Authors' Response

The detailed responses to the general and specific comments of the referees are first provided here together with corresponding changes applied to the revised manuscript, which follows (marked-up version: pages 17-54) in the second part of this document.

Point-by-point response to the reviews

Response to Referee #1

Small mountain river catchments are thought to play an important role in the erosion of particulate organic carbon (POC) and clastic sediment from the continents, delivering these materials to large river catchments and/or the coastal ocean. However, it is likely much of this POC flux occurs during storm events, which are challenging to sample. In order to better understand the processes operating in these catchments (and therefore what sets the rates of carbon export) it is necessary to examine these flashy events at high temporal resolution. Gourdin et al., contribute a detailed dataset, which examines the erosion of POC during an individual storm event in a small, tropical mountain river. In my opinion, the paper provides at least two novel insights which warrant publication and should interest the readership at Biogeosciences. First, the authors combine hydrological tracers (d18O) to quantify water sources and overland flow contribution. This allows them to interrogate the POC dataset in light of erosion pathways and processes. Second, it consists of three nested gauging stations, sampled at high resolution during the same storm event, providing the opportunity to track POC from hillslope to catchment-scale.

However, the paper was somewhat lacking in its analysis of the tracers of POC source. In my opinion, the work could be much improved by more detailed assessment of the stable isotope measurements (d13C and d15N) and element ratios (C/N) (points 1 and 2). In addition, I felt the two novel aspects I list above could be brought out more, especially the nested stations which weren't really discussed. I've outlined my thoughts on these points below. I've also provided some other comments, which I hope the authors find useful when making revisions.

1. d13C and C/N data: This data is very interesting, and not enough is made of it in the current manuscript. The description of the changes through the hydrograph are rather qualitative, and there is much more information to be gained. To illustrate that point, I've plotted d13C versus N/C for the data in the manuscript (see Figure 1) (N/C is chosen because the inverse of concentration versus its isotope ratio will reveal a binary mixture, or fractionating process, as a linear trend). The patterns are fascinating. They show at least two things which need further discussion. First, in S1 and S10, a trend from a C3 'soil-like' signature (d13C∼-26permil, N/C∼0.1) to a 'vegetation-like' signature with a higher N/C. This has a heavier isotopic signature, perhaps suggesting a C4 plant input (or could it be petrogenic? Or carbonate?). Material with this composition has not been collected in the catchment (Table 1). Second, why are the samples from S4, which is downstream of S1 and upstream of S10, not showing that 13C-enriched signal? Is this a sampling issue (different grain sizes?) or a real observation of fluctuating sources downstream? This point links to 3 below. The N/C vs d13C figure should be used to discuss these aspects in the paper. Related to this point, I think the authors need a more careful discussion of rock-derived ('petrogenic' or 'fossil') POC given the outcrops of sedimentary rocks in the catchment. Without 14C measurements, it is difficult to rule out its contribution with such high TSS (>1g/L is very high) given high petrogenic contributions are seen in other catchments where TSS reach that high (see the Taiwan work, and recent work in the Andes by Clark et al., 2013). The N/C and d13C data do suggest that C4 plant debris with low N/C is important, but they do not rule out a marine rock-source (d13C∼-21permil). Perhaps the high TOC% rule out a significant petrogenic source (which is likely to be more dilute? Unless a black shale?). A more careful discussion, aware of the caveats without 14C data, should be considered.

Response to point 1

The different particulate organic matter (POM) compositions recorded by δ^{13}C 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 C_4 plants (Job's tears) surrounding the gauging weir and the stream channel located immediately above is covered with Napier Grass (another C_4 plant). Therefore it is likely that suspended sediment loads are naturally labelled by ^{13}C-enriched vegetation debris (higher C/N) and by topsoil organic matter (lower C/N) supplies during the water level rising stage. At peak flow, ^{13}C-depleted compositions reflect the dominant contribution of remote fields, mainly cultivated with C_3-plants (i.e.: -25.5 ± 1.4 ‰ in the 0-10 cm topsoil layer; Huon et al., Agriculture, Ecosystems and Environments, 169, 43-67, 2013) that dilute the "C_4-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 C_3 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 (**Fig. 1** in the submitted manuscript), permanently covered with Taro (a C_3 plant) at its inlet and with Napier grass (a C_4 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 "C_4-signal" is weakly recorded downstream at S4 and only during the water level rising stage (see **Fig. 3** in the submitted article). 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 δ^{13}C increase slightly (up to -23‰) due to the contribution of vegetation and weakly mineralized C_4 labelled particulate organic matter (higher C/N). In the revised version of the manuscript we will provide these additional information 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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2. Role of carbonate: This is an important point, which needs more open discussion in the methods and results/discussion. The river suspended sediment samples weren't acidified to remove carbonate. This has some benefit, as the inorganic carbon removal protocol is known to attack some of the labile POC (Galy et al., 2007). However, it could severely bias the d13C (carbonate at -5 permil to +5 permil) and C/N (carbonate very high C/N). I think the N/C vs d13C plot points towards carbonate not being responsible for the 13C-enrichment, because the intercept at low N/C (the carbonate end member) is isotopically light. Still, there needs to be some commentary on this.

Response to point 2

We agree that the occurrence of particulate carbonate grains in suspended sediment loads may induce a problem for the interpretation of ^{13}C-enrichments in particulate organic matter with respect to C_3/C_4-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 CO_2 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 δ^{13}C averaged -26.2 ± 0.7 ‰ and we did not observe any ^{13}C-enrichment that could be explained by the deposition of carbonates. If they were present, we should observe a "shift" of δ^{13}C values in sediment deposits at the inlet of the swamp where water flow velocity drops down. Therefore the ^{13}C-enrichment of suspended organic matter composition can be attributed to the cultivation of C_4 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 $CaCO_3$ 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.

In the submitted manuscript, we thought that displaying the temporal evolution and trends of particulate organic matter - $\delta^{13}C$ (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 $\delta^{13}C$ trend at flow peak that indicates that suspended organic matter composition evolves towards the average composition of catchment soils or (2) the mixing of C_3-C_4 plant debris and soil-derived organic matter that is mainly found in the upstream section (S1) 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 added a figure (new **Fig. 6**) 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 ^{137}Cs, $^{210}Pb_{xs}$ and ^{7}Be activities (Gourdin et al., Journal of Hydrology 519, 1811-1823, 2014) that surface soil and riverbank sources of sediment explain the observed mixing trends. In a new figure (**Fig. 6**) we reported literature data from Hilton et al. (Geochimica et Cosmochimica Acta 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 if requested).

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3. Nested gauging stations: Very little seemed to be made of the nested gauging station and downstream transmission of sources. Particularly in the light of Figure 1 plotted here. This is a novel aspect which could be expanded upon.

Response to point 3

This question has been addressed in our response to the first comment.

All other specific comments and suggestions provided by the reviewer are addressed in the following

Comment #1: P9343-L12: Specify what subsurface samples, soil?

Reply to Comment #1: Subsurface soil samples were collected on the walls of gullies and riverbanks.The sentence was modified to specify the nature of collected samples.

Changes made: P17-L29-30: “soil surface and subsurface samples” was replaced by “soil surface (first 2 cm) and soil subsurface (gullies and riverbanks) samples”.

Comment #2: P9343-L22-25: Really, can you say that. Is it not more likely that the previous dataset don’t properly account for high flows? Rather than significant changes in land use?

Reply to Comment #2: The two last sentences of the abstract were rephrased in order to remove the former “too speculative” information and report information regarding the downstream transmission of suspended sediment loads (nested catchments).

Changes made: P18-L10-14: “Swampy areas located along the main stream that acted as sediment filter upstream and sediment sources downstream also controlled the composition of suspended organic matter. Despite the low magnitude of the flood, total organic carbon specific yields were high as this event was the first erosive of the rainy season, following the period of slash and burn in the catchment.

Comment #3: P9344-L11: why mention South American rivers here? Instead, is it useful to give some indication of the proportion of the global flux contributed? And which rivers you are referring to?

Reply to Comment #3: corrections made in the text (Asian tropical rivers)

Changes made: P18-L28-31: The sentence has been rephrased as follows: “Degens et al. (1991) identified the Asian tropical rivers (e.g., Mekong, Indus/Ganges/Brahmaputra) as the main contributors of dissolved (*ca.* 94 x 10^{12} gC yr^{-1}) and particulate (*ca.* 128 x 10^{12} gC yr^{-1}) organic matter to world oceans, accounting for more than 50% of global organic carbon inputs (about 335 x 10^{12} gC yr^{-1} excluding Australia)."

Comment #4: P9344-L15: I find this 'dilution' explanation potentially misleading. It is true that the %TOC can be reduced by adding inorganic (or mineral) sediments with low %TOC. However, at the same time, the total mass of suspended sediment increases (g/L), and therefore, the total mass of particulate organic carbon (g/L) also increases. You show this in your dataset pretty convincingly in Figure 5. I would suggest to rephrase this.

Reply to Comment #4: rephrasing done

Changes made: P19-L3-6: The sentence "indicating that particulate organic matter is diluted by high concentrations of mineral matter that is supplied to the rivers" was rephrased as follows "indicating that particulate organic matter is associated with higher concentrations of mineral matter in high TSS loads that are supplied to the rivers through erosion and sediment remobilization processes taking place along the river courses"

Comment #5: P9344-L27-28: This sentence jumps in logic, the thereby is misplaced. Please rephrase.

Reply to Comment #5: rephrasing done

Changes made: P19-L14-15: the sentence was rephrased as follows: "Suspended organic matter also contributes to water quality degradation (Tanik et al., 1999) and plays a major role in nutrient biogeochemical cycles (Quinton et al., 2010)".

Comment #6: P9345-L3-6: It seemed to me, the benefit of studies like this are to better understand the processes which mobilise organic matter (C and N) from soils and export them from river catchments. Surely this is the main contribution? I think this can be better explained.

Reply to Comment #6: sentence rephrased.

Changes made: P19-L20-22: The sentence "The design and implementation of appropriate management procedures require the identification of suspended organic matter sources and dynamics" was rephrased as follows: "The design and implementation of appropriate management procedures require the identification of the processes that mobilise organic matter from soils and export suspended organic matter to rivers."

Comment #7: P9345-L20-22: Linked to the previous comment, why are you doing this? This could be better explained.

Reply to Comment #7: sentences rephrased and information added.

Changes made: P20-L1-5: the sentence has been cut in two and the second half has been rephrased as follows: "The aim was to: (1) estimate the overland flow contribution to stream water and investigate its role for soil organic matter export, and (2) discriminate the respective contributions of soil and stream channel sediment supplies in order to identify the main processes responsible for particulate organic matter delivery at different nested spatial scales."

The sentence immediately following was also completed: "This study is complementary to a previous one, dedicated to the quantification of sediment dynamics from fallout radionuclide measurements (Gourdin et al., 2014), that highlighted the binary contribution of soil and stream channel sediment sources during the same erosive flood event."

Comment #8: P9346-L23: Is 'cliffs' needed here. What do you know about the %TOC content (and ideally C/N, d13C and d15N) of the sedimentary rocks? Somewhere in this section I feel you need to explain that the soil and gully samples were not collected from the steepest, highest elevation part of the S10 sub-catchment. Also, if rock samples were not collected, you should be upfront about that, and that you don't know their composition.

Reply to Comment #8: The term "cliffs" indicates that these vertical rock bars represent a very small area in the uppermost part of the catchment. The carbon content and the isotopic composition of basement rocks of the catchment were not studied as soil covers the entire catchment. These limestone bars (and some narrow stream channel sections) are the only outcrops of basement rocks. A sentence has been added in the text and precisions about the possible contribution of lithic sources of sediments will be addressed in section 3.1.

Changes made: P21-L9-11: sentence added: "Except for the limestone cliffs and some sections of the narrow streambed, soils or flooded soils cover the entire catchment".

P23-L8-9: sentence added :" No soil sample was collected in the south-eastern part of the catchment of S10."

Comment #9: P9348-L13: It's normally the case that particulate organic matter samples are filtered through 0.2-0.7micron filters. Was this not the case?

Reply to Comment #9: No, it was not the case. Total suspended sediment loads were recovered by total evaporation using a gas oven in the field. Temperature was *ca.* 60-80°C rather than 100°C (water ebullition) as written in the manuscript. Precisions will be added in the text in order to clarify this point.

Changes made: P22-L25-P23-L2: The sample preparation is detailed in a new paragraph: "Shortly after collection all samples were dried in 1 L aluminium trays in a gas oven (*ca*. 60-80°C) for 12-48 h. Preliminary studies carried out in 2002-2007 showed that dissolved organic carbon concentrations in the Houay Pano stream water are commonly low, 1.8 ± 0.4 mg L^{-1} (n = 74) and 2.0 ± 0.7 mg L^{-1} (n = 65), at base flow and discharge peak, respectively. With high-suspended sediment loads (see further in the Results section), a 3 mgC L^{-1} content for dissolved organic carbon would represent 1-10 wt% of the total (dissolved and particulate) organic carbon load. In average 97 ± 3 % of the total matter recovered is made of particulate matter, 90-95% during the water rising stage and 95-99% for the other water levels. We are confident that all measurements account for particulate organic matter with negligible dissolved loads and that the dynamics of organic compounds during the flood refers to particulate matter."

Comment #10: P9349-L6: Just a few pages ago you mention carbonate 'cliffs'. How can you be sure there is no carbonate? The TSS values are very high in your rivers (almost reaching Taiwan-like levels). It may be a logical assumption to make in acidic soils, but I'm not convinced that detrital carbonate is not playing a role (see also comments above).

Reply to Comment #10: The absence of carbonate in suspended sediment samples collected for different stages of the flood at S1 and S4 has been checked by adding drops of a 30% HCl solution and no CO_2-bubbling (that would have occurred in the presence of carbonate grains) could be observed. We therefore assume that, if present, this contribution is not significant and may be neglected. Precisions on the characteristics of the soils were added in the description of the study site (section 2, see above comment #6). The description of the HCl test has also been added in the material and method section 3.2.

Changes made: P21-L13-16: The following sentence has been added: "The soils have low pH ranging 4.4-5.5 (Chaplot et al., 2009) indicating that carbonate precipitation is not favoured in soils, even in the upper part of the catchment and, accordingly, cannot supply particulate inorganic carbon to suspended sediment loads."

P23-L25-30: The following sentence has been added: "The possible occurrence of carbonate minerals (or carbonate rock fragments) in TSS samples, collected at different stages of the flood at stations S1 and S4, was checked by pouring drops of a 30 % HCl solution on dry sample aliquots. No CO_2-bubbling, typical for carbonate dissolution, was observed. Therefore, common carbonate minerals such as calcite do not represent a detectable fraction of the suspended sediment loads and could be neglected."

Comment #11: P9350-L17: The d15N values seem very high for tropical vegetation and soil (see compilations from Martinelli et al., 1999 and recent work in Taiwan, Hilton et al., 2013). Is this worth commenting on?

Reply to Comment #11: We only measured soil $\delta^{15}N$ (typically enriched in ^{15}N with respect to vegetation) and Martinelli et al. (1999) reported an average $\delta^{15}N$ of 8 ‰ in bulk soils, consistent with our data. In contrast, Hilton et al. (2013) displayed $\delta^{15}N$ values ranging between 0.7 ‰ and 6.5 ‰ but this study accounted for soil and lithic sources of organic matter with variable mineralization status. The later should provide lower $\delta^{15}N$ than for soils as preservation of organic matter in sedimentary and low metamorphic grade rocks takes place at "high temperature" (lower $^{15}N/^{14}N$ fractionation) whereas incorporation and stabilization of organic matter in soils occurs at "low (surface) temperature" (higher $^{15}N/^{14}N$ fractionation). The paper by Amundson et al. (Global patterns of the isotopic composition of soil and plant nitrogen, Global Biogeochemical Cycles 17, 1031, 2003) provides $\delta^{15}N$ estimates for the first 50 cm of tropical soils covering our study area (*ca.* 6-10 ‰) that match our soil and suspended particulate organic matter data. High $\delta^{15}N$ is also an argument against important occurrence of rock-derived organic matter in suspended sediment loads.

Changes made: P25-L4-7: The following sentences were added: "Soil surface and subsurface sources can also be distinguished by their $\delta^{15}N$ values that are slightly lower for the former (**Table 1**). The overall values reflect high $^{15}N/^{14}N$ fractionation during incorporation and mineralization of plant tissues in soils, typical for tropical environments (e.g., Amundson et al., 2003)."

Comment #12: P9351-L4: these TSS values are very high. It is perhaps worth comparing to measurements made on other small tropical rivers.

Reply to Comment #12: This value corresponds to the maximum TSS concentration measured in overland flow at the 1m^2 scale. It is consistent with average values reported by Chaplot and Poesen (2012) at the same scale and in the same catchment (ranging between 2.8 and 8.4 g L^{-1}, respectively, from backslope to hillslope shoulder). At plot scale suspended loads are much higher up slope than down slope due to the deposition of soil-detached particles along catchment's slopes. It is difficult to provide direct comparisons with suspended loads of other small tropical rivers: physiographic setting, flood magnitude, land use and cultivation practise are too different.

Changes made: no change made in the revised manuscript.

Comment #13: P9351-L10: This observation has been made in small, steep catchments in other tropical settings (Clark et al., 2013) and temperate settings (Smith et al., 2013) and might be worth commenting on at this point.

Reply to Comment #13: Comments were added in order to compare the observed dynamics to the behaviours previously reported in the literature.

Changes made: P25-L25-29: The following sentence has been added: "Similar behaviours were reported by Clark et al. (2013) in the tropical Andes and interpreted as a greater contribution of non-fossil POC during the rising stage and the peak discharge and in the Swiss Alps by Smith et al. (2013) who interpreted the initial decrease of POC during the rising stage as resulting from in-channel clearing."

Comment #14: P9351-L24: it might be useful to refer to 2012 when using 23 May in the text (and subheadings) for clarity.

Reply to Comment #14: precision added.

Changes made in the revised manuscript as "23 May 2012 flood".

Comment #15: P9356-L1: why is this sentence a separate paragraph?

Reply to Comment #15: The sentence has been grouped with the following paragraph.

Changes made: The line feed has been deleted.

Comment #16: P9357-L8: This is a very long paragraph, and contains some novel and interesting observations. I'd recommend splitting it. Also, I think the discussion of organic matter sources needs to be more careful. The attached Figure 1 shows co-variation of N/C and d13C that needs to be discussed (see main comment above).

Response to Comment #16: This section has been rewritten and split into two paragraphs: "5.2.1 Sources of suspended organic matter in the catchment" and "5.2.2 Dynamics of suspended organic matter". The co-variation between TN/TOC and $\delta^{13}C$ is shown in a new **Fig. 6** placed in section 5.2.2 together with the composition of the possible mixing end-members determined for the catchment. Because carbonate and "fossil" organic matter sources of carbon in suspended sediment loads could be excluded or minimized, the co-variation is best explains by the mixing of surface soil and subsurface soil organic matter defined by the end-members. Considering the limited bedrock outcrops, the low magnitude of the flood, the absence of mass transport along catchment slopes and high $\delta^{15}N$ values in TSS loads (see above in the first reply), the correlation between TN/TOC and $\delta^{13}C$ highlights the mixing of C_3-C_4 labelled organic matter.

Changes made: major changes were made for this section. The former sentences were either completed or rewritten in the revised manuscript.

Comment #17: P9357-L14: I think it would be useful to link these concentration measurements to other places where 'fossil' POC has been observed, e.g. in the Andes (Clark et al., 2013) and Taiwan (e.g. Hilton et al., 2010).

Reply to Comment #17: Comparisons to literature data were added in the revised manuscript and reported in the new **Fig. 6** (see above comment #16).

Changes made: P31-L1-4: together with new sentences the following was added "In the Andes, Clark et al. (2013) identified fossil POC contributions associated with TSS concentrations above 1 g L^{-1}. In a Taiwanese river, Hilton et al. (2011) reported suspended sediment concentrations up to *ca.* 30 g L^{-1} leading to fossil POC concentrations up to *ca.* 0.1 g L^{-1}."

Comment #18: P9357-L20: What about the much larger, steeper Houay Xon river catchment (S10)? Where landslides/mass wasting processes occurring there?

Reply to Comment #18: The Houay Xon river catchment is larger but its channel is not steeper than the Houay Pano. In fact its slope is gentler and the connectivity of hillslopes with the main channel is lower. It is true that the S10 station drains the SE area that includes the highest elevations of the catchment, but this area is covered with old protected forests and no major tributary flows from it into the Houay Xon River. Considering land use and topography, sediments possibly generated by erosion in the upper part of the drainage area are deposited before reaching the main stream and the intermittent streams located upstream of S10 did not flow during the storm (Figure 1).

Changes made: P20-L30-P21-L5: the missing information was added in the revised manuscript in section 2 (study site): "The Houay Xon river catchment is larger but its channel is not steeper than for the Houay Pano subcatchment. Its slope is gentler and the connectivity of hillslopes with the main stream is lower. The drainage basin that includes the highest elevations of the catchment is covered with old protected forests but no major tributary flows into the Houay Xon River. Sediments generated by erosion in the drainage area can settle before reaching the main stream due to a decline of topography above the left bank of the river (**Fig. 1**). The intermittent streams located upstream of S10 did not flow during the 23 May 2012 flood."

Comment #19: P9357-L24: Is this a good point to split this long, but important paragraph?

Reply to Comment #19: Done

Changes made: Line feed added

Comment #20: P9359-L4: I wasn't convinced this section was useful, especially as this 137Cs data is not shown here.

Reply to Comment #20: As outlined at the end of the introduction section this study is complementary of a paper recently published (Gourdin et al., Journal of Hydrology 519, 1811-1823, 2014). The radionuclide measurements were carried out on the same sample aliquots (no transformation due to γ-counting) collected during the same flood than in this study. The main interest of referring to these data is that when fine suspended matter is tagged by ^{137}Cs, its origin can only be soils in surface position. Radionuclide fallout took place in the 1950-1970's during the period of maximum atmospheric nuclear bomb tests (maximum supply in 1963) with limited migration with soil depth. This radionuclide did not exist before atmospheric bomb tests started. Sediment labelling acts the same way ^{14}C does with organic matter and because soil organic matter is bound to fine soil clay particles, bedrocks are not labelled by ^{137}Cs. We think that mentioning this paper (where a full description and discussion is provided) in our discussion section will strengthen our interpretation as we already have a good idea of the contributing sources of sediments in the catchment.

Changes made: P30-33: we rephrased our discussion in this direction in the revised version of the manuscript in section 5.2.1 and 5.2.2.

Comment #21: P9360-L6: How do these storm specific POC yields relate to other measurements in tropical catchments? There are quite a lot of estimates from work in Taiwan.

Response to Comment #21: we reduced this part in the revised manuscript as we found out that the conclusions we could draw from the comparison between suspended organic matter collected a single low magnitude flood event (our study) with annual carbon budgets in the catchment (Chaplot and Poesen, 2012) or elsewhere were too speculative.

Changes made: several paragraphs were removed and the related modifications were made in the abstract, discussion and conclusion sections of the revised manuscript.

Comment #22: P9361-L13: It seems the discussion of the larger S10 catchment has been forgotten at this stage. I think the novelty of this study is the nested approach, which should come out in the conclusions.

Reply to Comment #22: we fully agree with this comment and the missing information and discussion were added in the revised version of the manuscript. Additional information for S10 was added in section 2 (study site) see above for comment #18. Information for the "nested catchment approach" is reported in a new rewritten section 5.2.3 reported below. Other changes were made in the concluding remarks section.

Changes made: "Nested approach". Changes were made in last part of the discussion section: 5.2.3 Suspended sediment and particulate organic carbon delivery. The following sentences were added and replace the former. "Compared to the 2002-2003 annual sediment yield at S4 (2090 kg ha^{-1} yr^{-1}) and S10 (540 kg ha^{-1} yr^{-1}) reported by Chaplot and Poesen (2012), the 23 May 2012 flood represented *ca.* 21% of the total annual exports recorded for both stations. These deliveries are high for a single event of moderate intensity. However, fallout radionuclide measurements (Gourdin et al., 2014) indicate that this flood was the first important erosive event of the 2012 rainy season and mainly consisted of remobilized river channel sediments (*ca.* 80%). The TSS yield (S_Y) of *ca.* 433 kg ha^{-1} (8.3 kgC ha^{-1}) at S4 is greater than at S1 and S10 (**Table 3**) and consistent with higher specific runoff and runoff coefficient values (**Table 2**). With a low value at S1, the succession of nested catchments was not related to a decrease in specific delivery when drainage area increased. This unusual behaviour is best explained by the occurrence of swamp areas along the main stream. In the upper part of the catchment, a natural swamp acts as a filter for sediments conveyed during low to medium magnitude floods (**Fig. 1**). Napier grass, the main aquatic plant forms dense masses of litter that reduce stream flow velocity during the rainy season. Nearly 33 Mg of soil-derived organic carbon was thus accumulated since the early 1960's (Huon et al., 2013). This swamp played a key role with respect to downstream export of suspended sediment during the 23 May 2012 flood. It also explains why the high $\delta^{13}C$ values of TSS loads, observed during the rising water stage upstream of the swamp (at S1), were only partly transmitted to S4. Soil-derived organic matter supplied by overland flow replaced the major part of the TSS during the rising stage, downstream of the swamp. A comparable picture can be drawn for the wetlands located at the outlet of the village. However in contrast this swampy area where streambanks are also encroached by Napier grass contributed to a rise of the $\delta^{13}C$ values of suspended organic matter at the monitoring station S10. This shift fingerprinted the extent of streambank sediment retention and mobilization processes taking place downstream in accordance with radionuclide activity measurements carried out for the same samples (Gourdin et al., 2014)."

Response to Referee #2

Gourdin et al. present a detailed characterization of riverine organic carbon composition during a storm event in a small catchment of Northern Laos. The authors use gauging data, water isotope and electric conductivity to characterize the hydrological response of the river system to the storm event. They then use riverine particulate organic carbon characterization (%C, %N, d13C, d15N) along with a characterization of soil organic matter at the plot scale to propose a model of organic carbon mobilization during the storm event. The combination of detailed characterization of hydrological/erosion processes and particulate organic carbon flux and composition assessments is interesting as it has the potential to provide a mechanistic understanding of particulate organic carbon mobilization during storms. In that regards the paper would deserve publication in Biogeosciences. That said, I am a bit disappointed by 1) the lack of in depth interpretation of the organic carbon composition (d13C, d15N, C/N) and, 2) the speculative nature of the last part of the discussion (i.e. comparison of the May 2012 organic carbon yields with previous estimates). As a result, I recommend that the paper be revised before publication. Detailed comments follow.

General comments

1) The authors claim that carbonate minerals are absent (and thereby justify not performing any acid treatment prior to organic carbon characterization) yet they mention the existence of "limestone cliffs" in the catchment. Even trace quantities of carbonates can severely affect the measured d13C, therefore the authors must demonstrate the complete absence of carbonate minerals.

Response to point 1

We agree that the occurrence of particulate carbonate grains in suspended sediment loads may induce a problem for the interpretation of ^{13}C-enrichments in particulate organic matter with respect to C_3/C_4-plant derived soil sources. We tested the possible presence of fine carbonate grains by adding 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 CO_2 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 δ^{13}C averaged -26.2 ± 0.7 ‰ and we did not observe any ^{13}C-enrichment that could be explained by the deposition of carbonates. If they were present, we should observe a "shift" of δ^{13}C values in sediment deposits at the inlet of the swamp where water flow velocity drops down. Therefore the ^{13}C-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 $CaCO_3$ 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 was synthesised and added to the revised version of the manuscript in the Materials and methods section (3.2. Particulate organic matter composition measurements).

"The possible occurrence of carbonate minerals (or carbonate rock fragments) in TSS samples, collected at different stages of the flood at stations S1 and S4, was checked by pouring drops of a 30% HCl solution on dry sample aliquots. No CO_2-bubbling, typical for carbonate dissolution, was observed. Therefore, common carbonate minerals such as calcite do not represent a detectable fraction of the suspended sediment loads and could be neglected. No additional treatment was applied."

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2) The authors claim that rock-derived organic carbon is not present in their samples, yet they do not demonstrate it. There is quickly growing body of literature dealing with the concentration, composition and dynamics of rock-derived organic carbon in rivers and as such the authors need to seriously consider this component of the organic carbon pool.

Response to point 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 Biogeochemical Cycles 14, 189-198, 2000; Huon et al., Advances in Soil Science, CRC Press 2006; Hilton et al., Geochimica et Cosmochimica Acta 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 $\delta^{13}C$ 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 $\delta^{15}N$ may help solving the problem. It is likely that $\delta^{15}N$ in sedimentary and meta-sedimentary rocks should provide lower values than soil organic matter that underwent low temperature $^{15}N/^{14}N$ fractionation processes during mineralization in soils. However only scarce $\delta^{15}N$ measurements have been reported for lithic sources of nitrogen 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). Field information do 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 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, ^{137}Cs and $^{210}Pb_{xs}/^{7}Be$ labelling of suspended sediment during the same flood indicate that suspended sediment in the stream was only supplied by surface (sub-surface) soil sources (Gourdin et al., Journal of Hydrology 519, 1811-1823, 2014).

Section 5.2 (P30-34) has been rewritten in order to better account for the fossil rock-derived source of organic matter together with a new **Fig. 6** (see in the revised manuscript and in comment 3 below).

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3) The authors did not make the most out of their organic matter characterization. They measured 3 conservative tracers (d13C, d15N and C/N) but haven't really exploited these data. For instance I would like to see cross plots such as d13C vs. N/C and d15C vs C/N. These should be very informative regarding the source/nature of the organic matter.

Response to point 3

In the submitted manuscript, we thought that displaying the temporal evolution and trends of particulate organic matter - $\delta^{13}C$ (together with several other parameters) during the flood was sufficient to picture the main changes in the sources of suspended sediments and their related thresholds, i.e., (1) the $\delta^{13}C$ trend at flow peak that indicates that suspended organic matter composition evolves towards the average composition of catchment soils or (2) the mixing of C_3-C_4 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 more comprehensive picture of the mixing processes as suggested by the reviewer. We added a new figure (**Fig. 6**, $\delta^{13}C$ *vs.* TN/TOC) in the revised manuscript and further discuss the possible contribution of "fossil organic carbon". We also reported literature data from Hilton et al. (Geochimica et Cosmochimica Acta 74: 3164-318, 2010) and Kao and Liu (Global Biogeochemical Cycles 14: 189-

198. 2000) for tropical mountainous catchments in Taiwan. We did not perform bedrock analyses in this study as we have shown using fallout ^{137}Cs, $^{210}Pb_{xs}$ and ^{7}Be activities (Gourdin et al., Journal of Hydrology, cited above) that surface soil and riverbank sources of sediment explain the observed mixing trends. The main information provided by this new **Fig. 6** is that our sediment loads do not match the published bedrock compositions (they can also be removed from the final figure). Plot of $\delta^{15}N$ *vs.* TOC/TN (Fig. A below) does not provide any new insight with respect to **Fig. 6**. 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 in the vicinity of S10.

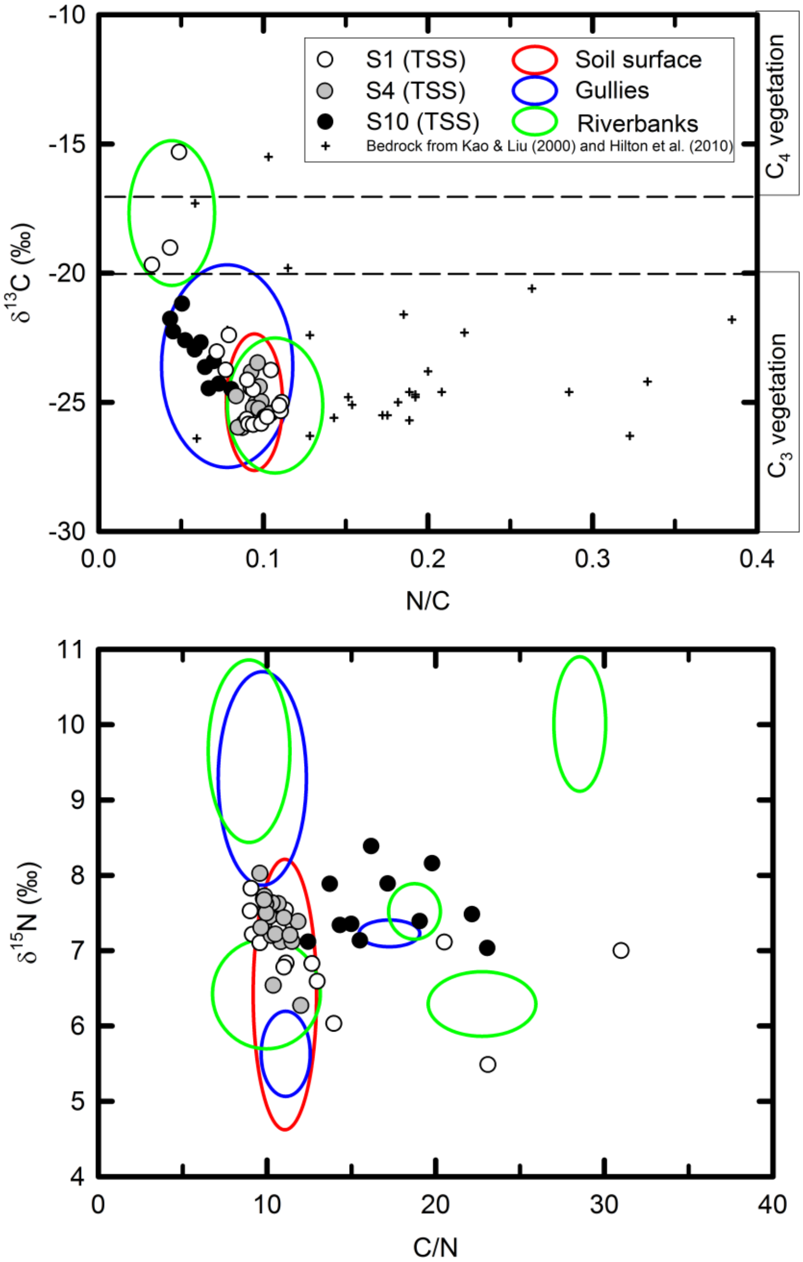

Figure A – Plots of $\delta^{13}C$ *vs.* TN/TOC (upper) and $\delta^{15}N$ *vs.* TOC/TN (lower) for total suspended sediment loads (TSS) showing the possible sources of sediments determined in the catchment (not displayed in the revised manuscript and replaced by new **Fig. 6**).

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4) The discussion of the temporal variation of the specific yields (section 5.2.3) is speculative. While it is possible that land use change explains the higher yield for the May 23rd storm the authors do not demonstrate it and other explanations (e.g. specific characteristics of the

storm) cannot be excluded. I recommend deleting this paragraph.

Response to point 4

We agree with the reviewer's suggestion but for a slightly different reason. Much more 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 has been shortened in the revised version of the manuscript (5.2.3. Suspended matter and particulate organic carbon deliveries) and new information on the transmission of suspended loads downstream with respect to the filtering role of swampy areas along the main stream replaces this former section. Related modifications have been made in the abstract and the concluding remarks (section 6).

P33-L25: New section 5.2.3: "Total suspended sediment exports are summarized in **Table 3** for S1, S4 and S10 sub-catchments. Compared to the 2002-2003 annual sediment yield at S4 (2090 kg ha^{-1} yr^{-1}) and S10 (540 kg ha^{-1} yr^{-1}) reported by Chaplot and Poesen (2012), the 23 May 2012 flood represented *ca.* 21% of the total annual exports recorded for both stations. These deliveries are high for a single event of moderate intensity. However, fallout radionuclide measurements (Gourdin et al., 2014) indicate that this flood was the first important erosive event of the 2012 rainy season and mainly consisted of remobilized river channel sediment (*ca.* 80%). The TSS yield (S_Y) of *ca.* 433 kg ha^{-1} (8.3 kgC ha^{-1}) at S4 is greater than at S1 and S10 (**Table 3**) and consistent with higher specific runoff and runoff coefficient values (**Table 2**). With a low value at S1, the succession of nested catchments was not related to a decrease in specific delivery when drainage area increased. This unusual behaviour is best explained by the occurrence of swamp areas along the main stream. In the upper part of the catchment, a natural swamp acts as a filter for sediments conveyed during low to medium magnitude floods (**Fig. 1**). Napier grass, the main aquatic plant forms dense masses of litter that reduce stream flow velocity during the rainy season. Nearly 33 Mg of soil-derived organic carbon was thus accumulated since the early 1960's (Huon et al., 2013). This swamp played a key role with respect to downstream export of suspended sediment during the 23 May 2012 flood. It also explains why the high δ^{13}C values of TSS loads, observed during the rising water stage upstream of the swamp (at S1), were only partly transmitted to S4. Soil-derived organic matter supplied by overland flow replaced the major part of the TSS during the rising stage, downstream of the swamp. A comparable picture can be drawn for the wetlands located at the outlet of the village. However in contrast this swampy area where streambanks are also encroached by Napier grass contributed to a rise of the δ^{13}C values of suspended organic matter at the monitoring station S10. This shift fingerprinted the extent of streambank sediment retention and mobilization processes taking place downstream in accordance with radionuclide activity measurements carried out for the same samples (Gourdin et al., 2014)."

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5) It appears to me that there is a large (relative to the size of the catchment) tributary that flows into the Houay Xon just upstream of S10. Given that the vegetation and land use in this sub catchment is drastically different (mostly old protected forest, see fig 1) one can imagine that the signal at S10 is dominantly controlled by the mixing proportions between the Houay Xon and this tributary. Interpreting the organic carbon composition at S10 would then require to at least characterize the composition of the organic matter in the tributary.

Response to point 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. We added the following information in the site description (section 2) of the revised version of the manuscript.

P20-L30-P21-L5: "The Houay Xon river catchment is larger but its channel is not steeper than for the Houay Pano subcatchment. Its slope is gentler and the connectivity of hillslopes with the main stream is lower. The drainage basin that includes the highest elevations of the catchment is covered with old protected forests but no major tributary flows into the Houay Xon River. Sediments generated by erosion in the drainage area can settle before reaching the main stream due to a decline of topography above the left bank of the river (Figure 1). The intermittent streams located upstream of S10 did not flow during the 23 May 2012 flood".

Specific comments

Comment #1: P9346 L21-23: any idea what the C concentration in the sandstones and greywackes is ?

Reply to comment #1: No, we did not perform any measurement for basement rocks that only scarcely outcrop: limestone cliffs in the uppermost NE part of the upper catchment and locally for a few 2-5 m sections of the streambed. The catchment is covered by soil and/or flooded soils in the swampy areas.

Changes made: P21-L7-10: The sentence has been rephrased as follows: "The geological basement of the Houay Pano upper catchment is mainly composed of pelites, sandstones and greywackes (not sampled), overlaid in its uppermost NE part by Carboniferous - Permian limestone cliffs (not sampled) that only cover a very small area in the catchment."

Comment #2: P9347 L1 (and throughout the ms): please use degrees for slopes, not %

Reply to comment #2: Slopes were converted from percentages to degrees has requested.

Changes made: P21-L19-20 "between 3 and 150%" was replaced by "between 2 and 57°" and P22-L16: "with 33% slope" was replaced by "with 18° slope".

Comment #3: P9348 L10: give sample volume

Response to Comment #3: The volume of the river water samples was 0.65 L.

Changes made P22-L22: "0.65 L" was added before "polyethylene bottles".

Comment #4: P9348-L11: what does 100 degrees C do to the organic matter? There is a possibility that the most labile compounds would degrade at this temperature.

Reply to comment #4: The sample preparation procedure was rewritten and details were added in the text in section 3.1. The temperature of the gas oven was lower than 100°C (no ebullition), likely *ca.* 60-80°C range) and labile dissolved organic phases were likely degraded.

Changes made: The sample preparation is detailed in a new paragraph: "Shortly after collection all samples were dried in 1 L aluminium trays in a gas oven (*ca*. 60-80°C) for 12-48 h. Preliminary studies carried out in 2002-2007 showed that dissolved organic carbon concentrations in the Houay Pano stream water are commonly low, 1.8 ± 0.4 mg L^{-1} (n = 74) and 2.0 ± 0.7 mg L^{-1} (n = 65), at base flow and discharge peak, respectively. With high-suspended sediment loads (see further in the Results section), a 3 mgC L^{-1} content for dissolved organic carbon would represent 1-10 wt% of the total (dissolved and particulate) organic carbon load. In average 97 ± 3 % of the total organic matter recovered is made of particulate organic matter, 90-95% during the water rising stage and 95-99% for the other water levels. We are confident that all measurements account for particulate organic matter with negligible dissolved loads and that the dynamics of organic coumpounds during the flood refers to particulate matter."

Comment #5: P9349: Please provide propagated uncertainty (i.e. taking into account precision and accuracy) for samples. Precision better than 0.1‰ for d15N is not common, please provide data supporting that statement.

Reply to comment #5: We fully agree with this comment. In fact there is a mistake in the text (an inopportune "copy and paste" of information relevant to a dual-inlet MS no longer used). One must read: precision is better than ± 0.2 ‰ for $\delta^{13}C$ and ± 0.3 ‰ for $\delta^{15}N$. The accuracy of MS measurements is based on repeated measurements of a 99% pure tyrosine standard (Girardin and Mariotti, 1991) still used in the lab. For each batch of 50 samples, 8 tyrosines are measured at the beginning and 10-12 additional tyrosines are placed between samples (every 5 sample intervals) to control the possible instrumental drift. However, some samples were repeated several times so that we can consider that precision can be lower than the assumed uncertainties ("is better than").

Change made P23-L20-25: The sentences: "Analytical precision was better than ± 0.1‰ *vs.* PDB-AIR standards (Coplen et al., 1983) and 0.1 mg g^{-1} (equivalent to 0.01 wt.%) for $\delta^{13}C$- $\delta^{15}N$ and TOC-TN, respectively. Data reproducibility was checked by replicate analyses of selected samples and of a tyrosine laboratory standard (Girardin and Mariotti, 1991)" were replaced by: "Analytical precision was better than ± 0.2 - 0.3 ‰ *vs.* PDB-AIR standards (Coplen et al., 1983) and 0.1 mg g^{-1} (equivalent to 0.01 wt.%) for $\delta^{13}C$- $\delta^{15}N$ and TOC-TN, respectively. Reproducibility was checked by replicate analyses of a 99% pure tyrosine laboratory standard (Girardin and Mariotti, 1991) using 18 tyrosines per batch of 50 samples. Selected sample measurements were also repeated during the course of the study.

Comment #6: P9350 L17-19: why are d15N values lower for surface organic matter ?

Reply to comment #6: surface soil organic matter is depleted in ^{15}N compared to deeper soil horizons because mineralization of plant tissues progressively enriches in ^{15}N the residual organic matter during its incorporation and burial in the soil. The lighter ^{14}N isotope is preferentially consumed and degraded by soil's microorganisms (e.g., Nadelhoffer and Fry, 1988. SSSAJ 52, 1633-1640; Martinelli et al., 1999, Biogeochemistry 46, 45-65). The $\delta^{15}N$ of soil organic matter increases with soil depth (e.g., between +1.1 and +4.2 ‰ at tropical sites, Martinelli et al., 1999) and mainly in the first 50 cm. Accordingly, the most superficial soil layer is less degraded and displays $\delta^{15}N$ values closer to the vegetation composition (typically *ca.* 0‰; e.g., Martinelli et al., 1999).

Changes made: none

Comment #7: P9351 L8-9: "that match topsoil organic matter composition" true at the beginning of the event, not so much by the end.

Reply to comment #7: some precision was added in the revised manuscript

Changes made P25-L22-23: the sentence has been completed: "with a slight evolution towards the composition of deeper superficial layers (1-3 cm) at the end of the event".

Comment #8: P9351 L9-10: "likely results from the preferential export of vegetation debris" is this supported by high C/N ratios?

Response to Comment #8: vegetation debris contain more C and N than soil organic matter due to the bacterial mineralization of plant tissues. Due to different mineralization rates C-rich compounds are more easily degraded than N-rich compounds and the TOC:TN ratio decreases during mineralization. Therefore, non-degraded vegetation or weakly mineralized soil organic matter should provide higher TOC/TN than soil organic matter. In contrast $\delta^{13}C$ and $\delta^{15}N$ increase due to preferential ^{14}N uptake during mineralization and accordingly non-degraded vegetation debris display lower values.

Changes made: none

Comment #9: P9354 L26-27: “high contribution of OF at this station” this is not that obvious when looking at the d18O – EF plot.

Reply to Comment #9: Yes, pre-event $\delta^{18}O$ values are missing, so the beginning of the dilution trend is not represented on this plot. However, we can see a major dilution pattern (EC decreased by more than 200 µS cm^{-1} in less than 10 min) at the beginning of the event (**Fig. 3IIIc**).

Changes made: P28 L25-27: the sentence has been rephrased as follows: “The EC values, decreasing from 450 to 155 µS cm^{-1} at the beginning of the event (**Fig. 3IIIc**), suggest a high contribution of OF at this station”.

Sources and export of particle-borne organic matter during a monsoon flood in a catchment of northern Laos

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Abstract:

Tropical rivers of Southeast Asia are characterized by high specific carbon yields and supplies to the ocean. The origin and dynamics of particulate organic matter were studied in the Houay Xon River catchment located in northern Laos during the first erosive flood of the rainy season in May 2012. The partly cultivated catchment is equipped with three successive gauging stations draining areas ranging between 0.2 and 11.6 km² on the main stem of the permanent stream, and two additional stations draining 0.6 ha hillslopes. In addition, the sequential monitoring of rainwater, overland flow and suspended organic matter compositions was realized at 1-m² plot scale during a single storm. The composition of particulate organic matter (total organic carbon, and total nitrogen concentrations, $\delta^{13}C$ and $\delta^{15}N$) was determined for suspended sediment, soil surface (first 2 cm) and soil subsurface (gullies and riverbanks) samples collected in the catchment (n = 57, 65 and 11 respectively). Hydrograph

separation of event water was conducted using water electric conductivity and δ^{18}O data measurements~~measured~~ for rainfall, overland flow and river water base flow (n = 9, 30 and 57, respectively). The composition of particulate organic matter indicates that upstream suspended sediments were mainly derived from cultivated soils labelled by their C_3 vegetation cover (upland rice, fallow vegetation and teak plantations) but that collapsed riverbanks, characterized by C_4 vegetation occurrence (Napier grass), significantly contributed to sediment yields in particular during water level rise~~ and at the downstream station~~. The highest runoff coefficient (11.7%), sediment specific yield (433 kg ha^{-1}), total organic carbon specific yield (8.3 kgC ha^{-1}) and overland flow contribution (78-100%) were found for the reforested areas covered by teak plantations. Swampy areas located along the main stream that acted as sediment filter upstream and sediment sources downstream also controlled the composition of suspended organic matter. Despite the low magnitude of the flood, ~~T~~total organic carbon specific yields were ~~up to 2.6-fold~~ high as this event was the first erosive of the rainy season, following the period of slash and burn in the catchment.~~er (at downstream station) than the annual ones calculated 10 years earlier, before the expansion of teak plantations in the catchment. They may be attributed both to the sampling period at the onset of the rainy season (following field clearing by slash and burn) and to the impact of land use change during the past decade.~~

1 Introduction

Soil is the largest terrestrial reservoir of carbon, exceeding biosphere and atmosphere storage capacities (e.g., Sarmiento and Gruber, 2002). Although tropical soils account for *ca.* 30% of the total carbon storage (e.g., Dixon et al., 1994; Zech et al., 1997), high intensity storms (e.g., Goldsmith et al., 2008, Thothong et al., 2011) as well as deforestation and land use change are responsible for high soil carbon losses and deliveries by rivers. For example Houghton (1991) estimated that deforestation in Laos, the sixth most affected tropical country according to the FAO / UNEP (1981), released *ca.* 85 x 10^{12} gC yr^{-1} to the atmosphere from 1979 to 1989. Degens et al. (1991) identified the Asian tropical rivers (e.g., Mekong, Indus/Ganges/Brahmaputra) as the main contributors of dissolved (*ca.* 94 x 10^{12} gC yr^{-1}) and particulate (*ca.* 128 x 10^{12} gC yr^{-1}) organic matter to world oceans, accounting for more than 50% of global organic carbon inputs (about 335 x 10^{12} gC yr^{-1} excluding Australia)~~, far before South American rivers~~. More recently, Huang et al. (2012) estimated that tropical rivers of Asia have the highest specific total~~ carbon~~, inorganic and organic, dissolved and particulate carbon yield in which *ca*. 25% of the delivery is made of particulate organic matter (POM). This latter component does not vary linearly with total suspended sediment load (Ludwig et al., 1996), indicating that particulate organic matter is ~~diluted~~ associated with~~by~~ higher concentrations of mineral matter in high TSS loads that ~~is~~ are supplied to the rivers through ~~soil and/or riverbank~~ erosion and sediment remobilization processes taking place along the river courses. Small mountainous headwater catchments play a key role in the delivery pattern because they are characterized by high specific discharges and sediment loads (Milliman and Syvitski, 1992). In this context, processes that control organic matter export from tropical catchments should be better understood and constrained, as they account for a significant component in the drawdown or emission of carbon dioxide (Lal, 2003).

Tropical storms may also result in the supply of large quantities of suspended sediment to streams (Descroix et al., 2008; Evrard et al., 2010) and lead to numerous problems downstream (Syvitski et al., 2005). Sediments can accumulate behind dams, which results in the siltation of water reservoirs (Downing et al., 2008; Thothong et al., 2011). Suspended organic matter also contributes to water quality degradation (Tanik et al., 1999) and plays~~ing~~ ~~thereby~~ a major role in nutrient biogeochemical cycles (Quinton et al., 2010). It also constitutes a potential vector for various contaminants such as metals, polycyclic aromatic hydrocarbons or faecal bacteria (Ribolzi et al., 2010; Gateuille et al., 2014). In order to reduce the extent of these negative impacts, sediment delivery by rivers needs to be monitored and controlled. The design and implementation of appropriate management procedures require the identification of the processes that mobilise organic matter from soils and export suspended organic matter to rivers~~sources and dynamics~~. To this end, total organic carbon (TOC) concentration measurements as well as natural $^{15}N/^{14}N$ (e.g., Mariotti et al, 1983; Kao and Liu, 2000, Huon et al., 2006) and $^{13}C/^{12}C$ (e.g., Masiello and Druffel, 2001; Hilton et al., 2010; Smith et al., 2013) stable isotope fingerprinting methods may be used on particulate material collected from hillslopes to rivers, either independantly or in combination with fallout radionuclides to document variations in sediment sources and pathways across catchments (e.g., Ritchie and McCarty, 2003; Ellis et al., 2012; Schindler Wildhaber et al., 2012; Ben Slimane et al., 2013; Koiter et al., 2013). In addition, complementary information on sediment conveyed to the river by runoff and overland flow can also be inferred from water tracers such as ^{18}O natural abundance (for a review see Klaus and McDonnell, 2013).

In this study, rainwater, stream water, overland flow and suspended sediment loads were sampled in the partly cultivated headwater catchment of the Houay Xon river, a small tributary of the Mekong River in Laos, during an erosive flood event that took place at the beginning of the 2012 rainy season. The aim was ~~in order~~ to: (1) estimate the overland flow contribution to stream water ~~and~~and investigate its role for soil organic matter export, and (2) discriminate the respective contributions of ~~surface~~ soil and stream channel ~~or material to particulate organic matter export~~sediment supplies in order to identify the main processes responsible for particulate organic matter delivery at different nested spatial scales. This study is complementary to a previous one dedicated to the quantification of sediment dynamics during the same erosive flood event from fallout radionuclide measurements (Gourdin et al., ~~under review~~2014), that highlighted the binary contribution of soil and stream channel sediment sources during the same erosive flood event.

2 Study site

The Houay Pano catchment, part of the MSEC (Monitoring Soil Erosion Consortium) network since 1998 (Valentin et al., 2008), is located 10 km south of Luang Prabang in northern Laos (19.84°N - 102.14°E; **Fig. 1**).

[Fig. 1]

The tropical monsoon climate of the region is characterized by the succession of dry and wet seasons. Almost 80% of annual rainfall (1960-2013 average: 1302 ± 364 mm yr^{-1}) occurs during the rainy season, from May to October (Ribolzi et al., 2008). The Houay Pano permanent stream has an average base flow of 0.4 ± 0.1 L s^{-1} and is equipped with 5 gauging stations that subdivide the catchment into nested sub-catchments. Two of these stations, S1 and S4, draining 20 ha and 60 ha respectively, are located along the main stem of the stream. Two additional stations (S7 and S8) draining two hillslopes (0.6 ha each) connected to the main stream between S1 and S4 were also monitored. Between S1 and S4, water flows through a natural swamp (0.19 ha), fed by a permanent groundwater table (**Fig. 1**). Only temporary foot slope and flood deposits can be found along the narrow section of the stream and the swamp represents the ~~major~~ main sediment accumulation zone in the upper catchment. The Houay Pano stream flows into the Houay Xon River (22.4 km² catchment) and crosses another swampy area (*ca.* 3 ha), partly occupied by fishponds (*ca.* 0.6 ha) at the outlet of the village. Its discharge is continuously monitored at S10 (draining a 11.6 km² sub-catchment), located 2.8 km downstream of S4. The Houay Xon River catchment is larger but its channel is not steeper than for the Houay Pano sub-catchment. Its slope is gentler and the connectivity of hillslopes with the main stream is lower. The drainage basin that includes the highest elevations of the catchment is covered with old protected forests but no major tributary flows into the Houay Xon River. Sediments generated by erosion in the drainage area can settle before reaching the main stream due to a decline of topography above the left bank of the river (**Fig. 1**). The intermittent streams located upstream of S10 did not flow during the 23 May 2012 flood. The Houay Xon is a tributary of the Nam Dong River, flowing into the Mekong River within the city of Luang Prabang (Ribolzi et al., 2010).

The geological basement of the Houay Pano upper catchment is mainly composed of pelites, sandstones and greywackes (not sampled), overlaid in its uppermost NE part by Carboniferous - Permian limestone cliffs (not sampled) that only cover a very small area in the catchment. Except for the limestone cliffs and some sections of the narrow streambed, soils or flooded soils cover the entire catchment. They ~~Soils~~ consist of deep (>2 m) and moderately deep (>0.5 m) Alfisols (UNESCO, 1974), except along crests and ridges where Inceptisols can be found (Chaplot et al., 2009). The soils have low pH ranging between 4.4 and 5.5 (Chaplot et al., 2009) indicating that carbonate precipitation is not favoured in soils, even in the upper part of the catchment and, accordingly, cannot supply particulate inorganic carbon to suspended sediment loads. Native vegetation consisted of lowland forest dominated by bamboos that were first cleared to implement shifting cultivation of upland rice at the end of the 1960s (Huon et al., 2013). Elevation across the Houay Xon catchment ranges between 272 and 1300 m a.s.l. As cultivation takes place on steep slopes ranging between ~~3~~ 2 and ~~150%~~57°, land use evolution in the catchment is prone to soil erosion (Chaplot et al., 2005; Ribolzi et al., 2011). Due to the decline of soil productivity triggered by soil erosion over the years (Patin et al., 2012) and to an increasing labour need to control weed invasion (Dupin et al., 2009), farmers progressively replaced rice fields by teak plantations in the catchment (**Fig. 1**). In 2012 the Houay Pano catchment was covered by teaks (36%), rotating cropping lands under fallow (35%), Job's tears (10%), bananas (4%), upland rice (3%) and secondary forest (<9%). The vegetation cover was different in the larger area drained by the Houay Xon River, with 56% of forests, 15% under teak plantations and 23% croplands.

3 Materials and methods

3.1 Sample and data collection

Rainfall, stream and overland flow waters were sampled during the 23 May ~~23~~ flood in 2012. Rainfall intensity (I) was monitored with an automatic weather station (elevation: 536 m a.s.l.;

Fig. 1) and stream discharge was calculated from water level continuous recording and rating curves. Estimates of event water discharge (EWD), defined here as the total water volume exported from each sub-catchment during the event minus the base flow discharge, were calculated by adding sequential water volumes corresponding to the average discharge between two water level measurements. Specific runoff (SR, in mm) was obtained by dividing EWD by the corresponding sub-catchment area (Chow et al., 1988).

Rainfall was sampled with three cumulative collectors located: in the village near the confluence between the Houay Pano and Houay Xon streams, near a teak plantation on the hillslopes located just upstream of the village and within the Houay Pano catchment (**Fig. 1**). The runoff coefficient (RC) corresponds to the fraction of total rainfall that was exported from the catchment during the event. Overland flow was collected at the outlet of 1-m^2 experimental plots (OF_{1m^2}) designed for runoff studies (Patin et al., 2012). For one of them (**Fig. 2**) the evolution of rainwater, overland flow and suspended organic matter composition was monitored during a rainfall event (June 1, 2012), simultaneously at its outlet and for a *ca.* 8-m^2 rain-collector set-up located a few meters apart. The experiment was conducted on a soil with ~~33%~~18° slope and *ca.* 60% fallow vegetation cover (*ca.* 10 cm high; **Fig. 2a**). The rain collector was installed at 1.8 m above soil surface to avoid splash contamination. Four samples were collected in the first 3 cm of a soil profile (0-5 mm; 6-10 mm; 11-20 mm; 21-30 mm) within a *ca.* 400-cm^2 area adjacent to the experimental plot to estimate the composition of organic matter in the topsoil layer (**Fig. 2b**).

[**Fig. 2**]

River water was collected in 0.65 L polyethylene bottles for each 20-mm water level change by automatic samplers installed at each gauging station. Sixty-nine total suspended sediment (TSS) samples were collected for five stations, S1, S4 and S10 on the main stem and S7 - S8 for hillslopes drained by temporary tributaries (**Fig. 1**). Shortly after collection all samples were dried in 1 L aluminium trays in a gas oven (ca. 60-80°C) for 12-48 h. Preliminary studies carried out in 2002-2007 showed that dissolved organic carbon concentrations in the Houay Pano stream water are commonly low, 1.8 ± 0.4 mg L^{-1} (n = 74) and 2.0 ± 0.7 mg L^{-1} (n = 65), at base flow and discharge peak, respectively. With high-suspended sediment loads (see further in the Results section), a 3 mgC L^{-1} content for dissolved organic carbon would represent 1-10 wt% of the total (dissolved and particulate) organic carbon load. In average 97 ± 3 % of the total organic matter recovered is made of particulate organic matter, 90-95% during the water rising stage and 95-99% for the other water levels. We are confident that all measurements account for particulate organic matter with negligible dissolved loads and that the dynamics of organic compounds during the flood refers to particulate matter.~~Samples were dried shortly after collection in an oven (t ≈ 100°C) for 12-48 h.~~ To complete the topsoil data set available for the catchment (Huon et al., 2013), additional soil cores were collected on hillslopes connected to the Houay Pano stream and the Houay Xon River (**Fig. 1**) in May and December 2012. Sampling was further completed with several gully (n = 5) and riverbank (n = 6) samples in December 2012 to document the characteristics of the potential subsurface sources of sediment to the river. No soil sample was collected in the south-eastern part of the catchment of S10.

Cumulated suspended sediment yields (SSY) were calculated at each station by adding the total suspended sediment (TSS) masses exported between two successive samples. The TSS concentration was considered to vary linearly between successive measurements. Specific sediment yields (S_Y) were calculated by dividing the cumulated SSY by the corresponding drainage area.

3.2 Particulate organic matter composition measurements

All samples were finely grounded with an agate mortar, weighed and packed into tin capsules (5 x 9 mm) for analysis. Total organic carbon (TOC) and total nitrogen (TN) concentrations, and $^{13}C/^{12}C$ and $^{15}N/^{14}N$ stable isotopes were measured using the Elementar® VarioPyro cube analyzer on line with a Micromass® Isoprime Isotope Ratio Mass Spectrometer (IRMS) facility (IEES, Paris). Analytical precision was better than ± 0.~~1~~2 - 0.3‰ *vs.* PDB-AIR standards (Coplen et al., 1983) and 0.1 mg g^{-1} (equivalent to 0.01 wt.%) for $\delta^{13}C$-$\delta^{15}N$ and TOC-TN, respectively. Data reproducibility was checked by replicate analyses of ~~selected samples and of~~ a 99% pure tyrosine laboratory standard (Girardin and Mariotti, 1991) using 18 tyrosines per batch of 50 samples. Selected sample measurements were also repeated during the course of the study. The possible occurrence of carbonate minerals (or carbonate rock fragments) in TSS samples, collected at different stages of the flood at stations S1 and S4, was checked by pouring drops of a 30% HCl solution on dry sample aliquots. No CO_2-bubbling, typical for carbonate dissolution, was observed. Therefore, common carbonate minerals such as calcite do not represent a detectable fraction of the suspended sediment loads and could be neglected. ~~Due to the absence of carbonate minerals in sediments and suspended loads,~~ ~~n~~No additional treatment was ~~requir~~applied. For the entire flood, total particulate organic carbon yields (C_{SSY}) were calculated by summing the successive TOC contents associated with suspended sediments (SSY multiplied by TOC concentration). The TOC concentration of particulate organic matter was assumed to vary linearly between successive samples. Specific TOC yields (C_Y) were calculated by dividing the cumulated C_{SSY} by the corresponding drainage area.

3.3 Water $\delta^{18}O$ and electrical conductivity measurements

Water aliquots were recovered in 30-mL glass flasks from stream, overland flow and rain samples (see **section 3.1** for details) and filtered using <0.2 µm acetate filters. Stable $^{18}O/^{16}O$ isotope measurements were carried out using the standard CO_2 equilibration method (Epstein and Mayeda, 1953) and determined with a VG Optima® mass spectrometer (IEES, Thiverval-Grignon). Isotopic ratios are reported using the $\delta^{18}O$ notation, relative to the Vienna-Standard Mean Ocean Water (V-SMOW; Gonfiantini, 1978) with an analytical precision better than ± 0.1‰. Water electrical conductivity (EC) was monitored every 6-min at the inlet of each gauging station using Schlumberger in situ CTD probes. Additional measurements were conducted using an YSI® 556 probe for manually collected samples. Hydrograph separation was carried out with end-member mixing equations using water electrical conductivity and $\delta^{18}O$ measurements (Sklash and Farvolden, 1979; Ribolzi et al., 2000; Ladouche et al., 2001).

4 Results

4.1 Composition of the potential sources of particulate organic matter in the catchment

The mean organic matter characteristics are reported in **Table 1** for surface soils, gullies and stream banks collected in the catchment, together with ^{137}Cs activity determined on the same sample aliquots (Huon et al., 2013; Gourdin et al., ~~under review~~2014). In contrast to the high ^{137}Cs activities measured in surface soil samples, gully and riverbank sites are depleted in this radioisotope (**Table 1**).

[**Table 1**]

Surface (soils) and subsurface (stream banks and gullies) sources of particulate organic matter are best discriminated by their TOC content that is higher in surface soils. The dominance of C_3 photosynthetic pathway plants across the catchment is reflected by low $\delta^{13}C$ values in soils (-25.5 ± 1.4‰). However, soil-originating particles accumulated in sediments of the swamp provide ^{13}C-enriched compositions, up to *ca.* -15‰, that are explained by the ~~strong~~

~~contribution~~input of ~~particulate~~ organic matter derived from C_4 photosynthetic pathway plant tissues. The latter are mainly Napier grass growing in the swamp and along limited sections of the stream channel, and to a much lower extent, Job's tears and maize cultivated on nearby hillslopes (Huon et al., 2013). Soil surface and subsurface sources can also be distinguished by their δ^{15}N values that are slightly lower for ~~surface sources~~the former (**Table 1**). The overall values reflect high ^{15}N/^{14}N fractionation during incorporation and mineralization of plant tissues in soils, typical for tropical environments (e.g., Amundson et al., 2003).

4.2 Monitoring water and particulate organic matter exports at the microplot scale during a rainfall event

The distribution of organic matter composition with soil depth is displayed on **Fig. 2b**. The TOC content decreases exponentially with depth together with TN (not plotted), leading to a nearly constant TOC : TN ratio of *ca.* 10 (**Fig. 2b**). Both δ^{13}C and δ^{15}N increase with soil depth from -26.3 to -24.7‰ and from 6.6 to 8.6‰, respectively, reflecting the contribution of fallow vegetation debris depleted in ^{13}C and ^{15}N with respect to soil organic matter (Balesdent et al., 1993). Overland flow samples (OF) were collected continuously at the outlet of the experimental plot during the June 1st storm that lasted for 45-min. Cumulated rainfall was *ca.* 11 mm and its intensity reached 30 mm h^{-1} during 20 min. Suspended sediment concentration increased to a maximum of 4.7 g L^{-1} (**Fig. 2c-d**). The estimated runoff coefficient was 77% during the entire storm with an average infiltration rate of 3.3 mm h^{-1}, assuming no evaporation during rainfall. As shown on **Fig. 2c**, suspended sediments exported from the experimental plot were characterized by TOC, TOC/TN, δ^{13}C and δ^{15}N values that match topsoil organic matter composition (**Fig. 2b**), with a slight evolution towards the composition of deeper superficial layers (1-3 cm) at the end of the event. The higher TOC and lower δ^{13}C and δ^{15}N recorded at the beginning of the storm likely result from the preferential export of ~~vegetation debris~~ fine soil organic matter. Similar behaviours were reported by Clark et al. (2013) in the tropical Andes and interpreted as a greater contribution of non-fossil POC during the rising stage and the peak discharge, and in the Swiss Alps by Smith et al. (2013) who interpreted the initial decrease of POC during the rising stage as resulting from in-channel clearing. The evolution of rainwater and OF δ^{18}O is shown on **Fig. 2d**. At the beginning of the storm, both displayed a similar decreasing δ^{18}O trend (from -3.8 to -5.5‰) with increasing rainfall intensity, concomitant to a rise of the suspended load. Overland flow EC averaged 20 ± 6 µS cm^{-1} (range: 15 - 36 µS cm^{-1}, n = 17). The values are consistent with the ones of two other cumulated OF samples, 21 and 43 µS cm^{-1}, collected in the Houay Pano catchment during the ~~May 23~~23 May 2012 event (see **section 4.3**). Contrasted increasing trends were also observed for rain- and OF-^{18}O contents (reaching -1.7‰ and -4.0‰, respectively) during the falling water stage. They reflected the mixing of progressively ^{18}O-enriched rainwater with former ^{18}O-depleted rainwater temporarily stored in the topsoil. It is likely that OF that triggers soil detachment and suspended sediment export will better reflect the contribution of event water to the main stream than rainwater.

4.3 Hydro-sedimentary characteristics of the ~~May 23~~23 May 2012 flood

This~~e May 23~~ flood was triggered by a 48 min storm that brought 27 mm of cumulated rainfall between 11:36 am and 12:24 pm. According to Bricquet et al. (2003), this event has a return period of *ca.* 0.01 year (34.7 mm day^{-1}). It was the first significant erosive event of the 2012 rainy season and the first event with rainfall intensity exceeding 80 mm h^{-1} (6-min time steps). The main hydro-sedimentary characteristics of the flood are reported for the three gauging stations in **Fig. 3 I-II-IIIa-b-c-d**.

[**Fig. 3**]

The lag time between stream discharge (Q) and rainfall intensity peaks differed at the successive stations. Q increased 10 min after the rainfall peak and reached its maximum 10 min later at S1 (**Fig. 3Ia**), whereas both peaks were synchronous at S4 (**Fig. 3IIa**). Downstream, the lag time between rainfall and Q peaks increased to 70 min at S10 (**Fig. 3IIIa**). The evolution of TSS concentration that peaked at 24-47 g L^{-1} (**Fig. 3I-II-IIIb**) displayed counterclockwise hysteresis dynamics (Williams, 1989; Lenzi and Marchi, 2000) at the three stations. Even though Q increased faster than TSS concentration at the beginning of the flood, water EC decreased concomitantly at the three stations (**Fig. 3I-II-IIIc**). This behaviour suggests the progressive mixing of pre-event water (i.e. groundwater) with a low TSS load by weakly mineralized event water (i.e. overland flow) with high sediment loads, the proportion of the latter increasing with decreasing EC. Pre-event EC values measured in the stream just before the flood were 394, 320 and 450 µS cm^{-1} at S1, S4 and S10, respectively (**Fig. 3I-II-IIIc**) in contrast with the low values determined for OF (see above). As expected, the highest values were recorded at S10, which is located downstream of riparian villages (Ribolzi et al., 2010) where high EC wastewaters are directly released into the river. In contrast, upstream of this village, stream waters exclusively originate from cultivated lands. Pre-event water ^{18}O content was estimated to -7.1‰ at station S4 with samples collected before peak flow rise (**Fig. 3IId**). However, for S1 and S10, automatic sampling only took place during the water rising stage and the composition of pre-event water had to be estimated. At S1, a $\delta^{18}O$ value of -8‰ corresponding to a maximum EC of 394 µS cm^{-1} was estimated by fitting the correlative trend (see **section 5**). Pre-event and event waters could not be distinguished with $\delta^{18}O$ signatures at S10. Overall, despite the limited number of samples collected, the composition of cumulated rainwater remained rather constant in the catchment (-5.1, -5.5 and -5.6‰), averaging -5.4 ± 0.3‰.

4.4 Particulate organic matter export at catchment scales during the ~~May 23~~23 May 2012 flood

~~Large~~ Important variations in suspended organic matter composition were recorded at S1 with TOC concentration (20-70 mgC g^{-1}, **Fig. 3Ie**), TOC/TN (8-31, **Fig. 3If**), $\delta^{13}C$ (-26 to -15‰, **Fig. 3Ig**) and $\delta^{15}N$ (5.5-8.0‰, **Fig. 3Ih**) measurements. They all indicate changes in the source delivering suspended organic matter during the rising water stage. The $\delta^{13}C$ signature of suspended organic matter reach the average composition (-25.5 ± 1.4‰; **Table 1**) of topsoil organic matter in the catchment at peak flow and during the recession stage (**Fig. 3I-IIg**). Due to larger and more heterogeneous areas drained at S4 and S10, the temporal evolution of TOC/TN, $\delta^{13}C$ and $\delta^{15}N$ in TSS (**Fig. 3II-III, e-f-g-h**) were less contrasted than at S1. At S10, the mean TOC/TN was higher (17.0 ± 3.2) than at S1 (13.1 ± 5.9) and S4 (10.3 ± 0.9), reflecting a greater contribution of vegetation debris and / or weakly mineralized organic matter downstream than in upper parts of the catchment (**Table A1**). Furthermore, the highest TOC/TN (23; **Fig. 3IIIf**) was obtained during the water discharge peak at S10 whereas it was recorded at the beginning of the rising stage at S1 (31; **Fig. 3If**).

5 Interpretation and discussion

5.1 Overland flow contribution to stream discharge

As overland flow is the main supply of eroded particulate organic matter to the streams during the flood, hydrograph separation in pre-event groundwater and event water contributions using end-members mixing equations should provide information on water dynamics and suspended sediment sources during the flood. However, several questions may arise regarding the relevance of using water mass tracers to constrain end-members signatures and provide reliable estimates of overland flow contribution.

5.1.1 Evolution of water composition during the flood

Water electrical conductivity and $\delta^{18}O$ measurements conducted on rainwater, overland flow and stream water highlight in-channel mixing processes between base flow groundwater (pre-event water) and event water characterized by contrasted signatures (**Fig. 4I**).

[Fig. 4]

At S1 (**Fig. 4Ia**), all samples are aligned between the PEW and OF_{1m^2} end-members during both rising and recessing stages, suggesting that the composition of corresponding source remained constant during the event. This condition is one of the assumptions underpinning hydrograph separation procedures (e.g. Buttle, 1994; Ribolzi et al., 2000; Klaus and McDonnell, 2013). At S4 (**Fig. 4Ib**), the evolution of stream water composition during the flood displays a more complex pattern, with the succession of three phases characterized by distinct behaviours. During the rising stage, a similar trend between PEW and OF_{1m^2} is observed as for S1. Near peak flow, stream water EC and $\delta^{18}O$ concomitantly decrease towards the signature of cumulated rainwater samples (**Fig. 4Ib**) until the dilution of PEW by EW reaches its maximum. This behaviour likely reflects the progressive depletion of rainwater in ^{18}O during the storm, as observed during the microplot experiment (**Fig. 2d**), following a Rayleigh-type distillation process (Dansgaard, 1964). The decrease of EC in stream water is also consistent with the supply of weakly mineralized overland flow water mixing rainwater and pre-event soil water with low and high dissolved loads, respectively. A remarkable point is that the water composition supplied by S7-S8 sub-catchments, referred to as $OF_{0.6ha}$ (**Fig. 4Ib**), closely matches the composition of stream water during this period. Finally, during the third phase corresponding to the recession period, the composition of the river water evolved towards the "initial" PEW signature along a third mixing line. At S10, stream water composition displayed large variations in EC but limited changes in $\delta^{18}O$ (range: from -6.0 to -5.2‰, **Fig. 4Ic**). The EC values, decreasing from 450 to 155 µS cm^{-1} at the beginning of the event (**Fig. 3IIIc**)~~ranging between 155 and 450 µS cm~~$^{-1}$, suggest a high contribution of OF at this station.

5.1.2 Catchment hydrological characteristics inferred from hydrograph separation

As highlighted by Klaus and McDonnell (2013), high-frequency analyses of rainfall-runoff are necessary to record end-members intra-event signature variations and reduce uncertainties on hydrograph separation. The microplot experiment previously described recorded such temporal variations during a single storm event (**Fig. 2d**). The OF signature displayed lower variations (-5.5 to -3.7‰) than rainwater (-5.6 to -1.7‰) as a result of mixing between rain and soil water. Although samples could not be taken during the ~~May 23~~23 May 2012 flood, a similar intra-storm evolution magnitude of *ca.* 2‰ for OF-δ^{18}O was assumed. In order to estimate event water contribution to total water discharge monitored at each station, this possible intra-storm variation of rainwater and overland flow signature must be taken into account, as suggested by McDonnell et al. (1990). The very close δ^{18}O values of the three rainwater samples collected on ~~May 23~~23 May 2012 across the catchment remain consistent with the first assumption formulated by Harris et al. (1995) regarding spatial uniformity of cumulated rainwater isotopic signature. However, the behaviour of stream water during peak discharge at S4 (**Fig. 3IId-4Ib**) suggests the evolution of the OF end-member signature towards low δ^{18}O (as recorded for $OF_{0.6ha}$ in **Fig. 4Ib**), consistent with a Rayleigh-type distillation of rainwater. Pre-event soil water signature, likely enriched in ^{18}O by evaporation at the onset of the rainy season (e.g., Hsieh et al., 1998), could not be characterized. Its higher δ^{18}O range can be assumed to be responsible for the higher δ^{18}O observed for OF_{1m^2} during the ~~May 23~~23 May 2012 flood (-3.9 to -2.5‰; **Fig. 4Ib**). The higher EC values recorded for $OF_{0.6ha}$ compared to OF_{1m^2} likely result from dissolved elements loading by runoff due to interactions between rainwater, vegetation, and soil particles along slopes. As the temporal evolution of rainwater and of the resulting OF-δ^{18}O values could not be measured during the ~~May 23~~23 May 2012 flood, we used EC only to provide estimates of overland flow contribution, taking into account the potential variation of this end-member's signature, from 20 to 150 µS cm^{-1}, during the event (**Fig. 4II**).

[Table 2]

Estimates of event water discharge (EWD), specific runoff (SR) and runoff coefficient (RC) are summarized in **Table 2**.

~~**[Table 2]**~~

Runoff coefficients are rather low in most parts of the catchment (4.0 and 3.9% at S1 and S10, respectively), except at S4 which displayed a higher value of 11.7% (**Table 2**). Overall, those low runoff coefficients remained consistent with the high infiltration rates reported by Patin et al. (2012) in the same area (>100 mm h^{-1}). Chaplot and Poesen (2012) reported an annual runoff coefficient of *ca.* 13% for twelve 1-m² plots monitored in this catchment. The v~~V~~alues decrease both with hillslope downward position of the experimental plots and for increasing drainage area, down to 6% for S4 and 1.5% for S10. Estimates of the OF contribution to total water discharge, based on the evolution of water EC, are displayed on **Fig. 4II**. At discharge peak, OF was lower at S1 (53-80%) than at S4 (78-100%) and S10 (67-95%). The highest value was obtained at S4 where the highest runoff coefficient was also recorded. This behaviour likely results from a different soil cover in this sub-catchment. Indeed, teak plantations prone to soil erosion and low infiltrability conditions (Patin et al., 2012) covered 32% of this sub-catchment area in 2012, whereas it had a two-fold smaller extension in the drainage areas of S1 (14%) and S10 (15%). Moreover, the annual runoff coefficients reported by Chaplot and Poesen (2012) at S4 and S10 were lower than those reported in this study, but they were measured when teak plantations covered a much lower part of the catchment (2002-2003, Chaplot et al., 2005). Overall, it is likely that teak plantations will enhance overland flow and soil erosion at least during the years following land use conversion.

5.2 Particulate organic matter delivery during the 23 May 2012 flood

5.2.1 Sources ~~and dynamics~~ of suspended organic matter in the catchment~~during the May 23 flood~~

Variations in the composition of particulate organic matter reflect changes in the source supplying suspended sediment in the catchment during the flood. For S1 and S4, this evolution follows hyperbolic trends with suspended sediment loads for TOC, $\delta^{13}C$ and $\delta^{15}N$ and tends to reach the mean composition of catchment surface soils during the main transport phase (**Fig. 5I-IIa-b**). As reported by Bellanger et al. (2004) in the Venezuelan Andes, this behaviour indicates that sheet erosion ~~i~~was likely the dominant process. Due to the absence of particulate inorganic carbon that could have biaised the measurements (see above in section 3.2), the composition of suspended sediments is consistent with the supply of carbonate free soil-detached particles exported from catchment's soils. ~~Furthermore, the ^{137}Cs activity of suspended sediments (Gourdin et al., under review) remains within the range of surface soil activities (>1 Bq kg^{-1}; **Table 1**) and supports this interpretation.~~

[Fig. 5]

However, Meybeck (1993) outlined that hyperbolic trends may indicate that a significant fraction of particulate organic matter exported from mountainous regions by rivers may be supplied by the direct erosion of sedimentary – metamorphic bedrocks (the so-called "fossil carbon" pool) and pointed out that neglecting this source induces a bias in carbon budgets. Fossil carbon may account for 90-100% of total particulate organic matter exported in rivers with average annual suspended loads exceeding 5 g L^{-1} (Meybeck, 2006), in the range recorded for this study. In the Andes, Clark et al. (2013) identified fossil POC contributions associated with TSS concentrations above 1 g L^{-1}. In a Taiwanese river, Hilton et al. (2011) reported suspended sediment concentrations up to *ca.* 30 g L^{-1} leading to fossil POC concentrations up to *ca.* 0.1 g L^{-1}. ~~Fossil particulate organic carbon contributions have been identified using ^{14}C natural abundance and C-N stable isotope measurements in various studies (e.g., Kao and Liu, 1997; Raymond and Bauer, 2001; Copard et al., 2007; Graz et al., 2012; Smith et al., 2013). In our~~The present study~~,~~ does~~we could~~ not support the hypothesis of a ~~identify any~~ significant supply of rock-derived fossil carbon~~. This export is~~, often associated with important sediment exports originating from gully systems (Duvert et al., 2010), landslides and mass movements that ~~(Huon et al., 2006), which~~ were not observed in the Houay Pano catchment during this medium magnitude flood. Bedrock outcrops are scares and not directly connected to the stream. Moreover the highest $\delta^{15}N$ values rather reflect the occurrence of soil derived organic matter than fossil organic matter (e.g. Huon et al., 2006). The later should theoretically provide lower $\delta^{15}N$ than for soils as preservation of organic matter in sedimentary and low metamorphic grade rocks takes place at "high temperature" (low $^{15}N/^{14}N$ fractionation with respect to vegetation) whereas incorporation and stabilization of organic matter in soils should occur at "low temperature" (high $^{15}N/^{14}N$ fractionation). Fossil particulate organic carbon contributions have been identified using ^{14}C natural abundance and C-N stable isotope measurements in various studies (e.g., Kao and Liu, 1997; Raymond and Bauer, 2001; Copard et al., 2007; Graz et al., 2012; Smith et al., 2013). For the Houay Xon catchment, the ^{137}Cs activity of suspended sediments measured on the same sample aliquots are in the range of surface soil activities (above 1 Bq kg^{-1}; **Table 1**; Gourdin et al., 2014). Paleozoic bedrocks could not be tagged by fallout ^{137}Cs whose supply only took place in the 1960-1970's (Ritchie and McHenry, 1990)~~Furthermore, suspended sediments are labelled by ^{137}Cs activities that reflect the dominant contribution of soil surface sources (Gourdin et al., under review)~~.

5.2.2 Dynamics of suspended organic matter

At S1, the ^{13}C-enriched compositions (**Fig. 5IIa**) first reflect the supply of organic matter derived from C_4 photosynthetic pathway plants ~~(Huon et al., 2013)~~as observed in the field. With increasing water discharge, suspended sediments progressively incorporate ^{13}C-depleted organic matter originating from soils covered by C_3 photosynthetic pathway plants that dominate in the drainage area. Decreasing TOC/TN (increasing TN/TOC) and increasing $\delta^{15}N$ trends during the flood are best explained by the re-suspension of weakly mineralized (low

δ^{15}N) C_4-plant debris (high TOC/TN), followed by their mixing with soil organic matter exported from cultivated fields and supplied by overland flow to the main stream (low TOC/TN, high δ^{15}N). Plot of δ^{13}C *vs.* TN/TOC shows that the composition of suspended sediment loads matches that of the main pools of particulate organic matter in the catchment, i.e., surface soils and subsurface soils (gullies and river banks, **Fig. 6**). Mixing between the two end-members is pictured by correlative behaviours for S1 and S10.

[Fig. 6]

It is worth noticing that bedrock source compositions available from literature for tropical catchments (i.e., Kao and Liu, 2000, Hilton et al., 2010) fall outside the observed mixing trends. In addition~~However~~, the occurrence of light density charcoal fragments produced by slash-and-burn cultivation might have slightly increased TOC/TN with respect to soil organic matter (Soto et al., 1995; Rumpel et al., 2006). Overland flow supply of particulate organic matter exported from soils that are currently or were previously cultivated with upland rice~~,~~ is largely dominant at S4~~,~~ compared to S1 (**Fig. 5I-IIa-b**). Fields cropped with C_4-plants only cover small areas in the catchment and their imprint on soil organic matter composition is therefore limited (Huon et al., 2013). The δ^{13}C recorded during and after the water discharge peak were similar (-25.7‰; **Fig. 5IIa-b**) to those of surface soils, reflecting the dominance of surface *vs.* subsurface sources in Houay Pano catchment. At S8, located close to S4 (**Fig. 1**), δ^{15}N increased noticeably from 6.5 to 8.3‰ during the storm, indicating that ^{15}N-depleted organic matter (i.e., vegetation debris) was first exported and that erosion progressively affected deeper ^{15}N-enriched layers of the topsoil (**Table 1**). In contrast to the two other stations, the maximum TOC/TN (23) recorded downstream at S10 occurred during the water discharge peak (**Figs. 3IIIf and 5Ic**). Fresh organic matter characterized by high ratios is exported with a time lag due to the remote location of its source (Gurnell, 2007). Suspended organic matter transported at the beginning of the flood (range: from -23 to -21‰; **Table A1, Fig. 5IIc**) is enriched in ^{13}C and ^{15}N compared to the mean surface soil ~~(-25.5 ± 1.4‰)~~ and matches subsurface soil signatures (stream banks and gullies, **Table 1**). This observation ~~validate~~supports previous findings showing the dominance of riverbank erosion ~~suggest~~characterized by the depletion in fallout radionuclides measured for sediments collected at this station (Gourdin et al., ~~under review~~2014). Positive correlative trends between soil TOC and ^{137}Cs inventories suggest that a similar process, i.e. erosion and erosion-induced carbon depletion, controlled their concomitant decrease since the onset of cultivation in the 1960's (Huon et al., 2013). Smith and Blake (2014) reported similar correlations for riverine sediments in parts of their study sites. No such relationships could be put forward during the 23 May 2012 flood (data not shown).

Contribution of overland flow to stream water discharge derived from hydrograph separation can be linked to the source of suspended organic matter (**Fig. 5 III**) as well as to the extent of particulate organic matter transfer (**Fig. 5 IV**). In terms of water - sediment dynamics, high OF contributions (above *ca.* 50%) supply large quantities of soil organic matter (fingerprinted by lower TOC contents and enriched isotopic compositions compared to fresh vegetation debris) to the river. In contrast, low OF contributions may indicate the dominance of riverbank erosion and remobilization of ~~material~~ sediment deposited on the riverbed during~~after~~ previous floods. Based on ~~this~~ hydrograph separation, it is then possible to draw sediment and particulate organic carbon budgets at the catchment's scale in areas where surface soil erosion dominates.

~~5.2.2 Suspended sediment TOC-^{137}Cs relationships~~

~~Positive correlative trends between soil TOC and ^{137}Cs inventories suggest that a similar process, i.e. erosion and erosion-induced carbon depletion, controlled their concomitant decrease since the onset of cultivation in the 1960s (Huon et al., 2013). Similar positive correlations were reported by Smith and Blake (2014) for riverine sediments in parts of their study sites. We could not derive such relationships for suspended sediment loads during the May 23 flood. This observation may reflect selective detachment and transport, with respect to cultivated soils, of small size mineral-bound organic matter to the rivers. It could however also result from the local contribution of channel bed organic matter, degraded with time, inducing TOC depletion and ^{13}C enrichment. This later interpretation is supported by the large proportion of remobilized sediments fingerprinted by the low ^{7}Be:$^{210}Pb_{xs}$ activity ratios measured in suspended sediment loads (Gourdin et al. under review).~~

5.2.3 Suspended sediment and particulate organic carbon deliveries~~y at catchment scale~~

Total suspended sediment exports are summarized in **Table 3** for S1, S4 and S10 sub-catchments.

[Table 3]

~~The sediment yield (S_Y) of *ca.* 433 kg ha^{-1} at S4 is greater than at S1 and S10 (**Table 3**) and consistent with higher specific runoff and runoff coefficient values (**Table 2**). Due to the low~~

~~S_Y observed at S1, the succession of nested catchments was not related to a decrease in specific delivery when drainage area increased.~~ Compared to the 2002-2003 annual sediment ~~deliveries~~ yield at S4 (2090 kg ha^{-1} yr^{-1}) and S10 (540 kg ha^{-1} yr^{-1}) reported by Chaplot and Poesen (2012), the ~~May 23~~23 May 2012 flood represent~~s~~ed *ca.* 21% of the total annual exports recorded for both stations. These deliveries are ~~very~~ high for a single event of moderate intensity. However, fallout radionuclide measurements (Gourdin et al., ~~under review~~2014) indicate that th~~e May 23~~is flood was the first important erosive event of the 2012 rainy season and ~~that exported matter~~ mainly consisted of remobilized river channel sediment~~s~~ (*ca.* 80%). ~~that may not have been fully taken into account in the previous study.~~ The TSS yield (S_Y) of *ca.* 433 kg ha^{-1} (8.3 kgC ha^{-1}) at S4 is greater than at S1 and S10 (**Table 3**) and consistent with higher specific runoff and runoff coefficient values (**Table 2**). With a low value at S1, the succession of nested catchments was not related to a decrease in specific delivery when drainage area increased. This unsual behaviour is best explained by the occurrence of swamp areas along the main stream. In the upper part of the catchment, a natural swamp acts as a filter for sediments conveyed during low to medium magnitude floods (**Fig. 1**). Napier grass, the main aquatic plant forms dense masses of litter that reduce stream flow velocity during the rainy season. Nearly 33 Mg of soil-derived organic carbon was thus accumulated since the early 1960's (Huon et al., 2013). This swamp played a key role with respect to downstream export of suspended sediment during the 23 May 2012 flood. It also explains why the high $\delta^{13}C$ values of TSS loads, observed during the rising water stage upstream of the swamp (at S1), were only partly transmitted to S4. Soil-derived organic matter supplied by overland flow replaced the major part of the TSS during the rising stage, downstream of the swamp. A comparable picture can be drawn for the wetlands located at the outlet of the village. However in contrast this swampy area where streambanks are also encroached by Napier grass contributed to a rise of the $\delta^{13}C$ values of suspended organic matter at the monitoring station S10. This shift fingerprinted the extent of streambank sediment retention and mobilization processes taking place downstream in accordance with radionuclide activity measurements carried out for the same samples (Gourdin et al., 2014).

~~Carbon specific deliveries (C_Y) suggest a higher erodibility of the S4 draining area, exporting *ca.* 8.3 kgC ha^{-1} of soil organic carbon, i.e. more than twice the quantity exported from S1 and S10 (2.9-3.7 kgC ha^{-1}; **Table 3**). This behaviour may be related to higher RC (11.7%; **Table 2**) and OF contribution at discharge peak (78-100%; **Fig. 4IIb**) estimated at this station. As for sediment delivery, we calculated a much higher carbon flux exported by the catchment than previously reported by Chaplot and Poesen (2012), i.e., 8.5 and 1.4 kgC ha^{-1} yr^{-1} for S4~~

~~and S10, respectively. To the best of our knowledge, this discrepancy may be explained by the different TOC concentrations used for carbon flux calculation in both studies. In this study the values are almost 5-fold higher for S4 (25 *vs.* 4.1 mgC g^{-1}) and 14-fold higher for S10 (36 *vs.* 2.6 mgC g^{-1}). As the same analytical method was used in both studies, these differences could also be explained by a greater contribution of deep soil layers through linear erosion (gullies and riverbanks) during the 2002 rainy season, responsible for the export of sediments with low TOC content (<5 mgC g^{-1}) in all catchments draining a surface exceeding 0.6 ha. Total organic carbon and total nitrogen concentrations of riverine sediments are usually higher than in soils due to preferential mobilisation and transport of fine and light soil organic fractions after aggregates destruction (Stoltenberg and White, 1953). However, Chaplot and Poesen (2012) observed rather similar TOC enrichment factors (close to 1), suggesting a good stability of soil aggregates in their study. The low carbon yields (8.5 and 1.4 kgC ha^{-1} yr^{-1}, for S4 and S10 respectively) reported by these authors indicate that nearly all soil particulate organic matter deposited on hillslopes before reaching the river channel. The connectivity of hillslopes to the stream channel may also have changed since 2002-2003 due to the replacement of cultivated plots by teak plantations initiated in 2009 in the catchment. Teaks are characterized by large leaves that concentrate rainwater and enhance raindrop erosivity, soil crusting and runoff, especially after 10 years (Patin et al., 2012). However, their impact on soil erosion and organic matter export is still poorly understood (C. Valentin, personal communication) and should be further investigated.~~

6 Concluding remarks

The composition of suspended organic matter and stream water, monitored during the first erosive – medium magnitude flood event of the 2012 rainy season in a cultivated catchment of northern Laos, provided an efficient way to quantify the evolution of particulate organic matter sources along a network of nested gauging stations.

In the upper part~~s~~ of the drainage basin (Houay Pano sub-catchment), the composition of suspended organic matter exported ~~wa~~shows that sediment mainly originated~~ing~~ from in-channel and nearby sources during the rising stage~~,~~ and from cultivated surface soils at peak flow and during the recessing stage.

Downstream, the composition of suspended ~~and deposited~~ organic matter in the Houay Xon River reflected the dominant supply of subsurface sources (riverbanks and gullies) and a subsequent dilution of ~~the~~ soil-derived organic matter delivery by channel - bank mixing and ~~re~~mobilization processes.

Wetlands and swampy areas played a key role in the procces by trapping sediment upstream in the steep part of the catchment and by remobilizing riverbank sediment downstream in the floodplain as highlighted by changes in the composition of suspended organic matter.

The ~~results of this study suggest that~~ relationships between water flow and suspended sediment load as well as~~nd~~ hydrograph separation procedures ~~at the outlet of catchments would~~can be better constrained using high-resolution monitoring of overland flow than direct rainfall as shown in this study.

Finally, ~~as higher suspended organic matter exports than in previous studies were determined, these results indicate that both~~ the sampling period, at the onset of the rainy season, ~~(~~following field clearing by slash and burn ~~in this study), and the impact of land use change played a key role for~~ explains the important sediment delivery observed at the outlet of the catchment for a medium magnitude flood.

Acknowledgements

The authors would like to thank the Lao NAFRI (National Agriculture and Forestry Research Institute in Vientiane) and the MSEC project (Multi-Scale Environment Changes) for their support. They are also grateful to Keo Oudone Latsachack, Bounsamai Soulileuth and Chanthamousone Thammahacksa for their help in the field, to Véronique Vaury (iEES-Paris) for organic matter composition measurements, and to Patricia Richard (iEES-Thiverval Grignon) for $\delta^{18}O$ measurements of water samples. Elian Gourdin received a PhD fellowship from Paris-Sud University, Orsay, France. This work received financial support from the French CNRS EC2CO / BIOHEFECT program (Belcrue project).

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Table 1. Mean organic matter composition and ^{137}Cs activity (± 1 standard deviation) for surface soils (n=64), gullies (n=5) and stream bank (n=6) samples in the Houay Pano and Houay Xon catchments. For ^{137}Cs activity measurements, see Gourdin et al. (~~under review~~2014).

Location	TOC (mgC g^{-1})	TN (mgN g^{-1})	TOC/TN	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	^{137}Cs (Bq kg^{-1})
Surface soils*	25 ± 5	2.1 ± 0.5	11.6 ± 2.0	-25.5 ± 1.4	6.7 ± 1.3	2.2 ± 0.9
Stream banks**	13 ± 6	1.1 ± 0.3	12.4 ± 7.7	-23.2 ± 4.4	8.6 ± 1.9	0.4 ± 0.3
Gullies**	14 ± 7	1.4 ± 0.6	9.6 ± 0.8	-22.7 ± 0.8	8.7 ± 2.1	0.4 ± 0.3

*Data from Huon et al. (2013) and this study (2012), **this study (2012).

Table 2. Estimates of event water discharge (EWD) and related specific runoff (SR) and runoff coefficient (RC) for the three stations during the ~~May 23~~23 May 2012 flood.

Station	Drainage area (km^2)	EWD* (x 10^6 L)	SR** (mm)	RC*** (%)
S1	0.2	0.215	1.1	4.0
S4	0.6	1.88	3.2	11.7
S10	11.6	12.2	1.1	3.9

* EWD = total water discharge minus baseflow discharge
** SR = EWD / drainage area
*** RC = 100 x (SR / rainfall) assuming an homogeneous cumulativ rainfall of 27 mm

Table 3. Total suspended sediment yield (SSY), total particulate organic carbon yield (C_{SSY}), specific total suspended sediment yield (S_Y) and specific total organic carbon yield (C_Y) for the May 2323 May 2012 flood.

Station	SSY (Mg)	C_{SSY} (kg)	S_Y* (kg ha^{-1})	C_Y** (kgC ha^{-1})
S1	2.3	58	115	2.9
S4	26	496	433	8.3
S10	130	4346	112	3.7

* S_y = 10 x SSY / drainage area in Table 2
** $C_Y = 10^{-2}$ x C_{SSY} / drainage area in Table 2

Appendix A: Table A1. Summary of data for stations S1, S4 and S10 during the ~~May 23~~23 May 2012 flood.

Label	Time* (hh:mm)	TSS* ($g\ L^{-1}$)	Q* ($L\ s^{-1}$)	EC* ($\mu S\ cm^{-1}$)	$\delta^{18}O$* (‰ vs. V-SMOW)	TOC* ($mgC\ g^{-1}$)	TN* ($mgN\ g^{-1}$)	TOC/TN*	$\delta^{13}C$* (‰ vs. PDB)	$\delta^{15}N$* (‰ vs. AIR)
Station S1										
LS0101	12:08	0.86	5	335	-7.2	42.0	2.0	20.5	-15.3	7.1
LS0102	12:09	0.56	7	317	-7.1	60.3	2.6	23.1	-19.0	5.5
LS0103	12:09	0.53	10	317	-7.0	-	-	-	-	-
LS0104	12:10	0.61	13	299	-6.8	66.2	2.1	31.0	-19.7	7.0
LS0105	12:10	-	16	299	-	-	-	-	-	-
LS0106	12:11	1.23	21	282	-6.9	32.2	2.3	14.0	-23.0	6.0
LS0107	12:13	1.70	27	262	-6.6	26.2	2.0	13.0	-23.7	6.6
LS0108	12:14	2.37	34	259	-6.2	25.0	2.0	12.7	-22.4	6.8
LS0109	12:19	3.65	40	241	-6.0	23.1	2.1	10.8	-24.4	7.2
LS0110	12:20	4.17	55	233	-6.1	23.4	2.2	10.7	-24.5	7.3
LS0111	12:21	4.65	76	224	-5.9	22.5	2.0	11.1	-24.1	7.5
LS0112	12:21	18.74	90	215	-5.8	27.4	2.0	11.1	-25.6	6.8
LS0113	12:30	29.98	68	184	-5.8	25.7	2.1	11.0	-25.8	6.8
LS0114	12:33	23.02	51	188	-5.5	25.8	2.2	10.7	-25.9	7.5
LS0115	12:37	24.05	38	194	-5.4	23.3	2.0	10.1	-25.8	7.5
LS0116	12:43	17.67	27	205	-5.6	20.8	2.5	9.8	-25.6	7.7
LS0117	12:50	16.38	18	218	-5.7	19.3	2.3	9.0	-25.3	7.8
LS0118	12:57	9.13	14	232	-5.8	18.7	2.4	9.0	-25.0	7.5
LS0119	12:58	14.37	13	233	-6.1	18.6	2.3	9.1	-25.1	7.2
LS0120	13:15	4.50	8	262	-6.2	19.3	2.1	9.6	-23.8	7.1
Station S4										
LS0403	11:57	1.53	15	297	-6.9	-	-	-	-	-
LS0404	11:58	1.21	24	306	-6.7	-	-	-	-	-
LS0403-4**	-	-	-	-	-	27.7	2.6	10.8	-23.8	7.1
LS0405	12:00	1.16	33	306	-6.5	29.9	2.9	10.4	-23.5	6.5
LS0406	12:01	2.71	42	262	-6.1	24.8	2.4	10.2	-24.4	7.2
LS0407	12:04	5.83	54	216	-5.5	22.6	2.2	10.5	-25.0	7.2
LS0408	12:05	6.83	76	205	-5.2	-	-	-	-	-
LS0409	12:06	7.25	114	198	-5.3	-	-	-	-	-
LS0408-9**	-	-	-	-	-	21.2	2.1	10.1	-25.0	7.5
LS0410	12:07	10.07	144	177	-4.7	22.1	2.1	10.7	-25.2	7.6
LS0411	12:07	11.89	185	161	-4.7	20.8	2.0	10.3	-25.2	7.6
LS0412	12:08	15.75	280	138	-4.5	19.2	1.9	9.9	-25.6	7.6
LS0413	12:09	20.05	309	121	-4.9	-	-	-	-	-
LS0414	12:10	31.56	358	99	-5.1	19.6	2.1	9.6	-25.4	8.0
LS0415	12:11	46.51	440	87	-5.2	21.1	2.1	10.0	-25.6	7.5

Label	Time* (hh:mm)	TSS* (g L^{-1})	Q* (L s^{-1})	EC* (µS cm^{-1})	δ^{18}O* (‰ vs. V-SMOW)	TOC* (mgC g^{-1})	TN* (mgN g^{-1})	TOC/TN*	δ^{13}C* (‰ vs. PDB)	δ^{15}N* (‰ vs. AIR)
LS0416	12:20	28.40	335	103	-5.4	24.5	2.1	11.5	-26.0	7.1
LS0417	12:23	23.00	277	105	-5.4	24.7	2.2	11.4	-25.8	7.2
LS0418	12:26	17.76	228	117	-5.6	24.7	2.1	11.8	-26.0	7.4
LS0419	12:34	11.70	183	152	-5.6	-	-	-	-	-
LS0420	13:20	12.62	145	164	-5.6	-	-	-	-	-
LS0419-20**	-	-	-	-	-	22.5	2.0	11.0	-25.8	7.4
LS0421	13:32	7.71	112	192	-5.8	19.0	1.9	9.8	-25.6	7.7
LS0422	13:46	6.92	84	201	-6.1	19.6	2.0	9.8	-25.6	7.7
LS0423	14:05	6.93	59	203	-6.0	-	-	-	-	-
LS0424	14:43	5.89	39	214	-6.2	-	-	-	-	-
LS0425	15:46	3.37	23	230	-6.2	-	-	-	-	-
LS0423-25**	-	-	-	-	-	20.9	2.2	9.6	-25.5	7.3
Station S10										
LS1002	12:24	7.94	204	227	-5.5	-	-	-	-	-
LS1003	12:28	5.57	455	220	-5.5	-	-	-	-	-
LS1002-3**	-	-	-	-	-	39	2.0	19.8	-21.2	8.2
LS1004	12:31	8.77	623	215	-5.9	-	-	-	-	-
LS1005	13:03	11.10	943	167.5	-5.6	-	-	-	-	-
LS1004-5**	-	-	-	-	-	36	1.9	19.1	-22.6	7.4
LS1006	13:06	23.63	990	167	-5.7	44	1.9	23.1	-21.8	7.0
LS1007	13:27	17.02	1535	156	-5.4	44	2.0	22.2	-22.3	7.5
LS1008	13:33	24.43	1350	155.5	-5.7	29	1.8	16.2	-22.7	8.4
LS1009	13:39	24.00	1187	157	-5.6	31	1.8	17.2	-23.0	7.9
LS1010	13:46	15.74	1038	160	-5.6	25	1.8	13.7	-24.3	7.9
LS1011	13:55	21.47	886	167.5	-5.7	27	1.9	14.3	-23.4	7.3
LS1012	14:06	18.01	735	174	-5.6	29	1.9	15.0	-24.5	7.4
LS1013	14:20	15.35	597	184	-5.8	24	2.0	12.4	-24.5	7.1
LS1014	14:38	12.80	485	198	-5.7	-	-	-	-	-
LS1015	15:14	10.17	308	222	-5.9	-	-	-	-	-
LS1014-15**	-	-	-	-	-	30	1.9	15.5	-23.6	7.1

* = Time of collection, total suspended sediment load (TSS), stream discharge (Q), water electric conductivity (EC) and δ^{18}O, total organic carbon in TSS (TOC), total nitrogen in TSS (TN), δ^{13}C and δ^{15}N for TSS, ** = composite sample, - = no value.

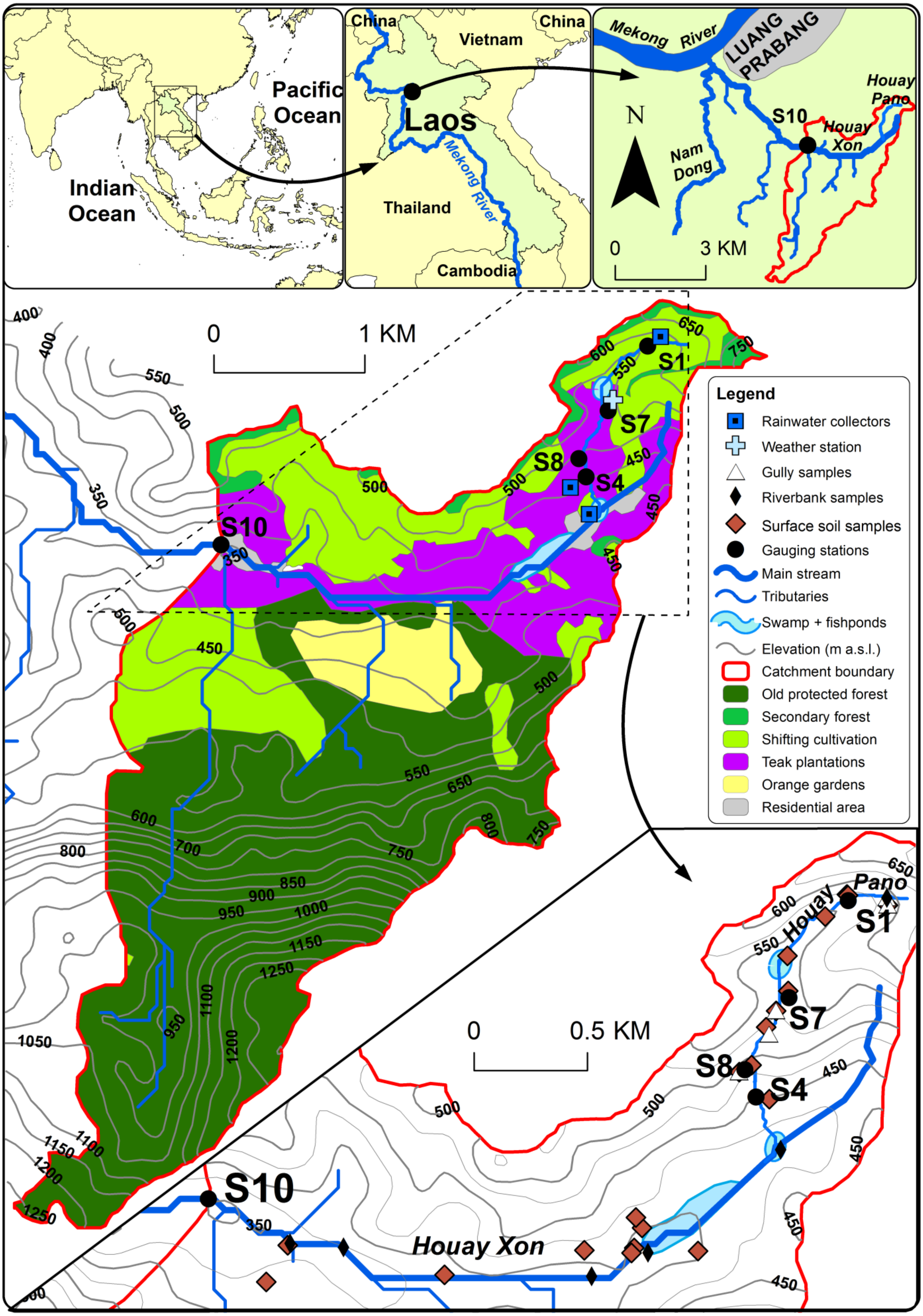

Fig. 1. Location of the Houay Xon River catchment in SE Asia (a). Topographic and land use map of the Houay Xon S10 sub-catchment in 2012 with location of the gauging stations (S1, S4, S7, S8, S10), rainwater collectors and automatic weather station (b), surface soil, gully and riverbank sampling locations (c).

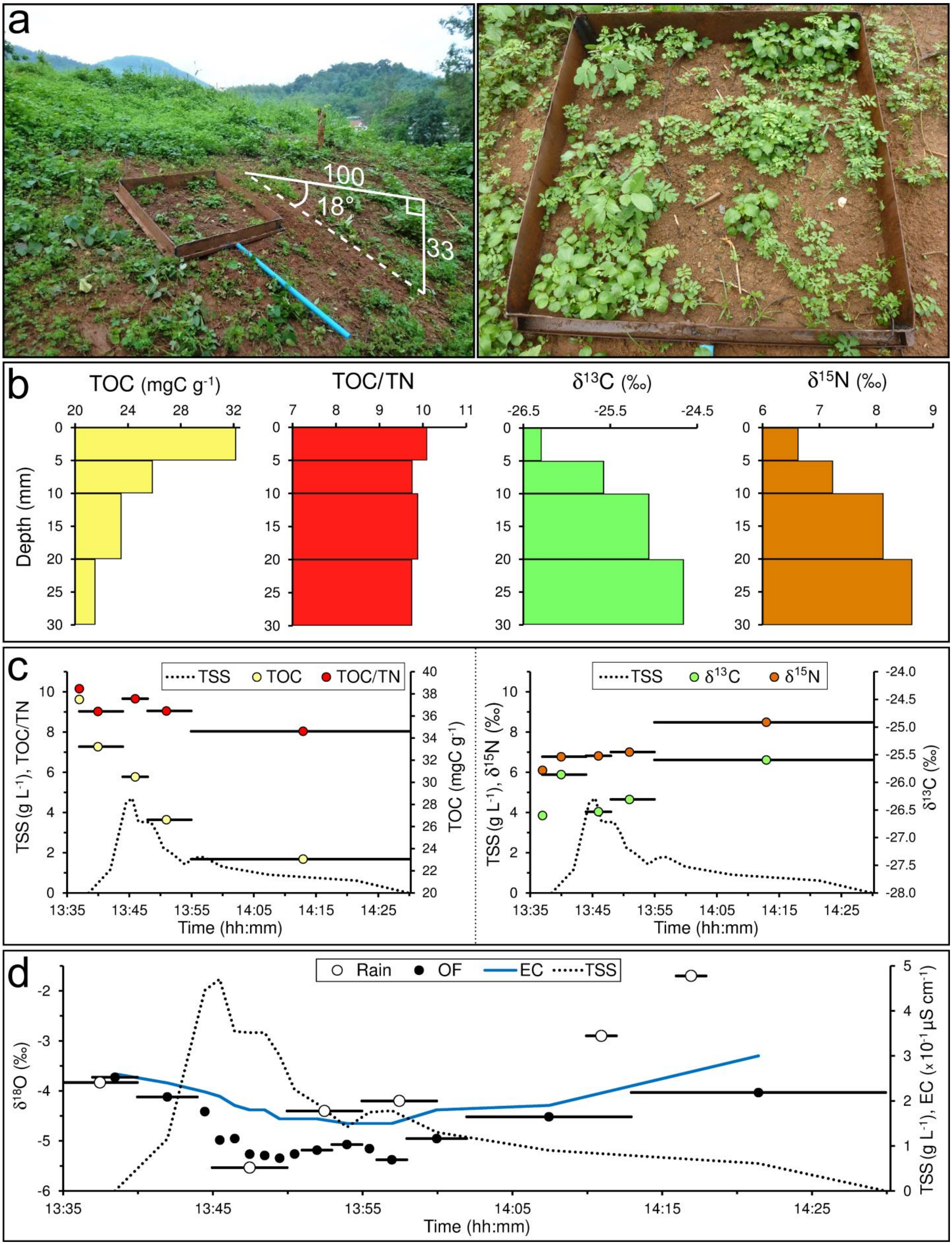

Fig. 2. Microplot experiment: (a) presentation of the 1-m² collecting system and its vegetation cover; (b) Distribution of topsoil total organic carbon (TOC) concentration, total organic carbon : total nitrogen ratio (TOC/TN), $\delta^{13}C$ and $\delta^{15}N$ with soil depth; (c) temporal evolution of the total suspended sediment load (TSS) plotted with TOC and TOC/TN in TSS (left) and with $\delta^{13}C$ and $\delta^{15}N$ in TSS (right) during the June 1st storm and (d) temporal evolution of the overland flow TSS load with rainwater-$\delta^{18}O$ (Rain), overland flow-$\delta^{18}O$ (OF) and overland flow electric conductivity (EC) during the June 1st storm.

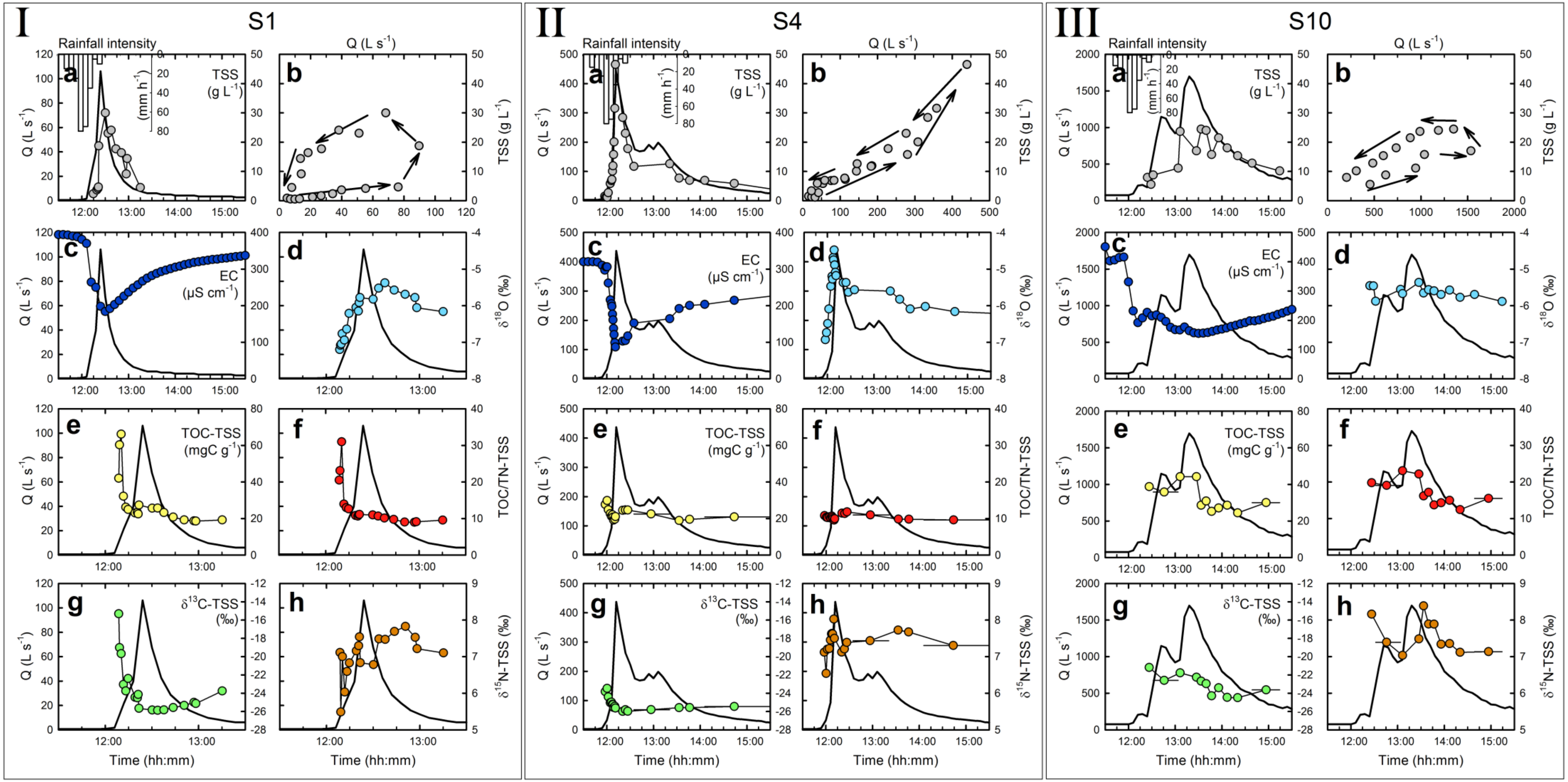

Fig. 3. Plots of the temporal evolution of (a) rainfall intensity, stream discharge (Q, thicker solid line), (b) total suspended sediment load (TSS), (c) water electric conductivity (EC), (d) streamwater-$\delta^{18}O$, (e) total organic carbon concentration in the TSS (TOC-TSS), (f) total organic carbon : total nitrogen ratio in the TSS (TOC/TN-TSS), (g) $\delta^{13}C$-TSS, (h) $\delta^{15}N$-TSS for : (I) the upstream station S1, (II) the intermediate station S4, and (III) the downstream station S10, during the ~~May 23~~23 May 2012 flood. Horizontal bars represent sampling period for composite samples.

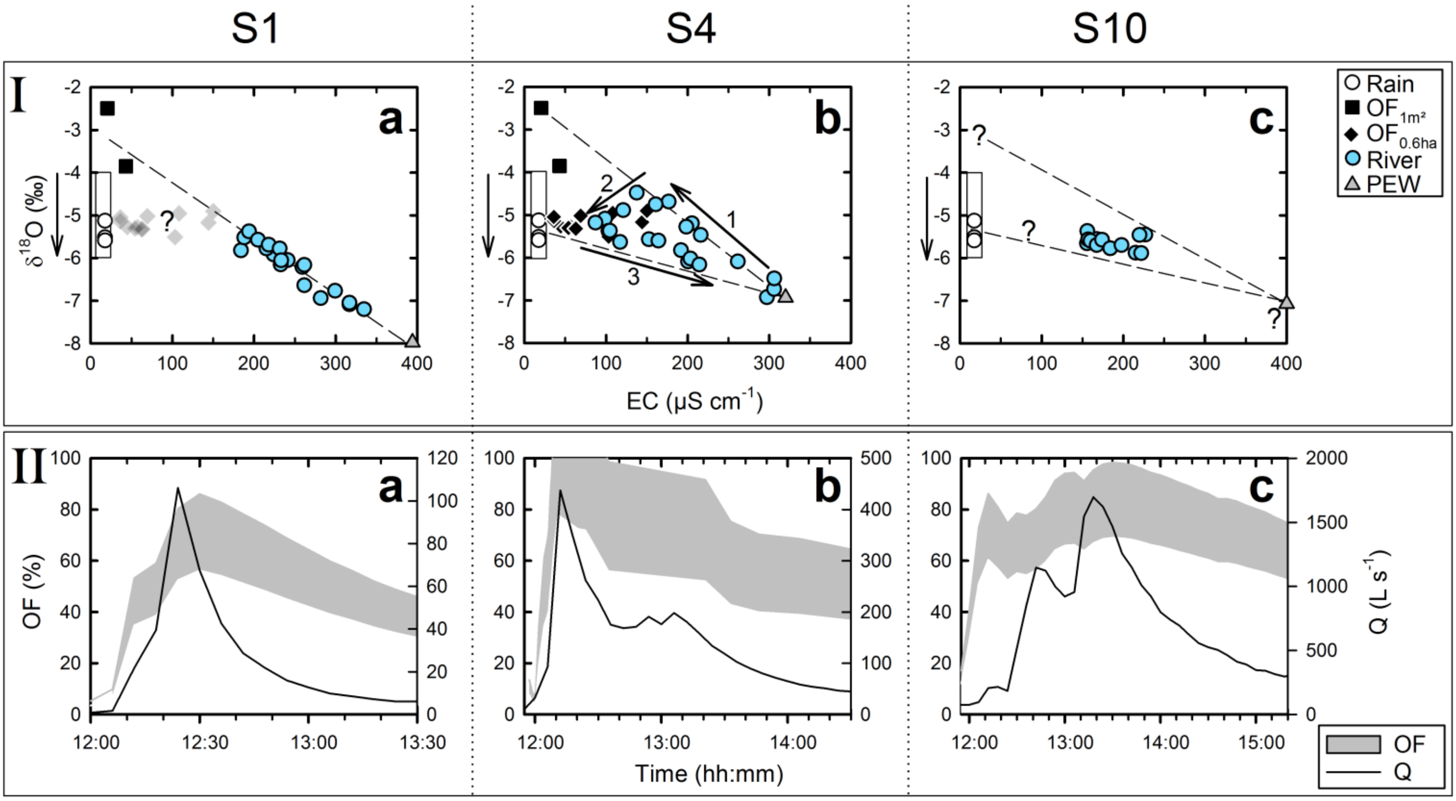

Fig. 4. Plots of: (I) relationships between water electric conductivity (EC) and water δ^{18}O, and (II) temporal evolution of stream water discharge (Q) with overland flow contribution estimates (OF) for (a) the upstream station S1, (b) the intermediate station S4, and (c) the downstream station S10, during the ~~May 23~~23 May 2012 flood. In (I), open circles correspond to rainwater, filled squares to cumulative overland flow obtained with 1-m² plots (OF_{1m^2}), filled diamonds to overland flow from S7 and S8 hillslopes ($OF_{0.6ha}$), filled colored circles to stream water, triangles to pre-event water (PEW). The rectangle areas and vertical arrows represent the potential temporal variability of rainwater-δ^{18}O during the storm. In (II), the shaded area corresponds to the variability range for the estimated overland flow contribution.

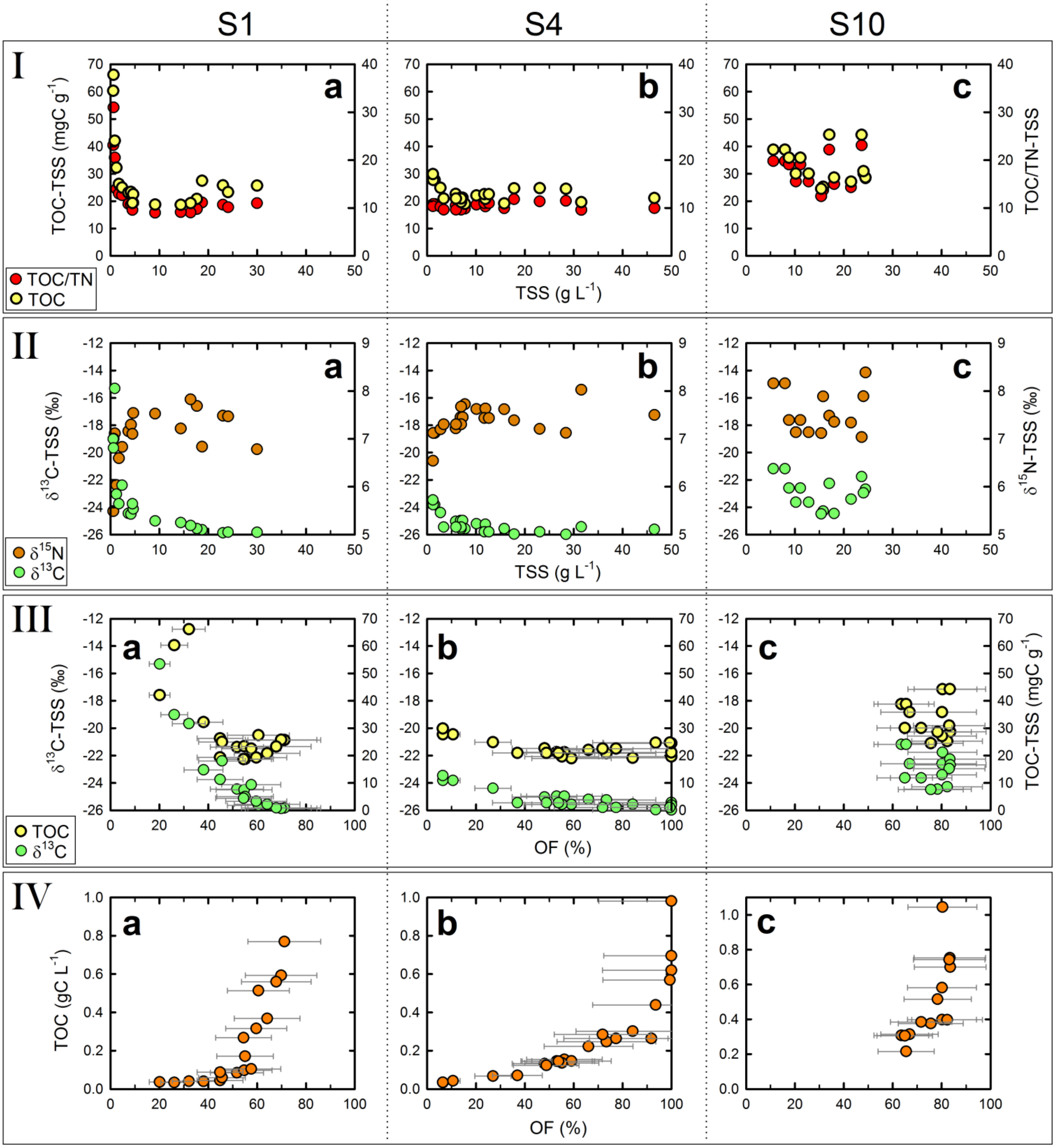

Fig. 5. Relationships between total suspended sediment load (TSS), total organic carbon concentration in the TSS (TOC-TSS), total organic carbon : total nitrogen ratio in the TSS (TOC/TN-TSS), δ^{13}C-TSS, δ^{15}N-TSS, total organic carbon load (TOC) and overland flow contribution estimates (OF): (a) at upstream station S1 (Houay Pano Stream), (b) at intermediate station S4, and (c) at downstream station S10, during the May 2323 May 2012 flood. In (III) and (IV), circles represent the median values of the variability range (horizontal bars) of estimated OF contribution.

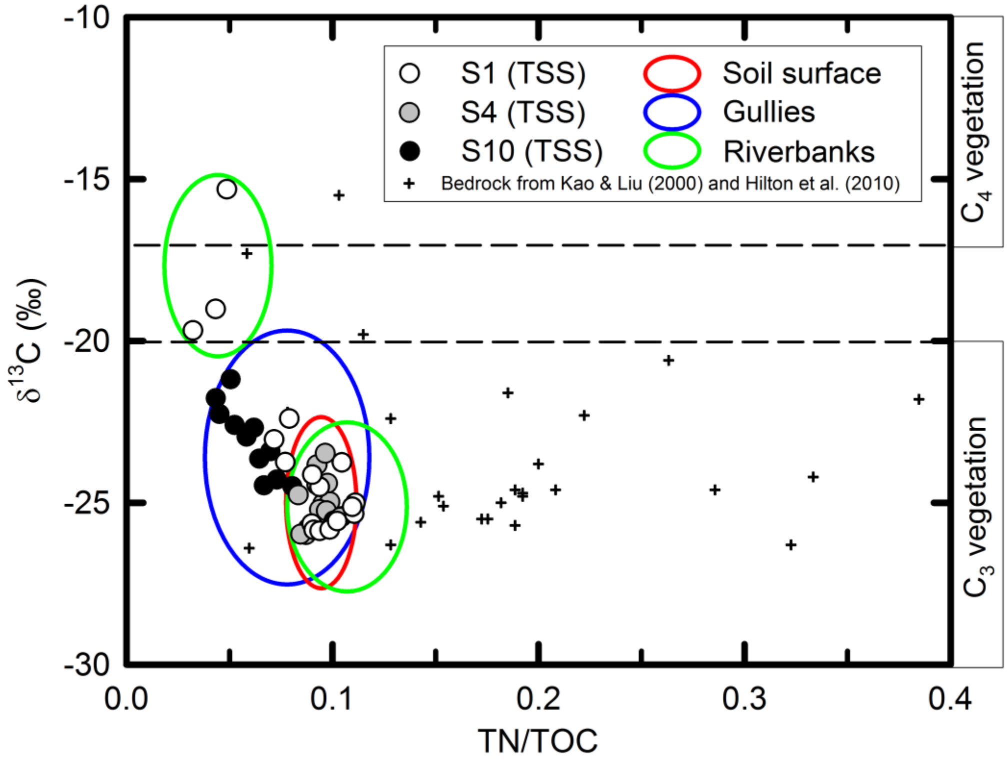

Fig. 6. Plot of $\delta^{13}C$ *vs.* TN/TOC for total suspended sediment loads (TSS) collected at S1 (open circles), S4 (grey circles) and S10 (closed circles) during the 23 May 2012 flood and for the potential sources of sediment (Soil surface: red area; Gullies: blue area; Riverbanks: green areas) determined in the catchment. Bedrock data (plus signs) are taken from literature (Kao and Liu, 2000; Hilton et al., 2010).