Answer to referee # 1

The authors present a study focussing on an expert-based interpretation of imagery data with the aim of mapping landslide features of a single landslide. Various data are tested and the mapping results are compared to reference data and field mappings.

The authors then give recommendations regarding the feasibility of the different mapping techniques and imagery data for landslide mapping. The employed methods are standard methods (dGPS, heuristic landslide mapping techniques), so there is no methodical innovation. The used software are commercial products. The results are difficult to reproduce, since only one expert did all the mapping. It would be interesting to see, how the landslide would have been mapped by further experts (>10). Furthermore, it remains unclear if the results are transferable to the relevant scale of event landslide inventories or to other types of landslides.

We thank this Reviewer (R1) for this comment. As correctly noted by R1, in this work we adopted different (standard) techniques and digital images to produce a landslide inventory. The techniques consist in field mapping and photointerpretation. For the latter we used six different digital products. However, we point out that the aim of the effort was not to investigate the feasibility of techniques, nor to give absolute criteria to choose among different images. The study focuses on the definition of criteria for the selection of remote sensing images for the specific purpose of mapping event landslides. For this reason, we relied upon a single expert to perform the landslide recognition and mapping. We considered the possibility to use more experts. However, this would have added the uncertainty inherent in the subjective interpretation of aerial photography for landslide mapping (see e.g., Carrara et al., 1992, Uncertainty in evaluating landslide hazard and risk. ITC Journal, 172–183). The uncertainty inherent with the interpreters would have mixed (and covered partially) the "signal" from the different imagery used for our experiment. Since the scope of the research was to investigate the information content of the imagery (and not of the interpreters) we ruled out the possibility of using more interpreters. Further, the researcher geomorphologist who interpreted the images and prepared the maps (MS) has a significant experience in photointerpretation for landslide mapping (he has prepared 25 landslides maps, including event maps, geomorphological maps, multi-temporal maps, covering more than 4000 km^2, obtained using both monoscopic and stereoscopic satellite images and stereoscopic aerial photographs). Thanks to the expertise of the mapper, in each digital image the relevant features of the landslide were recognized fully. Thus, we are confident that differences among the six maps are to be ascribed to the sole resolving power of the different images. We have clarified this point in the text (see below). Moreover, we selected a landslide having both morphological and photographical signatures, which are the two key features that allows to recognize and map landslides from digital images. For this reason, we maintain that the results we have obtained are valid at all scales, and for most landslide types.

The text is generally well written, but there are some minor mistakes of grammar and style. Some of them are addressed below, but it would be out of scope to raise every issue. Therefore, I recommend careful copy editing. Below, I focus on issues concerning the scientific content of the manuscript. Where numbers are given in the specific comments *they refer to the manuscript page and line. A major revision carefully addressing the raised issues below is required, before the paper can be considered for publication.*

We thank R1 for reading carefully or Manuscript. We amended the text following R1 suggestions, where applicable.

Specific Comments

Consider introducing the principle of heuristic, visual mapping of landslide features based on the interpretation of landslide signs ('geometric signature'; Pike, 1988). This is well explained in Section 4.2. However, an introductory description of the procedure would benefit the understanding of the reader. In this context, also explain the advantage of stereoscopic over monoscopic interpretation techniques.

In the Introduction, we added the following language to clarify the text:

"The heuristic visual mapping of landslide features is based on the systematic analysis of image photographic and morphological characteristics such as colour, tone, mottling, texture, shape, size, curvature (Pike 1988). These photographic and morphological characteristics encompasses all the possible landslide features that can be used for the (visual) interpretation of the available imagery."

Consider addressing the necessary positional accuracy of the mapped landslide features with respect to the intended use/scale of the compiled landslide inventory.

We accepted this suggestion of R1. In the Discussion section, we added the following sentence:

"Where possible, we recommend that the acquisition of images used for the production of event, seasonal or multi-temporal landslide inventory maps is planned considering the typical landslide signature, in addition to the purpose (event inventory, planning of monitoring systems), scale of the mapping (i.e. regional or slope scale), and the size and complexity of the study area (see Table 3)."

Consider adding a sentence addressing the potential of UAV-based imagery for efficiently analysing changes over time (e.g. Turner et al., 2015). Added to Discussion section.

We accepted this suggestion of R1. In the Discussion, we added the following sentence:

"The use of UAV images was recently proposed by Turner et al. (2015) for determining the landslide dynamics, exploiting time series of images that can be constructed using UAVs. The result is achievable thanks to centimetre co-registration accuracy of the UAV images."

Which type of landslide is it, what type of material is involved (since the area seems to be not very steep) and what are the causes and failure mechanism?

We accepted the comment of R1, and changed the text as follows:

“For our study, we selected the Assignano landslide, a slide-earthflow (Hutchinson, 1970) triggered by intense rainfall in December 2013 in the northwest-facing slope of the Assignano village, Umbria, central Italy (Fig. 1). The landslide develops in a crop area, where a layered sequence of sand, silt and clay deposits crop out (Santangelo et al., 2015)”.

Have there been changes during the winter months (e.g. retrogressive failure, erosion)?

For the purposes of the present study this information is not relevant. No changes were recorded between the field mapping and the time of the acquisition of the images. However, after the mapping procedure was completed, a retrogressive movement occurred in the landslide escarpment area. This is visible on the recent images provided by Google Earth.

Is the area cultivated/what is the land cover/land use?

To respond to the question of R1, we modified the text adding the following sentence:

“The landslide develops in a crop area, and the lithology consists in a sequence of sand, silt and clay layered deposits.”

Add a table specifying what was done by whom and when. Also include the abbreviations of the persons.

We considered carefully the option of adding a table, as suggested by R1. However, we concluded that this was not necessary, and would only add to the length of the paper, without improving clarity or readability. The abbreviation of the individuals who performed the GPS mapping and photointerpretation are given in sections 4.1 and 4.2.

Describe the 2.5D pseudo-stereoscopic data in more detail. Why was the landslide mapping based on the orthorectified UAV-imagery done in Google Earth and not using a more suited GIS software?

We acknowledge that our choice us using Google Earth™ was poorly explained. We have changed and expanded the text, that now reads:

“To interpret visually the ultra-resolution UAV image, the interpreter overlaid (“draped”) the image on Google Earth™. For the purpose, we first treated the UAV image with the gdal2tiles.py software to obtain a set of image tiles compatible with Google Earth™ terrain visualization platform. To the best of our knowledge, the platform is the only free, 2.5D image visualisation environment that allows the editing of vector (i.e., point, line, polygon) information. Other commercial (e.g., ArcScene) and open source (e.g., ParaView, GRASS GIS), 2.5D visualization tools do not provide editing capabilities. Google Earth™ is a user-friendly solution for mapping single landslides, and for preparing landslide event inventories for limited areas, with the possibility for the user to visualize a landscape from virtually any viewpoint, facilitating landslide mapping”.

Did you use the DEM included in Google Earth for aiding the mapping procedure?

The DEM available in Google Earth™ is low-resolution, pre-event DEM, that does not provide adequate information on the specific landslide morphology. On the other hand, the DEM proves useful to frame the landslide in the general morphology of the slope.

Why didn't you consider a DEM based on the UAV-point cloud?

Indeed, we considered this option carefully. However, to the best of our knowledge, there is no dedicated 2.5D GIS software that allows for editing on a custom DEM used to drape ortho-photographs. The only way to use the DEM based on the UAV-point cloud would have been to use a dedicated GIS for 2.5D visualization software, and a 2D GIS editing environment to transfer the information obtained from the visualization to a base map. The procedure would have introduced an additional source of uncertainty.

Since in most of the scene there is no high vegetation (trees), the landslide's morphology should be represented well. Also other derivatives of the resulting UAVC3 NHESSD Interactive Comment Printer-friendly version Discussion paper based DEM (e.g. shaded reliefs, e.g. Niethammer et al., 2010) could be used for landslide mapping. Then, also the morphometric features could have been mapped better using the UAV data.

The use of maps derived from the elevation data is out of the scope of the work, and of the paper that focuses on optical images. We acknowledge that the scope of the work was not fully clear. When have changed the tithe that now reads "Criteria for the optimal selection of remote sensing optical images to map event landslides". We also added the word "optical" in the Introduction, where we now write:

"These maps were compared to an eighth map considered to be the benchmark showing the "ground truth" i.e., the "true" position, shape and extent of the Assignano landslide. Based on the results of the map comparison, we infer the ability of different optical images, characterized by with different spectral and spatial characteristics, to portray the landslide features that can be exploited for the visual detection and mapping of landslides."

Describe the transfer of mapped landslide features from Google Earth to the GIS. Which GIS software was used?

To transfer the mapped landslide features from Google Earth™ to a GIS database we used the open source GIS software QGIS. The mapping produded in Google Earth™ was imported in QGIS as a Keyhole Markup Language (kml) file, and then converted in the ESRI Shapefile (shp) format.

Which coordinate system/projection was used for the individual datasets (can Google Earth handle ETRF-2000)?

Seven of the dataset were originally mapped in WGS 84 33 N (EPSG 32633). Concerning the question about the capacity of Google Earth to handle ETRF-2000 reference system, we acknowledge that some errors are expected when a raster map is warped on Google Earth, due primarily to the spherical Mercator reference system adopted by Google Earth). However, we did not observe relevant systematic positional errors. This is evident also when comparing the map obtained using the monoscopic UAV image with the map obtained overlaying (“draping”) the same image on Google Earth™.

Mention that you mapped the source/transportation area and the deposition area as separate landslide features. How did you discern the source/transportation area from the deposition area?

To respond to this comment of R1, we added language to the paragraph. The new text now reads:

“The source and transportation area is bounded locally by sub-vertical, 2 to 4-m high escarpments. In the landslide, terrain slope averages 11°, and is steeper (12°) in the source and transportation area than in the deposition area (9°). The landslide signature (Pike, 1988) is different in the different parts of the landslide. In the source and transport area the signature is predominantly photographical (radiometric), whereas in the landslide deposit it is mainly morphometric (topographic). The differences allow to separate the source and transportation area from the deposition area”.

Are there indicators beyond subjective visual recognition?

We are not sure we understand fully the question. However, we point out that visual recognition is by definition subjective, but it is based on objective and reproducible observations. As stated in section 2, the two landslide portions show different average slope and different photographical and morphological signatures. An expert geomorphologist is able to identify and classify the different landslide signatures, in the source and transport zone and in the deposition area.

How did you treat shadows during landslide mapping?

The images we used were free from shadows.
We added language in Section 3 to state that:

“Both satellite and UAV images are free from deep shadows (**Fig. 2**).”

Comment on the comparability of landslide features mapped on different scales (1:1.000 to 1:6.000).

We accepted this comment of R1, and we changed the text adding the following sentence to paragraph 4.2:

“The scale of observation was selected to obtain the best readability of each landslide feature and the surroundings, which is a common practice in image visual analysis for landslide mapping (Fiorucci et al., 2011). Hence, even if the maps were produced at slightly different observation scales, the differences arising from the comparison are due to actual features (i.e., the image resolution and radiometry), and not to the different observation scales.”

Technical comments

We thank R1 for the technical comments. We accepted all the technical comments of R1, and we corrected the text accordingly.

Figures and Tables

Figure 1: add information on the shown datasets in Fig. 1A (also add a reference to Google Earth), also specifying the source of the polygons and -lines.

To respond to this request of R1, we added language in the caption, that now reads:

"The Assignano landslide, located near Collazzone, Umbria, central Italy. (A) global view of the landslide. (B) detail of the landslide source area. (C) detail of the landslide transportation area. (D) detail of the landslide deposit. Base image obtained overlaying ("draping") the image on Google Earth™. Red line is the boundary of the landslide obtained using the RTK DGPS (benchmark)".

Figure 2: Add a north arrow. Change DGPC to DGPS in the caption.

In the new version of the manuscript Figure 2 has become Figure 5. We thank R1 for the suggestion, and we change the figure and the caption accordingly.

Table 1: change meter to metre in the caption

We accepted this suggestion of R1, and amended the caption accordingly.

Reference

We added to the list of references the three citations suggested by R1.