Scientific summary

Pockmarks of conflict: Detecting makeshift oil refineries in northeast Syria using satellite remote sensing

Keywords: Geographical Information Science, Remote Sensing, Random Forest classification, oil pollution, oil refineries, industrial heat sources, environmental degradation, Syria

Following the outbreak of the Syrian civil war in 2011 and the subsequent collapse of the national oil infrastructure, small-scale, makeshift oil refineries emerged in al-Hasakah Governorate as a new form of infrastructure to ensure local access to oil products. While reports have documented these developments and their widespread negative consequences for both humans and the environment, previous investigations have been limited by a reliance on manual labelling of imagery with low and inconsistent temporal resolution, and there are no recent reports on the developments of makeshift oil refining.

To address this gap, this thesis combines satellite imagery from Sentinel-2 with household surveys to examine the spatial extent and socio-environmental impact of makeshift oil refineries across al-Hasakah. The study produces a new, recent estimate for active refineries in 2025 in comparison with 2017. This is achieved through the development of a systematic two-phase approach which combines Random Forest classification of oil-contaminated soil with the detection of specific thermal anomalies derived from Sentinel-2's 2190-nm short-wave infrared band. The classification of oil-contaminated soil achieved moderate success with F1-scores of 0.67 in 2017 and 0.47 in 2025. While limited by low user's accuracy, the high producer's accuracy points to the ability of Random Forest classification to detect oil contamination even at small scales. Detecting active refineries via the short-wave infrared band proved highly effective, and exploratory results indicate that this approach outperforms the Active Fire data product from the VIIRS sensor.

The results of the two-phase approach showed that there were 67 active refineries in 2017, which were located across six subdistricts in the northeast and south of al-Hasakah. In 2025, 17 active refineries were detected almost exclusively in al-Qahtaniyah and al-Jawadiyah subdistricts in the northeast. The survey responses both converged with and diverged from these remote sensing results. Partial convergence occurred in the refinery-heavy subdistricts of al-Qahtaniyah and al-Jawadiyah, where the majority of respondents reported specific impacts, including degradation to their soil and crops. However, other survey responses diverged by reporting negative health impacts and oil-related air pollution in subdistricts with no known or detected refineries, including in northwest and central al-Hasakah.

The thesis highlights the potential of using short-wave infrared data to detect the thermal anomalies associated with active refineries but also demonstrates the challenges of detecting small-scale oil contamination over large areas. It concludes that while satellite remote sensing can systematically detect makeshift oil refineries, the inclusion of local knowledge is necessary to fully understand the nature and scale of the conflict-driven oil pollution and its socio-environmental consequences.