Model-based drought indicators improve the reliability of crop yield simulations with a statistical model in Poland

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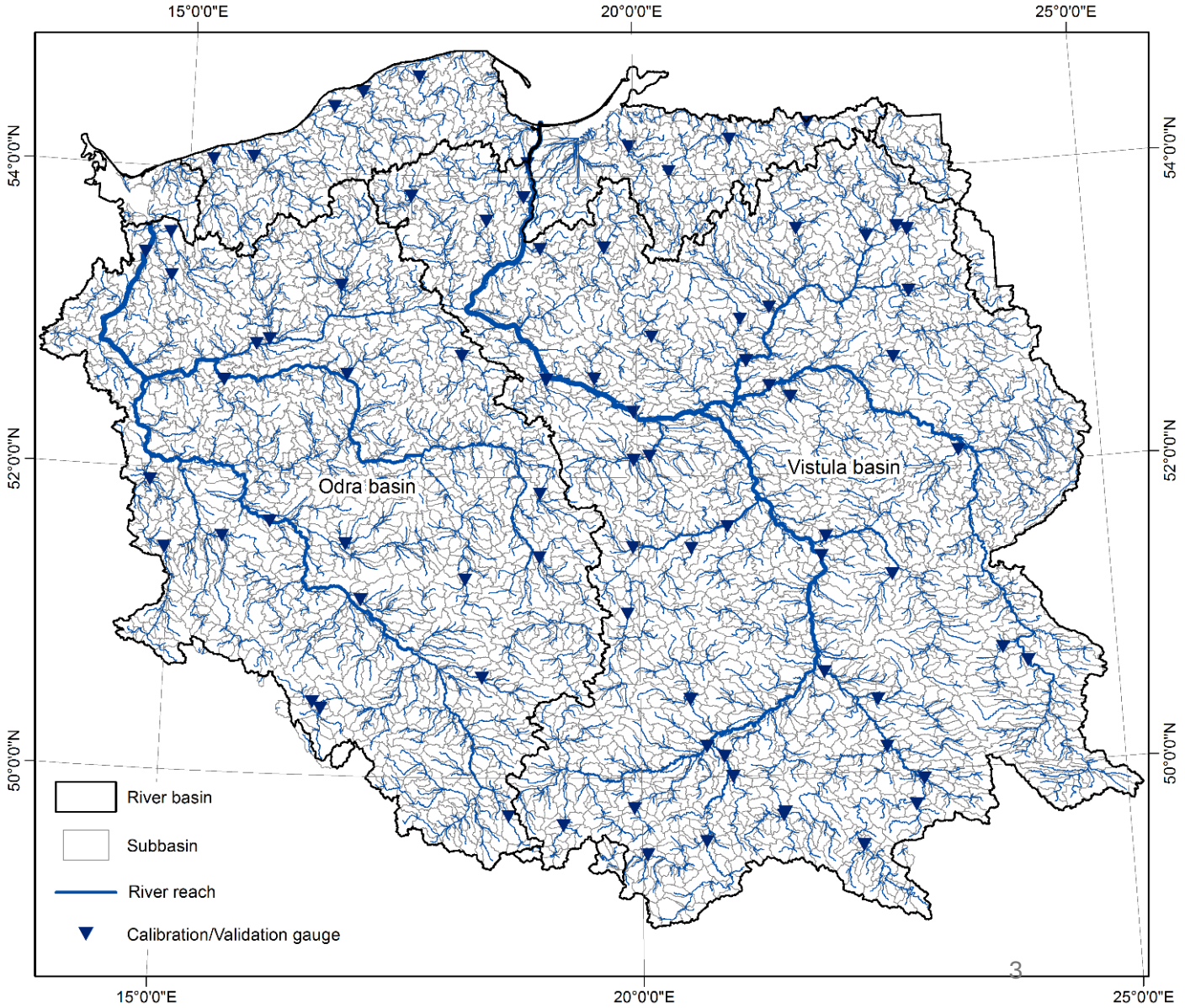
SZKOŁA GŁÓWNA
GOSPODARSTWA
WIEJSKIEGO

- **Idea**
  - Improving the accuracy of statistical crop yield modeling
  - Using SWAT to extract drought indicators such as agricultural drought indicators
  - Adding extracted indicators in a statistical model to increase the accuracy of crop yield simulations
  - Linking SWAT model and a crop yield model

SWAT setup for Poland

- **The study area (349,766 km^2) covers the entire territory of Poland (312,683 km^2) and source areas of Vistula and Odra basins (37,083 km^2) partly located outside the country borders.**

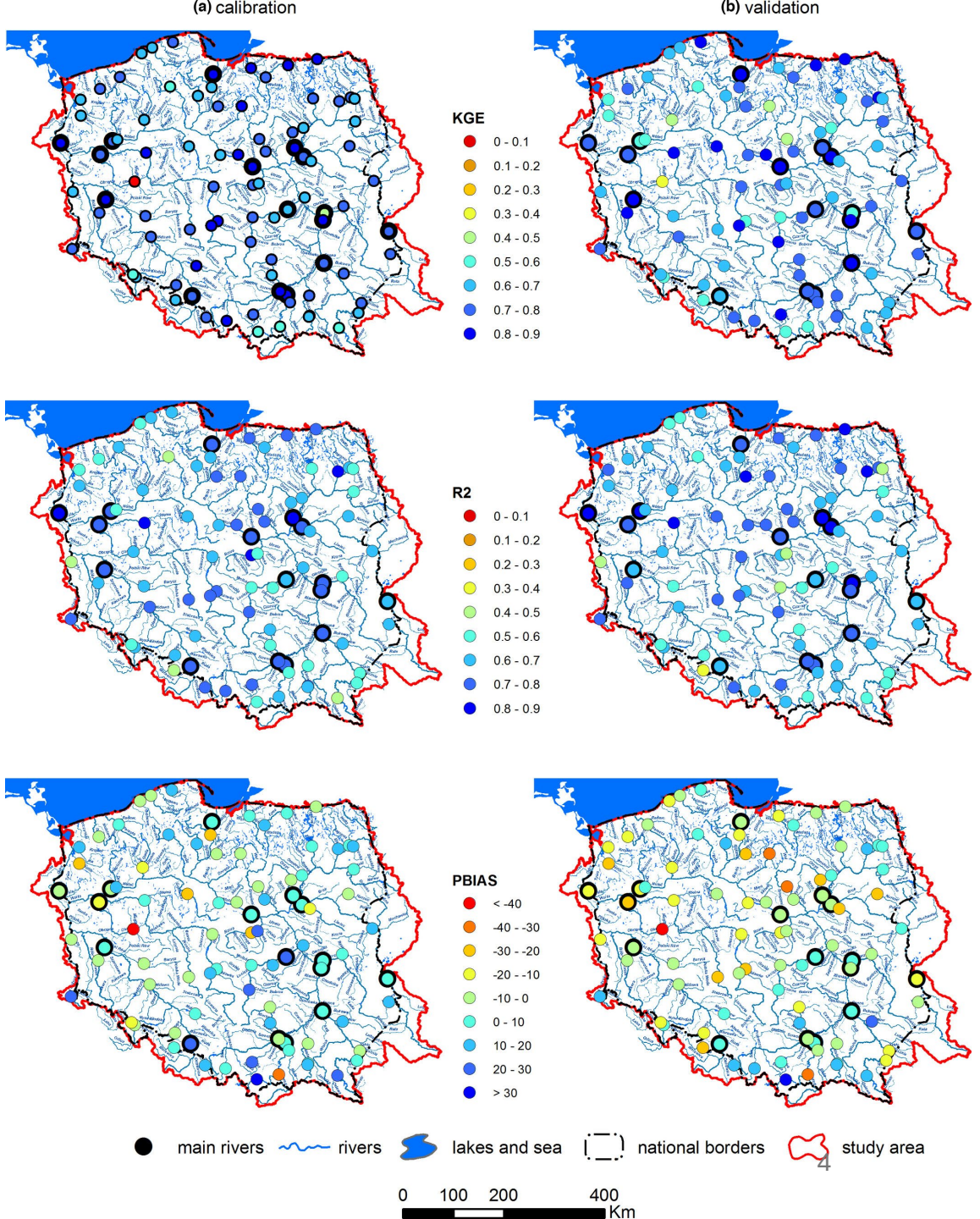
- **Land cover in Poland is predominantly agriculture (63%) and forests (32%) (CLC2018).**
- **It is characterized by relatively low water resources, and therefore is ranked among the countries with the lowest water resources per capita in Europe.**



Marcinkowski et al. "High-resolution simulated water balance and streamflow data set for 1951–2020 for the territory of Poland." **Geoscience Data Journal** 10.2 (2023): 195-207.

Model calibration

The SWAT model performance measured by KGE was satisfactory for almost all catchments (median KGE = 0.73) in the calibration and validation periods.



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Do we need another model?
Process-based or statistical models?

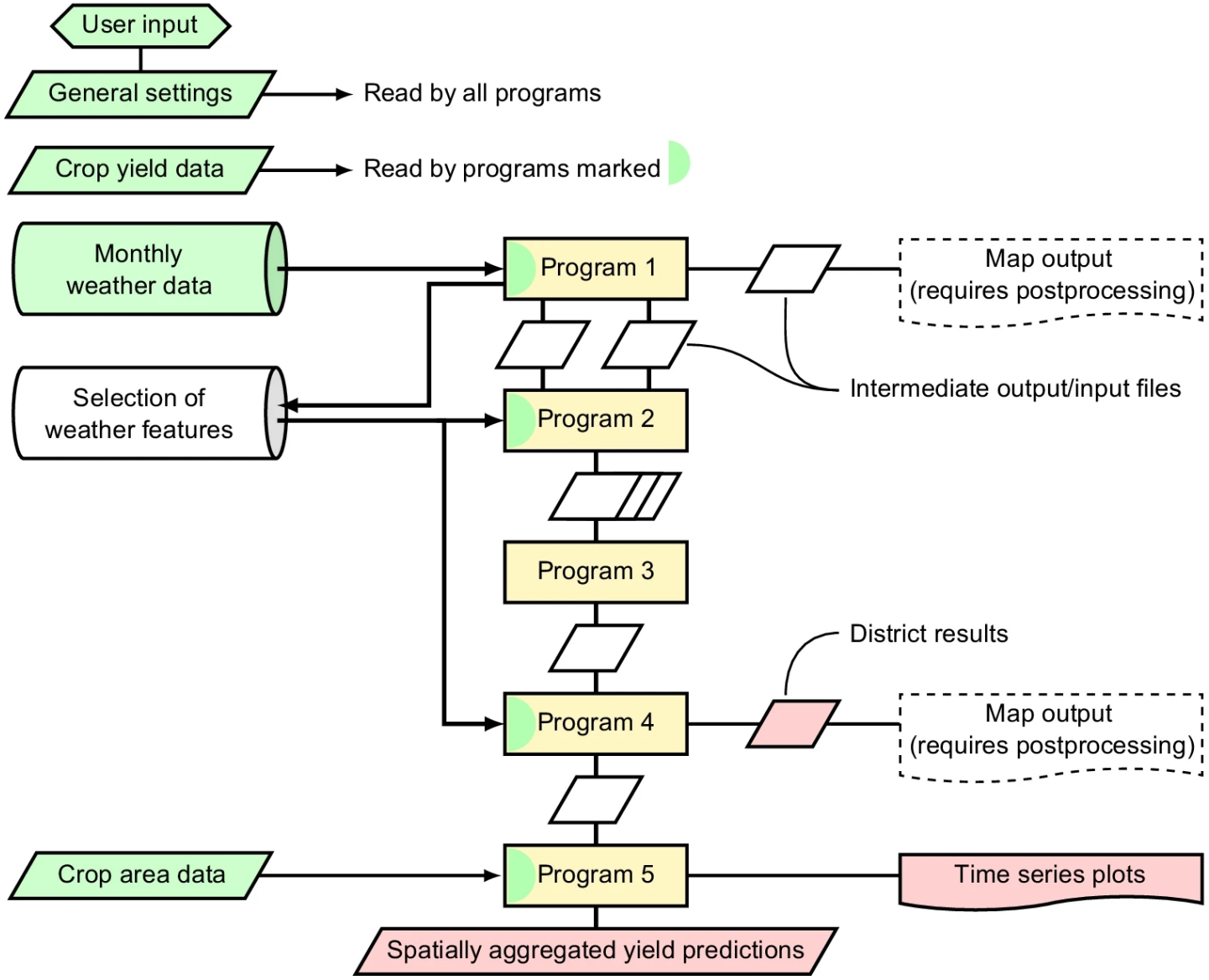
Weather-based crop yield predictions have a long history

- **Correlations between weather variables and agricultural yields had already been studied in the first quarter of the twentieth century:**
- **Meinardus 1901; Hooker 1907; Fisher 1924**

- **Among the 362 crop forecasting studies published in the years 2004–2019 (Schauberger et al. (2020)):**
- **there were 258 utilizing regression**
- **automated neural networks (28 cases)**
- **random forests (12)**

Crop yield simulator

ABSOLUT v1.2 (Assessing Best-predictive Sets fOr multiple Linear regressions throUgh exhaustive Testing)



Conradt, T., (2022) International Journal of Biometeorology 66.11 (2022): 2287-2300.

Crop yield simulator

Model inputs

What do you have?
It is possible to add only two variable to more variables

Available datasets (monthly)

Precipitation

Maximum Temperature

Minimum Temperature

Max-Min temperature difference

Mean Temperature

Radiation

Humidity (%)

SPI (Standardized Precipitation Index)

Additional datasets from SWAT

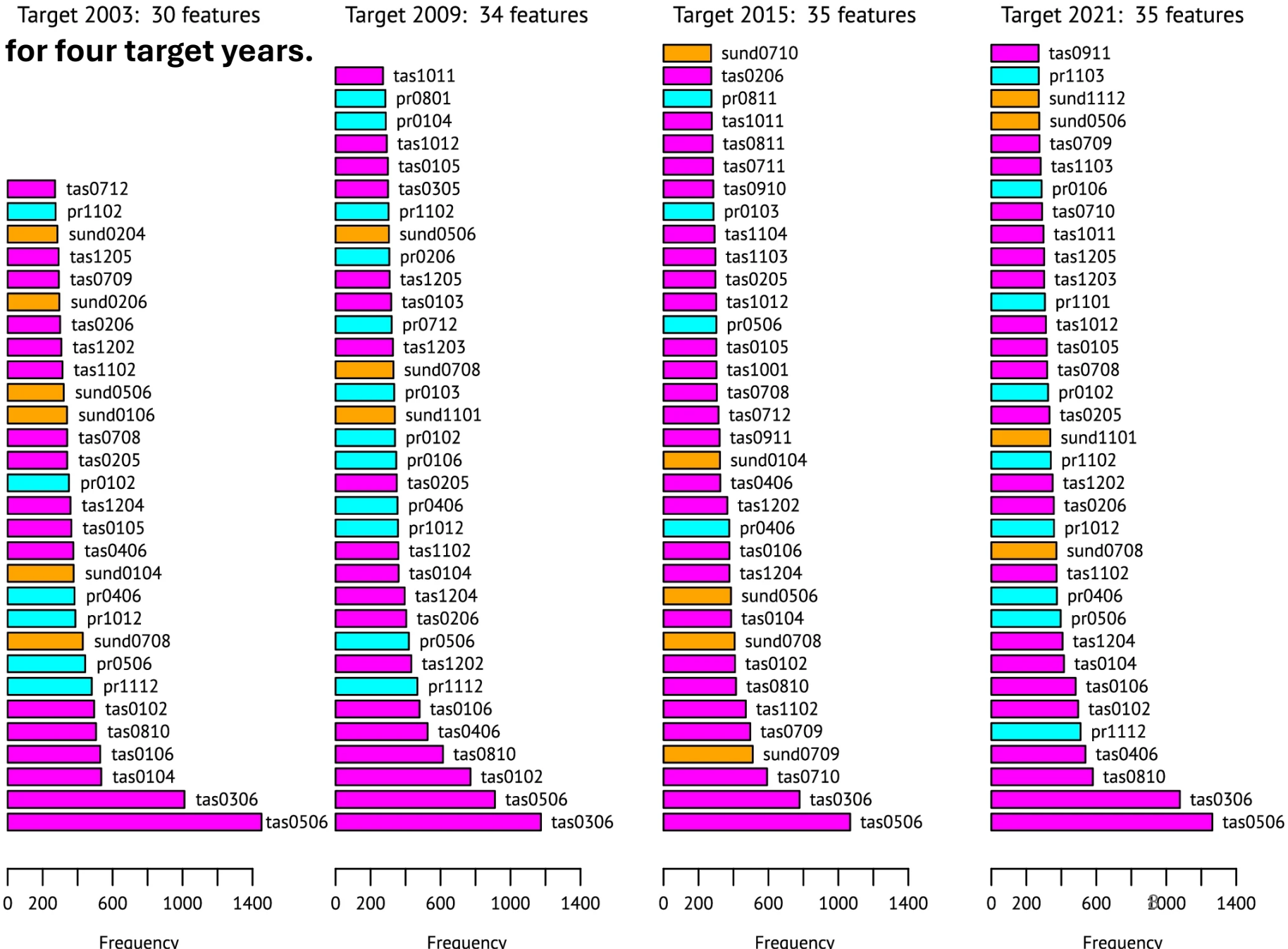
Soil Moisture

SMI (Soil Moisture Index) – average

SPEI (Standardized Precipitation Evapotranspiration Index)

Crop yield simulator

The selections and frequencies for four target years.



The feature names consist of variable acronyms
tas = temperature,
pr = precipitation,
sund = sunshine duration
and two-digit numbers of the start and end months of their time aggregation

The crop yield simulator was applied for the prediction of yield of major crops in Poland: winter wheat, spring barley, potatoes, sugar beet, and maize for 16 provinces of the country for 1999-2019.

Future yield projections were derived based on bias-corrected EURO-CORDEX simulations driven by two Representative Concentration Pathways (RCPs), RCP4.5 and 8.5.

GCM/RCM simulations

Model number	Institutions	Global model	Regional Model	RCM version	Model run scenario (RIP)
CM1	CNRM[1], CERFACS[2]	CNRM-CM5	CNRM-ALADIN63	v2	r1i1p1
CM2	DMI[3]	ICHEC-EC-EARTH	DMI-HIRHAM5	v2	r3i1p1
CM3	KNMI[4]	ICHEC-EC-EARTH	KNMI-RACMO22E	v1	r12i1p1
CM4	KNMI[4]	ICHEC-EC-EARTH	KNMI-RACMO22E	v1	r1i1p1
CM5	SMHI[5]	ICHEC-EC-EARTH	SMHI-RCA4	v1	r12i1p1
CM6	SMHI[5]	MPI-M-MPI-ESM-LR	SMHI- RCA4	v1a	r1i1p1

[1] National Centre for Meteorological Research - UMR 3589

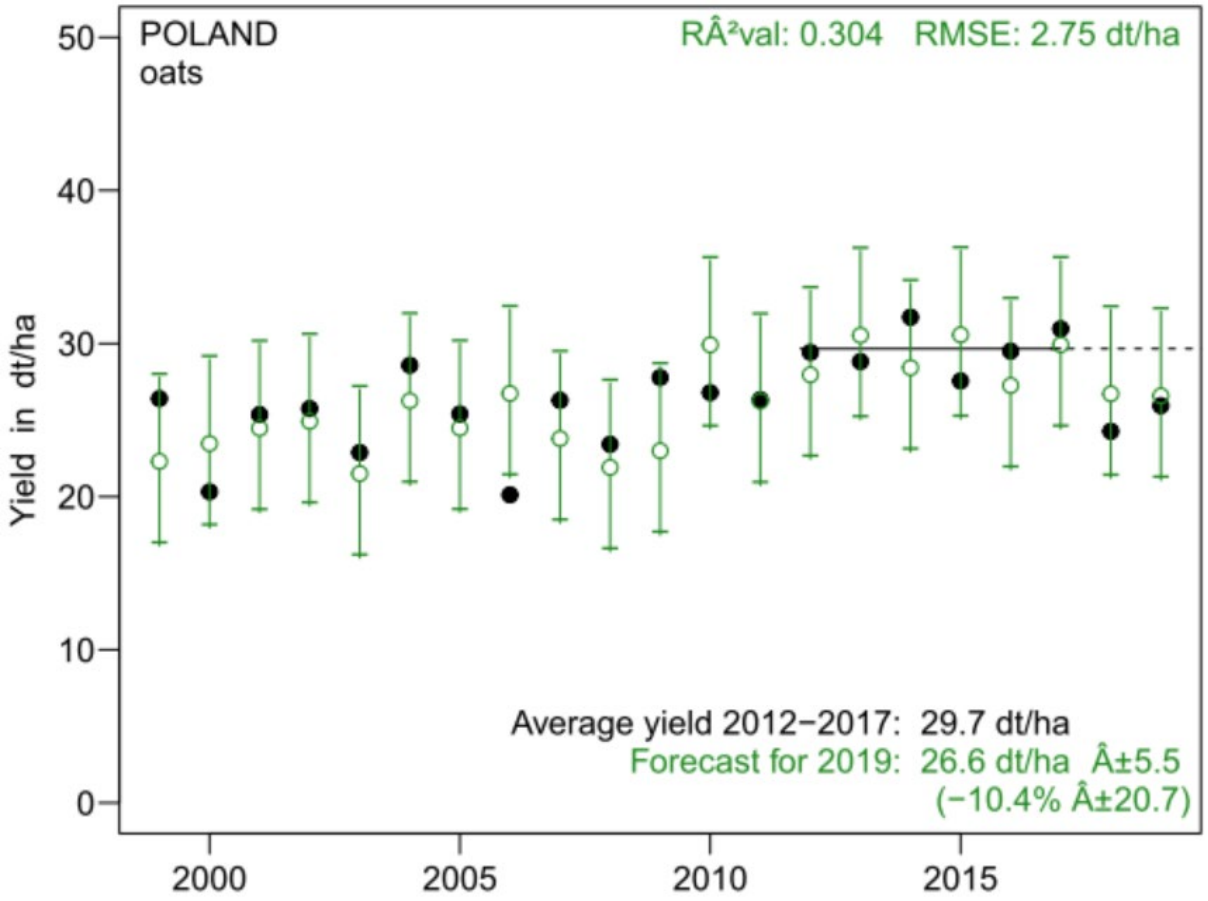
[2] Centre Européen de Recherché et de Formation Avancée en Calcul Scientifique

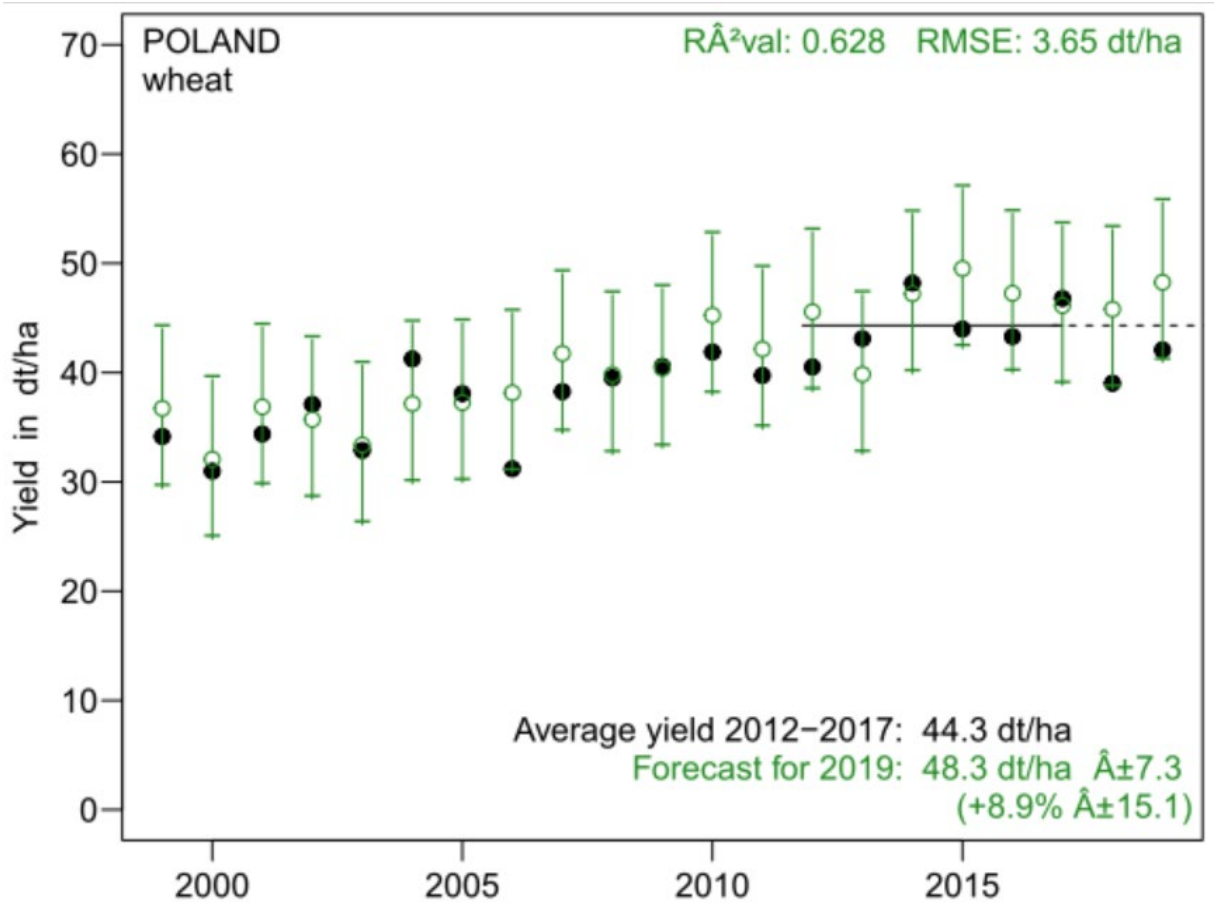
[3] Danish Meteorological Institute

[4] Koninklijk Nederlands Meteorologisch Instituut

[5] Sveriges Meteorologiska Och Hydrologiska Institut

Results


POLAND
oats
RÂ²val: 0.304 RMSE: 2.75 dt/ha
Yield in dt/ha
50
40
30
20
10
0
2000
2005
2010
2015
Average yield 2012−2017: 29.7 dt/ha
Forecast for 2019: 26.6 dt/ha Â±5.5
(−10.4% Â±20.7)


POLAND
wheat
RÂ²val: 0.628 RMSE: 3.65 dt/ha
Yield in dt/ha
70
60
50
40
30
20
10
0
2000
2005
2010
2015
Average yield 2012−2017: 44.3 dt/ha
Forecast for 2019: 48.3 dt/ha Â±7.3
(+8.9% Â±15.1)

1. Meinardus W (1901) Einige Beziehungen zwischen der Witterung und den Ernteerträgen in Nord-Deutschland. In: Verhandlungen des Siebenten Internationalen Geographen-Kongresses, Berlin, 1899. Sampson Low & Co., W. H. Kühl, and H. Le Sondier, London, Berlin, and Paris, pp II, 421–428, https://archive.org/details/verhandlungende19unkngoog/page/n457/mode/1up, last accessed in January 2022, scan lacks reproduction of tables.
2. Hooker RH (1907) Correlation of the weather and crops. J R Stat Soc 70(1):1–51. https://doi.org/10.2307/2339501
3. Fisher RA (1924) The influence of rainfall on the yield of wheat at Rothamsted. Philos Trans R Soc B 213(404):89–142. https://doi.org/10.1098/rstb.1925.0003

- Thanks for your attention.

- This study was supported by NCN, Poland.