RAPID ASSESSMENT OF WINDTHROWS USING SENTINEL-1 C-BAND SAR DATA

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Introduction

- After a storm event, immediate clearing up of the windthrown trees with limited resources is required to reduce additional economical loss through[1]
  - fungal infestation of the trunks
  - bark beetle dispersal
- Extreme storms occur on a regular basis in central Europe and their frequency is expected to increase in the future due to climate change
- Demand for a cost-efficient and rapid method to assess windthrow after a storm event across a wide region
- Synthetic aperture radar (SAR) is sensitive on vegetation structure and offers reliable and consistent images of the earth's surface since its acquisitions are independent on cloud cover and daylight[2]

- Objective: Analysis of the differences in SAR backscatter from windthrown vs. intact forest areas with the aim to develop a method for an automatic extraction of the locations of windthrows with a minimum size of 0.5 ha in an affected region
- Two independent study areas with different storm events in central Europe, both consisting of mixed temperate forests: Swiss study area (8 km^2, mainly Norway spruce & European beech), German study area (125 km^2, mainly European beech, European oak & Scots pine)

Methods

- Sentinel-1 (S-1) C-band SAR data processing
  - Radiometric terrain correction of acquisitions of both polarisations VV and VH[3]
  - Temporal compositing (LRW) of images within specific time periods for before (t1) and after (t2) the storm event[4]

- Pixelwise image differencing-based windthrow index (WI) to detect large differences in backscatter that indicate windthrow:

$$\mathrm{WI} = \left(\gamma^0_{\mathrm{LRW,VV,t2}} - \gamma^0_{\mathrm{LRW,VV,t1}}\right) + \left(\gamma^0_{\mathrm{LRW,VH,t2}} - \gamma^0_{\mathrm{LRW,VH,t1}}\right)$$

- Decision tree (Fig. 1) that includes two user-defined parameters to extract the windthrown areas within the forest mask (Fig. 2)
  - **a**: Magnitude of difference
  - **n**: Minimum count of associated candidate pixels

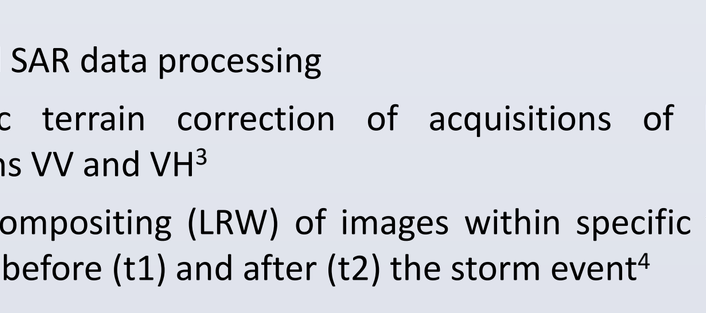

Fig. 1: Applied decision tree to obtain the windthrown areas from the windthrow index (WI). $\bar{\mathbf{x}}$ corresponds to the observed WI mean within the forest mask.

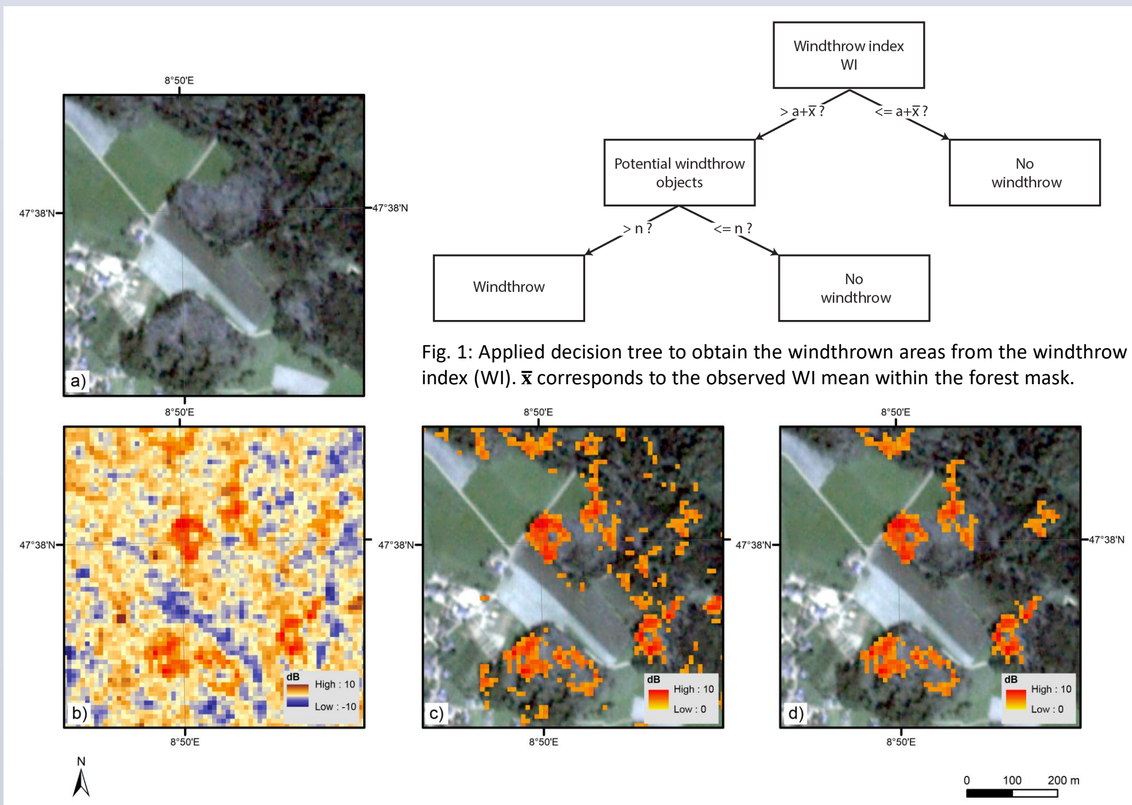

Fig. 2: Example of the functionality of the windthrow detection method. a) True colour Planet image of the region with the windthrown areas in grey values and b) windthrow index (WI) of the region in dB. In c) the result after the first branch in the decision tree with all potential windthrown areas in the forest. The final result in d), after the application of the minimum count (**n**) threshold. Only larger objects remain, leading to a more realistic representation of the windthrow in the forest.

Results

- Training of method in **Swiss** study area, with best parameter combination (Fig. 3) achieving producer's (PA) and user's (UA) accuracies of **0.85** and **0.65**, respectively

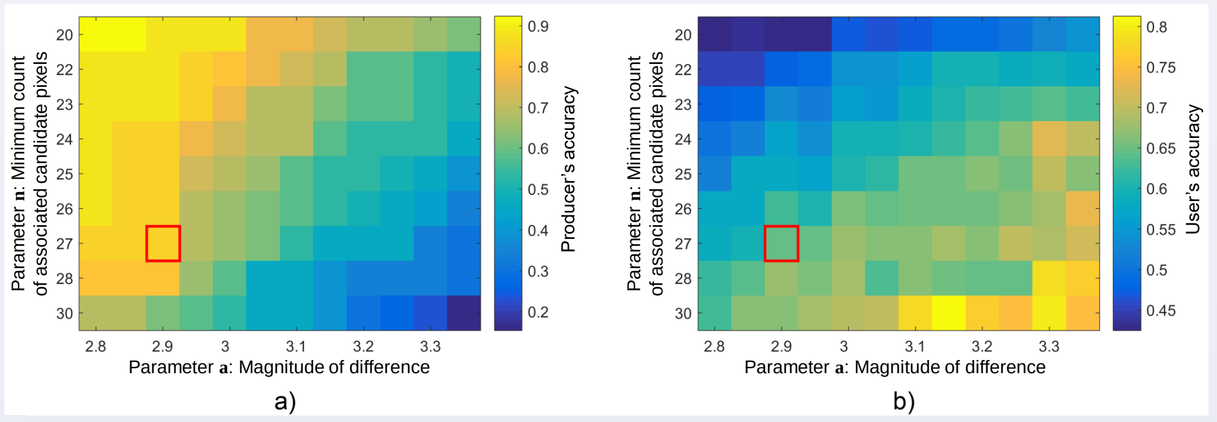

Fig. 3: Matrices of the performance measures a) producer's accuracy (PA) and b) user's accuracy (UA) for different combinations of the parameters **a** and **n** in the Swiss study area. Higher PAs were reached for lower **a** and **n**, higher UAs for higher **a** and **n**. The red rectangles indicate the chosen parameter combination.

- Validation of method in independent **German** study area. Same parameter combination, but evaluated for three different windthrow classes as more detailed independent reference was available
  - Areal windthrow (>90% windthrown trees): PA of **0.88** and UA of 0.21
  - Single standing trees (51-90% windthrown trees): PA of **0.29** and UA of 0.15
  - Single windthrown trees (<51% windthrown trees): PA of **0.48** and UA of 0.07
  - UA of general windthrow (all classes combined): **0.85**

- Analysis of the required number of S-1 acquisitions indicated that a minimum of **5** including ascending and descending ones were needed for a satisfactory quality (>0.7) of the windthrow map (Fig. 4)

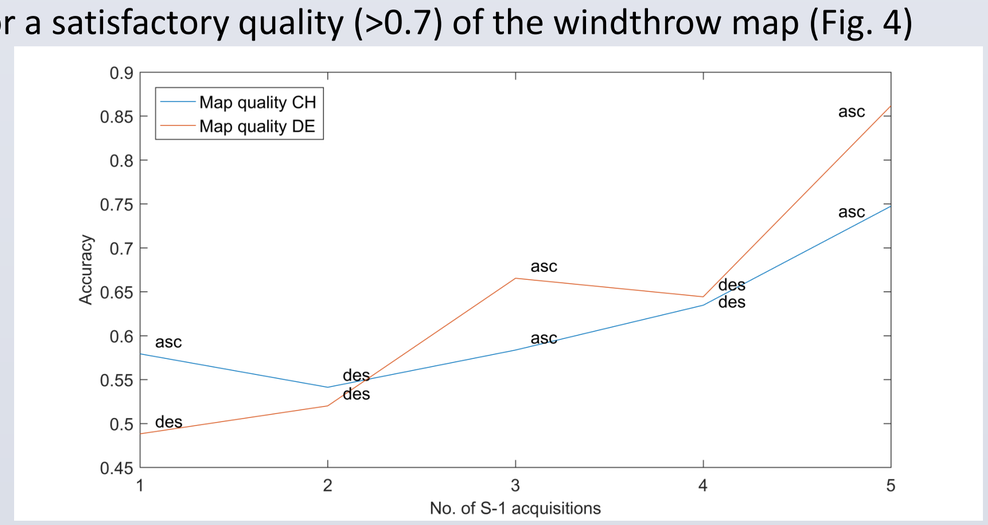

Fig. 4: Influence of the number of Sentinel-1 (S-1) acquisitions used in temporal compositing (LRW) for the windthrow map generation. The number of S-1 acquisitions after the storm event was gradually reduced from all five to just the first after the event for both study areas. The displayed map quality corresponds to the mean of producer's (PA) and user's accuracy (UA) for each map. 'asc' and 'des' indicate the additional acquisition's pass direction ascending and descending, respectively.

Discussion & Conclusion

- Structural differences in the windthrown areas after the storm event lead to changing C-band backscatter. Hence, it was possible to detect windthrow using **freely available** S-1 SAR data.
- The method showed great potential to detect areal windthrow, but areas with single scattered windthrown trees were not detected.
- The windthrow map indicates the location of windthrows with a minimum size of **0.5 ha** but not their areal extent. The extent was underestimated by a factor of **~0.5** in all cases in both study areas.
- As 5 acquisitions including both pass directions were required for a satisfactory detection performance, a detection map could be generated **within two weeks** for affected regions in Europe or regions with similar acquisition frequency.

References:
1. Schwarz, M.; Steinmeier, C.; Holecz, F.; Stebler, O.; Wagner, H. Detection of Windthrow in Mountainous Regions with Different Remote Sensing Data and Classification Methods. *Scand. J. For. Res.* 2003, *18*, 525–536.
2. Rüetschi, M.; Schaepman, M. E.; Small, D. Using multitemporal Sentinel-1 C-band backscatter to monitor phenology and classify deciduous and coniferous forests in northern Switzerland. *Remote Sens.* 2018, *10*, 55.
3. Small, D. Flattening Gamma: Radiometric terrain correction for SAR imagery. *IEEE Trans. Geosci. Remote Sens.* 2011, *49*, 3081–3093.
4. Small, D. SAR backscatter multitemporal compositing via local resolution weighting. In *International Geoscience and Remote Sensing Symposium (IGARSS)*; IEEE: Munich, Germany, 2012; pp. 4521–4524.