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Natural Hazards and Earth System Sciences
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Discussions

Interactive comment on "Analysis of changes in post-seismic landslide distribution and its effect on building reconstruction" *by* W. Yang et al.

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The authors would like to thank the reviewers for their invaluable comments and suggestions, which have been of significant help for revising and improving the quality of this paper. All figures have been revised and the "Results" section has been re-organized. The point-to-point response to referee's comments and corresponding changes are listed below.

Response to Referee 1:

1) This paper aimed at analyzing the distribution of post-seismic landslide and its effect on building reconstruction. In the manuscript, hazards are generally analyzed by using image interpretation and field survey. But some conclusions are ordinary or superficial.

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e.g. “houses were built on areas with gentler slopes, lower elevation areas and closer to the riverbed. The width and depth of the riverbed have changed dramatically because of material from landslides and debris flows.” This reviewer can not find innovation point from the manuscript, ether in theory or methodology.

Response:

Recent study on “risk evolution” (Schwendtner et al. 2013) shows that the dynamic change of built environment can lead to dramatic risk change in similar hazard conditions (Schwendtner et al. 2013). The 2008 Wenchuan earthquake occurred in China has caused huge volumes of erodible materials on slopes (Parker et al. 2011). It is believed that this major earthquake will have a long-term impact to the earthquake stricken areas by increasing activities of post-seismic geo-hazards (Huang and Fan 2013). We have continuously conducted field reconnaissance in the study area and found that most buildings in this area were quickly reconstructed one or two years after the major earthquake because of the dominant role played by the governments (Dunford and Li 2011). The accelerated reconstruction of permanent housing faced rising risks from frequent occurrence of post-seismic geo-hazards and flash floods in the study area. This paper aims to analyze the dynamic changes of distributions in both landslides and houses, and more importantly, the relationship between these two changes.

Due to the limitation of available data (landslides and houses information) in the study area, we have taken advantage of both multi-temporal very high resolution satellite images and consecutive field reconnaissance to obtain geographic mapping of houses, landslides and riverbeds before and after the earthquake. This kind of data enables us to quantitatively analyze the dynamic changes of houses, landslides, and riverbeds in a changing environment and their interrelations.

This paper differs from existing literatures in two aspects. First, much attention has been paid on hazards research after Wenchuan earthquake, while little work has been

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done to investigate the building reconstruction in the earthquake stricken areas. This research has focused on the analysis of geographic distribution of houses before and after the earthquake, and its relationship with the changing distribution of landslides. Second, using both satellite images and field investigation, this research has quantified the dynamic changes not only in hazards (co-seismic landslides, enlarged and new landslides) but also other two important factors that are crucial for understanding a disaster system: the topographic environment change (riverbed width and depth change) and exposures (old and rebuilt houses).

Several years after the Ms. 8.0 Wenchuan Earthquake, there are still repeated reports of post-seismic disasters, which show that the evolution of mountain geo-hazards did have impacts on newly rebuilt houses. There are obvious disconnections between post-disaster reconstruction and the proper perception of post-seismic geo-hazards and evolving risk. We believe this research contributes to better understanding of the interplay among changing hazards, exposure and environment in the mountainous areas after major earthquake.

2) Since the number of housing was 2136 and 2371 before and after earthquake respectively, it is unreasonable to use the house distribution percentage to distinguish the changes in different distances from surface rapture and riverbank or at different slopes and elevations, e.g, in Fig.3, the percentage of housing was 14 and 13 percents at distance 0 50m before and after earthquake, actually the number of housing was 300 and 308, which showed the houses before earthquake was less than that of after earthquake. This causes confusion to readers.

Response:

We agree with the reviewer. We have changed the percentage of houses to the number of houses. In addition, we have plotted the cumulative percentage of houses in 2002 and 2012 to compare the house distribution change (see Revised Fig. 3).

Revised Figure 3 Caption: Houses distributions in different distance buffers from the surface rupture in the study area (bars for numbers of houses and curves for cumulative percentage of houses).

3) As is well known, the Wenchuan earthquake area is about 50×104km2, and the number of geohazards induced by this earthquake reached more than 3×104. However, this manuscript only took a small basin as study area to reveal the interaction mechanism of mountain disasters. This reviewer doubts the representative of this research and advises adding some more typical study areas.

Response:

We agree with the reviewer that the study area should be able to represent typical areas affected by the Wenchuan earthquake. The study area was carefully chosen based on the following considerations.

First, with the surface rupture running through, this study area experienced Modified Mercalli Intensity (MMI) scale X and XI, and suffered extensive damage with more than 60 percents of housing collapse and most of the remaining structures being severely damaged during the 2008 Wenchuan Earthquake (Mao et al. 2009). The strong ground shaking also triggered large number of severe co-seismic landslides and three of these landslides in the study area are ranked among top 13 most fatal landslides during the earthquake (Yin et al. 2009). Although the size of the basin is relatively small compared with the whole earthquake-affected region, it represents the most heavily affected area in the earthquake.

Second, there is very limited coverage of high resolution satellite data available for the Wenchuan earthquake affected region, which is crucial for obtaining building construction information before the earthquake. Most rural houses in this region have small sizes and can only be recognized in very high resolution images with spatial resolution better than 1 m. To map pre-seismic rural houses in this mountainous region, we searched available commercial satellite image archives. We found that VHR images taken before the Wenchuan earthquake with a spatial resolution better than 1 m

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only cover very limited areas in the Wenchuan affected region. And the only available sources are from IKONOS and QuickBird. For areas experienced with severe damage along the surface rupture of the Wenchuan Earthquake, the available VHR imagery covers only this study area (chosen in this research), part of Yingxiu Town and part of Beichuan County.

Third, we have been investigating the geohazards and environment recovery in the study area since the occurrence of Wenchuan earthquake by conducting intensive field reconnaissance and analytical work. Our previous research outcomes on landslides mapping (Yang et al. 2013), vegetation recovery (Wang et al. 2014b) and landslides susceptibility (Wang et al. 2014a), data collected and experience gained in this study area enable us to further study the relationship between evolving landslides and changing building reconstruction.

Therefore, considering the seismic intensity and landsides occurrence, the availability of VHR satellite images and the continuity of research in this study area, we have chosen this basin area to analyze the interaction mechanism of mountain disasters after major earthquake.

4) It is rational to select the buried houses located on the riverbed as reference points to estimate the depth change of deposits along the stream. The site selection is an important step. However, in Fig.2, site a and site b were chosen on the river bend. So the hydraulic characteristics of river at site a and site b are quite different from these at site c and site d. Therefore, it is unreasonable to estimate the depth change of deposits along the stream based on site a-d.

Response:

The uplift of riverbed becomes extremely severe in the study area since 2012. We have used Figure 2 to illustrate the severity of riverbed uplift caused by large amounts of debris deposition along the stream. In order to quantify the depth change of riverbed, we have tried to find reference points to make reasonable estimation. The four reference

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points (sites a, b, c and d) are what we identified for this purpose because these are existing permanent construction in the widen riverbed. The depth of these four points in August 2012 is compared with that of September 2013 so the uplift of riverbed at these four sites can be estimated. The purpose of showing the quantified uplift is to present how severely and quickly the riverbed was filled by landslide debris under the force of flash floods just in one year. Our intention is not to estimate depth changes and make inter-comparison along the stream by using only four reference points.

We agree with the reviewer that the hydraulic characteristics may affect the deposition (amount and speed). We carefully re-checked the four reference points and found that the sites a, b and c are located at river bend, while site d is at a relatively straight location. The changes of depth at sites a, b and c are significantly higher than that of site d. That confirms the reviewer's concern of hydraulic effect. We appreciate the reviewer's opinion on this! The hydraulic effect on the river width and depth changes and other mountainous environment evolution after major earthquake should be further investigated.

5)This paper is not written well. The logic of the manuscript is a little poor and some contents are redundant. e.g. In Page 5508, lines 7-11ïij′LParagraph 2ïijL', and Page 5509, line 18-28ïij′LParagraph 4ïijL', there are some repetitive contents to introduce the elevation of the watershed. It should be condensed and refined. 6)The quality improvement of the English language is required. Weaknesses of grammar and style make some parts of the manuscript hard to be understood. e.g. In page 5510, line 10 "at Upper Hongxi, Jiankang and Nanba villages (Fig. 7a)". But "Nanba village" is not in Fig. 7a.

Response:

We have examined the logic flow of the manuscript and re-organized the "Results" section. To make the manuscript concise, we have deleted paragraph 2 and 3 in page 5508.

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In Page 5505, Line 13, "Northern Sichuan Province." is changed to "Northern Sichuan Province, as shown in Fig.1."

In Page 5508, Line 7-15, the text has been deleted.

In Page 5508, Line 16-29, the whole paragraph is re-organized as: "Because of the steep terrain, both pre- and post-earthquake houses are sparsely distributed within the study area. Based on overlay analysis, 145 houses were affected by coseismic landslides in 2008, including houses that were fully or partially covered by the landslides (Fig. 4a). Twenty-three landslides were identified as damage coseismic landslides that affected houses in the watershed. Two of these are listed within the top 20 fatal landslides of the Wenchuan Earthquake: the Maanshi landslide, and the Zhengjiashan landslide cluster (Yin 2008). The spatial distribution of post-earthquake houses differs from pre-earthquake houses, where some relocations were made from previously occupied locations to unoccupied new sites, the post-earthquake houses tend to cluster within major locations, and re-built housings clustered along riverbanks near Wenjiaba and east Jiankang (Fig. 4b and c). Besides, major decreases of housing were observed east of Hongxi village and the movement of housing clusters from east of Jiankang to Jiankang is obvious. Compared with pre-earthquake buildings, the number of post-earthquake houses increased from 2139 to 2371."

Figure 4. has been modified.

Revised Figure 4 Caption: Spatial changes in landslides and buildings.

In Page 5509, Line 8-28, the text has been re-organized to: "Figure 6a shows that there are more enlarged than newly generated landslides on all elevation intervals. New and enlarged landslides occur mainly below 1000m with fewer at higher elevations. Elevation in the watershed ranges from 684 to 2286 m, where the altitude of the residential houses ranges from 688 to 1650 m. The highest residential house pre- and post-earthquake was located near 1650m at the eastern margin of the watershed. Relocated houses were mainly distributed at lower elevation near Downstream Wenjiaba and Jiankang (Fig. 4b and c). Two peak distributions of houses occurred at elevation intervals of 688 to 900 m, and 1000 to 1300m for pre- and post-earthquake houses, respectively (Fig. 6b). Compared with the elevation of pre-earthquake houses, the major increase for post-earthquake houses occurs at elevations ranging from 688 to 800 m, showing that the lower elevations were preferred for the rebuilding of houses. Above 1200 m, fewer post-earthquake houses were built compared to the pre-earthquake situation.

The dominance of enlarged landslides over newly generated landslides indicates that most expansions of post-earthquake landslides are related to existing coseismic landslides. The active enlarged landslides on the lower slope gradients and elevations are caused by the downward movement of landslide debris to the valley bottom, where most post-earthquake buildings reconstructed become significantly susceptible to post-earthquake landslide activities."

In Page 5510, Line 2, “in the upper stream and a decrease in width in the lower stream (Fig. 7a).” is changed to “in the upper stream and a decrease in width in the lower stream (Fig. 7).”

In Page 5510, Line 6, “riverbed (Fig. 7a).” is changed to “riverbed (Fig. 7).”

In Page 5510, Line 8, “in Fig. 7a. After the earthquake,” is changed to “in Fig. 7. After the earthquake,”.

In Page 5510, Line 10, “at Upper Hongxi, Jiankang and Nanba villages (Fig. 7a).” is changed to “at Upper Hongxi and Jiankang villages (Fig. 2).”

In Page 5510, Line 18, “earthquake conditions (Fig. 7b).” is changed to “earthquake conditions (Fig. 8).”

Both Figure 7 and 8 are revised.

Revised Figure 7 Caption: Riverbed width change before and after the earthquake. Revised Figure 8 Caption: Distribution of housing in different distance buffers from the river in the study area.

In Page 5511, Line 5, “decreased channel width (Fig. 7c).” is changed to “decreased channel width (Fig. 2).”

7) Some small mistakes need to be revised. e.g. Page5519, Figure 3 “persontage” should be “percentage”.

Response:

In Page 5519, the caption for Figure 3 has been changed to “Figure 3. Houses distributions in different distance buffers from the surface rupture in the study area (bars for numbers of houses and curves for cumulative percentage of houses)”

8) Fig.4, Fig.5, Fig.6, Fig. 7 need to be drawn more clearly. And the annotation of each figure should be in accordance with that in text. e.g. authors should mark a and b Fig.5, Fig.6, Fig.7.

Response:

We have revised all figures in the manuscript including Fig. 4, Fig.5, Fig. 6 and Fig. 7.

Revised Figure 4 Caption: Spatial changes in landslides and buildings.

Revised Figure 5 Caption: Distribution of new or enlarged landslides and buildings on different slope units.

Revised Figure 6 Caption: Distribution of new or enlarged landslides and buildings on different elevation units.

Revised Figure 7 Caption: Riverbed width change before and after the earthquake.

References:

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Please also note the supplement to this comment:
http://www.nat-hazards-earth-syst-sci-discuss.net/2/C3413/2015/nhessd-2-C3413-

2015-supplement.pdf

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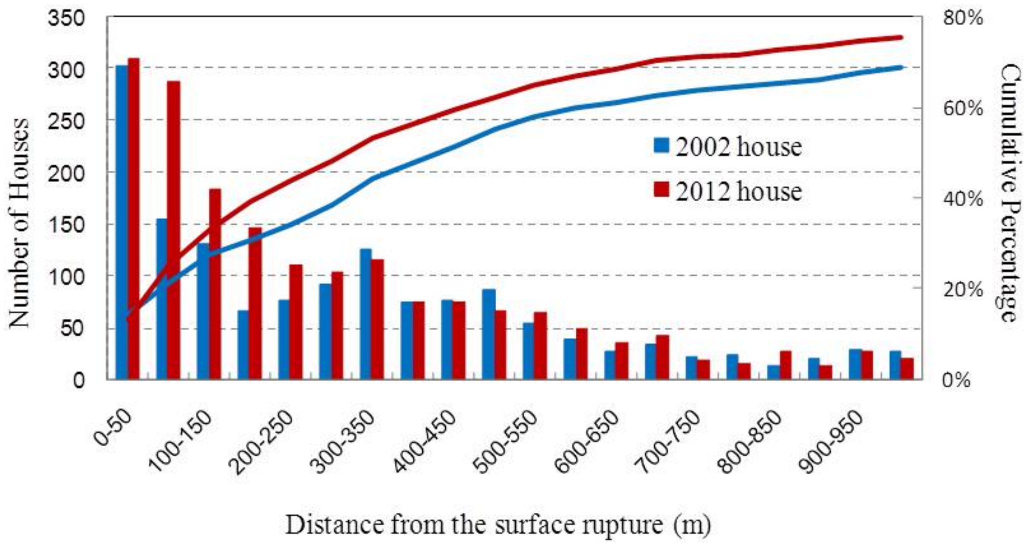

Fig. 1. Figure 3. Houses distributions in different distance buffers from the surface rupture in the study area (bars for numbers of houses and curves for cumulative percentage of houses).

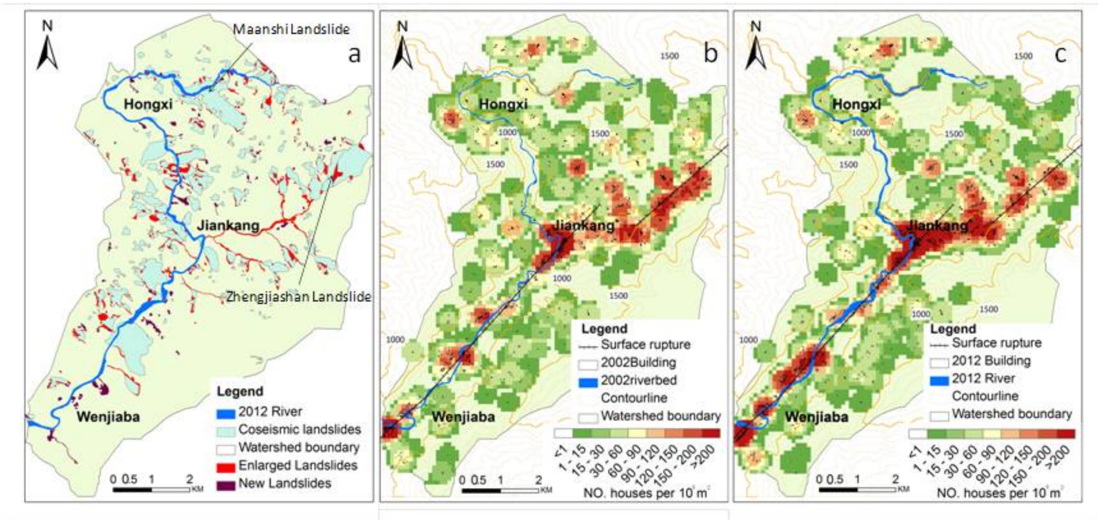

Fig. 2. Figure 4. Spatial changes in landslides and buildings.

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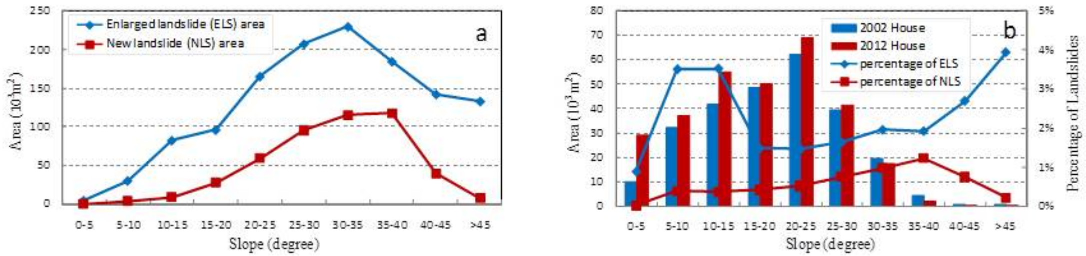

Fig. 3. Figure 5. Distribution of new or enlarged landslides and buildings on different slope units.

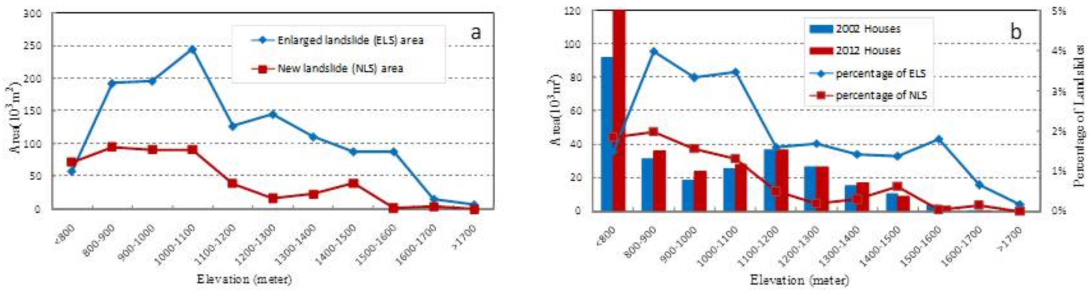

Fig. 4. Figure 6. Distribution of new or enlarged landslides and buildings on different elevation units.

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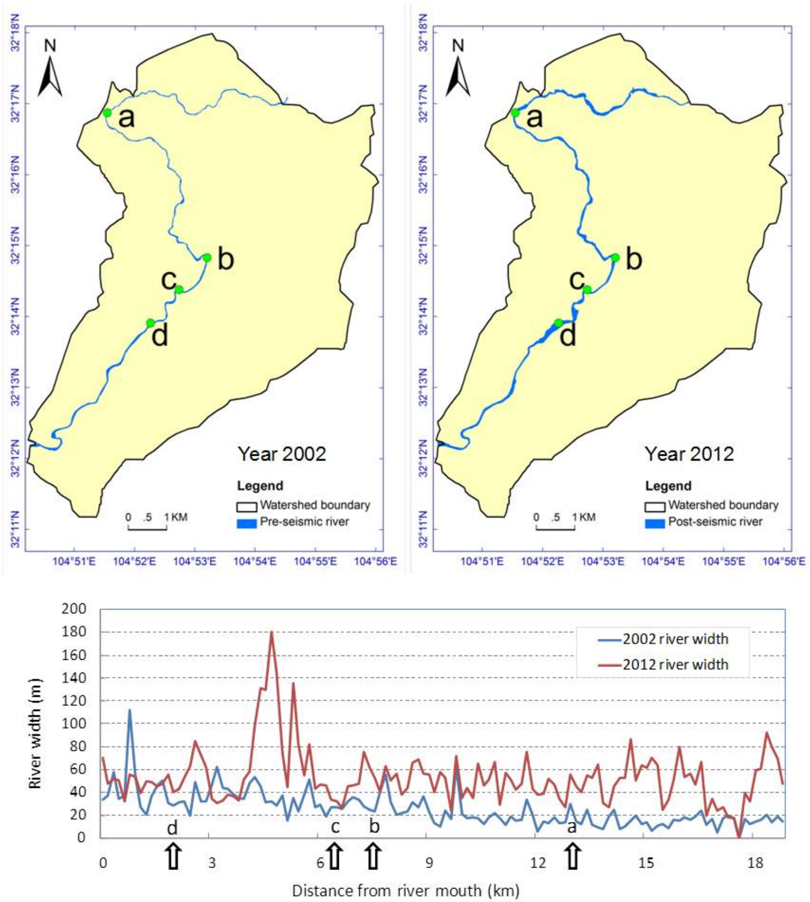

Fig. 5. Figure 7. Riverbed width change before and after the earthquake.

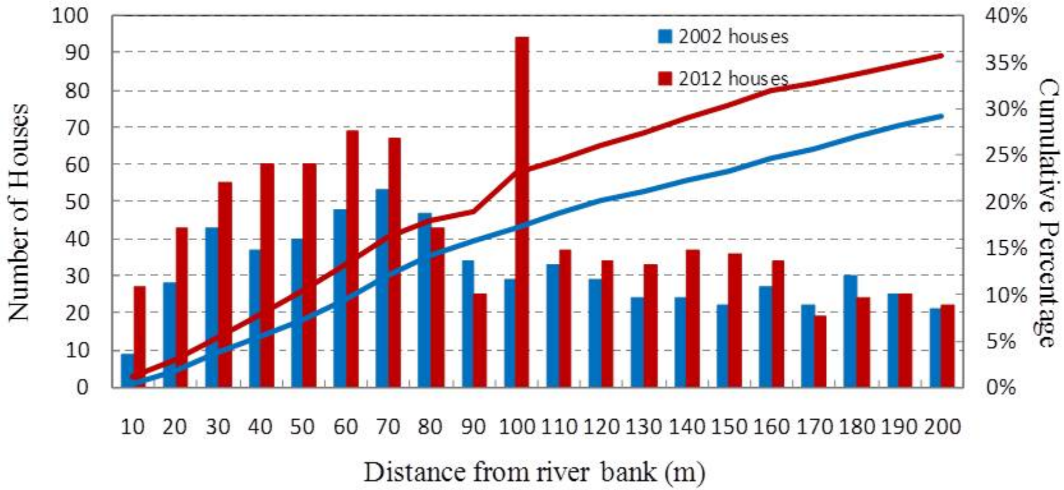

Fig. 6. Figure 8. Distribution of housing in different distance buffers from the river in the study area.

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