

May 06, 2015

Editor-in-Chief  
Natural Hazards and Earth System Sciences

Dear P. Tarolli:

Thank you for your letter and for the editors and reviewers' comments concerning our manuscript entitled "Modelling of the hydrological connectivity changes in the Minjiang Upstream after the Wenchuan earthquake using satellite remote sensing and DEM data". Those comments are all valuable and very helpful for revising and improving our paper, as well as the important guiding significance to our researches. We have studied comments carefully and have made correction which we hope meet with approval.

### **Comments and response to the referee #2**

We would like to thank the referee for the valuable comments and suggestions, which all have been considered in the final version of the manuscript. Then, we re-define the hydrological connectivity index model, and strengthen the methodology explanation. We would submit one manuscript "Spatial Analysis of Damaged Vegetation in the Mianyuan River Basin after the Wenchuan Earthquake", and this manuscript is focused the slope material stability model.

In addition, we would use a professional English editing service or have the revised manuscript checked by a native English speaking colleague.

The mainly revised parts of the manuscript as the following show;

## **1 Hydrological connectivity index model**

Mass wasting processes in mountainous terrain are not only dependent on the overall terrain, but also on the spatial organization and the internal connectivity of various topographic units (Bracken et al., 2014; Borselli et al., 2008; Blahut et al., 2010; Croke et al., 2005; Rogelis and Werner, 2014). Bracken et al (2014) proposed that the sediment connectivity can be used to explain the continuity of sediment transfer from a source to a sink in a catchment, and movement of sediment between different zones within a catchment: over hillslopes, between hillslopes and channels, and within channels (Bracken et al., 2014). Borselli et al (2008) defined one connectivity index (*IC*) to evaluate the potential connection between hillslopes and sinks. Based on the existing models, this paper presents one definition of hydrological connectivity index (*HCI*). The definition is based on the fact that mass wasting processes depend on its size of upslope source zone and position in the mountainous catchment (Fig.5), which consists of two components: the upslope component  $F_u$  and downslope component  $F_d$ . And, the definition model can be expressed as:

$$HCI = \ln\left(\frac{F_u}{F_d}\right). \quad (2)$$

This defined model is presented linking hydrological connectivity with the ecological processes in the Wenchuan Earthquake-hit region, for it assesses the weight factor of slope materials through monitoring the vegetation changes before and after the earthquake.

## 1.1 The upslope component $F_u$

The upslope component  $F_u$  depends on the conditions of the upslope contributing area, such as topographic environments, and vegetative conditions. It is aimed at estimating the sediment production and the flow accumulation of the upslope contributing area. And,  $F_u$  depends on the topographic conditions (e.g. size, relative relief, and slope gradient) and surface materials of the upslope contributing area. Among these, the topographic factors can be calculated from DEM data. Then,  $F_u$  can be estimated as follows:

$$F_u = \overline{W}_u \sin(\overline{S}_u) \overline{H}_u \sqrt{A_u}. \quad (3)$$

Where,  $\overline{W}_u$  is the weighting factor of the upslope contributing area,  $\overline{S}_u$  is the average slope gradient of the upslope contributing area (°),  $\overline{H}_u$  is the average relative altitude of the upslope contributing area (m),  $\sqrt{A_u}$  is the size of the upslope contributing area (m<sup>2</sup>).

## 1.2 The downslope component $F_d$

The downslope component  $F_d$  is used to describe the transport processes of the upslope sediment.  $F_d$  is strongly influenced by the flow pathway conditions, e.g. flow length, slope gradient along pathway, and surface materials along pathway. Hence, the upslope component  $F_d$  can be estimated as follows:

$$F_d = L \sum_i \frac{\cos(s_i) C_i}{w_{di}}. \quad (4)$$

Where,  $L$  is the horizontal distance to river (m),  $w_{di}$  is the weighting factor of the  $i^{\text{th}}$  cell along the downslope path,  $s_i$  is the slope gradient of the the  $i^{\text{th}}$  cell (°), and  $C_i$  is length of the the  $i^{\text{th}}$  cell along the downslope path (m).

## 1.3 The weight factor $W$ of the slope materials

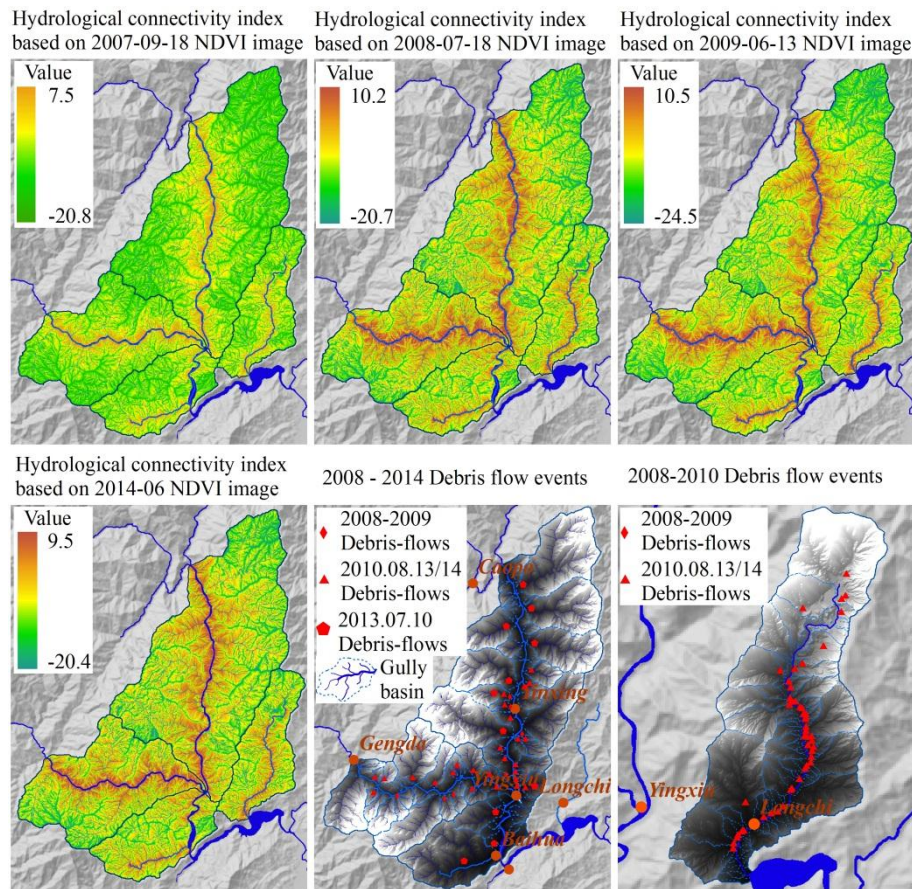
In the Wenchuan Earthquake-hit area, the earthquake-induced landslides destroyed large areas of vegetation that made the vegetation hydrological adjusting function diminished, and the large amounts of unconsolidated loose materials deposited on the steep slopes that changed the hydrologic progresses (i.e. infiltration reduced, runoff increased and flow concentration expedited) in catchment (Cui et al., 2012). In addition, vegetation roots add strength to the slope materials by the vertically anchoring to fractures in the bedrock through the slope materials and by laterally binding the materials across potential zones of the failures (Endo and Tsuruta, 1969; Prandini et al., 1977). Therefore, the weight factor of the slope materials can be evaluated by monitoring the vegetation changes before and after the earthquake.

In practice, the slope materials stability susceptibility ( $w$ ) model was trained through multivariate analysis of damaged vegetation and its survival environments in one given mountainous basin. And, the weight factor of upslope contributing area ( $\overline{W}_u$ ) can be simplified and expressed as the slope materials stability susceptibility ( $w$ ), which is related to the sediment production. Then, the

weight factor ( $w_{di}$ ) along the downslope path can be calculated as ( $\frac{1}{1-w}$ ).

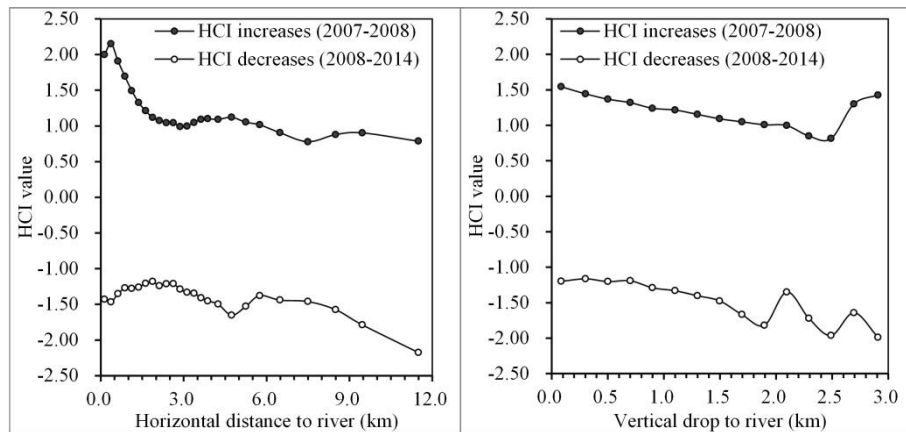
## 2 Hydrological connectivity changes at the study area

The study area was divided into vegetation-covered and bare areas, the slope materials stability of the vegetation-covered areas were calculated basing on the multi-temporal NDVI images, and the bare areas were regarded as 1. Finally, pre-earthquake and post-earthquake *HCI* maps were calculated and shown in Fig.8. Results showed that the high *HCI* values are zonally distributed along both sides of the river, especially in YY and GY watersheds.



**Figure 8.** The hydrological connectivity index map and the 2008–2013 debris-flow events at the study area.

For further analysis, the multi-temporal *HCI* changes with *H* and *L* was shown in Fig.9. Statistical results indicated that the areas with  $L < 2\ 000\text{m}$  have obvious *HCI* increases ( $>1.00$ ), which accounts for 37.2 % of the total areas, the areas with  $H < 500\text{m}$  have obvious increases ( $>1.00$ ), which accounts for 32.5 % of the total areas, and the high mountainous areas with  $H > 2\ 500\text{m}$  have obvious increases, too. Therefore, the areas with  $H < 500\text{m}$  and  $L < 2\ 000\text{m}$  have obvious increases ( $>1.00$ ), which accounts for 27.9 % of the total areas, and *HCI* values have slowly decreases and no obvious changing trends with *L* and *H*.



**Figure 9.** Statistical results of hydrological connectivity change processes from 2007 to 2014.

Since the earthquake, the study area had suffered severe debris-flow events (Fig.8). Statistical results showed that the areas with  $H < 500\text{m}$  and  $L < 2\,000\text{m}$  account for about  $>35\%$  of each debris flow gully area, and these areas have about obvious  $HCI$  increases and slower decreases with vegetation recovery. Therefore, we consider that the areas with  $H < 500\text{m}$  and  $L < 2\,000\text{m}$ , hereafter called the “susceptible areas for debris flow formation, SADFF”, are more susceptible to the debris flow formation, and if the SADFF account more than  $35\%$  of the total gully area, the gully has high potential for debris flow in the wet season.

#### Comments and response to the short comment

Interactive comments: *Have the authors considered the correlations between relative altitude and average slope of the upslope contributing area? If these variables are closely correlated, it would be questionable to use both of them in equation 3. In equation 4, the summation of cells size multiplied by the cosine of the slope angle adequately describes the flow path from each cell to the target (i.e., the receiving river). It is thus not clear why also the ratio of horizontal to vertical distance has been used in the computation of the downstream component of the model.*

Response: Thanks for L. Marchi kind advice. We consider the mass wasting processes as the potential energy release processes, both the relative altitude and slope of the upslope contributing area have strong influences on these processes. And, we use the sine values (ranges from 0.0 to 1.0) of average slope of the upslope contributing area, which mainly controls the initiation and processes of mass wasting in the upslope contributing area. And, the relative altitude mainly controls the magnitude of the potential energy in the upslope contributing area. In addition, we re-define the hydrological connectivity model, and we use the equation 4 to describe the horizontal and vertical processes of mass wasting along the downslope path.

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We deeply appreciate your consideration of our manuscript, and we look forward to receiving comments from the reviewers. If you have any queries, please don't hesitate to contact me at the address below.

Thank you and best regards.

Yours sincerely,  
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