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# WINDTHROWS DETECTION WITH SATELLITE REMOTE SENSING DATA: A COMPARISON AMONG SENTINEL-2, PLANET, AND COSMO SKY-MED DATA

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## ABSTRACT

Wind disturbances represent a great source of damage in forests, and an assessment of such damage is very important for adequate forest management. Remote sensing is an effective tool for this purpose and can be used by considering different data sources: active vs passive sensors. While passive sensors can provide a direct view of windthrows, they are often affected by clouds. Active sensors have the significant advantage of not being affected by the presence of clouds which can be prevalent in certain seasons in mountain areas. The objective of this study is to compare the capability of active (Cosmo SkyMed SAR sensor) and passive (Sentinel-2 and Planet sensors) data in detecting windthrows in different seasons of image acquisition. A study site was analysed, located in the Trentino-South Tyrol region (Italy), which was affected by the Vaia storm on 27-30 October 2018, which caused significant forest damage.

***Index Terms***— Windthrows, Remote Sensing, Sentinel-2, Planet, Cosmo SkyMed.

## 1. INTRODUCTION

Forest environments are affected by many natural disturbances that drive their natural regeneration and adaptation. Wind is one of them and it is responsible for more than 50% of the primary damages to the forest ecosystems [1]. If, from the natural perspective, windthrows are part of the natural regeneration of forests, from the economic perspective they represent a considerable economic loss. Due to the increase of the atmospheric temperature, it is expected that windthrows events will increase in the future, and thus there is a need in developing systems to detect damages due to such events. From a management point of view, it is very important to know where the damage is and to act to harvest the damaged trees. Remote sensing can be a very valuable tool for the detection of forest windthrows. Indeed, many studies exist in the literature that exploit different types of remote sensing data and different temporal approaches (i.e. one image after the event, or multitemporal images before and after the event) [2]–[7]. The most used type of data to detect forest windthrows are optical satellite ones, and in particular multitemporal images [3], [4], [6]–[13], although several studies make use of airborne [9], [14], [15] or UAV data [3], [16]. Some studies also exist that have used SAR data to detect windthrows [5], [6], [17]–[24].

The objective of this study is to compare the ability to detect forest windthrows of three satellite constellations (one SAR and two multispectral) in different seasons of image acquisition (summer, autumn, and winter).

## 2. STUDY AREA AND DATASETS

The study area (27.8 $km^2$) is located in North East Italy, in the Trentino-South Tyrol region (Figure 1) where between the 27th and the 30th of October 2018, the Vaia storm, one of the most intense storm events of Italy in the last decades, destroyed hectares of forests [10]. The selected area is covered mainly by Norway spruce forest. The three satellites use for comparison are: COSMO-SkyMed (CSK), Sentinel-2 and Planet Scope. CSK is a satellite space-based SAR constellation managed by the Italian Space Agency (ASI). Data are collected in the X-band. For this study we used archive data acquired in the stripmap mode in the HH polarization in ascending direction. The choice of the mode and polarization was due to the availability in the ASI archive. The images were provided by ASI through the COSMO-SkyMed Open Call for Science in the processing level 1B (DGM). Sentinel-2 (S2) is a constellation of two satellites managed by the European Space Agency (ESA). S2 images can be freely downloaded. Each S2 multispectral image has 13 spectral bands at three different spatial resolutions (10, 20 and 60 m). Planet Scope (PS) is a constellation of more than 200 nano-satellites owned by the imaging company Planet Labs, Inc. (www.planet.com) providing daily high resolution multispectral images, composed by up to eight spectral bands at 3 m spatial resolution. Though PS is a commercial satellite, many of its products are open access for research purposes and they can be downloaded from their website (www.planet.com).

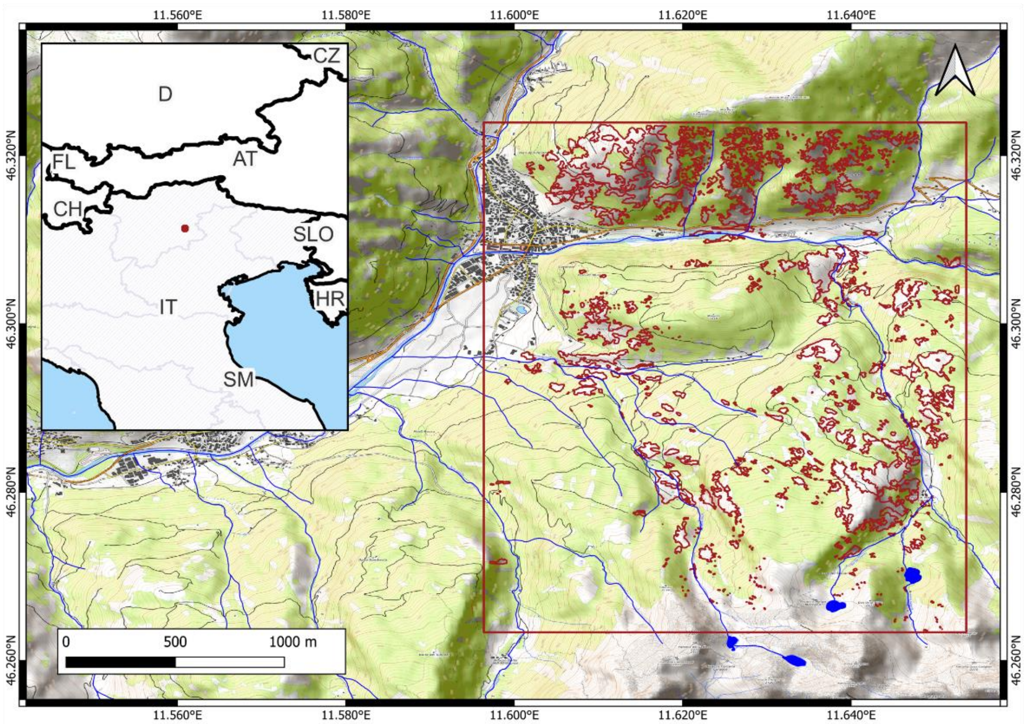


Figure 1. Location of the study area in the North-East part of Italy.

## 3. METHODOLOGY

Windthrows were detected on the three sets of images using different algorithms, all of them based on change detection strategies. CSK data were terrain corrected using ESA SNAP software using a high resolution local digital terrain model.

### 3.1. Windthrows detection in CSK data

The windthrows detection methodology used was developed starting from the one proposed by [25] to detect forest fires using ERS-1 SAR data. The proposed windthrows detection is organized into four steps (assuming data has been pre-processed): i) creation of the log ratio image: due to speckle noise present in these images, the statistical distribution of the data changes and cannot be compared by standard subtraction; ii) multiscale decomposition/reconstruction: windthrows happening in a given area have different sizes and cannot be compared at the same scale, otherwise smaller or larger windthrows would be missed; iii) Otsu thresholding of each multiscale component: given the work at different scales, different thresholds are required in order to improve detection capability; and iv) final decision using a majority rule for each pixel: a given pixel could be observed more than once at different scales, reporting different results, thus a majority rule helps to assign the best label. Afterwards an additional spatial filtering based on a majority rule is applied to the final map.

### 3.2. Windthrows detection in S2 and PS data

Regarding the S2 and PS image a standard Change Vector Analysis (CVA) technique was applied (following [7]). CVA exploits both multispectral and multitemporal information by considering a difference operator. Unlike CSK, statistical distribution of optical data allows us to use this sort of operator for detecting changes. Even though CVA can work in n-dimensions, it is commonly used in two dimensions. In this case Red and NIR bands were considered for the analysis by following the next steps: i) creation of a multispectral difference image: by using Red and NIR bands; ii) extraction of magnitude and direction variables: polar domain was considered in this case to improve visual inspection of changes; iii) thresholding selection for both magnitude and direction: the selection is performed automatically, by considering Otsu; and iv) creation of final windthrows map according to the selected thresholds.

## 4. RESULTS AND CONCLUSIONS

Table 1 and Figure 2 show the results obtained after applying the proposed approaches over the different satellite data. As it can be seen, the performances vary firstly according to the season of data acquisition. Data acquired near the event (autumn-winter) has worst performances compared to data acquired in optimal condition (summer-summer). Data acquired in summer before and after the event indeed are not subject to phenological changes that happen between autumn

Table 1. Comparison results from the three satellites considering different season conditions: Overall Accuracy (OA), Producer Accuracy (PA), User Accuracy (UA), True Positive (TP), True Negative (TN), False Positive (FP) and False Negative (FN).

| **Satellite** | **Season** | | **OA (%)** | **PAs (%)** | | **UAs (%)** | | **TP (%)** | **TN (%)** | **FP (%)** | **FN (%)** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **T1** | **T2** | | **NW** | **W** | **NW** | **W** | | | | |
| CSK | Summer | Summer | 89.9 | 94.8 | 55.5 | 93.7 | 60.6 | 6.9 | 83 | 4.5 | 5.6 |
| | Autumn | Winter | 64.7 | 63.9 | 70.6 | 93.8 | 21.8 | 8.8 | 55.9 | 31.6 | 3.7 |
| PS | Summer | Summer | 94.4 | 96 | 83.4 | 97.6 | 74.7 | 10.4 | 83.9 | 3.5 | 2.1 |
| | Autumn | Winter | 67.5 | 69.2 | 56 | 91.7 | 20.6 | 7 | 60.5 | 26.9 | 5.5 |
| S2 | Summer | Summer | 94.3 | 96.2 | 80.6 | 97.2 | 75.3 | 10.1 | 84.2 | 3.3 | 2.4 |
| | Autumn | Winter | 72.7 | 74.2 | 62.3 | 93.2 | 25.7 | 7.8 | 64.9 | 22.5 | 4.7 |

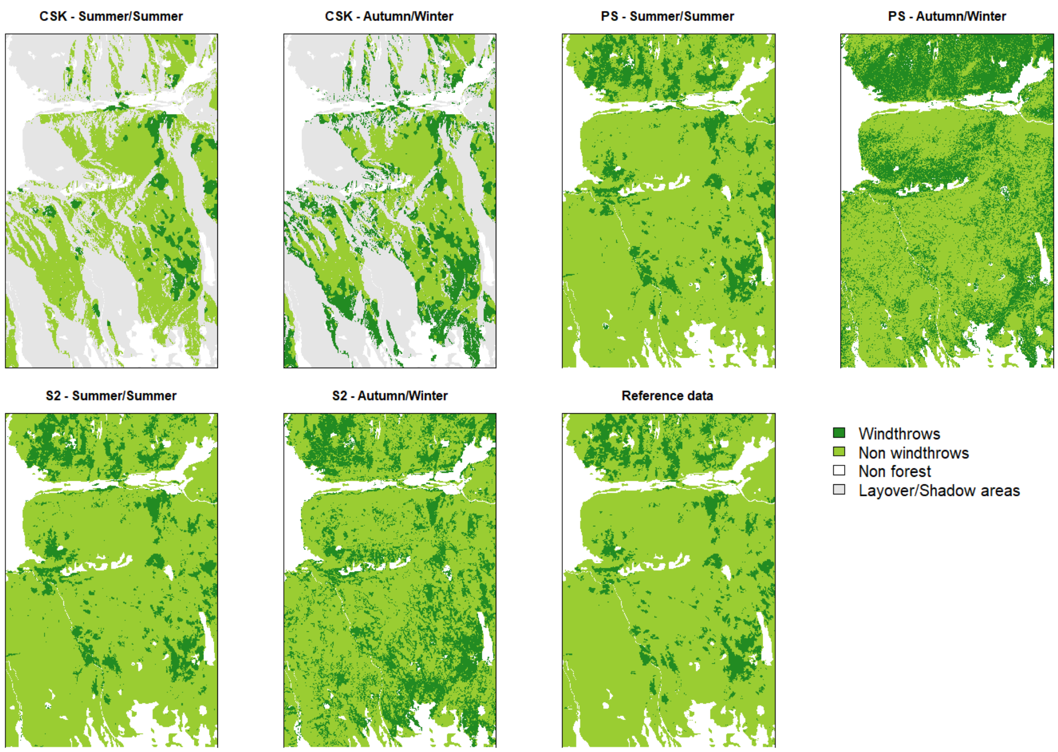


Figure 2. Windthrows detection maps on study area for the three satellites: CSK, S2 and PS and the two seasons considered.

and winter, and, they are not affected by other changes on the ground like the presence of snow in winter. Among the three data sources, PS seems to provide the best results while CSK the worst ones, even if still very good for the case summer-summer. The main limitation of CSK data is that many areas could not be mapped due to the presence of shadow and layover areas (see Figure 2) as the study area selected is mountainous. This is an important factor that should be kept into consideration when using SAR data in this context.

A comparison of windthrows detection for an area in Italy with both passive and active sensors has been presented. Given the nature of the data, two different approaches have been considered, showing better results for PS data (3m) and worst one for CSK. As future works, it would be interesting to consider data from Sentinel-1 for comparison.

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