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Interactive comment on “Alluvial plain dynamics in the southern Amazonian foreland basin” by U. Lombardo

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Received and published: 15 March 2016

R - The article presents interesting results on small tropical rivers from the Bolivian Amazon foreland. The study is based on a 2D planform multitemporal analysis of Landsat images. The major conclusions are: a) most of the sediments are deposited in small rivers and not transferred and stored along the Mamore collector system. b) frequency of crevasses is controlled by intrabasinal processes (annual to decade time scale), c) the frequency of crevasses is not linked to ENSO activity, d) location of the crevasses is controlled by climatic or neo-tectonic events on a millennial scale, e) it has implications for conservation in a RAMSAR site, etc. Although the river descriptions are of interest, the major problem is the lack of data to justify the results because only a 2D analysis is provided. The results are relevant but they do not cover and confirm all the

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postulations listed above because the limited analysis on fluvial morphodynamics. The lack of field surveys, the scarcity of quantitative data on sediment transport, sediment storage, volumetric calculations, water discharge, sedimentation rates, make unsustainable to support such a large set of conclusions. As suggested by another reviewer, inferences on spatial and temporal changes in sediment load, bed elevation, stream discharges, and floodplain deposition (specifically changes in floodplain elevation) are not directly observed, but speculative and derived from indirect evidence. My suggestions is to rewrite the discussion and conclusions making focus on conceptual models for the different types of rivers but without making conclusive quantitative assumptions on sediment storage, rates of sedimentation, etc which are not sustained by the available data. It is necessary to redefine the objectives and to decrease the expectations in terms of the concrete a sustainable answer the limited 2D approach can provides on river morphodynamics.

UL - I do agree with the reviewer that multitemporal landsat imagery alone can hardly provide quantitative data on sediment storage, rates of sedimentation, etc. In fact, all the conclusions based on the analysis of the Landsat dataset presented in my manuscript are qualitative, not quantitative. As I have also pointed out in the answer to the first reviewer, the general conclusions reached in the discussion are supported by the quantitative data on discharge, TSS, sediments grain size etc provided in Guyot et al., 1996 and do Nascimento Jr. et al., 2015. Several studies have shown how multi-temporal analysis of Landsat images can serve in order to infer river sedimentary loads, sedimentation rates atc. This has been made clearer in the introduction by adding the following: “Thanks to the availability of Landsat imagery with sub annual temporal resolution covering the last three decades, it is now possible to document river spatial and temporal changes and make inferences regarding large-scale changes in hydrology, sedimentation patterns and river sedimentary loads (Buehler et al., 2011; Peixoto et al., 2009; Constantine et al., 2014).” In addition, the following has been added at the end of the Introduction “Although the analysis of optical remote sensing imagery here presented does not provide quantitative data on sedimentary processes, it does

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allow a qualitative assessment of these processes and a re-interpretation of existing quantitative data.”

R - I also would suggest eliminating secondary discussions (ecology, hazards, etc) that are shallowly incorporated and that do not provide relevant information to the reader.

UL - I do believe that it is important that scientific papers establish transdisciplinary bridges and make an effort to interest an audience as diverse as possible. I understand this is also a fundamental policy of ESD, as it “solicits contributions that investigate these various interactions and the underlying mechanisms, ways how these can be conceptualized, modelled, and quantified, predictions of the overall system behaviour to global changes, and the impacts for its habitability, humanity, and future Earth system management by human decision making.” Including what reviewer 2 refers to as “secondary discussions” goes in this direction and, therefore, I think that it is appropriate.

R - I am listing some comments as follow. I hope they can be useful to improve this manuscript. R - a) Pages 2065-2066. Introduction: the intro is a sequence of disconnected citations on ecology, geomorphology, sedimentology, basin analysis, hazards, etc. Rewrite the intro making focus on the objectives of the work and state of the art on the knowledge of the area, etc.

UL - The comment about “disconnected citations” is not specific, as does not refer to any in particular. I don’t see the “disconnection” the reviewer 2 is referring to. It seems to me that this comment is partly related to the reviewer’s opinion that all the references to the ecological importance of the study area and the implication this study has on indigenous livelihoods and development policies should be avoided. On this, please see the previous answer.

R - Avoid incomplete sentences with conceptual problems, such as “through meandering, the formation of crevasse splays, avulsions and backswamp sedimentation, rivers fill sedimentary basins (Slingerland and Smith, 2004)”. Rivers fill sedimentary basins

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with more than just the processes listed in the paragraph. Even more, meandering rivers can (or not) fill sedimentary basins and many of the listed mechanism-process also happen in other types of rivers.

UL - The sentence reported by the reviewer is indeed incomplete, as it is a fragment taken from a larger sentence, which reads: “Through meandering, the formation of crevasse splays, avulsions and backswamp sedimentation, rivers fill sedimentary basins (Slingerland and Smith, 2004); they create an irregular topography, favouring the formation of diverse ecological niches (Lewin and Ashworth, 2014); they generate the flood pulses that maintain the biota in river-floodplain systems (Junk et al., 1989); and they cause disturbance in forest structure, which, in turn, is key in creating and maintaining biodiversity (Salo et al., 1986; Nelson et al., 1994).” Of course, this is a general statement which touches several aspects without entering into any detail or nuance. But such statements in the introduction are important to establish the reach of the study and to make it interesting to the different disciplines that can benefit from the study’s results.

R - b) Pages 2065-2066. Avoid conclusions in the introduction.. ” In the SAFB, the patterns of paleo channels show that it is not the large Río Mamoré but rather its tributaries that have deposited most of the sediments that form the modern alluvial plains (Lombardo et al., 2012; Lombardo, 2014; Hanagarth, 1993).” I understand that demonstrating this issue is a major objective of the paper, particularly because other authors postulated different results.

UL - This is a sentence that refers to the construction of the floodplain by the Mamoré tributaries in the past, throughout the Holocene, it is fully referenced and it is not a conclusion of this paper. The paper focuses on the behaviour of these rivers in the last 30 years and it concludes that recent river activity is consistent with the Holocene reconstructions cited, although the depozone of the modern rivers is closer to the Andes than that of the paleorivers.

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R - c) Pages 2070-2075. The section on avulsing rivers recurrently presents conjectures on rates of sediment transport, storage etc. Avoid speculative assumptions on sediment transport because no measurements or field data support the conclusions.

UL - See answer to the first reviewer's comment above

R - d) Pages 2065 and 2076. Several conceptual problems on fluvial Geomorphology appear along the manuscript. This for example is a wrong sentence. Crevasse splays and river avulsions are the most important depositional processes in alluvial plains (Slingerland and Smith, 2004; Smith et al., 1989). Avoid this generic and incomplete sentences. You made before a different assumption when citing Singerland and Smith, 2004. All depends of the channel-floodplain style and multiple processes that can be involved.

UL - The sentence now reads "In aggrading alluvial plains characterized by the presence of well-developed paleosols within fine-grained alluvium, as it is the case in the SAFB (Lombardo et al., 2012; Lombardo 2014), crevasse splays and river avulsions are the most important depositional processes (Slingerland and Smith, 2004; Smith et al., 1989).

R - e) Pages 2010-2079- The author emphasize the role of the tributaries in the production and storage of sediments and minimize the effect of the major collector systems. However, important references and results besides Aalto et al., 2003 are not included in the discussion. It is necessary to include the budget presented by Charriere et al, 2004; and also the results by Gautier et al., 2007 in the Beni River, which also includes some information on the Mamore River. Charriere et al suggest ca. 180,Mt of storage along 650km of the Mamore, downstream Puerto Villarroel, by meandering migrations and flood deposits. Charriere, M., Bourrel, L., Gautier, E., Pouilly, M., 2004. División geomorfológica del Rio Mamoré. In: Pouilly, M., Beck, S., Moraes, M., Ibañez, C. (Eds.), Diversidad biológica del Rio Mamoré. Fundación Simon I. Patiño, Santa Cruz de la Sierra, pp. 79–94 Gautier, E., Brunstein, D., Vauchel, P., Roulet, M., Fuertes, O.,

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Guyot, J.L., Bourrel, L., 2007. Temporal relations between meander deformation, water discharge and sediment fluxes in the floodplain of the Rio Beni (Bolivian Amazonia). *Earth Surf. Process. Landf.* 32 (2), 230–248.

UL - The following sentence has been added to the section about Río Grande: “Charriere et al. (2004) have estimated that the Mamoré River deposits about 150 Mt yr⁻¹ along the first 200 km of its course downstream of Puerto Villarroel (i.e. before reaching the PG gauging station)” The section has been partly re-written to make it clear that I used evidence from Landsat imagery to re-interpret the data published by Guyot et al. 1996 and to discuss previous estimates of TSS of the Grande-Mamoré system. The section now reads: “This data has been used by several authors to estimate the amount of sediment deposition along the Grande-Mamoré system. Charriere et al. (2004) have estimated that the Mamoré River deposits about 150 Mt yr⁻¹ along the first 200 km of its course downstream of Puerto Villarroel (i.e. before reaching the PG gauging station); while Constantine et al. (2014) have estimated that Río Grande provides 84% of the TSS of the Mamoré at PG. These estimates implicitly assume that other tributaries of the Mamoré (several other rivers joining the Río Grande and the Mamoré between Abapo and Trinidad: the Ichilo, the Piraí, the Chimoré, the Chapare, the Sacta, the Isiboro and the Yapacaní) do not represent an important contribution to its TSS at the PG gauging station. On the contrary, the new data coming from the analysis of Landsat imagery suggests that most of the Mamoré’s TSS at the station PG does not come from the Río Grande but from the other tributaries. The analysis of the meander migration rate of the Río Grande just before joining the Mamoré (Figure 11) suggests that, through the repeated formation of crevasses and avulsions, almost all of the Río Grande’s TSS is deposited in the alluvial plains before it reaches the Mamoré, forming alluvial deposits and extensive dune fields (May, 2013; Latrubesse et al., 2012). Immediately before the Río Grande joins the Mamoré, it receives water from the Río Yapacaní. The average meander migration rates of the Río Grande before and after receiving water from the Yapacaní are 0.46 ± 0.4 m yr⁻¹ and 3.53 ± 2.9 m yr⁻¹ respectively. This shows that an important part of the sediments that the Río

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Grande brings to the Mamoré actually come from the Yapacaní. In addition, although data on the TSS of the rivers joining the Río Grande and the Mamoré between Abapo and Trinidad is very limited, these rivers cause an almost tenfold increase in river discharge from AP (330 m³s⁻¹) to PG (2970 m³s⁻¹). Therefore, several observations suggest that far more than the previously estimated 50% of the sediments that the Río Grande brings from the Andes are sequestered in the alluvial plains before reaching the Mamoré: i) the important contribution of the other tributaries to the Mamoré's discharge; ii) the high meandering rate of some of them; iii) the high number of crevasses and avulsions experienced by Río Grande; and iv) the changes in Río Grande's Mr in the proximity of its connection with the Yapacaní". Reference to Gautier et al. has been added to the discussion, see answer to comment K.

R - f) Pge 2076- "Despite a large body of 10 studies, the exact mechanisms controlling crevasse splays and river avulsions are not entirely understood (Hajek and Edmonds, 2014; Stouthamer and Berendsen, 2007; Ashworth et al., 2004". The sentence is unnecessary because you are not providing in this paper an analysis on the mechanisms that trigger avulsion. Concentrate in describing your data and in presenting your conceptual model for the area.

UL - Although this paper's primarily focus is not the analysis the mechanism and triggers that lead to crevasse splays and avulsions, it does provides several case studies and a hypothesis, at least for the cases of Maniqui, Piraí and Grande, about how strong seasonality, lack of slope and a perched river channel control the frequency of crevasses and avulsions. The fact that this hypothesis needs to be backed by field evidence doesn't make the above cited sentence unnecessary. See also answer to comment H

R - g) Page 2076- "This increased precipitation towards the Andes causes an important rise in the rivers' discharge, whilst the floodplain water table remains relatively low. Under these conditions, the formation of crevasses becomes more likely because of the higher hydraulic head (Slingerland and Smith, 1998)." Where are the field and

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analytical data that sustain that conclusion?

UL - This sentence has been changed in response to a comment from reviewer 1. It now reads: “Under these conditions, the formation of crevasses becomes more likely because the water level inside the river channel rises faster than the water level in the surrounding floodplain (Aalto et al. 2003)”. This is a model proposed by Aalto et al (2003) to explain how the sedimentary events of the Mamoré River are linked to the ENSO activity. But see also answer to comment K

R - h) Page 2076- Eliminate the following sentence as you do not provide data to sustain changes in discharge, or trends in sediment transport or the description of logjams in the field, as related to decrease of sediment transport, avulsion, etc. “The behavior of these three rivers seems to be controlled by the seasonal lowering of the water table that takes place at the end of the rainy season. This causes a sharp reduction in the rivers’ sediment transport capacity, increased channel infilling and likelihood of logjam formations. However, as described in the similar case of Río 5 Pilcomayo in the Chaco plains (Martín-Vide et al., 2014), it could also be the result of an increased sediment discharge due to modern landuse change in the Andes.

UL - This sentence has been moved to discussion. It is a mechanism I propose to explain the behaviour of the Maniqui, Piraí and Grande rivers. It start saying “it seems. . .”, highlighting its speculative nature. Nevertheless, to my understanding, this is the most likely explanation for the rivers’ behaviour and serves as a working hypothesis for future research. Therefore, it is appropriate in the discussion section. See also answer to comment F.

R - i) Page 2077. “This research adds new evidence to the idea that most of the modern continental sedimentary basins are filled primarily by distributive fluvial systems (Weissmann et al., 2013; Hartley et al., 2010) and shows that the SAFB is an excellent natural laboratory for the study of river processes in sedimentary basins”. Many systems can be radial or avulsive but they do not accomplish with the conceptual def-

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inition of “distributive systems” as postulated by Weismmann and collaborators. That happens with several of the rivers described in this paper. I would suggest checking this additional reference: Latrubesse, E. (2015) Quaternary megafans, large rivers and other avulsive fluvial systems: a potential "who is who" in the geological record. EarthScience Reviews 146, 1-30

UL - From Hartley et al., 2010: “We use the term “distributive fluvial system” (DFS) to mean the deposit of a fluvial system which in planform displays a radial, distributive channel pattern. We do not imply that all of the channels are, or were, active at the same time, although in some of the cases it is clear that they were. This broad definition of distributive fluvial systems includes at the largest scale fluvial megafans, at the mid scale fluvial fans, and at the smallest scale alluvial fans, although it should be noted that not all DFS necessarily display a fan-shaped morphology.” To my understanding this means that if a system is radial it does accomplish with the conceptual definition of “distributive systems”. The above mentioned definition of DFS has been added to the text.

R - j) Pages 2078-2079. Avoid this general sentences on hazards and ecologyconservation. If you consider that the results are relevant for environmental planning and environmental management, then, produce another specific paper to discusse those aspects.

UL - This comment has already been addressed above

R - k) Conclusions-page. It is claimed that “Most studies about alluvial plain dynamics in Amazonia have focused on large rivers, concluding that alluvial plain sediment accumulation is primarily the result of crevasse splays triggered by large, rapid-rise ENSO floods”. Be careful and change the sentence. Your conclusion is not correct because other studies are not suggesting that floods are the most important factor that trigger high accumulation rates in the floodplain. Contrarious to that, Gautier et al, 2007 and Charriere et al 2004 suggest that sedimentary storage is the consequence of mean-

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dering migration in Beni and Mamore rivers. They also make assumptions on the type of hydro-sedimentological regime that control migration rate and conclude that flood events are not the dominant process triggering high sedimentation rates- storage and cut-offs.

UL - The sentence now reads: “Several studies about alluvial plain dynamics in Amazonia have focused on large rivers, concluding that they cause most of the alluvial plain sediment accumulation. It has been proposed that this sedimentation is primarily the result of crevasse splays triggered by large, rapid-rise ENSO floods.” The following sentence has been added to discussion: “However, the validity of this hypothesis has been challenged by Gautier et al. (2007), who did not find any evidence of crevasse-splay formations along the Beni River.”

Interactive comment on Earth Syst. Dynam. Discuss., 6, 2063, 2015.

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