Deposited Sediment Source Fingerprinting in a Tropical Environment

P.L.T. Lima[1], M.L.N. Silva[2], J. Quinton[3], B. Maher[4], A. Armstrong[5], N. Curi[6]

Water erosion promotes water quality impairment and siltation of streams and reservoirs. Finding the origin of the sediments can ensure high agricultural productivity with preservation of natural resources, by targeting sediment control strategies. Use of soil tracers in soil erosion has been proposed. Methodologies are based on the principle that suspended sediments retain some of the properties acquired at their origin such that a sediment sample transported through the landscape can be compared to those from potential sources within its watershed.

One of the main tracer types is magnetic tracing, which is based on the principle that soils, sediments and rocks have unique magnetic properties that can be easily quantified. Different substances exhibit different magnetic properties, enabling mineral identification and classification as well as lithological process identification. Several factors can directly influence variables that can be used for tracing the sources, such as magnetic properties of tropical soils. Soil parent material can be considered the main factor which directly influences soil iron oxides quantity. Other factors include relief, landscape position, weathering conditions and climate. Magnetic environmental fingerprinting can be successfully used for sediment source identification, as several properties can be used as a fingerprinting tool (Maher et al., 2009).

To understand potential sources, soil samples were collected at the Federal University of Lavras (UFLA), in Lavras, Brazil. Soil samples were taken from two toposequences, classified according to the Brazilian System of Soil Classification as: dystrophic Red-Yellow Latosol (RYL); and as dystroferric Red Latosol (RL) (Embrapa, 2013). Both soils classes are equivalent to an Oxisol by the US Soil Taxonomy Classification System (Buol et al., 2011). At each soil sampling site, 1 m triplicate undisturbed profiles using 50 millimeter diameter PVC (Polyvinyl chloride) cores were taken. Soil profile cores were sliced into 10 cm layers in order to measure magnetic properties. Similarly, sediments from two reservoirs were sampled, also using 50 mm diameter PVC cores. Those samples were collected near the embankment of each reservoir (Figure 1). The cores from the reservoirs were then sliced into 2 cm layers in order to measure magnetic properties.

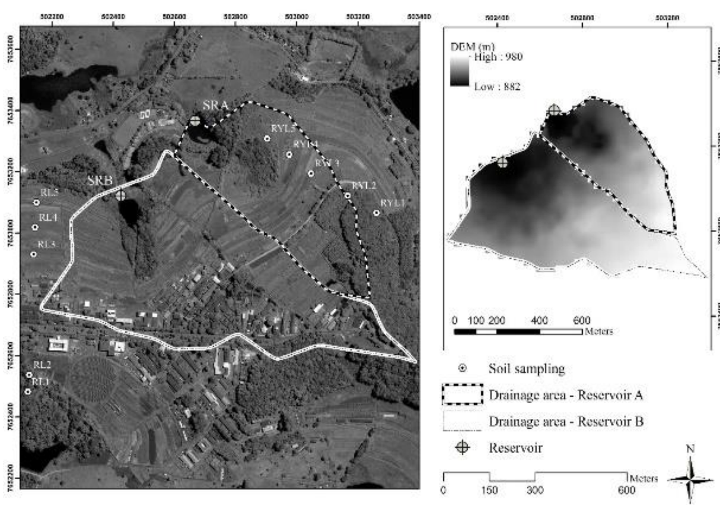

Figure 1. Soil sampling transects and drainage area for the two reservoirs

Non-parametric Spearman's Rank correlation coefficient tests were performed in order to identify low correlation (nonparametric) between two sets of properties, so that such data could properly be used in fuzzy clustering analysis. Magnetic property

[1]Pedro L.T. Lima, Visitor Professor, Federal Univ. of Lavras (UFLA), Lavras, Brazil; [2]Marx L.N. Silva, Professor, UFLA, Lavras, Brazil; [3]John N. Quinton, Professor, Univ. of Lancaster, Lancaster, U.K.; [4]Barbara Maher, Professor, Univ. of Lancaster, Lancaster, U.K.; [5]Alona Armstrong, Professor, Univ. of Lancaster, Lancaster, U.K.; [6]Nilton Curi, Professor, UFLA, Lavras, Brazil. Corresponding author: P.L.T. Lima, email: pedroterralima@yahoo.com.br.

combinations that presented the lowest Spearman's Rank correlation coefficient test results (rho) value (statistically significant at 5% probability) were χ_{LF} (in 10^{-7} m^3 kg^{-1}) versus χ_{ARM} (normalised with respect to the IRM_{100mT}) (in 10^{-5} m A^{-1}). Moreover, these property relationships were used in fuzzy clustering analysis showing differentiation between sources and dominant cluster affiliation of reservoir sediments.

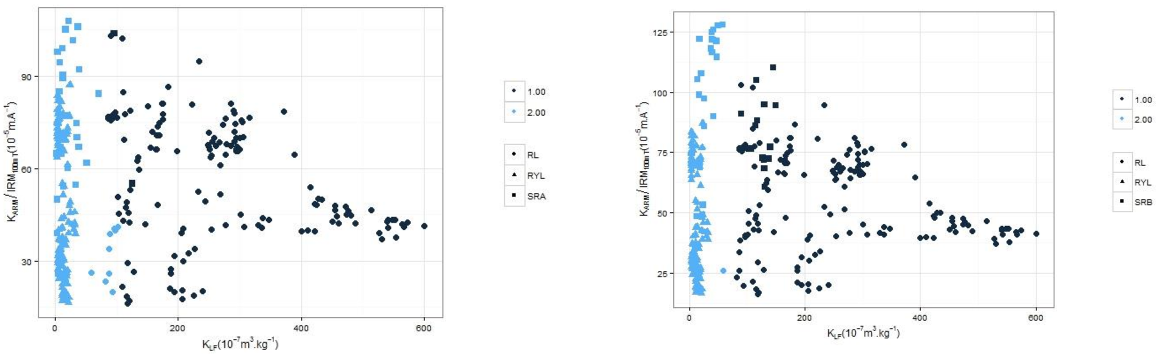

Figure 2. Results of the fuzzy clustering analysis showing differentiation between sources (RYL and RL), and the dominant cluster affiliation of Reservoir A and Reservoir B sediments.

Fuzzy cluster fuzzy indicated a dominant RYL sediment source at reservoir A. Approximately 93% of the sediments sampled at reservoir A presented higher cluster affiliation to RYL samples, and reservoir A sediments were also characterized by low χ_{LF}. Clustering results agreed with drainage area indicated in Figure 1, which was delineated near the RYL transect sampled. In Figure 2, the clustering analysis shows that sediments from both soils have affinity to reservoir B sediments, indicating that they both contribute significantly to the sediment load. About 42% of the reservoir sediments presented a higher cluster affiliation to the RL samples, while 58% showed a similar behavior to RYL samples.

The proportion that each source contributes to the mixture varies in time and space, a result of erosion processes that are currently taking place in the watershed. Interactions between climate, natural relief and soil type, intensified by constant agricultural activities at the site, promotes elevated erosion rates for RYL, and consequent high sediment production.

Research processes to identify possible route of sediments in watersheds involving magnetic properties have been widely carried out in temperate environments at Northern latitudes, but there have been very few studies in tropical regions. This research provides one of the first demonstrations of the use of sediment fingerprinting using magnetic parameters to identify possible sediment sources in a tropical environmental, especially in the Brazilian setting. Although both soils were classified as Oxisols, two soil classes could be clearly distinguished by magnetic property evaluation and the origin of sediments of downstream reservoirs precisely allocated to their sources.

References

Buol, S.W., R.J. Southard, R.C. Graham, and P.A. McDaniel. 2011. Soil Genesis and Classification, sixth ed. Wiley-Blackwell, Ames, Iowa. 543 pp.

Empresa Brasileira de Pesquisa Agropecuária – EMBRAPA. 2013. Sistema Brasileiro de Classificação de Solos, 3rd ed. Embrapa Solos, Rio de Janeiro. 353 pp.

Maher, B.A., S.J. Watkins, G. Brunskill, J. Alexander, and C.R. Fielding. 2009. Sediment provenance in a tropical fluvial and marine context by magnetic 'fingerprinting' of transportable sand fractions. Sedimentology 56: 841–861.