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Hydrology and Earth System Sciences Discussions

Interactive comment on "Influence of basin connectivity on sediment source, transport, and storage within the Mkabela Basin, South Africa" *by* J. R. Miller et al.

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Reply to A. Parsons' Comments on "Influence of basin connectivity on sediment source, transport, and storage within the Mkabela Basin, South Africa" by Miller et al

General Issues

The review raises three important issues that require further discussion, including (1) the validity of mapping sediment provenance onto land use if the land use is not constant through time, (2) the assumption that the utilized mixing model assumes that all

sediment leaves all sources and arrives at the sampling point simultaneously, and (3) the technique (geochemical tracing) is capable only of telling us the ultimate source of sediment and not its proximal one. With regards to the latter point, we agree; the method is intended to determine the ultimate source of the sediment that was deposited and sampled within the wetland and reservoir. It is possible that sediment was eroded from a defined sediment source, transported downvalley and temporally deposited within the channel (or some other site) before being remobilized and transported to its current resting point where it was sampled. We believe that deposition and remobilization along the studied drainage system was minimal because the catchment areas upstream of the sampled sites are relatively small (< 1000 ha). The limited catchment areas increase the probability that eroded sand-sized and smaller sediment will be transported from the source to the point of deposition within the timeframe represented by a sample extracted from the analyzed cores (see below). Nonetheless, the point is well taken and will be discussed in the revised text.

Attempts to model complex processes generally require simplifying assumptions, and the use of sediment mixing models to assess sediment provenance is no exception. It is important to note, however, that constant erosion, transport, and depositional times only applies to mixing models when used to determine the relative amount of material eroded from a given sediment source. Let's take, for example, our 7 cm thick sampling interval collected from the core and assume that all of the sediment is derived from only two sources. One source is located immediately adjacent to the coring location, whereas the other is located a considerable distance from the site. Also assume that equal amounts are eroded from both sediment sources, and that 50 % of the sediment from both sources is deposited at the sampling site as the material is transported downstream. At the onset of the runoff event sediment from the closest site will reach the core first; thus, the lower portions of the sampling interval will be composed of material from only this source. As the event continues, material from the other source reaches the site, and equal proportions of the sediment from both sources are deposited at the site. If the entire 7 cm is not composed of a single event, the other events will follow the same pattern until 7 cm of sediment has been deposited. When the mixing model is applied to the sample, it will correctly indicate that a larger relative percent of sediment was derived from the closest site over the timeframe represented by the 7 cm increment. Thus, sediment provenance with respect to the deposit has been correctly assessed within the errors inherent in the statistical analysis. However, if the intent is determine the relative amount of sediment eroded from the two source areas, the results will be biased such that the model will overestimate the amount of material eroded from the closest source. A similar argument applies to differences in transport rates of different sized particles. Our interests here are primarily focused on the relative contribution of sediment from the various source types that comprise wetland and reservoir deposits as these differences are reflective of downstream sediment delivery and connectivity. We are also clearly interested in the amount of upland erosion from the defined sediment sources. We recognize that the estimated contributions with regards to upland erosion rates are biased, but minimal because with the exception of the vegetable plots (which includes areas of corn plus other vegetables such as cabbage), the defined sources upstream of the sampled wetland and reservoir are distributed throughout much of the catchment. It also is important to note that the results from the mixing model apply only to the deposits sampled from the wetland and upstream-most reservoir and cannot be extrapolated quantitatively downstream to the core collected from the riparian wetlands within the lower subcatchment (as discussed in more detail in the reply to the comments by A. Brosinsky).

The mapping of sediment provenance onto land use when land use has changed through time is a recognized problem associated with the use of geochemical fingerprinting techniques. Primarily at issue is whether alterations in land use will lead to changes in the concentration of the elements used to define the geochemical fingerprint such that the geochemistry of the sediment source samples reflects both its current and past land cover history. Or, perhaps more accurately, inhibits the identification of a geochemical fingerprint capable of defining a specific land use type. While potentially problematic, we believe that shifting land use did not significantly affect our

results. Land areas covered in wattle and pine forests as well as pasture have presumably changed little over a timeframe measured in decades. Areas planted in sugar cane also are relatively stable through time; although some minor areas of sugar cane were converted to corn (maize), sugar cane typically remains at a particular site for periods measured in years. We will attempt to quantify the timing and areas of these latter changes in land use more thoroughly for the revised manuscript by interviewing landowners. In addition, it should be recognized that difficulties in creating a fingerprint as a result of land-use alterations are most like to be associated with elements applied to agricultural fields (e.g., Cu and Zn) as a soil amendment. These amendments (fertilizers, etc.) may result in rapid geochemical changes in the analyzed materials. The geochemical fingerprints developed for the various land-use types defined in this study were based on highly immobile rare Earth elements that are less likely of exhibiting rapid changes in concentration within the sampled materials. Moreover, the discriminate analysis conducted within the study suggested that the developed fingerprints, while not perfect, were effective in differentiating land-use types in spite of the fact that some changes land cover occasionally occurred through time.

In light of the above, we agree that all three issues should be more fully discussed in the paper. Specifically, we will more fully explain the assumptions upon which the mixing model is based. We do not believe, however, that the issues raised above invalidate our primary conclusions including: (1) fine-grained sediment within the wetland and reservoir are ultimately derived from fine-grained lowland soils frequently used for vegetable plots and pastures, (2) the sand-sized sediment within the wetland and reservoir are geochemically distinct from sampled fine-grained units, and are ultimately derived from coarse-textured soils found on steep slopes, (3) the coarser sand-sized particles are transported to the wetland and reservoir during relatively moderate to high magnitude runoff events, and (4) a significant and abrupt change in sediment source to the wetland and reservoir occurred as a result of the constructed ditch through the wetland, and that this change in source explains the abrupt and systematic alterations in sediment geochemistry observed within multiple sediment cores extracted from along the drainage system.

Specific Comments

(1) We thank the reviewer for his constructive editorial comments and will incorporate the suggestions/corrections into the text. In order to more effectively visualize the linkages between land use and soil type, a land use map will be provide within the revised manuscript.

(2) Page 10158, L13-14: Comment: “This assumes that erosion is interill. Do you have evidence to support this assumption?” Unsupported 210Pb is atmospherically deposited across the landscape and concentrated within the upper centimeter of the land surface. Sediments containing unsupported 210Pb may then be eroded and transported downstream where it is deposited within a wetland, reservoir, or floodplain. As these deposits are buried, unsupported 210Pb content of the sediment decreases by means of radioactive decay, and it is this decrease that can be used to determine the age of the sediments as a function of depth. However, the method only works if the eroded material is derived from the uppermost soil surface which contains unsupported 210Pb from atmospheric deposition. Rill erosion of sediments from deeper horizons will possess limited unsupported 210Pb concentrations, and 210Pb measured in sediment cores will appear uniform. The 210Pb data collected in the wetland core of this study, that exhibited a systematic downward trend in unsupported 210Pb concentrations, suggests that sediment was primarily derived from the soil surface. It was these materials that were sampled to develop a fingerprint.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 9, 10151, 2012.