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Biogeosciences
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Interactive comment on "Sources and export of particle-borne organic matter during a monsoon flood in a catchment of northern Laos" *by* E. Gourdin et al.

E. Gourdin et al.

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Reply to Anonymous Referee #1

Reply to comment #1. The different particulate organic matter (POM) compositions recorded by δ13C measurements for the two sampling stations of the Houay Pano sub-catchment (S1 and S4) are most likely due to changes in the composition of sediment sources within the catchment and, downstream, to sorted sediment transport. Upstream of S1, i.e. the uppermost sampling station, the stream is directly connected to hillslopes cultivated with C4 plants (Job's tears) surrounding the gauging weir and the stream channel located immediately above is covered with Napier Grass (another

C4 plant). Therefore it is likely that suspended sediment loads are naturally labelled by 13C-enriched vegetation debris (higher C/N) and by topsoil organic matter (lower C/N) supplies during the water level rising stage. At peak flow, 13C-depleted compositions reflect the dominant contribution of remote fields, mainly cultivated with C3-plants (i.e.: -25.5 $\pm$ 1.4 ‰ in the 0-10 cm topsoil layer; Huon et al., Agriculture, Ecosystems and Environments, 169, 43-67, 2013) that dilute the "C4-signal" at the sampling station. In contrast, S4, i.e., the outlet gauging station of the Houay Pano sub-catchment, is located ca. 1.4 km downstream of S1 and drains a mosaic of steep cultivated fields with dominant C3 plant covers (upland rice) and tree plantations (teaks). The depleted composition of POM sampled during the flood is consistent with the land cover of the middle - lower part of the sub-catchment. However, between S1 and S4, the Houay Pano stream flows through a 0.19 ha swampy area (Figure 1 in the submitted manuscript), permanently covered with Taro (a C3 plant) at its inlet and with Napier grass (a C4 plant) in its central and outlet parts. The swamp acts as sediment filter (Huon et al., 2013) and a part of the suspended load is trapped and does not reach S4, except during high magnitude floods. For low to intermediate magnitude floods, like the one sampled in this study, downstream export mainly involves sediment conveyed during high water discharge periods. It is why the "C4-signal" is weakly recorded downstream at S4 and only during the water level rising stage (see Fig. 3 in the article submitted). A similar process can be observed further downstream between S4 and S10 (close to S4, Figure 1 in the submitted article) where another swampy area covered by Napier grass is found. The δ13C increase slightly (up to -23‰ due to the contribution of vegetation and weakly mineralized C4 labelled particulate organic matter (higher C/N). In the revised version of the manuscript we will provide these additional informations in the result and discussion sections. We will also further discuss the transfer of particulate organic matter along the three nested stations in order to take better into account the filtering role of swamps along the course of the stream as outlined in previous articles published for the same catchment (i.e., Huon et al., 2013).

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Reply to comment #2. We agree that the occurrence of particulate carbonate grains in suspended sediment loads may induce a problem for the interpretation of 13C-enrichments in particulate organic matter with respect to C3/C4-plant derived sources. We tested the possible presence of fine carbonate grains by adding a few drops of a 30 % HCl solution on suspended sediment separates collected at S1 and S4 during the water level rising stage and at peak flow but we did not observe any CO2 bubbling, typical for Ca-carbonate dissolution. It is likely that carbonate grains, "if present", do not represent a significant fraction of the sediment. Other arguments can be inferred from a previous study conducted in the swamp located between S1 and S4 (Huon et al., 2013). A 1.9 m-long sediment core (corresponding to the sediment sequence accumulated during the last 60 years) was sampled at the inlet of the swamp and the composition of sedimentary organic matter was analysed for each 10 cm depth interval and following the same analytical procedure as in this study. The δ13C averaged -26.2 $\pm$ 0.7 ‰ and we did not observe any 13C-enrichment that could be explained by the deposition of carbonates. If they were present, we should observe a "shift" of δ13C values in sediment deposits at the inlet of the swamp where water flow velocity drops down. Therefore the 13C-enrichment of suspended organic matter composition can be attributed to the cultivation of C4 plants in upper parts of the catchment. A last argument against the presence of significant carbonate contribution is that soils of the Houay Pano catchment have low pH (4.4 – 5.5, Chaplot et al., SSSAJ 73, 3, 769-779, 2009) indicating that CaCO3 cannot occur in the soil, even in the upper part of the catchment. Accordingly, soil erosion cannot supply significant amounts of particulate carbonate in suspended sediment loads. It is not the case for dissolved loads that are characterized by high water electrical conductivities controlled by carbonate dissolution and water residence time in upstream aquifers. As recommended, this information will be synthesised and added to the revised version of the manuscript in the "Materials and methods" section and as a separate paragraph at the beginning of "Discussion" section.

In the submitted manuscript, we thought that displaying the temporal evolution and trends of particulate organic matter - δ13C (together with several other parameters) during the flood was sufficient to illustrate the main changes in the sources of suspended sediments and their related thresholds, i.e., (1) the δ13C trend at flow peak that indicates that suspended organic matter composition evolves towards the average composition of catchment soils or (2) the mixing of C3-C4 plants and soil-derived organic matter that is mainly found in the upstream section during the water level rising stage. We are aware that mixing diagrams can be built up from our data and may provide a comprehensive picture of the mixing processes as suggested by the reviewer. We could then add a figure (displayed below) and further discuss the contribution of another possible source of particulate organic matter, i.e. "fossil organic carbon" (not relevant for our study). We did not perform bedrock analyses in this study as we have shown using fallout 137Cs, 210Pbxs and 7Be activities (Gourdin et al., Journal of Hydrology, on line http://dx.doi.org/10.1016/j.jhydrol.2014.09.056) that surface soil and riverbank sources of sediment explain the observed mixing trends. In a new figure A we reported literature data from Hilton et al. (Geochimica et Cosmochimica 74, 3164–318, 2010) and Kao and Liu (Global Biogeochemical Cycles 14, 189-198. 2000) for tropical mountainous catchments in Taiwan. The main information provided by this new figure is that our sediment loads do not match the published bedrock compositions (they can also be removed from the final figure).

Reply to comment #3. This question has been addressed in our reply to the reviewer's first comment.

All other specific (minor) comments and suggestions provided by the reviewer will be addressed in the revised version of the manuscript.

Reply to Anonymous Referee #2

Reply to comment #1. We agree that the occurrence of particulate carbonate grains in suspended sediment loads may induce a problem for the interpretation of 13C-enrichments in particulate organic matter with respect to C3/C4-plant derived sources. We tested the possible presence of fine carbonate grains by adding a few drops of a 30 % HCl solution on suspended sediment separates collected at S1 and S4 during the water level rising stage and at peak flow but we did not observe any CO2 bubbling, typical for Ca-carbonate dissolution. It is likely that carbonate grains, “if present”, do not represent a significant fraction of the sediment. Other arguments can be inferred from a previous study conducted in the swamp located between S1 and S4 (Huon et al., Agriculture, Ecosystems and Environments, 169, 43-67, 2013). A 1.9 m-long sediment core (corresponding to the sediment sequence accumulated during the last 60 years) was sampled at the inlet of the swamp and the composition of sedimentary organic matter was analysed for each 10 cm depth interval, following the same analytical procedure as in this study. The δ13C averaged -26.2 $\pm$ 0.7 ‰ and we did not observe any 13C-enrichment that could be explained by the deposition of carbonates. If they were present, we should observe a “shift” of δ13C values in sediment deposits at the inlet of the swamp where water flow velocity drops down. Therefore the 13C-enrichment of suspended organic matter composition can be attributed to the cultivation of C4 plants in upper parts of the catchment. A last argument against the presence of significant carbonate contribution is that soils of the Houay Pano catchment have low pHs (4.4 – 5.5, Chaplot et al., SSSAJ 73, 3, 769-779, 2009) indicating that CaCO3 cannot occur in the soil, even in the upper part of the catchment. Accordingly, soil erosion cannot supply significant amounts of particulate carbonate in suspended sediment loads. It is not the case for dissolved loads that are characterized by high water electrical conductivities, controlled by carbonate dissolution and water residence time in upstream aquifers. As recommended, this information will be synthesised and added to the revised version

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of the manuscript in the “Materials and methods” section and as a separate paragraph at the beginning of “Discussion” section.

Reply to comment #2. We are aware that lithic sources of particulate organic matter (so called “fossil carbon”, Meybeck, Advances in Soil Science, CRC Press, 2006) may represent a significant part of the particulate organic carbon exported, as shown in other catchments (e.g., Kao and Liu, Global Biogeochem. Cycles 14, 189-198, 2000; Huon et al., Advances in Soil Science, CRC Press 2006; Hilton et al., Geochimica et Cosmochimica 74: 3164–318, 2010). However, evidence for such a supply is often difficult to put forward. Sedimentary and meta-sedimentary rocks provide total organic matter δ13C that may overlap soil organic matter values. This approach is more relevant in large river systems (Galy et al., Geochimica et Cosmochimica Acta 72: 1767-1787, 2008; Clark et al. Geochemistry, Geophysics, Geosystems. 14: 1644-1659, 2013) and for simple binary mixtures with sediments originating from geographically distinct locations with contrasted geomorphic evolution or when these different areas are covered with contrasted vegetation (e.g., using C3 vs. C4 vegetation natural fingerprinting). It is not the case for the Houay Pano catchment covered by a mosaic of cultivated fields. The use of δ15N may help solving the problem (see new figure B). It is likely that δ15N in sedimentary and meta-sedimentary rocks will provide lower values that soil organic matter that underwent low temperature 15N/14N fractionation processes during mineralization in soils. However only scarce δ15N measurements have been reported for lithic sources of N and these measurements account for both organic matter and mineral bound ammonium contributions (e.g., Boudou et al., Fuel 63: 1508-1510, 1984; Bebout and Fogel, Geochimica et Cosmochimica Acta, 56: 2839-2849, 1992; Kao and Liu, previously cited 2000; Huon et al., previously cited 2006). Other field information does not support the hypothesis of an important supply of lithic sources of organic matter. We did not observe any mass movements along hillslopes of the catchment that could have induced a massive input of lithic material. This flood, representative

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of most of the events taking place in the region during the rainy season, was of low to intermediate magnitude and could be easily sampled and monitored. Finally; 137Cs and 210Pbxs/7Be labelling of suspended sediment during the same flood indicate that sediment in the stream was supplied by surface sources only (Gourdin et al., Journal of Hydrology, on line http://dx.doi.org/10.1016/j.jhydrol.2014.09.056).

Reply to comment #3. In the submitted manuscript, we thought that displaying the temporal evolution and trends of particulate organic matter - δ13C (together with several other parameters) during the flood was sufficient to illustrate the main changes in the sources of suspended sediments and their related thresholds, i.e., (1) the δ13C trend at flow peak that indicates that suspended organic matter composition evolves towards the average composition of catchment soils or (2) the mixing of C3-C4 plants and soil-derived organic matter that is mainly found in the upstream section during the water level rising stage. We are aware that mixing diagrams can be built up from our data and may provide a comprehensive picture of the mixing processes as suggested by the reviewer. We could then add a new figure (displayed below) and further discuss the contribution of another possible source of particulate organic matter, i.e. “fossil organic carbon”. We did not perform bedrock analyses in this study as we have shown using fallout 137Cs, 210Pbxs and 7Be activities (Gourdin et al., Journal of Hydrology, on line http://dx.doi.org/10.1016/j.jhydrol.2014.09.056) that surface soil and riverbank sources of sediment explain the observed mixing trends. In a new figure A we reported literature data from Hilton et al. (Geochimica et Cosmochimica 74: 3164–318, 2010) and Kao and Liu (Global Biogeochemical Cycles 14: 189-198. 2000) for tropical mountainous catchments in Taiwan. The main information provided by this new figure A is that our sediment loads do not match the published bedrock compositions (they can also be removed from the final figure).

On new figure C, The composition of TSS is well constrained for S1 and S4 with some deviation from the identified end-members for S10 due to insufficient “riverbank” and “gullies” sampling for organic matter measurements in the vicinity of S10. However, better constraints were provided by 137Cs and 210Pbxs/7Be measurements (Gourdin et al., Journal of Hydrology, on line http://dx.doi.org/10.1016/j.jhydrol.2014.09.056).

Reply to comment #4. We agree with the reviewer’s suggestion but for a slightly different reason. Additional sediment data and land use information are required to strengthen the comparison between previously published 2002-2003 annual sediments yields (Chaplot and Poesen, Catena 88: 46–56, 2012) and the flood sampled in 2012 (work in progress). This section will be shortened in the revised version of the manuscript.

Reply to comment #5. Our figure does not provide information on the contribution of this minor ungauged stream that did not convey significant sediment loads during the flood. This forgotten information will be added to the site description section of the revised version of the article.

All other specific (minor) comments and suggestions provided by the reviewer will be addressed in the revised version of the manuscript.

Interactive comment on Biogeosciences Discuss., 11, 9341, 2014.

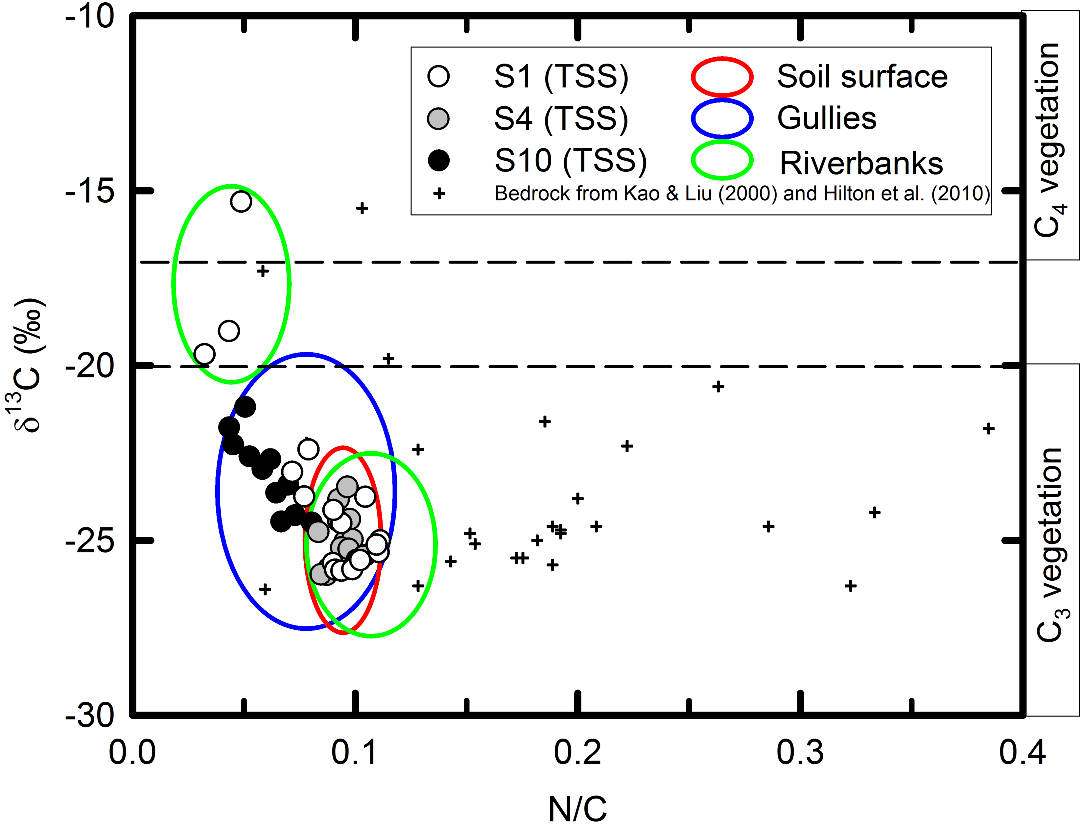

Fig. 1. New figure A – Plot of δ13C vs. N/C for total suspended sediment loads (TSS) in this study showing the possible sources of sediment. Bedrock data are taken from literature (see text).

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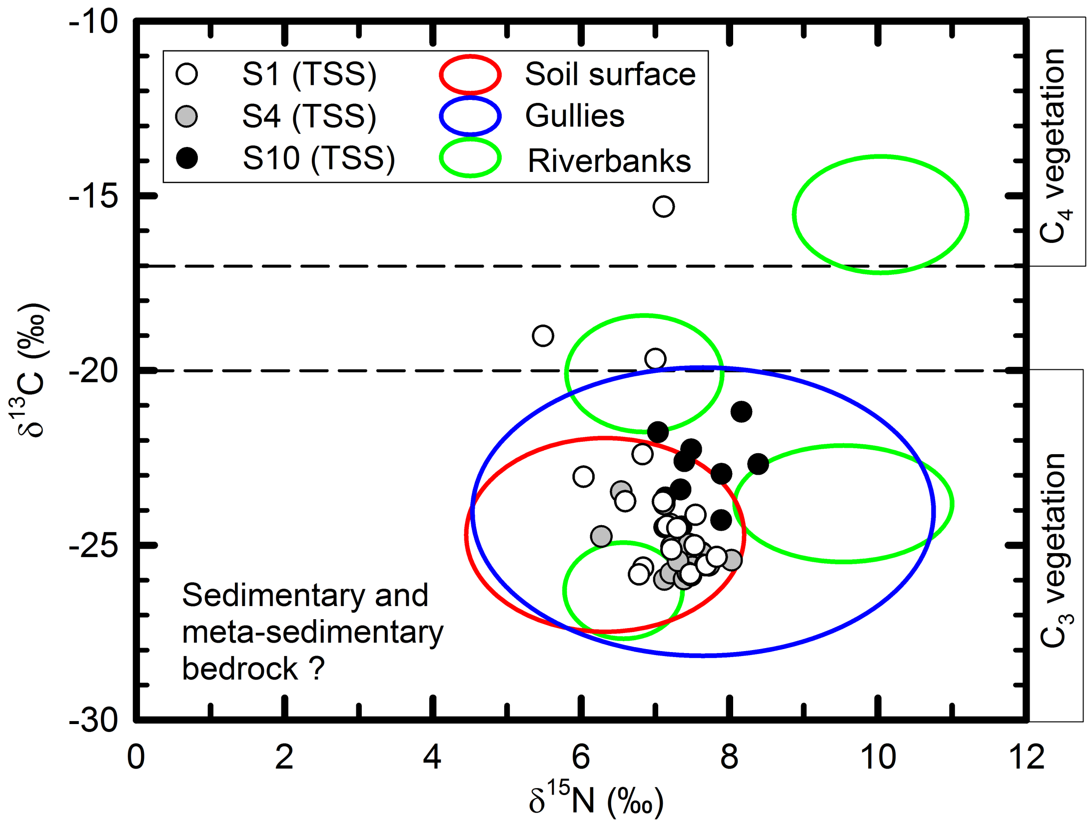

Fig. 2. New figure B - Plot of δ13C vs. δ15N for total suspended sediment loads (TSS) in this study showing the possible sources of sediment determined in the catchment.

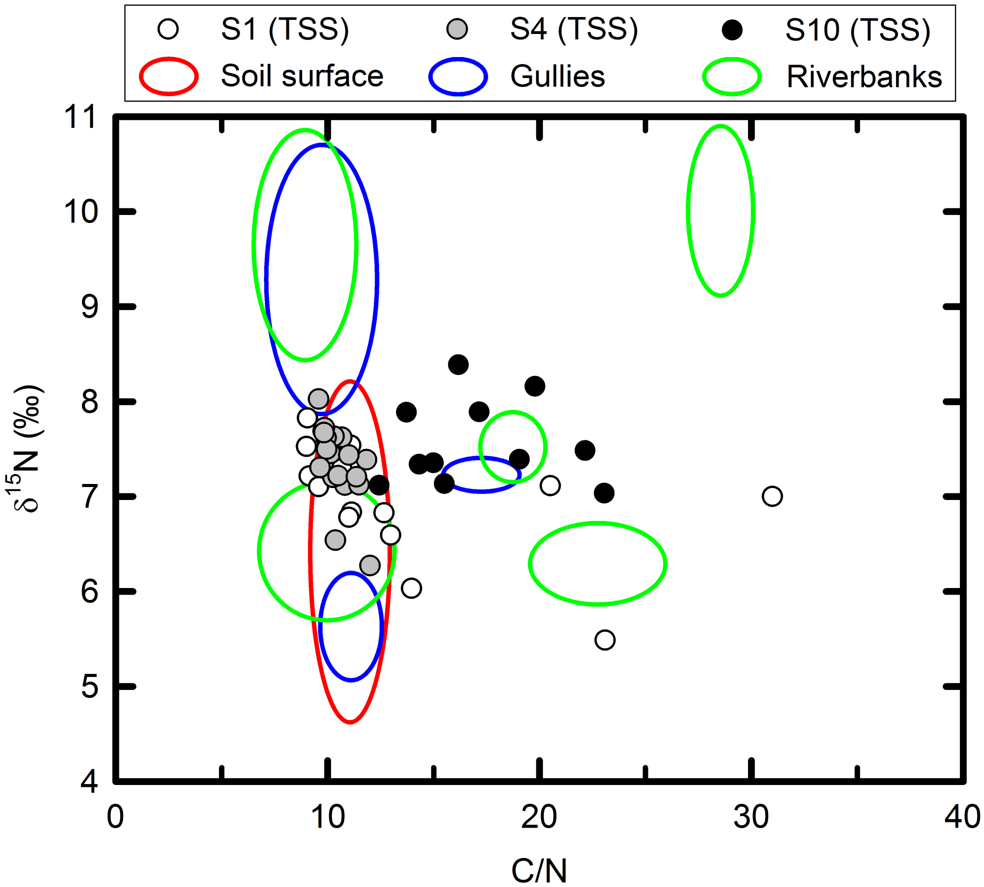

Fig. 3. New figure C – Plot of δ15N vs. C/N for total suspended sediment loads (TSS) showing the possible sources of sediment determined in the catchment.