Geophysical Research Abstracts,
Vol. 11, EGU2009-7652, 2009
EGU General Assembly 2009

Evaluation of commercial magnetic iron oxides as sediment tracers in water erosion experiments

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Water erosion is one of the mayor concerns to sustainability of agricultural systems in Mediterranean countries, e.g. olive farming areas in Southern Spain. Despite an increase in the number of published studies on erosion rates and conservation measures, significant uncertainty persists on actual erosion rates in these areas (Gómez et al., 2008; Fleskens and Stroosnijder, 2007). Due to the limitations and cost of technologies traditionally used in erosion measurement, there is a growing interest in the use of innovative erosion tracers that could be applied to the soil and used to monitor erosion and deposition rates at experiments performed at different scales and environments. An example of these innovative traces, which could complement the potential of more traditional tracers like Cs-137, is rare earths oxides. Due to its size, D_{50} ranging from 1.23 to 16.38 μm (Zhang et al., 2003), these rare earth oxides tagged soil aggregates more or less homogeneously and have been used in tracking sediment movement at laboratory and field scale, e.g. Polyakov and Nearing, (2004).

One of the shortcomings of the use of rare earth oxides in the cost derived of the need to use Inductive Coupled Plasma Mass Spectrometry to determine its concentration in the tagged soil. The use of mineral magnetic measurements provide a less expensive alternative to complement erosion and sediment delivery in eroding landscapes (Royall, 2001), and is also an area of active research. However, most of the studies are based on measurements of magnetic properties inherent to soil materials, and little research has been done about the possibility of tagging soils with magnetic materials. Ventura et al. (2002) tagged a loamy soil with a magnetic tracer for use in rainfall simulation experiments. They concluded that the magnetic tracer used, magnetic beads of 3.2 mm of mean weight diameter, although useful in determining erosion and deposition areas presented a tracer to soil ratio that did not remain constant, probably due to the large size of the tracer, and hence impede their use in quantifying erosion and sedimentation rates.

This communication presents our current results on the evaluation of the potential use of magnetic iron oxides (Fe_3O_4), sold commercially as a pigment, as erosion tracers. Due to its size, similar to that or rare earth oxides, and little mobility in soils they have the potential to substitute, or complement, rare earth oxides as a tracer elements, with the advantage of using non-expensive and quick measurements, magnetic susceptibility, instead of ICPMS. This communication will present our preliminary results on the performance of these magnetic tracers that were applied as a dry mixed on the soil following the methodology of Zhang et al. (2003). Our results suggest that the tagged soil following this methodology vary moderately their average aggregate size distribution in most of the cases, Table 1, although not systematically.

Soil	D_{50} (mm)		Significant diferences $p<0.05$
	Blank soil	Tagged soil	Blank *vs* Tagged soil
Alameda	1.17	1.72	yes
Benacazón	0.59	0.47	yes
Conchuela	3.53	3.14	no
Pedrera	2.67	3.72	yes

With the mixing procedure used, the magnetic tracer tend to concentrate relatively homogeneously among aggregate sizes between 8000 and 63μm, with an increase in aggregates smaller than 63 μm and a decrease in aggregates larger than 4 mm, Table 2.

Sieve size (μm)	Dry soil weight (g)	Magnetic susceptibility (m^{-3} kg^{-1})
$>$ 8000	15.66	1.10E-05
$>$ 4000	14.66	1.22E-05
$>$ 2000	11.53	1.22E-05
$>$ 1000	7.12	1.13E-05
$>$ 500	5.59	1.38E-05
$>$ 250	6.29	1.44E-05
$>$ 125	14.41	1.30E-05
$>$ 63	16.30	1.50E-05
$>$ 45	6.17	1.98E-05
$>$ 25	2.21	2.23E-05
$>$ 10	0.05	3.55E-05

Percolation tests suggest that the magnetic oxide used is strongly bond to the soil aggregates, and it is not significantly leached to deeper soil layer, not tagged, trough percolated water, Table 3.

Soil	Before percolation test (m^{-3} kg^{-1})		After percolation test (m^{-3} kg^{-1})	
	Average	Stdsv	Average	Stdsv
Alameda	1.40E-05	9.24E-07	1.34E-05	7.43E-07
Benacazón	1.48E-05	3.54E-07	1.36E-05	2.76E-07
Conchuela	1.31E-05	1.67E-06	1.35E-05	7.39E-07
Pedrera	1.28E-05	1.38E-06	1.36E-05	2.91E-07

Table 3: Magnetic susceptibility of tagged soil layer before and after the percolation test.

Evaluation of the soil loss estimated trough variation of magnetic susceptibility of the tagged soil layer on soil boxes, 0.7 m^2, during rainfall simulation tests provides an indication of the viability of this technique to estimate soil losses by water erosion without direct collection of the lost runoff and sediment, Table 4. It is important to indicate that results in Table 4 were obtained using bulk density values that incorporate the effect of soil consolidation on the variation of the magnetic susceptibility of the soil.

Soil	Measured soil losses (t/ha)			Estimated soil losses (t/ha)		
	S1	S2	S3	S1	S2	S3
Alameda	11.37	27.98	47.15	17.73	17.60	53.43
Benacazón	1.88	6.87	14.78	-	10.73	19.42
Conchuela	16.80	46.66	86.58	23.30	47.56	89.27
Pedrera	14.03	33.38	52.33	22.72	31.48	46.44

Table 4: Measured and estimated cumulative soil losses (t/ha) of four soils after three rainfall simulations.

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