

Artillery and Rocket Crater Detection with Very High Resolution Satellite Imagery

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Massive use of heavy weaponry across Ukraine



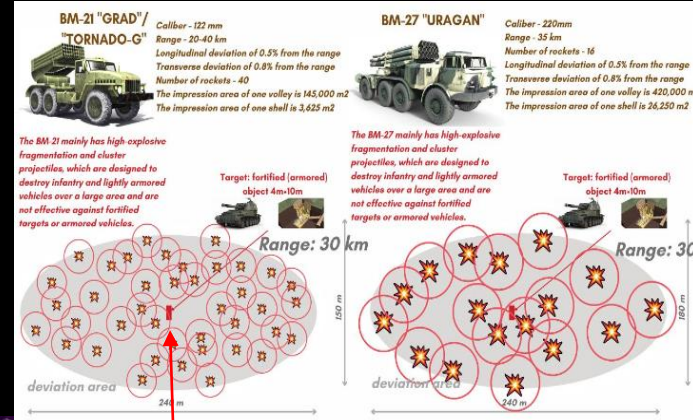
M-46 130mm field gun



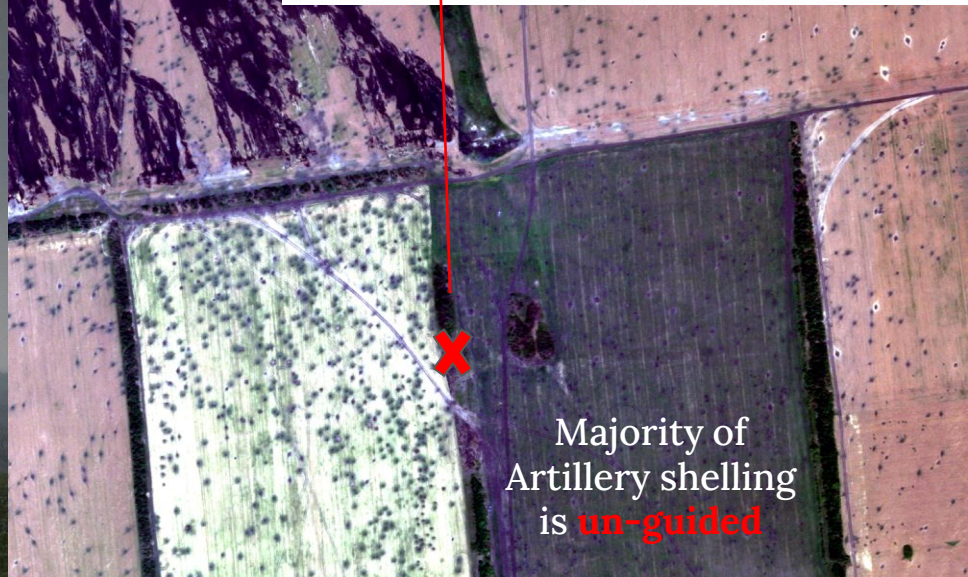
~ Using 110,000 shells per month
~ Asking for 250,000 shells per month



~ Estimated 5,000,000 shells fired
~ Up to 60,000 per day in July, 2022



BM-21 Grad



Majority of Artillery shelling is **un-guided**

- Failure Rates? – So far unknown.
- Current front lines cover over 1,000 km

The Results: UXO

-No information about fields which have not been surveyed

-no information about PRIORITY of NTS

-no information about NON-hazardous fields in hazard area



Training A Crater Detection Model, with 2014 Imagery



VHR Training
Imagery Selection

Image Preprocessing
Pipeline *



Processed Imagery

18,472 Craters Marked



Crater Locations + VHR Imagery

U-Net CNN
Crater-Detection
Model

Mapping With Trained Model



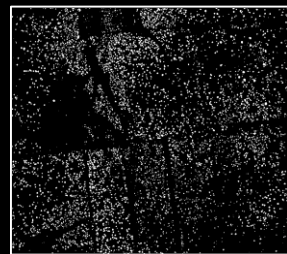
VHR Training
Imagery Selection

Image Preprocessing
Pipeline



Processed Imagery

Apply Model



Binary Detection Masks

Raster Postprocessing *







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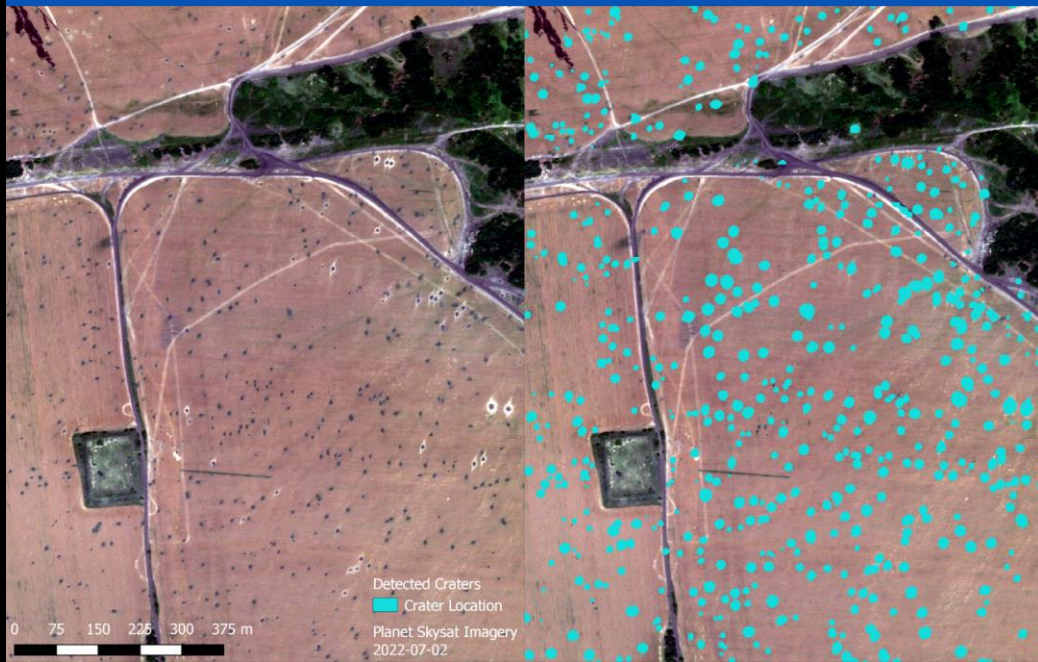


Detection and mapping of artillery craters with very high spatial resolution satellite imagery and deep learning

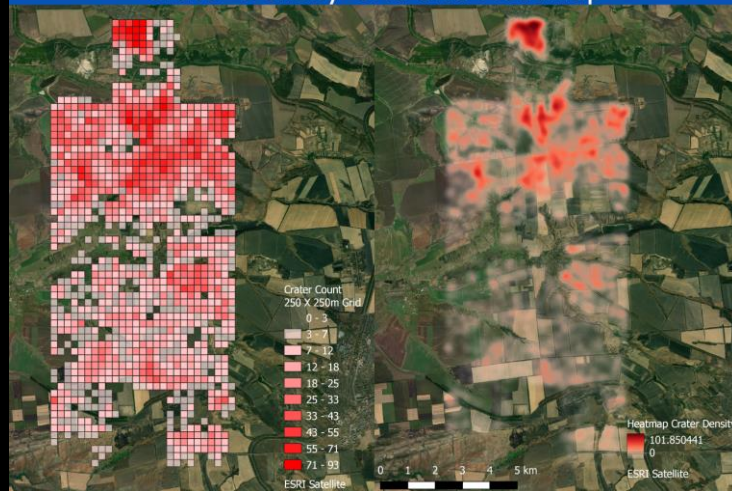
Erik C. Duncan^{a b 1}, Sergii Skakun^{a c 1}  , Ankit Kariryaa^{b d},
Alexander V. Prishchepov^{b 1}

What can we build from individual detections?

Crater Detection in Planet Skysat Imagery



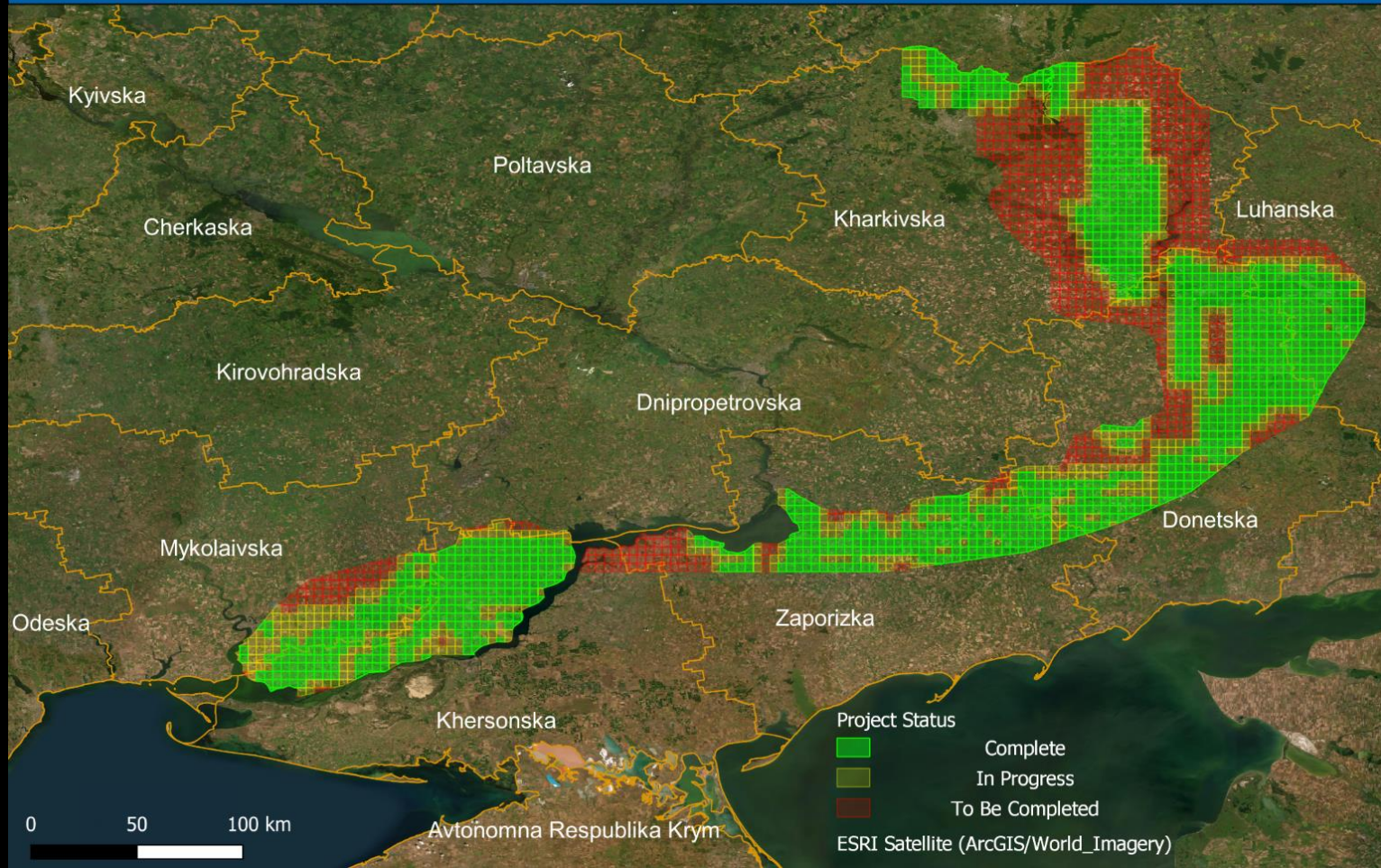
Crater Density Grid and Heatmap



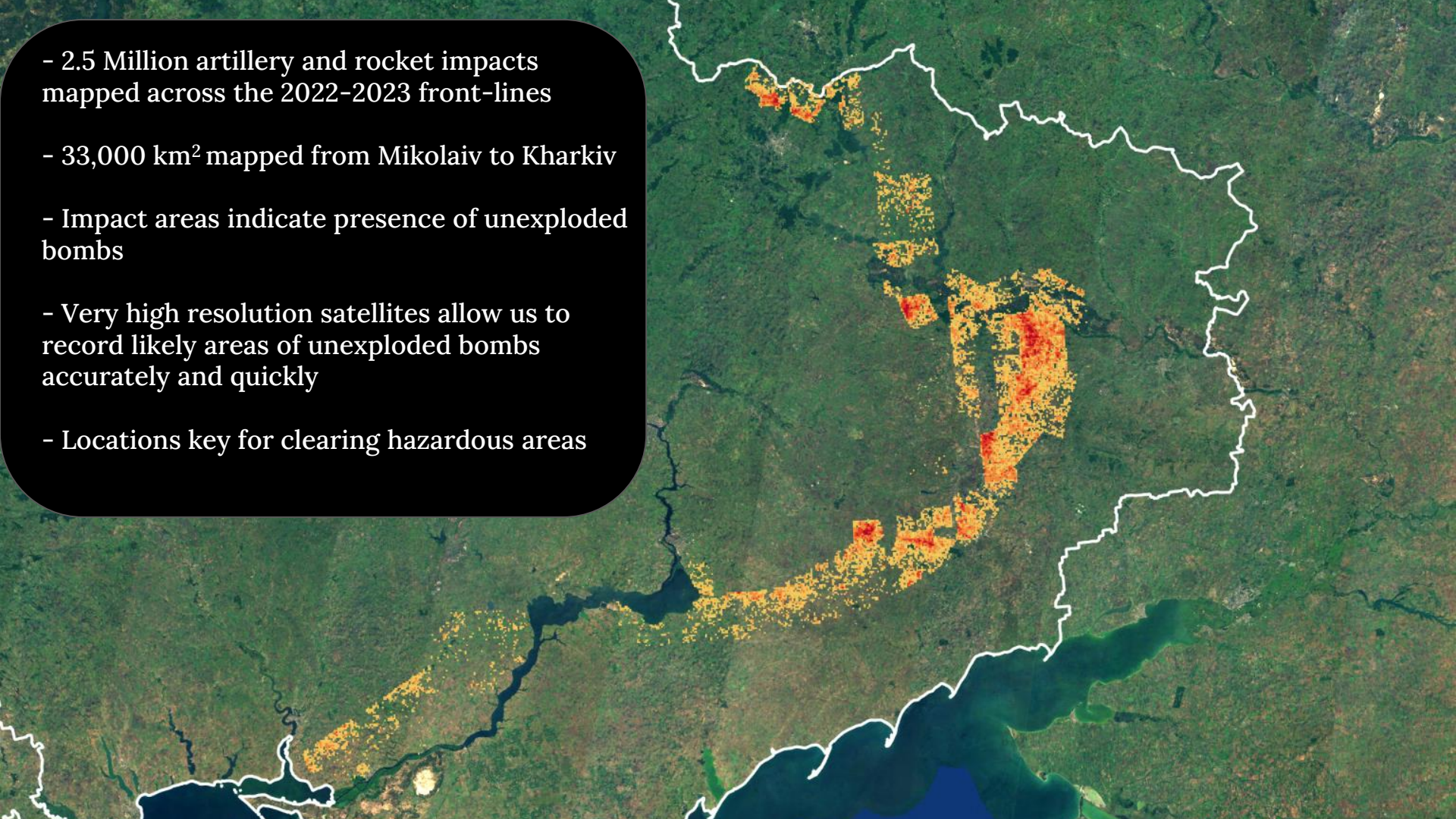
Crater Density Reference



Artillery Crater Mapping Status



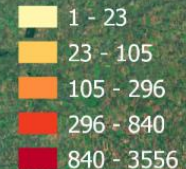
- 2.5 Million artillery and rocket impacts mapped across the 2022-2023 front-lines
- 33,000 km² mapped from Mikolaiv to Kharkiv
- Impact areas indicate presence of unexploded bombs
- Very high resolution satellites allow us to record likely areas of unexploded bombs accurately and quickly
- Locations key for clearing hazardous areas



Per-Field Damage

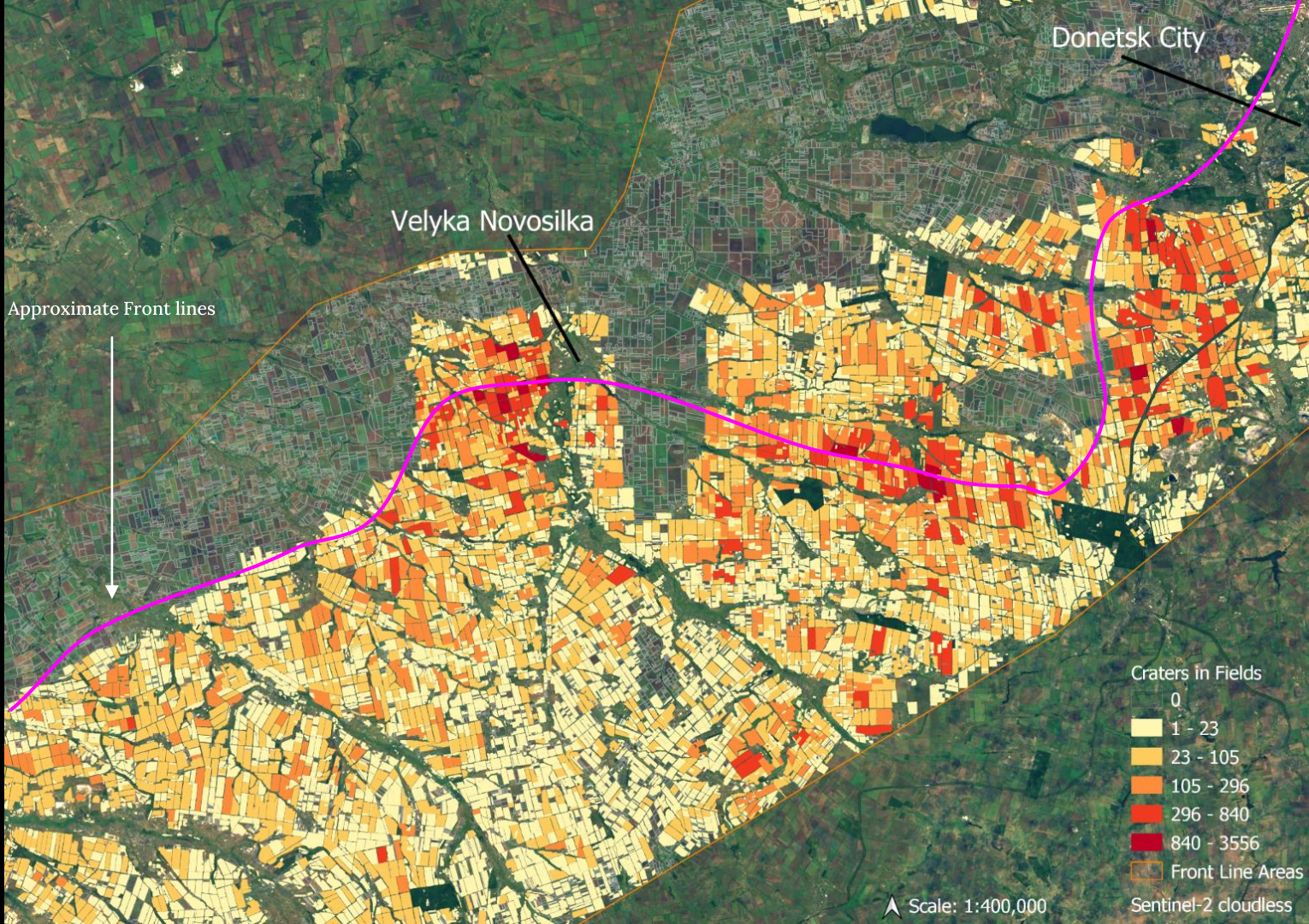
- 81,000 Fields have been analyzed
- Field boundaries automatically generated
- 1.21 Million craters within agricultural fields
- Average of 15 craters per field, median of 3
- Many fields contain more than 1000 craters

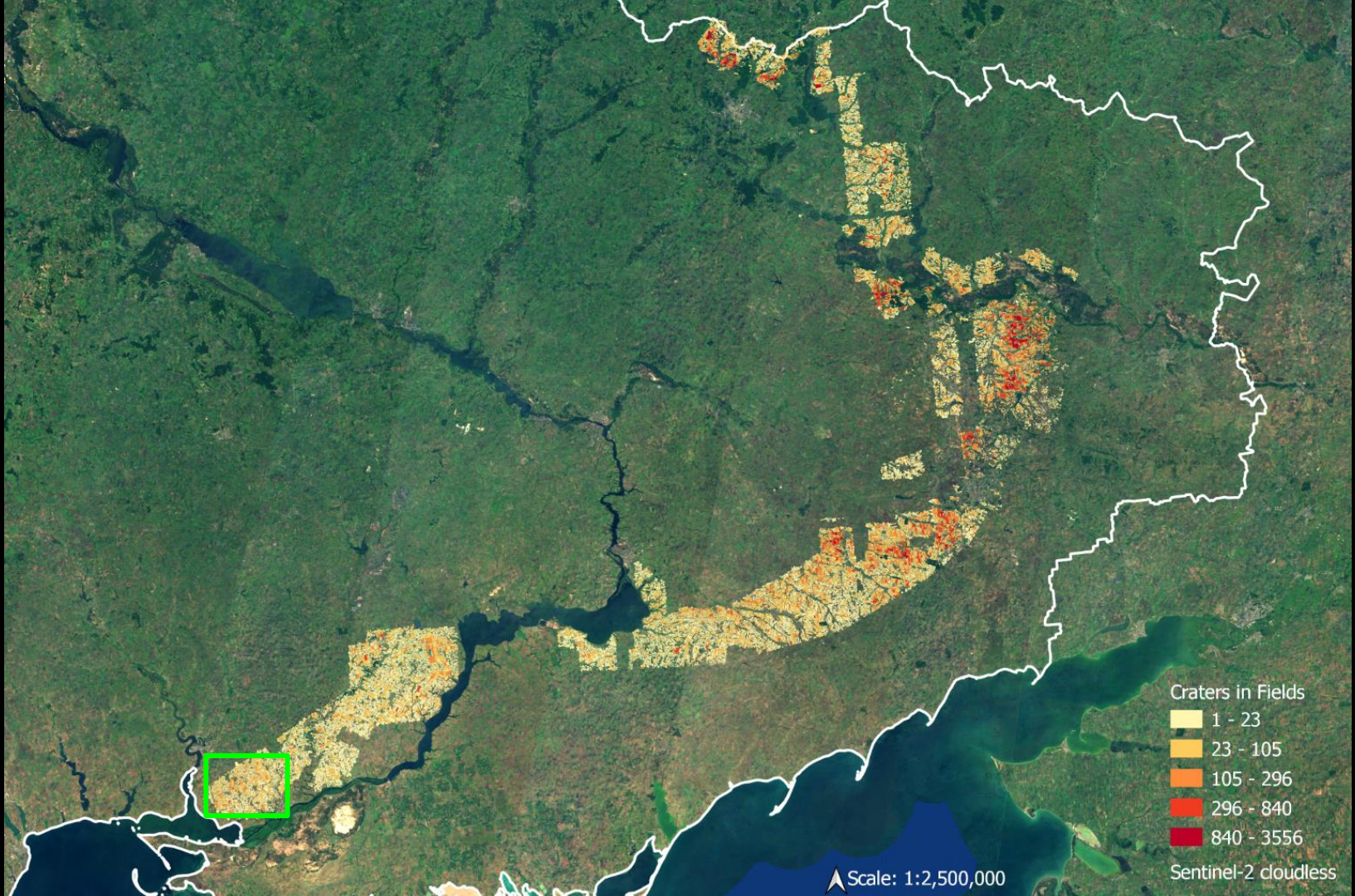
Craters in Fields



Scale: 1:2,500,000

Sentinel-2 cloudless





Craters in Fields

1 - 23

23 - 105

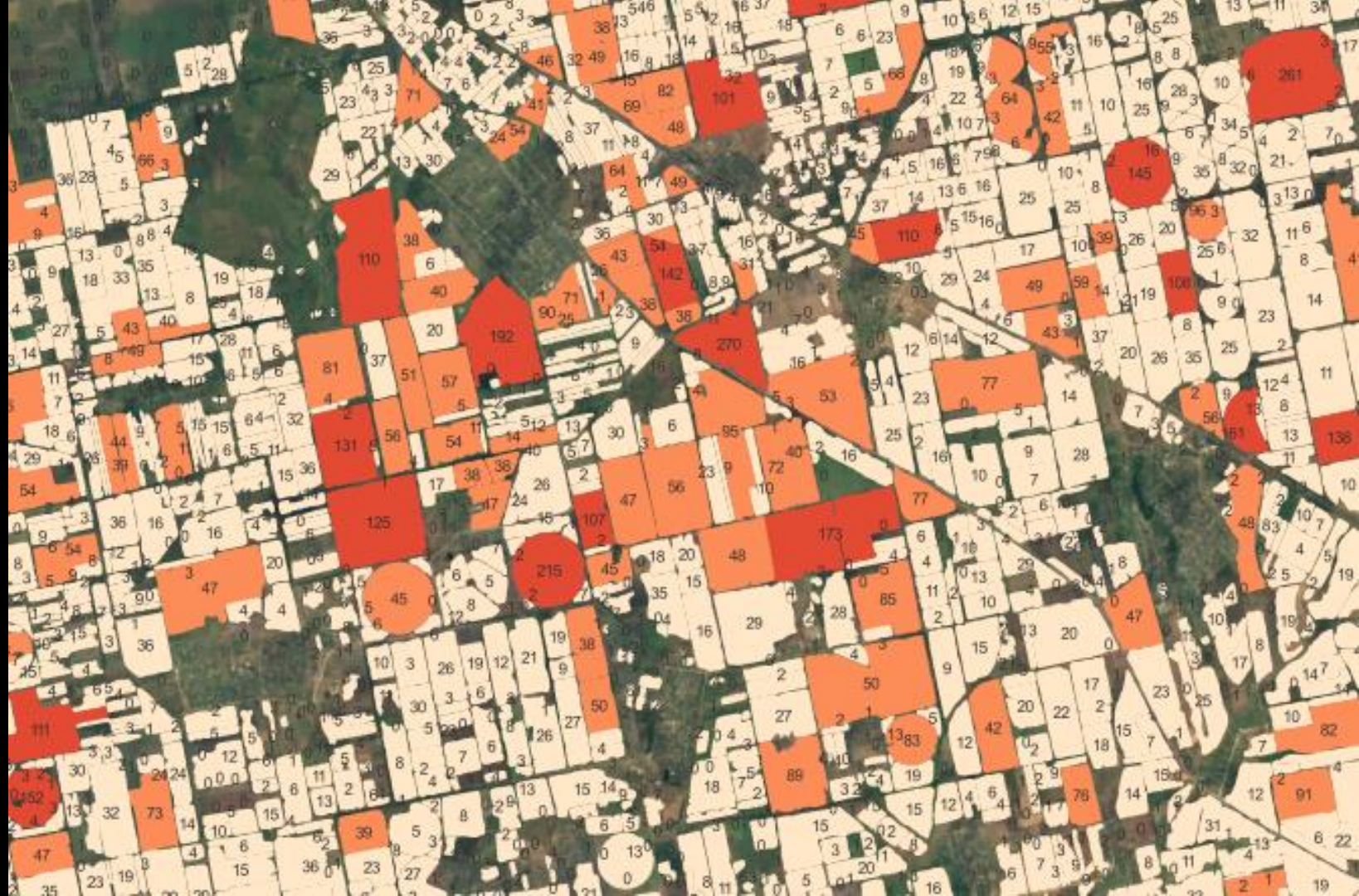
105 - 296

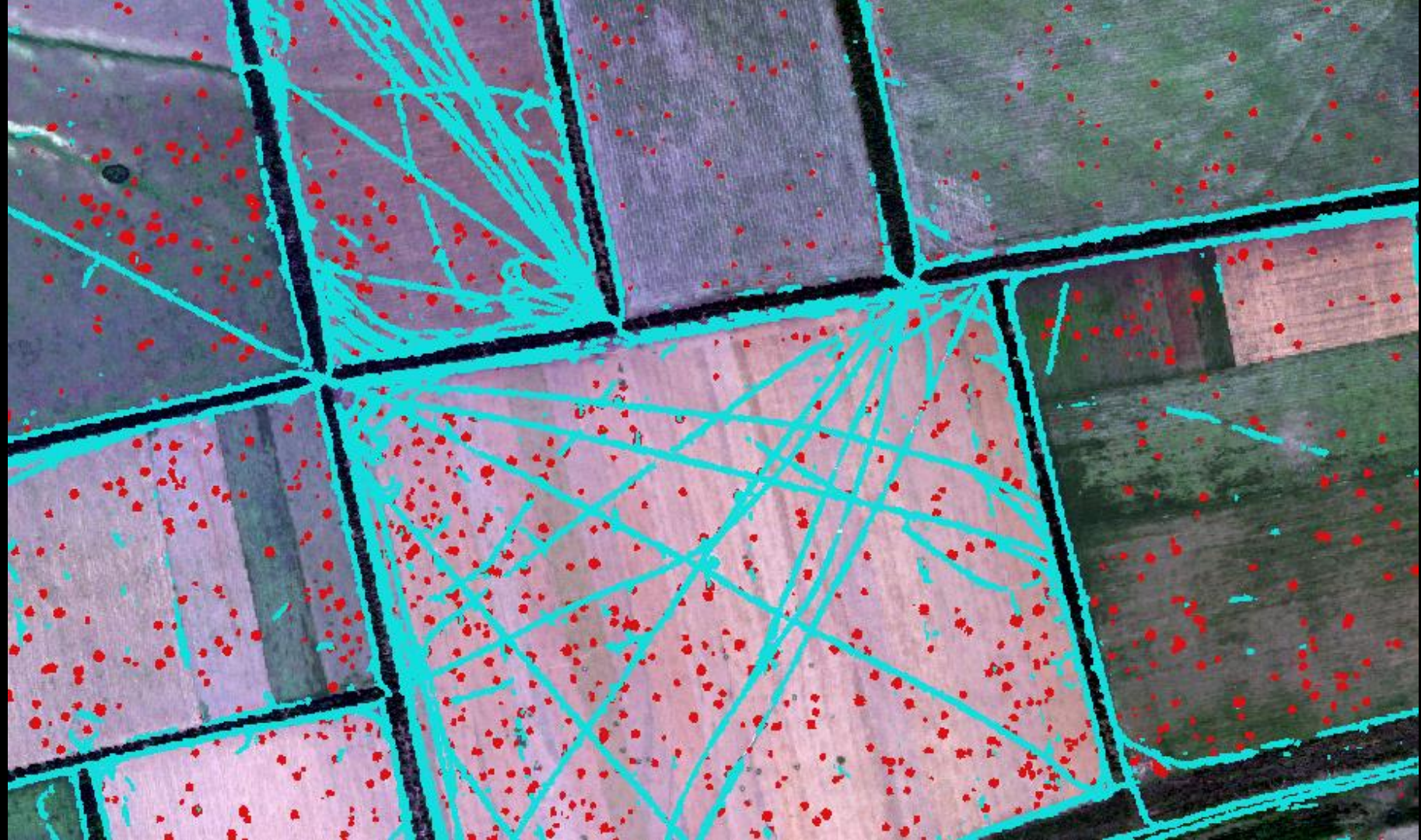
296 - 840

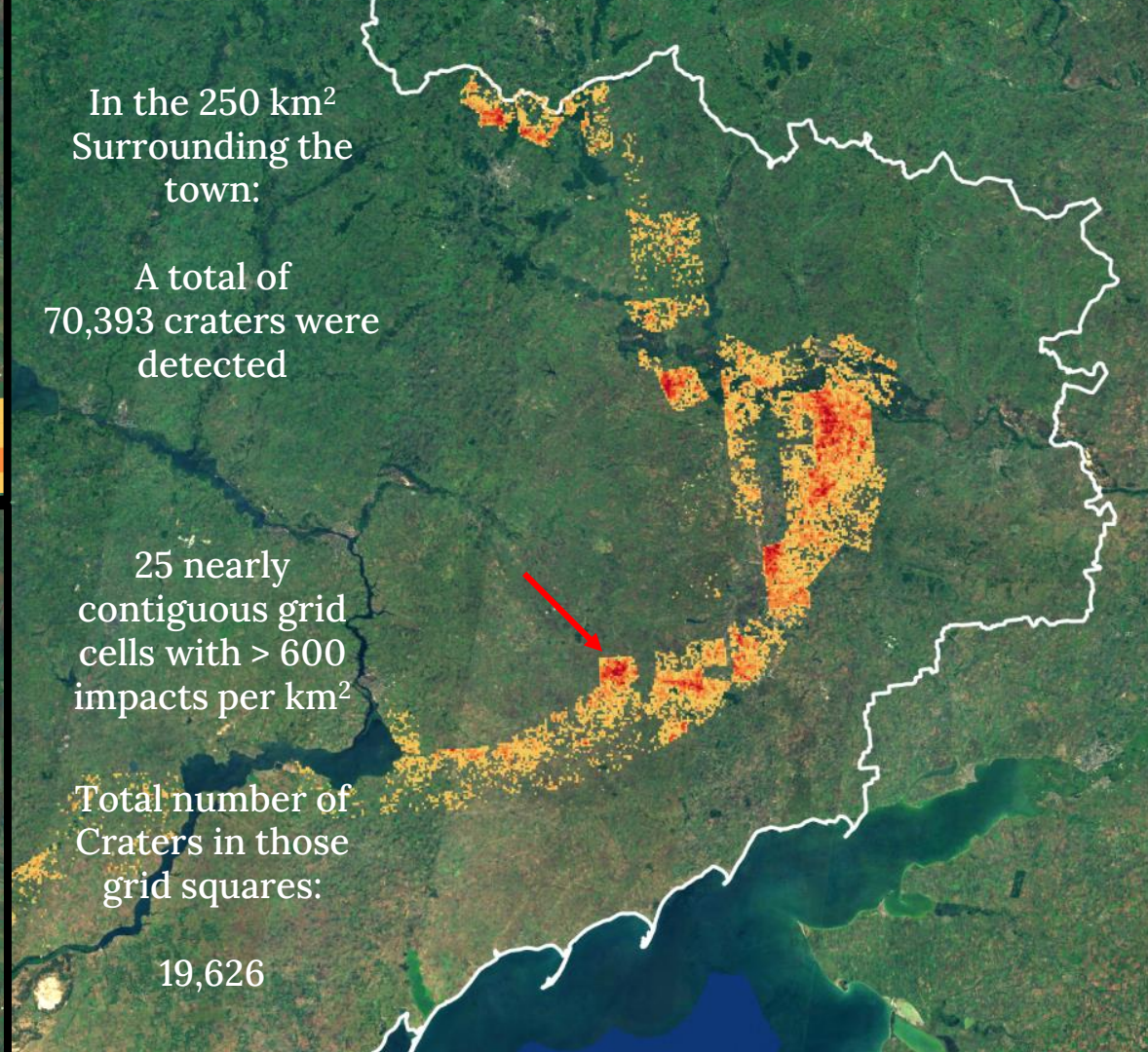
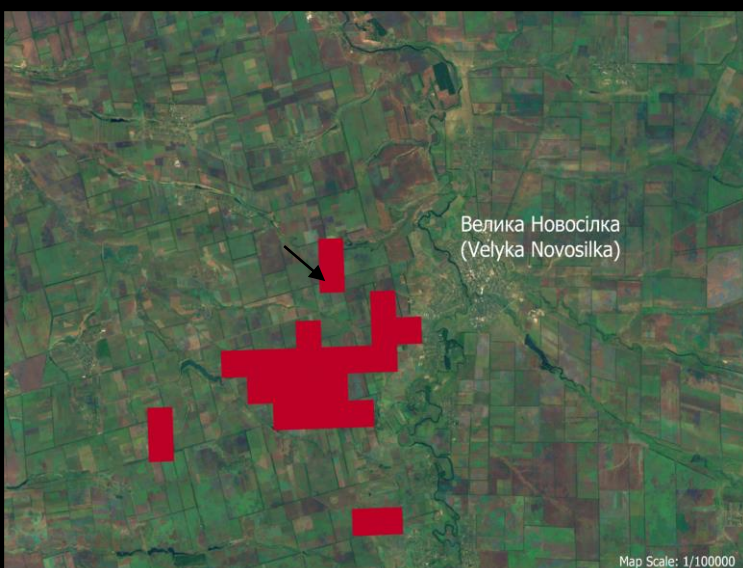
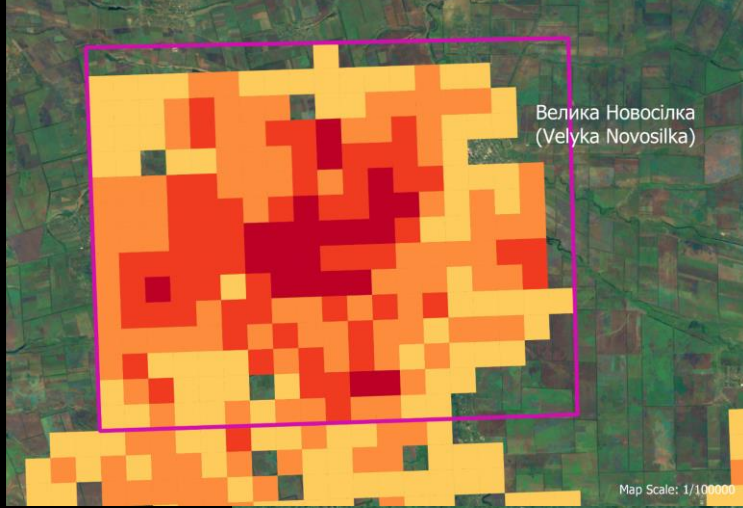
840 - 3556

Sentinel-2 cloudless

Scale: 1:2,500,000







Footage Date: ~3/23/2023



Detection Imagery Date: 9/21/2022




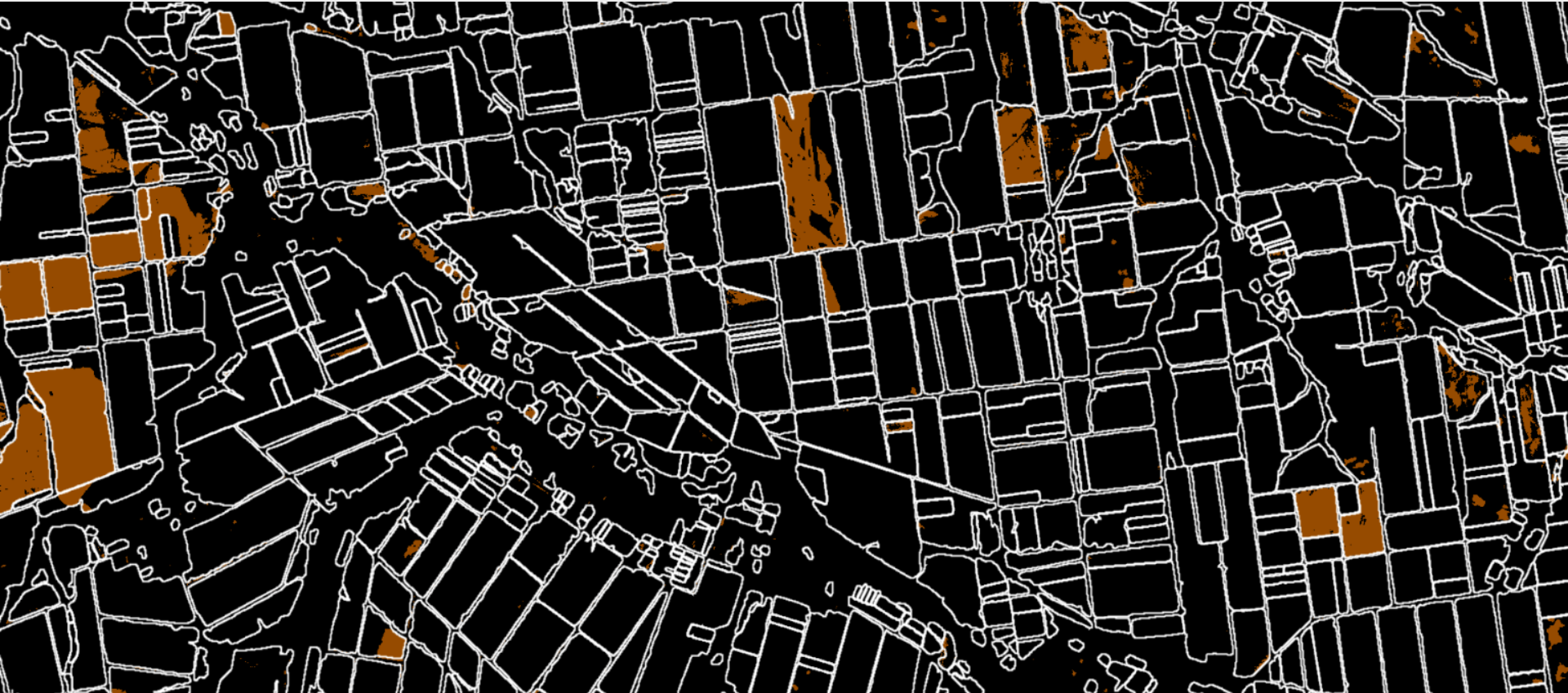


BURNT AREA



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 Burnt Fields

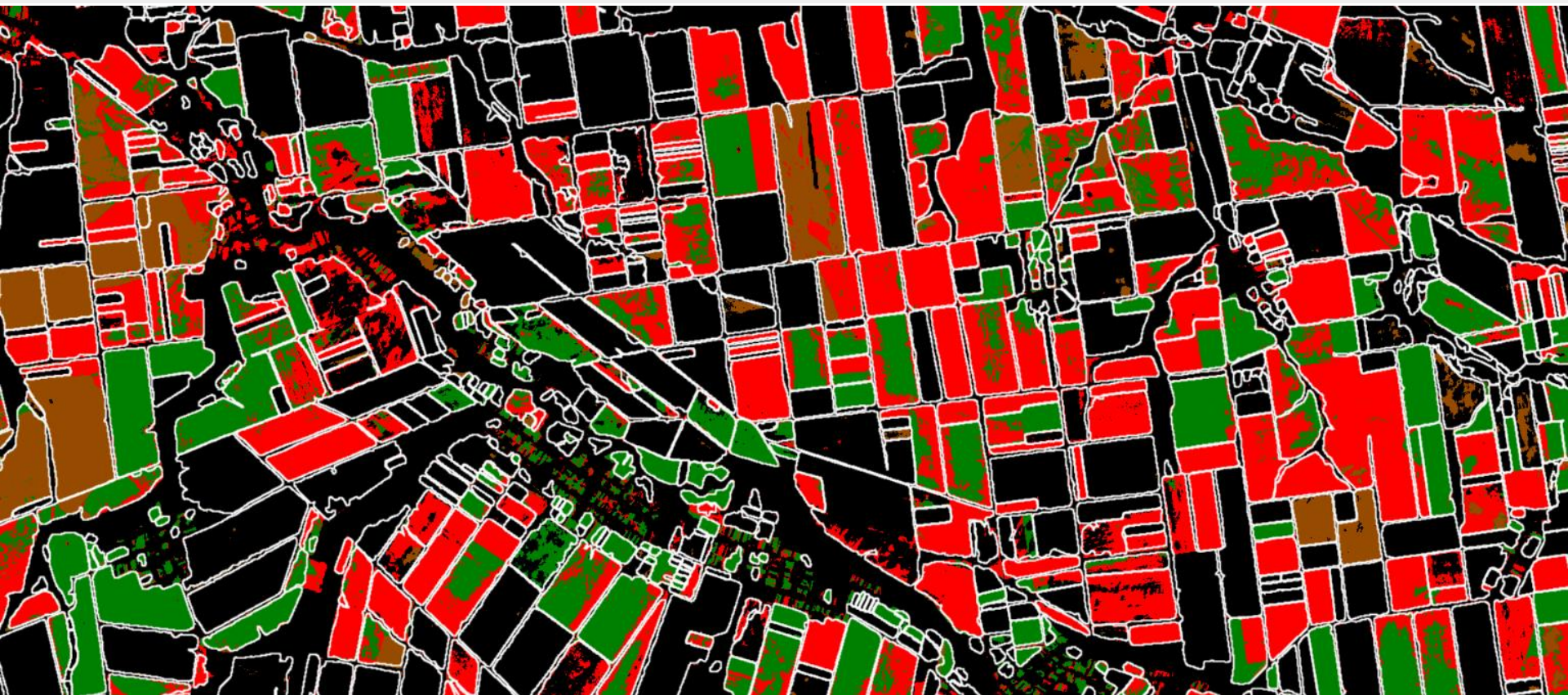




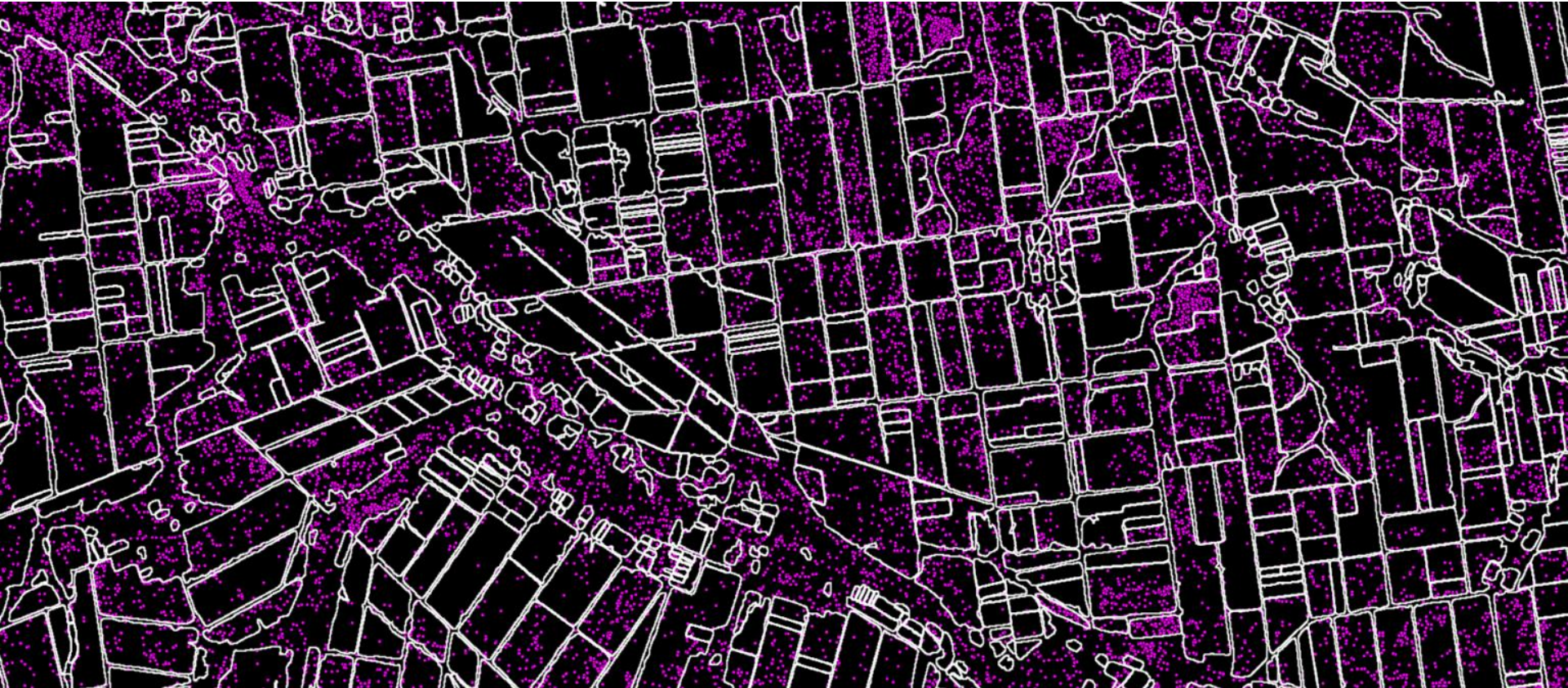
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WINTER HARVEST

-  Non Harvested Winter Crops
-  Burnt Fields
-  Harvested Winter Crops



CRATERS



CRATERS + BURNT AREA + FIRE EVENTS + WINTER HARVEST



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Craters



Non Harvested
Winter Crops



Burnt Fields



Fire Events



Harvested
Winter Crops

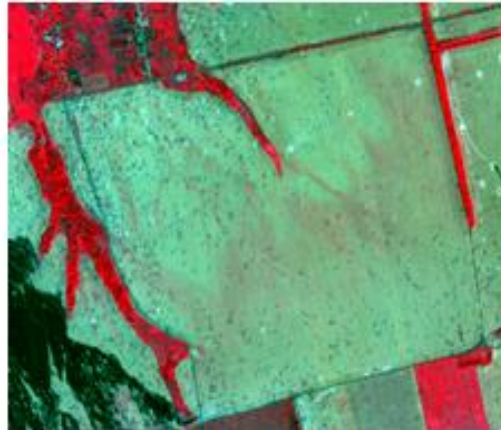


Operationalization

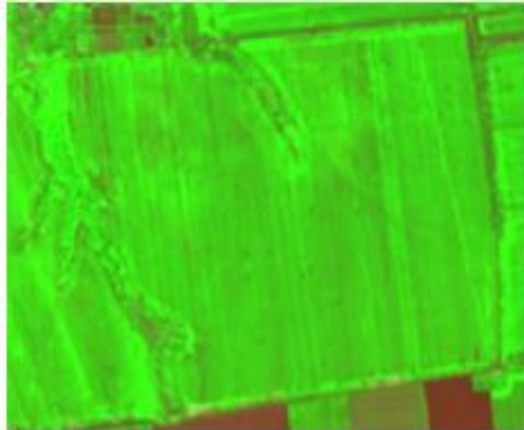
- Creating prioritization of Non-Technical-Surveys
- Hazard scores
- Simplification for operators
- Monitoring agriculture can have outcomes that you wouldn't initially think about



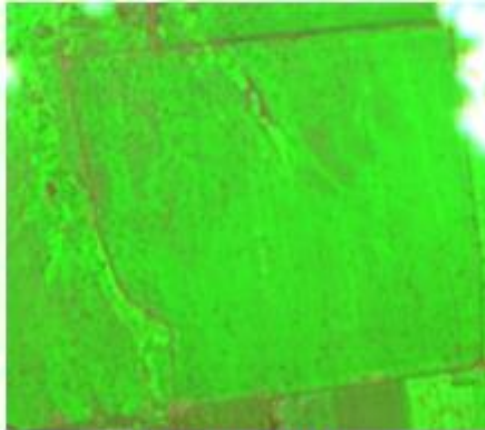




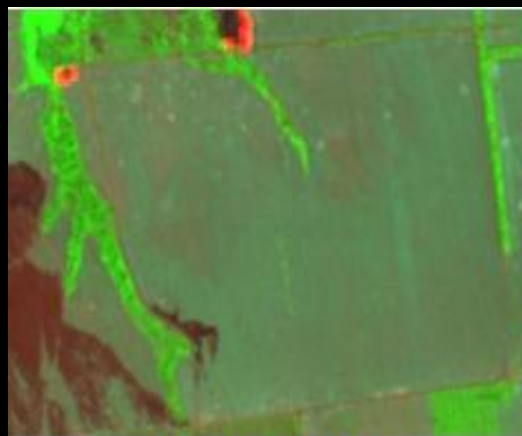
(a) 2022-07-02



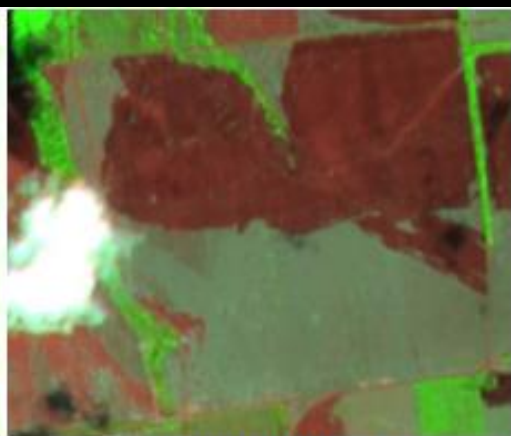
(b) 2022-05-08



(c) 2022-06-12



(d) 2022-07-07



(e) 2022-07-17

What we Have Accomplished

- The first deep learning application for artillery and rocket impact detection
- 40,000 km² of front line areas have been mapped
 - 81,000 agricultural fields, covering 15,600 km²
- 2.5 million craters have been identified, 1.21 million of which are in agricultural fields
- Rapid and robust processing pipeline for large amounts of image data

Next Steps

- Continued monitoring of front lines, increased coverage
- Large scale validation of 2022/2023 detections
- Exchange of demining information from demining results
- Bring demining organizations new solutions for early stage planning (NTS...)