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Biogeosciences Discussions

Interactive comment on "Erosion-induced massive organic carbon burial and carbon emission in the Yellow River basin, China" *by* L. Ran et al.

L. Ran et al.

ranlishan@gmail.com

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Dear reviewer,

We thank you very much for your comments on our manuscript.

The manuscript presents a detailed sediment and sediment-burden carbon budget of the Yellow River for the time from 1950-2010 AD. The authors try to fill the notable research gap of large scale sediment and carbon budgets; which is a very significant contribution not only to the biogeochemical and geomorphological community. Thus the manuscript is of high scientific significance and I highly recommended a publication in Biogeosciences. However, the manuscript needs minor revisions to improve the scientific and presentation quality. I have not doubt that the manuscript will increase

from very good to excellent, if the given issues are addressed

General comments: The script is very long and difficult to read due to the large number of estimated budget components and the wealth of the presented data. To simplify the structure of the script is suggest to present the conceptual sediment and c-budget framework at the beginning of chapter 3 and describe data sources and methods for each budget component afterwards. Therefore, I suggest deleting chapter 3.1 and moving text within 3.1 to the associated budget components. "As suggested, in order to simplify the structure, the conceptual sediment and OC budget framework was presented at the beginning of Chapter 3. Chapter 3.1 presenting data sources and methods was deleted and its text was moved to the associated components (mainly Section 4.1.1 and Section 4.2). In addition, we have greatly shortened the manuscript length."

Concerning the budget framework, I wonder if the differentiation between soil erosion and slope soil control is correct. I assume that the term "soil erosion" accounts for the eroded soils. If slope control measures are installed soil erosion should decline. Therefore total amount of eroded soils (given with 134 Gt) is the net/effective soil erosion, e.g. the amount of soils that is eroded despite the installation of erosion measures. If I understand Table 1 correctly, the referenced works include human-induced reductions (e.g. Chen 1983, Wang et al 2003, Fu 2011 ïĆő measuring soil erosion in 2000 AD after soil protection). If this is correct you reduce the human impact twice. Please comment on this. "The total soil erosion amount presented in this budget framework is the soil erosion before significant human impacts (i.e., during the 1950-1970s). Large-scale soil conservation and dam construction activities in the Yellow River basin started in the 1970s, and since then, the sediment load measured at the mainstem channel has showed a declining trend (see Fig. 3). In this study, we used the reconstructed soil erosion for the period 1950-1970s (e.g., Chen 1983; Wang et al 2003(this reference has been clarified in the revised version, it is for the period 1949-1970s)) by assuming that no significant human impacts occurred in this period. Also, in Table 1, the soil erosion amount was reconstructed mostly by summing up the actual observations at hydrological gauges and the reductions by human activities to get the soil erosion in the period 1950-1970. For example, Chen (1983) first estimated the soils controlled through soil conservation measures during 1960s-1979, and the sediment amount trapped by dams and the sediment delivery ratio during the same period, and finally reconstructed the soil erosion in the 1950-1970s by summing up the human-controlled soils and the hydrological gauge measurements in 1979. So, we used the reconstructed soil erosion amount (1950-1970s) and investigated its redistribution on the landscape. Fu (2011) estimated the soil erosion amount for the year 2000 through the USLE model and obtained a high value (2.11 Gt/yr). This high amount is comparable to the reconstructed erosion for the period 1950s-1970s, indicating soil erosion in the Yellow River is still very severe although human-induced soil control has been conducted for more than 40 years."

Chapter 4.3 and subsection in the discussion are partially redundant. Thus, I suggest to start the Discussion with a summary of the sediment budget and a plausibility test (assessments of uncertainties) "We have shortened the text and removed the redundant arguments in this chapter and the discussion section. A summary of the sediment budget and assessment of the uncertainty related to the budget terms have been added into the revised manuscript (please see Table 4 and related discussion)."

The English needs to be improved. I made several suggestions.

Abstract: The abstract is well structured and informative. I suggest to add a final statement regarding the implications of the presented study with respect to the source-sink discussion of soil erosion. "We have added a statement on the implications of this study into the abstract: Erosion-induced OC redistribution on the landscape likely represented a carbon source, although a large proportion of OC was buried'."

Introduction: The introduction starts with a short description of the importance of soils in the global C cycle and subsequent statements on soil erosion. Then there is a

break at transition from second to third paragraph, which deals with the Yellow River. I suggest to present the state of art on C transport in rivers in general: give references on the transport and processes of C in rivers, e.g:

Cole, J. J., et al. (2007), Plumbing the global carbon cycle: Integrating inland waters into the terrestrial carbon budget, Ecosystems, 10(1), 171-184. Battin, T. J., L. A. Kaplan, S. Findlay, C. S. Hopkinson, E. Marti, A. I. Packman, J. D. Newbold, and F. Sabater (2008), Biophysical controls on organic carbon fluxes in fluvial networks, Nature Geoscience, 1, 95-100.

Battin, T. J., S. Luyssaert, L. A. Kaplan, A. K. Aufdenkampe, A. Richter, and L. J. Tranvik (2009), The boundless carbon cycle, Nature Geoscience, 2(9), 598-600.

Aufdenkampe, A. K., E. Mayorga, P. A. Raymond, J. M. Melack, S. C. Doney, S. R. Alin, R. E. Aalto, and K. Yoo (2011), Riverine coupling of biogeochemical cycles between land, oceans, and atmosphere, Frontiers in Ecology and the Environment, 9(1), 53-60. "We have added a transition on carbon transport in rivers and the importance of rivering carbon transport studies into the text. Several important references have also been added to justify the argument: 'Rivers represent important conduits of carbon from terrestrial ecosystems to the oceans and the atmosphere (Cole et al., 2007;Battin et al., 2009;Aufdenkampe et al., 2011). Studying river transport of the eroded OC plays a critical role in understanding carbon cycle at the watershed level'."

I suggest to discuss your results in comparison to following reference: Hoffmann, T., Schlummer, M., Verstraeten, G., and Notebaert, B.: Significance of sediment and carbon storage on hillslopes and floodplains, Global Biogeochemical Cycles, 27, doi:10.1002/gbc.20071, 22013, 2013. "As suggested, we have added discussion on our results in comparison with Hoffmann et al. (2007; 2009; 2013)."

I suggest to more clearly define the aims of the studies. What are the detailed aims, e.g. which components of the C-cycle do you want to study? Currently the given aim is very general. The link between the aims and the used methods should be very clear.

Define your time scale here; and repeat it in the methods and results section. Why do you focus on the 1950-2010 time-scale? "We have rephrased the aims of the study. The aim of this study is to provide estimates of the OC redistribution on the landscape and the amount of decomposed OC induced by soil erosion within the Yellow River basin during 1950-2010. Because significant human activities have occurred since the 1970s and with continuous hydrological records since 1950, this long time-period allows us to analyze human impacts on OC cycle at the watershed level. The time scale has been repeated several times in the revised version."

Data and Methods Due to the wealth of data and studies I suggest to restructure the methods and results chapter: first present the concept and afterwards the data and the results (e.g. delete chapter 3.1). "Agreed and changed."

Eq.1: 1. Does soil erosion Es represent the "potential for soil erosion" without soil conservation? (see comment above) 2. If I correctly understood your approach Rs is the residual to balance the sediment budget Eq. 1! If correct, please clearly highlight that fact. I have the feeling that hillslope deposition is strongly underestimated. A hillslope SDR of >0.9 is very unlikely; discuss these limitations (e.g. compare with Hoffmann et al, 2013, GBC). "1. Yes, the soil erosion Es in the budget equation represents the 'potential for soil erosion' without soil conservation and other significant human impacts (e.g., dam trapping). 2. Yes, Rs is the residual to balance the budget equation. We have more clearly highlighted this in the revised text. Due to hyper-concentrated flow characteristics (suspended sediment concentration >300 kg/m3) and the flow's strong sediment-carrying capacity and the fine sediment property on the Loess Plateau, almost all the sediment in motion may be regarded as wash load, and thus the sediment delivery ratio is extraordinarily high, >0.9 and sometimes close to 1 (e.g., Walling and Fang, 2003. Global and Planetary Change, 39, 111-126; Xu, 1999. Catena, 36, 1-19 and references therein). This high sediment delivery and low hillslope deposition was further analyzed in relation to Hoffmann et al (2013)'s study in Central Europe."

Results

Sediment deposition within dams and channels does only consider sedimentation in reaches along depositional basins and excludes deposition on floodplains. The given values are, for sure, minimum values since the full depositional length of the Yellow river and its tributaries and the floodplains are not considered. Recent results from Hoffmann (2009 and 2013) indicate that a large fraction of C has been deposited on the floodplains.

To simplify the presentation of your results I suggest to summarize all results in one table: this table should include total sediment storage (or mean sedimentation from 1950-2010, including the relevant reference), mean SOC content, and OC-deposition for each considered budget-component. If budgets components are resulting from a sum of different sub-components, this should be represented in the table as well (e.g. soil control measures is the sum of revegetation and terrace formation). "We have further analyzed the uncertainties related to channel deposition. 'As the full depositional length of the Yellow River and its tributaries was not taken into account when estimating the channel deposition in the budget, the channel deposition would have been underestimated. In fact, a large number of tributary floodplains are important sinks of sediment and thus the associated OC (Hoffmann et al., 2007; 2013)'. We have included these references to justify the argument. In addition, we have summarized all results into one table as suggested (Table 4 in the revised version). Necessary notes are also provided."

Discussion Large-scale sediment and C-budgets are inevitably link with large uncertainties. Thus, this study provides a valuable distribution despite these uncertainties. However, the uncertainty assessment requires a more robust statistical sensitivity analysis. Please indicate in a summarizing table (as suggested above), which components are of high confidence and which have very low confidence. Indicate which values are taken from literature, and which are calculated by yourself. Further I suggest to propagate the uncertainties to the estimation of the residuals of Eq. 1 and 2. "As suggested, we have summarized these budget results in Table 4, indicating the confidence level and descriptions of how they were obtained. We have also more clearly clarified the propagated uncertainties in the revised text. The sediment hillslope redistribution and OC decomposition terms are determined through the budgetary calculations and there are uncertainties with each component, we have accounted for the propagated errors for the two components by treating the errors on the individual components as being statistically independent (although not entirely true). A similar uncertainty assessment method was also used by Smith et al. (2001. Global Biogeochemical Cycles, 15, 697-707). References have also been added to justify our argument."

Statements in Chapter 5.3 are very general and should be supported by your data. "Agreed and our own data were added to support the argument"

Figures: Figure 1: Increase font size; currently is rather small "done"

Figure 2: I suggest adding terms from budget eq. 1 and 2 in that sketch. Increase the font size. "done"

Figure 5: Add the desert to the legend and give references to the map in the figure caption. "done"

Figure 6: 1. I suggest to plot two budget figures (e.g. 6a and 6b): one for sediments and one for carbon. 2. If plotting two figures, I suggest to give absolute numbers (preferred in Gt / yr) and relative numbers (based on soil erosion = 100%) 3. Indicate then which numbers are associated with human impact (as you do in the paper) and which budget components are estimated by balancing the budget "As also suggested by another reviewer, we have simplified this figure to only present the carbon fluxes in Tg/yr so that it can be compared with other studies in terms of carbon flux."

Figure 7: This Figure does not add any new information. Can be deleted. "We want to show the redistribution pattern (in percent) of the eroded soils and OC on the landscape. Figures 4 and 8 are removed from the text."

Tables: I suggest to add a table with the total sediment storage, applied mean OC

concentrations and total OC storage, including the used references for each number and for each budget component in Eq. 1 and2. "We have summarized all results in one table as suggested (Table 4). The used references have been presented in Tables 1 and 3."

Specific comments: P2l8: natural processes and human activity are interacting rather than integrated "done"

P2l10: change slope lands to 'hillslopes' throughout the text "done"

P2l10: delete "Among the produced sediment" "done"

P3l5: cycle ïĆő cycles "done"

P3l6: difficulty ïĆő difficulties "done"

P3l25: change to "...concerning the OC-cycling in the..." "done"

P3l26: change to "...is transported as particulate OC, while..." "done"

P3l27: the total ïĆő the total C-flux "done"

P4l6: What do you mean with "conventional methods"? "Conventional methods usually use models and assume a 20-40% OC decomposition to assess OC redistribution."

P4l7: fates ïĆő fate "done"

P4l10: change to "The Yellow River flows from its origin in the Qinghai-Tibet Plateau at an altitude of 5000-6000 m along a 5464 km course towards eastern China, ..." "done"

P4l13: change to " ..., ranging from humid climates in the SE section to subarid climates ... to arid cliamtes... " "done"

P4l21: change to "Mean annual water discharge from 1950 to 2010 at Lijin..." "done"

P5l01: add the following reference: Hassan, M. A., M. Church, J. Xu, and Y. Yan (2008), Spatial and temporal variation of sediment yield in the landscape:

Example of Huanghe (Yellow River), Geophysical Research Letters, 35, L06401, doi:06410.01029/02008GL033428, 032008. “done”

P5l05: sediment flux ïĆő sediment yield “done”

P5l12: How much does this represent of the total discharge? “It represents about 25% of the total water discharge at Huayuankou station. This has been added into the text.”

P5l16: change to “...Quaternary loess is usually 130-180m thick, up to ...” “done”

P5l27: use terminology of FAO-classification “done”

P6l09: “...national soil survey conducted sine 1979 by thee Institute...” “done”

P6l08: “The Yellow River basin is covered...” “done”

P6l14: “a soil profile” ïĆő “one soil profile” “done”

P6l16: remove “...in soil horizon...” “done”

P6l17: change ”... because it is the topsoil horizon that closely correlates with soil erosion processes.“ ïĆő " ...because soil erosion is limited tot he topsoil horizon. “done” “ P7l04: change to: "Soil erosion by water at the basin scale is usually composed of three phases, including detachment, transport, and deposition of soil particles. The detachment occurs at uplands where soil is vulnerable to erosion. The eroded soil...“ “done”

P7l08: remove the sentence: “Understanding erosional effect...all three phases.” “done”

P7l09: "...all the three phases...“ ïĆő"...all three phases...” “done”

P7l15: Eq.1 is not a transport model rather a budget equation “agreed and changed”

P7l15: I suggest to visualise each term in Figure 2 “done”

P7l17: remove “The subscript S represents bulk sediment”. “done”

P7l22: budgetary ïĆő budget “done”

P8l08: change to “Equivalent to Eq. 1, a similar budget equation can be obtained for OC:” “done”

P8l12: remove “The subscript C represents OC.” “done”

P8l22-23: give references “done”

P9l2-4: give units for terms in Eq.4 “done”

P10l09: “for the studied 61 years”: so far the study period (1950-2010) is only mentioned in the abstract. I suggest to repeat it several times in the text (for example in the methods chapter; please indicate why 61 years?). “done”

P10l11: remove the first sentence of the paragraph “done”

P10l14: remove “...in the basin...” “done”

P10l15: “Temporally, the sediment transport...” ïĆőwhich 4 stages do you mean? I suggest to remove this sentence. “done”

P10l23: approx.. 2.83 km3 or 22.4% of its initial storage capacity has been lost due to sedimentation (Ministry...)” “done”

P10l26: change to “...Ran et al (2013c) estimated reservoir sedimentation within the Yellow River basin.” “done”

P11l13: Change 17.8 Gt to mean sedimentation given in Gt/yr “done”

P12l07: Is the value (1.3 Gt) included in the 3 Gt given in line 274? “No, the 1.3 Gt is the sediment stabilized by vegetation restoration during the last decade, while the 3.0 Gt is the sediments stabilized by soil conservation measures during 1950-1996.”

P13l14: what is the mean sediment yield in the period from 1950-1968? Give numbers! “The mean sediment flux was about 1.24 Gt/yr during the 1950-1968. Added in to the text.”

P14l03: plummeted ïĆődeclined “done”

P14l05: How did the SDR changed through time? Do you have any numbers? “Due to dam trapping, the sediment delivery in the Yellow River has been greatly reduced. For example, the sediment flux was about 1.24 Gt/yr during the 1950-1968, and now it is only 0.15 Gt/yr. Current sediment flux represents only 12.1% of that during 1950-1968. Added into the text.”

P15l05: Is the higher SOC in the headwaters a result of higher input of OC or lower decomposition? “It is probably due to high OC input, because the headwaters are mostly covered with a meadow ecosystem as a result of relatively high precipitation.”

P18l24: This paragraph could introduce chapter 5.3. “done”

P19l01: “...increasingly more on human...” ïĆő “...increasingly on human...” “done”

P19l02: change to “...have dominated soil erosion, transport and storage.” “done”

P20l22: what do you mean with “reconstructed soil erosion rate”? Why reconstructed? “We used the estimated soil erosion during the period prior to significant human activities (1950-1970s) to investigate the redistribution of the eroded soils and OC on the landscape, and the impacts of human activities. This soil erosion amount was mostly reconstructed by summing up the actual amount measured at hydrological gauges and the reductions due to human activities, mainly dam trapping and soil conservation. ”

P20l16: Change to ‘The soil erosion rate of the Yellow River basin during the last 61 years ranges between 1.7-2.5 gt a-1 with a mean of 2.2 gt a-1. “done”

P20l18: remove ‘indeed’ “done”

P20l21-23: unclear “The statement is more clearly explained- ‘Given the temporal variability and the difficulty to assess the erosion in each year, we adopted the estimated soil erosion rate during the period prior to large-scale human activity (i.e., 1950-1970s, Table 1). This rate was then applied to analyze the redistribution of sediment and OC,

and also the impact of human activity’.”

P20l26: It is unquestionable that sand mining is not important at that scale. I suggest deleting that sentence. “done”

P21l1-10: Currently the deposition on floodplains is not considered. Could you comment on the importance of floodplain deposition after the construction of flood protection measures? The embanked part of the floodplain might be characterized by very high sedimentation rates, which are not effected by the sediment regulation. As shown by Hoffmann et al (2007, The Holocene and 2009, Geomorphology), the large number of small tributary floodplains may significantly contribute to the storage of sediment and OC. Please refer to these papers. “Uncertainties related to channel deposition is further analyzed. Simplification in the estimate method would have underestimated the channel deposition because not the full depositional length of the mainstem channel and its tributaries was considered. In fact, a large number of tributary floodplains are important sinks of sediment and thus the associated OC (Hoffmann et al., 2007; 2009; 2013). We have included these references to justify the argument.”

P21l18: Please specify that you are talking about the hillslope SDR “done”

P21l27: Can you give a range of possible SDR values? “The SDR would decrease to about 0.15.”

P23l04: change unpractical ïĆőunlikely “done”

P25l11: change ‘three phases of soil erosion’ to ‘erosion, transport and deposition’ “done”

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