

# Crop Growth Monitoring and Yield Forecast for Winter Wheat Under Different Soil-Water Conditions in Poland and South Africa as the contributing to the Global Earth Observations System

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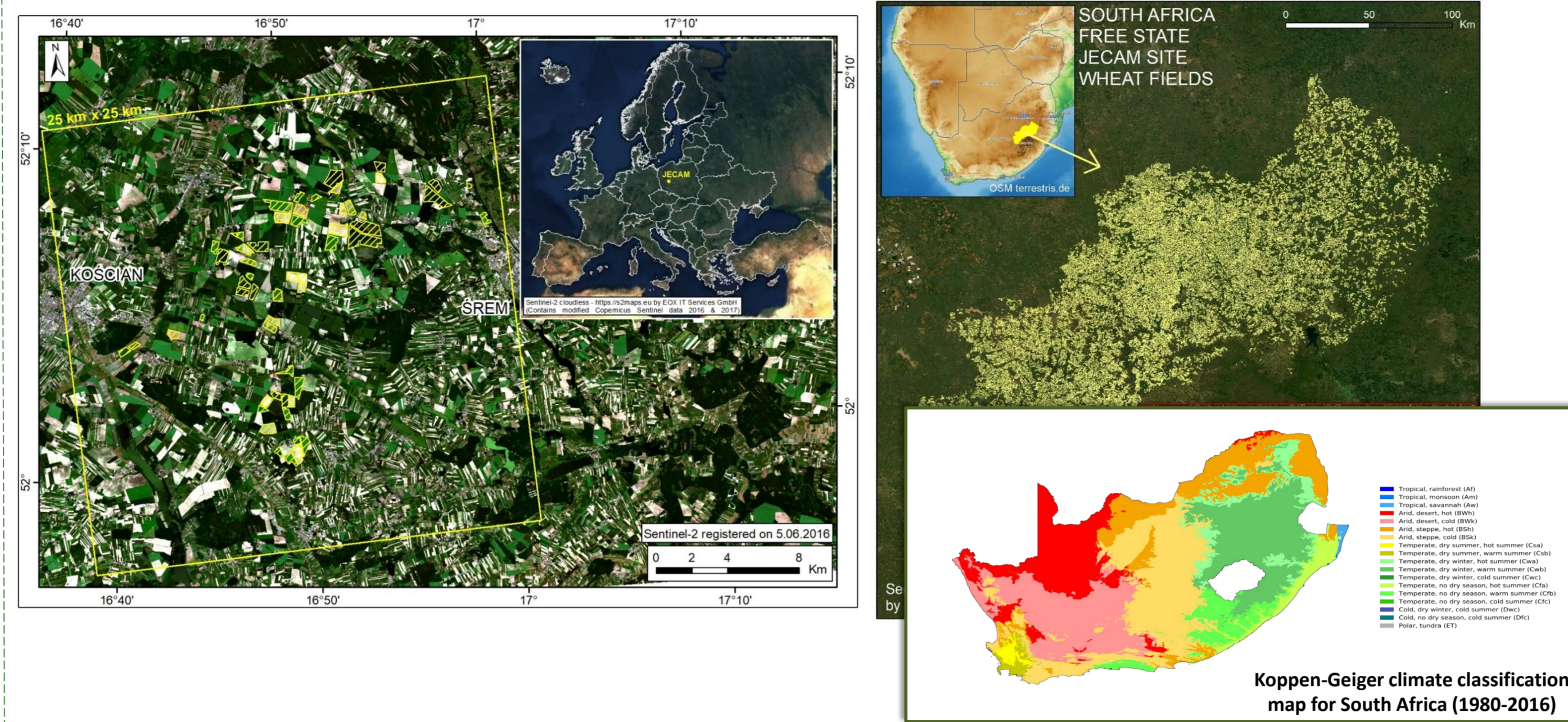
## INTRODUCTION

The project has been carried out in two countries Poland represented by the Institute of Geodesy and Cartography and South Africa represented by Agricultural Research Council – Institute for Soil, Climate and Water (ARC-ISCW). The approach is based on synergy of new-generation satellite data from the Copernicus Programme, low-resolution satellite data as Terra MODIS, meteorological data and in-situ observations. The created System will deliver information on crop conditions, water deficit in the course of crop development, yield forecast and early warning related to crop hazards.

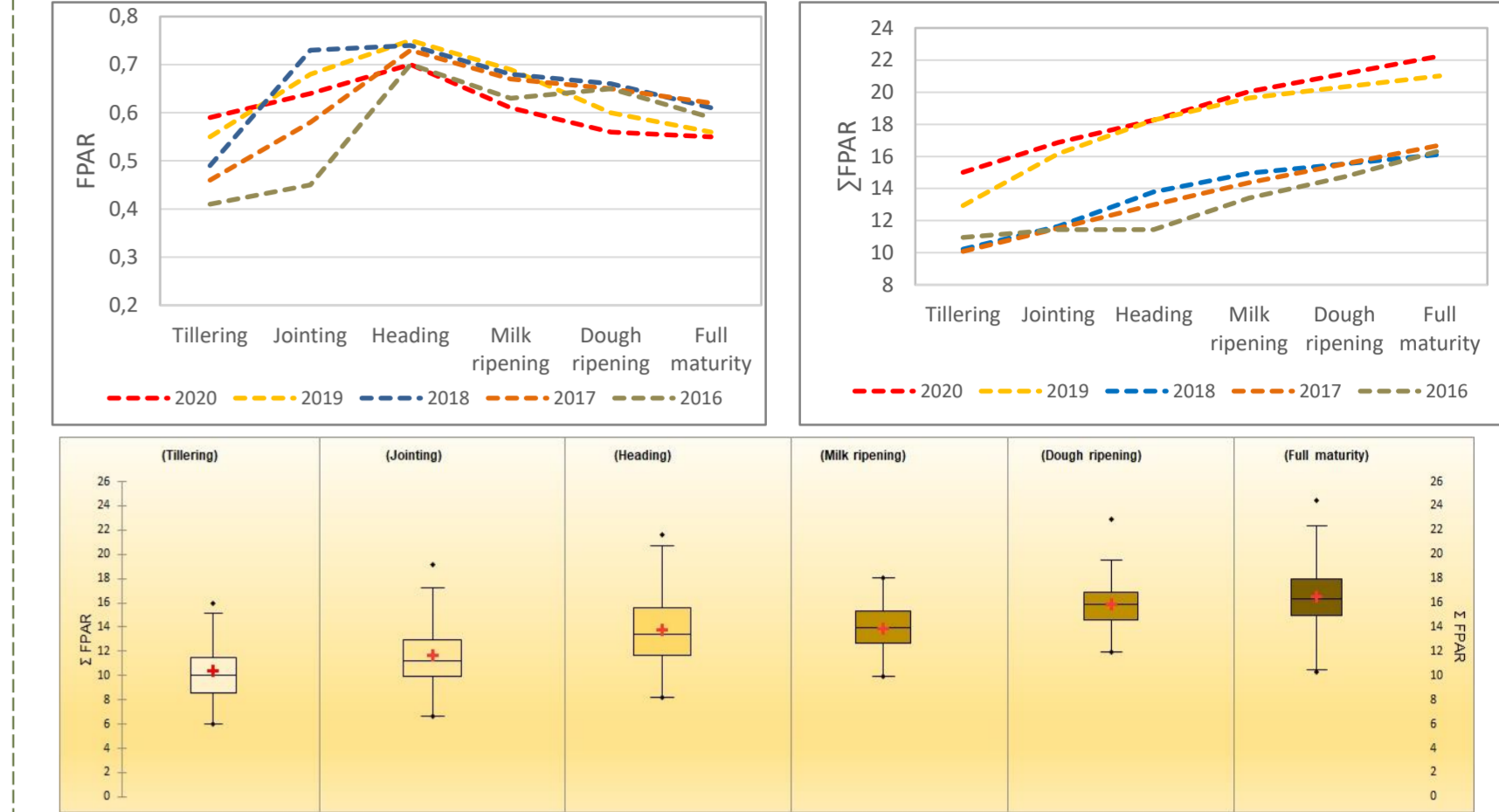
The measurements were carried out at the JECAM sites in both countries. The yield at JECAM site in Poland ranged in 2018 from 10-70 dt/ha. In the analysis for the model, the relation between yield and cumulative values of NDVI of Sentinel2 between the phenological phases were taken.

To build the model, the cumulated NDVI from Terra MODIS data and cumulated values of (LST-TA) for the period of the phases were calculated. The ratios of the increase of the accumulations values of NDVI and (LST-TA) between the phases are the independent factors having influence on wheat yield estimation. Accumulation of two indices NDVI and (LST-TA) step by step during the vegetation period of winter wheat can be the descriptor of phenological phases recognition in both countries. The FPAR as a product from Terra MODIS was used to determine the different crop phenology. A set of classification functions to distinguish the winter wheat was estimated for the time of the phenological stages.

## JECAM test sites in Poland and in Africa



## FPAR - TerraMODIS



The tillering phase is observed when FPAR totals reach 10.00, jointing closer to 12.00, heading and milk ripening at a similar level of FPAR totals 14.00 and then dough ripening reaching FPAR totals 16.00. Full maturity follows when FPAR totals exceed 16.00

## IN-SITU MEASUREMENTS

- 1) Spectral responses by the ASD FieldSpec4 Hi-Res - Poland
- 2) Drone-level measurements in Africa
- 3) Ground measurements in Africa



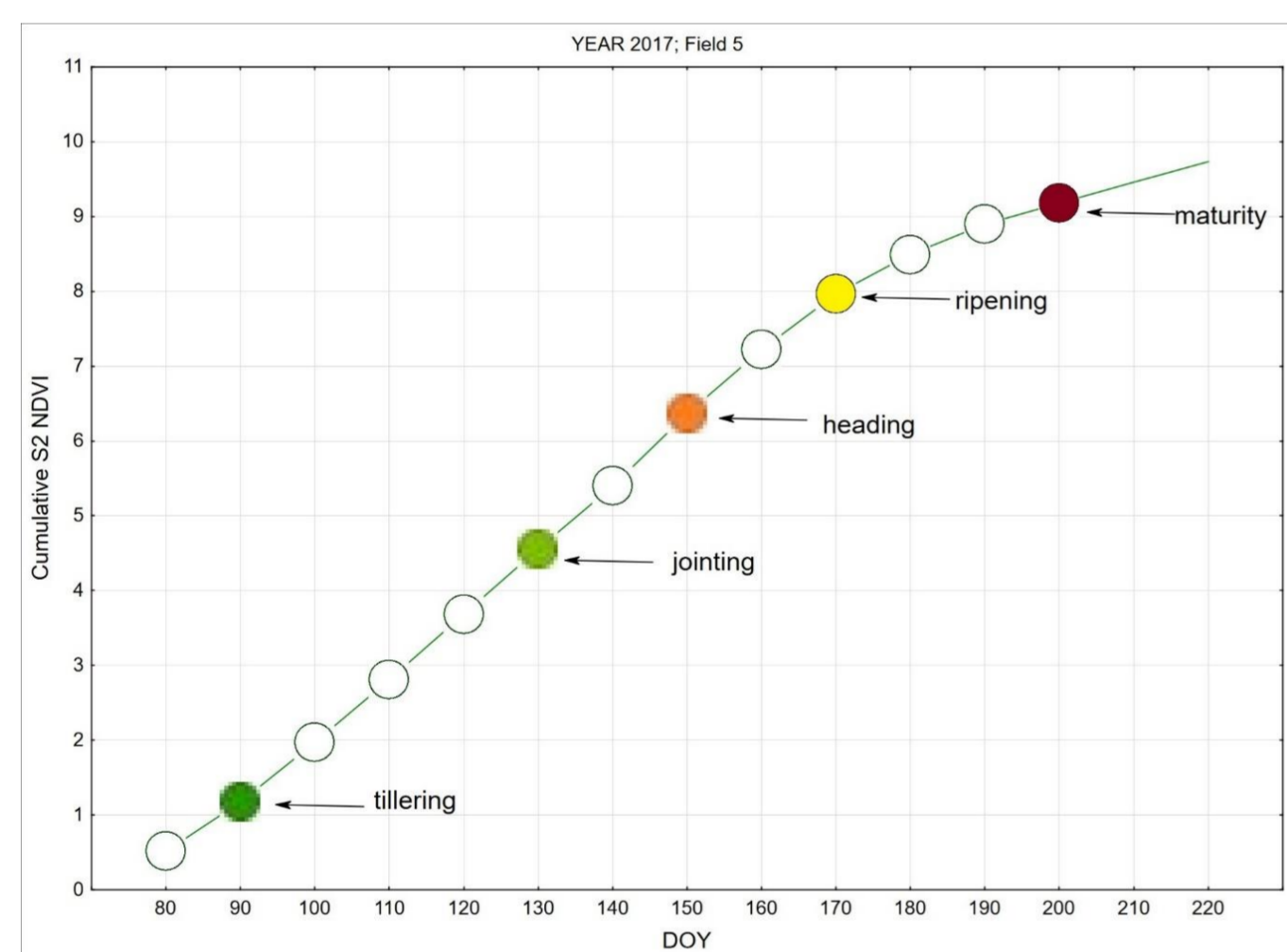
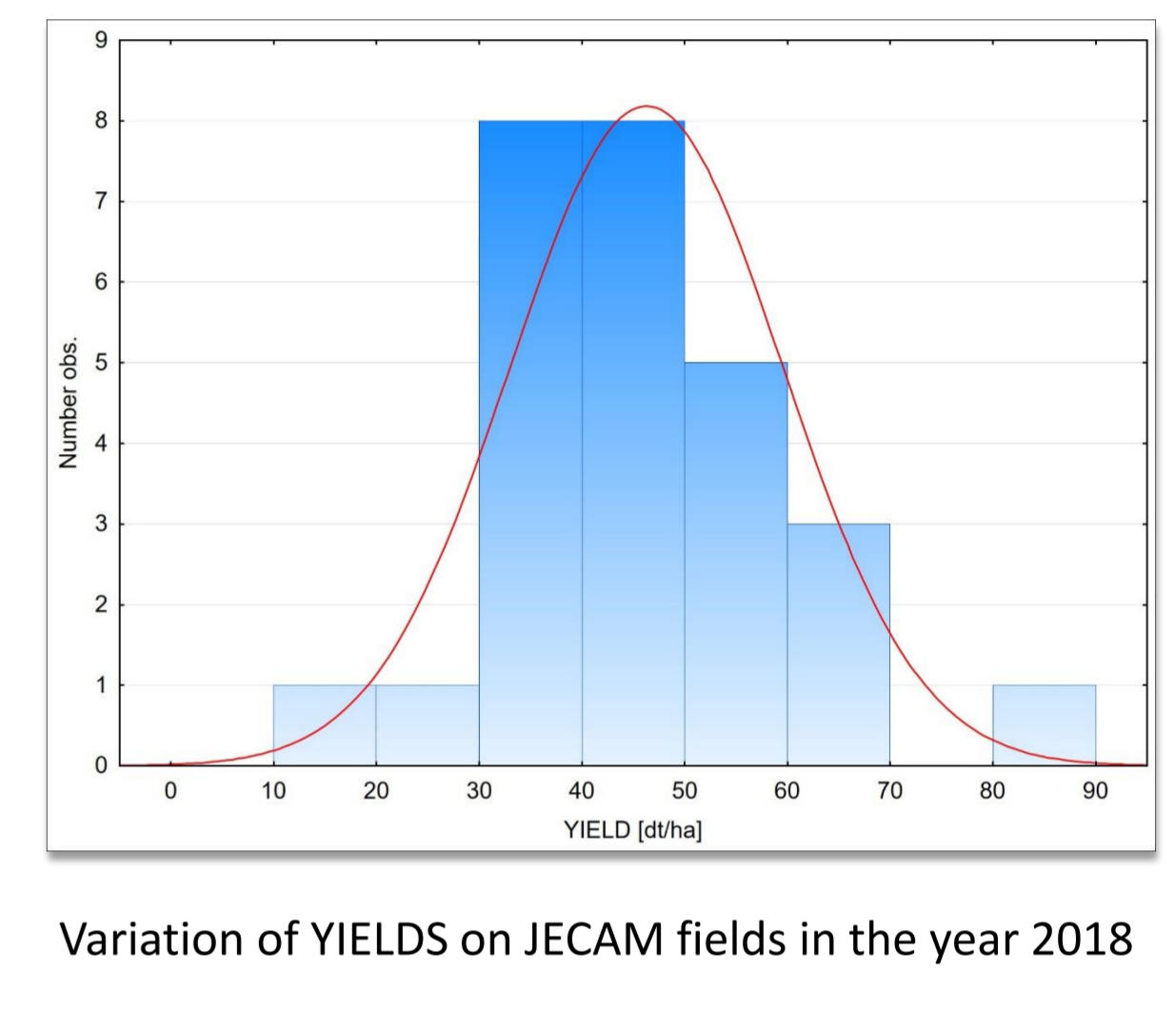
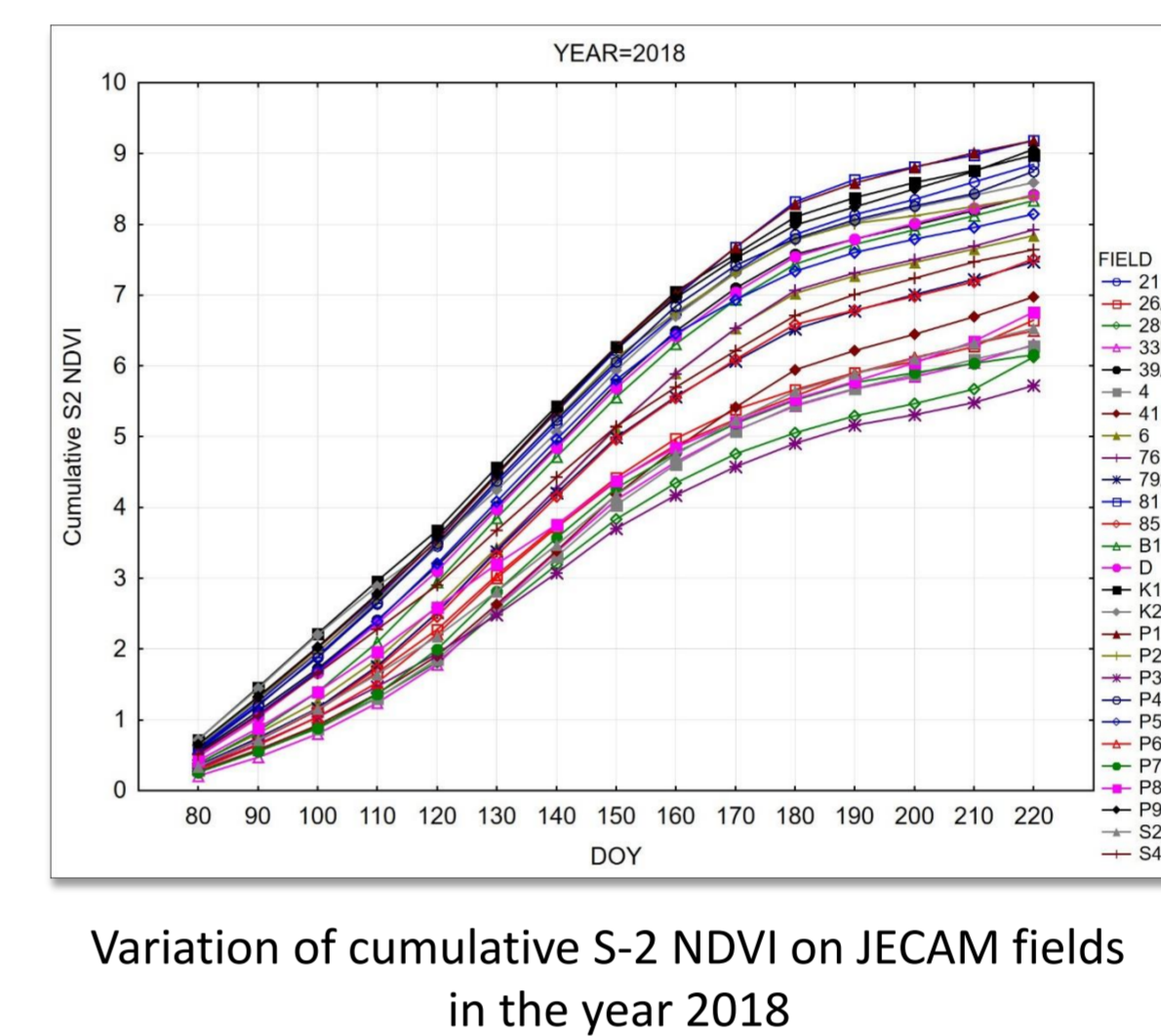
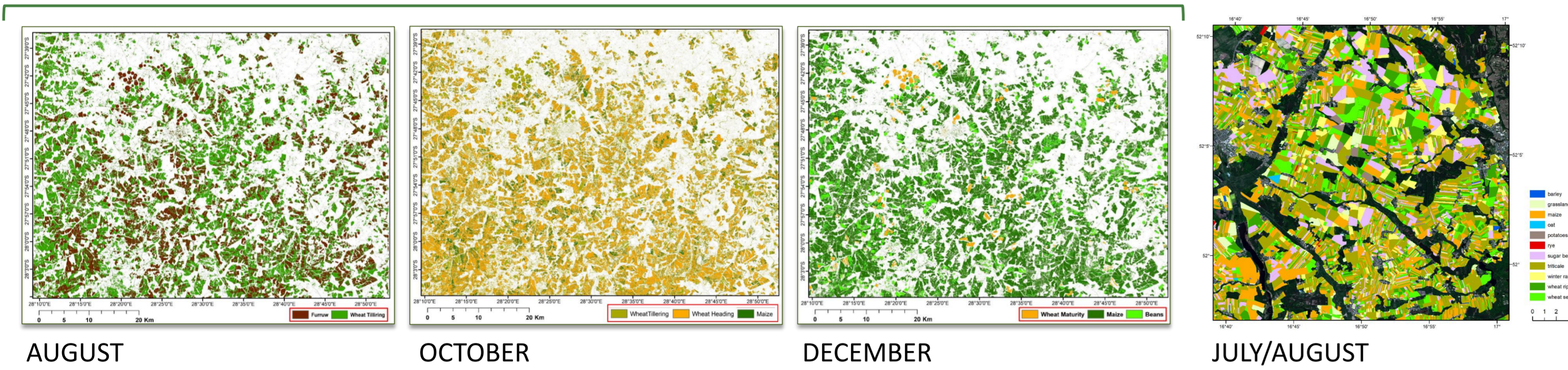
## Accumulation of Sentinel2 NDVI in the yield forecast on wheat JECAM fields

The measurements of NDVI concerns a set of experimental fields in the agricultural region Wielkopolska. The meaning variation of the NDVI course during growing period exists. The example for 2018 illustrates the graph below in the form of cumulative values of NDVI. The yields of this fields are also diversified this year, what the histogram shows. The yield value range in 2018 is 10-70 dt/ha.

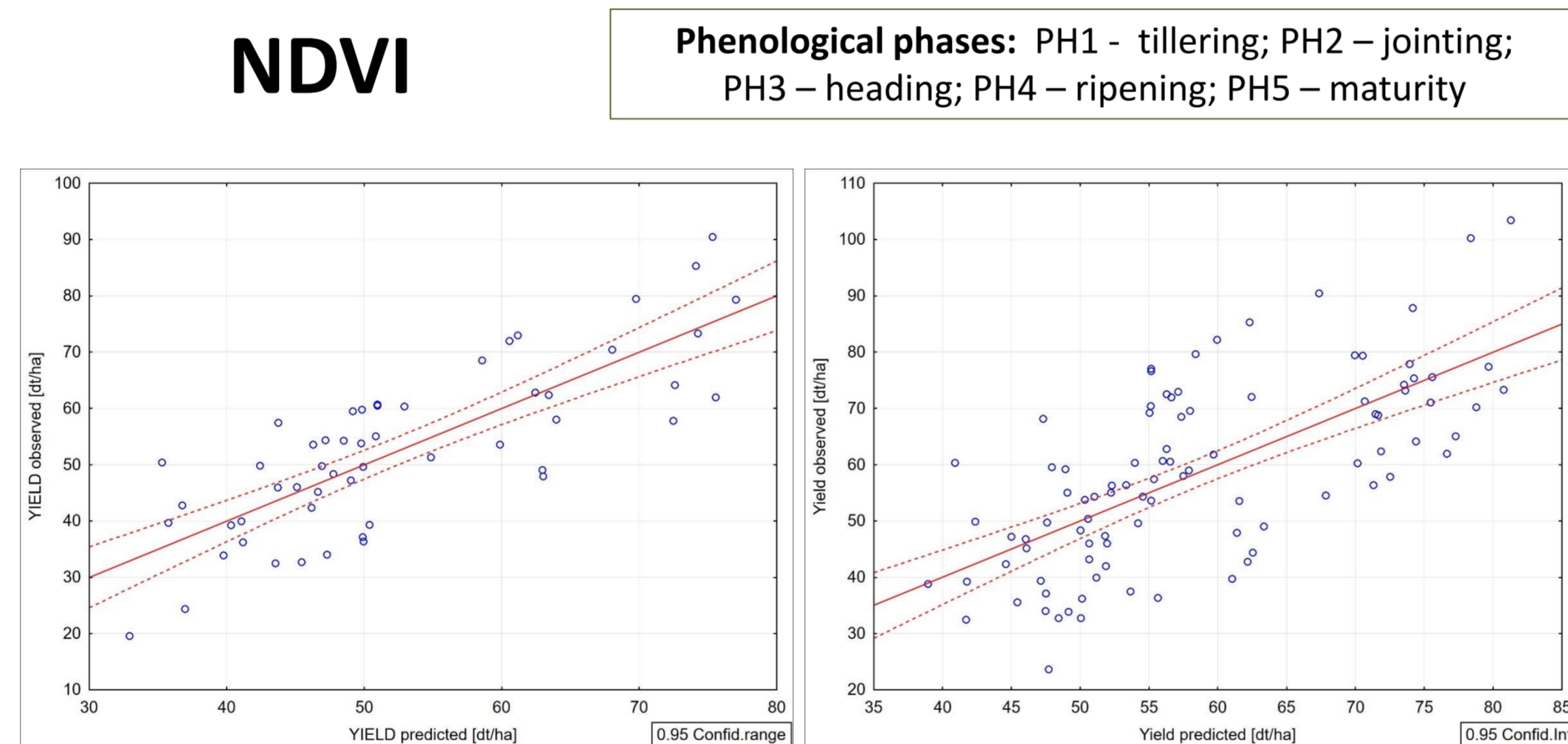
## CROP TYPE CLASSIFICATION

### JECAM AFRICA

### JECAM POLAND



Cumulative S2 NDVI and phenological phases on the field 5 in the year 2017



Scatterplot of yield observed and predicted model-1

Scatterplot of yield observed and predicted model-2

$cNDVI\_PH1 = \sum NDVI$  from start to phase 1 (tillering), and next analogously;  $dNDVI\_PH2 = cNDVI\_PH2 - cNDVI\_PH1$ , and next analogously

**1** MODEL Sentinel-2; years 2017-2022; time-step 10 days. Estimated equation:

$$Yield = 33.5 + 14.9 * cNDVI\_PH1 + 4.4 * dNDVI\_PH2 - 9.9 * dNDVI\_PH3 + 8.2 * dNDVI\_PH4$$

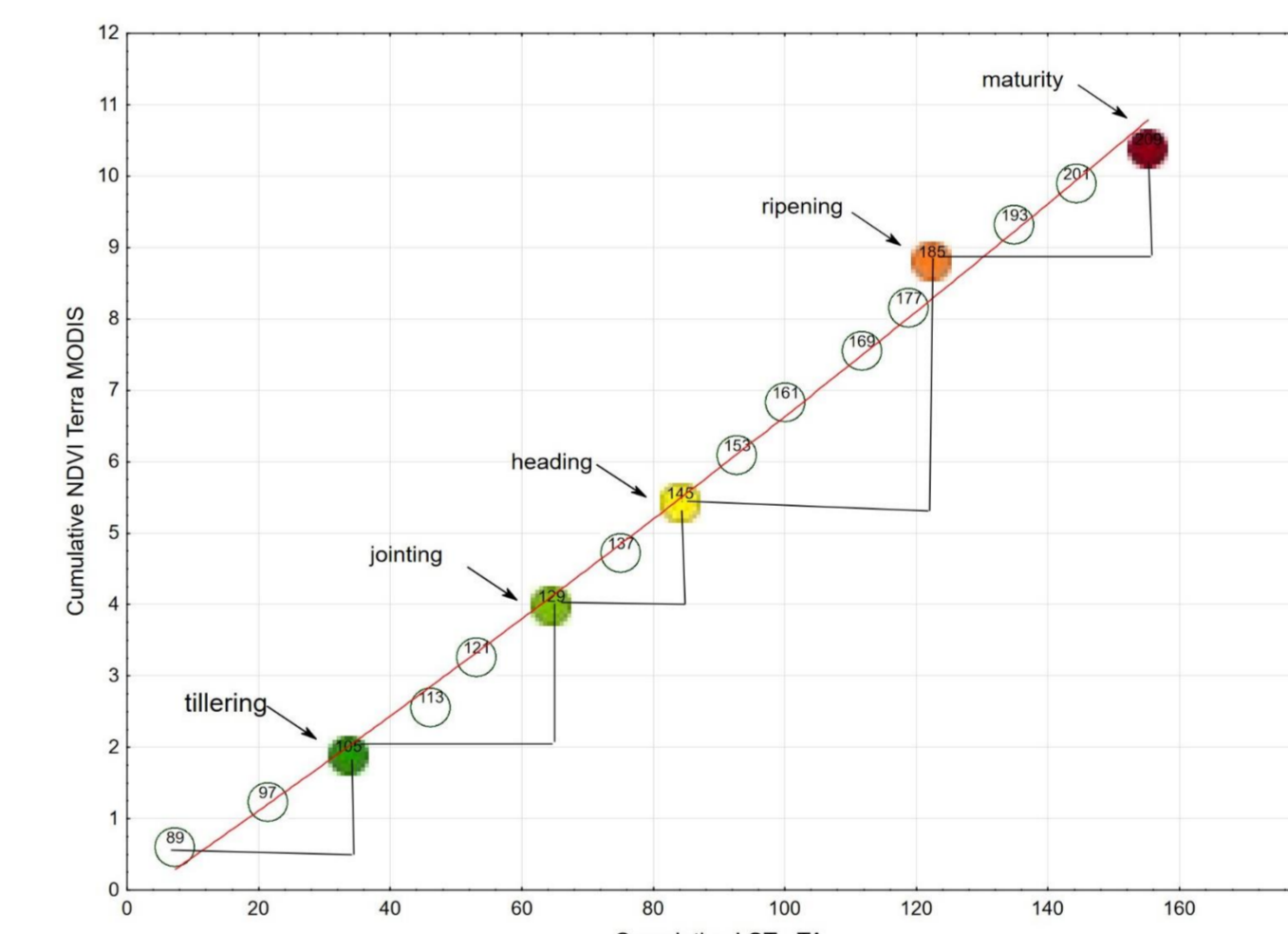
The Pearson's parameter R=0.8; standard error is equal 9.4 dt/ha; N=54

**2** MODEL Terra MODIS years 2003-2005, 2014-2022; time-step 8 days. Estimated equation:

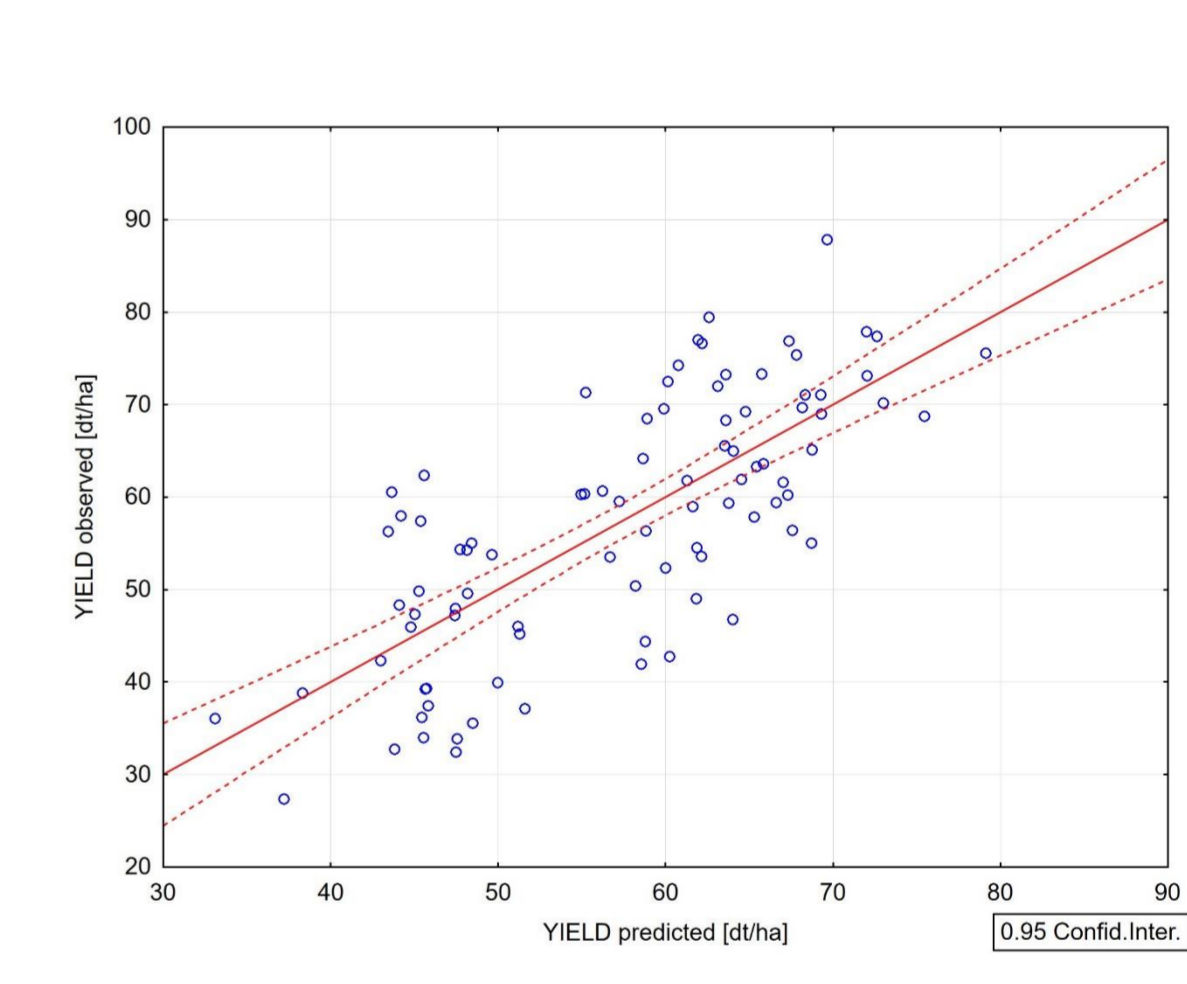
$$Yield = 4.4 * cNDVI\_PH1 + 4.7 * dNDVI\_PH2 + 9.0 * dNDVI\_PH3 + 9.5 * dNDVI\_PH4 + 9.8 * dNDVI\_PH5$$

The Pearson's parameter R=0.68; standard error is equal 12.3 dt/ha; N=94

## NDVI, LST-TA



Scatterplot of cumulative NDVI and LST-TA from MODIS in growing period DOY's 2020 field no 15.



Scatterplot of yield observed and predicted model-3

$Ratio\_PH1 = \log(dNDVI\_PH1/dLST-TA\_PH1)$  from start to phase 1 (tillering) and next analogously;

**3** MODEL Terra MODIS; years 2003-2005, 2014-2022; time-step 8 days.

$$Yield = 123.8 + 19.5 * Ratio\_PH1 - 11.9 * Ratio\_PH2 + 1.9 * Ratio\_PH3 + 6.8 * Ratio\_PH4$$

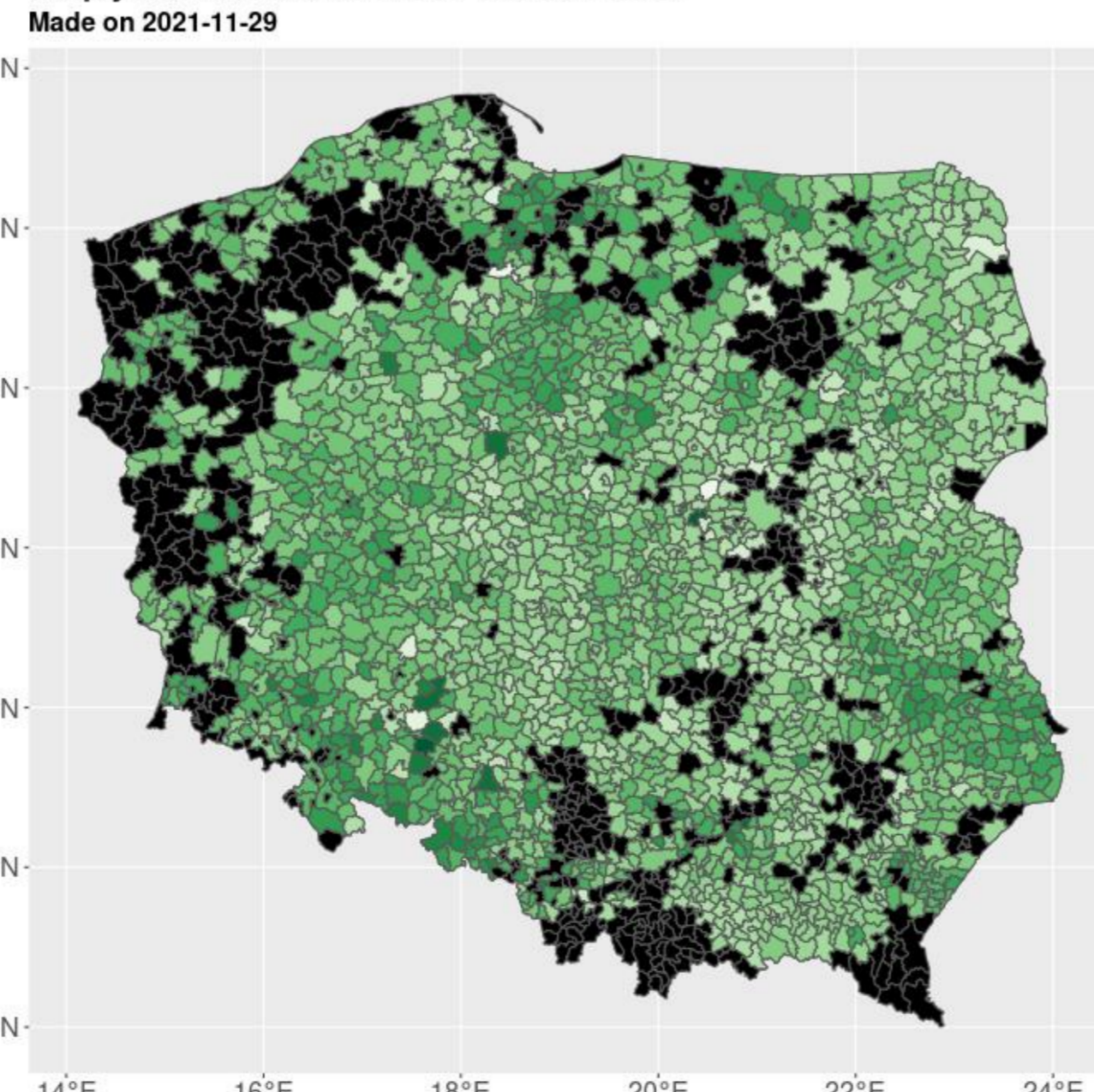
The Pearson's R=0.74 and standard error equal 9.3 dt/ha

## MODELING OF WHEAT YIELD FOR LAU-2

### Map of first predictors in LAU-2

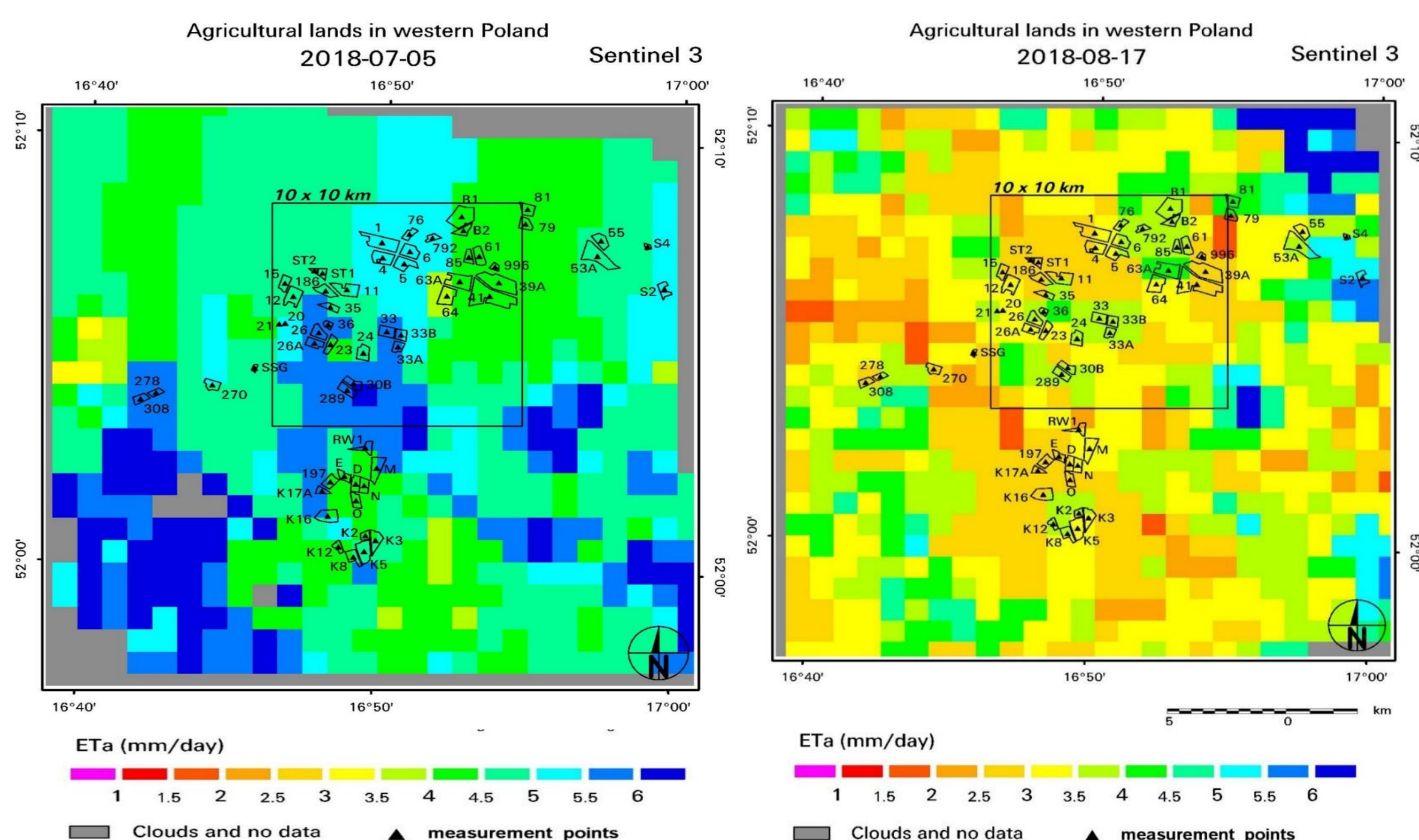
- Variables:
- CDSsm
  - cum\_NDVI
  - cum precipitation
  - cum\_SIS
  - DISS
  - FAPAR\_max
  - FAPAR\_sm
  - FAPAR\_sum
  - LST
  - Max temp/day
  - Min temp/day
  - NDVI\_max
  - NDVI\_sm
  - NDVI\_sum
  - SIS
  - Average temp/day
  - Sum of precipitation/day
  - TaTs
  - TCl
  - VCI\_sm

### Crop yield forecast for winter wheat in 2021



## DIFFERENT SOIL-WATER CONDITIONS

### DAILY EVAPOTRANSPIRATION



Bojanowski JS, Sikora S, Musiał JP, Woźniak E, Dąbrowska-Zielinska K, Slesiński P, Milewski T, łączynski A. Integration of Sentinel-3 and MODIS Vegetation Indices with ERA-5 Agro-Meteorological Indicators for Operational Crop Yield Forecasting. *Remote Sensing*. 2022; 14(5):1238. <https://doi.org/10.3390/rs14051238>



The research work was conducted within the project financed by the National Centre for Research and Development under Contract No. PL-RPA/02/SAPOL4Crop/43/2018., titled "SA Polish collaborative crop growth monitoring and yield assessment system for early warning utilizing new satellite Earth Observations data from Copernicus Programme".

