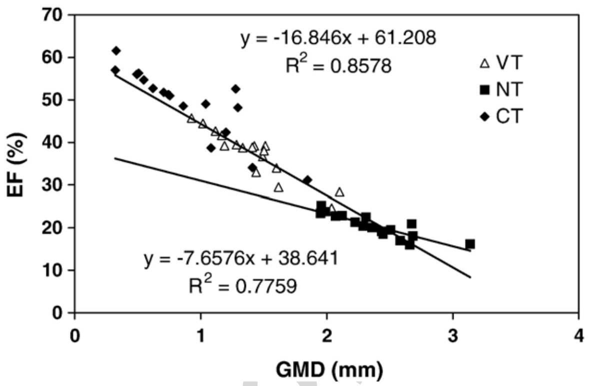

Fig. 2. Relationship between the erodible fraction (EF) and the geometric mean diameter (GMD).

Fig. 1b shows that EF varied between 20% and 61.5%. Mean EF values of all sampling dates were significantly smaller ($P<0.05$) in NT (20.4%) than in VT (37.2%) and CT (49.2%). These results can be attributed to the better aggregation produced by higher OM contents in NT and the breakdown of larger aggregates by tillage in VT and CT (Six et al., 1998; Wright and Hons, 2004). López et al. (2001) reported that EF varied between 5% and 80% in soils of Spain. This variability was greater than found here, probably because those authors included a larger variety of soil types, with contrasting textures and management conditions. Measured EF values were similar to those presented by Siddoway (1963) who studied the effect of different tillage systems on EF in a silty loam soil of NE USA, similar in texture to the soil in our study.

Bravo and Silenzi (2000) also found EF values greater in CT than in NT soils of the southeastern Pampas of Argentina. However, EF values reported by these authors (35% in CT) were smaller than our value (51%). Such differences can be attributed to the better aggregation of the Petrocalcic Paleustoll studied by these authors than the soil studied here.

Variability of EF among sampling dates was smaller in NT (SD=2.75) than in VT (SD=5.71) and CT (SD=8.26), presumably from soil disturbance produced by tillage operations in CT. A significant interaction between tillage and sampling dates exists for EF ($P<0.001$). The LSD test showed that EF values were smaller in NT than in VT and CT on most sampling dates. This agrees with the increasing soil disturbance produced by tillage operations in the same sequence, and with the lower aggregation of CT in relation to NT and VT as a consequence of lower organic matter contents (Buschiazzo et al., 1999). EF increased 44% in CT and 81% in VT from the first to the last sampling date, but it remained almost unchanged in NT. This indicates that a deterioration of soil structure occurred in both tillage systems that included soil plowing and that the deterioration was not due to time-related factors.

Increases of EF observed in CT in December 2002 were probably linked to tillage practices conducted shortly before sampling, while increases produced between April 03 and October 03 seem to be more closely associated with rains that

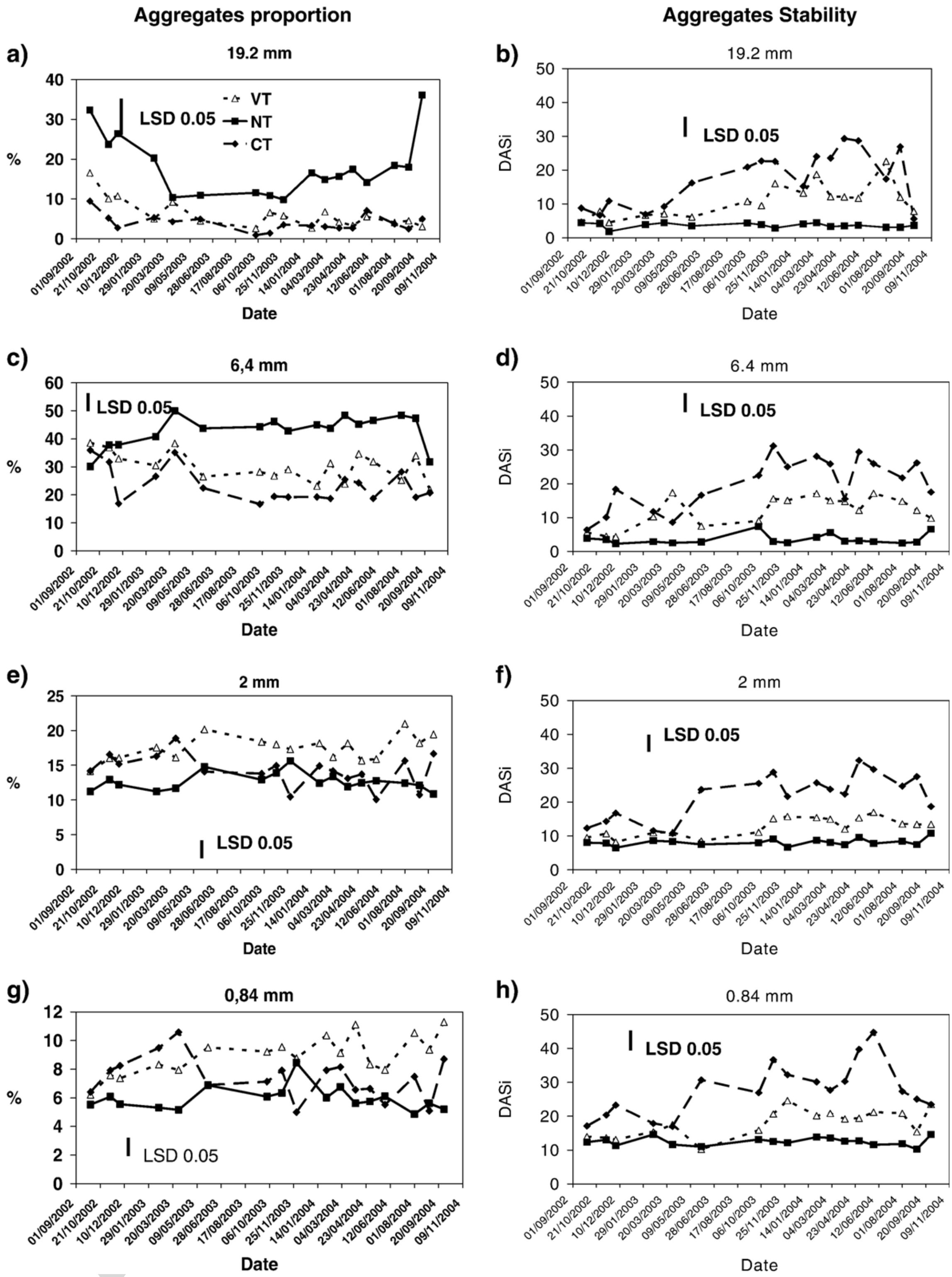

Fig. 3. Proportion and dry aggregate stability for each aggregate size fraction coarser than 0.84 mm (DASi) of a) and b) the 19.2 mm sized aggregates, c) and d) the 6.4 mm sized aggregates, e) and f) the 2 mm sized aggregates, and g) and h) the 0.84 mm sized aggregates for each tillage system and sampling date.

occurred in this period (54 mm). It is known that rains can decrease soil aggregation due to the destruction of aggregates. Zobeck and Popham (1990) reported that rains decreased aggregation in a recently tilled fine-loamy Aridic Paleustalf. This decrease of aggregation occurred until rains reached 130 mm. Beyond this rainfall depth, aggregation tended to increase.

Previous results indicate that EF values can be highly variable in soils submitted to contrasting tillage practices. This is particularly important if EF is not measured in the field but calculated on the basis of Eq. (2). This is because the factor I, calculated on the basis of the amount of the non erodible fraction of the soil (100-EF), is used by WEQ to deduce the potential soil erodability. If Eq. (2) is applied with data of Table 1, neither EF values (45 to 47%) nor the factor I (27 to 31 t ha^{-1} year^{-1}) differ much between tillage systems, but if measured data are used, the I factor results 2 t ha^{-1} year^{-1} for NT, 18 t ha^{-1} year^{-1} for VT and 33 t ha^{-1} year^{-1} for CT. This indicates that wind erosion predictions can be overestimated by at less 25 t ha^{-1} year^{-1} in NT and by 9 t ha^{-1} year^{-1} in VT and give adequate results for CT in Argentinian Entic Haplustolls.

Measured EF and GMD were linearly and negatively correlated ($P<0.01$), but in a different way in CT and VT than in NT (Fig. 2). The slope of the regression equation for VT and CT (−16.85) was greater than for NT (−7.66).

The aggregate stability of the whole soil (DASt) varied between 24% and 91.6% (Fig. 1c). Averaged DASt values for all sampling dates were significantly smaller in CT (49%) than in VT (70%) and NT (88%) ($P<0.05$). These results agree with those of Yang and Wander (1998) who found that the dry aggregate stability of soils of northeastern USA decreased with the intensity of tillage practices. Bravo and Silenzi (2000) found similar results for soils of the southeastern Pampas of Argentina.

DASt variability over time was smaller in NT (SD = 1.99) than in VT (SD = 8.00) and CT (SD = 16.31), suggesting soil disturbance by tillage practices in the same sequence as a causative factor. DASt remained almost unchanged in NT but it decrease by 40% in VT and CT during the period of the study.

Fig. 3 shows that the 6.4 mm sized aggregates were the prevailing aggregate size (32% as average of all tillage systems and sampling dates), followed by the 2 mm (14%) and the 19.2 and 0.84 mm sized aggregates (9.4 and 7.4%, respectively). NT had greater amounts of aggregates coarser than 6.4 mm than VT and CT, and smaller amounts of fine aggregates (0.84 and 2 mm) than CT on most sampling dates. It is likely that dry sieving produced a larger breakdown of coarser aggregates into smaller sizes in CT and VT, which accounted for the relative larger increase of smaller aggregates, mainly the <0.84 mm, in both systems in relation to NT.

The variability of the 19.2 mm sized aggregates among sampling dates was higher in NT (SD = 18) than in VT (SD = 6) and CT (SD = 4). However, the variability of the 6.4 mm sized aggregates (SD = 5.5) was similar in all tillage systems. The 2 mm and the 0.84 mm sized aggregates were less variable in NT (SD = 1.25 and 0.83, respectively) than in VT (SD = 1.77 and 1.37, respectively) and CT (SD = 2.32 and 1.49, respectively).

The DASi of all sized aggregates (Fig. 3) was lower in NT (8.1% as average of all sampling dates) than in VT (14.1%) and CT (23.1%), but was less variable between sampling dates in NT (SD = 1.1), than in VT (SD = 4) and CT (SD = 7.6). Within the same tillage system, the DASi of fine aggregates was greater than DASi of coarse aggregates. The average DASi value for all sampling dates in NT was 3.7% for the 19.2 and 6.4 mm sized aggregates, 8.2% for the 2 mm aggregates, and 12.5% for the 0.84 mm aggregates. In VT DASi was, in the same sequence, 10.7, 11.9, 12.7 and 18.0%, and in CT 17.4, 20.0, 21.8, and 27.7%. The relationship between aggregate size and aggregate stability was confirmed by means of a simple regression analysis. Both variables correlated negatively and significantly ($y = -1.755x + 86.46$, $R^2 = 0.56$, $P<0.001$), indicating that the contribution of aggregates larger than 0.84 mm in size to the formation of <0.84 mm aggregates is, on average, 10% higher for the 19.2 mm sized aggregates than for 0.84 mm sized aggregates. NT formed aggregates were 5 to 7% more stable than VT aggregates and 13 to 16% more stable than CT aggregates. These results can be partially attributed to an interference of the sieving technique, as the finer aggregates may increase their proportion as a consequence of the breakdown of coarser aggregates during the dry sieving with the rotary sieve.

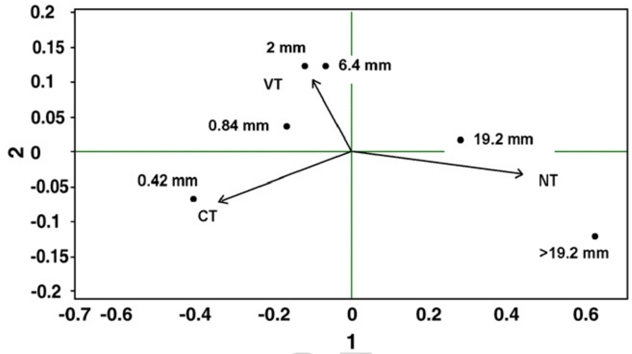

Fig. 4. Correspondence analysis between aggregate sizes and tillage systems.

DASi of all aggregate sizes remained almost unchanged with time in NT, but it decreased in VT and most notably in CT. This tendency is reflected by the lack of differences in DASi between tillage systems at sampling start (September 2002) and the increasing differences with time, reaching a maximum of 20 to 25% between NT and CT and 10 to 15% between NT and VT. These results indicated that a progressive deterioration of aggregates stability with time occurs in VT and CT.

The two last sampling dates showed unexpected increases of DASi in VT and CT. Such results can be attributed to the low water content of the soil during these two sampling dates (accumulated rains of the period were only 5 mm). It is known that dry initial soil water contents can increase dry aggregate stability as a consequence of the cementation produced by some inorganic substances like clays and free lime (Coote et al., 1990; Perfect et al., 1990).

Fig. 4 shows the correspondence analysis for tillage systems and aggregate sizes. This analysis defines, in one plane, the regions that characterize the different tillage systems and the distribution of the aggregates by size within them. It can be seen that the smaller aggregates (<0.42 mm) were associated with CT, the medium sized aggregates (0.84 mm) with VT and the largest aggregates (>6.4 mm) with NT. This agrees with results of Tiessen and Stewart (1983) and indicates that more aggressive tillage results in smaller soil aggregates.

4. Conclusions

Results obtained in this study allow us to conclude that tillage practices produced significant differences in GMD, EF, DASt, and DASi. GMD and DASt were the greatest and EF the smallest in NT, and inverse results were found in CT. VT showed intermediate values of these parameters. Soil disturbance by tillage produced higher variations with time of all studied parameters in CT and VT. The parameters were more time invariant in NT. The Eq. (3) was adequate for estimating GMD in less disturbed soils (NT and VT) but produced measurable overestimations in high disturbed soils (CT). The Eq. (2) overestimated EF in NT and underestimated it in CT. The application of WEQ with the estimated EF can lead to wind erosion overestimations of at less 25 t ha^{-1} $year^{-1}$ in NT and by 9 t ha^{-1} $year^{-1}$ in VT, but predicts adequately in CT.

NT showed greater amounts of aggregates coarser than 6.4 mm than VT and CT, and smaller amounts of fine aggregates (0.84 and 2 mm) than CT in most sampling dates. The variability of the 19.2 mm sized aggregates between sampling dates was greater in NT than in VT and CT, while the variability of the 6.4 mm sized aggregates was similar in all tillage systems. An increase of the 0.84 mm sized aggregates and a decrease of the 19.2 mm sized with sampling time was observed in CT, indicating that the 19.2 mm aggregates were broken into 0.84 mm aggregates by tillage.

DASi of all sized aggregates was higher and less variable in NT than in VT and CT. The stability of aggregates increased with decreasing diameter, and aggregates of NT were 5 to 7% more stable than VT aggregates and 13 to 16% more stable than CT aggregates. These results were partially attributed to an interference of the sieving with the rotary sieve, which produced a relative increase of the finer aggregates by the breakdown of the coarser aggregates.

Tillage practices affect all parameters deduced from dry aggregate size distribution at different rates. Corrections of these parameters on the basis of previous management conditions should be further developed.

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