Determination of Flood Subsidy (2023/2024) Based on SAR Images for Agricultural Land in Lower Saxony, Germany

Chia-Hsiang Yang, Carsten Stemmler, Christian Röttger, Cordt Büker

EFTAS Remote Sensing Transfer of Technology, Münster, Germany - chia-hsiang.yang@eftas.com

Keywords: Flood Monitoring, SAR, Sentinel-1, Agricultural Remote Sensing, Disaster Management.

Abstract

Following the severe flood event over the 2023/2024 New Year period, the Lower Saxony Ministry of Food, Agriculture, and Consumer Protection initiated a flood subsidy program for agricultural businesses. To evaluate the extent and duration of flooding across approximately 10,000 parcels, manual assessment was impractical. EFTAS leveraged Synthetic Aperture Radar (SAR) data, primarily from Sentinel-1, to develop a semi-automated process for detecting and quantifying flood coverage over multiple time points. The workflow is designed to integrate modules from SNAP and custom algorithms on a cloud-computing platform, generating backscatter coefficients to distinguish flooded and non-flooded areas. A GIS-based decision tree further refined the results by excluding permanent water bodies. Our project covers an area of 47,618 km^2, utilizing 45 Sentinel-1 image packages, with observations every 3–5 days. The image quality was enhanced through adaptive non-local filtering. The results included precise flood extents, exemplified by dynamic changes near Lake Dümmer. The additional datasets, such as Sentinel-2 imagery and local photos, validated our flood evaluations. Our operational workflow demonstrates the adaptability of SAR for diverse applications, from post-event flood evaluation to near real-time emergency response. Future improvements include incorporating high-resolution imagery for urban assessments and leveraging rapid-revisit SAR constellations like Capella and ICEYE. This project underscores the cost-effectiveness and reliability of SAR-based flood detection, aiding decision-makers in subsidy allocation while paving the way for broader applications in disaster management.

1. Introduction

Following the severe flood event over the 2023/2024 New Year period, the Lower Saxony Ministry of Food, Agriculture, and Consumer Protection introduced a flood subsidy program for agricultural businesses. Farmers can apply for the subsidy, which will be allocated based on the extent and duration of flooding affecting their lands. Given that approximately 10,000 parcels of land require assessment, a manual investigation is impractical, especially considering the lack of timely and reliable evidence, such as airborne imagery captured immediately after the heavy rain and flooding. To address this challenge, the Lower Saxony Ministry of Food, Agriculture and Consumer Protection commissioned EFTAS to evaluate the flooding impact for each request using SAR remote sensing techniques. This evaluation analysed the data from multiple time points during the flood period to check the presence and duration of water coverage on the affected parcels.

SAR plays the major role in our flood monitoring scheme for two reasons. First, an active imaging SAR is independent from illumination and slightly disturbed by the weather. Second, the approaches for flood detection have been long refined and standardized in national and international institutes (Martinis et al., 2015; Serpico et al., 2012), e.g., Copernicus Emergency Management Service (https://emergency.copernicus.eu/). Many automatic or semi-automatic approaches (Martinis, 2010; Matgen et al., 2011) have been applied to this purpose. Among them, three widely used methodologies are thresholding, change detection, and classification. From our point of view, these approaches undoubtedly suffice flood detection if qualified experts are involved.

This paper outlines our approaches and results from a practical perspective for a commercial project. Our goal is not only to meet contractual requirements but also to ensure cost-effectiveness. The free Sentinel-1 data are utilized to detect the flood areas over multiple time points. Each region of interest under investigation could be observed repeatedly in 3 to 5 days. Additional data sources, such as Sentinel-2 imagery and local photographs, are employed for cross-comparison and validation. Leveraging open-source tools, we have developed a semi-automated evaluation process, minimizing manual efforts while maintaining reliability and efficiency.

2. Methodology

Our standard flowchart for flood detection is illustrated in Figure 1. This process is fully automated by integrating modules from SNAP (Sentinel Application Platform) and deploying our custom algorithms on a cloud-computing platform. All SAR images relevant to the investigation, based on the flood's temporal and spatial scope, are downloaded and pre-processed. The subsequent SAR processing generates backscattering coefficients, including beta, sigma, and gamma, following established methodologies (Schreier, 1993). These coefficients quantify the radar signal intensity reflected from the ground back to the SAR antenna. Typically, radar signals reflected from flooded areas exhibit significantly weaker intensities due to mirror-like reflections, in contrast to signals from non-water surfaces (Martinis et al., 2015). For each parcel of land registered for subsidy evaluation, the flood coverage is determined by applying a threshold to the backscattering coefficients for all SAR images captured at different dates during the flood period. The threshold is set after analysing statistical the differences in backscatter behaviour between water and non-water surfaces. A GIS-based decision tree is implemented to narrow down and refine the flood coverage. For example, this step excludes existing water bodies such as rivers and reservoirs, which are not considered part of the flood. The flood-covered proportion is then converted into the corresponding land area size (m^2) for subsidy evaluation. A final report for a parcel would state: Flood coverage is 80%, 60%, 100%, and 10% at four time points during the flood period. Please note that the ultimate decision regarding subsidy allocation rests with the Lower Saxony Ministry of Food, Agriculture, and Consumer Protection, as determined by applicable laws and policies. Our role is to provide accurate and reliable analyses to support the decision-making process.

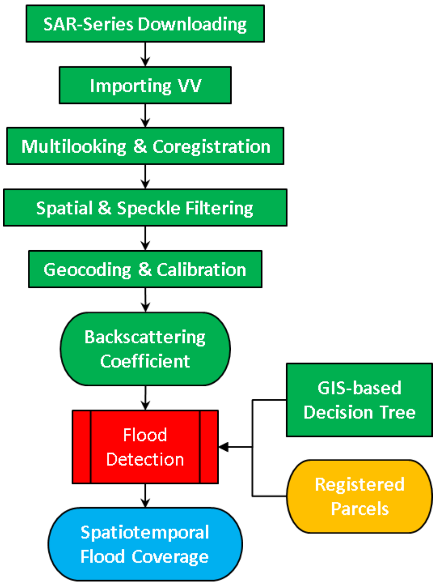

Figure 1. Flowchart of flood detection using SAR images.

Additionally, the farmer-submitted imagery was incorporated to fine-tune the classification threshold, ensuring consistency between on-site observations and SAR-derived flood assessments. It is important to note that not all water-affected areas exhibit visible surface water, yet they can still severely impact crop growth. Both subsurface saturation and waterlogging effects were considered in our classification to account for potential agricultural losses beyond visibly flooded regions.

3. Results

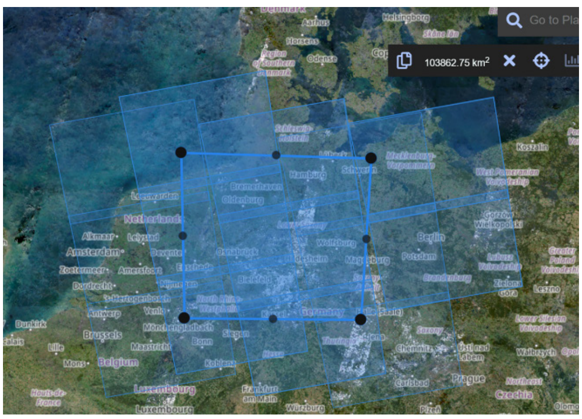

Figure 2. Coverage of Sentinel-1 scenes across Lower Saxony of 47,618 km^2 (© Copernicus Program).

Our contracted Area of Interest (AOI) encompasses the entire state of Lower Saxony, covering approximately 47,618 km^2 (Figure 2). The analysis focuses on the flood events in January 2024. SARscape was first used to test our SAR processing. We utilized a total of 45 Sentinel-1 image packages, including two ascending and two descending orbit passes. Typically, the parcels were observed every 3 to 5 days. The VV-polarized radar data were calibrated into Gamma at a ground resolution of 15 m × 15 m. To enhance the data quality, we applied an adaptive non-local SAR filtering (Deledalle et al., 2009) to reduce speckle and noise.

An illustrative example of our analysis highlights the flood coverage (depicted as dark areas) around Lake Dümmer on January 6, 2024 (Figure 3). The water overflow from a canal created a distinct flood boundary on the western side. Five days later, as shown in Figure 4, the floodwaters receded, leaving muddy areas on the periphery (indicated as grey regions).

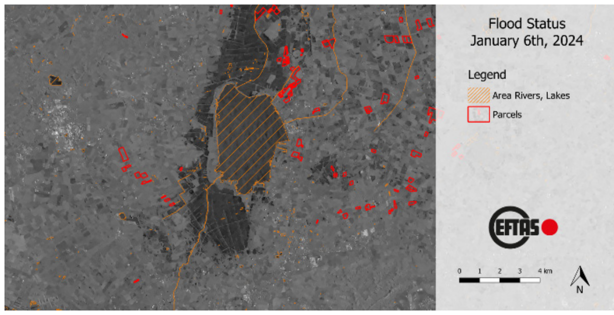

Figure 3. Flood status, revealed by Sentinel-1 VV Gamma, around Lake Dümmer on January 6th, 2024. All water surfaces, including lake, river, and flood, appear dark. Lake and river (orange region) are excluded from flood. Red regions, parcels under investigation.

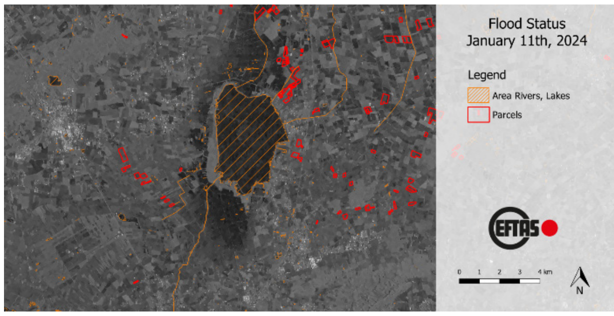

Figure 4. Flood status, revealed by Sentinel-1 VV Gamma, around Lake Dümmer on January 11th, 2024. All water surfaces, including lake, river, and flood, appear dark. Lake and river (orange region) are excluded from flood. Red regions, parcels under investigation.

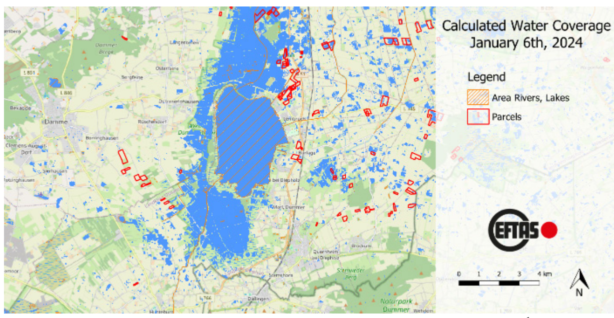

Figure 5. Flood around Lake Dümmer on January 6th, 2024 is indicated by blue areas (all water surfaces) without orange covers (lake and river). Red regions, parcels under investigation.

Our deliverables to the customer include a shapefile indicating the flood coverage (in m^2) for each parcel across different dates, as well as raster-based flood maps (Figure 5). A detailed example of a parcel is shown in Figure 6, along with the associated shapefile properties. The attributes hw_0101, hw_0111, hw_0121, and hw_0131 represent the flood status on January 1th (Figure 7), January 11th (Figure 8), January 21th (Figure 9), and January 31th (Figure 10), 2024, respectively. These attributes provide the flooded area in m^2; for example, a value of 6027 indicates 6027 m^2 of flooding. By January 31th, the floodwaters had receded entirely, i.e., hw_0131 is 0. This information is crucial for subsidy allocation, as claims for flood-affected land near the end of January, if submitted, will be carefully reviewed and cross-validated with additional data sources. In this example, a photo submitted by the farmer (Figure 11) shows a partially flooded area, which corresponds well with the SAR-derived flood coverage. This cross-validation highlights the reliability of the SAR imagery in assessing flood extent and supporting accurate subsidy decisions. Another example (from Figure 12 to Figure 17) shows the land was covered by flood for the whole January in 2025.

Figure 6. Parcel along with attributes for delivery.

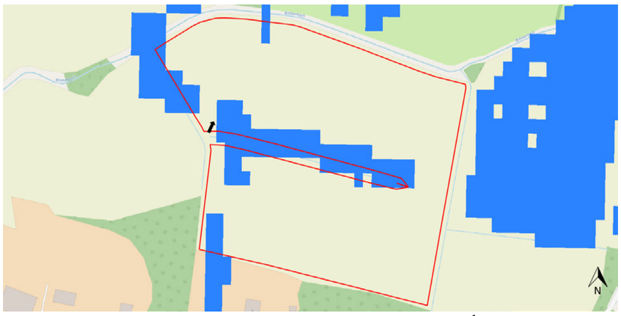

Figure 7. Flood status hw_0101 on January 1th within parcel (red). Blue within parcel, detected flood.

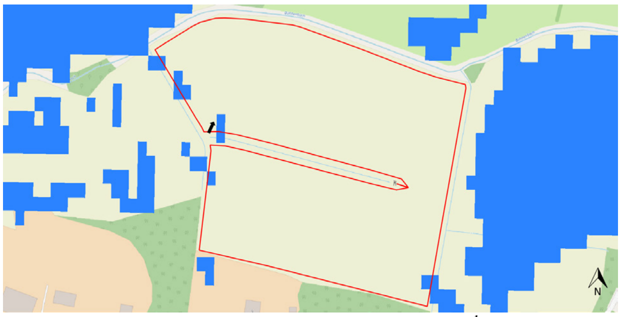

Figure 8. Flood status hw_0111 on January 11th within parcel (red). Blue within parcel, detected flood.

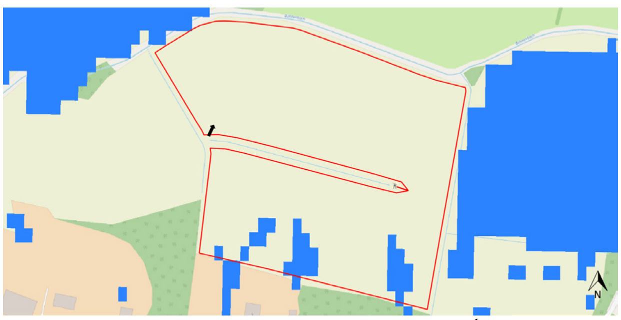

Figure 9. Flood status hw_0121 on January 21th within parcel (red). Blue within parcel, detected flood.

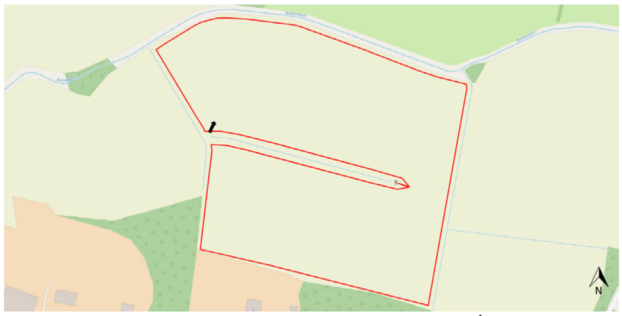

Figure 10. Flood status hw_0131 on January 31th within parcel (red). Blue within parcel, detected flood.

Figure 11. Photo of flood submitted in January 2025 by farmer as supplementary along with request. The orientation of taking photo is aligned with the black arrows from Figure 7 to Figure 10.

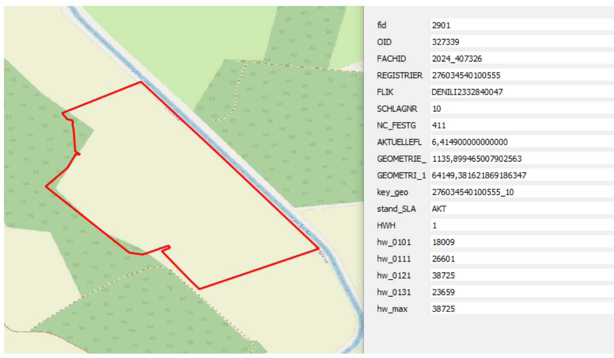

Figure 12. Parcel along with attributes for delivery.

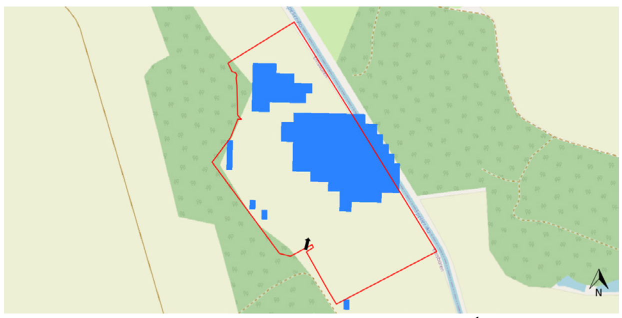

Figure 13. Flood status hw_0101 on January 1th within parcel (red). Blue within parcel, detected flood.

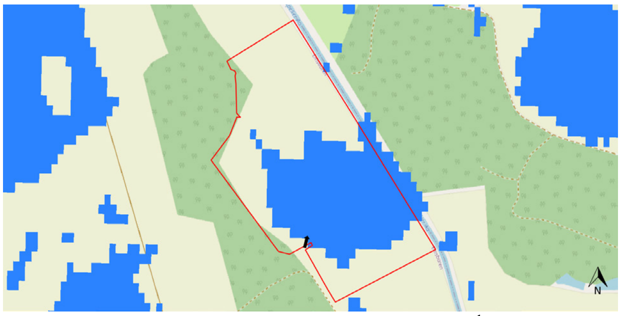

Figure 14. Flood status hw_0111 on January 11th within parcel (red). Blue within parcel, detected flood.

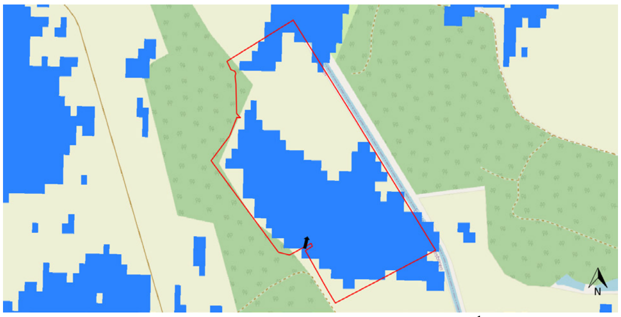

Figure 15. Flood status hw_0121 on January 21th within parcel (red). Blue within parcel, detected flood.

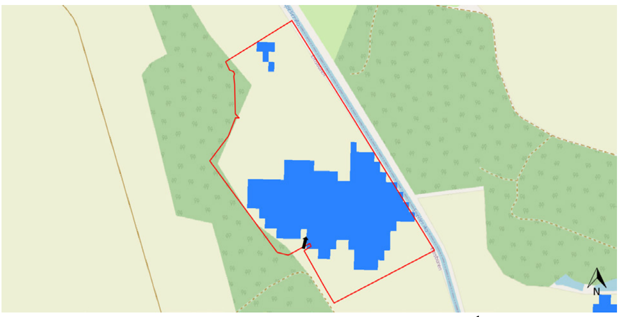

Figure 16. Flood status hw_0131 on January 31th within parcel (red). Blue within parcel, detected flood.


Figure 17. Photo of flood submitted in January 2025 by farmer as supplementary along with request. The orientation of taking photo is aligned with the black arrows from Figure 13 to Figure 16.

4. Summary and Outlook

This paper presents a practical case study of flood detection for evaluating subsidy claims from agricultural businesses following the 2023/2024 New Year flood event. The farmer requests were systematically assessed using spaceborne SAR imagery and supplementary resources, such as locally captured photographs. The free Sentinel-1 data formed the foundation of the detection process, with a classical thresholding method employed to identify water bodies. A GIS-based decision tree further refined the analysis, delineating flood areas and excluding permanent water bodies. The methodology ensures alignment with customer requirements, particularly regarding policy and legal frameworks. This project highlights the effectiveness of leveraging free SAR data for cost-efficient and reliable flood detection, demonstrating its potential for broader applications in disaster management and subsidy allocation.

Our SAR-based flood detection service is operational for a wide range of applications, supported by existing and upcoming SAR satellite missions, such as Tandem-L, ROSE-L, Sentinel-1C, Capella, and ICEYE. In this study, we applied a post-event flood evaluation to assist the public sector in making subsidy decisions. Our workflow is adaptable and can be adjusted as needed for specific cases. Relevant datasets, such as land use and land cover, can be incorporated into the analysis to refine results or derive meaningful features. For urban areas, high-resolution images may be required to precisely delineate flooded streets and buildings. In the case of near real-time flood detection, particularly for emergency rescue operations, collaboration with SAR constellation data providers, such as Capella and ICEYE (both of which are strategic partners of EFTAS), becomes critical. Their SAR constellations offer rapid revisit capabilities, with observation intervals reaching the hourly level and continuing to improve as additional compact satellites join their networks.

5. Acknowledgement

We thanks the Lower Saxony Ministry of Food, Agriculture, and Consumer Protection for their trust and support in the project. The Sentinel-1 data we used are provided by Copernicus Program.

References

Deledalle, C.A., Denis, L., Tupin, F., 2009. Iterative weighted maximum likelihood denoising with probabilistic patch-based weights. *IEEE Trans. Image Process.*, 18(12), 2661–2672.

Martinis, S., 2010. Automatic near real-time flood detection in high resolution X-band synthetic aperture radar satellite data using context-based classification on irregular graphs. Ph.D. Thesis, Ludwig Maximilian University of Munich.

Martinis, S., Kersten, J., Twele, A., 2015. A fully automated TerraSAR-X based flood service. *ISPRS J. Photogramm. Remote Sens.*, 104, 203–212.

Matgen, P., Hostache, R., Schumann, G., Pfister, L., Hoffmann, L., Savenije, H.H.G., 2011. Towards an automated SAR-based flood monitoring system: Lessons learned from two case studies. *Phys. Chem. Earth*, Parts A/B/C, 36(7–8), 241–252.

Schreier, G., 1993. SAR Geocoding : Data and Systems. Wichmann, Karlsruhe, Germany.

Serpico, S.B., Dellepiane, S., Boni, G., Moser, G., Angiati, E., Rudari, R., 2012. Information extraction from remote sensing images for flood monitoring and damage evaluation. *Proc. IEEE*, 100(10), 2946–2970.