

ANALYSIS OF CHANGES IN SELECTED CHARACTERISTICS OF SAR DATA DEPENDING ON DAMAGE TO AGRICULTURAL LAND

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Monitoring anthropogenic and natural damage to agricultural and uncultivated land using optical satellites is often hindered by cloud cover, which limits observation periods and as a result amount of collected data. Synthetic Aperture Radar (SAR) offers an all-weather alternative, but its application is complicated by the unique nature of damage in agricultural settings, which is often localized (e.g., karst, craters, trenches) within large, homogeneous fields [1].

The objective of the report is to analyze changes in Sentinel-1 SAR backscatter characteristics (VV and VH polarizations) to distinguish damaged from undamaged agricultural areas in the selected region of Ukraine.

The study focuses on Luhansk Oblast in eastern Ukraine (48.5°N - 49.5°N, 37.8°E - 39.5°E), a region characterized by predominantly agricultural land cover (>80%). The analysis integrates information from multiple datasets. Ground-truth information consists of 98 potential conflict event locations reported by ACLED organization [2] between March and October 2022, serving as the validation set for evaluating detection performance.

Radar observations are derived from Sentinel-1 imagery at 10 m spatial resolution in both VV and VH polarization channels. Optical reference data from Sentinel-2 L2A (10 m) is used to generate a baseline damage mask via an NDVI-based classifier, which identified 32 of the 98 examined events.

When using coarse-to-moderate resolution data (10m), the backscatter signal from this localized damage can be “spatially diluted” when averaged over a larger analysis unit (e.g., field or predefined buffer area). So, one of the central methodological challenges in this research was the problem of spatial dilution. Each ACLED event was analyzed using a 200 m radius buffer (~125000 m²), within which highly localized damage such as a cluster of shell craters totaling roughly 100-150 m² occupies less than 0.2% of the examined area. A conventional mean-aggregation workflow, which compares the mean backscatter of pre-event and post-event composites [3], proved ineffective as the damage signal was overwhelmed by the 99.9% of unaffected pixels, resulting in successful detection for only 8.2% of events. To address this, we adopt a pixel-level change-detection strategy inspired by recent optical-based methods [4]. Rather than assessing average backscatter, this approach computes per-pixel change and identifies pixels exceeding a defined damage threshold (e.g., $\Delta\sigma_{VH} < -2$ dB). Events are then classified based on the count of such high-change pixels. This reframes the problem from detecting a shift in mean backscatter to identifying the number of pixels exhibiting strong localized decreases, substantially improving sensitivity to small-area damage.

The pixel-level features demonstrated clear discriminatory power, with pixel count metrics achieving strong class separation (Cohen’s d = 0.89). Analysis of polarization channels showed that VH backscatter served as the primary indicator of

damage-related disturbance, reflecting its sensitivity to changes in volume scattering associated with structural destruction, vegetation loss, and heavy surface disruption. VV backscatter provided a complementary signal linked more strongly to alterations in surface roughness, such as soil disturbance, trenching and karst. High pixel count values in either channel (e.g., >200 VH-decrease pixels or >150 VV-decrease pixels) frequently corresponded to verified damage, indicating that the two polarizations capture distinct but reinforcing mechanisms. The SAR response also varied with damage type: strong VH decreases (>3 dB) were associated with extensive cratering, structural damage, or vehicle activity; moderate decreases (2-3 dB) aligned with trench systems or partial field disturbance. Conversely, cases dominated by vegetation loss, such as burns or crop destruction, were often detected by optical NDVI signals but produced weak SAR response, highlighting modality-specific sensitivities.

The obtained results highlight strong complementarity between SAR and optical-based damage detection. Using a 200-pixel threshold, the SAR method identified 27 events (27.6%), a rate comparable to the optical classifier (32.7%). However, overlap between the two was limited: only 15 events were jointly detected, while 12 were detected by SAR alone and 17 by optical data alone, yielding an agreement of just 34.1%. This low overlap is advantageous, indicating that each sensor captures distinct forms of damage. Combining both modalities increased the total number of unique detections from 32 (optical only) to 44, representing a 36% improvement. The 12 SAR-only detections are especially noteworthy, with 67% (8 of 12) occurring in March 2022, a period of heavy cloud cover that severely restricted optical visibility, demonstrating SAR's operational value under obstructed conditions.

Future work will aim to enhance the accuracy of the SAR-only classifier and ultimately integrate SAR and optical features within a multi-sensor fusion framework to enable more robust and comprehensive conflict damage monitoring.

References

1. Svitenko, H., & Romanenkov, Yu. (2025). Detection of damage on agricultural lands based on SAR data and machine learning. In *Information systems and innovative technologies in project and program management: Collection of proceedings of the International Scientific and Practical Conference* (pp. 254-256). (in Ukrainian).
2. The Armed Conflict Location & Event Data Project (ACLED). [Online]. Available: <https://acleddata.com/about-acledd/>.
3. Hussain, M., Chen, D., Cheng, A., Wei, H., & Stanley, D. (2013). Change detection from remotely sensed images: From pixel-based to object-based approaches. *ISPRS Journal of photogrammetry and remote sensing*, 80, 91-106. DOI: <https://doi.org/10.1016/j.isprsjprs.2013.03.006>
4. War Damage Detection Based on Satellite Data / Andrii Shelestov, Sophia Drozd, Polina Mikava, Illia Barabash, Hanna Yailymova // In *Proceedings of International Conference on Applied Innovation in IT , (ICAIIIT)*. – 2023. – Pp. 97–103. – Bibliogr.: 16 ref. DOI: <https://doi.org/10.25673/101924>.