Coseismic landslides triggered by the 8th August 2017 Ms 7.0 Jiuzhaigou earthquake (Sichuan, China): factors controlling their spatial distribution and implications for the seismogenic blind fault identification

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**Online Resource 2: Volume estimation**

The volume of the coseismic landslides was calculated by means of various empirical relationships, which were proposed by various authors (Guzzetti et al., 2009; Larsen et al., 2010; Parker et al., 2011; Xu et al., 2016) to obtain a quick, first-order estimation of the landslide volumes based on the sole areas mapped through the interpretation of remote sensing images. The empirical relationships were calibrated by the respective authors using landslide depths, areas and hence volumes derived from direct field measurements or differential DEM techniques on datasets of different sizes.

The equation obtained by Guzzetti et al. (2009) was calibrated from a catalogue of 677 landslides of the slide type, the area of which varied from as low as 2 m2 to as high as 109 m2. The equation given by Larsen et al. (2010) was obtained from a dataset comprising 4,231 landslides, that included both soil slides and bedrock failures with sizes ranging from 1 m2 to 107 m2. Parker et al. (2011) calibrated their empirical relationship using field measurements of 41 coseismic landslides triggered by the 2008 Wenchuan earthquake. The size of the landslides used for the calibration was not given. Finally, Xu et al. (2016) obtained their empirical relationship from a dataset of field observations and remote sensing analyss of 1,415 coseismic landslides triggered by the 2008 Wenchuan earthquake, with size larger than 104 m2.

The empirical relationships are all in the form:

where *V* is the calculated landslide volume, *A* is the mapped landslide area and α and γ are fitting parameters. Generally, a higher value of γ denotes an abundance of deep bedrock landslides in the dataset, while lower values of γ are more realistic for shallow landslides, as discussed by Parker et al. (2011). In fact, the average depth *H* of the landslides can be estimated as follows:

The equations employed in this study, with the uncertainties (i.e. ±1σ) on the parameters as given by the respective authors, are as follows:

i) (Guzzetti et al., 2009)

ii) (Larsen et al., 2010)

iii) (Parker et al., 2011)

iv) (Xu et al., 2016)

The total landslide volume is, obviously, the result of the sum of the individually computed landslide volumes:

where the *Ai* are the areas of the individually mapped landslides. As observed by Parker et al. (2011), if the inventory includes clusters of landslides that were mapped as single polygons, the estimation of the total volume will be affected by a systematic overestimation. However, in the present study, this possibility seems limited, as the polygon-based mapping was performed by visual interpretation with field-checking on high-resolution images, rather than by semi-automatic mapping techniques, which have been shown to be more susceptible of this kind of mapping error (e.g. Marc and Hovius, 2005).

The results of the calculations using the various empirical equations are as follows:

i) Vtot = 44.4·106 m3 (40.6-48.6·106 m3) (Guzzetti et al., 2009)

ii) Vtot = 27.5·106 m3 (25.3-29.9·106 m3) (Larsen et al., 2010)

iii) Vtot = 34.5·106 m3 (14.8-81.3·106 m3) (Parker et al., 2011)

iv) Vtot = 75.4·106 m3 (66.5-85.4·106 m3) (Xu et al., 2016)

where the first value in each line was obtained using the relationships (i-iv), and the values in brackets are the result of the variability of α and γ (±1σ).

The largest variability comes from the equation given by Parker et al. (2011), due to the large uncertainty of the γ parameter, which is possibly a consequence of the limited dataset used by the authors for the calibration. The largest average volume is obtained with the equation proposed by Xu et al. (2016). However, such value seems unlikely, given that the equation is calibrated on landslides that are mostly larger (A > 10,000 m2) than those of the inventory in the current study, hence a systematic volume overestimation may be present. Both the equations from Guzzetti et al. (2009) and Larsen et al. (2010), even though they do not derive from datasets of coseismic landslides, were calibrated on large datasets comprising landslides with areas as small as 1-2 m2. In particular, Larsen et al. (2010) used a dataset of more than 4,000 landslides, comprising both soil landslides and bedrock landslides. Their equation (ii) seems the most reasonable one for the estimation of the volumes of the coseismic landslides triggered by the Jiuzhaigou earthquake. However, such estimation has to be considered as a first-order approximation only, and only for statistical purposes. A more accurate estimation, based for instance on a combination of field measurements and remote sensing is certainly advisable. The resulting dataset could be then interpreted by a better performing empirical relationship.

**References**

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