

The impact of war in Ukraine on crop areas

S. Skakun, I. Becker-Reshef

University of Maryland, College Park MD, USA



LCLUC Team



PI



Sergii Skakun
UMD

Co-I's



Joanne Hall
UMD



Natacha Kalecinski
UMD



Jean-Claude Roger
UMD



Yiqun Xie
UMD

Collaborators



Nataliia Kussul
SRI/NTUU KPI



Andrii Shelestov
NTUU KPI



Alexander Prishchepov
U. Copenhagen

Graduate students



Yiming Zhang
UMD

FINESST



Abdul Qadir
UMD



Michael Adegbenro
UMD



Christian Abys
UMD

FINESST



Leonid Shumilo
UMD



Jaemin Eun
UMD



Erik Duncan
UMD



Gasmine Myers
UMD



NASA Harvest Ukraine Rapid Assessment Team



Inbal
Becker-Reshef



Josef Wagner



Shabarinath Nair



Yuval Sadeh



Sheila Baber



Blake Munshell



Brian Barker



Ritvik Sahajpal



Abdul Quadir



Sergii Skakun



Mehdi Hosseini



Saeed
Khahhazan



Michael Humber



John Kenisten



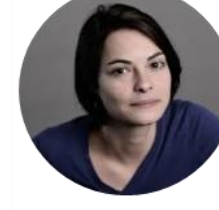
Erik Duncan



Fangjie Li



Mary Mitkish



Natacha Kalecinski

Ukrainian Partners & Advisory



Taras Vysotskyi



Denys Palamarchuk



Shamil Ibatullin



Oleksandr Sikachyna



Dmitry Prikhodko

Russian Invasion of Ukraine

February 24, 2022

The Economist

- Inside the Putin show
 - What next for SoftBank?
 - Graphene and decarbonisation
 - Is China uninvestible?
- MAY 21ST - 27TH 2022

The coming food catastrophe



Ukraine war 'catastrophic for global food'

7 March · Comments

Russia-Ukraine war



By Emma Simpson
Business correspondent, BBC News

The war in Ukraine will deliver a shock to the global supply and cost of food, the boss of one of the world's biggest fertiliser companies has said.

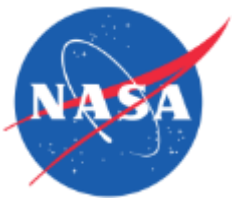
Forty Percent of the World Food Program's Wheat Supplies Come from Ukraine

By Ambassador Mark Green on June 2, 2022

FOOD AND AGRICULTURE

UKRAINE





Uncertainties

- **Cropland** under Russian occupation?
- How much of the **wheat** would be harvested in 2022?
 - Wheat was planted in Fall 2021
 - Wheat: #7 producer, #5 exporter
- How much of **sunflower** would be planted in 2022?
 - Sunflower oil: #1 producer, #1 exporter

Partnership with the Ministry of Agrarian Policy & Food of Ukraine

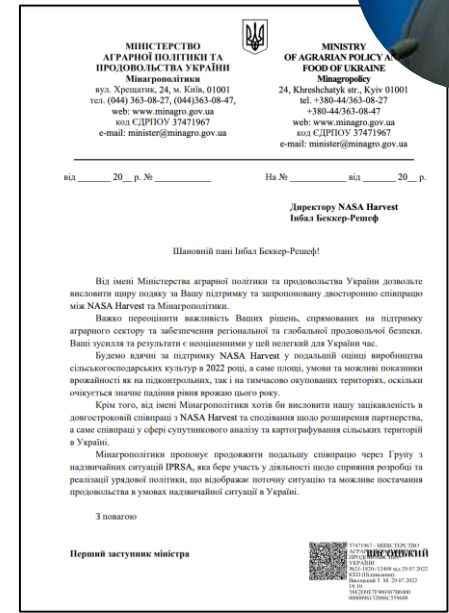


Міністерство
аграрної політики та
продовольства України

First Deputy
Minister T.
Vysotskyi



- Builds on longstanding cooperation with various entities in Ukraine including Ministry, Hydromet Center, Kyiv Polytechnic University & USDA FAS attache in Kyiv.
- Short term focus: estimating impact of war on agriculture, particularly within the occupied territories where ground data is not available
- Longer term: boost capacity at the Ministry for use of satellite data in agricultural assessments





Crop production

- Crop **mapping** and **area estimation**, crop **yield** forecasting and assessment

$$Production = Yield \times Area$$

$$\frac{\Delta P}{P} = \sqrt{\left(\frac{\Delta Y}{Y}\right)^2 + \left(\frac{\Delta A}{A}\right)^2}$$

- Example Ukraine, winter wheat (2021):
 - Yield ~4.5 t/ha, Area ~7.1 Mha,
assuming ~10% uncertainty in both yield and area:

$$Production = 31.9 \pm 4.5 \text{ MT (14\%)}$$



Land area estimation

- Maybe done pure statistically without Earth observations
- Satellite-based observations
 - A key strength of RS is that it enables **spatially exhaustive, wall-to-wall coverage** of the area of interest
 - **Pros**
 - Graphical **support** for groundwork and quality control of ground measurements
 - **Stratification**: Improve the sampling design of ground measurements
 - **Covariate** for a posteriori improvement
 - **Issues**
 - The maps results are **rarely perfect**
 - **Errors** can also result from the mapping process, the data used, confusion between classes, and analyst biases
 - **Pixel counting** estimator: quick but might be **biased**



Land area estimation

Remote Sensing of Environment 148 (2014) 42–57



Contents lists available at ScienceDirect

Remote Sensing of Environment

journal homepage: www.elsevier.com/locate/rse



Review

Good practices for estimating area and assessing accuracy of land change

Pontus Olofsson ^{a,*}, Giles M. Foody ^b, Martin Herold ^c, Stephen V. Stehman ^d,
Curtis E. Woodcock ^a, Michael A. Wulder ^e



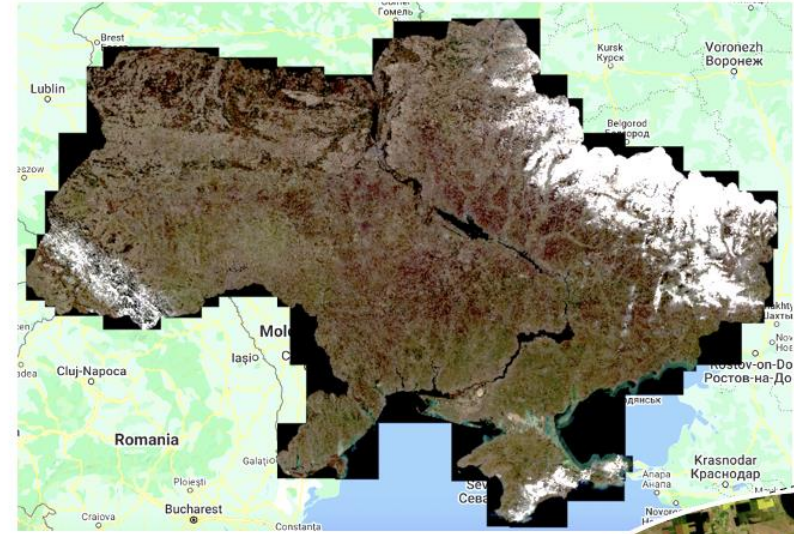
Stratified random sampling, where strata are coming from maps

Challenge: Ukraine can be very cloudy!

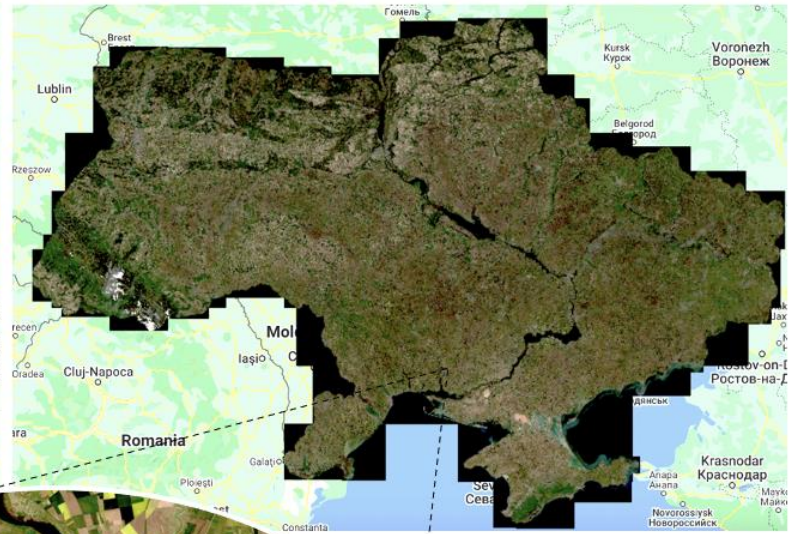


+ Input: Bi-Weekly Planet Composites @ 3 meters

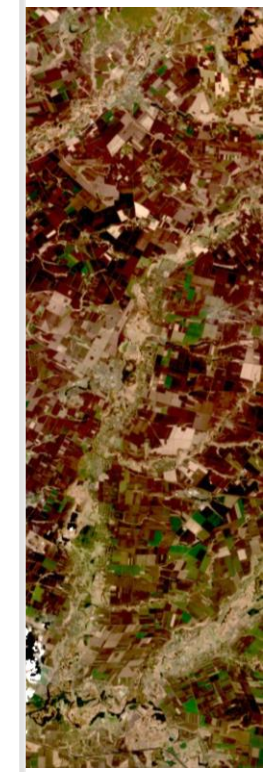
Ukraine, March 21st, 3 meter resolution data



Ukraine, May 15th, 3 meter resolution data

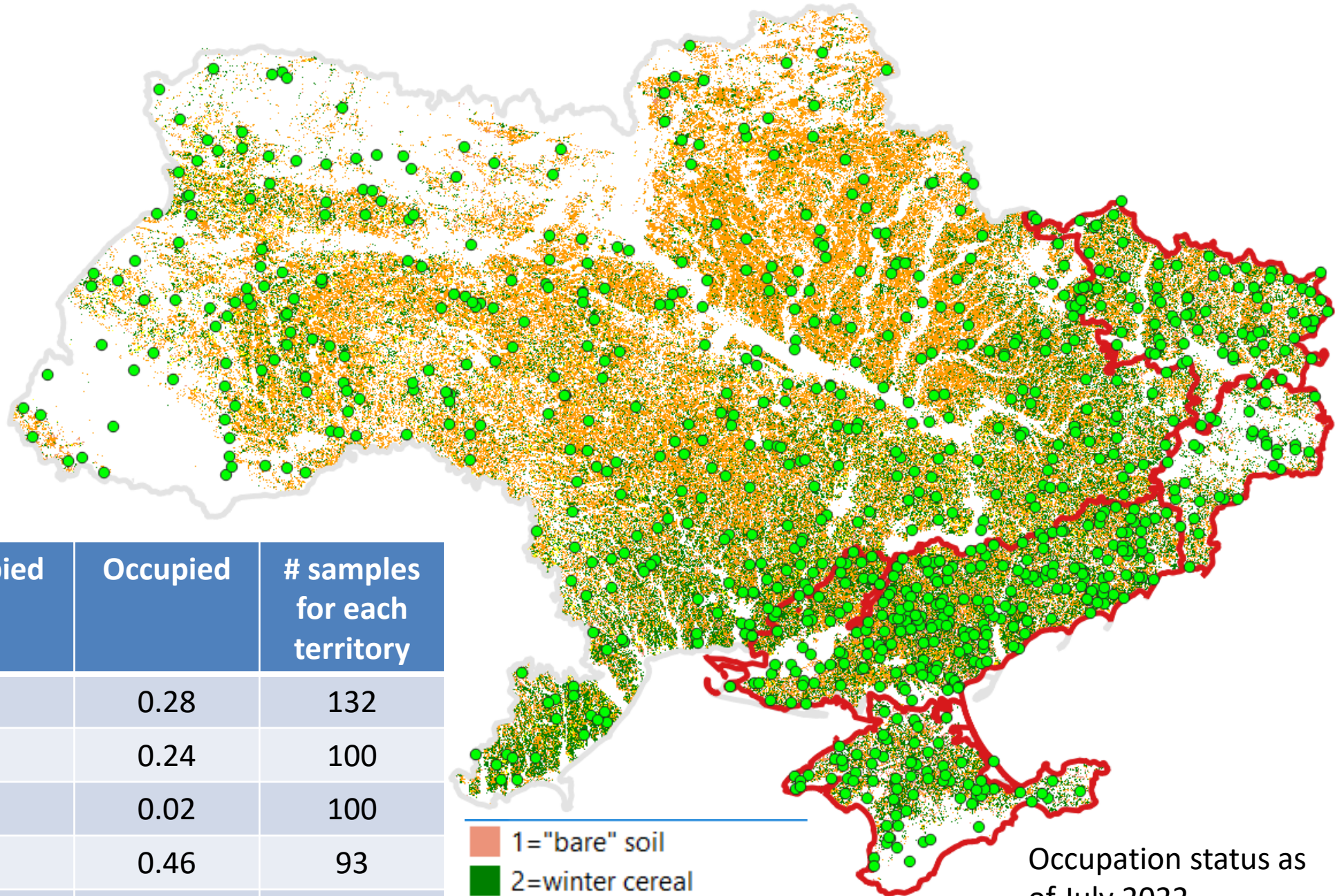


COMPOSITE
DOLTAVA



- Flowering rapeseed
- Winter wheat
- Bare soil





Stratum	Unoccupied	Occupied	# samples for each territory
Summer crops	0.31	0.28	132
Winter cereal	0.13	0.24	100
Rapeseed	0.02	0.02	100
Non-cropland	0.53	0.46	93
Total	1	1	425

- 1="bare" soil
- 2=winter cereal
- 3=rapeseed
- 4=summer/spring crops

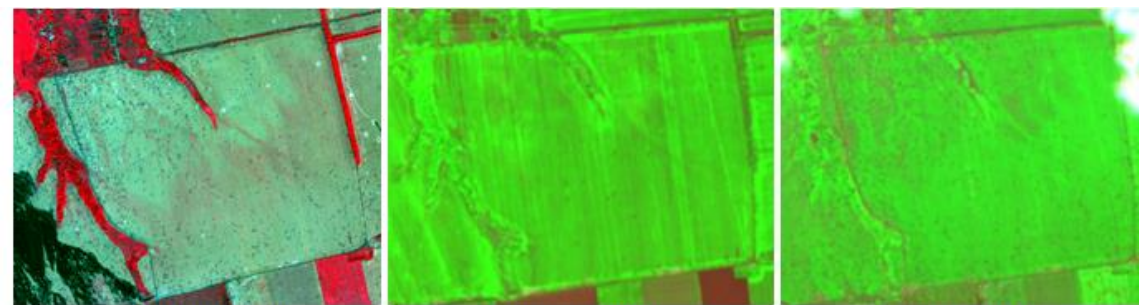
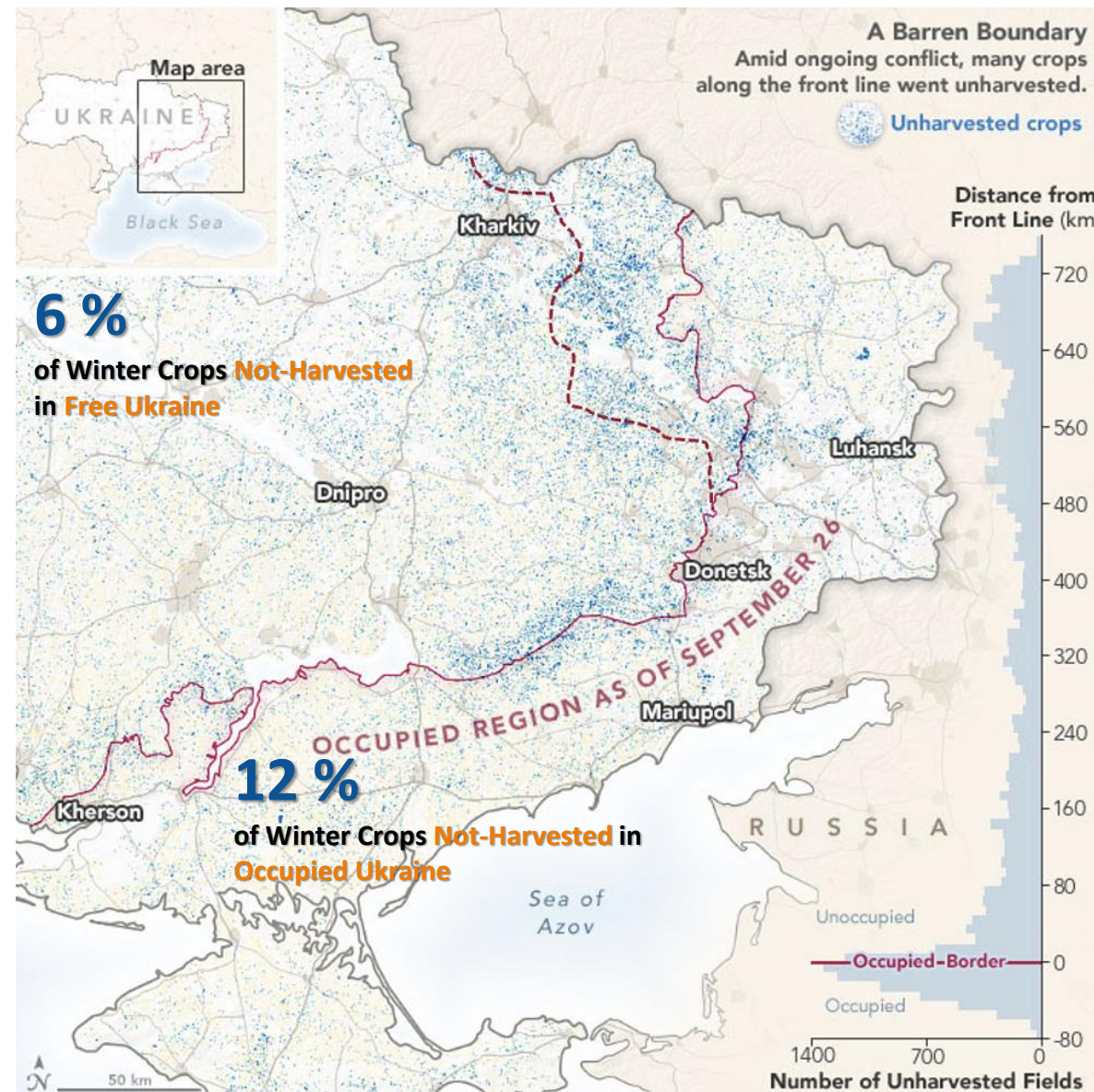
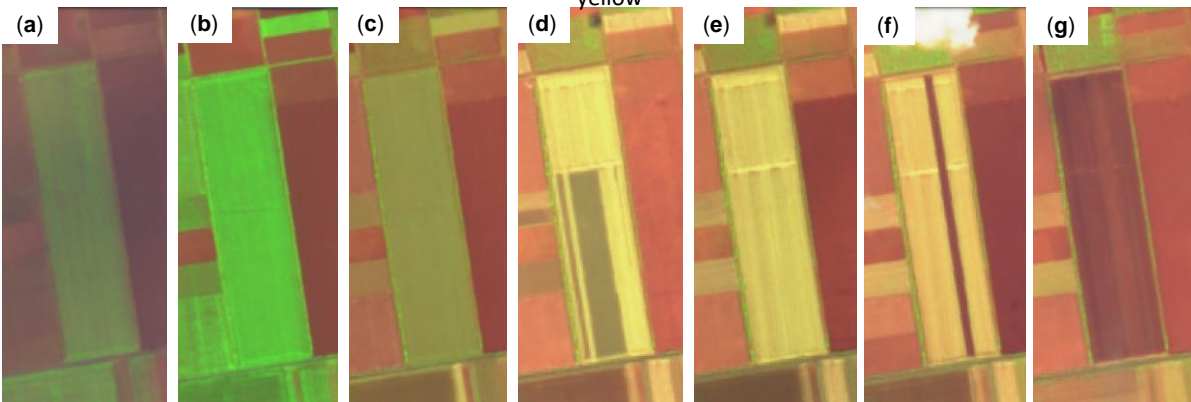
Occupation status as of July 2022
Source: ISW



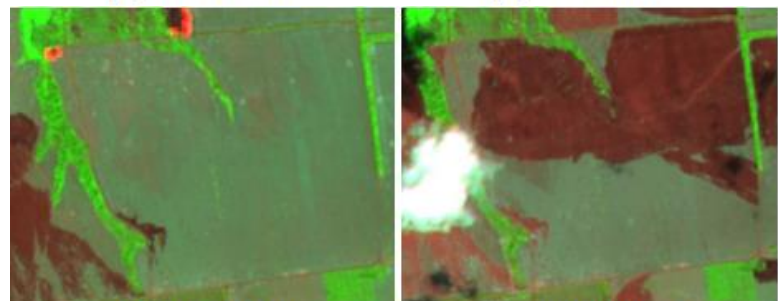
Harvesting of winter wheat fields



2022-03-30: Winter crop in "green"
 2022-06-03: Good conditions early summer
 2022-07-03: Senescence
 2022-07-15: Start of harvest. Crop residue in "yellow"
 2022-07-18: Harvest complete
 2022-07-23: Start of tilling
 2022-07-30: Tilling complete



(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).

NASA Harvest Wheat Production Estimates

much higher than expected, largely due to higher harvested area

~22% of Ukraine's wheat was harvested in occupied territories. This translates to > USD 1 billion harvested in Russian controlled territories. Losses are much higher when accounting for destroyed machinery, grain elevators, burned fields & other damage caused by the war

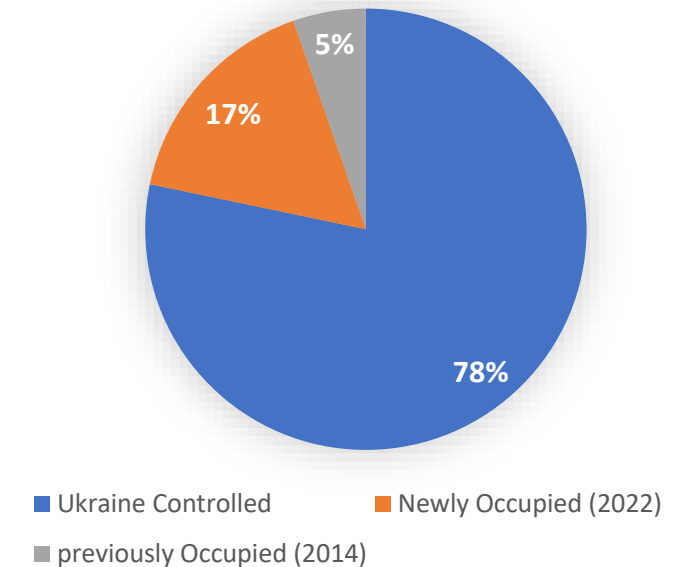
NASA Harvest Wheat 2022 Estimates

Territory	Production	Yield	Area harvested	Area Planted
All Ukraine	26.6	3.98	6.74	7.20
Ukraine Controlled	20.8	4.08	5.14	5.40
total occupied	5.8	3.66	1.60	1.80

Comparison with leading wheat estimates

	NASA Harvest	USDA	FAO	IGC
Production All Ukraine	26.6	20.5	20.0	21.5
Area Harvested	6.74	5.25		

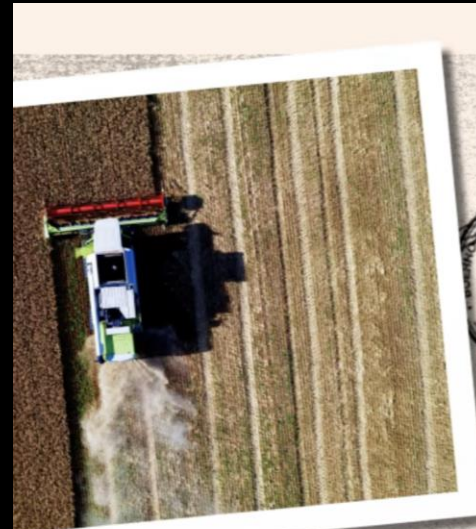
Percent Wheat Production by Occupation Status (September 26th)



- Area based on satellite driven planted area & harvested estimates
- Yield based on official harvested yields & NASA Harvest ARYA model where data was not available (in the occupied territories)

Where will the 22% (5.8MT) end up & who will reap the economic benefit ?

Azov before picking up the commodity in Sevastopol, as Amur 2501 does on its trips.



Photographer: Chris McGrath/Getty Images

How Russian Ships Are Laundering Grain Stolen From Occupied Ukraine

A screenshot of a Financial Times article. The article title is "How Russia secretly takes grain from occupied Ukraine". The sub-headline reads "Documents and photos reveal a complex shadow operation managed by private companies and arms of the Russian state". To the right of the article is a document with a blue stamp and a photo of a ship. The stamp is from the "Государственный зерновой оператор" (State Grain Operator) and includes the text "ПОЛОЖЕНИЕ О ГОСУДАРСТВЕННОМ УНИТАРНОМ ПРЕДПРИЯТИИ «ГОСУДАРСТВЕННЫЙ ЗЕРНОВОЙ ОПЕРАТОР»". The document also mentions "СТРИАН АРАБ РЕПУБЛИК" (Syrian Arab Republic) and "MINISTRY OF TRANSPORT".

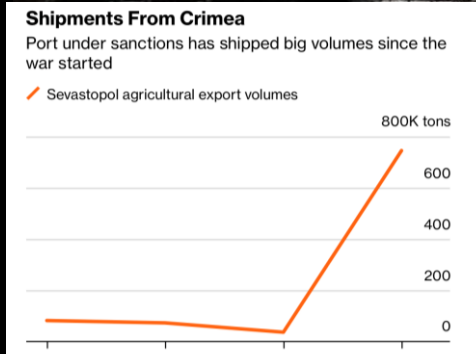
FINANCIAL TIMES

The Big Read War in Ukraine + Add to myFT

How Russia secretly takes grain from occupied Ukraine

Documents and photos reveal a complex shadow operation managed by private companies and arms of the Russian state

THE WALL STREET JOURNAL. SIGN IN SUBSCRIBE



While satellites can provide a lot of critical information, they cannot determine who is harvesting the fields, who is purchasing the grain, where it is stored, or exported to

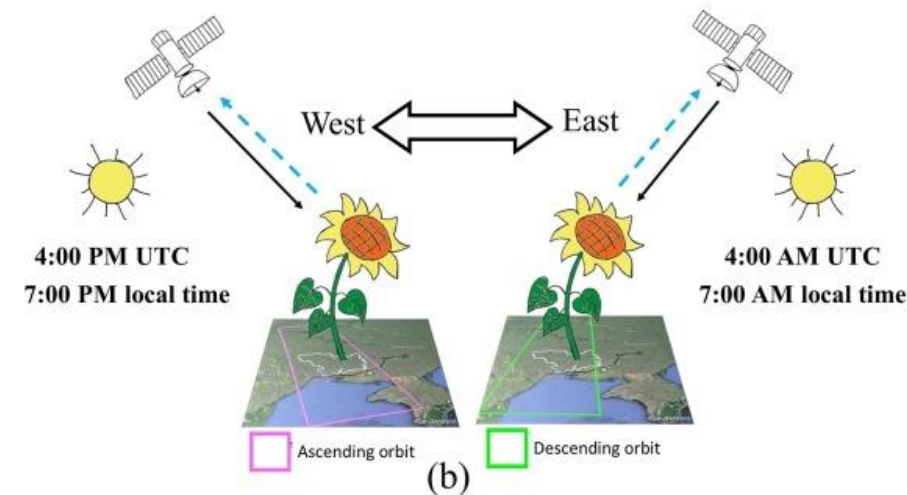
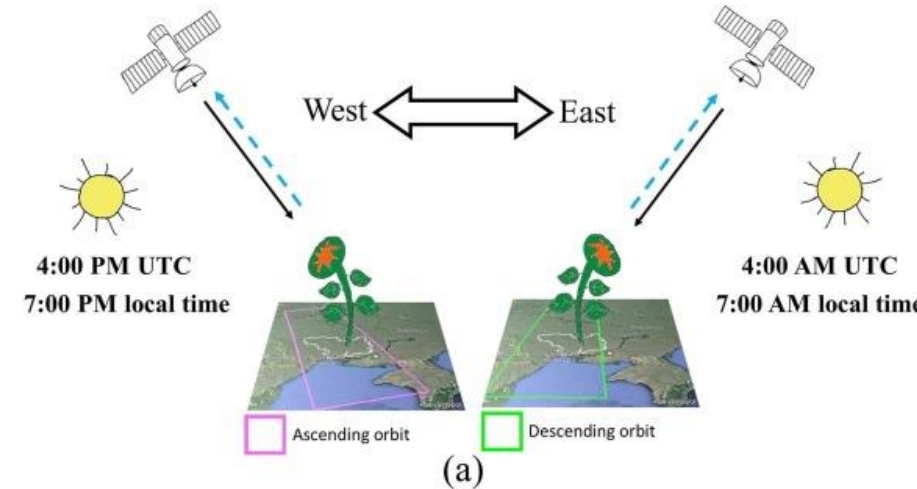


Sunflower mapping using Sentinel-1 data



- **Heliotropic** and directional **behavior** of sunflower in Sentinel-1/SAR imagery
- SAR-based **generalized model** for automatic sunflower mapping
- High PA/UA accuracy (>85%) early **in season**

Remote Sensing of Environment 295 (2023) 113689



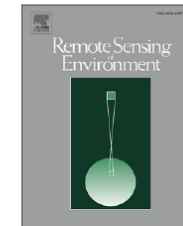
Heliotropic/directional behavior in sunflower as detected by Sentinel-1 ascending and descending orbit during initial (a) pre-flowering stage and (b) during flowering stage. 15



Contents lists available at ScienceDirect

Remote Sensing of Environment

journal homepage: www.elsevier.com/locate/rse



Sentinel-1 time series data for sunflower (*Helianthus annuus*) phenology monitoring

Abdul Qadir^{a,*}, Sergii Skakun^{a,b}, Jaemin Eun^a, Meghavi Prashnani^a, Leonid Shumilo^a

^a Department of Geographical Sciences, University of Maryland, College Park, MD 20740, USA

^b College of Information Studies (iSchool), University of Maryland, College Park, MD 20740, USA



Sunflower: sampling

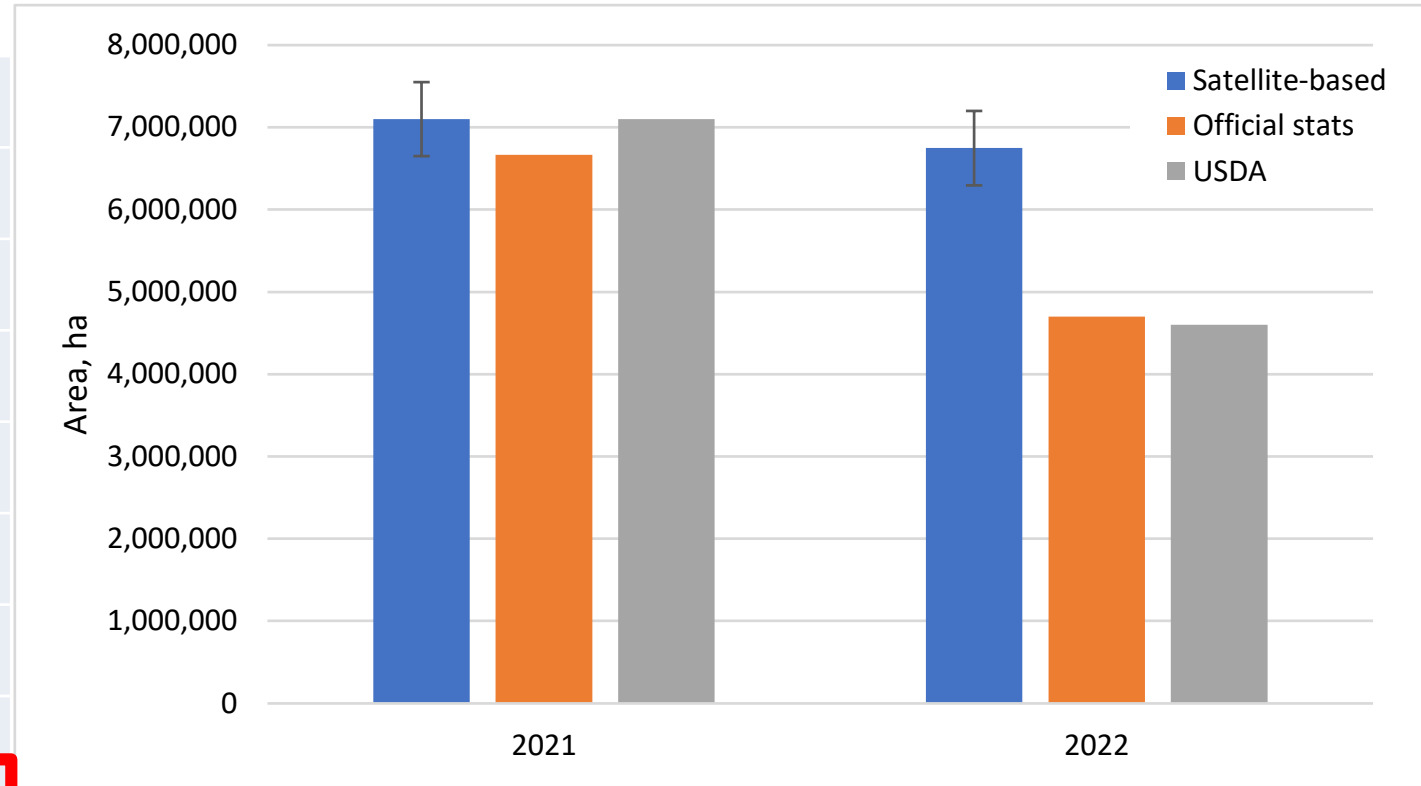
Strata	Wh	nh
Stable sf	0.011	200
2021 sf, 2022 nsf	0.111	200
2021 nsf, 2022 sf	0.106	200
Stable nsf cropland	0.328	100
Stable nsf non-cropland	0.445	100
Total	1	800

sf=sunflower, nsf=non-sunflower



Sunflower

	Area, Mha	CI, Mha
Sf 21-22	0.61	0.07
Sf 21, Nsf 22	6.5	0.4
Nsf 21, Sf 22	6.1	0.4
Sf 2021	7.1	0.4
Sf 2022	6.7	0.4
Difference 2022-2021	-0.35	0.19



Temporary occupied territories

Impact of war on sunflower crop

- Sunflower hotspots moved from South-East Ukraine to Center
- Almost 5% decrease in overall sunflower area in comparison to 2021
- Decrease in sunflower area in Temporary occupied territories compensated by increase in sunflower area in free Ukraine

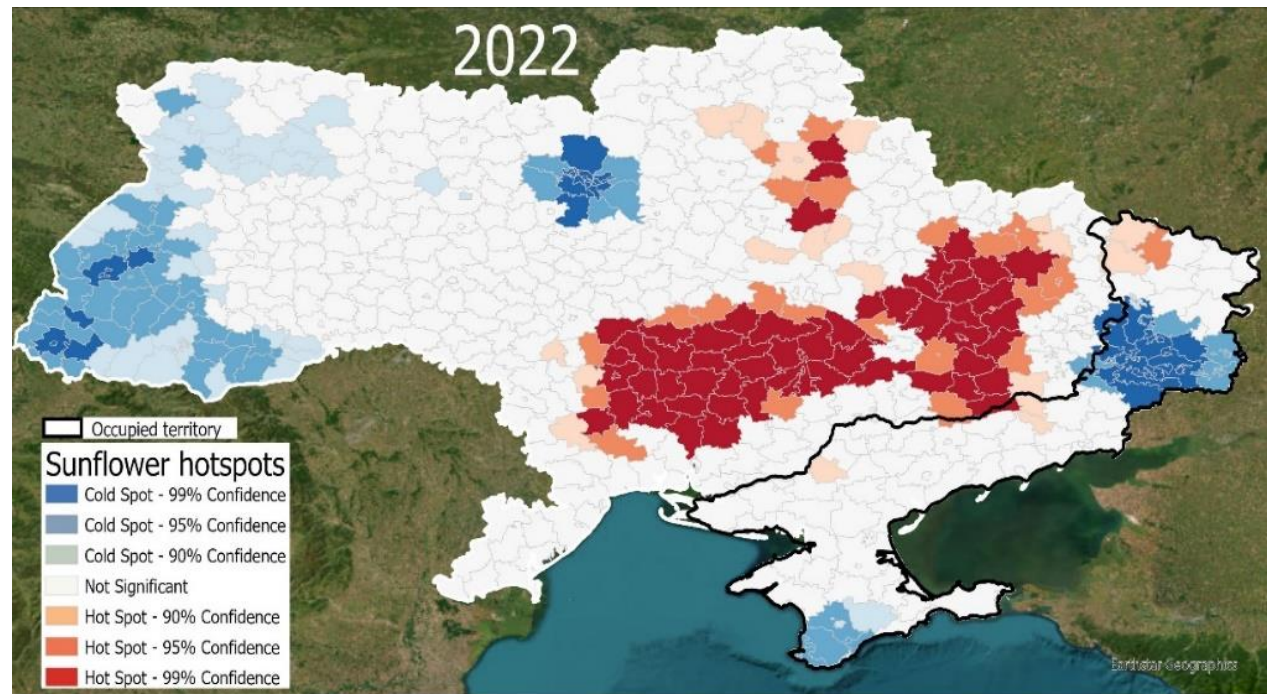
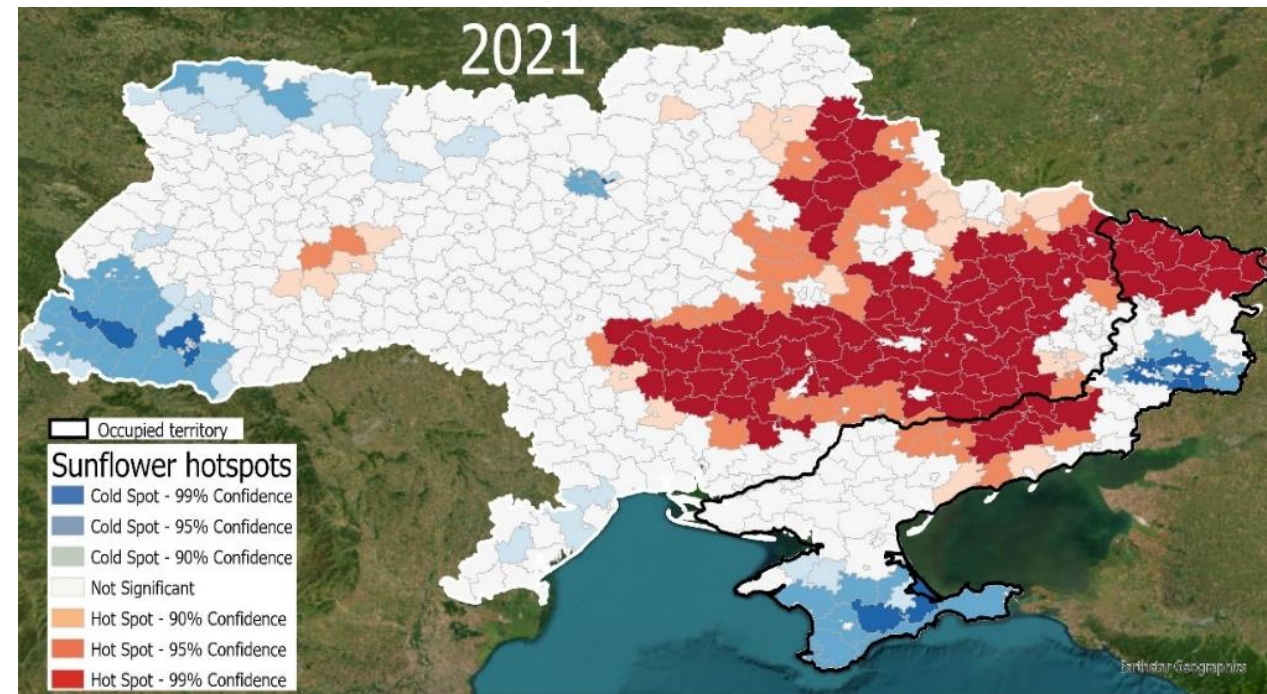
Hotspot analysis

Statistically significant spatial clusters of **high values (hot spots)** and **low values (cold spots)**

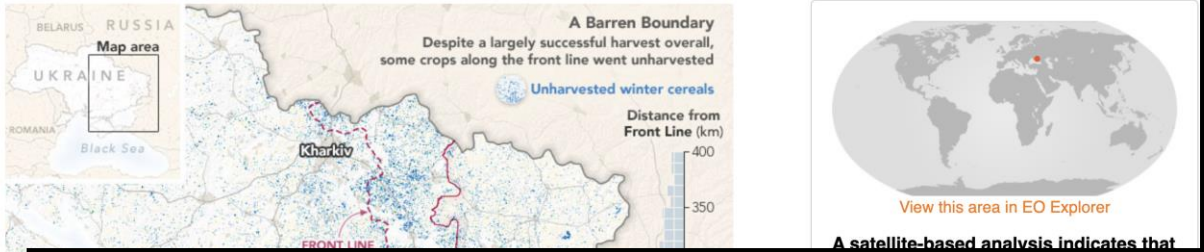
Getis-Ord G_i^* statistic:

$$G_i^* = \frac{\sum_{j=1}^n w_{i,j} x_j - \bar{X} \sum_{j=1}^n w_{i,j}}{S \sqrt{\frac{n \sum_{j=1}^n w_{i,j}^2 - \left(\sum_{j=1}^n w_{i,j} \right)^2}{n-1}}}$$

where \bar{X} and S are mean and std



Larger Wheat Harvest in Ukraine Than Expected



Russia Reaped \$1 Billion of Wheat in Occupied Ukraine, NASA Says

- NASA Harvest uses satellite imagery to model wheat crop
- A quarter of Ukraine wheat is grown on land claimed by Russia

The timeliness, objectivity, and transparency of the information remain essential factors in shaping a balanced and effective agrarian policy. We acknowledge and appreciate the vital role of NASA Harvest's solutions and calculations in assessing the real state of agricultural production development in Ukraine, ensuring regional food security, and determining the export potential to support global food security.

Letter from First Deputy Minister of Agrarian Policy and Food of Ukraine, Mr. Taras Vysotskyi

