Dear Editor,

We are very grateful to you for expressing appreciation for our answers to the comments made by the two reviewers. Thanks also for kindly inviting us to revise and resubmit our manuscript.

The paper has been modified taking into account the reviewers suggestions/comments and our own answers. Some changes have also been made to improve the quality and clarity of the text, as well as its general structure based on recommendations and the suggestions of the reviewers.

The corrections and/or changes are highlighted in yellow.

We would very much appreciate if you could consider our resubmission and we look forward to hearing your final decision as soon as possible.

Yours truly, Antonio Contino and co-authors

RESPONSE TO THE FIRST REVIEWER

Comment from referee: Dear authors thank you for your approach to reconstruct the circumstances of historic rockfalls. The procedures presented provide a valuable description on how to perform such an analysis.

Author's response: Dear Reviewer #1, We are very grateful to you for expressing appreciation for our paper and providing us with useful suggestions and insightful comments. Below, you will find our answers to your careful suggestions, as well as changes made to our manuscript based on the corrections that you have recommended.

Comment from referee:

Your title starts with “multidisciplinary approach to”. In the article itself you did not go into detail of the multidisciplinarity. Therefore, I suggest to change the title to “Historical analysis of rainfall-triggered....”.

Author's response:

We are very glad to accept your precious suggestion to change the initial part of the title, because it places emphasis on the innovative historical approach developed in the paper.

Author's changes in manuscript:

Initial part of the title (P1L1) as follows:

Historical analysis of.

Comment from referee:

P1L27-29: I do not see the relevance of this paragraph for the article and I would remove it.

Author's response:

P1L27-29: Text and respective references, removed.

Author's changes in manuscript:

Text in P1L27-29 (first version) and respective references (Walter, 2001, P17L559-560, first version), removed.

Comment from referee:

P1-2L30-44: Are these paragraphs relevant for the article? They are more or less a definition of landslide processes, aren't they? You could bring P2L45ff first and then explain the landslide definitions that they are later used in the article (are they?)

Author's response:

P1-2L30-45 This part, introducing the topic of landslides, is not essential. We welcome your valuable suggestion to change its position in the paper (P2L45ff), because it improves its readability.

Author's changes in manuscript:

Position of P2L45ff (first version), changed in P1L28-29.

Comment from referee:

P2L70: "1.60m" above which level?

Author's response:

P2L70: "1.60m above road level". Added.

Author's changes in manuscript:

"1.60m above road level". Added in P3L75.

Comment from referee:

P7L228: "6,7" –> "6.7"

Author's response:

P7L228: "6,7" –> "6.7". Corrected.

Author's changes in manuscript:

"6,7" –> "6.7". Corrected in P7L235.

Comment from referee:

P8L252 ("understanding of the rockfall event") You did a nice analysis regarding the geology, landscape, the rainfall event and of the buildings. All based on a comprehensive literature research. The article title, however, promised information on "rockfalls".

This would mean, mass involved, The event itself has not really been described yet.

If possible, can you give some estimations on total height difference/horizontal distance/ shadow angle/rock mass etc.?

Author's response:

P8L252: Based on our estimations: total height difference (height of fall) is about 385 m; horizontal distance (length of runout) is about 572 m; shadow angle is about 31°-32°. Ratio of H/L = 0.67.

A reliable estimation of the rock volume deposit is very difficult, because no pre-event topographic map, to be compared with subsequent surveys (e.g., official maps of Italy, 1878), is available. The official cartography of the Bourbon Kingdom, "Map of the Palermo Region" (scale 1:20,000; equidistance: 18.52 m; original survey of the "Topographic Office" in Naples: 1849-52) originally included the Sclafani section. Unfortunately, this section is missing in the cartographic archives of the Italian Military Geographical Institute (Florence).

By using a new empirical relationship proposed by Guzzetti et al. (2009), which links the surface area to the volume of the landslide, we have attempted to estimate the rock volume, obtaining a value of about 6.8×10^5 m^3. The same magnitude is obtained using the graph of volume versus ratio of H/L (Tianchi, 1983).

It is not possible to estimate the mass due to the heterogeneity of the deposit and the difficulty of determining the percentages of its constituent materials.

Author's changes in manuscript:

In page 12, line 377-390, as follows:

Some geometrical parameters of the Sclafani landslide could be determined: total height difference (height of fall) is about 385 m; horizontal distance (length of runout) is about 572 m; empirical shadow angle is about 31°-32°; ratio of H/L = 0.67.

Historical record collections do not include estimations of volume. Hence, a reliable estimation of the rock volume deposit and thickness is very difficult, because no pre-event topographic map, to be compared with subsequent surveys (e.g., official maps of Italy, 1878), is available. The official cartography of the Bourbon Kingdom, "Map of the Palermo Region" (scale 1:20,000; equidistance: 18.52 m; original survey of the "Topographic Office" in Naples: 1849-52) originally included the Sclafani section. Unfortunately, this section is missing in the cartographic archives of the Italian Military Geographical Institute (Florence).

An attempt to estimate the rock volume by using a new empirical relationship proposed by Guzzetti et al. (2009), which links the surface area to the volume of the landslide. The resulting value was about 6.8×10^5 m^3. The same magnitude was obtained by using the volume vs. of H/L ratio graph (Tianchi, 1983).

Similarly, it was not possible to estimate the mass due to the heterogeneity of the deposit and the difficulty of determining the percentages of its constituent materials.

Comment from referee:

P10L337: If more than 60000m^2 are covered with accumulated rock material the event might not been classified as simple rockfall but a rockslide? What would you recommend?

Author's response:

P10L337: Your question has been very enlightening. Undoubtedly, it is not easy to accurately classify a historical event that took place 150 years ago considering, among others, subsequent natural and anthropogenic changes (e. g., planting of tree species, terracing, excavations for road construction). The road built in 1930, whose excavation required the use of explosives, had a significant impact on the landscape, heavily changing its morphology, especially near the source area).

The event was a complex one; the type of initial failure evolved into another movement mechanism, when the material moved along the slope and changed its volume, incorporating materials entrained in its path. Indeed, in the kinematics of the event, the rockfall component cannot be ruled out, because the fragmented rock had to move beyond a break-away scarp (difference in height of about 70-90 m; topographical gradient of about 50°-60°, see fig. 05) at the lower cliff.

The accumulated material does not reflect the composition of the lithotypes outcropping in the source area (Ellipsactinia breccias), but rather the one of the rocks present in the entire slope (Ellipsactinia breccias, radiolarites, siliceous shales, marls, calcilutites, dolomites etc.).

Failing eyewitness reports, documentary data do not permit to easily classify the event.

Synchronous documentary sources report the Italian term “scoscendimento”, which at that time referred to a catastrophic landslide event, a veritable collapse of rock (see P10L324-327). In view of this, and considering that the surface covered by the accumulated material is significant, it is reasonable to suppose that the type of initial failure was a rockslide, probably a “rock collapse” (sensu Hungr and Evans, 2004).

Author's changes in manuscript:

In page 11 line 342-344, as follows:

Undoubtedly, failing eyewitness reports, documentary data do not permit to easily classify this historical disaster which took place over 150 years ago considering, among others, subsequent natural and anthropogenic changes (e.g., planting of tree species, terracing, excavations for road construction).

In page 11, line 346-348, as follows:

The event was a complex one: the type of initial failure evolved into another mechanism of movement, when the material advancing along the slope and changed its volume, by incorporating materials entrained in its path.

In page 11, line 349-351, as follows:

Indeed, in the kinematics of the event, the rockfall component cannot be ruled out, because the fragmented rock had to move beyond a break-away scarp (difference in height of about 70-90m; topographical gradient of about 50°-60°, see fig. 5) at the lower cliff.

In page 11, line 369-371, as follows:

Moreover, the accumulated material does not reflect the composition of the lithotypes outcropping in the source area (Ellipsactinia breccias), but rather the one of the rocks present in the entire slope (Ellipsactinia breccias, radiolarites, siliceous shales, marls, calcilutites, dolomites etc.).

In page 12, line 395-397, as follows:

In view of this and considering that the surface covered by the accumulated material and the estimated volume are significant, it is reasonable to suppose that the type of initial failure was a rockslide, probably a “rock collapse” (sensu Hungr and Evans, 2004).

In page 12, line 406, page 13, line 408, as follows:

This road, whose excavation required the use of explosives, had a significant impact on the landscape, heavily changing its morphology, especially near the source area.

RESPONSE TO THE SECOND REVIEWER

Comment from referee: The authors should be acknowledged for their efforts in reconstructing the rockfall event. However, in my opinion, their work lacks of a significant scientific contribution and novelty.

Author’s response:

Dear Referee #2,

Our paper underlines the crucial importance of documentary data analysis to reconstruct the circumstances of landslide events that occurred in historical times, providing a significant methodological and scientific contribution of a pioneering nature.

We acknowledge your effort to identify the correct target of our paper. However, in our opinion, your attempt has failed. Indeed, your comments lack an objective assessment of the fundamental role that historical datasets (documentary data, ancient maps, ancient engravings, etc.) play in the study of past landslide events.

Author’s changes in manuscript:

In page 2, line 59-61, as follows:

The paper underlines the crucial importance of documentary data analysis to reconstruct the circumstances of landslide events that occurred in historical times, providing a significant methodological and scientific contribution of a pioneering nature.

Comment from referee:

The manuscript presents a summary of the historical documents describing the event.

Author’s response:

Your comments oversimplify and underestimate our archival contribution, reducing it to a mere “summary of the historical documents that describe the event". Our meticulous archival research work, with three documentary appendices (see Supplementary Information) including plenty of selected historical data, most of which unpublished (e.g. those from manuscript sources), was intended to offer a comprehensive analysis of historical sources in support of our assumptions and not just a list of collected data.

An example that can help clarify the mutual interaction between historical and geological data is the mapping of the landslide deposits from the Sclafani event. Geological and geomorphological evidence collected during field surveys, analysis of ancient maps, aerial and/or satellite images and historical data fit perfectly together, providing a detailed mapping of the area covered by the landslide deposits. We believe that there is no dichotomy between the data recorded in natural archives and those reported in historical archives: both are fundamental to the study of natural disasters. Our research rests upon the assumption: History for Earth Sciences, not History vs. Earth Sciences.

In recent times, Hungr (2004) stressed the importance of historical evidence, "potentially more accurate" than geological evidence (proxy data), even if “limited to the length of the historical period, often little more 100 years in much of the world”. The catastrophic event of Sclafani, happened over 150 years ago, constitutes an interesting and emblematic case study.

Our historical reconstruction of the severe rainstorm of March 1851, and of the related Sclafani catastrophe, is supported by three different types of evidence. The first type is the direct description of the area of the thermal springs prior to the disaster by contemporary sources. These memories hold precious information about the landscape near the ancient thermal baths prior to the extreme event. The second type of documentary source is represented by the records of local and regional authorities concerning measures taken to respond to the terrible disaster (destruction of thermal baths, water mills, roads etc.). A third source is the weather data kept by the Astronomic Observatory of the Palermo University (official) and by the Nautical Institute of Palermo (not official). We used these records to confirm the exact day of the disaster (previously incorrectly reported), as well as the impact and magnitude of the rainstorm, i.e. the main triggering factor. We consider that the manifold pieces of the Sclafani event puzzle, provided by documentary and geological evidence, fit entirely together, yielding a consistent picture of the impact of the disaster. The case study of Sclafani is an emblematic example that revives a catastrophic event ignored by the Italian inventories of landslide events (e.g. databases of ISPRA IFFI, AVI etc.).

Author’s changes in manuscript:

In page 12, line 374-376, as follows:

Geological and geomorphological evidence collected during field surveys, analyses of ancient maps, aerial and/or satellite images and historical data fit perfectly together, providing a detailed mapping of the area estimated (about 63,403 m^2) to be covered by the landslide deposits.

In page 2, line 55-58, as follows:

In recent times, Hungr (2004) stressed the importance of historical evidence, "potentially more accurate" than geological evidence (proxy data), even if "limited to the length of the historical period, often little more 100 years in much of the world". The catastrophic event of Sclafani, which happened over 150 years ago, constitutes an interesting and emblematic case study.

In page 8, line 246-253, as follows:

The historical reconstruction of the severe rainstorm of March 1851, and of the related Sclafani catastrophe, was supported by three different types of evidence: i) direct description of the area of the thermal springs prior to the disaster by contemporary sources; these memories hold precious information about the landscape near the ancient thermal baths prior to the extreme event; ii) records of local and regional authorities concerning measures taken to respond to the terrible disaster (destruction of thermal baths, water mills, roads etc.) and iii) weather data kept by the meteorological station of the OAP (official) and by the INP (non-official). These records made it possible to confirm the exact day of the disaster (previously incorrectly reported), as well as the impact and magnitude of the rainstorm, i.e. the main triggering factor.

In page 13, line 421-425, as follows:

The manifold pieces of the Sclafani event puzzle, provided by documentary and geological evidence, fit entirely together, yielding a consistent picture of the impact of the disaster. The analysis of historical data i.e. that are the goals of the research study played a crucial role. The case study of Sclafani is an emblematic example that revives a catastrophic event so far ignored by the Italian inventories of landslide events (e.g. databases of ISPRA IFFI, AVI etc.)

Comment from referee:

Contrary to the stated by the authors, the approach presented is not multidisciplinary…

Author's response:

The word "multidisciplinary" (in the title) was intended to highlight the dual contribution of different academic disciplines (Earth Sciences and History) to our research approach.

Author's changes in manuscript:

According with the recommendations of the reviewer 1#, Initial part of the title (P1L1) has been changed as it follows:

Historical analysis of.

Comment from referee:

….as the results of the aerial photointerpretation and satellite images are not included.

Author’s response:

The “results of the aerial photointerpretation and satellite images” that, in your opinion, "are not included", are given in the map of Fig. 5, which outlines geological and geomorphological features (e.g. landslides) with a high degree of accuracy. The map is the synthesis of a detailed field survey, which was fine-tuned through a careful interpretation of topographical and cadastral maps, aerial photographs and satellite images.

Author’s changes in manuscript:

In page 6, line 192-194, as follows:

The map of Fig. 5 is the synthesis of a meticulous field survey, which was fine-tuned by carefully interpreting of topographical and cadastral maps, aerial photographs and satellite images.

Comment from referee:

Both the geological and geomorphological contexts, including maps and figures, are described at a scale too small for a proper appraisal of the predisposing factors in the slope and the development of the event.

Author’s response:

For general assessments of geomorphological mapping in geohazards, Lee (2001) recommends 1:10,000 as a suitable scale. The map scale of 1:10,000 is the one of the Regional Technical Map of the Sicily Region. This is the scale chosen to build Italian official geological, geomorphological and hydrogeological maps (see ISPRA site, CARG Project). The area shown in the map is the minimum one that is required to describe the natural section outcropping in the environs of Sclafani.

Author’s changes in manuscript:

In page 6, line 191-192, as follows:

For general assessments of geomorphological mapping in geohazards, Lee (2001) recommends 1:10,000 as a suitable scale.

Comment from referee:

No attempt is made to estimate the volume of the detached rock mass,…

Author’s response:

Historical record collections do not include estimations of volume. A reliable estimation of volume and thickness is not possible, as no pre-event maps are available.

Author’s changes in manuscript:

In page 12, line 380, as follows:

Historical record collections do not include estimations of volume.

Comment from referee:

…..the trajectories and extent of the deposits.

Author’s response:

With regard to the area of the deposit, see P10L338. The exceptional rainfall event of March 1851, which devastated this north-western area of the Madonie mountains, must have certainly changed the lower talus slope (documentary sources report that the event caused an increase in ravines). As a result, any attempt to obtain a model of the possible trajectories related to the landslide would be unreliable. In addition, the soft rocks (radiolarites and siliceous shales), which form the lower talus slope, are prone to erosion; in 150 years, they certainly experienced denudation and modelling processes (above all during extreme rainfall events: 1886, 1890, 1895, 1919, 1925, 1929, 1931, 1954, 1964, 1976-77; 1985, see Aureli et al. 2008) making any model useless. Finally, the synchronous engraving (see Fig. 09), which represents the site of the ancient thermal spa, shows the vegetation cover of the talus; this vegetation is supposed to have had an impact on the trajectories of fall of the material. Unfortunately, Italian maps prior to the 20th century lack indications on vegetation covers.

Author’s changes in manuscript:

In page 11, line 359-368, as follows:

The exceptional rainfall event of March 1851, which devastated this north-western area of the Madonie mountains, must have certainly changed the lower talus slope (documentary sources report that the event caused an increase in ravines, see Supplementary Information, Table S1, source 14). As a result, any attempt to obtain a model of the possible trajectories related to the landslide would be unreliable. In addition, the soft rocks (radiolarites and siliceous shales), which form the lower talus slope, are prone to erosion; in 150 years, they certainly experienced denudation and modelling processes (above all during extreme rainfall events: 1886, 1890, 1895, 1919, 1925, 1929, 1931, 1954, 1964, 1976-77; 1985, see Aureli et al. 2008) thus making any model useless. The synchronous engraving (see Fig. 9), representing the site of the ancient thermal spa, shows the vegetation cover of the talus; this vegetation is supposed to have had an impact on the trajectories of fall of the material. Unfortunately, Italian maps prior to the 20th century lack of reliable indications on vegetation covers.

Comment from referee:

The description of both predisposing and triggering factors is vague and not based on directly observed features in the rockfall source and other evidences. In fact, nothing is known about key features such as the rock mass strength, the joint pattern or the failure mechanism (p9, lines 280-283).

Author’s response:

The main triggering factor was the exceptional rainfall event of 12-13 March 1851. There is a cause-effect relationship between the exceptional rainstorm and the landslide, as substantiated by the numerous historical data that we retrieved. The area of Sclafani, typically mountainous, is subject to freeze-thaw conditions (see P9L286-289). The earthquake events that produced macroseismic effects in the study area in the first halves of the 19th century took place in 1818-19 and 1823 (Billi et al., 2010).

Predisposing factors are many; some are intrinsic (related to the stratigraphic and tectonic setting), while other ones include selective erosion (hard-on-soft landforms, see P6L193-194; 199-200, 202-203). The anthropogenic impact changed the landscape near the source area (e.g. the road built in 1930, whose excavation required the use of explosives).

Author's changes in manuscript:

In page 13, line 437, page 14 line 445, as follows:

The main triggering factor of the Sclafani landslide was the exceptional rainfall event of 12-13 March 1851. There was a cause-effect relationship between the exceptional rainstorm and the landslide, as substantiated by the numerous historical data retrieved in this study (see Supplementary Information, Tables S2-S3). The area of Sclafani, typically mountainous, is subject to freeze-thaw conditions. The earthquake events that produced macroseismic effects in the study area in the first half of the 19th century took place in 1818-19 and 1823 (Billi et al., 2010). Predisposing factors were many; some were intrinsic (related to the stratigraphic and tectonic setting), while other ones included selective erosion (hard-on-soft landforms). The anthropogenic impact changed the landscape near the source area (e.g. the road built in 1930, whose excavation required the use of explosives).

Comment from referee:

The conclusions do not reflect the content of the paper as the dynamics of the event has not been addressed and it is unlikely that the details provided could contribute to the quantification of the susceptibility of the slope to failure. The current stability conditions of the slope are not analyzed.

Author's response:

The conclusions show that geological and historical data fit reciprocally, making it possible to reconstruct a coherent picture of the event; a crucial role derives from the analysis of historical data that are the goals of the research carried out (see P11L357-362 and 366-368).

The event was a complex one; the type of initial failure evolved into another movement mechanism, when the material moved along the slope and changed its volume, incorporating materials entrained in its path. Indeed, the accumulated material does not reflect the composition of the lithotypes outcropping in the source area (Ellipsactinia breccias), but rather the one of the rocks present in the entire slope (Ellipsactinia breccias, radiolarites, siliceous shales, marls, calcilutites, dolomites etc.).

In the final part of your comments, you stated that: "it is unlikely that the details provided could contribute to the quantification of the susceptibility of the slope to failure". The data that we provided are propaedeutic. We never claimed that we could contribute “to quantifying” the susceptibility of the slope to failure (see P1L20-22). In P11L361-363, we merely reported the opinions of Authors (Porter and Orombelli, 1980; Wieczorek and Jäger, 1996) without comments. Finally, in the conclusions, with regard to susceptibility, we emphasise the need for conducting further investigations in order to gain more insight into our research findings (see P12L380-384).

As data on discontinuities are not available (see P9L280-283), no stability analysis is feasible.

In over 150 years, the lower talus slope certainly underwent erosion phenomena; therefore, its morphology cannot be regarded as constant in time; furthermore, empirical models are unable to predict the travel distance of future landslides (see Ayala-Carcedo et al., 2003) based on the data obtained for past events (e.g. the Sclafani catastrophe of March 1851).

Author’s changes in manuscript:

In page 13, line 428-430, as follows:

According to some authors (e.g. Porter and Orombelli, 1980; Wieczorek and Jäger, 1996) detailed analyses of documentary data are crucial to identifying the mechanisms triggering rockfalls, evaluating the susceptibility of the various slopes to rockfalls and developing magnitude-frequency relationships.

In page 9, line 298-299, as follows:

Hence, given the lack of reliable discontinuity data, no stability analysis was feasible. This topic will be discussed in a future publication.

In page 11, line 371-373, as follows:

In addition, the morphology of the lower talus slope cannot be regarded as constant in time; therefore, empirical models are unable to predict the travel distance of future landslides (see Ayala-Carcedo et al., 2003) based on the data obtained for past events.

Comment from referee:

Finally, I strongly disagree with the statement (p11, lines 370-371) on that the location, scale and frequency of rockfalls are unpredictable.

Author’s response:

Finally, in (P11L370-371), we merely quote the opinion of Zellmer (1987) without comments. We know that some researchers studied some possible precursors of rockfalls (mountain deformations: e.g. Bovis, 1990; seismic: Wang et al., 2003; Amitrano et al., 2005), including through monitoring systems (e.g. Schenato et al., 2013), in order to investigate the issue of prediction of these events, which are often catastrophic.

Author's changes in manuscript:

In page 14, line 446-450, as follows:

According to Zellmer (1987) the time, place and frequency of occurrence of rockfall disasters, as well as their scale, are unpredictable. However, some researchers are studying some possible precursors of rockfalls (mountain deformations: e.g. Bovis, 1990; seismic: Wang et al., 2003; Amitrano et al., 2005), including through monitoring systems (e.g. Schenato et al., 2013), in order to investigate the issue of prediction of these events, which are often catastrophic.