Answer to referee # 2

This paper aims at comparing different geological mapping of the perimeter of an Italian landslide within a temperate area partially covered with forested vegetation. The authors realize that high resolution, various wave length and stereoscopic views helps a lot in order to precise the external geometry of some sections of this landslide (crown transport and sedimentation areas). Moreover, authors quantify the misfit in between those different mappings relative to a benchmark (Field RTK DGPS survey) through a useful error matrix. The differences in the mapping partly derived from the forest cover that hide the exact perimeter of this landslide.

To my point of view, the main teaching of this paper is not new as geologists/geomorphologists experts in mapping know since a long time that very high resolution, as well as False color composition (relative to True color) and stereoscopic analyses are major and compulsory keys for a precise and exact geological/geomorphological mapping of any geological/geomorpholoigcal objects. Moreover, planimetric differences of mapped objects also are not new see for instance the work on various fractal distances on the measurements of a Britany shoreline that change a lot function of the scale and the resolution (see the basic work of the mathematician benoit Mandelbrot ENSMP Fontainebleau and his team in the 1980's). The interest of this paper is to illustrate it correctly with a pedagogic example and to recall to any scientists these facts using a specific example. In that sense it is interesting for NHESS to publish it.

We thank this Reviewer (R2) for this comment. R2 is correct in saying that our work (and the paper) article does not introduce novelty concerning the adopted techniques used to recognize and map landslides. Indeed, the purpose of the work is to identify which images characteristics are more suitable to map landslide features. With this respect, and to the best of our knowledge, we maintain that there are not very many examples in the landslide literature. Mapping differences are not related to the presence of vegetation (we are working in a crop area and not in forested terrain), but rather to the ability of the images to highlight the two key landslide features, namely: the morphological and photographical signatures. Moreover, we show that the highest resolution or the FCC may not be the best choice for landslide recognition and mapping. Since landslide features are predominantly morphological, this work shows that it can be preferable to use stereoscopic images with smaller spatial resolution than ultra-resolution monoscopic images.

Could you differentiate more clearly the 3 sections of this landslide on those various mapping erosional part (crown), transport section, and at least the sedimentational section (toe). With which image (and why) do we have the best and the more exact geological mapping of this landslide?

The best (and "more exact") landslide mapping could be considered the one obtained using stereoscopic satellite TC image for the deposition area (E = 0.21) and the monoscopic UAV image for the source and transportation area (E = 0.15). Overall, and considering the entire landslide, the best mapping (i.e., the one most similar to the benchmark) is the one obtained using Stereoscopic Satellite TC image (E = 0.18). The mentioned numerical values of the error (Error Index proposed by Carrara et al., 1992) are shown in Figure 6. Concerning the choice of a single "best" image, the issue is discussed in the last paragraphs of the "Concluding remarks". The discussion is done from a wider point of view than the investigation of the specific landslide considered in this work. In fact, we conclude that the choice of the best type of image is dictated by technical and cost-related constraints. We stress that this work focuses on the identification of the characteristics of the images that enable the best recognition and mapping of landslide features. Distinguishing between the different kinematic domains of the landslide, or recognizing geological or geotechnical features of the landslide, is out of the scope of this research wor

Could you precise the inputs and differences through local case examples on a new figure of high resolution DTM, FCC and stereoscopic mapping in order that the reader will be able to get an independent position.

To respond to this comment of R2, we added a new figure (Figure 2). In this Figure we show the WorldView-2 images in TC and FCC, and the UAV image. For each image, we also show a detail of the source and of the deposition area. We decided against adding a stereoscopic image, mainly because a printed anaglyph does not provide the same information of a digital stereoscopic system, that is the one used by the geomorphologist to produce the maps. As such, the anaglyph would have provided potentially misleading information. Lastly, we did not use the high-resolution DEM to prepare the landslide maps.

Please finally dealing with your experience on that landslide what (and why) is your best and more exact mapping? please justify it?

We maintain we have already answered to this question of R2.

What is your best methodological solution to map precisely such Italian landslides?

The Assignano landslide represents an instructive, didactic example of a landslide that has both clear photographical and morphological signatures. By using different images, with different spectral and spatial characteristics, and comparing the maps obtained to a defined benchmark, the more accurate and cost-effective mapping is the one obtained by using the UAV image heuristic interpretation method. This is clearly the case if one considers the mapping of just one landslide. We stress that selecting the best mapping of the Assignano landslide is not the goal of this work, as clearly stated in the "Concluding remarks", and specifically in the last paragraph, where we write:

"Although we conducted our study on a single landslide (Fig. 1), we maintain that the findings are general, and can be useful to decide on the optimal imagery and technique to be used when planning the production of a landslide inventory map."

To further clarify the issue, in the revised version of the manuscript, we added the following sentence in the Introduction:

"We maintain that the results obtained in our test case are general, and should be considered for the optimal selection of images for the detection and mapping event landslides.".

If you compare the benchmark and the mappings the map E (stereoscopic image seems the best fit... could you comment on that?

A comparison between the different mappings and the benchmark are shown in Figure 5 and quantified, using the Error Index *E*, in Figure 6-III. The smallest *E* value corresponds to Map E. This means that the stereoscopic satellite image with true colours has the characteristics to resolve the photographical and morphological signature of the landslide. Thus, for our test case, it is the best image. When the morphological and photographical features are investigated separately, the best choice is Map E for the morphological features, and Map G for the photographical features, as shown in Figure 6-II and Figure 6-I, respectively.

Definitely I do not understand the misfit between map A (field DGPS survey) and map B (field landslide mapping), could you comment on the expert's landslide mapping discrepancies?

The field mapping activities consisted in (i) a reconnaissance field survey and (ii) in RTK GPS aided survey are described in detail in Section 4.1. The two mapping methods have inherently different levels of accuracy. The reconnaissance field survey is a multi-step, manual procedure, whereas the RTK GPS aided survey consists in an automatic measurement, with a well-defined accuracy dictated by the D-GPS technology of about 2 to 5 centimeters. The explanation is given in Section 4.1.

into details:

p4. line92-94: precise ...predominantly photogrammetric... and morphometric...

The signature of a landslide is photographical and not photogrammetric. For photographic signature we intend that the landslide is recognizable on the images thanks to photographic characteristic of the image, including tone, colour, tone, mottling, and texture. We change the word "morphometric" with the word "morphological".

p5. line 108: an horizontal...

We do not accept this editorial suggestion of R2. This is because the "h" of "horizontal" is pronounced as an aspirate.

page 6, line 162: field

We thank R2 for this suggestion. We corrected the error accordingly.

page7 line 182: perform an heuristic

As before, do not accept this editorial suggestion of R2. This is because the "h" of "horizontal" is pronounced as an aspirate.

page 8, l221: this source area was characterized by small cracks (please show on a figure those features.

To respond to this request of R2, we have added the new Figure 2.

page 9, line 228 to 257 the comments of the table 2 is difficult to follow could you find an easier solution more convenient and easier to understand to present those results?

We maintain that providing (e.g., in Table 2) and describing landslide key and standard measures is useful. For this reason, we have not changed this part of the text.

P.11 , line 282 poor agreement please precise...

We acknowledge the problem, and we chanced the text. In the attempt to clarify the meaning, we now use "high value of the error index" instead of "poor agreement".

P.11, line 287: good agreement please precise...

We acknowledge the problem, and we chanced the text. In the attempt to clarify the meaning, we now use "low value of the error index" instead of "good agreement".

P.13, line 343 please precise a sentence on the resolution of the NIR datasets used herein and what could be the inputs if the NIR dataset if it would have 3x3cm^2 ground resolution...

To respond to this comment of R2, we added the following sentence:

"We conclude that use of the additional information contributed by the Near Infrared (NIR) band in the 1.84-m resolution satellite image did not improve the quality of the mapping. On the other hand, the contribution of the NIR in the 3-cm UAV image remains unknown."

P.14 line 385 ...is comparable...is to my point of view poor... We do need to have precision on the differences in between mapping from stereoscopic and high resolution... You are working on a local case example you should go farther on your reflection and give to the scientific community your choice of the best way to map such kind of landslide.

The comparison among the different maps obtained using stereoscopic satellite images and UAV images is supported by the value of the error index E, which is $0.20 \geq E \geq 0.26$ for the entire landslide, $0.21 \geq E \geq 0.29$ for the deposition area, and $0.20 \geq E \geq 0.25$ for the transportation area. The mentioned E values are given in the manuscript, and our conclusions are unambiguously drawn on the basis of the analysis of such values. In particular, the main difference between maps obtained from stereoscopic and UAV images is in the mapping of the deposition area, where the morphological signature of the landslide was better detected using the stereoscopic satellite image than using the ultra-resolution monoscopic images ($0.21 \geq E \geq 0.29$). This is also stated in the "Concluding remarks". We maintain that the selected test case is well representative of the scenarios one may be presented with in the visual mapping of a earthlow.

P.14, lines 396-397: and partly independent from the local lighting conditions including the cloud cover... please precise...

The acquisition of an UAV image can be planned selecting the best light conditions. This because, most commonly, is the UAV operator that decides when to fly. Also, the flight altitude of a UAV is typically much lower than the clouds height.

p.15, l 407 flying

We thank R2 for picking up the error. We amended the text accordingly.

P.15, l. 412: large or very large areas...

To respond to this comment of R2, we modified the text as follow:

"Fourth, a comparative analysis of the technological constrains and the costs of acquisition and processing of ultra-resolution imagery taken by UAV, and of high, or very-high resolution imagery taken by optical satellites, revealed that the ultra-resolution images are well suited to map single event landslides, clusters of landslides in a single slope, or a few landslides in nearby slopes in a small area (up to few square kilometres, Giordan et al., 2017) , and prove unsuited to cover large and very large areas where the stereoscopic satellite images provide the most effective option (Boccardo et al., 2015)".

p.16, l 447-448: a better resolution and spectral resolution did not contribute significantly to reducing the mapping errors: ??? please precise...

R2 is right in saying that the highest resolution images did not provide the best result for the purpose of this work and for the test case. This is mainly due to the fact that resolution is not the only characteristic of a remotely-sensed image. Other characteristics relevant to landslide recognition and mapping are the stereoscopic view and the spectral content. The outcome of this work shows that stereoscopic view is a key requirement to accurately recognize and map landslide features. In the depositional area, the lowest error is obtained using the stereoscopic satellite images. Even if the UAV images have a spatial resolution higher than the satellite images, the mapping error in the depositional area remains larger than the error obtained using the stereoscopic satellite images. On the other hand, the comparison between the mapping obtained from the stereoscopic satellite images in TC and stereo satellite images in FCC, don't highlight differences, meaning that to map depositional area with mainly morphological signature, stereoscopy is the most important characteristic. To clarify the issue, we added the following sentence:

"FCC and TC in the stereoscopic satellite images give similar values of the error. This indicates that the spectral resolution of the images does not provide useful information to recognize and map the landslide morphological features. On the other hand, the high spatial resolution provided by the UAV images reduces the error, when compared to the monoscopic satellite imagery. However, the error obtained using the UAV images remains higher than that obtained using stereoscopic satellite images, despite the latter having a pixel one order of magnitude larger than the UAV images. We conclude that the increase in the spatial resolution improves the ability to map morphological features when using monoscopic images.

p.16, l 461: *prove to be very effective*

We thank R2 for the suggestion, and we amended the sentence accordingly.

P. 17, 8 l 481 acknowledgments the references needs to be carefully checked.

We checked the acknowledgments the list of references.

Fig.1 to 4: please give comments within the legend that give the key points of the figures.

We changed the captions of Figures 4, 5 are 6 accordingly, to give to the reader a key point of the figure.

Figure 4. We add in the caption the following sentence:

“The photographs taken in the field and the Google Earth™ image were used to prepare the reconnaissance field map.”

Figure 5. We added the following sentence to the caption:

“Visual inspection of the images reveals the maps most similar to the benchmark.”

Figure 6. We added the following sentences to the caption:

“The error index (*E*) proposed by Carrara et al. (1992), was used to compare quantitatively the different landslide maps.”

“E spans the range from 0 (perfect matching) to 1 (complete mismatch).”

Add a figure with specific details inputs of the landslide and compare it to the different geological mappings.

We have added the new Figure 2 to show the WorldView-2 images in TC and FCC, and the UAV image. For each image details of the landslide source and depositional areas are also shown.