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Exploring the uncertainty in attributing sediment contributions in fingerprinting studies due to uncertainty in determining element concentrations in source areas.

Jose Alfonso Gomez (1), Phillip N. Owens (2), Alex J. Koiter (2), and David Lobb (3)

(1) Institute for Sustainable Agriculture. CSIC., Agronomy, Cordoba, Spain (joseagomez@ias.csic.es), (2) University of Northern British Columbia, Prince George, British Columbia, Canada, (3) Watershed Systems Research Program, University of Manitoba, Winnipeg, Canada

One of the major sources of uncertainty in attributing sediment sources in fingerprinting studies is the uncertainty in determining the concentrations of the elements used in the mixing model due to the variability of the concentrations of these elements in the source materials (e.g., Kraushaar et al., 2015). The uncertainty in determining the "true" concentration of a given element in each one of the source areas depends on several factors, among them the spatial variability of that element, the sampling procedure and sampling density. Researchers have limited control over these factors, and usually sampling density tends to be sparse, limited by time and the resources available. Monte Carlo analysis has been used regularly in fingerprinting studies to explore the probable solutions within the measured variability of the elements in the source areas, providing an appraisal of the probability of the different solutions (e.g., Collins et al., 2012). This problem can be considered analogous to the propagation of uncertainty in hydrologic models due to uncertainty in the determination of the values of the model parameters, and there are many examples of Monte Carlo analysis of this uncertainty (e.g., Freeze, 1980; Gómez et al., 2001). Some of these model analyses rely on the simulation of "virtual" situations that were calibrated from parameter values found in the literature, with the purpose of providing insight about the response of the model to different configurations of input parameters. This approach – evaluating the answer for a "virtual" problem whose solution could be known in advance – might be useful in evaluating the propagation of uncertainty in mixing models in sediment fingerprinting studies. In this communication, we present the preliminary results of an on-going study evaluating the effect of variability of element concentrations in source materials, sampling density, and the number of elements included in the mixing models.

For this study a virtual catchment was constructed, composed by three sub-catchments each of 500 x 500 m size. We assumed that there was no selectivity in sediment detachment or transport. A numerical excercise was performed considering these variables: 1) variability of element concentration: three levels with CVs of 20 %, 50 % and 80 %; 2) sampling density: 10, 25 and 50 "samples" per sub-catchment and element; and 3) number of elements included in the mixing model: two (determined), and five (overdetermined). This resulted in a total of 18 (3 x 3 x 2) possible combinations. The five fingerprinting elements considered in the study were: C, N, 40K, Al and Pavail, and their average values, taken from the literature, were: sub-catchment 1: 4.0 %, 0.35 %, 0.50 ppm, 5.0 ppm, 1.42 ppm, respectively; sub-catchment 2: 2.0 %, 0.18 %, 0.20 ppm, 10.0 ppm, 0.20 ppm, respectively; and sub-catchment 3: 1.0 %, 0.06 %, 1.0 ppm, 16.0 ppm, 7.8 ppm, respectively.
For each sub-catchment, three maps of the spatial distribution of each element was generated using the random generator of Mejia and Rodriguez-Iturbe (1974) as described in Freeze (1980), using the average value and the three different CVs defined above. Each map for each source area and property was generated for a 100 x 100 square grid, each grid cell being 5 m x 5 m. Maps were randomly generated for each property and source area. In doing so, we did not consider the possibility of cross correlation among properties. Spatial autocorrelation was assumed to be weak. The reason for generating the maps was to create a "virtual" situation where all the element concentration values at each point are known. Simultaneously, we arbitrarily determined the percentage of sediment coming from sub-catchments. These values were 30 %, 10 % and 60 %, for sub-catchments 1, 2 and 3, respectively. Using these values, we determined the element concentrations in the sediment.
The exercise consisted of creating different sampling strategies in a virtual environment to determine an average value for each of the different maps of element concentration and sub-catchment, under different sampling densities: 200 different average values for the "high" sampling density (average of 50 samples); 400 different average values for the "medium" sampling density (average of 25 samples); and 1,000 different average values for the "low" sampling density (average of 10 samples). All these combinations of possible values of element con-

centrations in the source areas were solved for the concentration in the sediment already determined for the "true" solution using limSolve (Soetaert et al., 2014) in R language. The sediment source solutions found for the different situations and values were analyzed in order to: 1) evaluate the uncertainty in the sediment source attribution; and 2) explore strategies to detect the most probable solutions that might lead to improved methods for constructing the most robust mixing models. Preliminary results on these will be presented and discussed in this communication.

Key words: sediment, fingerprinting, uncertainty, variability, mixing model.

References

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