Identification and mapping of missiles craters and unexploded ordnance in agricultural fields in Ukraine using very high spatial resolution satellite imagery

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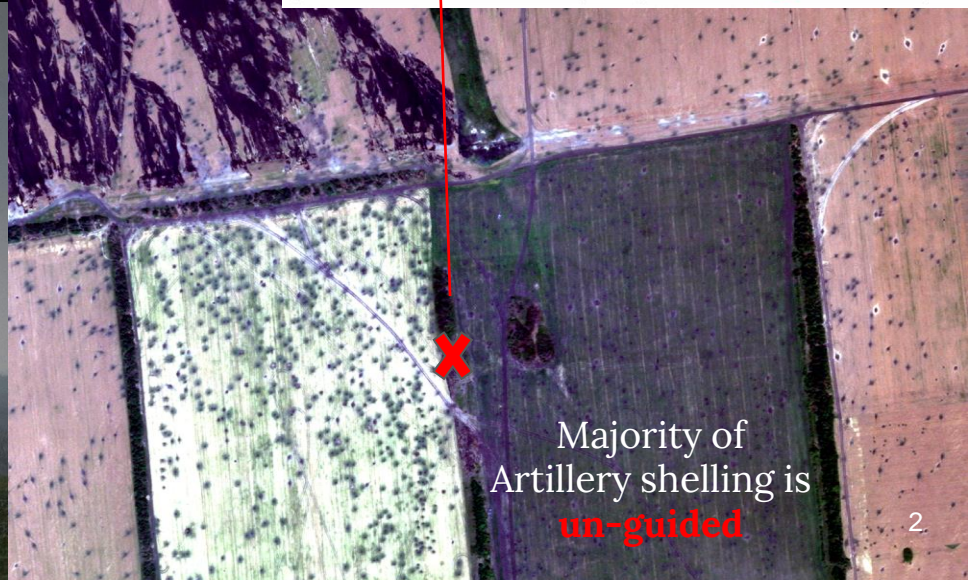(University of Marylnd, College Park)

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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" / "TORNADO-G"
Caliber - 122 mm
Range - 20-40 km
Longitudinal deviation of 0.5% from the range
Transverse deviation of 0.8% from the range
Number of rockets - 40
The impression area of one volley is 145,000 m2
The impression area of one shell is 3,625 m2

The BM-21 mainly has high-explosive fragmentation and cluster projectiles, which are designed to destroy infantry and lightly armored vehicles over a large area and are not effective against fortified targets or armored vehicles.

Target: fortified (armored) object 4m×10m

Range: 30 km

deviation area

BM-27 "URAGAN"
Caliber - 220mm
Range - 35 km
Number of rockets - 16
Longitudinal deviation of 0.5% from the range
Transverse deviation of 0.8% from the range
The impression area of one volley is 420,000 m2
The impression area of one shell is 26,250 m2

The BM-27 mainly has high-explosive fragmentation and cluster projectiles, which are designed to destroy infantry and lightly armored vehicles over a large area and are not effective against fortified targets or armored vehicles.

Target: fortified (armored) object 4m-10m

Range: 30

deviation area

BM-21 Grad

Majority of
Artillery shelling is
un-guided
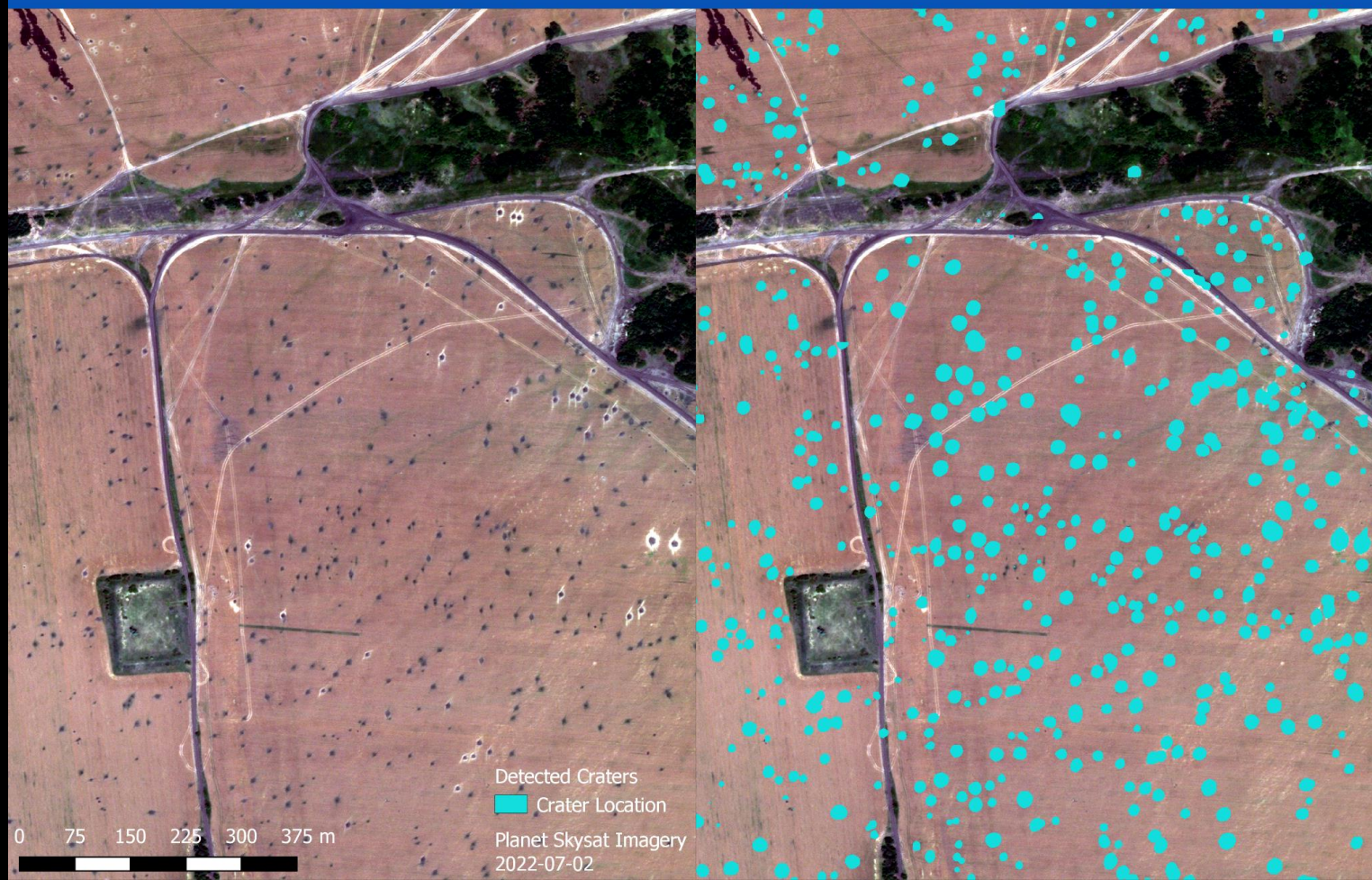
The Results:
Unexploded ordnance (UXO)

- Failure Rates? – So far unknown.

- Current front lines cover over 1,000 km

- No information about fields which have not been surveyed

- No information about PRIORITY of NTS

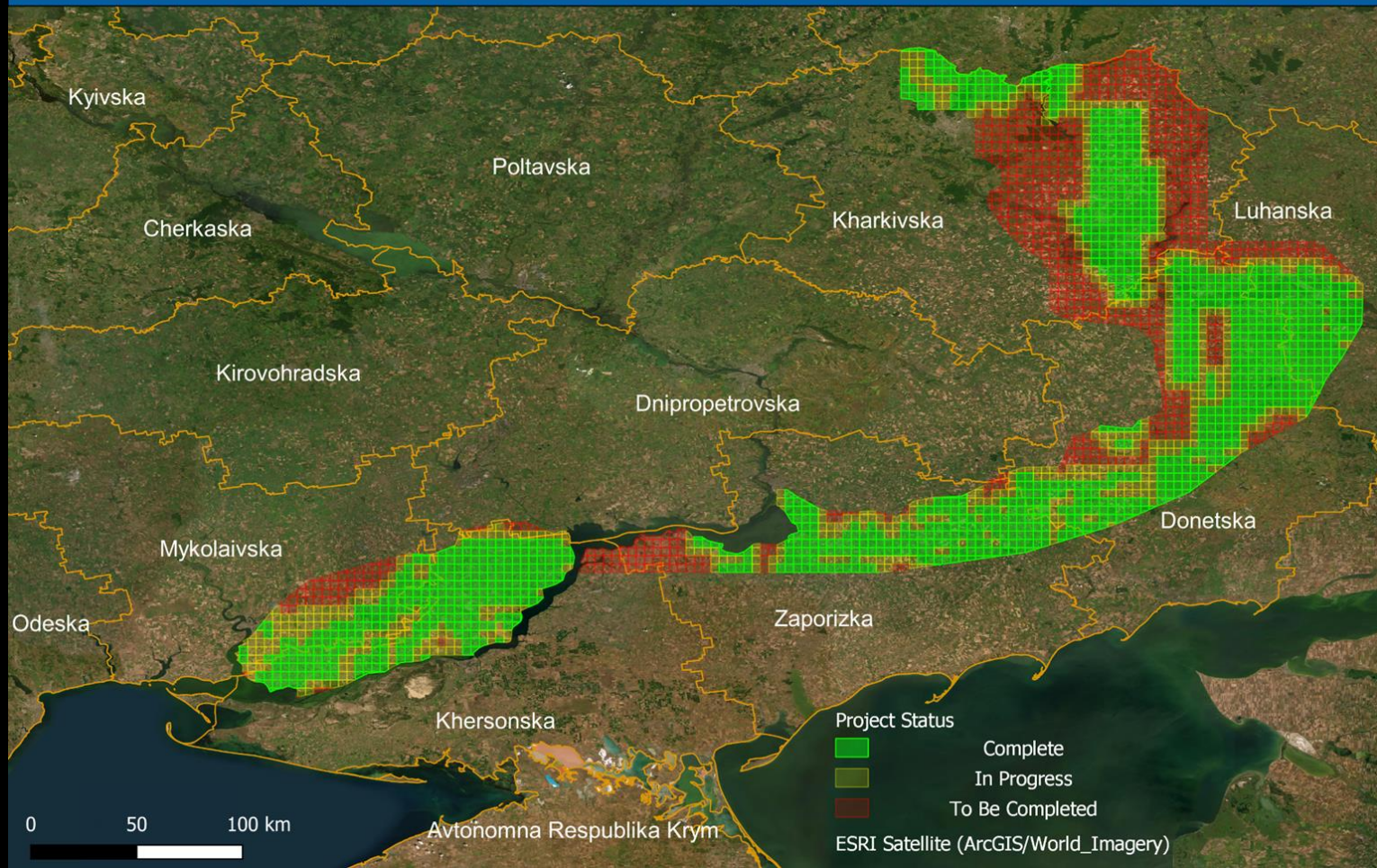- No information about non-hazardous fields in hazard area

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

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Crater Detection in Planet Skysat Imagery

Detected Craters
Crater Location

Planet Skysat Imagery
2022-07-02

0   75   150   225   300   375 m

Artillery Crater Mapping Status

Kyivska

Poltavska

Cherkaska

Kharkivska

Luhanska

Kirovohradska

Dnipropetrovska

Mykolaivska

Donetska

Odeska

Zaporizka

Khersonska

Avtonomna Respublika Krym

0   50   100 km

Project Status
- Complete
- In Progress
- To Be Completed

ESRI Satellite (ArcGIS/World_Imagery)

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

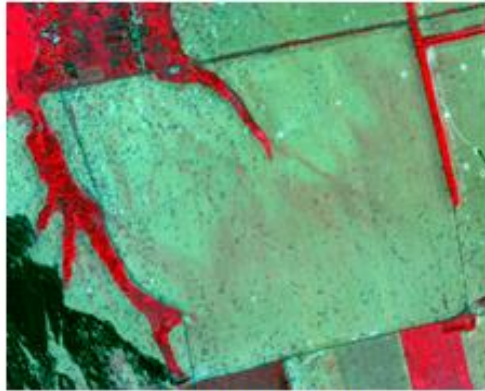-Many fields contain more than 1000 craters

Craters in Fields
- 1 - 23
- 23 - 105
- 105 - 296
- 296 - 840
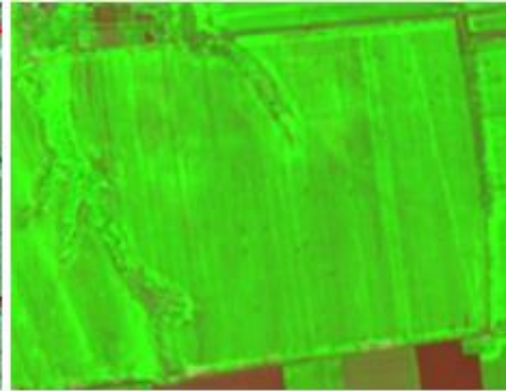- 840 - 3556

Scale: 1:2,500,000

Sentinel-2 cloudless

Commercial Imagery Not publicly available over many Ukrainian Positions.

Approximate Front lines

Donetsk City

Velyka Novosilka

Craters in Fields
0
1 - 23
23 - 105
105 - 296
296 - 840
840 - 3556
Front Line Areas
Sentinel-2 cloudless
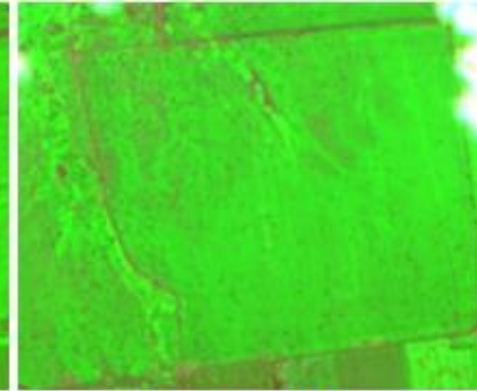
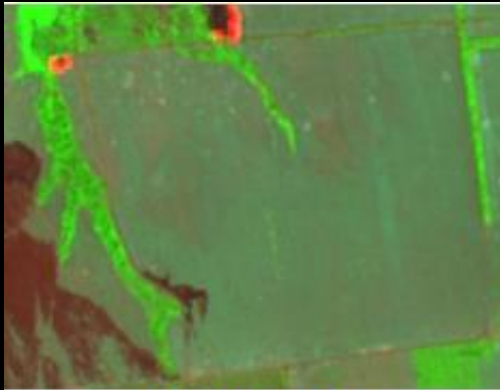Scale: 1:400,000

8
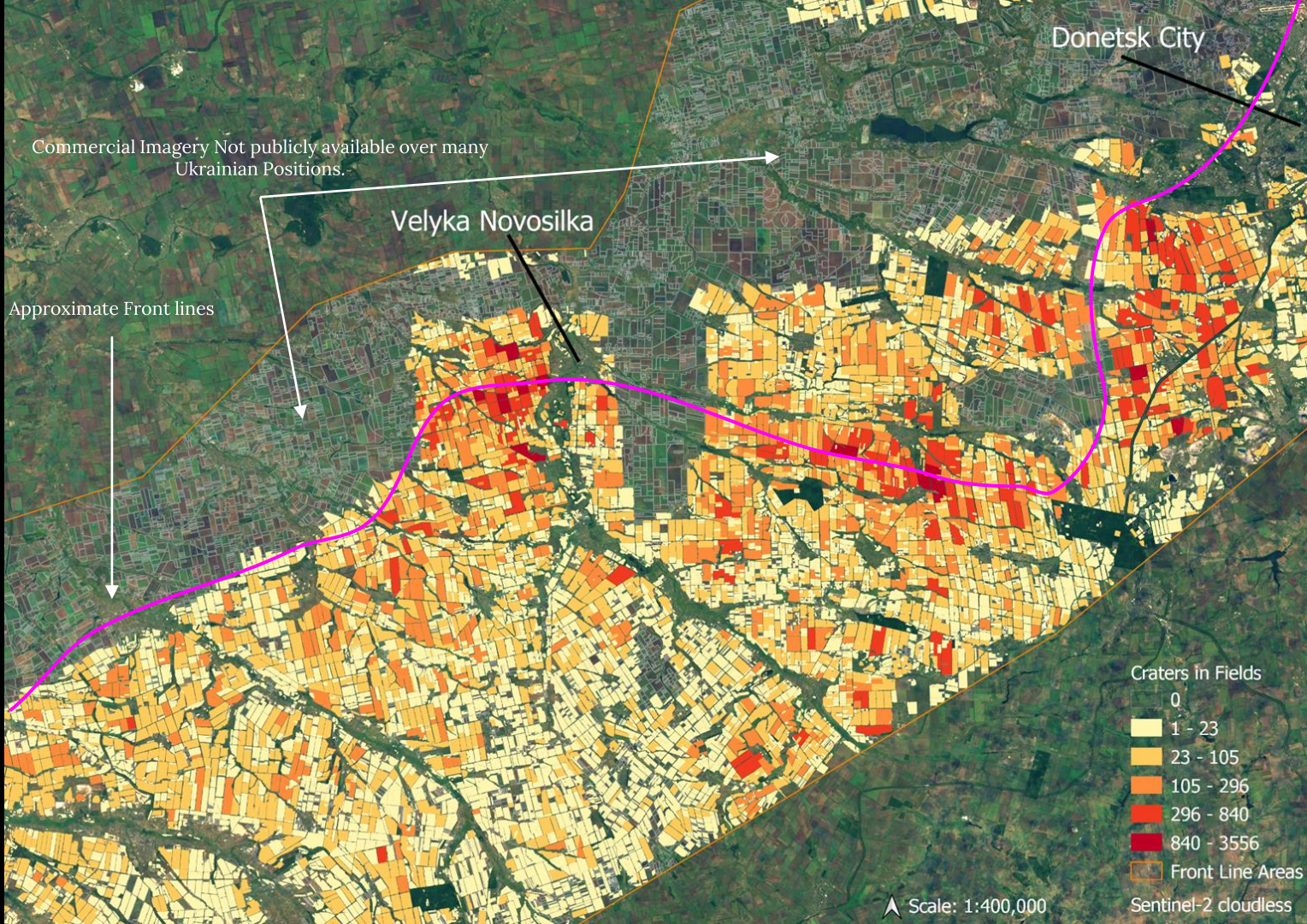
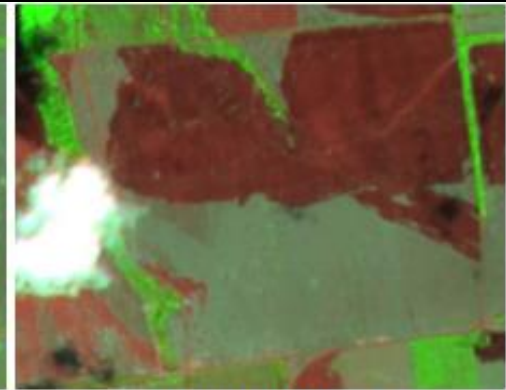# Example: unharvested field

(a) 2022-07-02   (b) 2022-05-08   (c) 2022-06-12

(d) 2022-07-07   (e) 2022-07-17

(a) SkySat false color (NIR-red-green) image. (b)-(e) Sentinel-2 false color (SWIR1-NIR-red).

In Early May (b) the field was in very good condition; however, shelling occurred mid-June as seen by both Sentinel-2 (c) and SkySat (a). Fire onset is seen in (d) and the field is seen burned in (e).

What we Have Accomplished	Next Steps
The first deep learning application for artillery and rocket impact detection	Continued monitoring of front lines, increased coverage
40,000 km^2 of front-line areas have been mapped	Large scale validation of 2022/2023 detections
81,000 agricultural fields, covering 15,600 km^2	Exchange of demining information from demining results
2.5 million craters have been identified, 1.21 million of which are in agricultural fields	Bring demining organizations new solutions for early stage planning (NTS...)
Rapid and robust processing pipeline for large amounts of image data	