

The manuscript includes an original study on flood mapping using various remote sensing image sources and techniques. Therefore it has practical significance. In the literature, as also referenced in the study, there are so many research articles studying the evaluated data types and the techniques, however this study uses most of the available data sources and techniques for a single case showing the efficiency of results. Therefore, a comparative study in which the results of maps using optical and SAR images processed with different remote sensing techniques is presented.

In general, the proposed approach was explained well, the experiments were conducted properly, and the results were discussed in the manuscript. However, there still exists some missing points in the manuscript in terms of the completeness of the paper. Therefore, if they are corrected considering the minor issues highlighted below, the article is recommendable for publication.

Reviewer recommends: Minor revision

R: we would like to thank you the Reviewer for the detailed revision and his important suggestions. We improved the manuscript following your input. In the following, we present reviewer's suggestions and relative answers.

In section 3.1.1

1) It is noted that available COSMO-SkyMed image has been classified into three main land cover classes as; water-covered areas, i.e., flooded (low amplitude), urban areas (high amplitude) and soil/vegetation (intermediate amplitude). There, what is the type of the classification method used? The result of the accuracy assessment of the classification process was not given?

R: thank you for the request. We have improved the manuscript with a more detailed explanation. In particular, we added: *"The Cosmo-SkyMed image provided is a simple, not-geocoded image in grayscale format (0-255). After the geocoding we re-classify the SAR amplitude images using empirical thresholds in three main classes: water covered areas (0-60) soil/vegetation (60-160) and urban area (160-255). The investigated area is almost flat, so it is not affected by problems related to geometrical distortions. The validation of the data accuracy was made by comparing the reclassified image with aerial photos, optical images, and land-use."*

2) Authors are recommended to give at least the overall accuracy of the classification! Please also note that in section 4.1.1, the classification accuracy of COSMO-SkyMed was not presented.

R: We verified the accuracy in terms of classification reliability of this method using aerial photo and CORINE land-use. We add also the table 6 where is resumed accuracy in terms of flooded area detection. About the section 4.1.1 We modified the text (line 346):

1) Co-flood mapping, reclassified amplitude of COSMO-SkyMed data. Results of image classification are shown in Figure 3A, where three classes of SAR amplitude were defined by means of empirical thresholds: i) low that correspond to water covered area (blue); ii) intermediate like soil/vegetation (green); iii) high that are urban areas (pink). In the figure are also overlapped the quarry lake from ancillary data (cyan). The accuracy in the correct detection of land-use type is quite good ranging from 80 % for soil and vegetation, 67% for urban area to 61% for water body (tested in quarry lakes). Vegetation and buildings are factors that reduce the detection of water covered areas even using a full-resolution images and more complex processing (Pierdicca et al., 2018). In a second step we selected with a GIS query the low resolution (water covered) class that mostly correspond to the inundated areas and we compared with the it real flooded area. Also the accuracy in the correct detection of flooded areas is quite good: it ranges from 57 % in the lower Oitana stream to 2% in the Po area near Moncalieri. This is related to the time of satellite acquisitions (05:05 UTC of 26 November 2016) some hour before the flood peak. This can be appreciated especially along the Po river, where upstream (near Pancalieri) about the 40% of flooded area was detected, while downstream (Carignano) decrease to 10%. The urban area of Moncalieri limits the capability detection of inundated areas. The false positive errors are less than 5% of the area.

In Section 3.1.2

3) Did the authors apply atmospheric correction to MODIS data?

R: this is an important question. In the first version of the manuscript we didn't apply atmospheric corrections, but then we searched for already corrected product and we made a comparison with the original dataset. In particular, we used MYD09 processed images: (Vermote E. - NASA GSFC and MODAPS SIPS - NASA. (2015). MYD09 MODIS/Aqua L2 Surface Reflectance, 5-Min Swath 250m, 500m, and 1km. NASA LP DAAC. <http://doi.org/10.5067/MODIS/MYD09.006>). We compared the corrected images with the previous ones and, since the study area is small and the available atmospheric parameters for correction have 1 km of spatial resolution (water vapour, ozone or aerosol), we did not find significant changes.

We wrote also in the manuscript that no further atmospheric correction was applied to MODIS image.

4) It was also noted that a supervised classification was applied to MODIS by SAGA-GIS. Which supervised classification method was used? Quantify the accuracy of the classification result.

R: We used Maximum Likelihood method with absolute probability reference. For this revisions we refined the classification, using corrected images, and we also add spectral angle classification. To answer to the question related to accuracy, in terms of flood detection capacity, please see new table 6. In the manuscript line 218 we re-write as follow:

Supervised classification of co-flood image. Supervised classifications has already been used in literature to map flooded areas, using machine learning, as described in Ireland et al., (2015). In our work we made a simple supervised classification with SAGA GIS. We first manually defined the training areas with principal land use typologies visible on the false colour image. We try different methodologies for the classifications and we chose as most accurate the maximum likelihood with absolute probability reference and spectral angle methods. We validate the reliability of these classifications with a comparison with false colour image and land-use database. Then we using a GIS query extracted the category "area covered by water or wetland" that mostly correspond to the flooded area for accuracy statics reported in result chapter.

In Section 3.2.1 and 3.2.2

5) DSM is generated from high resolution images. Digital Surface Model (DSM) is not a Digital Terrain Model (DTM). Authors should know the difference between surface and terrain model.

R: Yes. We used LIDAR DTM downloaded from Regione Piemonte for our Water Depth models (section 3.3). The Digital Surface Model (DSM) were produced by us from SfM processing of aerial and UAV images and we used DSM for 3D model and for the detection of geomorphological features but as a base layer for WD model. We checked in the manuscript if the terms DTM and DSM were properly used.

In section 3.3

6) How did the authors perform water level measurements by GPS-RTK positioning? Give a little detail.

R: We modified the text to fix this issue: we validated and integrated SfM measures of water level using manual measurement of water level geolocated with high precision using a GPS-RTK positioning.

In section 4.1.2

7) In Figure 4, in the figure caption, the letter of the final item D) appears as C) second time! Correct it:

R: Ok we corrected it and a new version of figure 4 was made (see below)

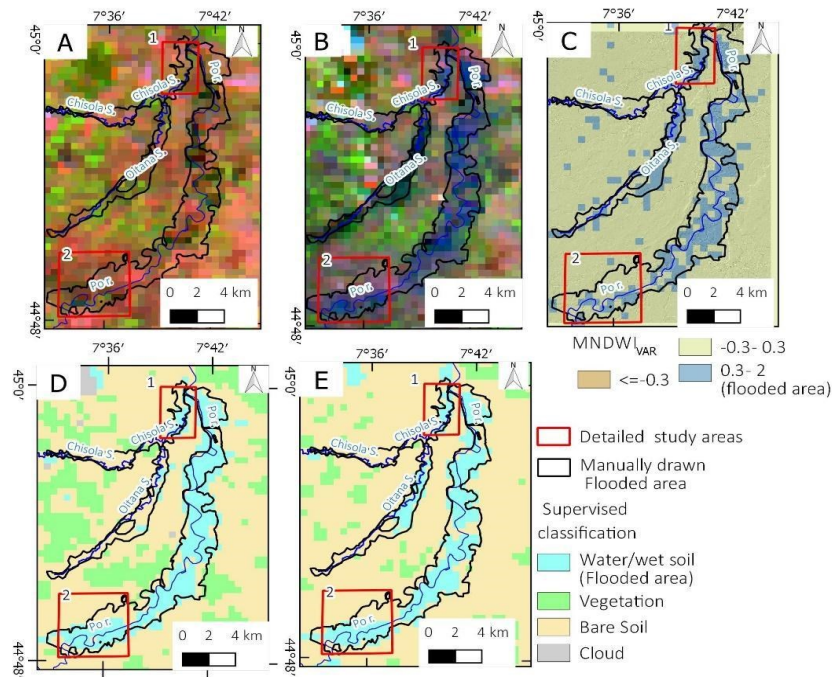


Figure 4: MODIS Aqua satellite image A) False colour band composition 7-2-1 acquired the 12 November 2016.; B) False colour band composition 7-2-1 acquired the 26 November 2016.; C) automatic detection of the flooded area using $MNDWI_{var} > 0.3$; automatic detection of the flooded area using supervised classification with maximum likelihood method (D) and with spectral angle method (E). The red box identifies the local case history of Moncaleri (1) and Pancalieri (2)

8) It is observed that MODIS image is classified into Cloud, Water, Wet soil, Vegetation, and Bare soil whereas COSMO-SkyMed image has been classified into three main land cover classes as water-covered areas (i.e., flooded), urban areas, and soil/vegetation. It looks like only a GIS query can be done between the classes "Water" and "Water-covered areas" classes derived from CSKM and MODIS images, respectively. Authors need to explain in detail how they used maps generated from the classified images.

R: Yes, we used a GIS query to select the flooded pixels, but for each dataset the query is based on different criteria; in particular:

- In the case of supervised classifications of MODIS data, flooded pixels correspond to water or wet soil classes. We modify the manuscript (line 375) as follows:**
"Supervised Classification. We also made a supervised classification of 26 November MODIS image using maximum likelihood (MLC) (Fig. 4 D) and spectral angle (SA) (Fig. 4 E) methods. In the study area, we classified, four primary land cover: vegetation, bare soil, cloud, and water body / wet soil that almost identify the flooded sector (the water bodies like the quarry lakes are too small for MODIS pixel). After a visual checking of the classification reliability, we used a GIS query to select the "water covered and wet areas" classes. The query creates a boolean rasters of flooded areas. The accuracy of flood map based on supervised classification is good: it identifies most of the flooded areas for Po river (> 70 %) with low false positive pixel (table 6). Worst results for the are flooded by Chiosla and Oitana.
- In the case of bands ratio (NDVI, MNDWI) made with Sentinel-2 and MODIS DATA, we adopted numerical thresholds empirically based. In the manuscript we write line 369 "In figure 4 C we identified flooded area using a GIS query with the value $MNDWI_{var} \geq 0.3$. This value is an empirical threshold that select most of detectable flooded area and minimizes false positive errors." And line 383: "For both indexes we used GIS queries with empirical thresholds to extract the flooded area."**
- In the case of CSKM, we better specified in the text and in figure 3 that SAR Amplitude Image of CSKM was divided in three classes, based on empirical numerical thresholds, that correspond to different land-use: low (water covered area), medium (soil and vegetation) and high (urban**

areas). We assumed that water covered areas are almost flooded areas. We modify the manuscript (line 346) as already reported in reply to the comment (2).

In addition, in the introduction of par 4.1 (line 339) we better write how we have generated maps from classified images:

“The flooded area limits were manually extrapolated considering satellite data and geomorphological features obtained using the hillshade model derived from 5-m DTM of Regione Piemonte and used as a benchmark for the evaluation of the performance of remote sensing analyses. For Po and part of Chisola, the flooded areas were mapped also with help of water height simulation on the base of DTM.”

Is now changed as follow:

“We manually extrapolated the flooded area perimeters considering both satellite data and geomorphological features observed in the hillshade model derived from 5-m DTM of Regione Piemonte. For the evaluation of automatic flooded area maps based on satellite data we applied a GIS query for each map to create boolean rasters of flooded / not flooded area. Then we overlap the raster with manual polygon for a geo-statistical analysis and accuracy evaluation as reported in table 6.”

In Section 4.2.3

9) Authors declared that " *During the post processing, we realized that the quality of the images extracted from the video was insufficient for the SfM application. For this reason, after a month we performed a second survey along the same path*" Explain the insufficient qualifications for the extracted images used for the SfM application.

R: Yes, we add the following sentence: “: ...the bitrate was too low and the frames are too pixelated. For this reason, after a month we performed a second survey with a higher bit rate along the same path, but only six marks still visible (Fig 10 A)”.

In Section 5

10) It was written that*" the combined used of InSAR data of Sentinel-1 and Cosmo, and multispectral data of MODIS-Aqua and Sentinel-2 allowed creating maps of the flooded area. InSAR data showed a good performance in the real time flood mapping while are weaker for post event mapping....."* Here, instead of InSAR data the use of SAR data is recommended. It is because, the only amplitude value of the SAR data was used and no interferometric process was applied.

R: Yes it is true, we have corrected it.

In the discussion and results section

11) Rather than using expressions such as "good agreement", "more precision", "good accuracy", etc; quantify the accuracy or the quality of maps, results, etc .

R: Thank you for your suggestion, we add some quantitative evaluation of quality of the maps in this section. At end of section 4.1 we also add the table 6 that quantifies the accuracy in flood detection for the automatic processing that we used

Table 6. Accuracy in automatic flooded and not flooded area detection

Sector	Area km ²	Sentinel-2		MODIS-Aqua			CSKM	Sentinel-1
		MNDWI _{var}	NDVI _{var}	MNDWI _{var}	MLC	SA	Recl Ampl	$\Delta\sigma^{\circ}$
Not Flooded	259.5	87%	87%	91%	94%	95%	96%	99%
Flooded area								
- Po	47.8	48%	37%	49%	70%	64%	23%	4%
- Oitana	11.6	49%	42%	60%	11%	36%	37%	1%
- Chisola	7.3	21%	51%	30%	24%	23%	12%	1%
- Chisola urban	1.1	4%	24%					

12) Last but not least, the difficulty of this study is that the satellite data might have not always been received at the time of the hazard occurred! The authors can add a better flow chart that shows the missing data can be replaced by the other, taking into account the image data sorted from high resolution to low resolution:

R: Yes, it is true: the time of satellite pass over the flooded area is a limit especially with fixed revisit time sensors that we decided to use. Following your suggestion, we create a better flowchart in which we purpose the parameters for the choice the data used for flood mapping.

In the manuscript we add this chart as figure 13 and we add the section 4.3 in which our model is explained:

4.3 A flood mapping strategy flow chart

The flowchart in figure 13 shows the approach that we purpose for the choice of instruments and methods to map the flooded areas, based on the results of this study.

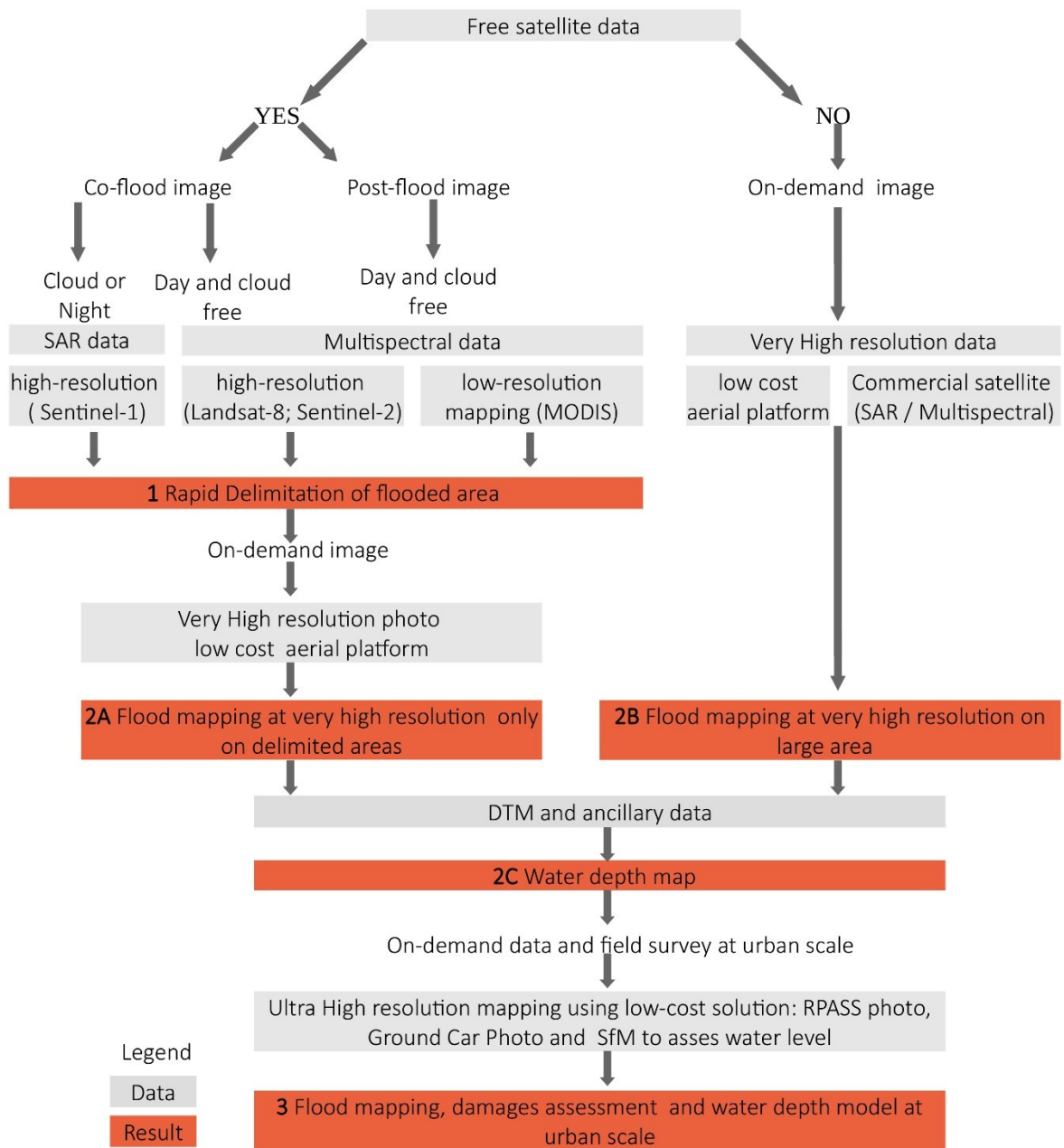
If free satellite data are available, it is possible to sort them taking into account the parameters of time elapsed from flood and the spatial resolution:

I) The priority is to search for co-flood images that allow an easy mapping. In case of night and cloudy conditions it is necessary to use SAR image (Sentinel-1) while for multispectral data acquired during the day the choice is related to spatial resolution: for instance, Sentinel-2 or Landsat-8 data are more resolute than MODIS data.

II) In the case we have post-flood satellite pass only multispectral data can be used. Also this case the Spatial Resolution and time elapsed from the flood are the parameters that should drive the choice. The use of post-flood data implies more complicated post-processing (e.g., bands index variation) and with the support of ancillary data to extract the flooded area map. In general, the rapid access to data portal of free satellite data allows to download the data and to make an evaluation of the best solution for the case under study, that not necessarily is the data with high spatial resolution.

After this step it is possible to make a first delimitation of flooded areas, that in case good data may be an already corrected and ready to use map. Then it is possible to focus the acquisition of on-demand of high-resolution sensors only in the most critical or unclear areas (case 2A). If we use only on-demand data, without rapid satellite mapping, we could map at high-resolution large areas (case 2B). This solution however implies higher cost. In case of direct mapping at very-high resolution it is better to use low-cost aerial platforms that are more flexible respect to commercial satellites. After the integration with DEM data the water depth model at basin scale (2C) should be the final result of this chain.

Urban area flood mapping (3) can be considered a hotspot priority inside the general flood map. It needs a more accurate and high-resolution mapping with use of ground-based measures (like SfM model based on car photo), RPASS survey, and the creation of a water depth model that is essential for a precise flood magnitude assessment.



Flood mapping strategy proposed