IMPACT OF HAIL EVENTS ON AGRICULTURE: A REMOTE SENSING-BASED ANALYSIS OF HAIL DAMAGE IN THE CONTEXT OF CLIMATE CHANGE

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(1) Introduction

In the project HAGL ("Impact of hail events on agriculture: A remote sensing-based analysis of hail damage in the context of climate change"), we analyse the effects of hail damage on agriculture. In the context of climate change and the associated increased risk of extreme weather events to society and the economy, this project deals with a locally catastrophic natural hazard that causes high costs, namely, hail. The influence of climate change on local weather patterns (e.g. thunderstorms) is still relatively unexplored, but evidence points to an increase in weather patterns causing hail and an increase in hailstone sizes. With this in mind, the significance of (semi)-automated methods for assessing hail damage becomes evident.

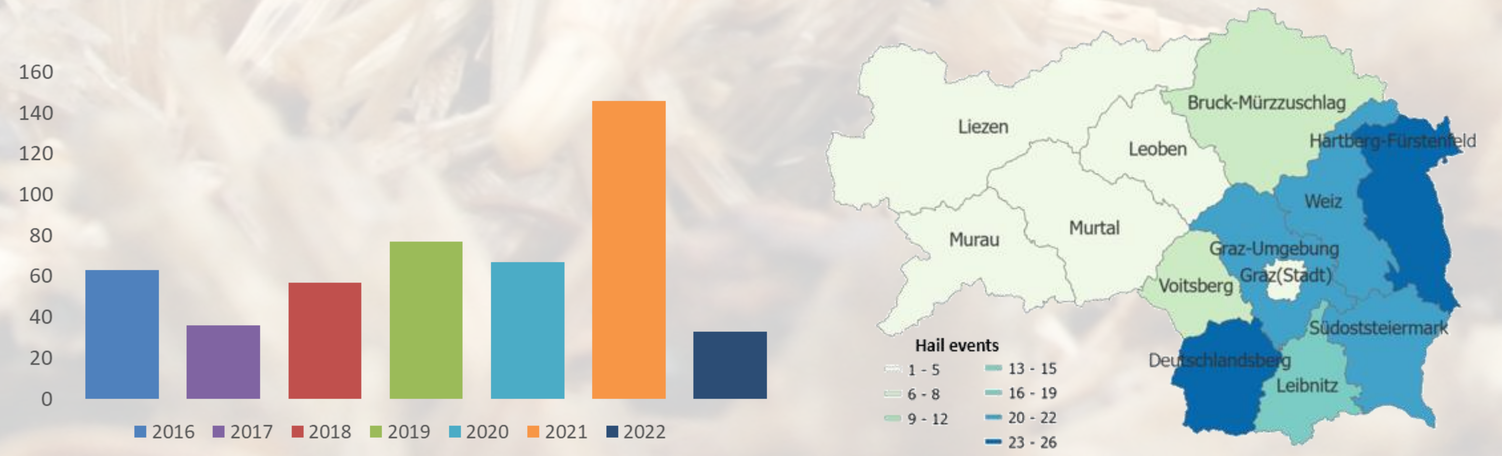
(2) Motivation and Objectives

Hail, combined with severe storms, causes millions of Euros of damage to agriculture in Austria every year. We aim to develop an efficient method to determine the damage to agriculture caused by hail using optical and synthetic aperture radar (SAR) remote sensing data.

Examples of hail damage to various crops in Styria, Austria: a) lettuce; b) and c) oil pumpkin; d) and e) maize; f) soya. Photos: © Austrian Hail Insurance

(3) Study Area & Data

In Austria, especially southeastern Styria with its various crops is frequently affected by extreme hail events. Yield losses due to hail damage can be existence-threatening for farmers, which is why an effective damage assessment is of great interest.

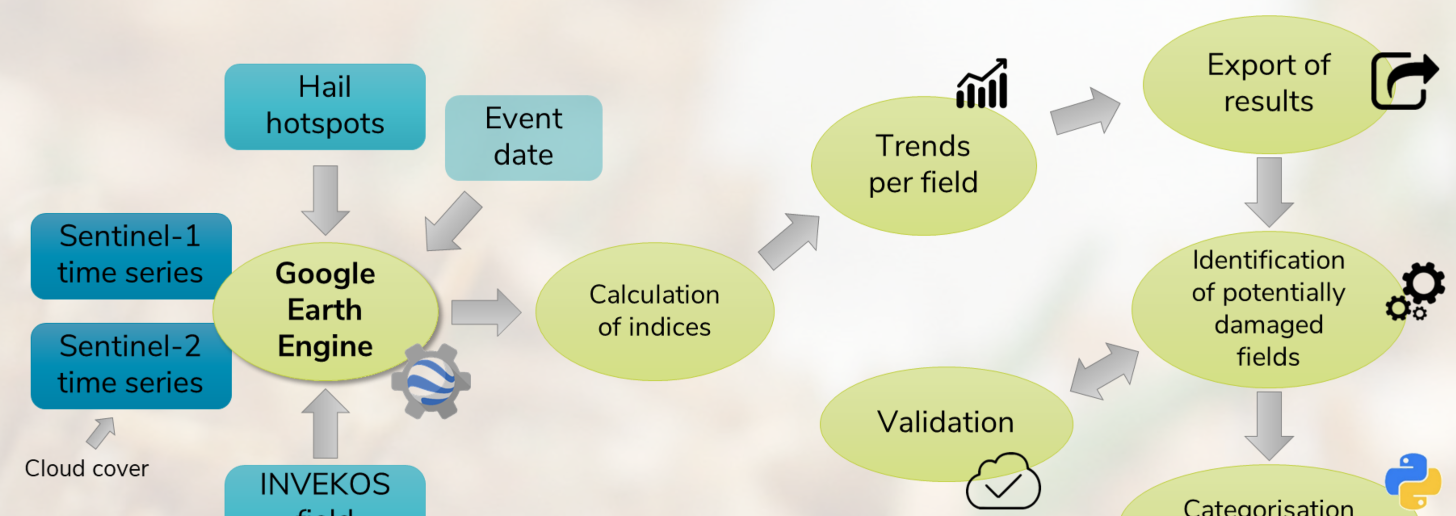


Number of hail events in Styria (left); Hail events per district since 2016 (right)

Data for hail events were collected from different sources: GeoSphere/ZAMG, European Severe Weather Database (ESWD), Austrian Hail Insurance, etc. Additionally, the INVEKOS („Integriertes Verwaltungs- und Kontrollsystem") field delineations were used. For the analysis of hail damage, we used freely available Sentinel-1 and Sentinel-2 satellite data (cf. Sarvia et al., 2020; Sosa et al., 2021) from the European Union's Earth Observation Programme, Copernicus.

(4) Methods

Through a spatial hotspot analysis, we identify regions in southeastern Styria that are particularly affected by hailstorms to test and validate our method. We perform a combined analysis of Sentinel-2 optical and Sentinel-1 SAR data using object-based image analysis (OBIA) methods and different vegetation indices derived from the multispectral data as well as radar backscatter signals to detect hail damage. Finally, we aim to create a damage categorisation that could support insurance work in the event of a disaster and make it more efficient by providing a first estimation of the damage before an onside assessment is conducted.



Workflow for the detection of potential hail damage

Indices – Plant health	Description
Normalized Difference Vegetation Index (NDVI)	Indicator for plant health and density
Green Normalized Difference Vegetation Index (GNDVI)	Indicator for photosynthesis activity
Modified Soil-Adjusted Vegetation Index (MSAVI2)	Indicator for plant health and density at the beginning of the phenology
Soil-Adjusted Vegetation Index (SAVI)	Soil-adjusted NDVI
Plant Senescence Radiation Index (PSRI)	Indicator for the aging process of leafs and seedlings
Enhanced Vegetation Index (EVI)	Indicator for canopy area and canopy density
Advanced Vegetation Index (AVI)	Indicator for changes in the plant health
Atmospherically Resistant Vegetation Index (ARVI)	Atmospherically corrected AVI
Leaf Area Index (LAI)	Indicator for leaf area
Modified Chlorophyll Absorption Ratio Index (MCARI)	Indicator for chlorophyll content

Indices for plant health calculated based on Sentinel- 2

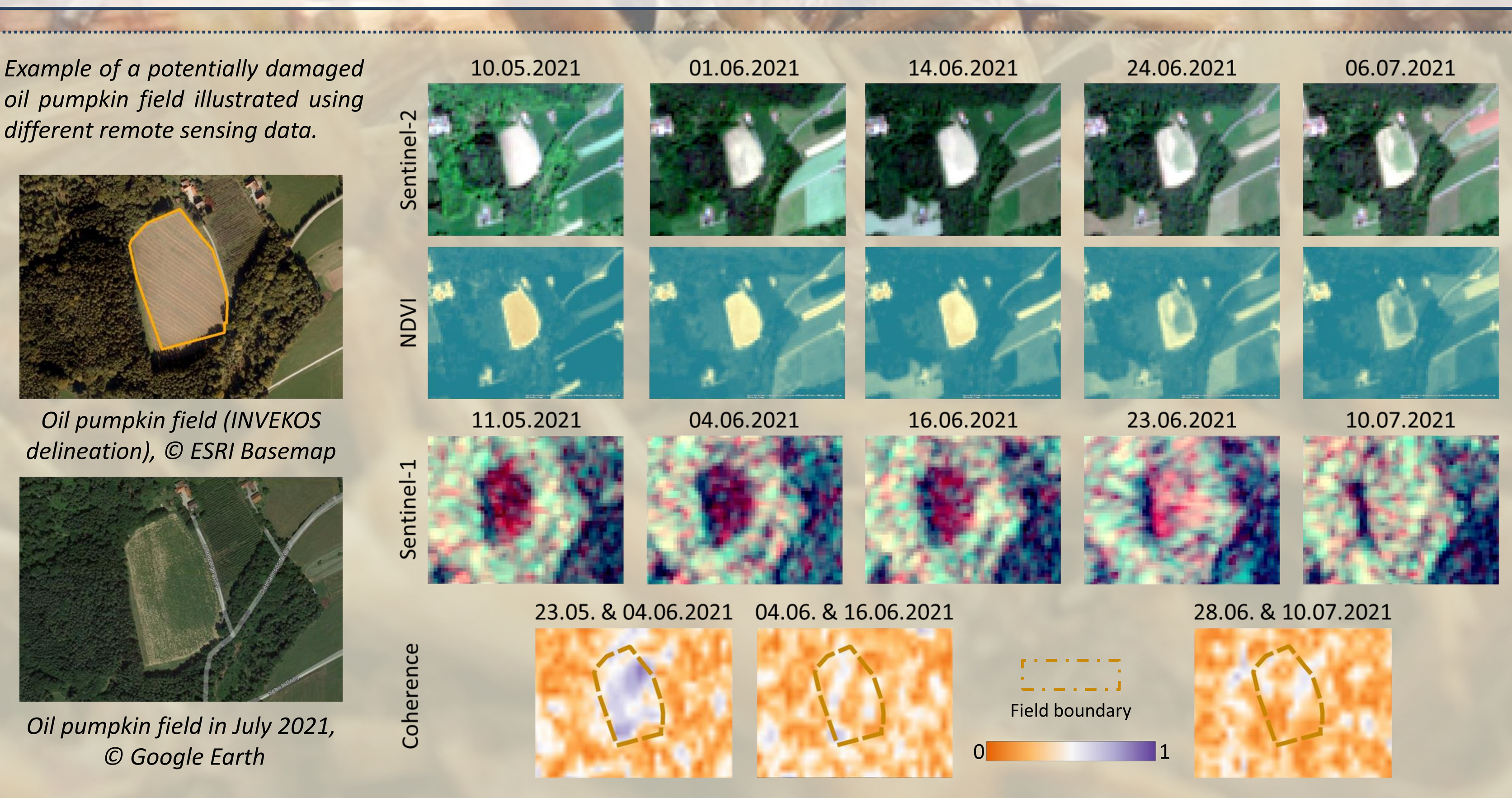
Indices – Water content	Description
Moisture Stress Index (MSI)	Water content of leaves
Normalized Difference Water Index (NDWI)	Indicator for water content in plants and soil

Indices for water content calculated based on Sentinel- 2

Indices – Phenology/ Biomass	Description
Dual-Pol Diagonal Distance (DPDD)	Indicator for biomass
Vertical Dual Depolarization Index (VDDPI)	Quantification of biomass
Radar Vegetation Index (RVI)	Indicator for phenology stages
Radar Vegetation Index for Sentinel-1 (RVI4S1)	Indicator for biomass

Indices for phenology and biomass calculated based on Sentinel- 1

Example of a potentially damaged oil pumpkin field illustrated using different remote sensing data.



Oil pumpkin field (INVEKOS delineation), © ESRI Basemap

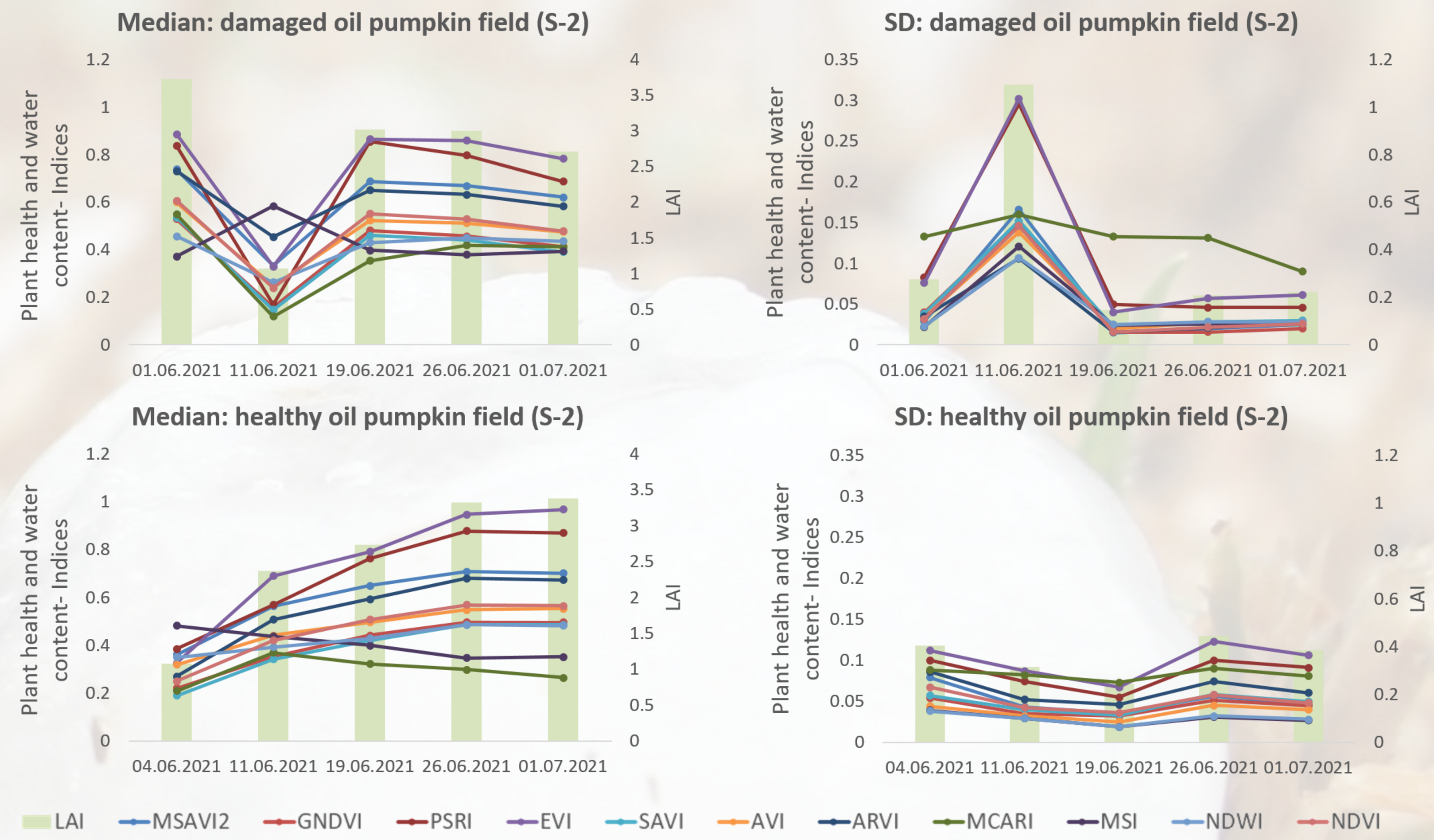
Oil pumpkin field in July 2021, © Google Earth

We calculated the interferometric coherence using (a) pre- and pre-event images, (b) pre- and post-event images, and (c) post- and post-event images. For agriculture crops, the loss in coherency (closer to 0) can be an indicator of the fast growth of crops or wind-induced movements, which cause temporal decorrelation. A higher coherence (close to 1) indicates no significant change between the two images.

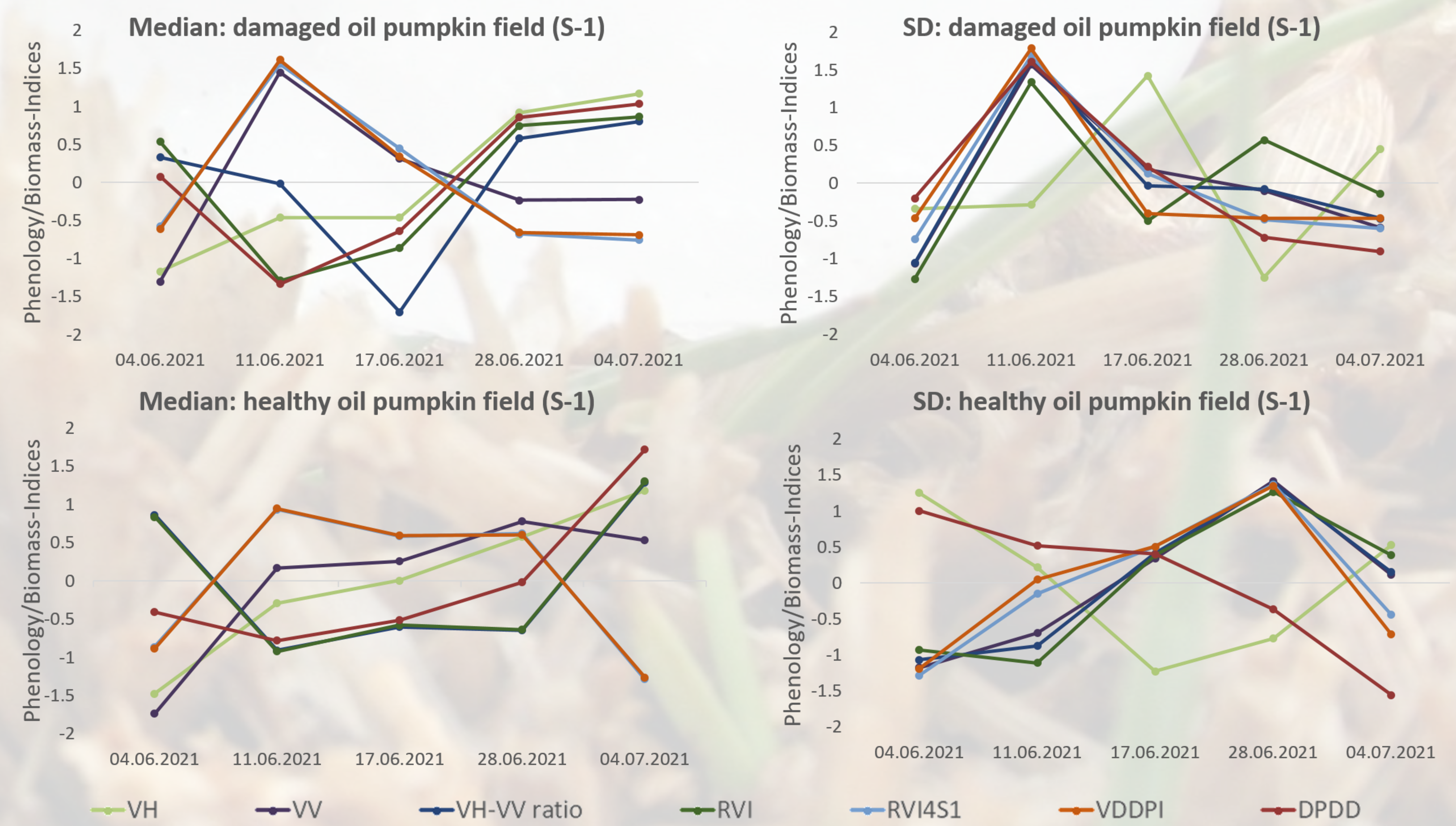
(5) Results & Discussion

Exemplary results of the time series analysis for the tested indices (median and standard derivation (SD)) based on Sentinel-2 (top) and Sentinel-1 (bottom) are shown in the figures below. In each case, the first row shows an example of a potentially damaged oil pumpkin field, and the second row shows a healthy oil pumpkin field. For the validation of our results, we will perform fieldwork in Styria and collect feedback from the Austrian Hail Insurance.

Sentinel-2



Sentinel-1



(6) Conclusion

The automated hail damage detection workflow can be transferred to other regions. It can support the detection of hail hotspot areas and implementation of appropriate adaptation measurements. Especially for large agricultural fields, an automated assessment would save time and resources by making it possible to priorities areas with high damage and organise the fieldwork of insurance employees accordingly. However, further research is needed to reduce false positive detections that are not related to hail damage (e.g., harvesting, heterogeneous field structures, soil properties).

References

Sarvia, F., De Petris, S., Borgogno-Mondino, E., 2020. A Methodological Proposal to Support Estimation of Damages from Hailstorm Based on Copernicus Sentinel 2 Data Time Series. *Computational Science and Its Applications – ICCSA 2020. Lecture Notes in Computer Science*, vol 12252. Springer, Cham.

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