FORECASTING WHEAT YIELD OVER THE MAJOR WHEAT EXPORTING COUNTRIES.

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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.**

FOOD SECURITY, RESILIENCY

PRICE VOLATILITY, VULNERABILITY

- Launched October 2017

- 5 years initial award (annual renewal)

- End user driven

- Impact focused
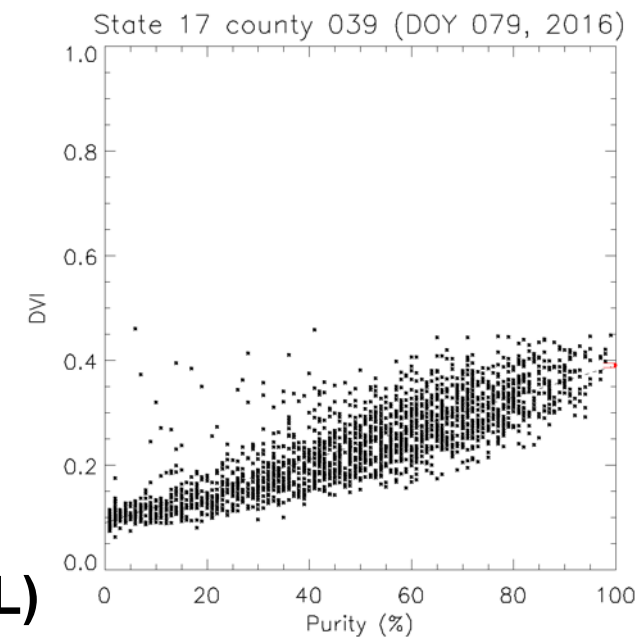
ARYA method

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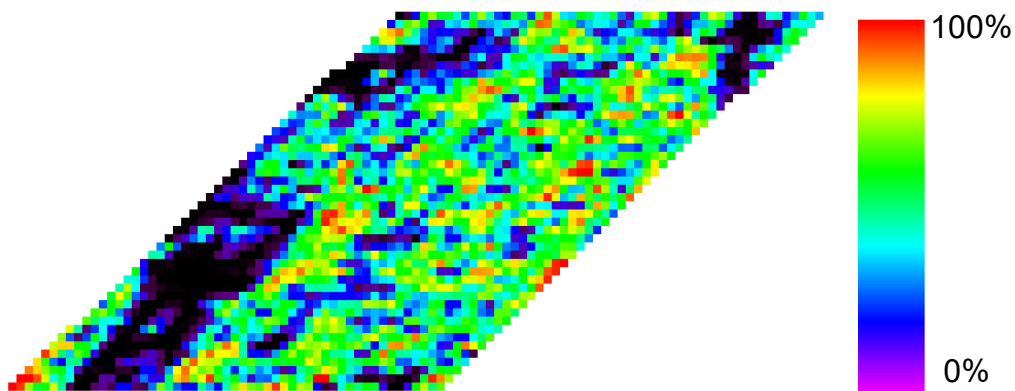$Wpct$: percentage of wheat within the pixel or wheat purity

State 17 county 039 (DOY 079, 2016)

MODIS 1km RGB (2/21/2017)
Harper county (Kansas)

2017 wheat mask (from CDL)
Harper county (Kansas)

Franch, B., Vermote, E., Skakun, S., Santamaria-Artigas, A., Kalecinski, N., Roger, J. C., ... & Sobrino, J. A. (2021). The ARYA crop yield forecasting algorithm: Application to the main wheat exporting countries. *International Journal of Applied Earth Observation and Geoinformation*, *104*, 102552.

Yield **forecasting**

Forecast DOY=110 2004 (17039)

$y = 0.23 * e^{(-0.5*((x-0569)/233)^2)} + 0.14$

Yield **forecasting**

Forecast DOY=130 2004 (17039)

$y=0.25*e^{(-0.5*((x-0697)/325)^2)} + 0.13$
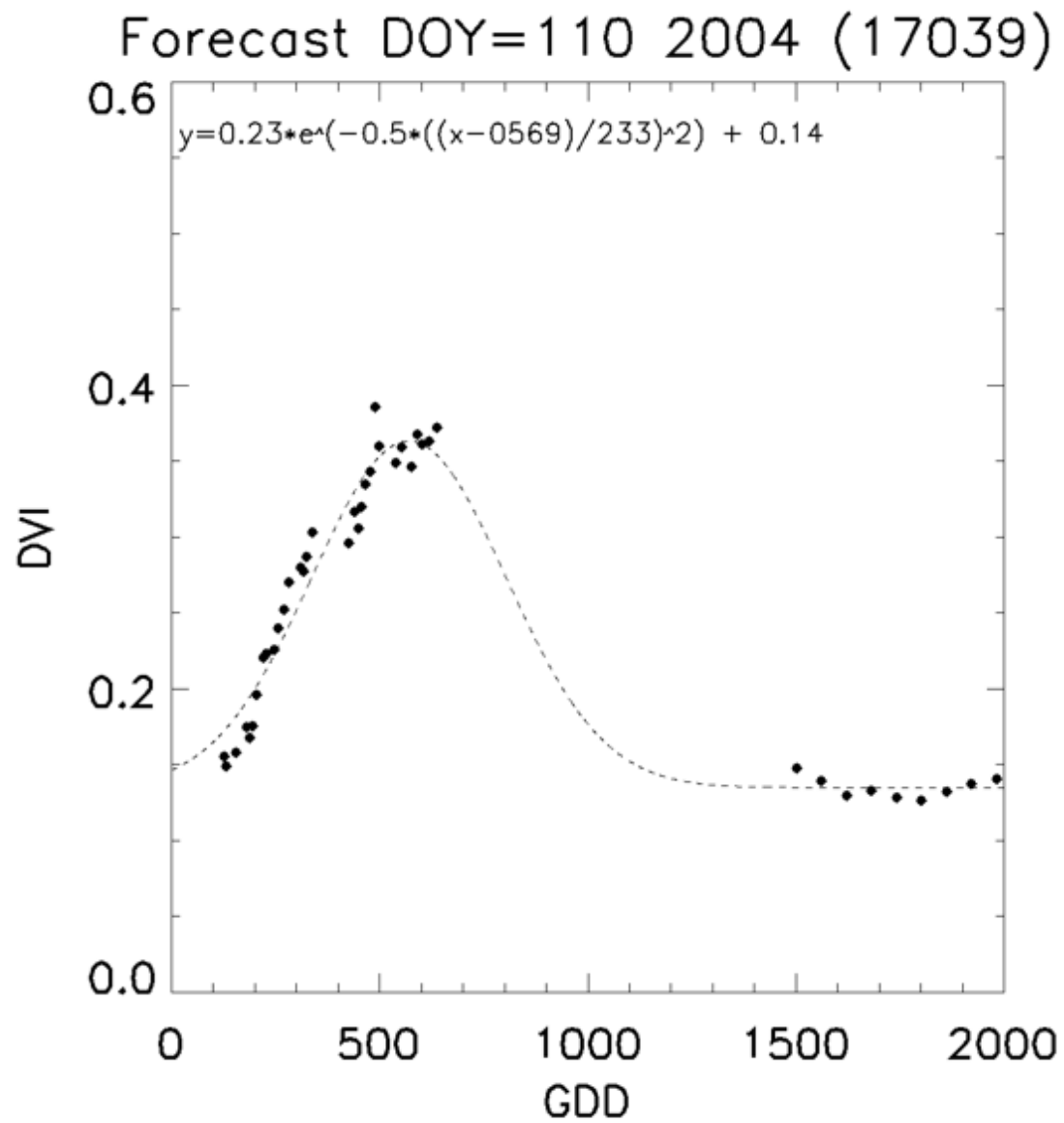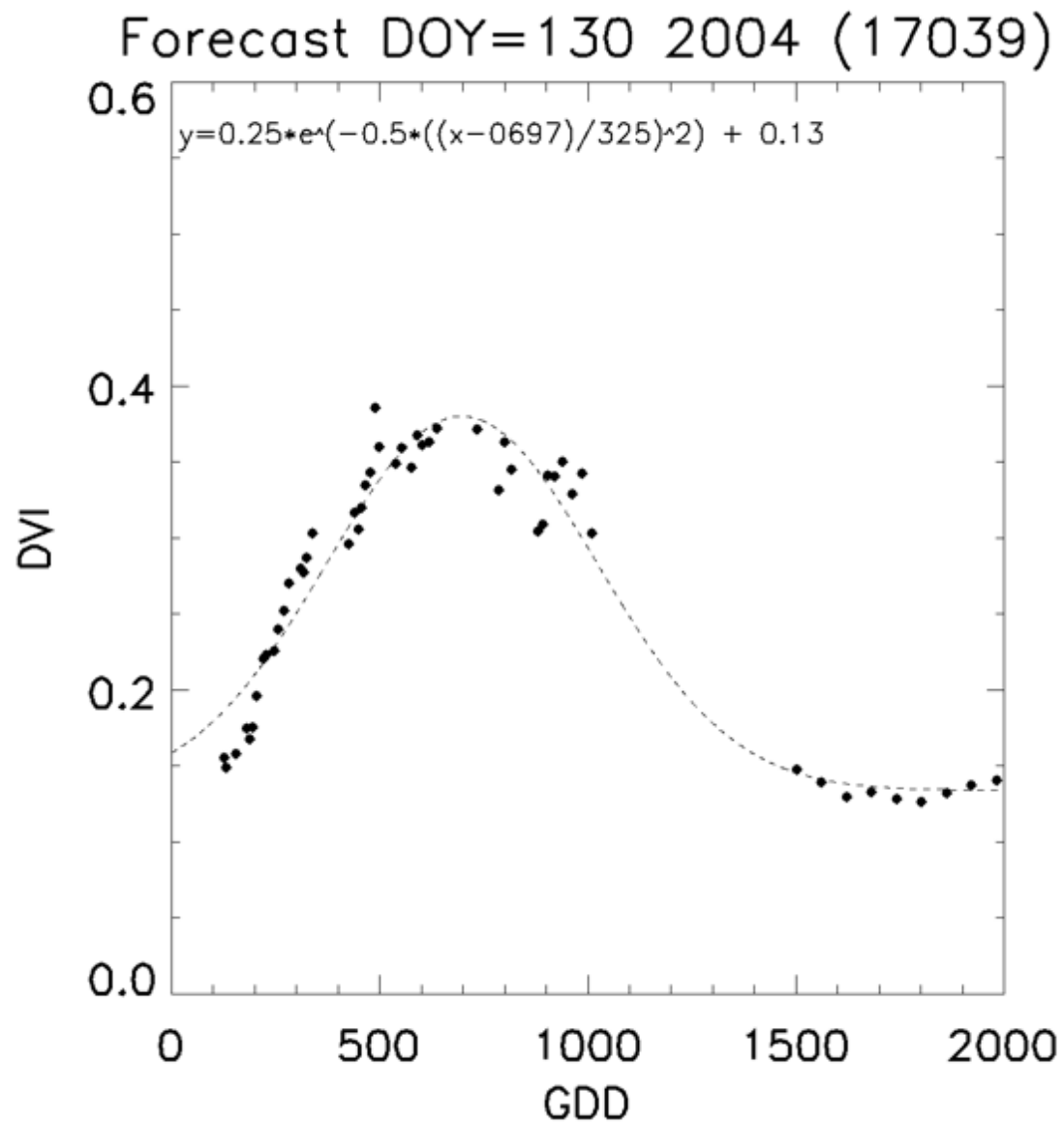
Yield **forecasting**

State 17 County 039 (2004)
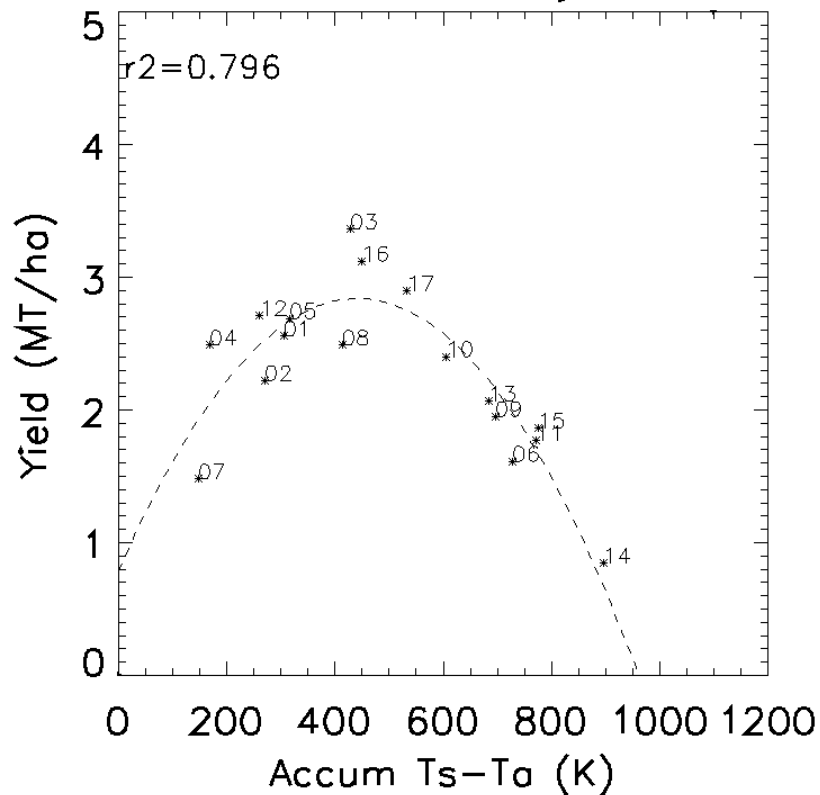
$y = 0.24 \ast e^{(-0.5 \ast ((x-0723)/348)^2)} + 0.14$
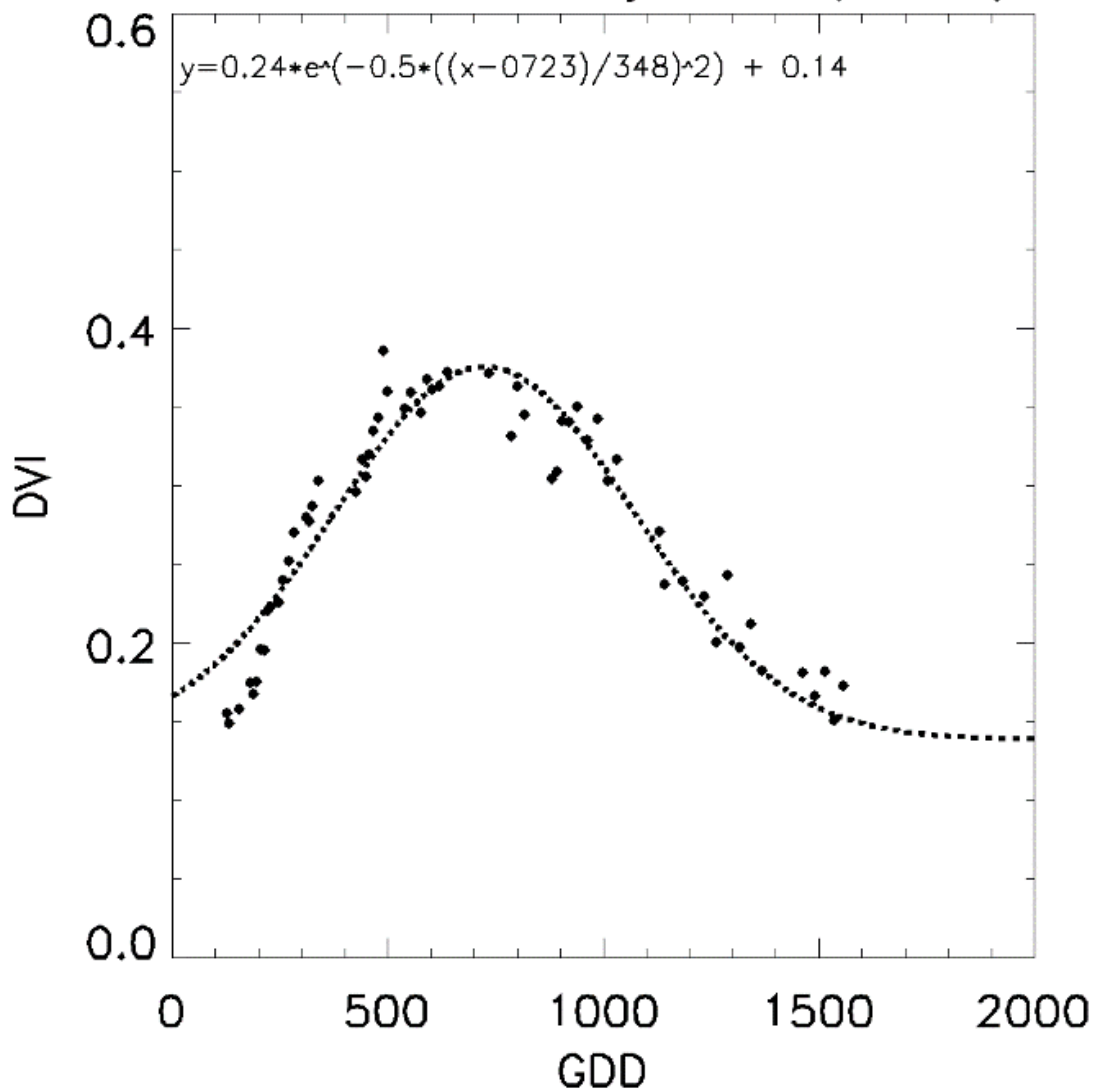
Influence of the LST?

Ts-Tair
- > 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
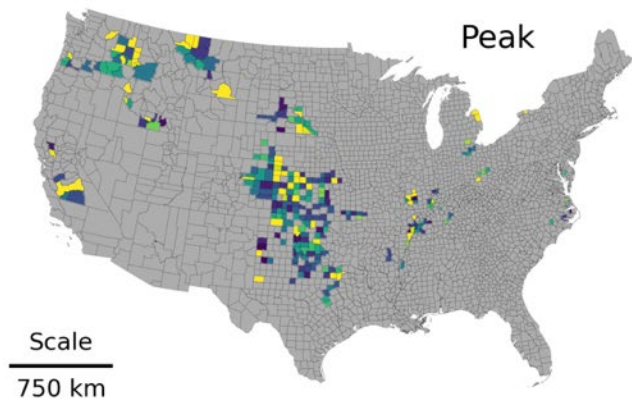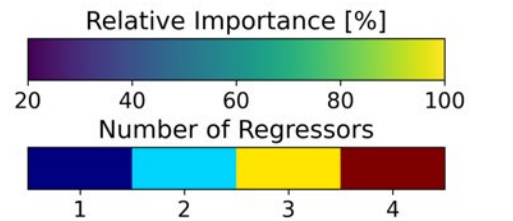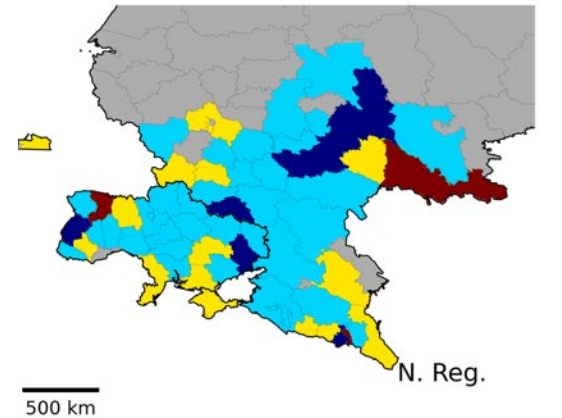
Accumulation
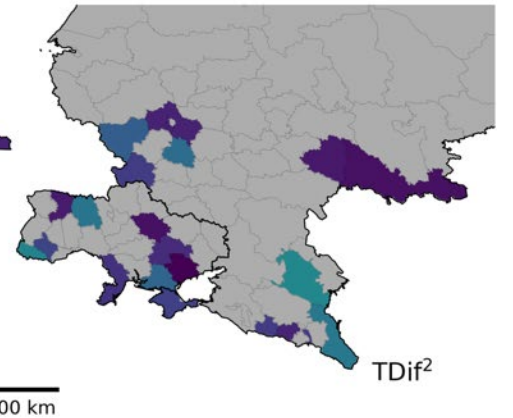40 days after the peak

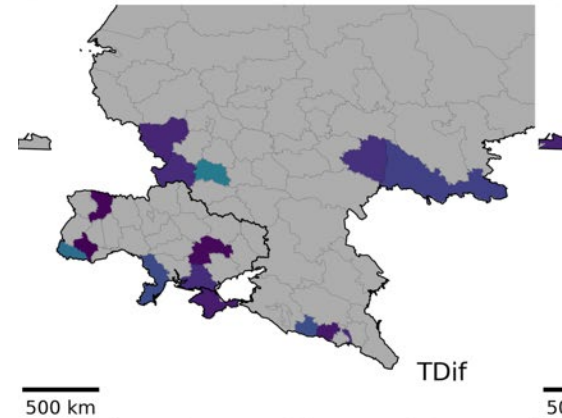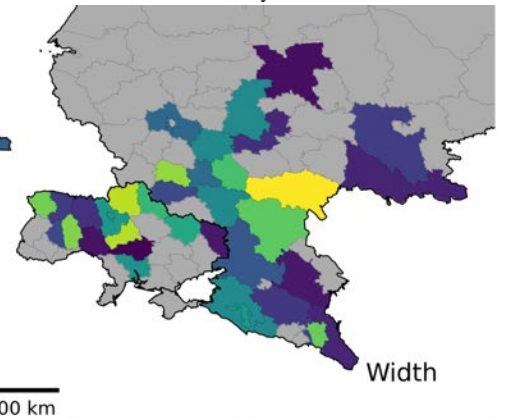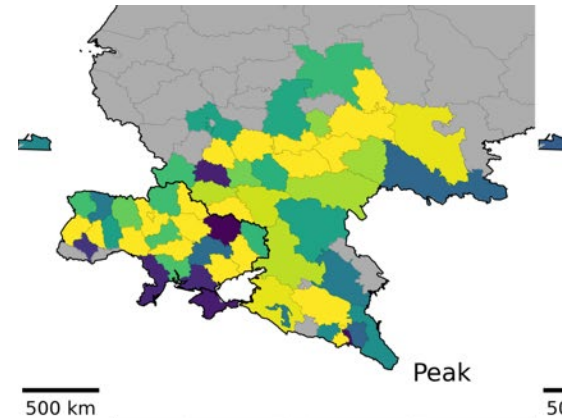**4 regressors to be considered against yield**

| DVI Peak value (A) | Width of the DVI curve (C) | LST-Tair accum | (LST-Tair accum)^2 |

$$yield_{i,t} = c1_{i,t} \cdot A_{i,t} + c2_{i,t} \cdot C_{i,t} + c3_i \cdot TDif_{i,t} + c4_i \cdot TDif_{i,t}^2$$
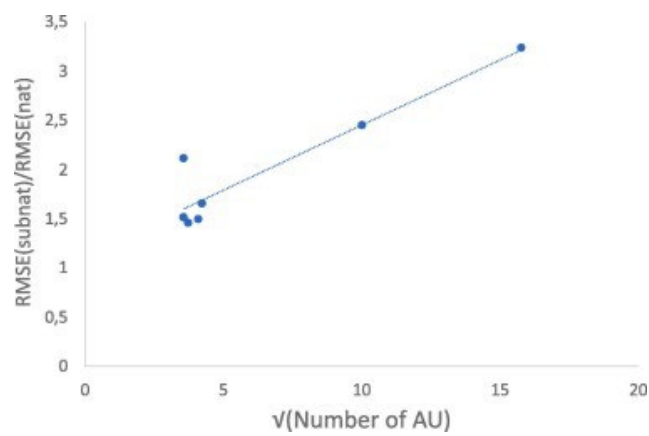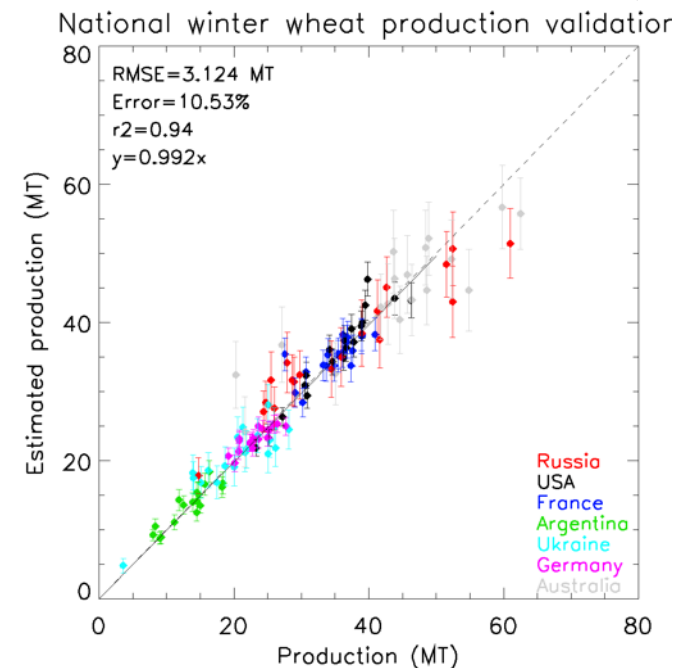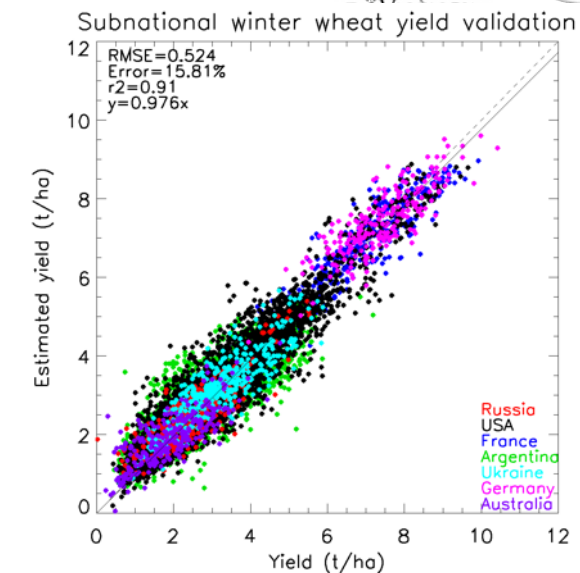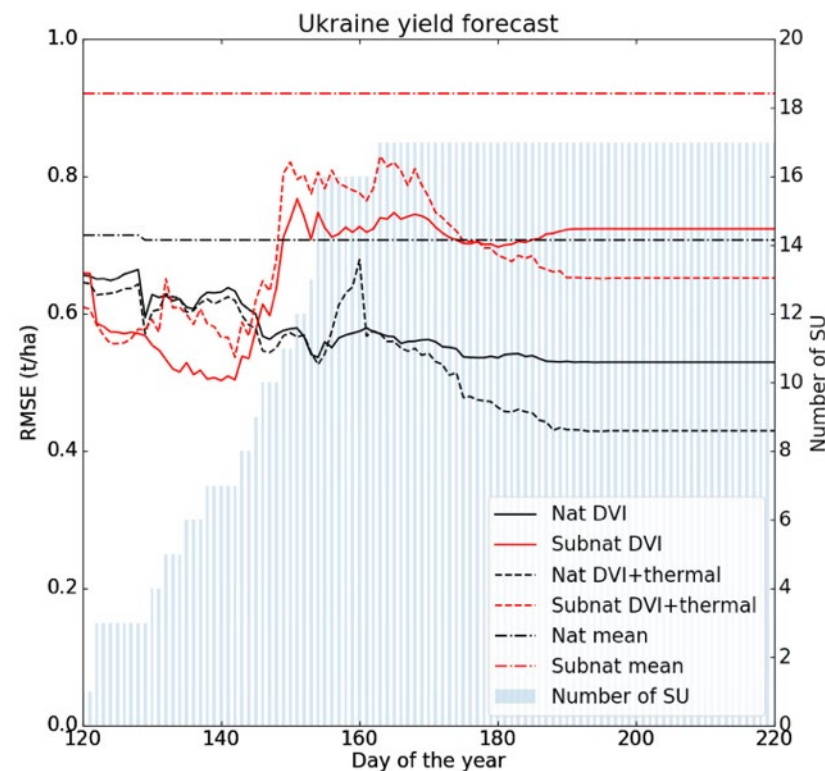
ARYA calibration
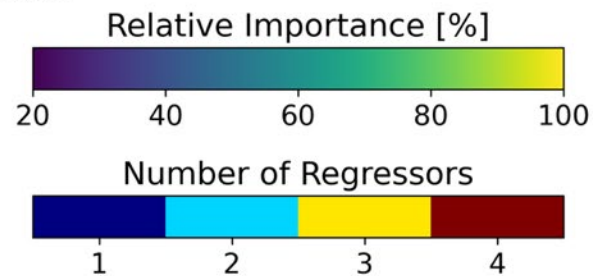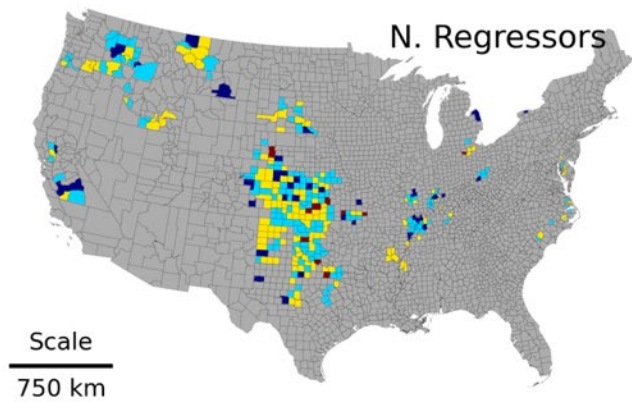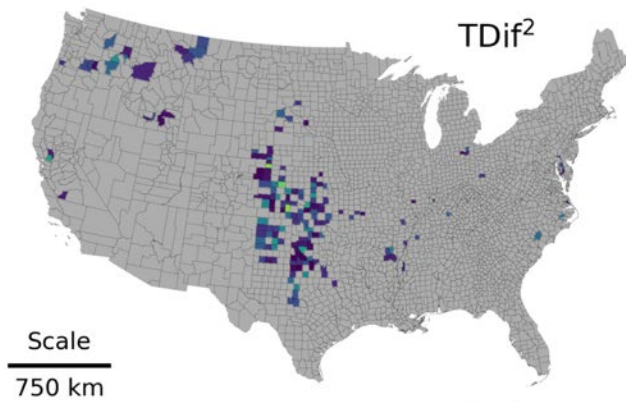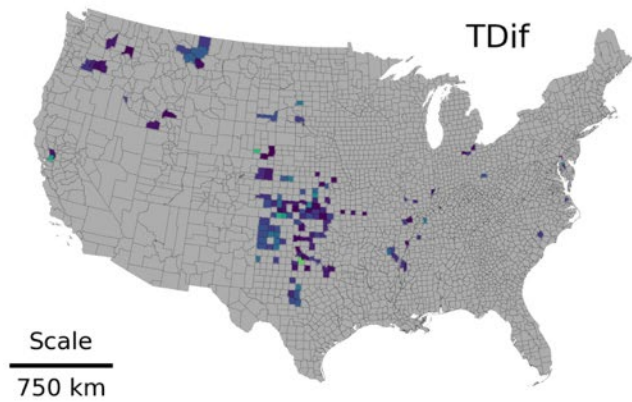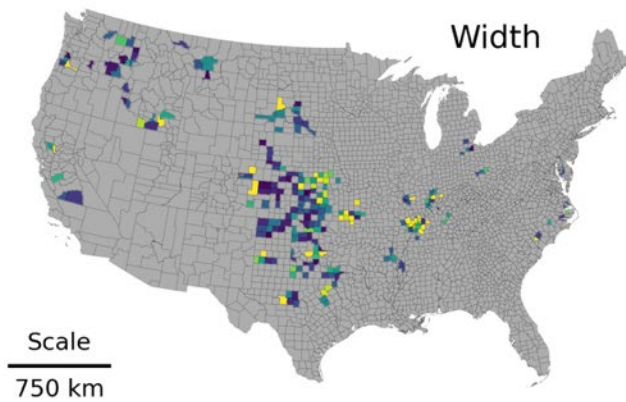
ARYA cross-validation
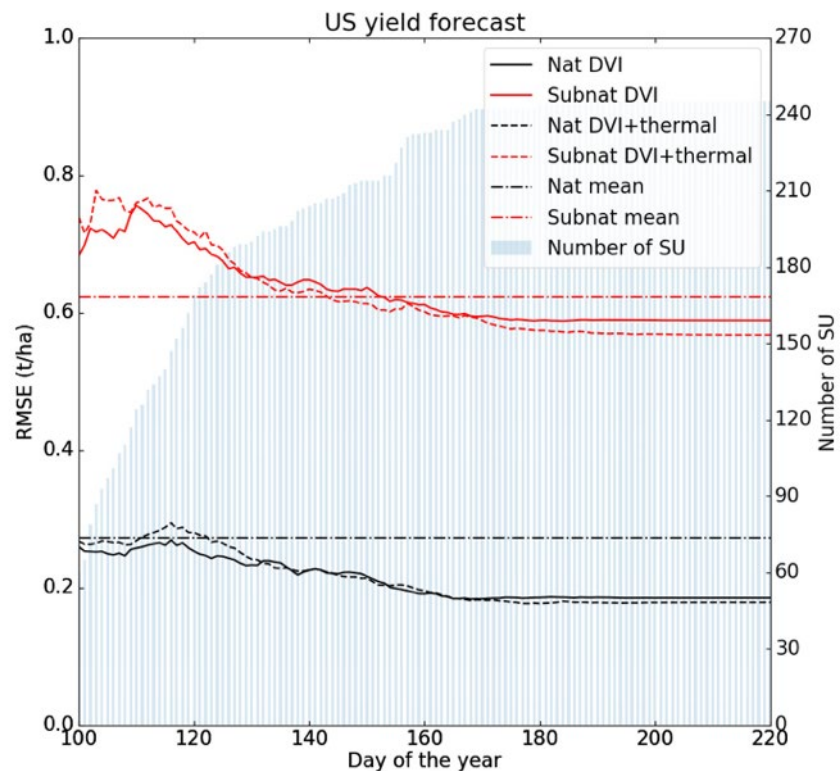
Reliable forecasts
(4-10% error at national and
8-20% error at subnational level)
from 2-2.5 months prior to harvest

ARYA is operational

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

Forecast Gaussian fit UKRAINE (11.0), DOY= 120 , YEAR = 2021
$y = 0.12 + 0.35\, e^{-0.5 \cdot ((x-901.45)/309.8)^2}$
DOY 120

Forecast Gaussian fit UKRAINE (11.0), DOY= 125 , YEAR = 2021
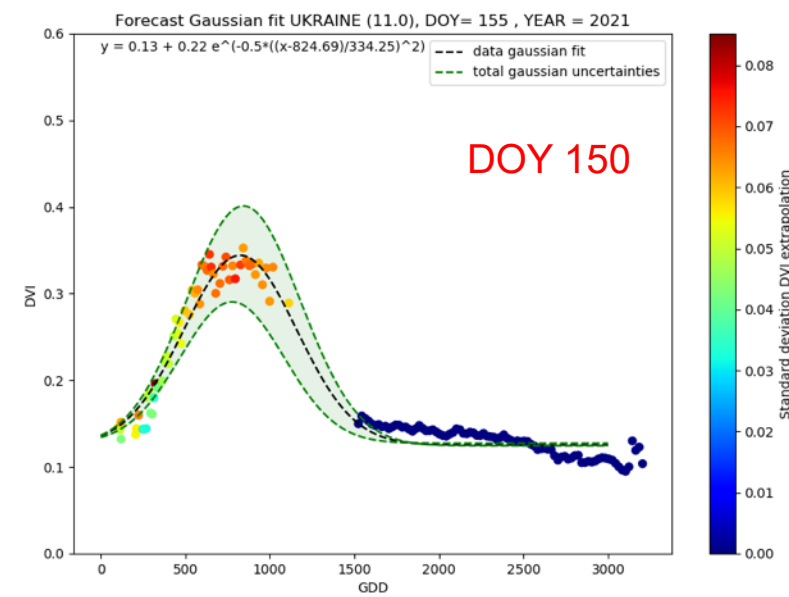$y = 0.12 + 0.31\, e^{-0.5 \cdot ((x-896.68)/323.58)^2}$
DOY 130

Forecast Gaussian fit UKRAINE (11.0), DOY= 155 , YEAR = 2021
$y = 0.13 + 0.22\, e^{-0.5 \cdot ((x-824.69)/334.25)^2}$
DOY 150
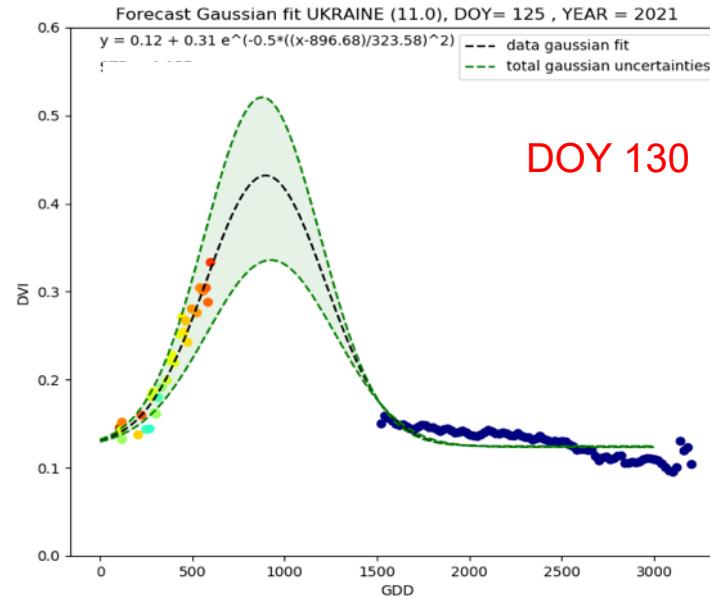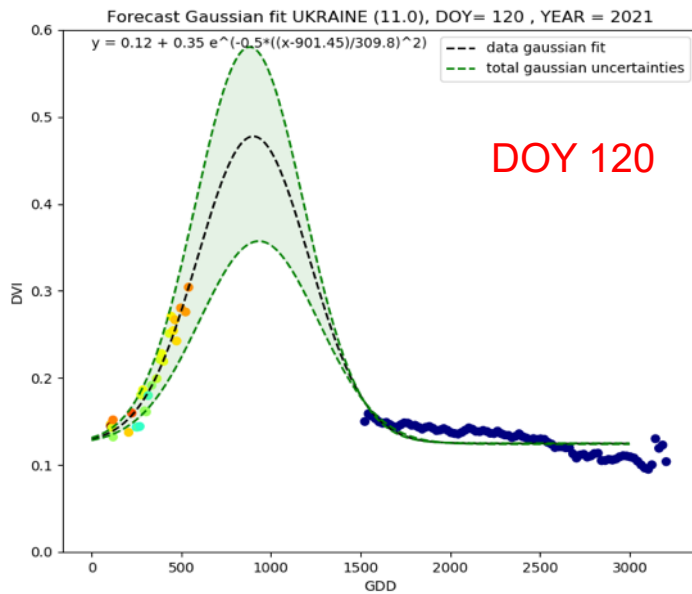
ARYA is operational

ARYA OPER 2021 : DOY 150

RUSSIA

UKRAINE

Final yield=3.5t/ha

Final yield=4.46t/ha
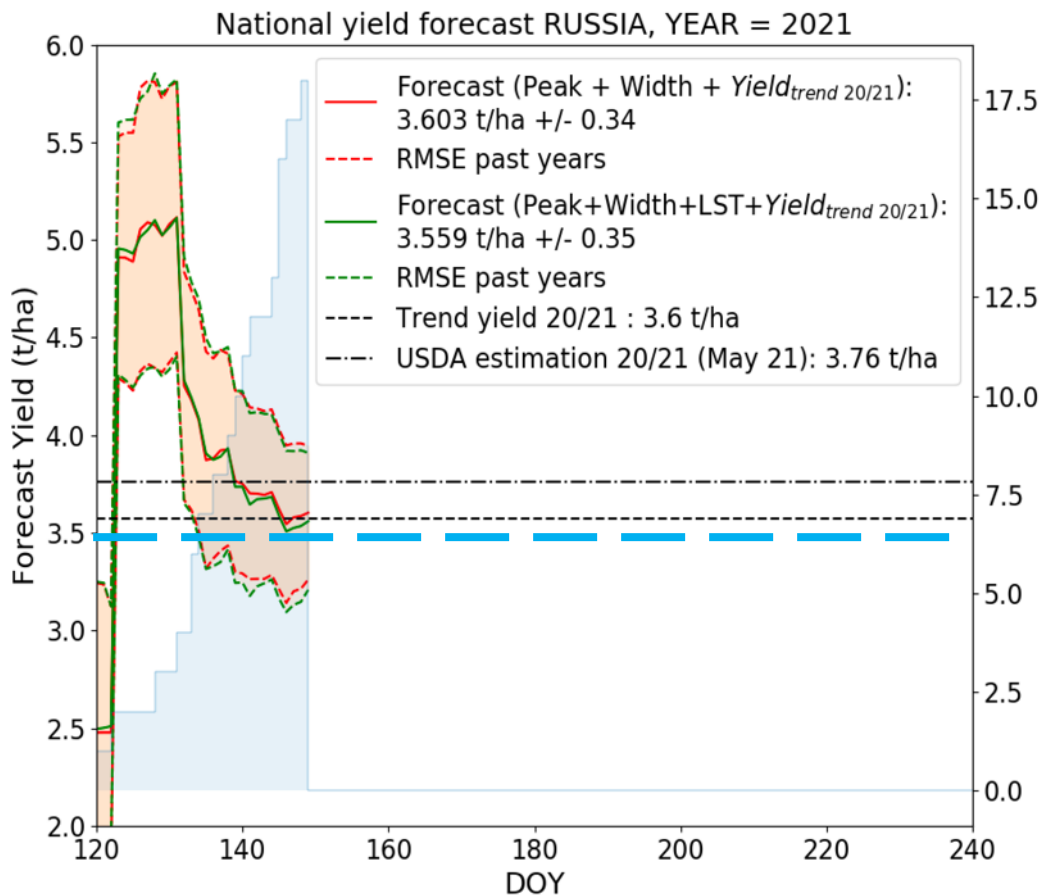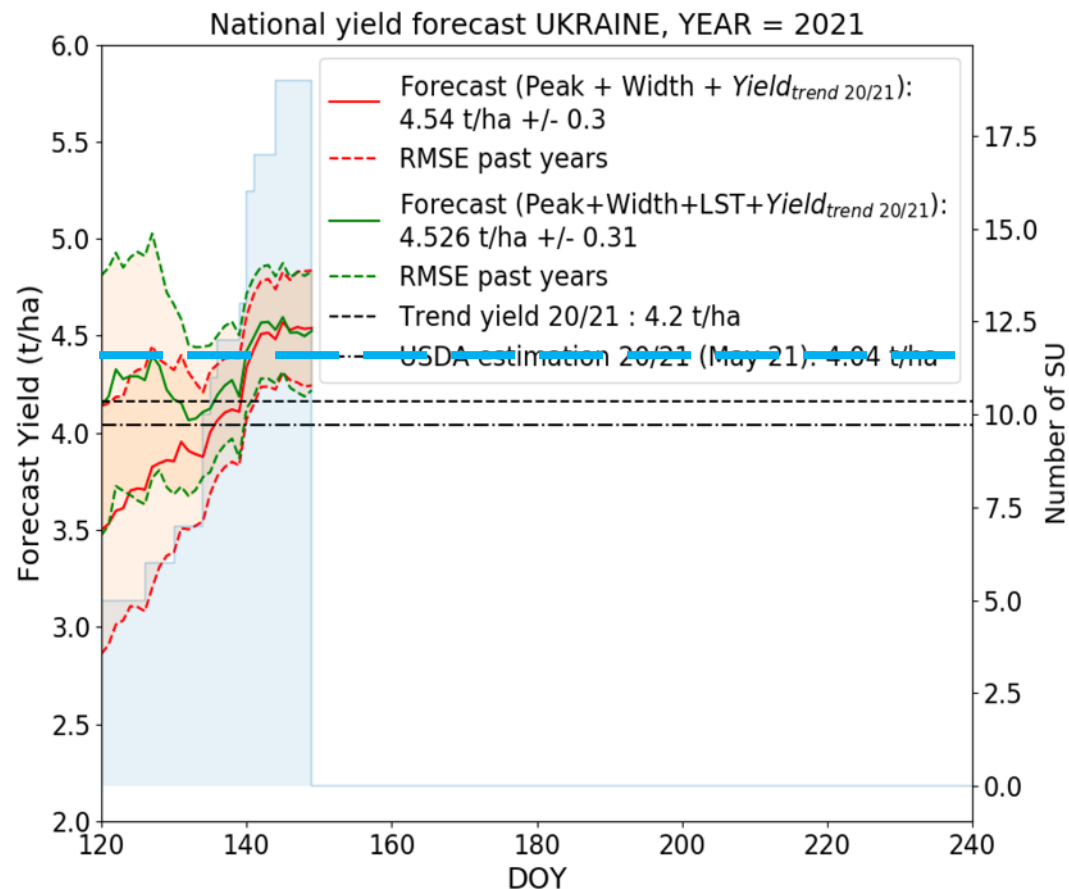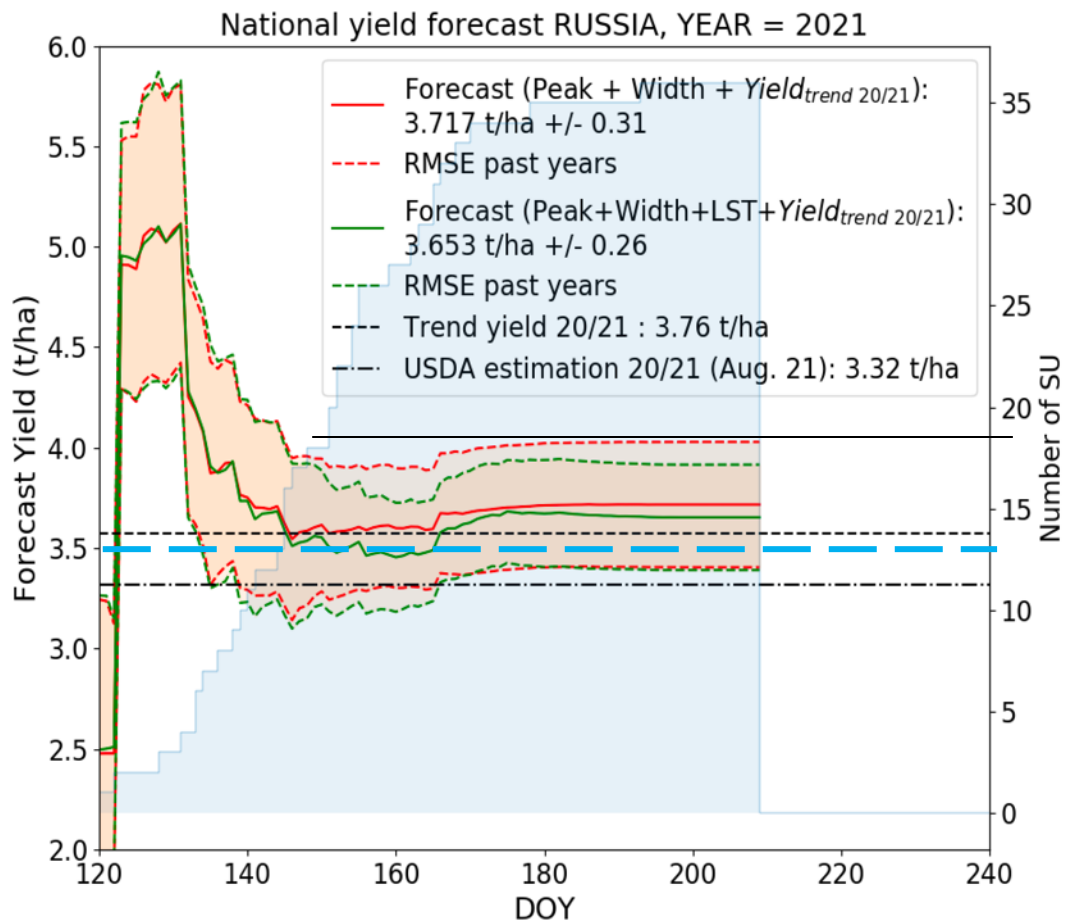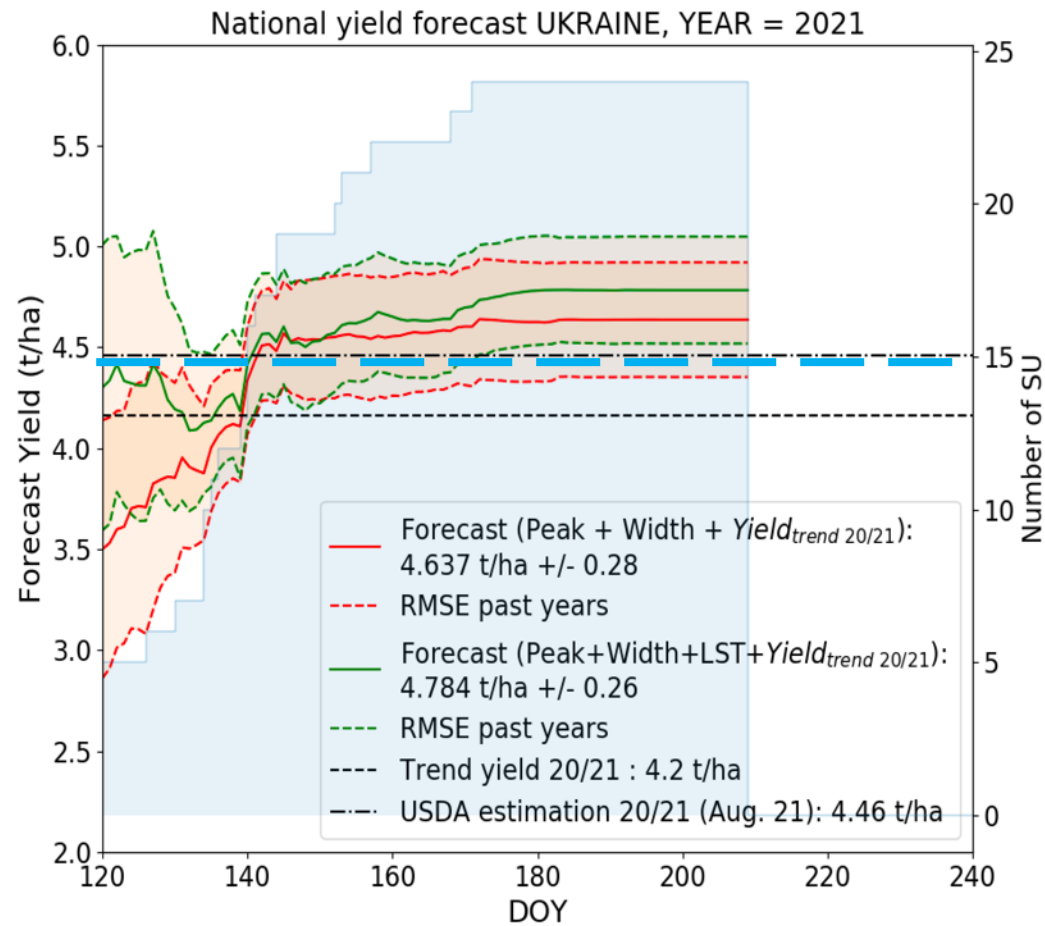
ARYA is operational
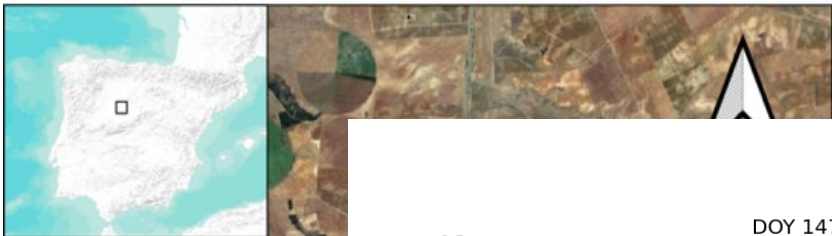
ARYA OPER 2021 : DOY 210
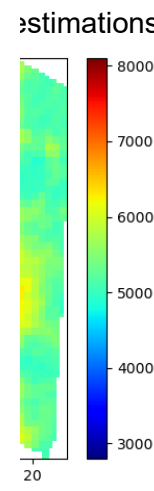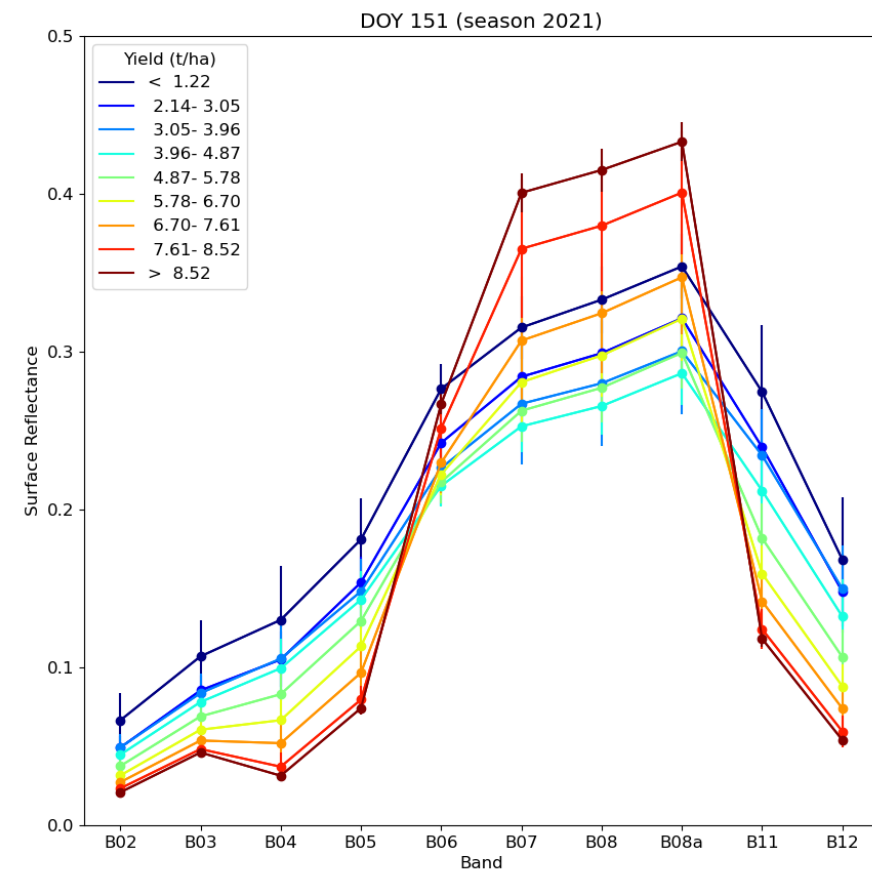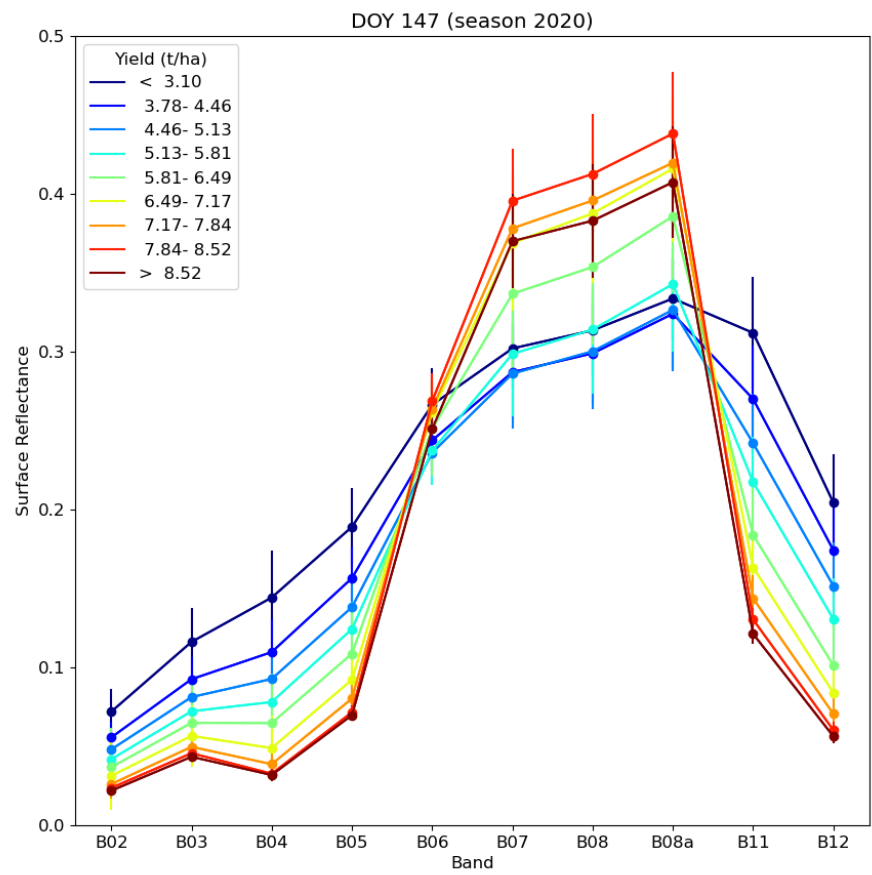
RUSSIA

UKRAINE

Final yield=3.5t/ha

Final yield=4.46t/ha

Application at within-field scale?

Sentinel-2 DVI

$DVI=A*e^{\wedge}(-$

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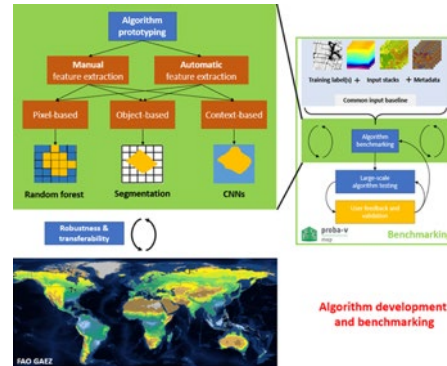**FAO, GEOGLAM, G20 AMIS
& 21 users around the world**

Phase 1; prototyping

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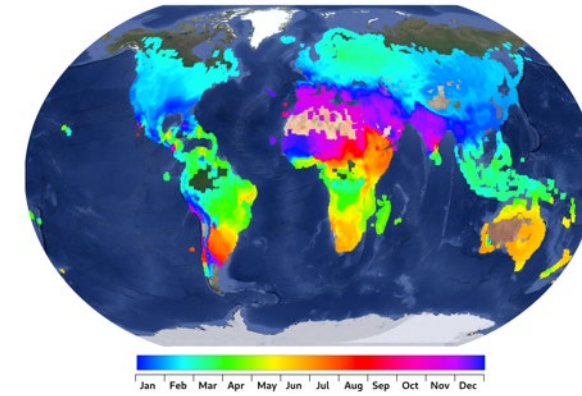- ❖ Large scale demonstration (area selection, Production, validation)

Completed

Phase 2; Implementation

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

Ongoing

Consortium

Selected zones for large scale demonstration	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,…
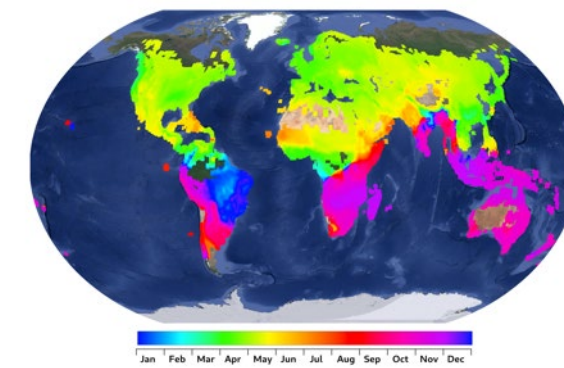
Global Reference data

Generation of global pixel-based crop calendars

Winter cereals SOS

Summer 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., Guilliams, S., Koetz, B., Szantoi, Z., Whitcraft, A. (2022) Global crop calendars of maize and wheat in the framework of the WorldCereal project. **GIScience and Remote Sensing (In press)**

THE EUROPEAN SPACE AGENCY

Annual cropland Mask

Annual cropland	Geo-Wiki data		User accuracy	CI
	No cropland	Cropland		
No cropland	533	61	89.70%	2.44%
Cropland	14	371	96.40%	1.87%
Producer accuracy	97.40%	86.00%		
CI	1.30%	2.87%		
Overall accuracy			92.4%	1.65%

Winter Cereals

Summer Maize

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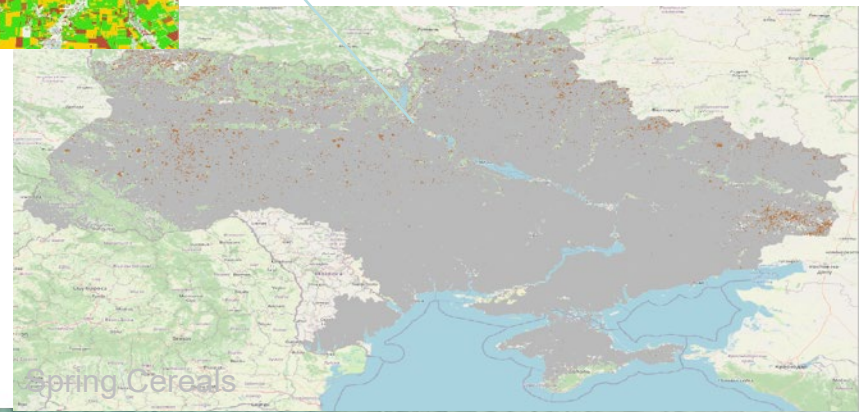- Spring Cereals
- Summer maize

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

Spring Cereals

WorldCereal

→ THE EUROPEAN SPACE AGENCY

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