IMPROVING THE STRUCTURAL STABILITY OF CROPPED SOILS IN OLITE (NAVARRE) USING CONSERVATION TILLAGE TO REDUCE WATER EROSION

Del Río, I.*, Fernández, O., Imaz, M.J., Enrique, A., Bescansa, P.

Universidad Pública de Navarra. Dpto, de Ciencias del Medio Natural, Campus Arrosadía s/n. 31006. Pamplona, Spain.
*iker.delrio@unavarra.es

1. Introduction

Soils in semi-arid climates are highly susceptible to erosion due to their low organic matter (SOM) contents, and, in some cases, their weakly developed structure. Erosion might affect soil quality through the degradation of the soil physical, chemical and biological properties, leading to reduced agricultural productivity.

Aggregate stability has been shown to be a major indicator of the soil susceptibility to water erosion (Karlen and Stott, 1994). This type of erosion is caused by the impact of raindrops on the bare soil, and by the effect of runoff water on the soil surface. The stability of soil aggregates in face to this process is controlled by two opposing factors: the development of stresses inside the aggregate pore space during wetting due to the compression of the entrapped air and the different water affinity of its components, and the strength of the inter-particle bonds (Concaret, 1967). The importance of such factors in gully erosion modelling has recently been summarized by Sidorchuk (2005). SOM influences aggregate stability by reducing the rate of wetting and increasing the resistance to stresses generated during wetting (Monnier, 1965; Quirk and Murray, 1991; Rasiah and Kay, 1995; Caron et al., 1996).

Erosion reduces soil surface stability and redistributes topsoil. As a result, the soil physical conditions for plant growth deteriorate and nutrient and organic materials are depleted. The interaction between tillage, SOM and aggregation has been long time studied (Six et al., 2004). In general, tillage reduces the SOM content and aggregate stability, accelerating erosion. Conservation Agriculture practices, where tillage is reduced and crop residues are left on the soil surface can decrease soil losses by erosion, by two means. On the one hand, reducing tillage intensity can help to maintain the SOM levels; on the other hand crop residues provide a surface mulch that protects the soil from raindrops and slows down runoff flow velocity (Karlen and Cambardella, 1996).

The objective of this work was to compare the soil wet aggregate stability and its relationship to the soil organic matter stock in an agricultural soil under different types of tillage in a semi-arid area of Northern Spain.

2. Materials and Methods

2.1. General Experiment Setup

The experimental site was established in 1994 in a semi-arid area in Olite (Navarre), Northern Spain. Mean annual rainfall is 525mm, and mean annual potential evapotranspiration (PET) is 740mm. The soil was classified as a clay-loam *Calcic Haploxerept* and the area was described as of moderate water erosion risk by Donézar et al. (1990).

The experimental design was a randomized complete block with four replicates. Plots were 9 x 24 m in size (216 m^2). Treatments were: no-tillage (NT), reduced tillage (RT) and conventional tillage with mouldboard plough (MT). For NT, seeding was done without any previous seedbed preparation. RT consisted of an initial 0.15 m-deep chisel tillage followed by a cultivator pass before seeding. MT consisted of a 0.25 m-deep primary tillage with mouldboard plough, followed by a float. In the RT and MT treatments, crop residues were incorporated into the arable layer during tillage. In NT, crop residues were left on the soil surface after harvest. Barley (*Hordeum vulgare* L. var. Tipper) was planted in all plots at the same seeding rate.

2.2. Soil Sampling and Handling

Soil was sampled for laboratory analyses in March 2003. Samples were collected from the surface layer (0-0.05 m), using a spade. Once in the laboratory, they were air-dried and gently sieved in an 8 mm-openings sieve.

2.3. Measurements

Wet aggregate stability was determined by wet sieving. Air dried soil samples were washed through a column of six sieves of decreasing openings-size (6.3, 4, 2, 1, 0.5 and 0.25mm), using a Restsch VS 1000 sieving apparatus connected to a source of water that simulated rainfall on the top sieve. After one minute of washing and sieving, the fraction remaining on each sieve was collected, oven-dried at 105°C, and weighed. Wet aggregate stability was quantified by the Mean Weight Diameter (MWD) of the recovered fractions after sieving, defined as:

$$MWD = \sum_{i=1}^{n} \frac{r_{i+1} + r_i}{2} . m_i \qquad (1)$$

where r_i = aperture of the ith mesh (mm); m_i= proportion of the mass remaining on ith sieve with respect to the total sample; n=number of the sieves.

Total soil organic matter (SOM) of the soil samples was analyzed by wet oxidation (Walkley-Black), and the results were expressed in g C kg $soil^{-1}$.

IV International Symposium on Gully Erosion. J. Casalí and R. Giménez (Eds.)
 ISBN 978-84–9769-198-7

2.4. Statistical Analyses

Statistical analyses were performed using SPSS 10.0 software (SPSS Inc., 1999. Chicago, IL.). Data were analysed as repeated measures over space using ANOVA (univariate linear model). Post-hoc analyses were performed by Duncan test. Correlation among variables was tested, and the significance was declared at $P \leq 0.05$.

3. Results and Discussion

Aggregate size distribution after wet sieving is shown in Figure 1 for the studied treatments. Macroaggregates < 2 mm and 0.25 – 2 mm in size, and microaggregates (< 0.25 mm) were chosen because these fractions represent the different hierarchical stages at which the different binding agents act in soil (Six et al., 2004), according to the hierarchical theory of aggregate formation and stabilization (Tisdall & Oades, 1982; Franzluebbers and Arshad, 1996; Pinheiro et al., 2004; Wright and Hons, 2005; cited by Six et al., 2004). Although microaggregates were the dominant fraction in the soil under all the studied treatments, their mass was significantly bigger under MT. NT resulted in the lowest amount of aggregates of this size. Concurrently, the inverse was shown for the >2 mm aggregate fraction, so that RT displayed an intermediate aggregate size-distribution between NT and MT.

The intermediate macroaggregate fraction (2-0.25 mm) represented the smallest proportion of soil mass under all treatments, and showed no differences in relation to tillage.

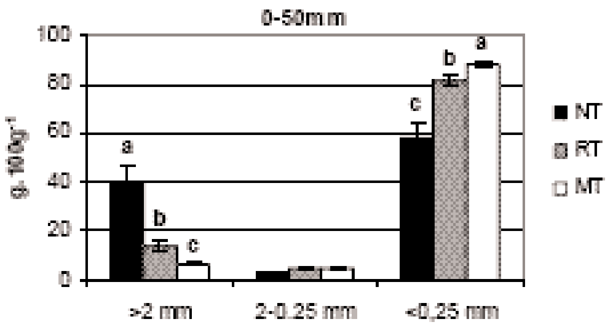

Fig. 1. Aggregate size-distribution after wet sieving.

Table 1 shows data on SOM content and the MWD index corresponding to each of the studied treatments. MWD was significantly higher under NT than under RT and MT, while RT and MT did not show statistical differences between them.

As it is has been widely documented, SOM values were significantly higher under NT than under RT and MT, where no statistical differences were found. Increased SOM mineralization associated to aggregate destruction, oxygenation of the soil profile and enhanced access to SOM for microbial decomposers are the causes generally accepted for SOM loss in tilled soils.

Table 1. Aggregate stability measured by the wet sieving method.

	MWD (mm)	SOM (g/kg)
NT	2,833 a	29,46 a
RT	0,784 b	23,18 b
MT	0,441 b	20,64 b

A positive correlation was thus observed between the soil organic matter content and aggregate stability in this soil (Imaz, 2005). This means that even in this calcareous soil, where organic matter is not likely to be the major factor in control of aggregation, the increment in SOM in the topsoil due to NT contributes to enhancing the aggregate stability to the stresses of drying and wetting processes, improving the soil structure and physical characteristics.

4. Conclusions

The higher stability of soil aggregates to the action of water, along with the existence of an organic layer on the soil surface that decreases runoff velocity and reduces the energy of raindrop impacts in the soil under NT, increased the soil resistance to be swept out by the runoff water in the studied area. Considering that surface aggregate detachment plays a major role in gully erosion (Sidorchuk, 2005), and that NT has been seen to increase water infiltration in the studied soil , we conclude that NT is more effective than RT and MT in reducing water erosion in the croplands of semiarid areas in Navarre.

References

Caron, J., Espindola, C.R., Angers, D.A. 1996. Soil structural stability during rapid wetting: Influence of land use on some aggregate properties. *Soil Science Society of America Journal 60*: 901-908.

Concaret, J. 1967. Etude des mécanismes de la destruction des aggregats de terre au contact de solutions acqueuses. *Annales Agronomiques 18*: 99-144.

Donézar, M., Ilarregui, M., del Valle de Lersundi J. 1990. Erosión Actual en Navarra. *Publicación Gobierno de Navarra e Instituto Tecnológico Geominero de España.*

Imaz, M.J. 2005. Determinación y selección de indicadores de calidad del suelo para la evaluación de sistemas de Agricultura de Conservación en cultivo de cereal de zonas semiáridas en Navarra. *Doctoral Thesis*. *Universidad Pública de Navarra.*

Karlen, D.L., Cambardella, C.A. 1996. Conservation strategies for improving soil quality and organic matter storage. *Structure and organic matter storage in agricultural soils*. *Advances in Soil Sciences Series*: 395-420.

Karlen, D.L., Stott, D.E. 1994. A framework for evaluating physical and Chemical Indicators Of soil Quality. In: Defining Soil Quality for a Sustainable Environment. *SSSA Special Publication N.35; Soil Science Society of America: Madison WI, 1994*:53-72.

Monnier, G. 1965. Action des matières organiques sur l'estabilité structurale des sols. *Annales Agronomiques 16*: 327-400.

Quirck, J.P., Murray, R.S. 1991. Towards a model for soil structural behaviour. *Aust. J. Soil Res 29*: 828-867.

Rasiah, V., Kay, B.D. 1995. Characterizing rate of wetting: Impact on structural destabilization. *Soil Science 160*: 176-182.

Sidorchuk, A. 2005. Stochastic components in the gully erosion modelling. *Catena 63*: 299-317.

Six, J., Bossuyt, H., Degryze, S. and Denef, K. 2004. A history of research on the link between (micro)aggregates, soil biota, and soil organic matter dynamics. *Soil and Tillage Research*, *79*: 7-31.