

Optimizing the potential of iron oxide-based tracers

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Introduction

So far, it does not exist any tracer which fulfill all the characteristics for being an ideal sediment tracer such as, environmentally friendly, inexpensive or easily analyzed (Zhang et al., 2001). For this reason, and in order to address some of the unsolved issues of water erosion processes, more research enquiring into the development of these soil and sediment tracers is needed. Iron oxide-based tracers has been already tested in several water erosion trials with satisfactory results (e.g. Guzmán et al., 2010, 2013, 2015). In 2015, three cascade plots with a different iron oxide (magnetite, hematite and goethite) each were set up in order to evaluate soil redistribution after the rainy season (Obereder et al., 2016). While these authors presented the total iron content of sediments after clorhydric acid extraction, the present study will show only the free iron content of soil and sediments using a different extraction method (CBC, citrate-bicarbonate-ditionite), as this method is more adequate in high iron content soils, which is is our case.

Materials and methods

The cascade plots consisted of three consecutive uncultivated runoff plots of 20 x 4 m (length and width, respectively) along the maximum slope direction. Each one was separated to the downstream one by a stone bund. The experimental setup allowed the measurement of side flow (SF) along each stone bund and the measurement of overflow (OF) over the last stone bund. Different tracers were used to assess the pathway and the spatial distribution of the sediments. A mix of soil and a tracer was applied at the plot furthest uphill with Magnetite (C1), at the middle plot with Hematite (C2) and at the lowest one with Goethite (C3). The tracer strips were 40 cm wide and 2 cm high, Figure 1. The side flows (SF1, SF2, and SF3) and the overflow (OF3) were collected with perforated pipes and directed to sample dividers. More details about the experimental design can be found in Obereder (2016).

In this study, iron oxide was extracted from soil following the citrate-bicarbonate-dithionite procedure, CBD, (Mehra and Jackson, 1960). In this procedure, the dithionite extracts the free iron content after 16-24 hours in isothermal agitation. At that interval of time, the extraction of iron oxide from the standard sample is over 90%. Prior to shaking, the sample together with the reagents should be put at 60°C in an oven for one hour to start the reaction.

The main modification performed in this study is the significant reduction of samples' weight, especially in soils with high iron oxides content, which is the case in the study site. The reduction was a decimal part of the original method, which ranged between 0.1-0.2 g instead of 1-2 g. The explanation for reducing the weight is to avoid several posterior dilutions, thus reducing the error.

The iron concentration in all the CBD extracts was determined by the orthophenanthroline method. Prior to the samples' analysis from the trial, a batch of inert sand and weighted concentrations of tracers was measured to determine the mean recovery rate and therefore correct the trial's extractions.

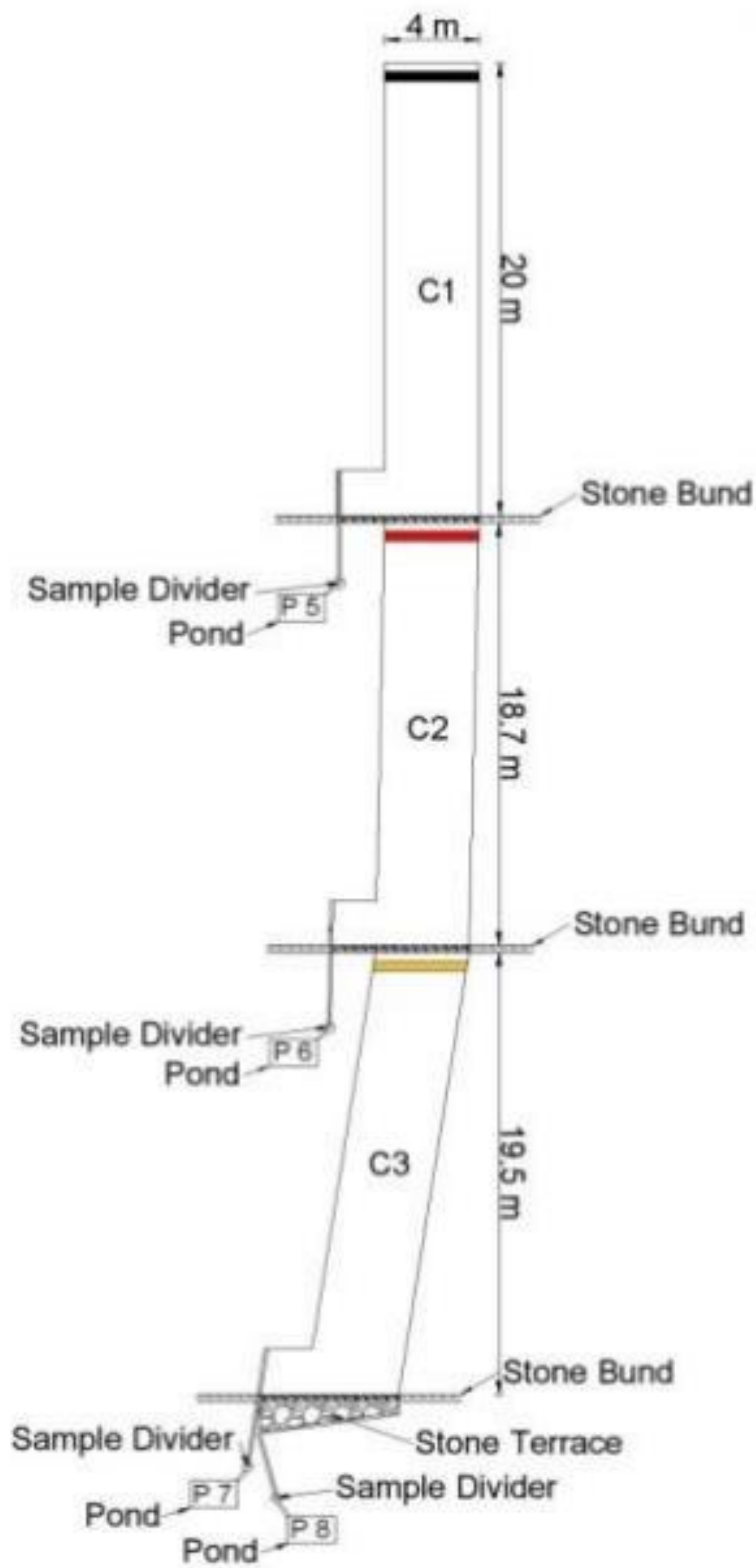


Figure 1. Plot layout of the cascade experiment (Obereder, 2016).

Results

Iron oxide content from the different combinations of sand and tracers were used to determine the capability of the modified method to extract the iron oxide content, added by the tracer's application, Figure 2.

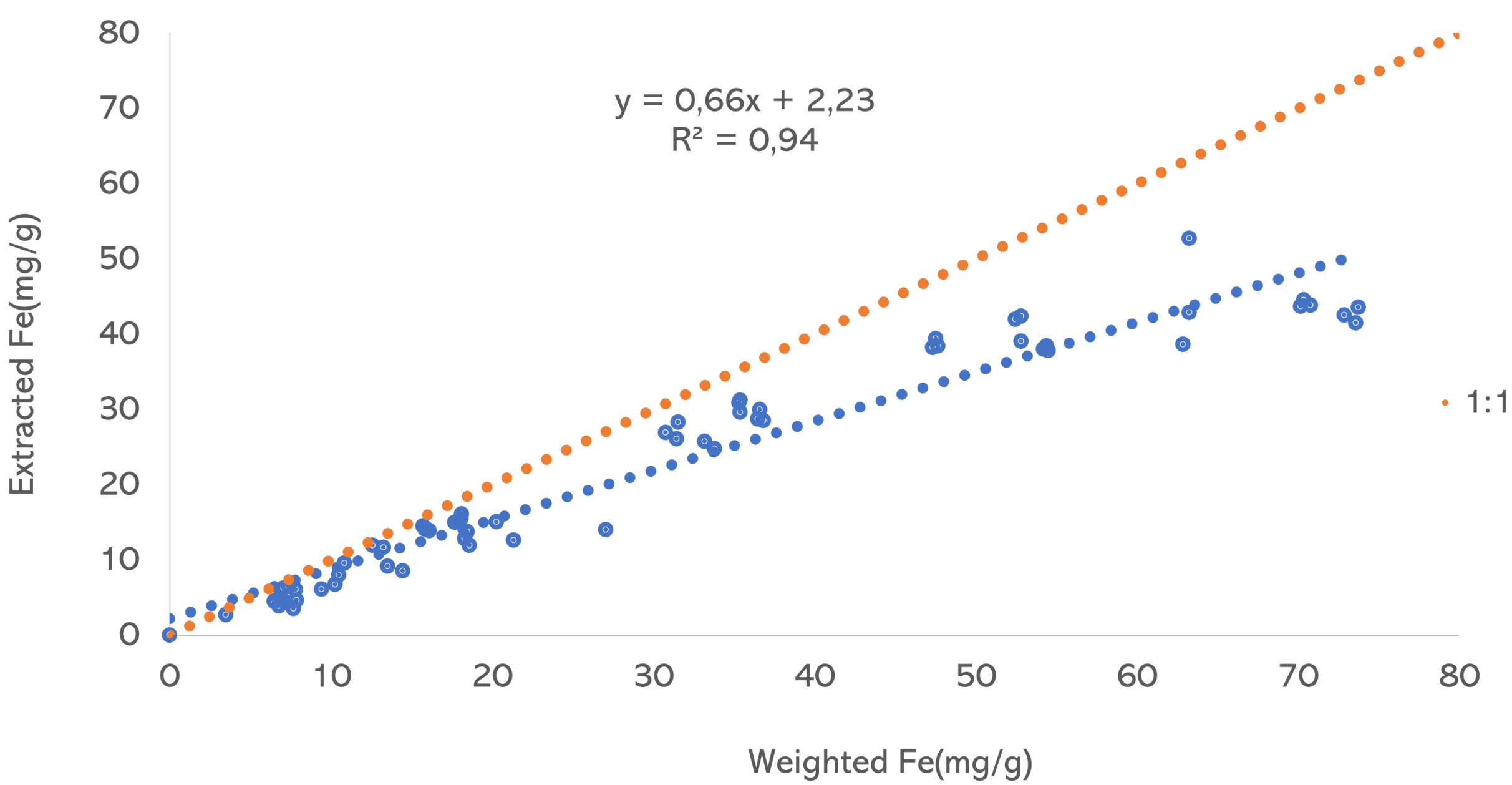


Figure 2. Weighted and measured iron content (X and Y axis) of prepared samples.

Textural class differs comparing soil and sediments at the trial, Table 1. These results combined with the ones shown in Figure 3, indicate some selectivity in sediment transport which might affect tracer concentration which tend to be linked to finer particles.

	Clay (%)	Silt (%)	Sand (%)
Sediment	65.03 ± 0.02 b	30.28 ± 0.03 a	4.70 ± 0.01 a
Soil	53.21 ± 0.05 a	31.05 ± 0.02 a	15.74 ± 0.05 b

Table 1. Average clay, silt and sand content and standard deviation of bulk soil and sediments at the trial. Different letters indicate significant differences (Kruskal-Wallis test, p<0.05).

Conclusions

The results depict the suitability of the CBD method extracting the three tracers with an average recovery rate ranging from of 0.8 to 0.6 based on the tracer combinations, concentrations and soil nature. That makes this procedure suitable for low amounts of soil samples, such as sediments, and high iron content soils. Further textural and visible spectrum analysis of the samples will allow to determine the selectivity factor and to discriminate qualitative and quantitatively hematite and goethite tracers.

The analysis of the iron content of soil and sediment samples indicates a relatively low movement of soil although showing significant statistical differences with background and mixture values, Figure 3, that is some sediment upslope reaches the lower areas. These results are in line with the ones detected by the magnetic susceptibility measurements (Obereder, 2016).

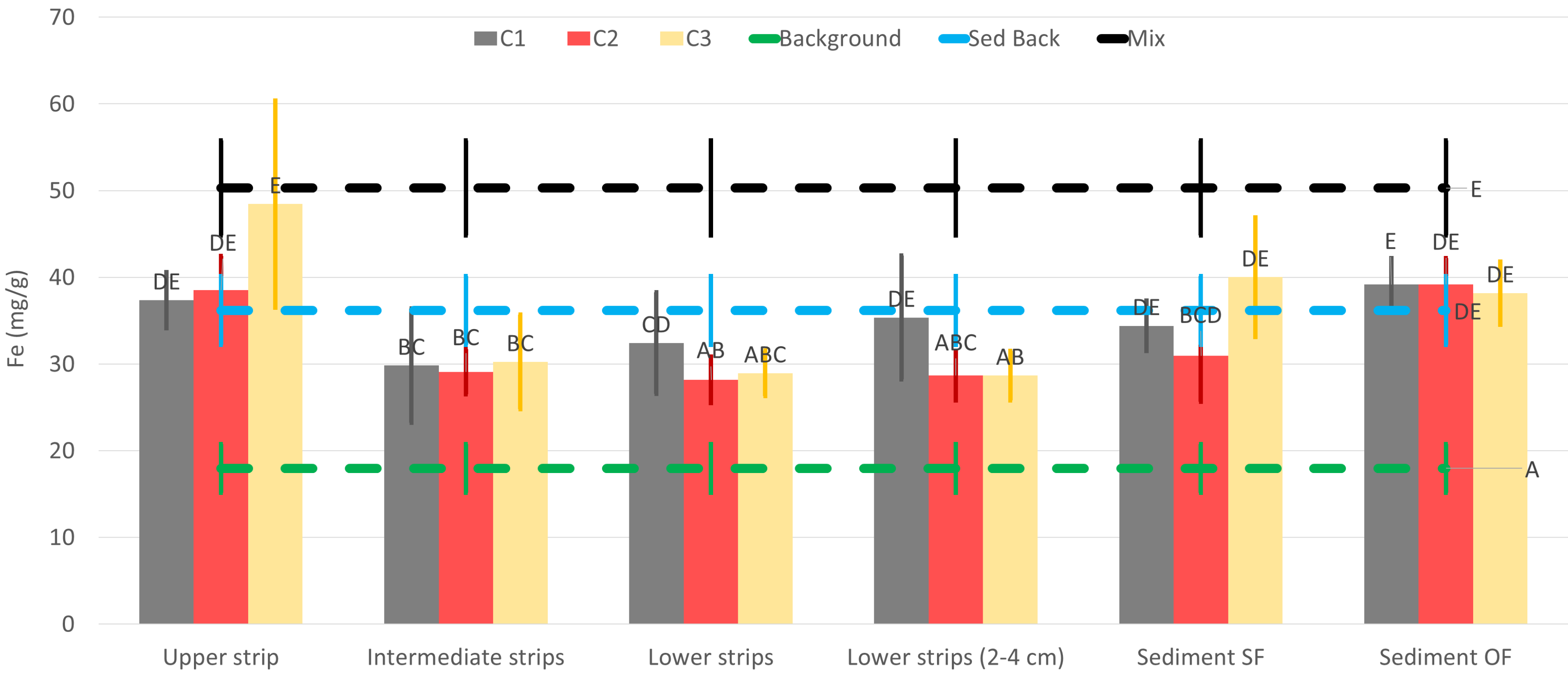


Figure 3. Average iron content and standard deviation from the trial. Different letters indicate significant differences (Kruskal-Wallis test, p<0.05).

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