Evaluating mixing modelling for soil erosion hot spot identification through the use of artificial soil mixtures

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Soil erosion and associated sediment redistribution are key environmental problems in Central Argentina. Several land uses and management practices, such as intensive grazing and crop cultivation, are considered to drive and increase significantly these processes.

To prove the above hypothesis, a mixing modelling approach (CSSIAR v1.00), using Energy Dispersive X Ray Fluorescence (EDXRF) data as fingerprint of sediment sources and sinks, is aimed to identify critical hot spots of erosion in a typical Argentinian agro-ecosystem. The study site is an Estancia Grande subcatchment with an area of 1235 hectares, located 23 km north east of San Luis (in the center of Argentina) and which is characterized by highly erodible Haplic Kastanozem soils.

However, before the mixing modelling approach can be used, validation is needed. This can be achieved by the composition of artificial soil mixtures based on existing sediment sources collected from the targeted studied subcatchment. The proportion of these sources in the artificial mixtures is estimated by the mixing model, whose result is then compared with the true values of the apportionment.

Four artificial soil mixtures were created using known quantities of the most representative sediment sources of the studied catchment. The first mixture (MIX 1) was composed of four sources characterised by crop cultivation in rotation. The second (MIX 2) and the third mixture (MIX 3) were built using different proportions of four different soil sources including soils from a feedlot, a rotation crop, a walnut forest and a from a native pasture for grazing. The last tested mixture (MIX 4) contained the same sources as MIX 3 but with the addition of a fifth source collected along the river banks.

The geochemical element content analysis of the mixtures and sources samples was performed by EDXRF. For determining the best suitable fingerprint elements of the sources, a four-step selection process was developed and tested. After applying a traditional approach for fingerprint selection which includes statistical tests such as Kruskal–Wallis H-test and Discriminant Function Analysis (DFA), we used (1) the known information on the source proportions in the mixtures and (2) the subset of tracers that passed the previous mentioned tests, to select the specific elemental tracers that are in agreement with the expected mixture contents. Our selection process was completed after a final test using the mixing model CSSIAR v1.00 to compute all possible combinations of the reduced number of tracers obtained. Alkaline earth metals especially Barium (Ba) and Strontium (Sr) were identified as the most effective elemental fingerprints which provided a reduced Mean Absolute Error (MAE) of around 2% when reconstructing the four artificial mixtures.

This study, which has been presented during EGU 2017, demonstrates that the elemental fingerprinting approach using EDXRF performed very well to reconstruct our original mixtures, especially in identifying and quantifying the contribution of the 4 rotation crop soil sources in MIX 1 as well as in recognizing the major and minor source contributors in MIX 3 (Fig. 1).

**Support from the STEP fellowship programme is kindly acknowledged. Through its Sandwich Training Educational Programme (STEP), ICTP and its UN partner, the International Atomic Energy Agency (IAEA), offer fellowships to PhD students from developing countries in the fields of physics and mathematics.*

SMWCN Laboratory STEP fellow preparing sample for EDXRF analysis

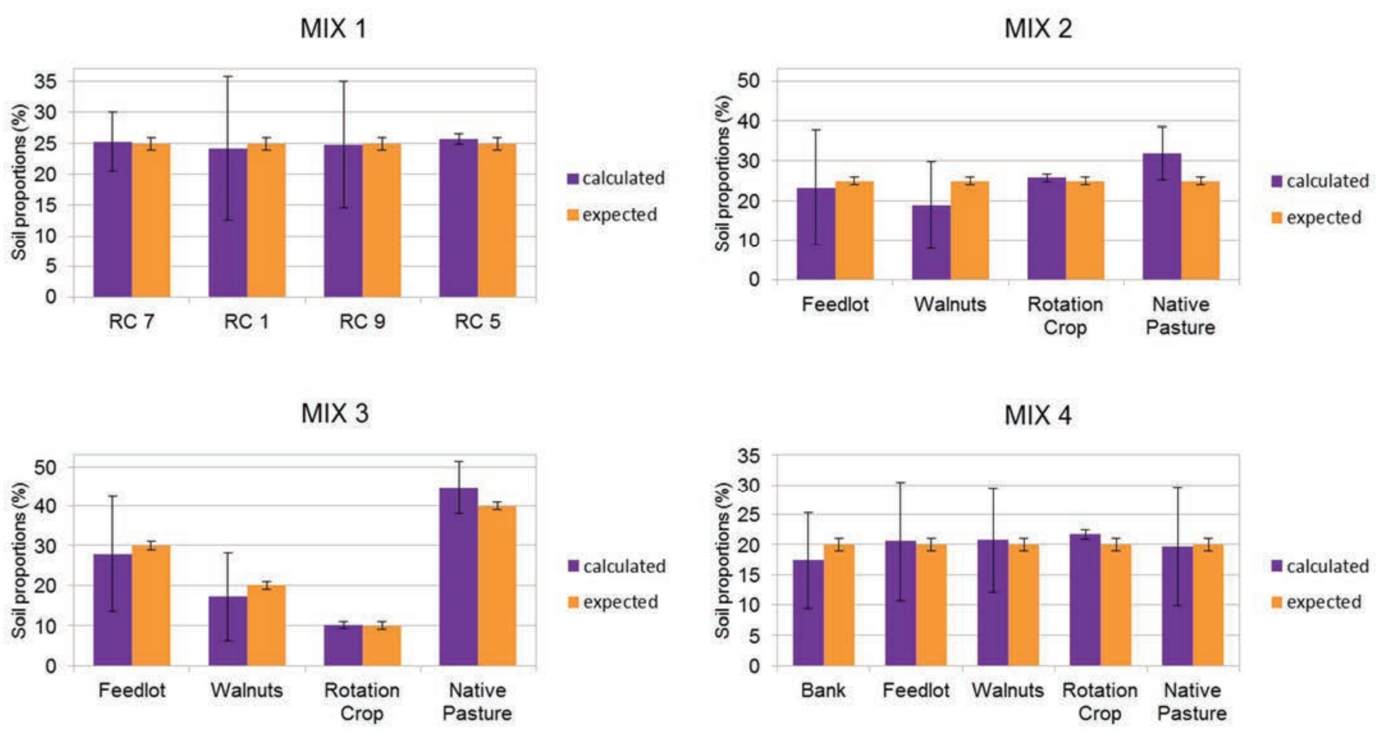

FIG. 1. Comparison of the expected and calculated proportion contribution of the different sources for each tested artificial mixtures

Evaluating the effectiveness of mulch application to store organic carbon in agricultural soils

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Soils contain more carbon than plants and the atmosphere combined and increased soil carbon content provides multiple benefits including climate change mitigation, improved soil quality and larger plant production. Depending on the type of farming techniques applied, agricultural soils can either store more carbon belowground, or further release carbon, in the form of CO_2, into the atmosphere. Mulch application is a farming technique that is frequently proposed to increase carbon content belowground and improve soil quality and it can be used in efforts to reduce greenhouse gas levels, such as in the '4 per 1000' Initiative. To test the effectiveness of mulch application to store carbon belowground in the short term, we maintained agricultural soils with low and high organic carbon content (disturbed top soil from local Cambisols and Chernozems, respectively) in greenhouse mesocosms with controlled moisture (Fig. 1) as well as in agricultural field Cambisols (Fig. 2). A legume-maize rotation was maintained in the mescosms and a legume-maize rotation as well as sole maize production or legume production was maintained in the agricultural field experiment. Plant residues from these productions were reapplied to soils after harvest as mulch to mimic procedures a farmer would apply. After 4 years of maintenance in the mesocosms and 2 years maintenance in the field, soil were sampled to measure carbon and nitrogen pools and isotopic composition in the top 15 cm. Mulch was expected to increase carbon and nitrogen content and ho have a greater effect on soils with low organic matter than soils with high organic matter.

Fig. 1. Maize and soybean were grown yearly in rotation in greenhouse mesocosms and mulch was removed or applied after harvest at 2 ton/ha dry matter. Soil disturbance was kept to a minimum, with only surface disturbance of a few centimeters to keep soil free from weeds.

In mesocosm Cambisols with low organic carbon content and larger predicted potential to increase soil carbon, mulch application did not increase soil carbon or nitrogen pools. However, mulch application significantly increased the $\delta^{13}C$ of soil organic carbon by 0.55‰, indicating a shift in belowground processes, such as increased decomposition coupled with increased ^{13}C-enriched maize carbon inputs. In mesocosm Chernozems with higher organic carbon content and lower potential to increase soil carbon, mulch application decreased microbial carbon by 44%. Mulch application also increased $\delta^{13}C$ of soil organic carbon by 0.51‰, likely indicating a decrease in decomposition and increased maize carbon inputs. Field plots in Cambisols confirmed these greenhouse mesocosm results and showed that legume-maize rotations with mulch application do not increase soil or carbon nitrogen pools but do increase $\delta^{13}C$ of soils. Interestingly, however, sole maize production in the field resulted in an increase in soil organic carbon by 30-32% with mulch application but $\delta^{13}C$ did not increase. Sole legume did not increase soil carbon or $\delta^{13}C$ with mulch application. Contrary to initial presumption, mulch application did not increase soil carbon pools with legume-maize rotation or sole legume Mulch application only increased soil organic carbon pools in maize plot. This, in combination with the increase in $\delta^{13}C$ in mesocosm and plot with legume-maize rotation indicates that mulch application under maize contributes to an increase of organic carbon but that this is muted with the addition of legumes to soils as well. This was largely explained by the decrease in the soil C:N ratio by legumes that likely stimulates increased decomposition and carbon loss.

Fig. 2. Maize and vetch were grown in the field in agricultural Cambisols with low organic carbon content. Plant production was maintained for 2 years.

International networking for improving stable isotope methods to quantify isotopic composition of nitrates in water samples

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Dr. David Soto, a Marie Curie Fellow from the Department of Earth and Environmental Sciences, University of Leuven, Belgium, was at the SWMCN Laboratory on 13-17 February 2017 as a short-term consultant. An expert in bacterial denitrification and laser spectroscopy, Dr. Soto assisted the SWMCN laboratory team in the calibration and experimental setup of the Los Gatos N_2O Analyzer, as well as in streamlining the bacterial denitrification method set up in the lab. The training benefitted the SWMCN Laboratory's work in quantifying the isotopic composition of nitrate, in particular $\delta^{15}N$ and $\delta^{18}O$, which in turn could assist in improving soil and water management practices.

During the week-long training by Dr. Soto, the specific focus was on (1) implementation of improvements to experimental processes established in the laboratory, (2) training on usage of the Los Gatos N_2O Analyzer, including machine calibration and measurement, and (3) training on data extraction, management and bias corrections. Experiments were also initiated to explore the effects of sonification of samples on $\delta^{18}O$ measured.

SWMCN Laboratory team being trained o calibration of the Isotopic N_2O Analyzer

Through this consultant visit, the SWMCN Laboratory staff learnt how to reduce the number of processes performed in laminar hood, which would assist Member States in eliminating costs when implementing the bacterial denitrification method. The method was also further refined such that the process is more streamlined and can be completed from water sample inoculation to analysis in a shorter period.