Attachment 1

Table S1 Empirical-statistical models for landslide motion prediction

General approach	Keywords to characterize the method	Triggering condition, Type	References
Travel angle	Volume Log $H/L=C_1$Log $V+C_0$	Rock fall/slide/avalanche debris flow/avalanche, earthflow	Scheidegger, 1973; Corominas, 1996
	downslope angle $H/L=C_1 \tan S+ C_0$	soil slides, snow avalanches, nonseismic	*Hunter et al., 2003; Lied et al., 1980; McClung et al., 1987*
Total travel distance	Rock type, volume, slope transition angle Log $L=C_1Rt+C_2$Log $V+ C_3 \sin S+C_0$	rock/soil slide and rock/debris avalanche, earthquake	Guo et al., 2014
	Log $L=C_1$ Log $H +C_2$ Log $\tan S+C_0$	Soil landslides, Artificial slopes	Finlay et al., 1999
	$L=C_1V^{C_2}$	Debris slides, debris flowslides rainfall	Jaiswal et al., 2011

Note: C_0, C_1, C_2, C_3 are the constants. L is the travel distance. H is the total height. V is the volume. S is the average slope angle. Rt is the rock type.

Attachment 2

4.1 Apparent coefficient of friction

Apparent coefficient of friction, also called the reach angle, is a well-known index to express the landslide mobility. It is the angle of the line connecting the crown of the landslide source area to the toe of the displaced mass. This angle is firstly conducted by Heim (1932) in the famous energy-line model as the average coefficient of friction of slide mass from initiation to rest. The apparent coefficient of friction is supposed to possess the ability of landslide mobility prediction because of its tendency to decrease with the increase of landslide volume illustrated by many researchers (Scheidegger, 1972; Corominas, 1996). Yet, the large scatter existed in these studies have impeded the application of apparent coefficient of friction. The ratio H/L is also queried by some researches to be physically meaningless (Legros, 2002)

In this study, the influence of landslide size, drop height, and terrain slope on the apparent coefficient of friction of the channelized rock avalanches are examined respectively (Figure S1 to S4). A negative correlation is between the Log10 volume and Log10 apparent coefficient of friction (See Figure S1) in accordance of historical studies (Scheidegger, 1972; Corominas, 1996). In order to consider the effect of potential energy on the H/L, the effective drop height defined as the total height minus the height of source area is used instead of the total height which excludes the superposition of source height and total height. That is especially useful for landslides with large-size initiation but limited travel distance. A significant positive correlation is observed between the H/L and effective drop height ignoring the four lower scatters in the Figure S2. From Figure S3 and S4, obvious positive correlation between the H/L and both the slope angle and channel angle can be determined. Although other robust evidences are missing, we suggest that the mobility (H/L) of channelized rock avalanches is controlled by local topography.

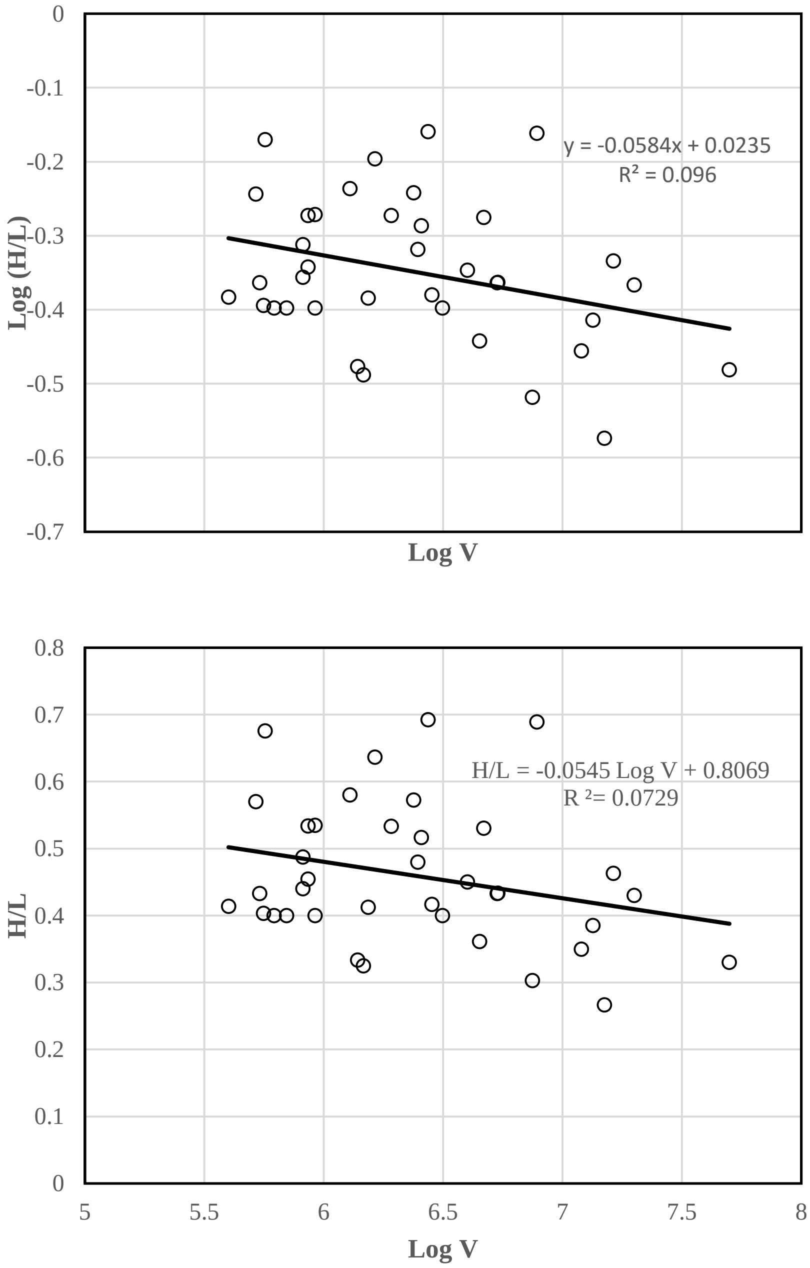

Figure S1 Relationship between reach angle and volume

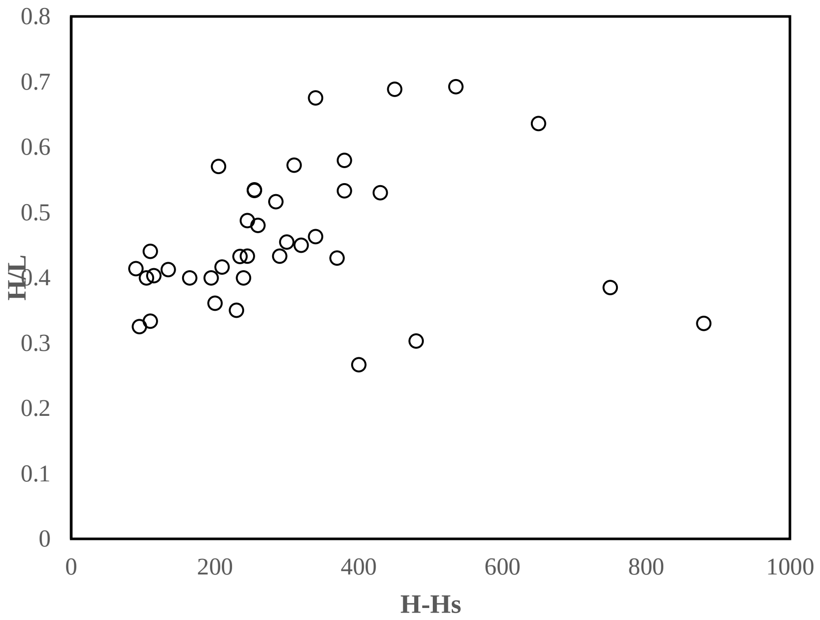

Figure S2 Relationship between reach angle and effective drop height

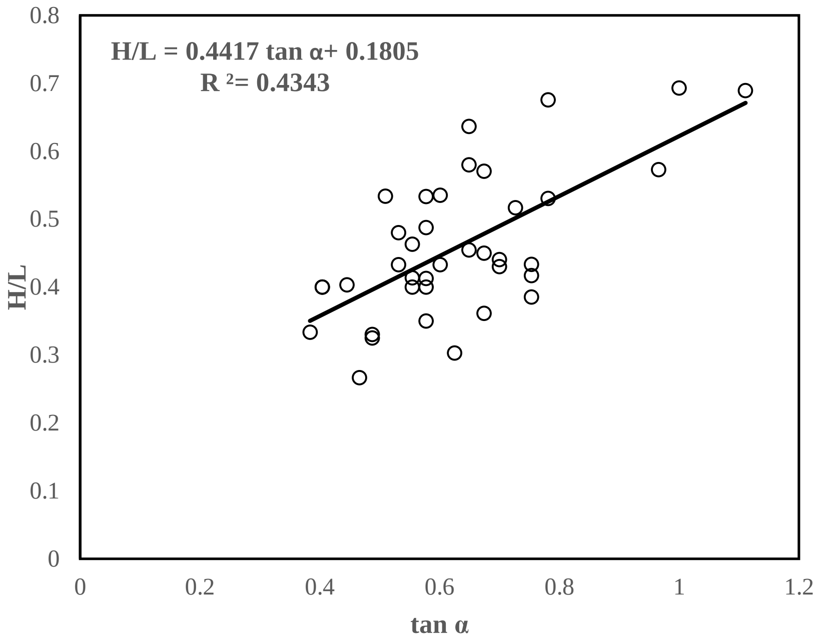

Figure S3 Relationship between reach angle and slope angle

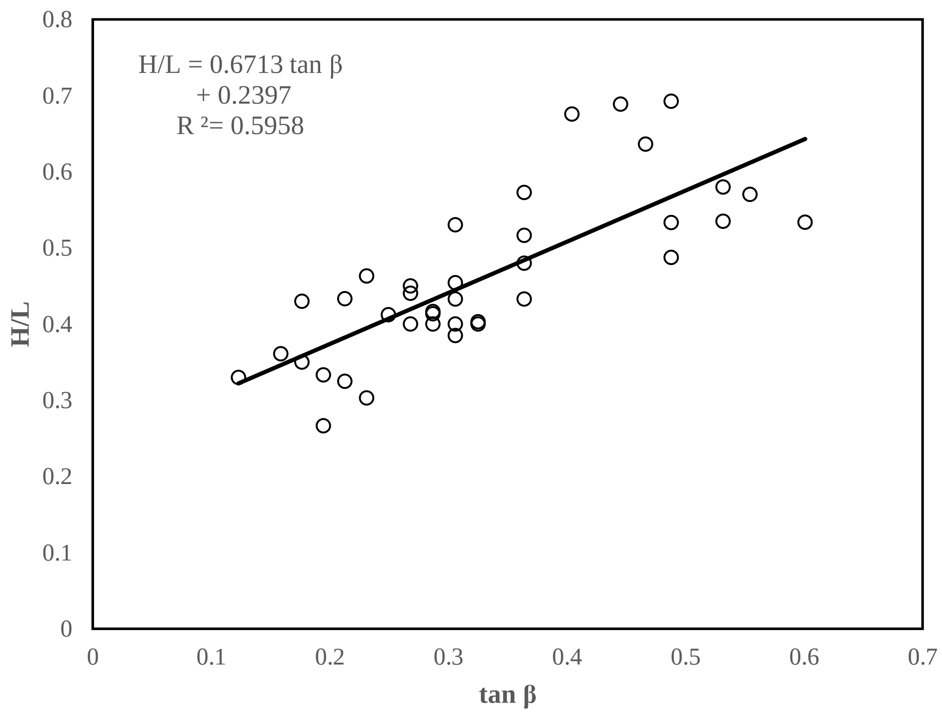

Figure S4 Relationship between reach angle and channel angle

Attachment 3

5.2 The mobility of channelized rock avalanche

The mobility of landslides is influenced by varieties of factors, such as topography, landslide size, material type, landslide type water content and so on. The vital role of topography constrains on the landslide mobility can be referred from the high positive correlation of H/L with effective drop height, slope angle and channel angle (see Figure S2~S4). Besides, some micro topography like drop cliff and broad depression will influence the motion and deposition of rock avalanche remarkably. The rock avalanches corresponding with the four large bias scatter in Figure 8 are the Wenjia gully, Hongshi Gully, Niumian Gully and Donghekou rock avalanche, whose flow path has cliffs in the upper end of channels with notable drop height as 260 m, 150 m, 60 m and 160 m respectively referring to the field investigations. Moreover, fluidization characteristics such as super-elevation near curve transitions can be found in the channel section of these four rock avalanches. These findings manifest the steep micro-geotopography will enlarge the mobility of rock avalanches as this kind of topography will lead the slide mass to undergo the drop, collision, fragmentation effects in the early motion stage which will facilitate motion mode transformation from sliding to flowing. This transformation will enhance the motion mobility of rock avalanche to travel a much longer distance than predicted one. Attention also need be paid to the broad depression near the upper end of the channel. Taking Wenjia Gully rock avalanche for an example, almost a half of total volume of the landslide deposited on the beginning of the channel (red dash circle area in Figure 9), leading to that the travel distance lower than the expected one.

As for the effects of landslide types on the landslide mobility, we firstly compare our dataset with the dataset collected by Guo et al.(2014) in order to avoid the influences of triggers and topography. After the elimination of superposition parts between two datasets, 32 other landslides including debris avalanches, rock slides, soil slides in the same area are introduced. We plot the relationship between L with V and H respectively marking different types landslide (see figure S5 and S6). According to figure S5 and S6, rock avalanches show the strongest mobility while soil slides show the weakest one, and the mobility of rock slides is equable to the mobility of debris avalanches while the later one has large variation.

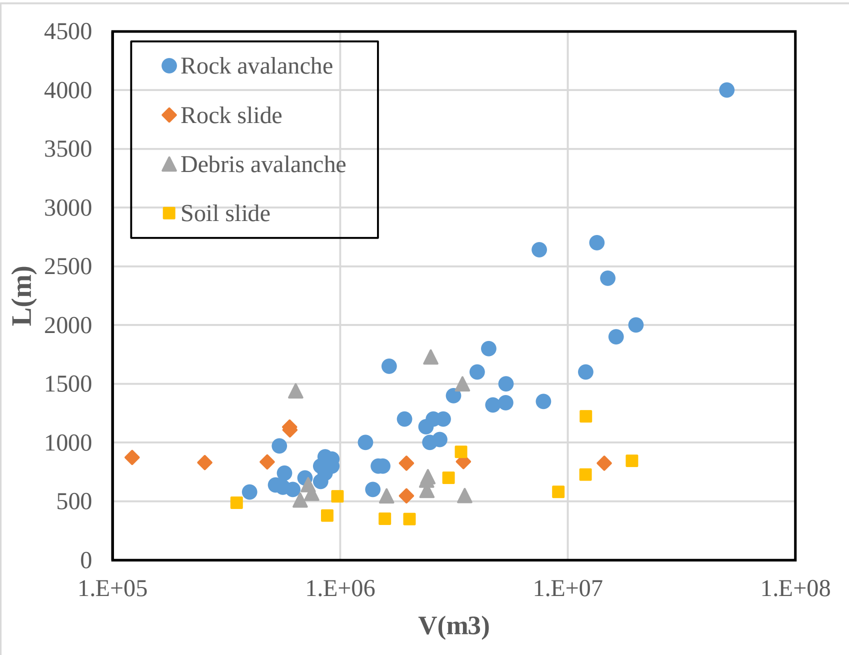

Figure S5 Relationship between the volume and travel distance of different-type landslides triggered by Wenchuan earthquake (rock slides, debris avalanches and soil slides data are from Guo et al, 2014)

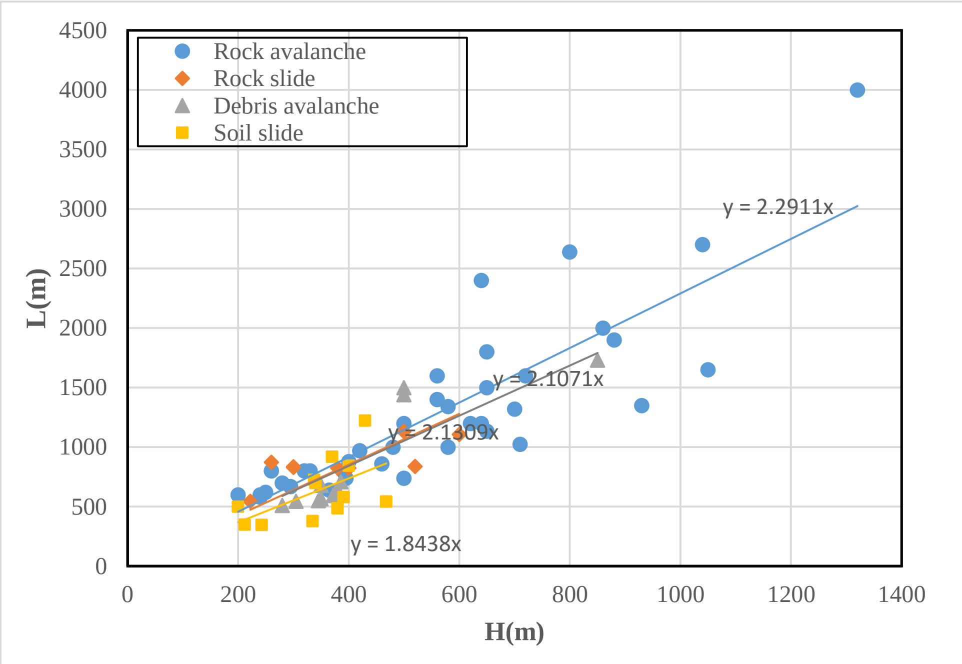

Figure S6 Relationship between total height and the travel distance of different-type landslides triggered by Wenchuan earthquake (rock slides, debris avalanches and soil slides data are from Guo et al, 2014)

While compared with the worldwide datasets (see figure S7 and S8),

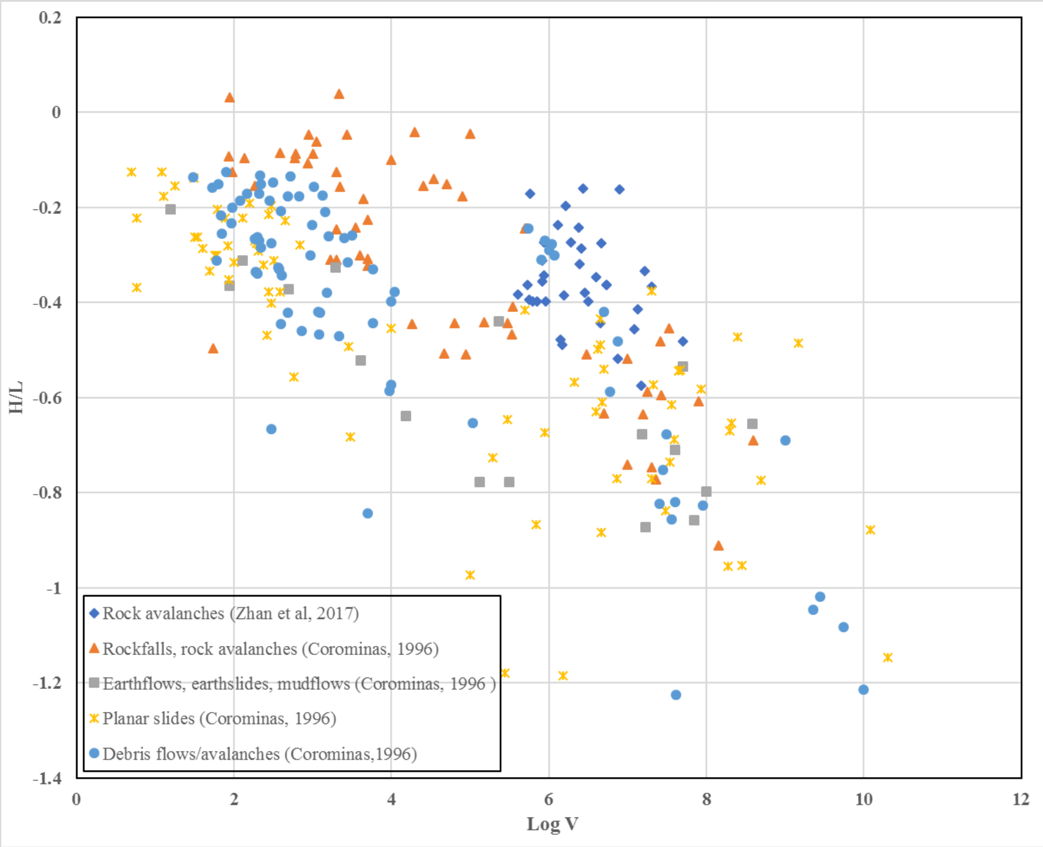

Figure S7 Relationship between the volume and H/L ratio of different-type landslides from the worldwide dataset

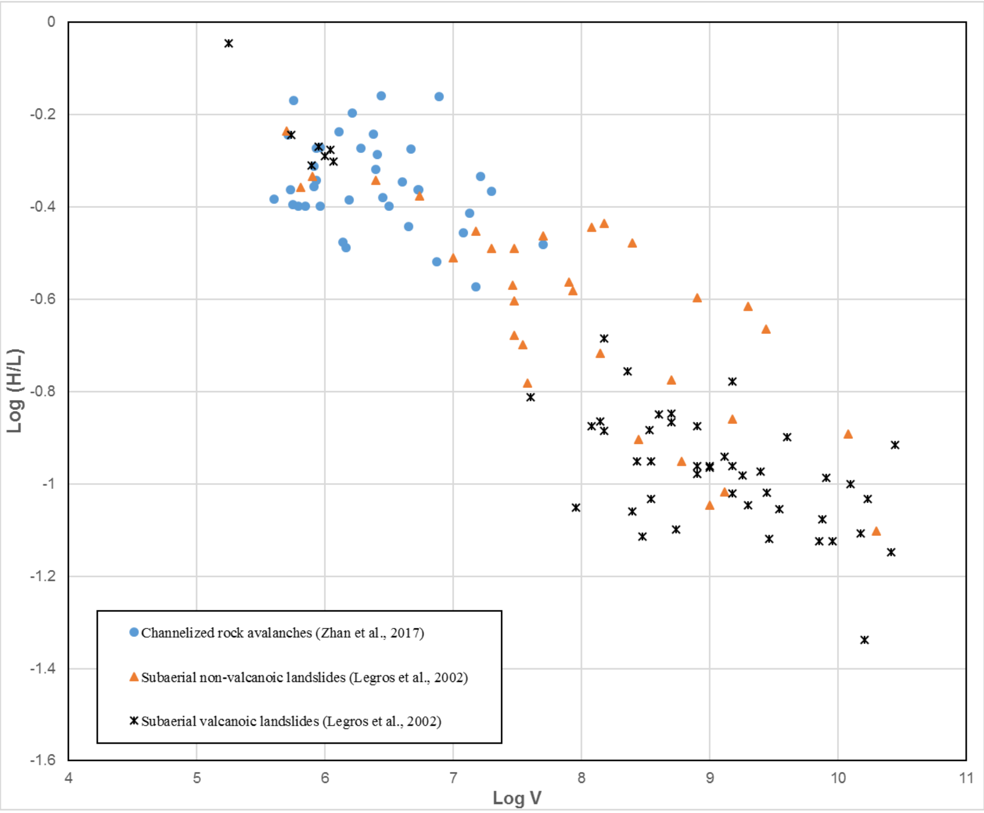

Figure S8 Relationship between the volume and H/L ratio of different-type landslides from the worldwide dataset

As for the effect of rock types on the landslide mobility, we use the combined dataset of landslides induced by Wenchuan earthquake. The rock type classification use the same standard used by Guo et al (refer to table 1 in Guo et al. 2014). The rock type is numbered by the sort from strongest to the weakest, namely R1 presents strongest rock type. According to figure S9 and S10, the mobility of landslide seems to increase with the increase of rock strength.

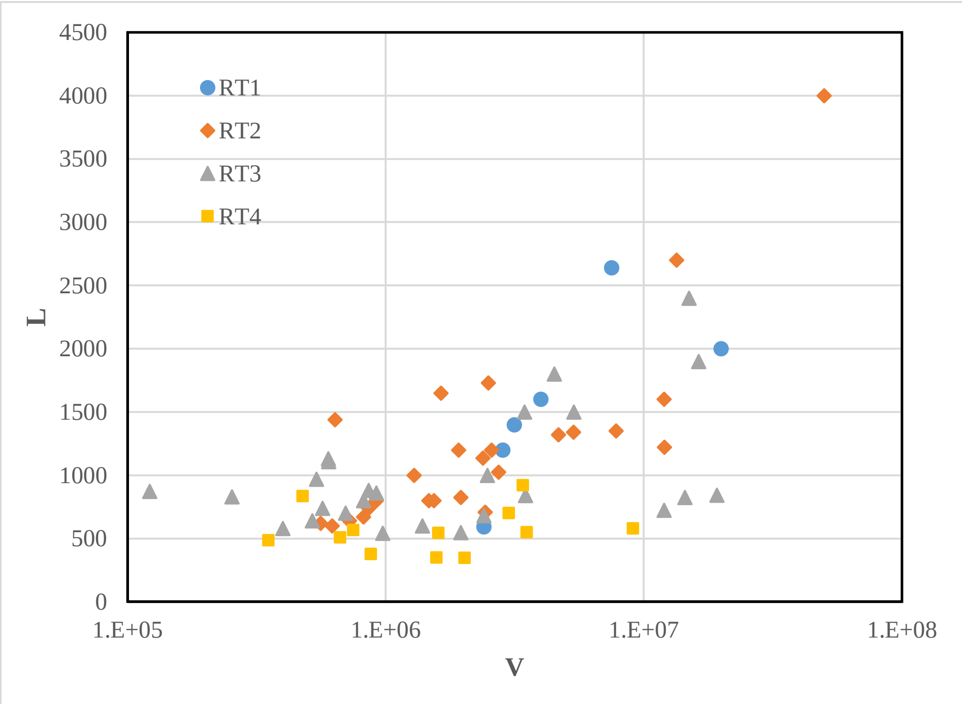

Figure S9 Relationship between the volume and travel distance of landslides with different rock types

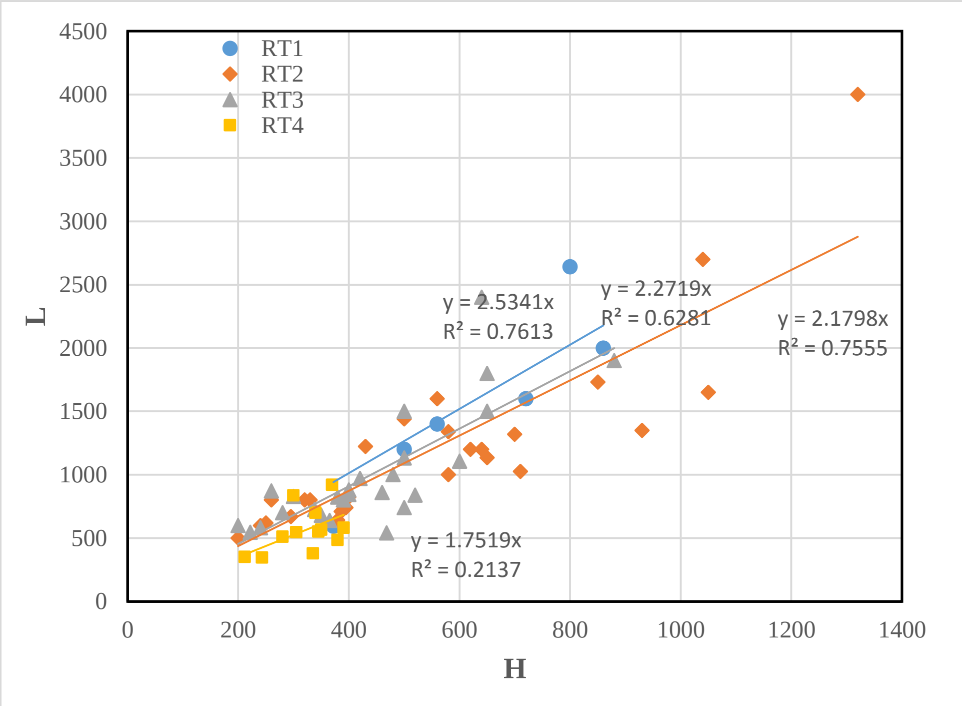

Figure S10 Relationship between the total height and travel distance of landslides with different rock types

The common causes of landsides are earthquakes and rainfall. While the influences of triggers on landslide distribution is well studied, the effects of triggers on the landslide mobility is still a scientific gap. Zhang et al. (2013) indicated that rock avalanches triggered by earthquakes have slightly lower mobility than ones not triggered by earthquakes, and rock avalanches close to the seismic fault do not always have higher mobility even if a rock avalanche near the seismic fault is subjected to higher ground accelerations. Guo et al. (2014) also mentioned that the seismic acceleration plays less influence than rock type, sliding volume, slope transition angle and slope height on landslide travel distance. According to the table 4, two rainfall-induced rock avalanches show stronger mobility than earthquake-induced ones. The rock avalanches induced by rainfall express a stronger mobility than the earthquake-induced ones may due to lubrication effect of water. Hummocky surfaces are observed on the deposition of the Ermanshan rock avalanche. However, detailed study on the influence of triggers on the landslide mobility need further dataset.