



# FORECASTING WHEAT YIELD OVER THE MAJOR WHEAT EXPORTING COUNTRIES.

*B. Franch*<sup>1,2</sup>, *E. Vermote*<sup>3</sup>, *S. Skakun*<sup>2,3</sup>, *A. Santamaria-Artigas*<sup>2,3</sup>, *N. Kalecinski*<sup>2,3</sup>, *J.-C. Roger*<sup>2,3</sup>,  
I. Becker-Reshef<sup>2</sup>, B. Mollà-Bononad<sup>1</sup>, A. San Bautista<sup>4</sup>, C. Rubio<sup>4</sup>, *C. Justice*<sup>2</sup>, J.A. Sobrino<sup>1</sup>

<sup>(1)</sup> Universitat de Valencia, Image Processing Laboratory, Global Change Unit, Paterna, Valencia, Spain

<sup>(2)</sup> University of Maryland College Park, Department of Geographical Sciences, College Park, MD, United States,

<sup>(3)</sup> NASA Goddard Space Flight Center, Code 619, Greenbelt, MD, United States

<sup>(4)</sup> Departamento de Producción Vegetal, Universitat Politècnica de València (Valencia), 46022, Spain

**belen.franch@uv.es**

**befranch@umd.edu**



# EARTH DATA FOR INFORMED AGRICULTURAL DECISIONS



**NASA Harvest** is a multidisciplinary Consortium commissioned by NASA and led by the University of Maryland to enhance the use of **satellite data** in **decision making** related to **food security and agriculture** domestically and globally.



- Launched October 2017
- 5 years initial award (annual renewal)
- End user driven
- Impact focused





# ARYA method

## ARYA AGRICULTURE REMOTELY SENSED YIELD ALGORITHM



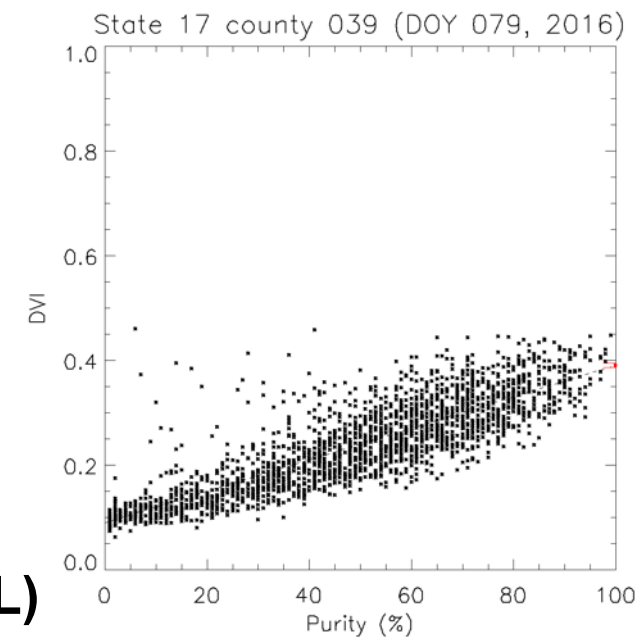
For each AU and a given date, the total DVI signal from each pixel can be written as:

$$DVI_i = (DVI_{wheat} - DVI_{others}) \cdot Wpct_i + DVI_{others}$$

$DVI_{wheat}$ : DVI signal from the wheat

$DVI_{others}$ : DVI from other surfaces within the pixel

$Wpct$ : percentage of wheat within the pixel or wheat purity



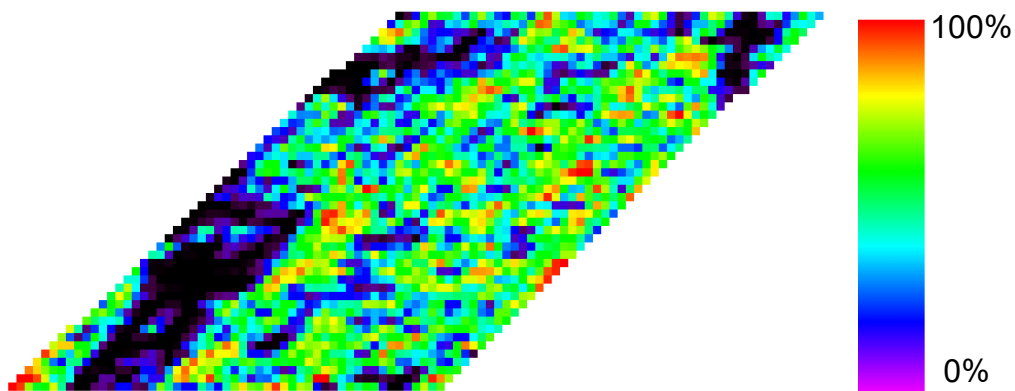
**MODIS 1km RGB (2/21/2017)**

Harper county (Kansas)



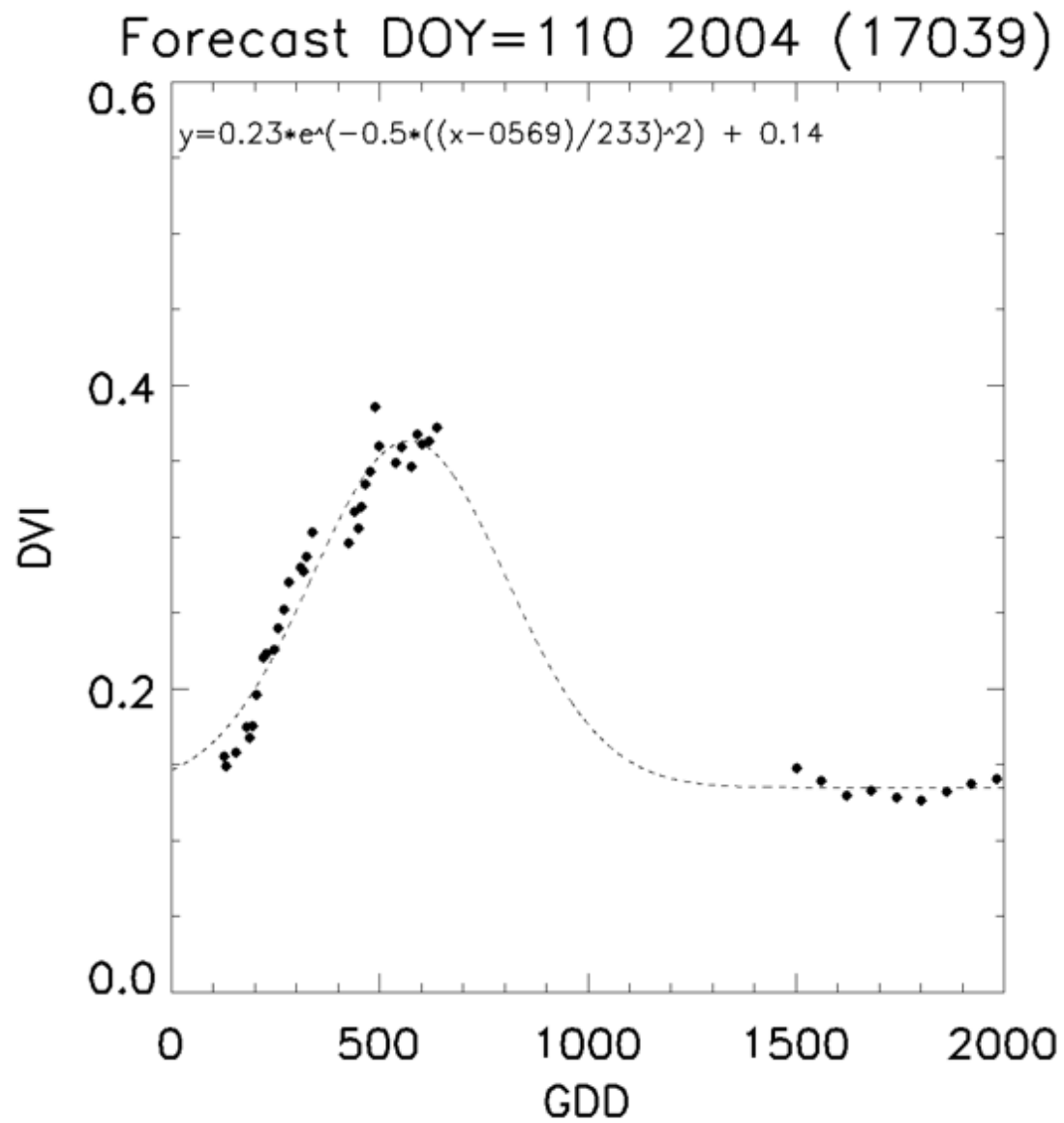
**2017 wheat mask (from CDL)**

Harper county (Kansas)



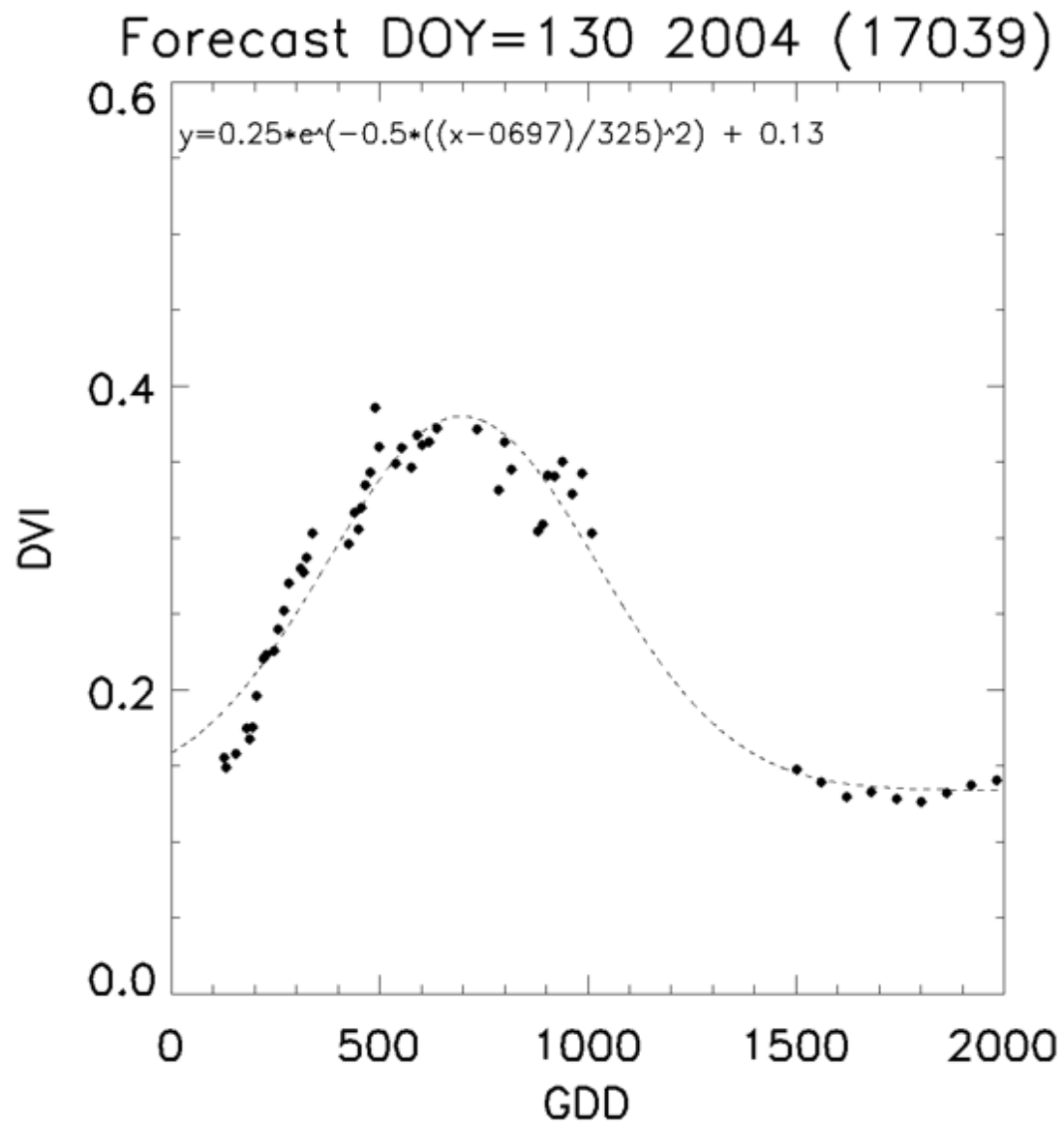


# Yield forecasting



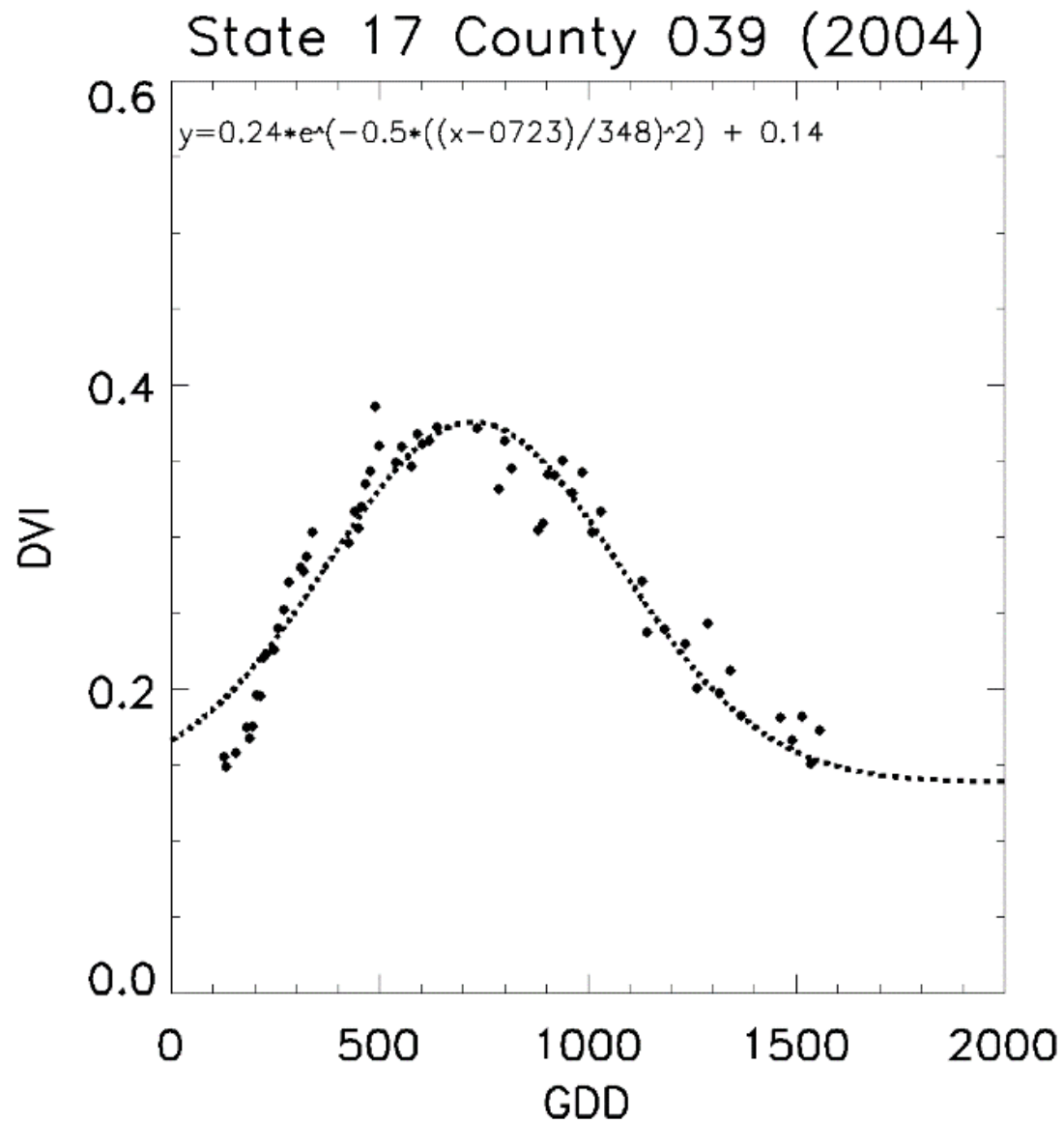


# Yield forecasting





# Yield forecasting

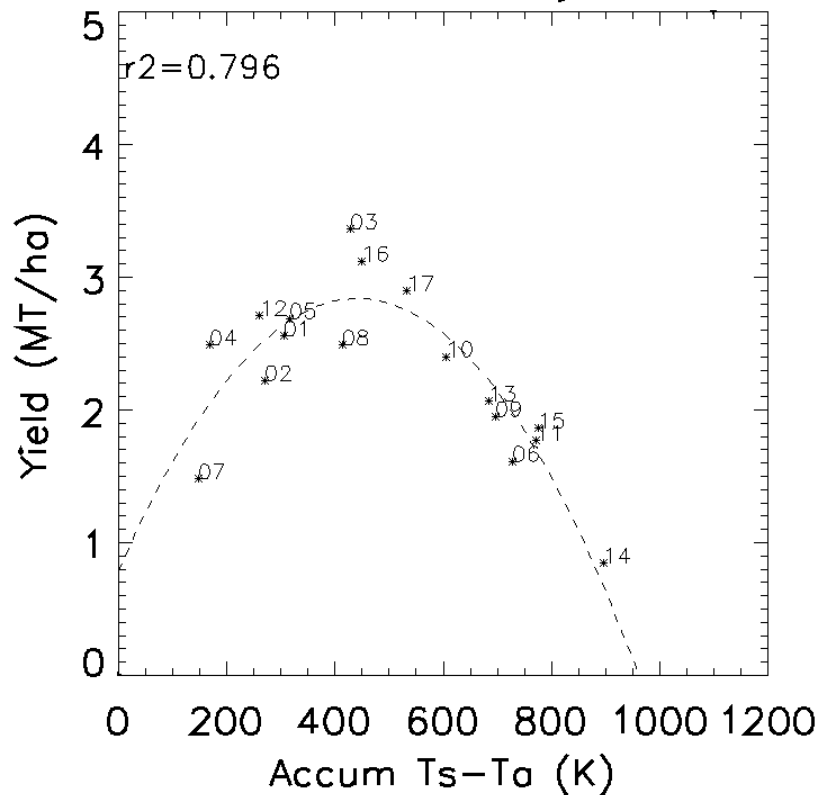


# Influence of the LST?

$T_s - T_{air}$ 

- > 0 : plant has **higher** temperatures than the surrounding, might be related to water stress conditions
- < 0 : plant has **lower** temperatures than the surrounding, might be related to frost conditions

Accumulation  
 40 days after the peak  
 State 17 county 039

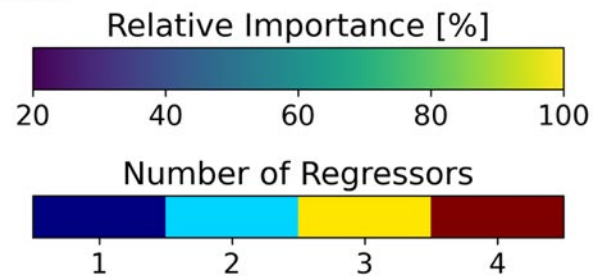
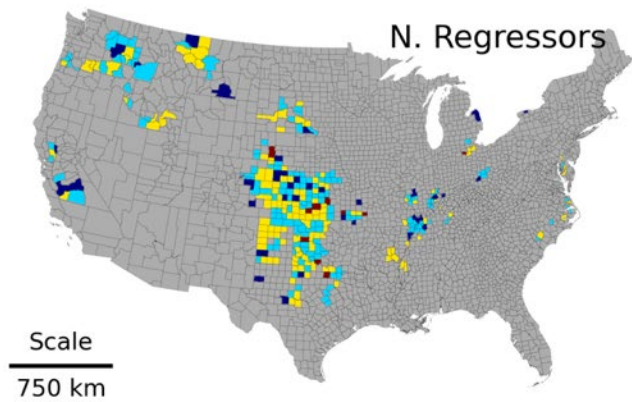
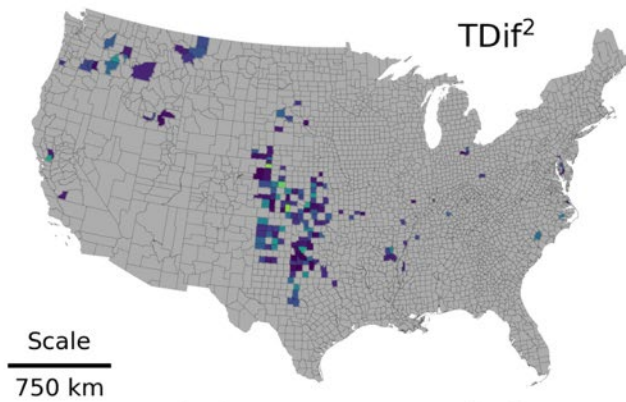
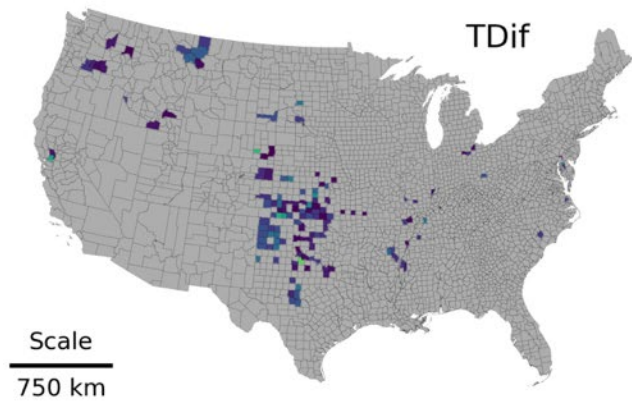
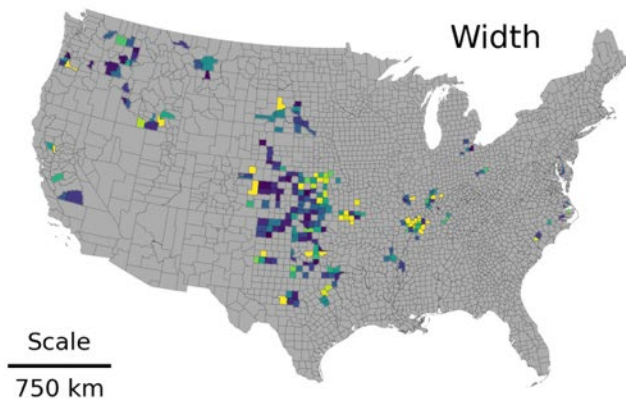
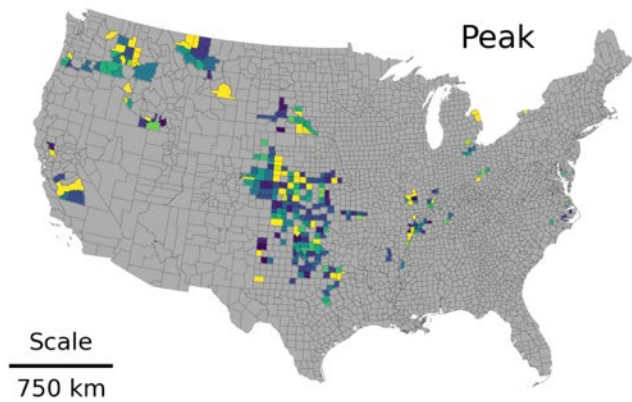


## 4 regressors to be considered against yield

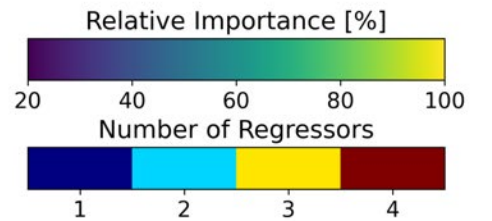
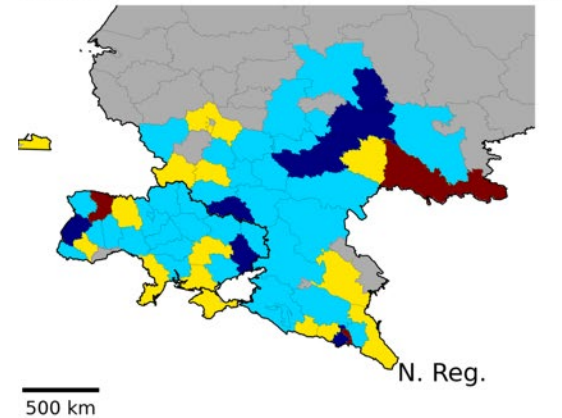
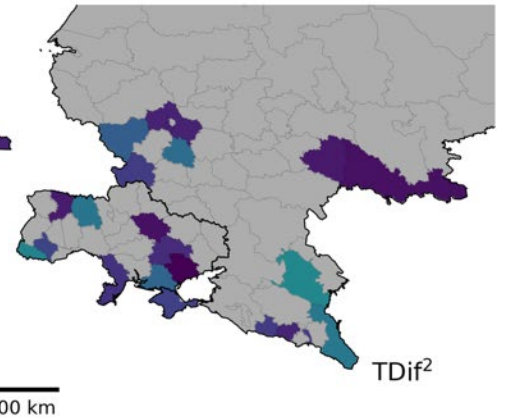
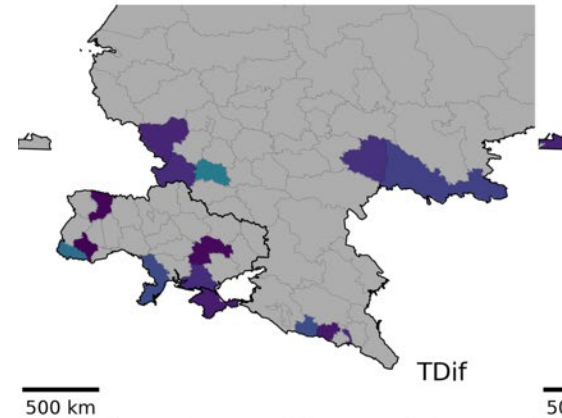
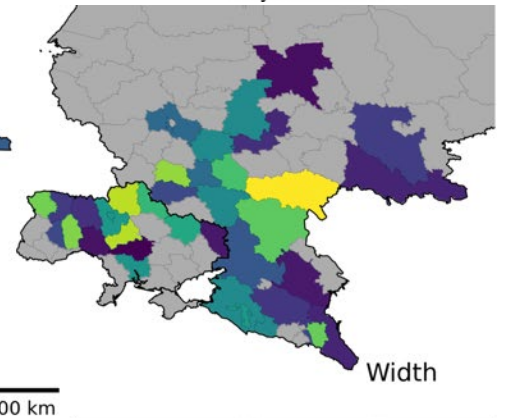
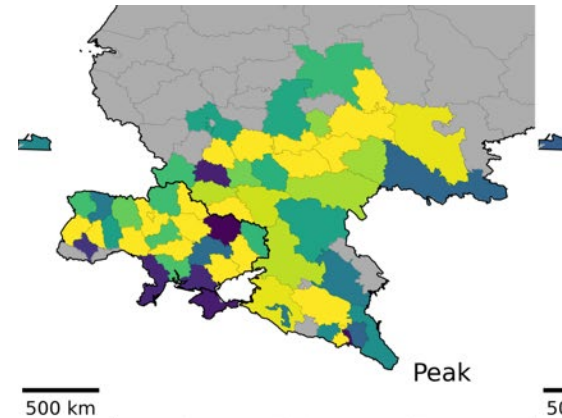
- DVI Peak value (A)
- Width of the DVI curve (C)
- LST-Tair accum
- (LST-Tair accum)<sup>2</sup>

$$yield_{i,t} = c1_{i,t} \cdot A_{i,t} + c2_{i,t} \cdot C_{i,t} + c3_i \cdot TDif_{i,t} + c4_i \cdot TDif_{i,t}^2$$

# ARYA calibration



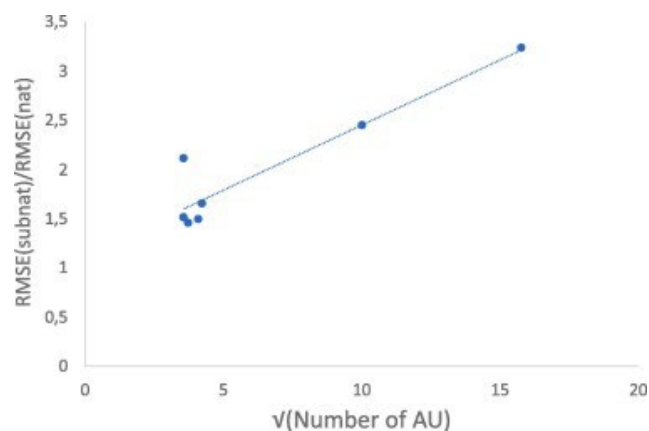
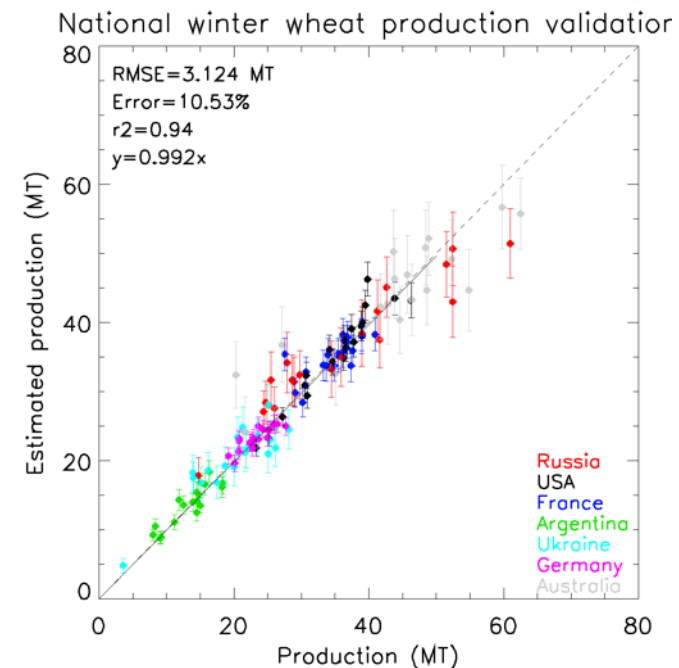
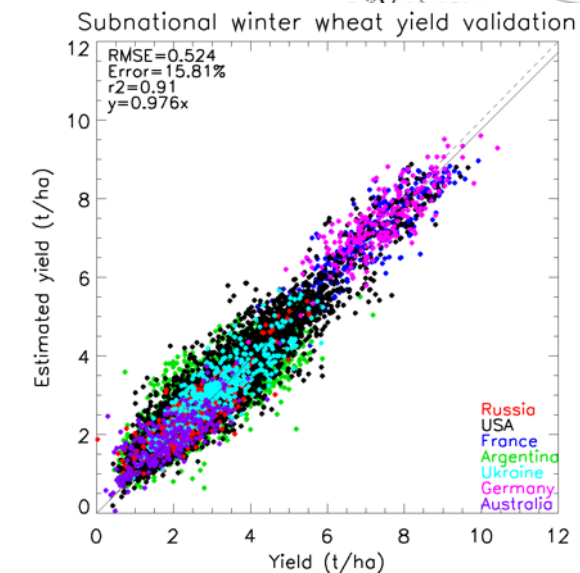
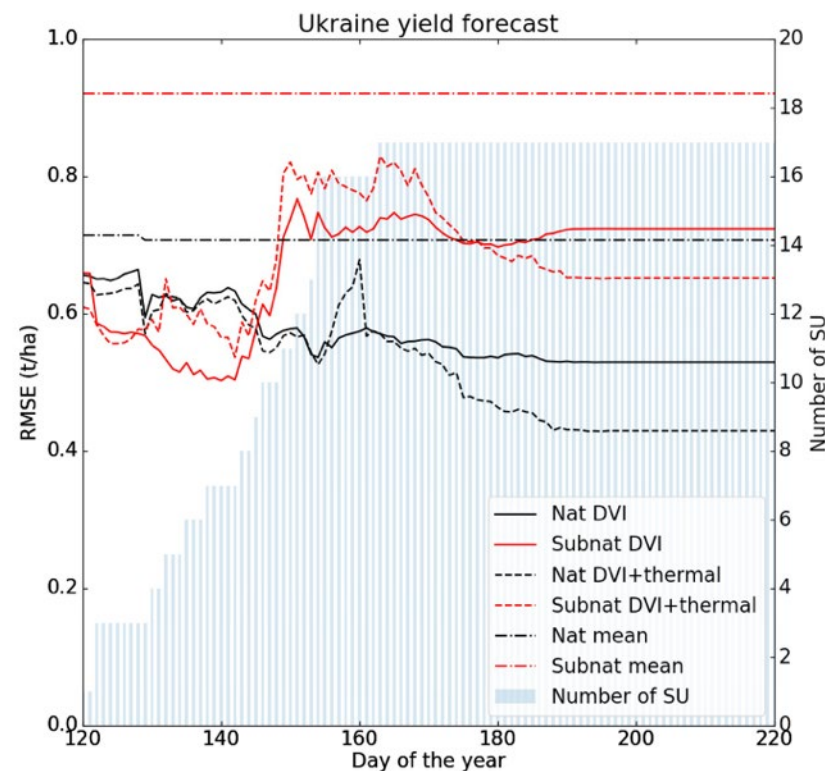
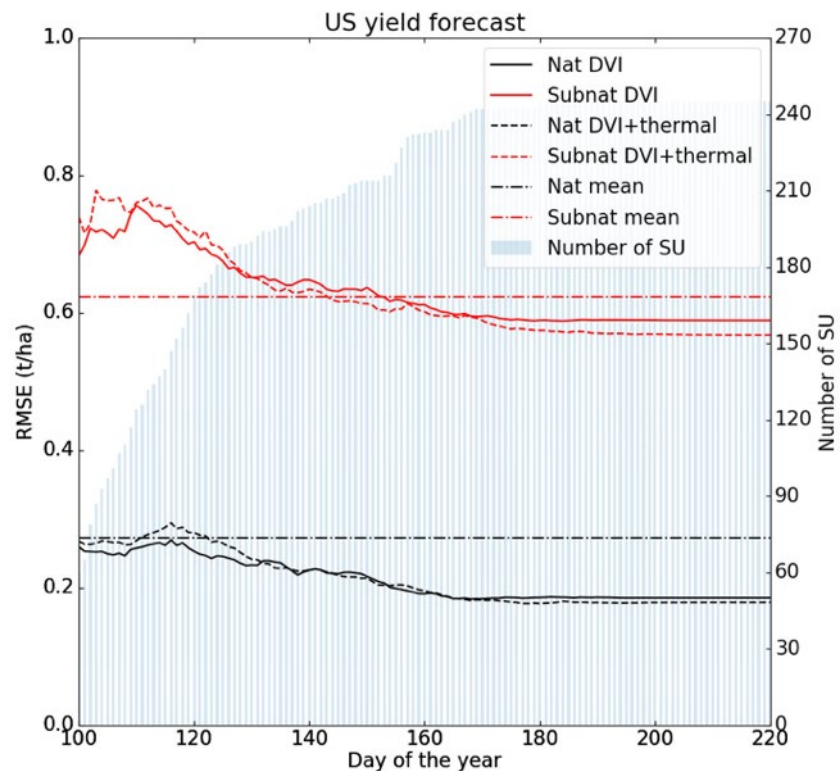
Map Projection:  
North America Lambert Conformal Conic



Map Projection:  
World Winkel Tripel

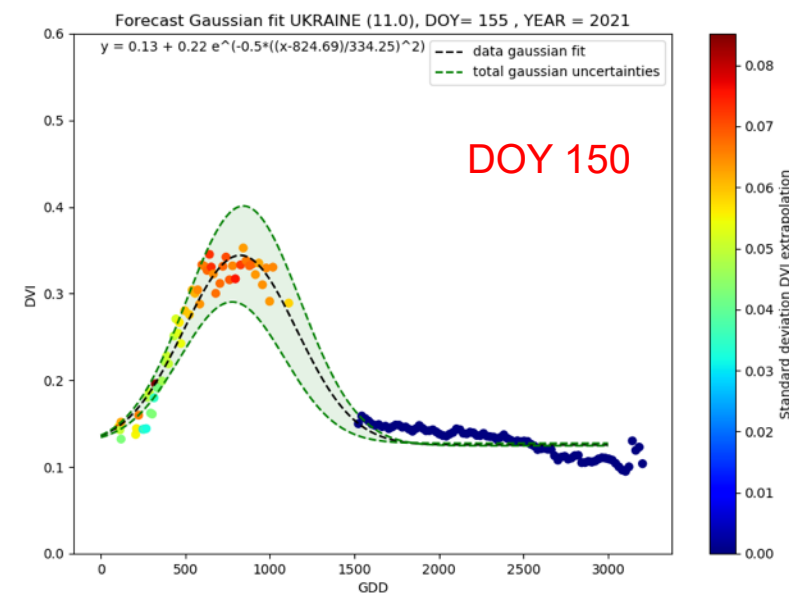
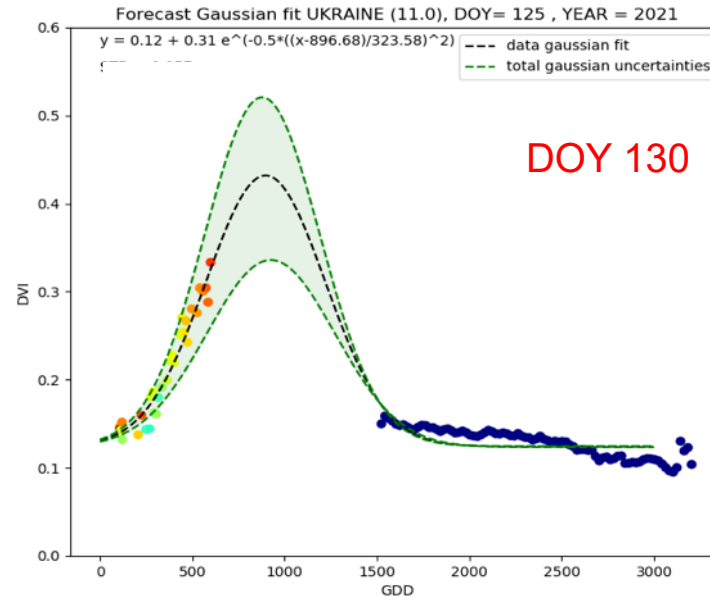
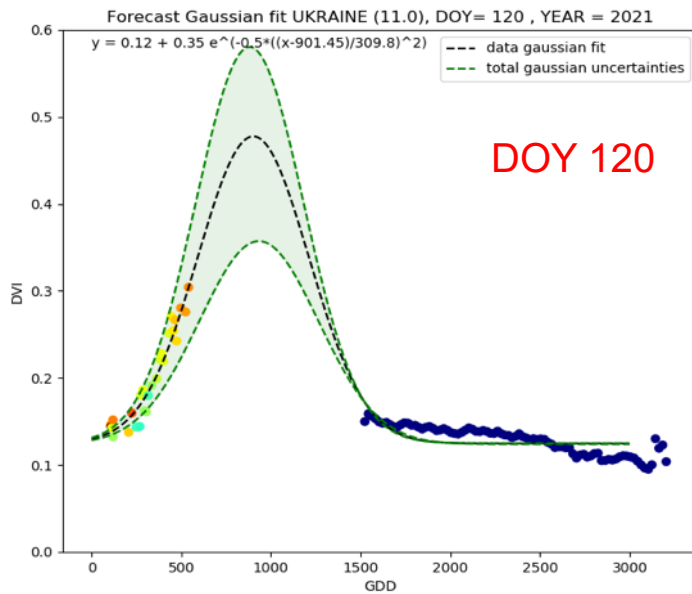


# ARYA cross-validation



**Reliable forecasts  
(4-10% error at national and  
8-20% error at subnational level)  
from 2-2.5 months prior to harvest**

## ARYA OPER 2021 Russia & Ukraine Every week: Gaussian Fit DVI/GDD : Peak & Width





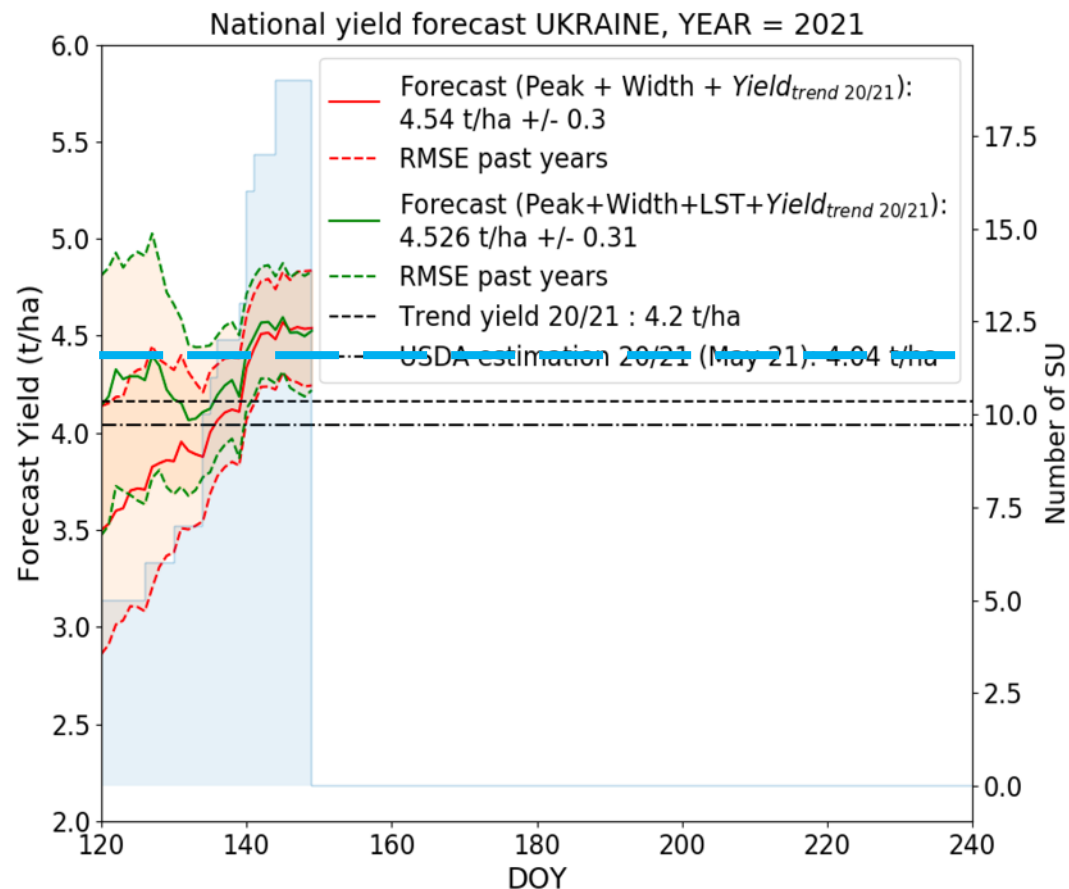
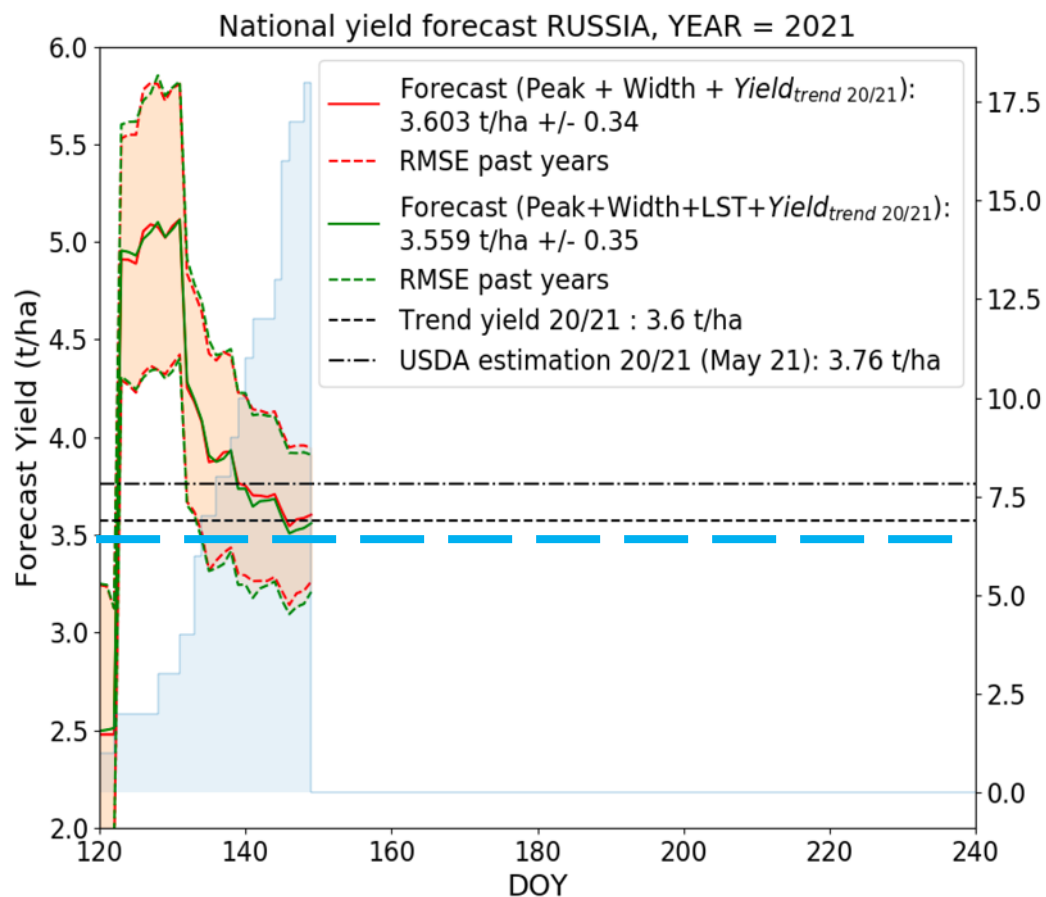
# ARYA is operational



## ARYA OPER 2021 : DOY 150

RUSSIA

UKRAINE

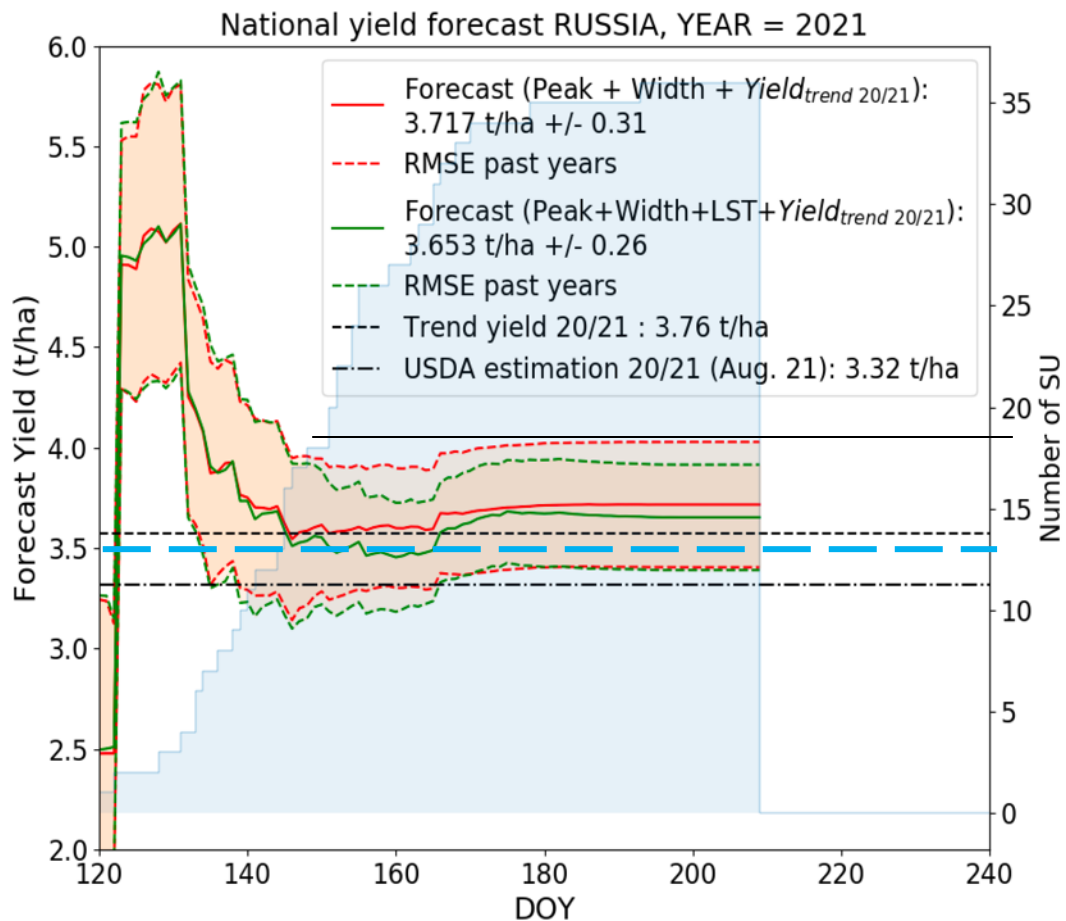


# ARYA is operational

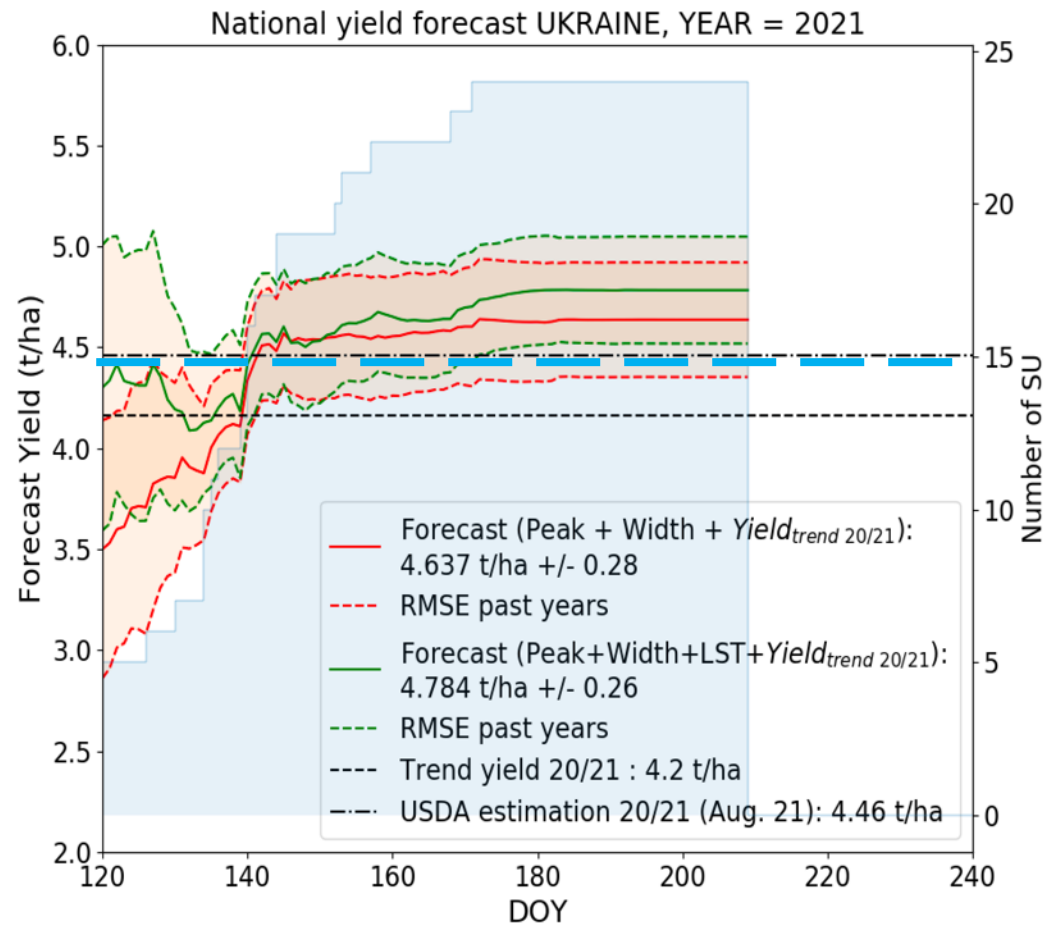
## ARYA OPER 2021 : DOY 210

RUSSIA

UKRAINE

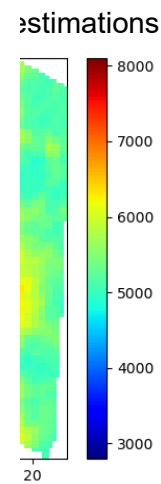
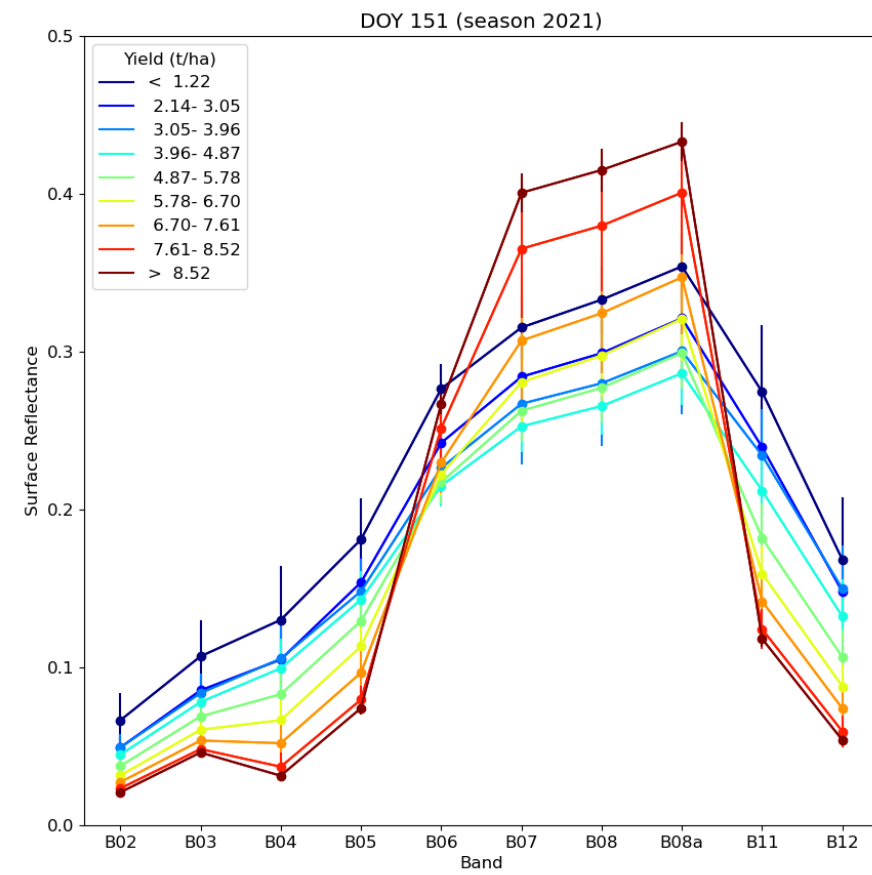
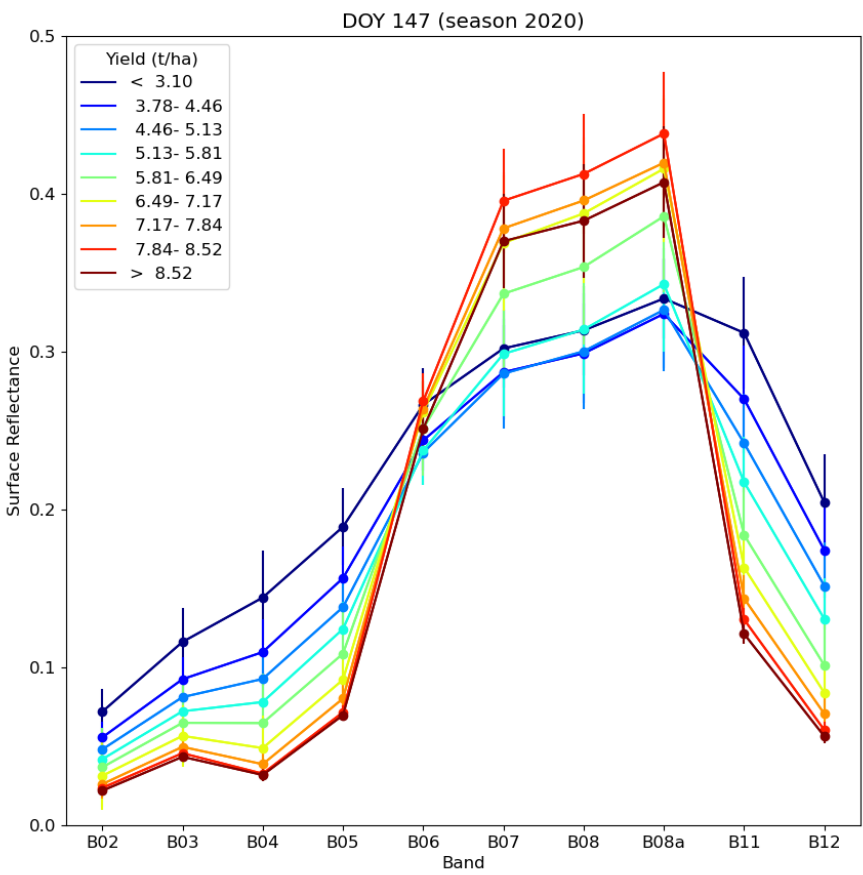
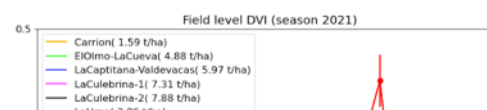
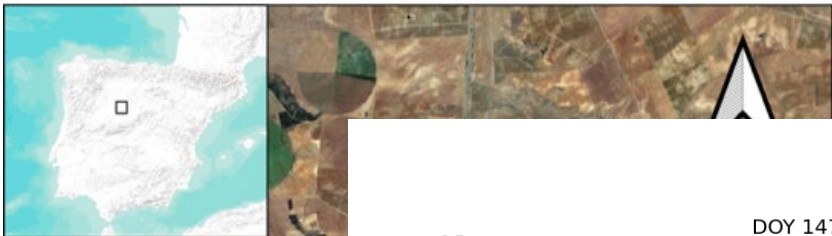


Final yield=3.5t/ha



Final yield=4.46t/ha

# Application at within-field scale?



Sentinel-2  
DVI

$$DVI = A * e^{(-...)}$$

at pixel level

# WorldCereal: Demonstration global seasonal crop mapping

Based on open and free Data (S1, S2, L8) products at 10m resolution (annual cropland, maize map, wheat map, irrigation and active cropland marker)



KO June 2020

2 phases: Prototyping & Implementation  
1.5 MEUR (inc. user & processing costs)

Phase 1: 5 large areas on 3 continents

Phase 2: global crop coverage

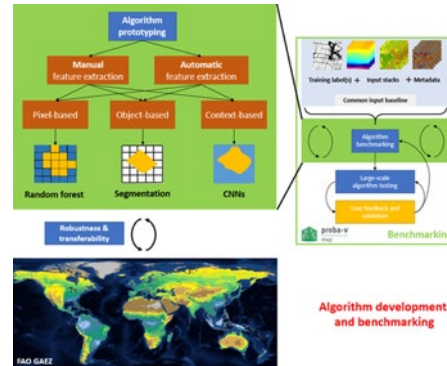
Core users:  
FAO, GEOGLAM, G20 AMIS & 21 users around the world



## Phase 1; prototyping

- ❖ User requirement consolidation
- ❖ system design
- ❖ Benchmarking
- ❖ Building global reference database
- ❖ Large scale demonstration (area selection, Production, validation)

**Completed**



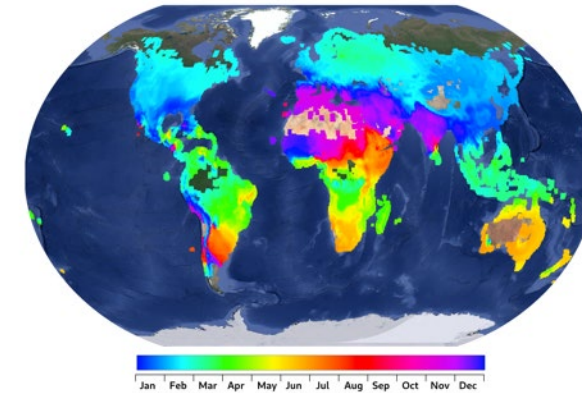
## Selected zones for large scale demonstration

Zone	Overall accuracies cropland maps
France	(OA 96,6%)
Spain	(OA 83,7%)
Ukraine (central)	(OA 95,7%)
Northern Tanzania	(OA 89,3%)
Argentina	(AO 90,3%)

Selected based on discussion with users, number of seasons, field sizes, agro ecological zones, cloud cover, climatology, availability of ground data, field sizes,...

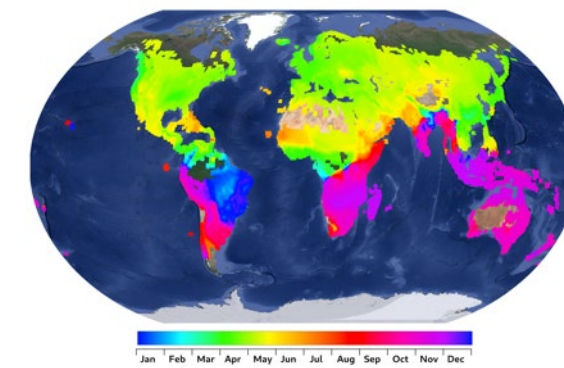
## Generation of global pixel-based crop calendars

Winter cereals SOS



Franch, B., Cintas, J., Becker-Reshef, I., Sanchez-Torres, M.J., Roger, J., Skakun, S., Sobrino, J.A., Van Tricht, K., Degerickx, J., Guillems, S., Koetz, B., Szantoi, Z., Whitcraft, A. (2022) Global crop calendars of maize and wheat in the framework of the WorldCereal project.

Summer cereals SOS



**GIScience and Remote Sensing (In press)**

## Phase 2; Implementation

- ❖ Running the global system
- ❖ Capacity building
- ❖ Utility and benefit assessment

**Ongoing**



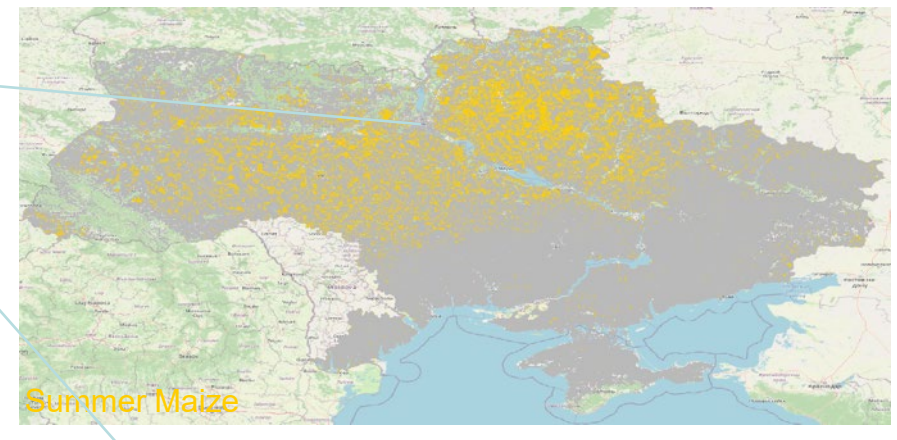
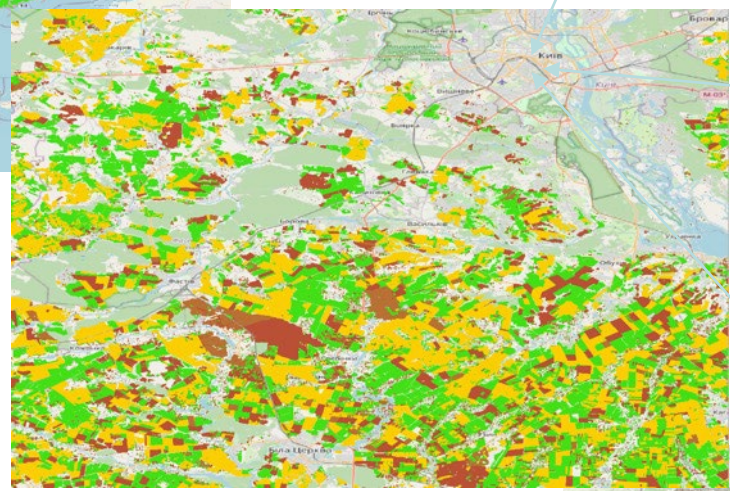
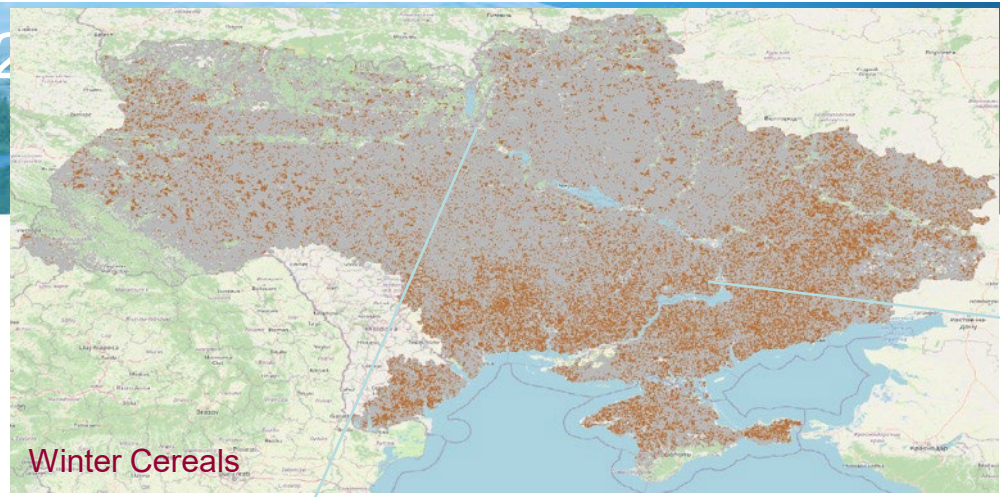
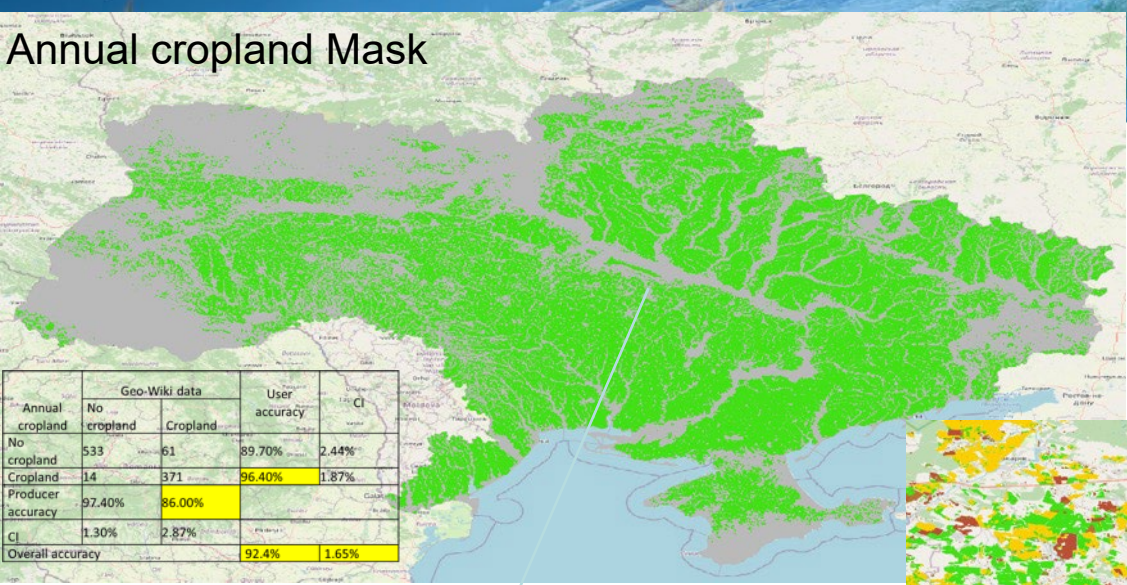
## Global Reference data



## Consortium



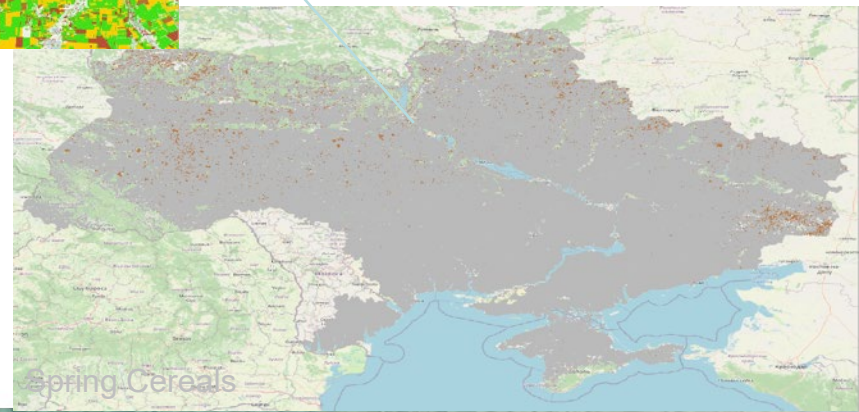
## Annual cropland Mask



- Annual Cropland
- Winter Cereals
- Spring Cereals
- Summer maize

↕

Combining annual cropland map with winter and spring cereals and summer maize. Green pixels, cropland but not maize nor cereal during summer or winter.



Annal Cropland 2021 Validated  
 Croptype maps 2021 Validation ongoing



# Conclusions

- ARYA can forecast yield over the main wheat exporting countries from 2-2.5 months prior to harvest with an accuracy
  - **7%** at national level
  - **15%** at sub-national level
- Applied successfully over the main wheat exporters
- Operational in Ukraine and Russia. Good results in 2021
- Field level results suggest better results using spectral information rather than VIs
- WorldCereal project global crop calendars and crop type maps at 10m resolution will enhance the ARYA performance