Response to reviewer 1

Dear colleague reviewer 1,

We thank you for this second detailed revision of the paper. We would like to apologize for this remaining error on figure 2 (it is definitely a graphic error as you can check on table 3). Thank you also for the wording and typos corrections. We replied in detail to all of your comments included in the pdf file. We are also pleased to read that the paper was considered as "a very interesting contribution to sediment connectivity research".
Best regards,

EC & MF

Dear colleagues,

you have submitted a revised manuscript that has greatly improved. However, there are still errors (very regrettably, Fig. 2 STILL or AGAIN shows wrong numbers) and a small number of suggested changes. Moreover, I tried to improve wording and correct typos in the passages that apparently were not proofread by an English native speaker. However, I'd like to ask you to deal with the remaining comments (see attached PDF) as thoroughly as you did with the first revisions. I'm very sure it's worth it, and your paper will be a very interesting contribution to sediment connectivity research. Best wishes

Our response to the reviewer's general comments is written in bold italic in the following text.
The reviewer's specific comments (integrated in the pdf file) have been listed page by page and numbered, based on the revisited manuscript (please see the attached document). Our responses are written in bold following each comment.
All substantial modifications that have been included in this new revisited version of the manuscript are written in red.

Nombre : 1 Auteur : reviewer Sujet : Notiz Date : 06/02/2017 23:14:32

Formula 4 is wrong.

It is not the sum of di divided by wi*si, it is the sum of (di divided by wi*si) ! See formula 3 in Cavalli et al. (2013) !

Corrected

Nombre : 2 Auteur : reviewer Sujet : Durchstreichen Date : 06/02/2017 23:15:14

OK

Nombre : 3 Auteur : reviewer Sujet : Notiz Date : 06/02/2017 23:18:36

well, it is not the cell i itself that contributes greatly - it's its upslope contributing area ! The potentially large sediment flux from a large, steep and smooth upslope area has good chances of reaching the target if the downslope connectivity is high (i.e. a short, steep and smooth path to the target). So the "great contribution" is routed through the cell i, not contributed by it.

Sorry for being picky, but I think it is necessary...

This has been corrected to be more accurate: "highlighting those cells that may efficiently route the sediment flux at the outlet."

Nombre : 4 Auteur : reviewer Sujet : HervorhebenDate : 06/02/2017 23:16:06

OK

Nombre : 5 Auteur : reviewer Sujet : Notiz Date : 06/02/2017 23:20:13

you should give an example.

Foerster et al. use a remote-sensing derived C factor that changes between seasons to assess temporal changes to connectivity:

We agree. We cited the two case study applications of the Broseeli/Cavalli IC to illustrate. Here are the additional references:

Foerster, S., Wilczok, C., Brosinsky, A., Segl, K., 2014. Assessment of sediment connectivity from vegetation cover and topography using remotely sensed data in a dryland catchment in the Spanish Pyrenees. J Soils Sediments 14, 1982-2000.

López-Vicente, M., Nadal-Romero, E., & Cammeraat, E. L. (2016). Hydrological connectivity does change over 70 years of abandonment and afforestation in the Spanish pyrenees. Land Degradation & Development.

Page: 5

Nombre : 1 Auteur : reviewer Sujet : Notiz Date : 06/02/2017 23:23:02

this only refers to "pure" sources, i.e. landforms that exclusively act as sources. It could be that a "link" node also "produces" sediment, additionally to what it receives from upslope, and is therefore partially a source...

The meaning of "source" differs from graph theory (node with no upstream contributor; starting points of the network) to geomorphology (node that can potentially supply sediments; which can be any node of the graph). This was clarified in the text (please see page 5 lines 13 to 15). It also replies to comment P6N2

Nombre : 2 Auteur : reviewer Sujet : Notiz Date : 06/02/2017 23:24:04

each edge is attributed/assigned a flow ?

Is assigned!

Nombre : 3 Auteur : reviewer Sujet : HervorhebenDate : 06/02/2017 23:23:39

OK

Nombre : 4 Auteur : reviewer Sujet : Notiz Date : 06/02/2017 23:25:06

really ? but that does not account for the aforementioned nodes that receive sediment, generate (through erosion) additional sediment, and pass that on !

2 sentences were integrated to clarify this point. Please see page 5 lines 21-23

Nombre : 5 Auteur : reviewer Sujet : Notiz Date : 08/02/2017 08:20:13

The "network effect" (references) describes how the network structure...
or
implies that the network structure...

Spelling corrected

Nombre : 6 Auteur : reviewer Sujet : Eingefügter Text Date : 06/02/2017 23:25:53

to

OK

Page: 6

Nombre : 1 Auteur : reviewer Sujet : Durchstreichen Date : 06/02/2017 23:27:38

OK

Nombre : 2 Auteur : reviewer Sujet : Notiz Date : 06/02/2017 23:30:44

again, I'd like to caution that the sources as defined by you are not necessarily the ONLY sources in the network, unless clearly defined so in a didactic example. In reality, a talus cone receiving a certain amount of rockfall sediment can yield sediment at higher rates through debris flows, fluvial incision and undercutting at the base. In your definition, it would be a link, and the outflux would have to equal the influx. In reality, it would be a net source...

Please see reply 5.1

Nombre : 3 Auteur : reviewer Sujet : Durchstreichen Date : 06/02/2017 23:31:09

Corrected

Nombre : 4 Auteur : reviewer Sujet : Eingefügter Text Date : 06/02/2017 23:31:38

various

Corrected

Page: 7

Nombre : 1 Auteur : reviewer Sujet : Notiz Date : 08/02/2017 08:12:15

continue review, Feb 6th

Nombre : 2 Auteur : reviewer Sujet : Durchstreichen Date : 08/02/2017 08:14:23

Corrected

Nombre : 3 Auteur : reviewer Sujet : Eingefügter Text Date : 08/02/2017 08:14:11

A

Corrected

Nombre : 4 Auteur : reviewer Sujet : Notiz Date : 08/02/2017 08:18:01

lines 12-14 should be moved to 2.2, for example to page 4 line 28 (before "both"). I think it is important to formalise the notation of a graph before measures (like the betweenness centrality and the Shimbel index on page 6) are introduced.

We agree. This was modified accordingly

Nombre : 5 Auteur : reviewer Sujet : Hervorheben Date : 08/02/2017 08:21:41

Nombre : 6 Auteur : reviewer Sujet : Notiz Date : 08/02/2017 08:22:10

we have to count the number of paths from j to o that include i (F_ijo)

This was modified accordingly

Nombre : 7 Auteur : reviewer Sujet : Notiz Date : 08/02/2017 08:27:07

this equation is not correct given the notation that you just introduced.
If F_ijo is the numbers of paths to the outlet via i, you don't need the sigma in the numerator.
If F_ijo is to be divided by the total number of paths, the denominator must be F_jo, not F_ijo.
If the sigma is correct (because there are many nodes j), it must be also in the denominator.
Please check this thoroughly !

Thank you for notifying this error. This was modified accordingly

Furthermore, I'd like to suggest that the "number of paths from j to o passing through i" should be Fjio (because that represents the order more intuitively: paths starting at j, passing through i, arriving at o)

You are right, but the mathematical reading of contingency table differs from our way of reading this i.e.: For the node i, supplied from j and arriving at o. So that you can notify, for example, for the node called A F_{Ajo} for a node B F_{Bjo} etc.

Nombre : 8 Auteur : reviewer Sujet : Notiz Date : 08/02/2017 22:07:31

The F index is a centrality measure, similar to "betweenness centrality" with the exception that the latter counts ALL paths between pairs of nodes that pass through i. Your F index counts the paths between nodes j and ONE target node o that pass through i.
Consider addressing F as a betweenness centrality measure for node i.

The "betweeness centrality" can only be applied to undirected graphs. So that we assume that it would generate more confusion to refer to it again here.

Nombre : 9 Auteur : reviewer Sujet : Eingefügter Text Date : 08/02/2017 08:28:32

weighting factor, for example related to slope gradient

This was modified accordingly

Nombre : 10 Auteur : reviewer Sujet : Eingefügter Text Date : 08/02/2017 08:34:42

S_n in Eq. 8; S0 represents the initial condition.
Consider rephrasing lines 29-2

We rephrased, so that is should be now clearer. Please see page 8 Lines 1 to 9

Page: 8

Nombre : 1 Auteur : reviewer Sujet : Durchstreichen Date : 08/02/2017 08:29:39

Corrected

Nombre : 2 Auteur : reviewer Sujet : Eingefügter Text Date : 08/02/2017 08:29:48

n

Corrected

Nombre : 3 Auteur : reviewer Sujet : Notiz Date : 08/02/2017 16:12:04

To me, the node that is located along a large number of paths to the outlet is influential (=> centrality). A node with a very small distance between source and outlet is not necessarily connected to other nodes, and thus need not have a big influence on the overall cascade... Please think that over...

To be clearer, we rephrased the overall paragraph. We distinguish the case of nodes located along a large number of paths from the case of network sources. Please see page 8 lines 15-21

Nombre : 4 Auteur : reviewer Sujet : HervorhebenDate : 08/02/2017 16:13:35

Corrected

Nombre : 5 Auteur : reviewer Sujet : Notiz Date : 08/02/2017 21:58:30

again: "to minimise" means to "MAKE something as small as possible".
How can a node MAKE something small ? It HAS a distance to the outlet, but it does not make this distance small.
Do you mean "particularly those sources that have a very small distance to the outlet" ?
As this sentence is not written in blue, I suppose it is unmodified compared to the first version.

We mean “small distance”, this was corrected accordingly (see line 20-21, page 8).

Nombre : 6 Auteur : reviewer Sujet : Eingefügter Text Date : 08/02/2017 22:11:56

ratio

Corrected

Nombre : 7 Auteur : reviewer Sujet : Eingefügter Text Date : 08/02/2017 22:12:06

the length of

Corrected

Nombre : 8 Auteur : reviewer Sujet : Eingefügter Text Date : 08/02/2017 22:10:32

to

Corrected

Nombre : 9 Auteur : reviewer Sujet : Eingefügter Text Date : 08/02/2017 22:12:39

and the total length of paths within the network.

Corrected following you recommendation

Nombre : 10 Auteur : reviewer Sujet : Eingefügter Text Date : 08/02/2017 22:13:53

; c.f. the upslope component of Borselli's IC

Corrected following you recommendation

Page: 9

Nombre : 1 Auteur : reviewer Sujet : Eingefügter Text Date : 08/02/2017 22:16:04
digitised

Corrected

Nombre : 2 Auteur : reviewer Sujet : Eingefügter Text Date : 08/02/2017 22:16:25
s

Corrected

Nombre : 3 Auteur : reviewer Sujet : Notiz Date : 08/02/2017 22:21:37
please quote the igraph package:

Csardi, G., Nepusz, T., 2006. The igraph Software Package for Complex Network Research. InterJournal Complex Systems.

Ref. Added

Nombre : 4 Auteur : reviewer Sujet : Eingefügter Text Date : 08/02/2017 22:20:43
for simplicity: The distance between adjacent pairs of geomorphic units is unity and not the Euclidean distance

Sentence corrected

Nombre : 5 Auteur : reviewer Sujet : Eingefügter Text Date : 08/02/2017 22:22:37
used as an example

Corrected

Nombre : 6 Auteur : reviewer Sujet : Eingefügter Text Date : 08/02/2017 22:25:11
that receives input from

Corrected

Nombre : 7 Auteur : reviewer Sujet : HervorhebenDate : 08/02/2017 22:30:23
what is "an overflow of sediments" ?
Deposition in the floodplain ? Why should that block a sediment pathway ?
Or do you mean a sediment surplus that leads to aggradation ?

We mean a sediment surplus that leads to aggradation. We replaced using your suggestion

Nombre : 8 Auteur : reviewer Sujet : Durchstreichen Date : 08/02/2017 22:26:11

Corrected

Nombre : 9 Auteur : reviewer Sujet : Eingefügter Text Date : 08/02/2017 22:26:09
the latter

Corrected

Page: 10

Nombre : 1 Auteur : reviewer Sujet : HervorhebenDate : 08/02/2017 22:28:18

why that ? Do you associate a short distance with small accomodation space for sediment storage ? Please explain this assumption !

This has been explained in the text, please see page 10 lines 13-14

Nombre : 2 Auteur : reviewer Sujet : Eingefügter Text Date : 08/02/2017 22:52:29

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Corrected

Nombre : 3 Auteur : reviewer Sujet : Eingefügter Text Date : 08/02/2017 22:52:32

:

Corrected

±] Nombre: 1 Auteur: reviewer Sujet: Durchstreichen Date: 08/02/2017 22:54:49

Corrected

Nombre: 1 Auteur: reviewer Sujet: Eingefügter Text Date: 08/02/2017 22:57:39
"valley glacier" OR only "glacier"

Corrected

Nombre: 1 Auteur: reviewer Sujet: Notiz Date: 08/02/2017 23:03:45

or the overwhelming of a buffer

Corrected

Page : 15

Nombre : 1 Auteur : reviewer Sujet : HervorhebenDate : 08/02/2017 23:08:47

do you mean a storage landform ? It could be overflowing or be exhausted. In case of exhaustion, one could even parametrise the decrease of sediment flux with time (e.g. Ballantyne's exhaustion model)

Yes, we agree that storage landform is much more correct and accurate. We modified accordingly

Nombre : 2 Auteur : reviewer Sujet : Eingefügter Text Date : 08/02/2017 23:11:38

"virtual velocity" of sediment transfer

Corrected

Nombre : 3 Auteur : reviewer Sujet : Notiz Date : 08/02/2017 23:12:52

you should also cite Borselli et al. who use the C factor as the impedance, and Cavalli et al. who use a roughness measure derived from a high-resolution DEM !

We added the references.

Nombre : 4 Auteur : reviewer Sujet : Eingefügter Text Date : 08/02/2017 23:11:51

M

Corrected

Nombre: 1 Auteur: reviewer Sujet: Notiz Date: 08/02/2017 23:16:42

check formula (Isuggested a change in the text)

Corrected

Nombre: 2 Auteur: reviewer Sujet: Notiz Date: 08/02/2017 23:14:40

typo: sediments, not sediements

Corrected

Nombre : 1 Auteur : reviewer Sujet : Notiz Date : 08/02/2017 23:20:20

there is an error, again (or still):

in the first step, one unit of sediment is routed
A=
>D
B=>
C
C=
>D
and
D=
>E

so, there is 0 on A and B (correct)
2 on D (correct)
but only 1 in C (wrongly given a 2)

as E receives two units (one from G that now correctly has 0, and one from D), there is another error (one instead of two).

Frankly, this does not increase my confidence in this depiction of the approach... It's more difficult and tedious to check whether the numbers in (c) are correct, but if they are not in (b)...

Thank you for noticing this. This was (again) only a graphic error. This was corrected accordingly. Since it seems you do not have a good confidence in the depiction of the approach, we added reference to table 3 in the figure caption (which is the table used for this calculations) to facilitate the link between the two figures. Then the table can be used to complement and validate the graphic output.

Suggestions for revision or reasons for rejection (will be published if the paper is accepted for final publication)

Review of "Assessment of structural sediment connectivity within catchments: insights from graph theory" by Cossart and Fressard for Earth Surface Dynamics.

Dear colleague reviewer 2,

We would like to warmly thank you for your helpful comments on this second version of the manuscript that will help to improve the quality of the paper.

You reported two main general comments we will address here (in bold italic font format). Then, a stepwise reply to your specific comments is provided. All substantial modifications that have been included in this new revisited version of the manuscript are written in red.

The first general comment deals with the confusion arising from the fact that we used the same name as Borselli and Cavalli (IC) for our index. This is a major issue we didn't notice, and we agree that it is important to provide an original name so that the argumentation will be clearer for the readers. We named our index the "Network Structural Connectivity index" (NSC). We believe that it would be now easier to distinguish both of them in the text and that it would be also easier to identify the original contribution of this work.

The second general comment suggests comparing our index with Borselli's IC on our study area. It appears to us complicated to provide it since the two approaches are based on very different assumptions. The Borselli and Cavalli index is strictly based on DEM attributes using raster data and weighting factor. It is, using this method, difficult to assess disconnections and reconnections of geomorphological components of the catchment (i.e. the impact of geomorphic buffers, barriers are blankets). One main objective of our work is to provide an index that could integrate this geomophological expertise to the analysis (i.e. connections and disconnections in the catchment and related sediment supply etc.) based on a geomorphological map. Therefore, we switched from a raster representation of space to a graph representation which is more adapted and flexible to integrate the (dis)connections and sediment availability in the catchment. The algebraic formalization allows this development. Then, we believe that a comparison with the IC (Borselli and Cavalli) would go beyond the scope of this paper since it will necessitate further discussions on space representation, spatial resolution and type of connectivity represented etc. We assume that such a comparison will obviously be very interesting, but would certainly necessitate a dedicated paper. Nevertheless, additional discussion points have been added to the appropriate section to discuss this issue. Please see on page 15 lines 13-16.

This review is of a revised manuscript following a first round of review comments. I note that I was a reviewer during the first round of review.

I commend the authors in reorganizing and revising the manuscript toward much improved clarity! Now it is more clear to me the novel contributions of this work. This manuscript presents a review of approaches for assessing structural sediment connectivity and describes relevant metrics from graph theory for measuring structural sediment connectivity. The authors point out that the connectivity index (IC) presented in Borselli et al 2008 and Cavalli et al 2013 is incapable of assessing how changes on the landscape affect sediment connectivity (delivery). Therefore, this work provides a network-based method for assessing structural sediment connectivity, by presenting a new way to compute

IC, to address this problem. The manuscript concludes with an application of this new approach to a catchment in the French Alps.

My main issue is that the variable IC reported in this paper is presented with two entirely different definitions without distinguishing between the two with even a superscript or subscript. IC has been defined in the paper according to Borselli et al 2008 and Cavalli et al 2013 and the authors use the same IC variable in this manuscript but redefine how to compute it using network attributes rather than DEM attributes (e.g., slope). I suggest adding a subscript to the variable name to distinguish the two or call the new IC something else entirely. If the new and old way of reporting IC are similar, I would like to see a qualitative comparison (map) of the IC computed both ways for your study catchment. That way readers can get a sense if both methods provide similar insight and then further see that the new IC computed with network attributes offers additional benefits in that you can assess how landscape changes directly affect structural sediment connectivity. I think this comparison would strengthen the paper greatly.

This manuscript advances the field of sediment connectivity, worthy of publication in Earth Surface Dynamics. However, I believe this manuscript would benefit from some minor revisions.

Detailed manuscript comments (P, page; L, line):

P 1, L 16: I suggest adding here that this hypothesis is guiding this work. When I first read this I was wondering if this hypothesis was being tested herein. I suggest "The main hypothesis guiding this work is that the network structure…" or something similar.

This has been modified accordingly

P 3, L 3-7: This is a great addition that helps frame the manuscript and inform the reader where the manuscript is headed. Much appreciated!

Thanks!

P 3, L 12: The Sediment Delivery Ratio (SDR) is defined improperly. As it is written it represents the volume of sediment eroded (Vh) divided by the volume of sediment delivered to the outlet (Vo). Vh is > Vo, so in this context would be a number >1. The spirit of the SDR is to provide a percentage of the eroded sediments that reach the outlet. Therefore, SDR should be written as Vo/Vh to provide a number <1, consistent with the literature and your discussion on SDR (P 3, L 15-16). The results and conclusions of the manuscript are unaffected by this issue as mention of the SDR was given as contextual background.

This has been corrected accordingly. This was a typing error.

P 6, L 10: "it can represents" should be "it can represent" or "it represents"

Corrected

P 6, L 11: "arious" should be "various"?

Corrected

P 7, L 8-11: "…we have developed the calculation of the IC (index of connectivity)…" Is this the same IC referred to as the "connectivity index" that was developed by Borselli et al 2008 and Cavalli et al 2013

No, it refers to our index. Since the name has been modified, it should now be clearer.

(P 4, L 2)? When you say you are "developing the calculation of the IC" it is unclear whether you are stating that you have developed the IC or that you are developing your own method for calculating IC that is different from that proposed by Borselli et al 2008 and Cavalli et al 2013. From looking ahead, it appears that you are proposing a way to calculate the IC using network characteristics. I wonder if calling this new variable the IC is the best way to go as it adds confusion in that you have an IC that can be computed in two different ways! As an aside, I wonder if you compute the IC from the two different methods if you would obtain similar results or not. Maybe add a subscript to IC such that IC_w is the watershed assessment of IC from Borselli et al 2008 and Cavalli et al 2013 and IC_n to denote that this is the IC computed from the network. Or change the name of IC computed from the network to a different name/variable altogether. I think this was where some of my initial confusion on the reading of the previous version of the manuscript lie because I thought IC had been developed before and you were just redescribing and applying it here.

We are actually developing our own connectivity index based on graph theory analysis. We assume the confusion that may arise given that both indices have the same name. We then changed the name of the one we developed so that it will now be clearer for the reader to make the distinction from what we developed to the Borselli and Cavalli IC. Our index is now called the Network Structural Connectivity index (NSC)

P 7, L 21: I think the denominator should be F_jo? Same in figure 1. Otherwise, why mention F_jo?

Thank you for noticing this. Corrected!

P 8, L 22: F and Shi do provide a "description of the sediment cascade skeleton" but more generally provide a description of the river-network skeleton. At this point, F and Shi are metrics characterizing directed graphs and could be used to assess cascades of other constituents through river networks, not just sediment.

We rephrased this part to include your comment. i.e. that these metrics goes beyond the sediment connectivity

P 8, L 31: The denominator is Ai and I think it should be Shi? Again, I think it is confusing to have IC essentially defined twice (equation 2 and again at equation 11). Maybe the spirit of IC is preserved in this new definition with the upstream and downstream terms and also with what it is trying to represent, but this a completely different variable.

This was corrected. We omitted in the first review.

P 9, L 14: I am not sure "reduced-complexity network" is the best term for describing your simplified network. You also use "virtual sediment cascade" (P 1, L 21) and a "fictive and simple sediment cascade" (P 3, L 4). I suggest choosing one term throughout and maybe "conceptual sediment cascade" or "conceptual network" to illustrate the concept of this work.

This was homogenized in the text using the term "conceptual sediment cascade network"

P 9, L 20: I suggest adding the specific variable you are referring to for clarity, both in text, in caption, and on the figures. For instance, here "…a map of potential fluxes (Fi)…" reminds the reader that by potential fluxes you are referring to Fi, and also add Fi to figure 2c. Figure 1 helps sort this out easily and is a very nice addition to the paper! Similarly, for accessibility (Shi).

We agree with this comment and modified the text and the figures captions accordingly

P 13, L 21: At this point I am more convinced that there needs to be more clarity between the IC of Borselli et al 2008 and Cavalli et al 2013 and the network based IC calculated herein. Otherwise it will present confusion in the literature to which IC someone is referring to. Also, I would be interested in seeing if calculating IC both ways would give similar insights. This would be a nice addition and could really help showcase the strength of your new approach compared to that of Borselli et al 2008 and Cavalli et al 2013. It seems like you should already have all the information necessary to quickly perform this computation for your catchment. I do not think this further analysis is critical, but it would be a nice intermediate step for the community to see if the suggestion is to move away from the IC of Borselli et al 2008 and Cavalli et al 2013 and to using the network based IC developed herein.

This comment is addressed in the "general comments" section

References: In looking through the references, I did not see "Gran and Czuba, 2015" which upon checking the final published form is "Gran and Czuba, 2017".

Corrected