EO4EU

Earth Observation Data & Service Accessibility

Use Case: Food security

SISTEMA, MEEO, CMCC

Funded by the European Union

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7 Use Cases (UC)

UC1 – Health care

UC2 – Ocean monitoring

UC4 – Forest ecosystem

UC3 – Food security

UC5 – Soil erosion

UC6 – Environmental pests

UC7 – Civil protection

UC3 - Food Security

Challenge

- Climate change
- Need for a resilient agriculture

Earth Observation (EO) data

Through these data it is possible to **monitor**:

- **Crops' health**
- **Water resources**
- **Pests and diseases** dispertion
- **Climatic conditions** trends

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UC3 - Food Security

Objectives

Thanks to **EO data** it is possible to:

- Analyse the **climate change impact** on crops
- Estimate the **risk of crop losses**
- Identify **new** favourable **areas**
- Identify **crops** suitable **for new conditions**

Beneficiary sectors

- **Insurance**
- **Precision farming**
- **Financial** markets

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UC3 - Food Security

Benefits from the EO4EU Platform

The Food Security use case makes use of various components provided by the EO4EU Platform to:

- **Easily access** the data sources needed to run the implemented model (Knowledge Graph component)
- **Download** data
- Build the **workflow**
- **Visualise** the results
- Allow the users to **customise** the model

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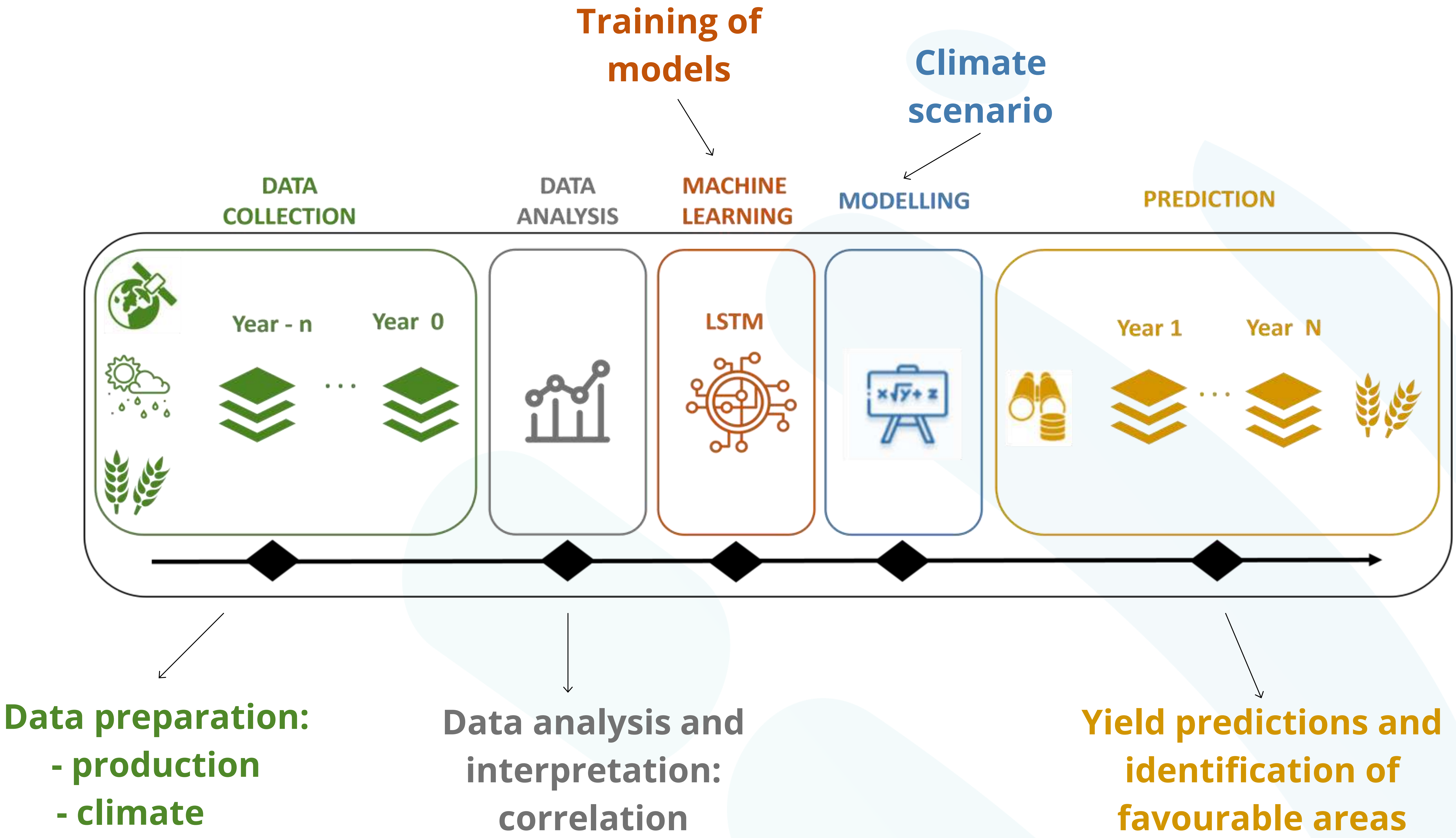
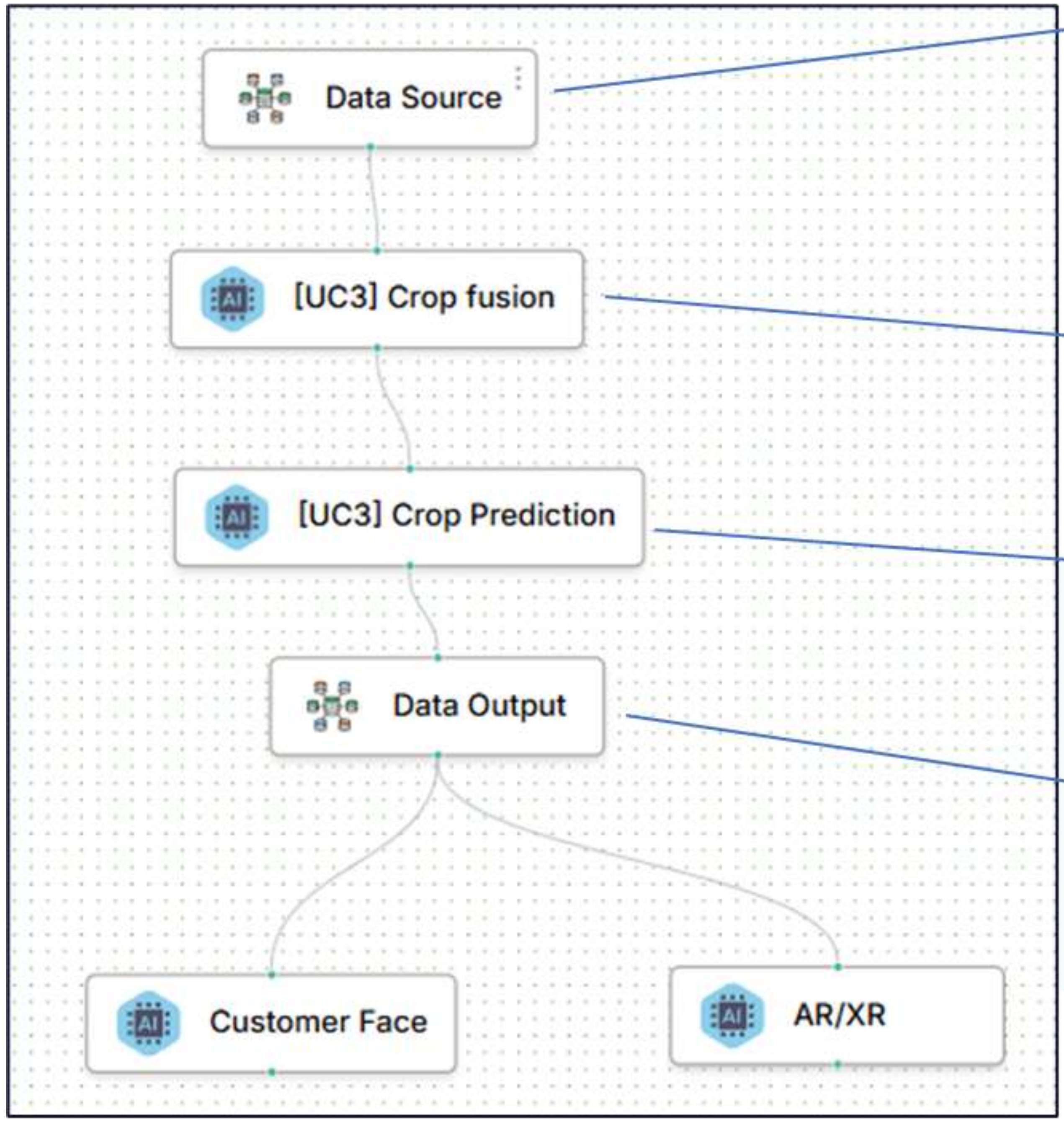
UC3 Workflow



UC3 through the EO4EU Platform



UC3 workflow on EO4EU Platform

In-situ input data

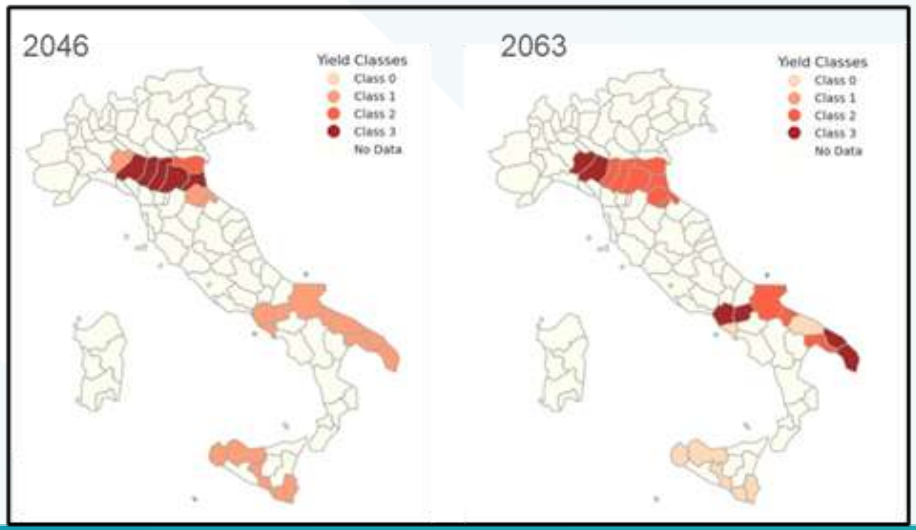
CMCC VHR climate projections
Soil data
Digital Elevation Model
European provinces

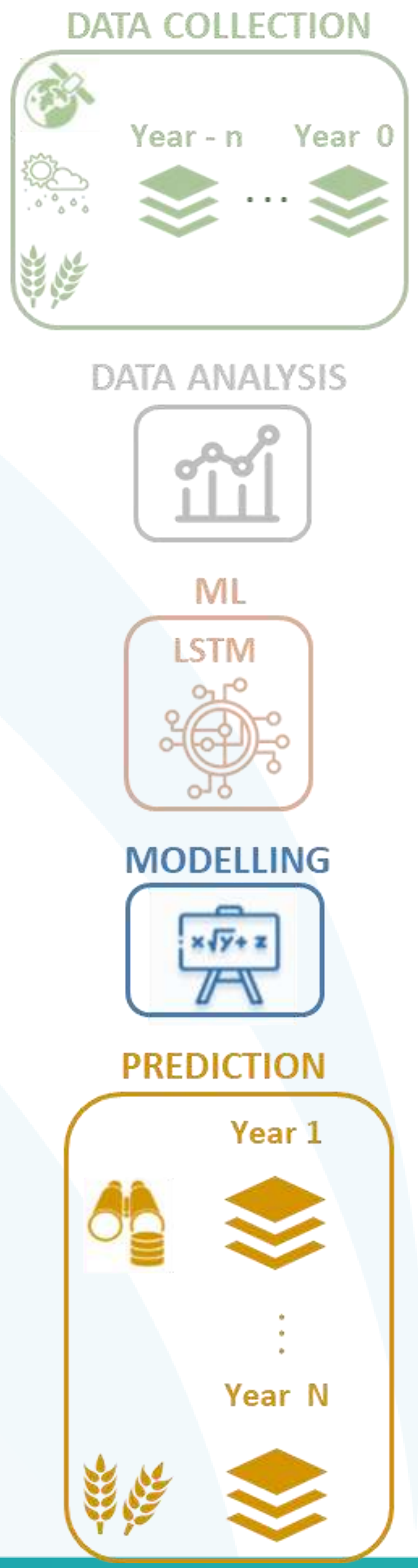
Pre-processing (features extraction)

ML model inference

Crop yield classes prediction

Yield Classes
- Class 0 - from 0 to 366 q/ha
- Class 1 - from 366 to 530 q/ha
- Class 2 - from 530 to 685 q/ha
- Class 3 - from 685 q/ha
- No Data





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Challenges

- **Our expertise:** algorithm implementation and climate indicator generation
- Initial objectives were **recalibrated** based on difficulties encountered during the development and based on the feedback received from the stakeholders

Limits

- Limited availability of **accurate data** on abiotic factors other than temperature that influence yield
- Little information on '**climatic stresses**', i.e., the critical duration of extreme weather conditions and the ability of crops to recover after a severe stress or event
- **Unresolved issues** to be addressed with stakeholders' support
- Potential **alternative solutions** suggested by the stakeholders

EO4EU progress and adjustments

- **Technical implementations** of the platform and their **timing**
- Evaluation of the **actual usefulness** of the technologies employed
- **Continuous evolution** of the adopted technologies

Food security UC methodology

Target crop

- Industrial tomatoes
- Maize

Area of interest

- Italy
- Spain
- France

Input data

- Copernicus **ERA5** (temperature and precipitation)
- **Sentinel-2** plus derived indices
- Very high-resolution datasets from **CMCC simulations** (historical and projections)
- **ISTAT** (distribution and yield of Italian crops at local scale)
- **Copernicus Digital Elevation Model** (DEM) with 30 m resolution
- **Soil information** (SoilGrid data source): clay, sand, nitrogen, dissolved organic carbon, water pH
- European territorial **boundaries**

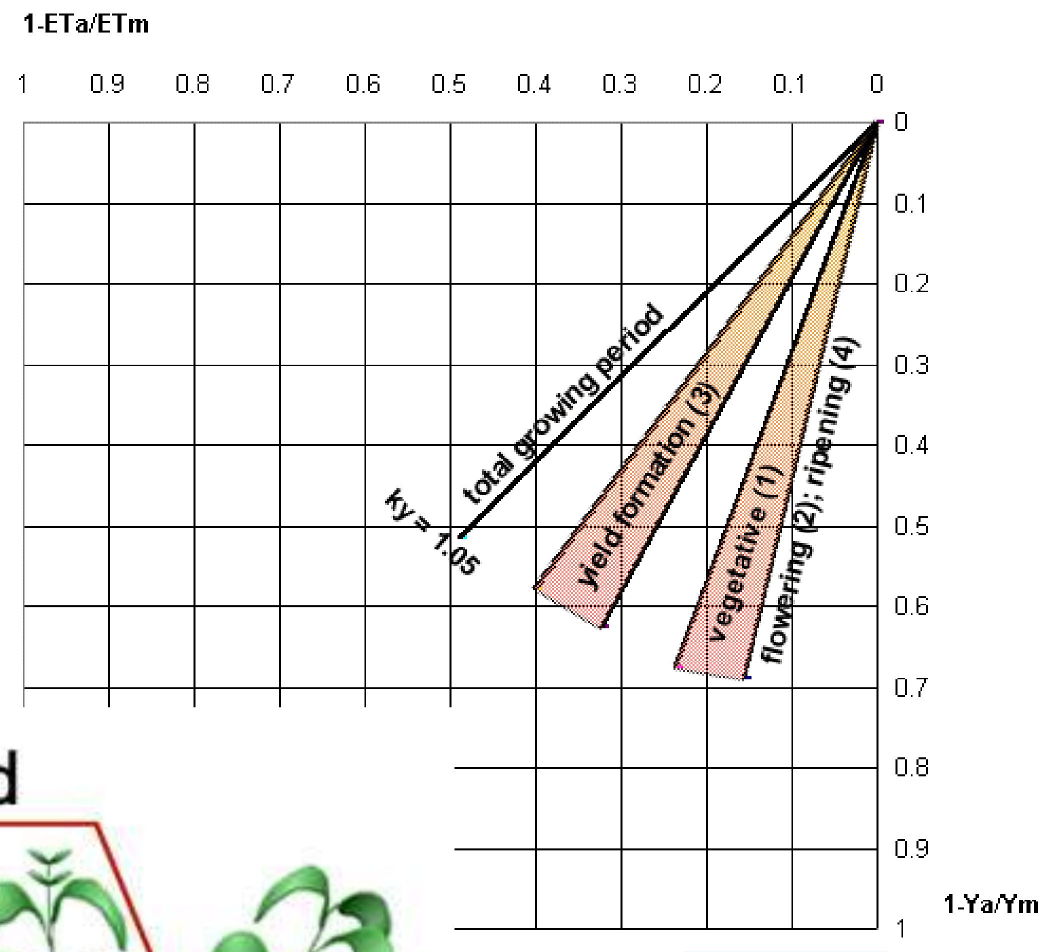
Preliminary studies

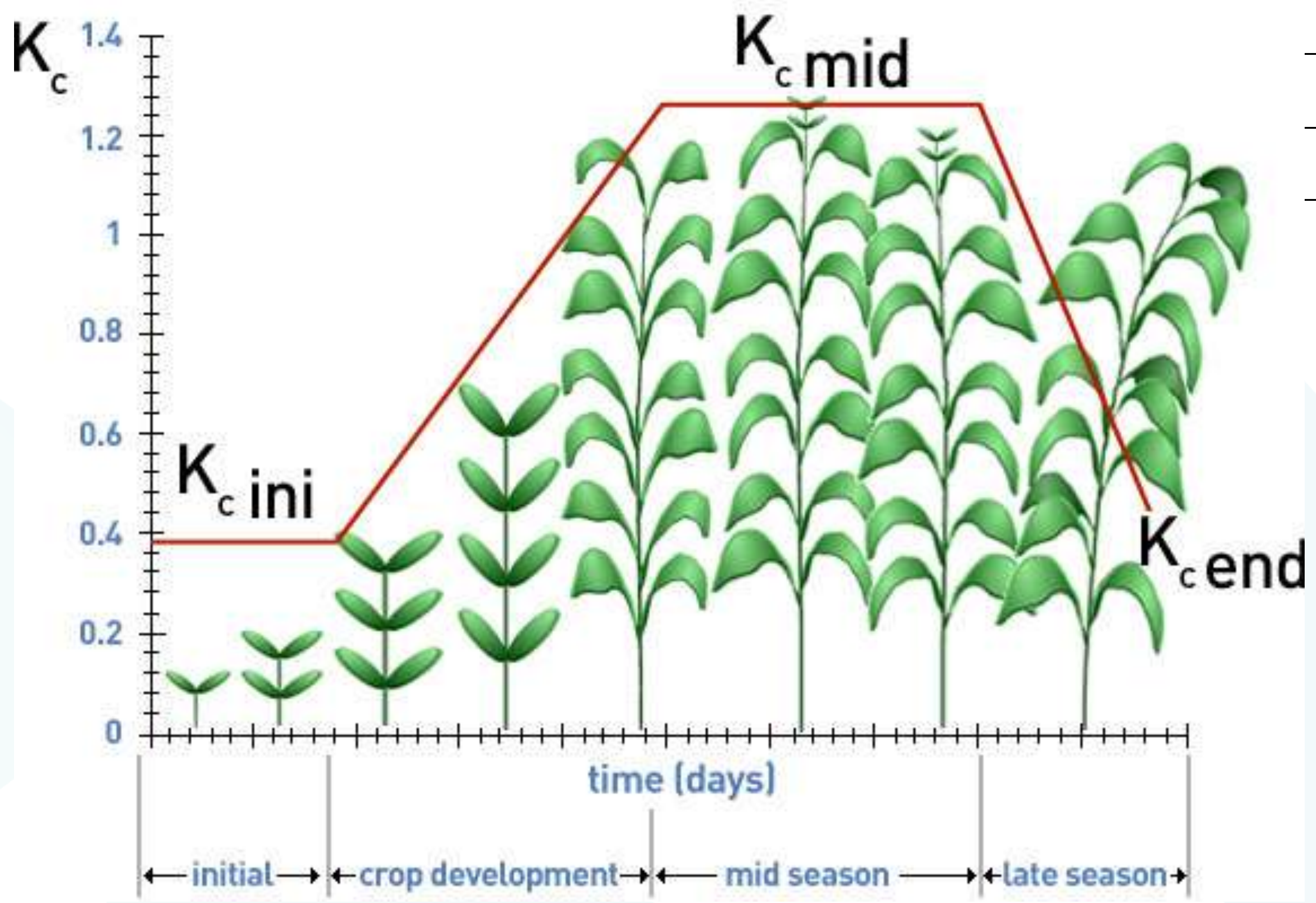
Production
- Area, production, yield
- Trend of costs

Temperature
- Optimum 18-25°C
- Killing temperature: > 35 / < 10 °C
- Temperature stress

Water
- 400 - 600 mm during cultivation period
- Soil moisture 0.8 - 1.5
- Rainfall stress

Further information
- Growing season (April - September)
- Growth and resistance phases (critical moment)
- Evapotranspiration





Data extraction

- Use of yield as a comparative production index
- Data collection from 2006 to 2023
- Comparison of climate data (hourly and daily) with annual yield data

Economic-production data

Territorio	anno	superficie totale - ettari	produzione totale - quintali	resa
Bologna	2012	360	226000	627.777778
Bologna	2013	296	198320	670.000000
Bologna	2014	340	205020	603.000000
Bologna	2015	363	232320	640.000000
Bologna	2016	405	287400	709.629630
Bologna	2017	305	222600	729.836066
Bologna	2018	305	208670	684.163934
Bologna	2019	412	247200	600.000000
Bologna	2020	344	233160	677.790698
Bologna	2021	368	294400	800.000000
Bologna	2022	313	228490	730.000000

Daily climatic data

PragaDate	DAILY_TMIN	DAILY_TMAX	DAILY_TAVG	DAILY_PREC
2012-01-01	-1.2	9.1	2.8	0.0
2012-01-02	0.0	5.5	3.5	6.9
2012-01-03	0.9	7.9	4.8	1.0
2012-01-04	-1.5	3.4	1.3	0.0
2012-01-05	0.1	11.2	4.1	2.0
2012-01-06	2.4	10.9	6.2	0.3
2012-01-07	1.9	12.0	6.4	0.0
2012-01-08	0.3	12.1	5.4	0.0
2012-01-09	0.7	13.3	6.2	0.0
2012-01-10	0.6	12.2	5.4	0.0
2012-01-11	-1.6	9.9	3.1	0.0

Hourly climatic data

PragaTime	TAVG	PREC
2012-01-01 00:00:00	0.5	0.0
2012-01-01 01:00:00	0.9	0.0
2012-01-01 02:00:00	0.3	0.0
2012-01-01 03:00:00	-0.2	0.0
2012-01-01 04:00:00	-0.5	0.0
2012-01-01 05:00:00	0.0	0.0
2012-01-01 06:00:00	0.3	0.0
2012-01-01 07:00:00	0.2	0.0
2012-01-01 08:00:00	1.0	0.0
2012-01-01 09:00:00	3.7	0.0
2012-01-01 10:00:00	5.0	0.0
2012-01-01 11:00:00	6.5	0.0
2012-01-01 12:00:00	7.3	0.0
2012-01-01 13:00:00	8.1	0.0
2012-01-01 14:00:00	8.5	0.0
2012-01-01 15:00:00	8.0	0.0

Single dataset generation

Territorio	anno	resa	giorni_30C	giorni_35C	giorni_25C	giorni_10C	Cumulative_Prec
Bologna	2012	627.777778	21	8	42	33	390.5
Bologna	2013	670.000000	10	3	28	21	717.1
Bologna	2014	603.000000	12	2	43	23	713.1
Bologna	2015	640.000000	17	0	46	21	570.9

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Indicators' extraction

84 indicators, broken down by crop cycle period:

- Entire growth cycle (April–September)
- Planting and initial growth phase (April–June)
- Production season (July–September)
- Most critical month (May)

- ***Indicators based on:***
  - Precipitation
  - Temperature
  - Precipitation + Temperature
  - Soil texture
  - Nitrogen
  - Organic carbon density
  - pH levels
  - Radiation
  - Moisture

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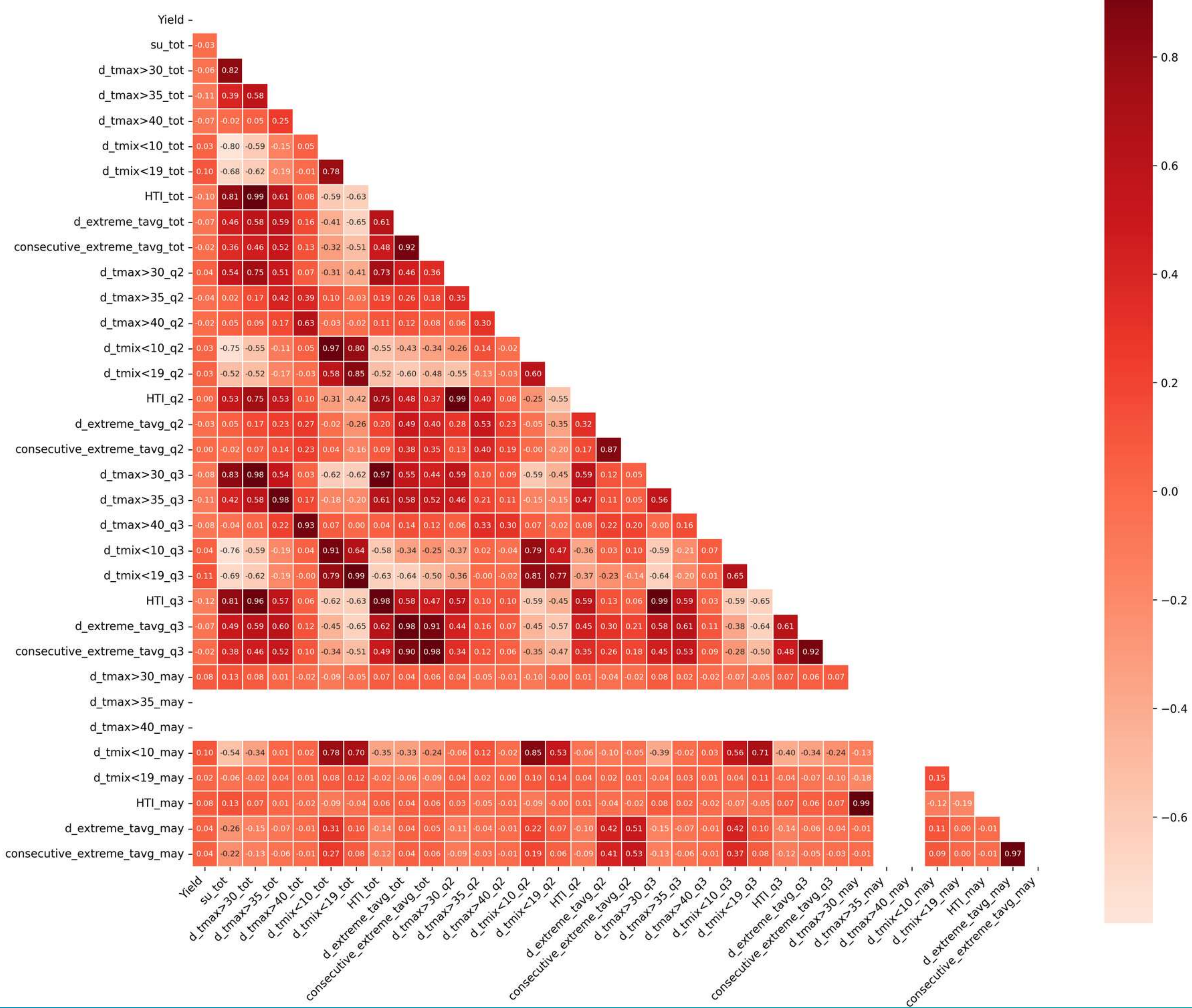
Correlation between crop yield and temperature indicators



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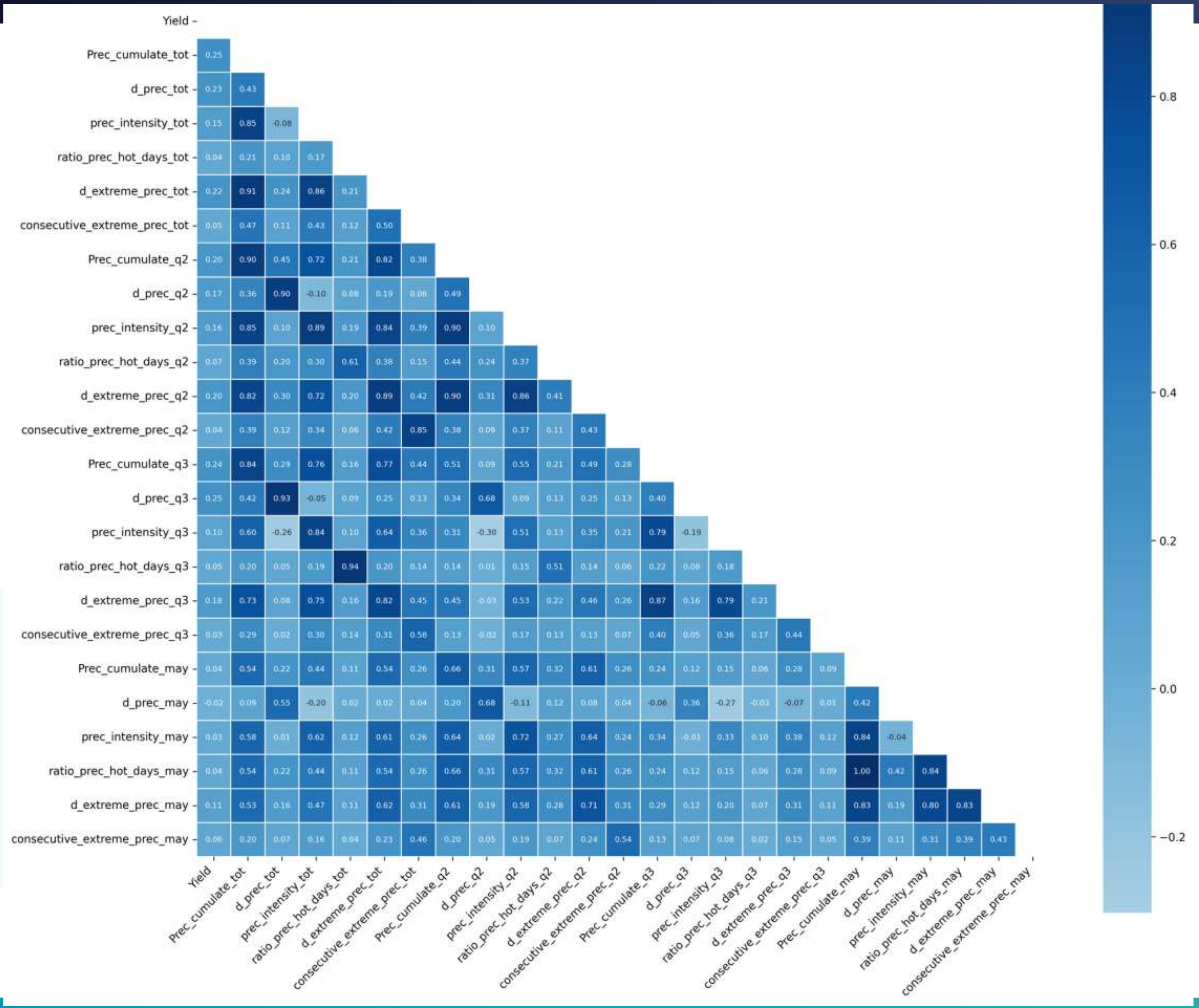
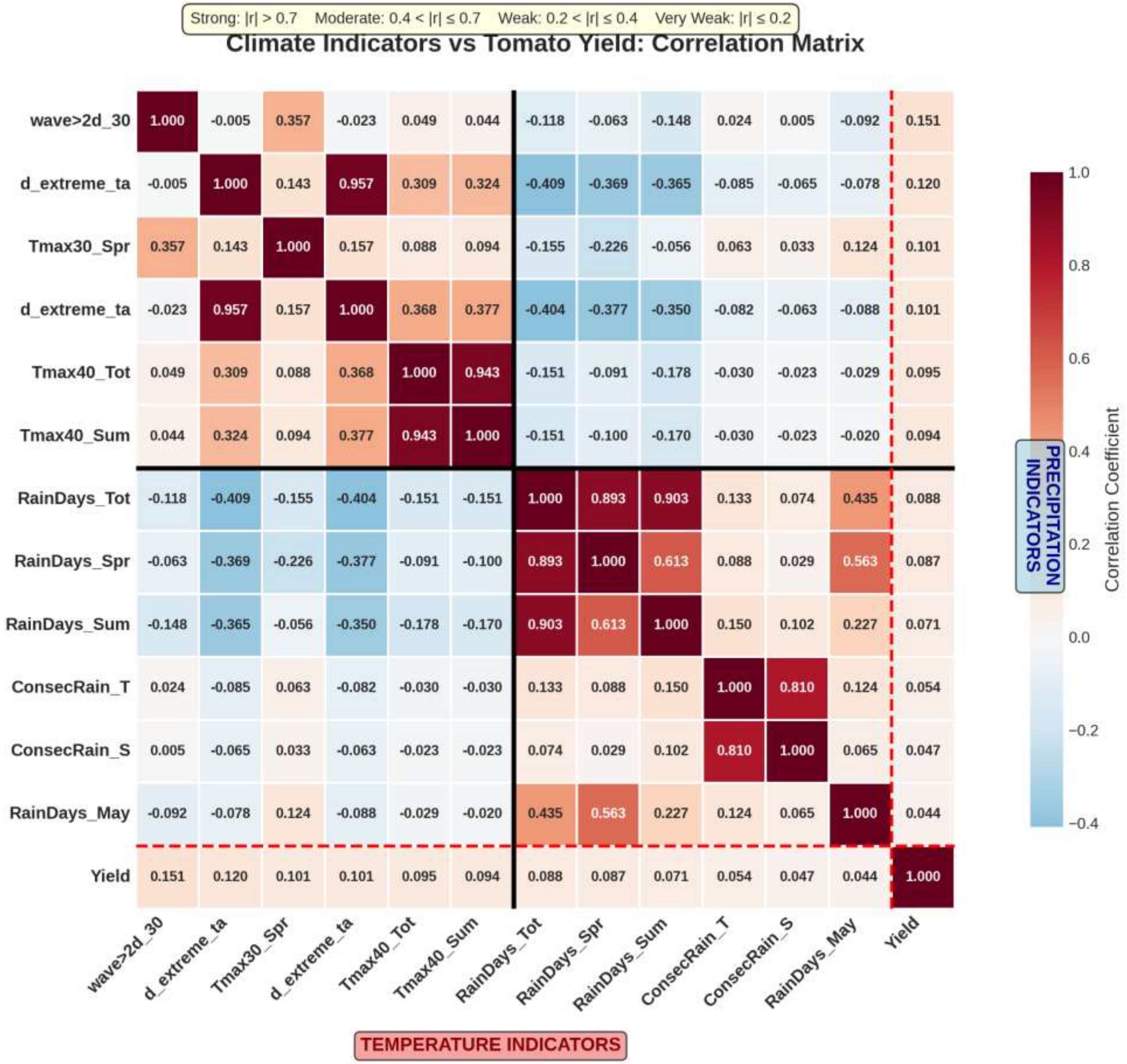
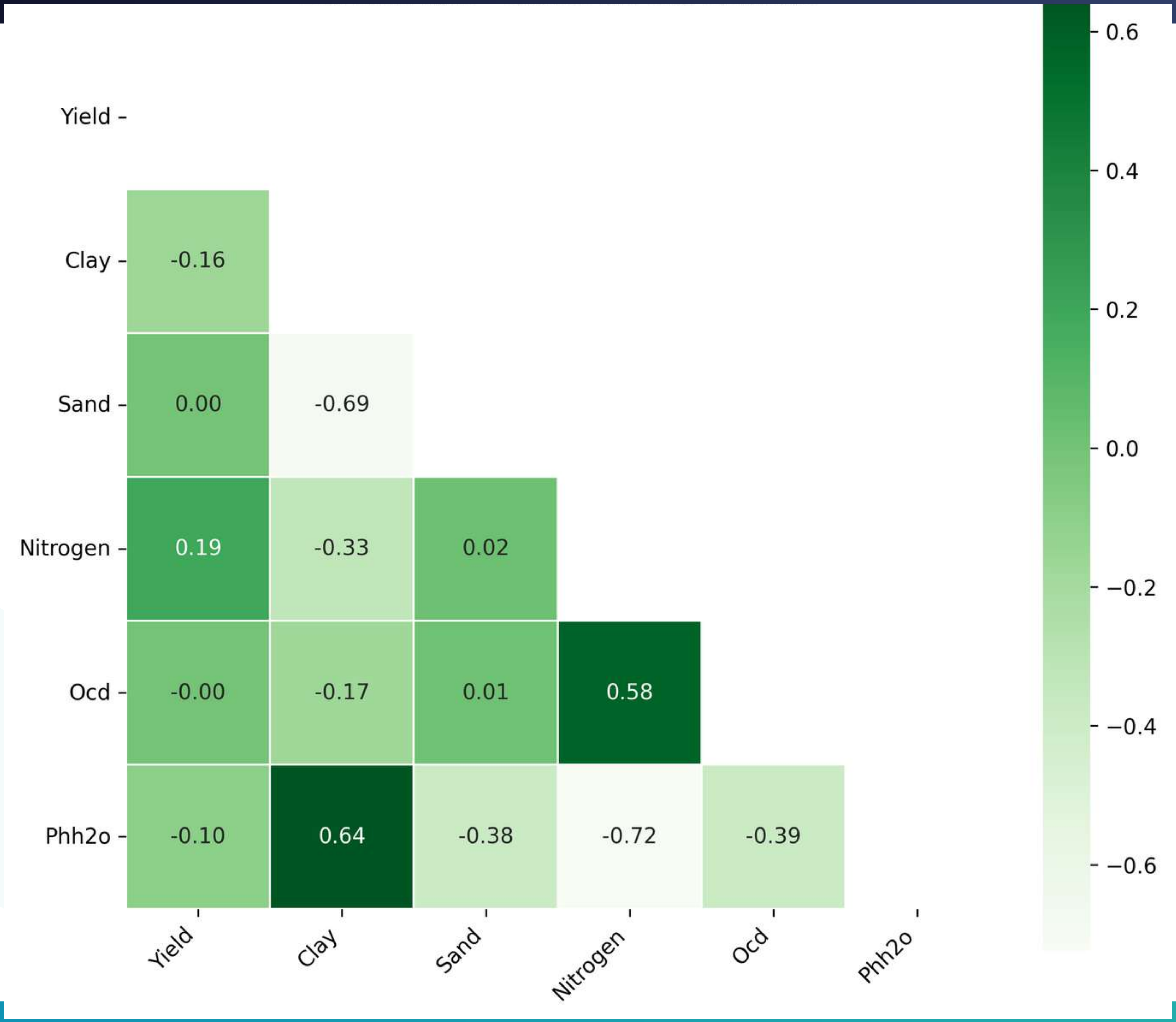
Correlation between crop yield and precipitation indicators



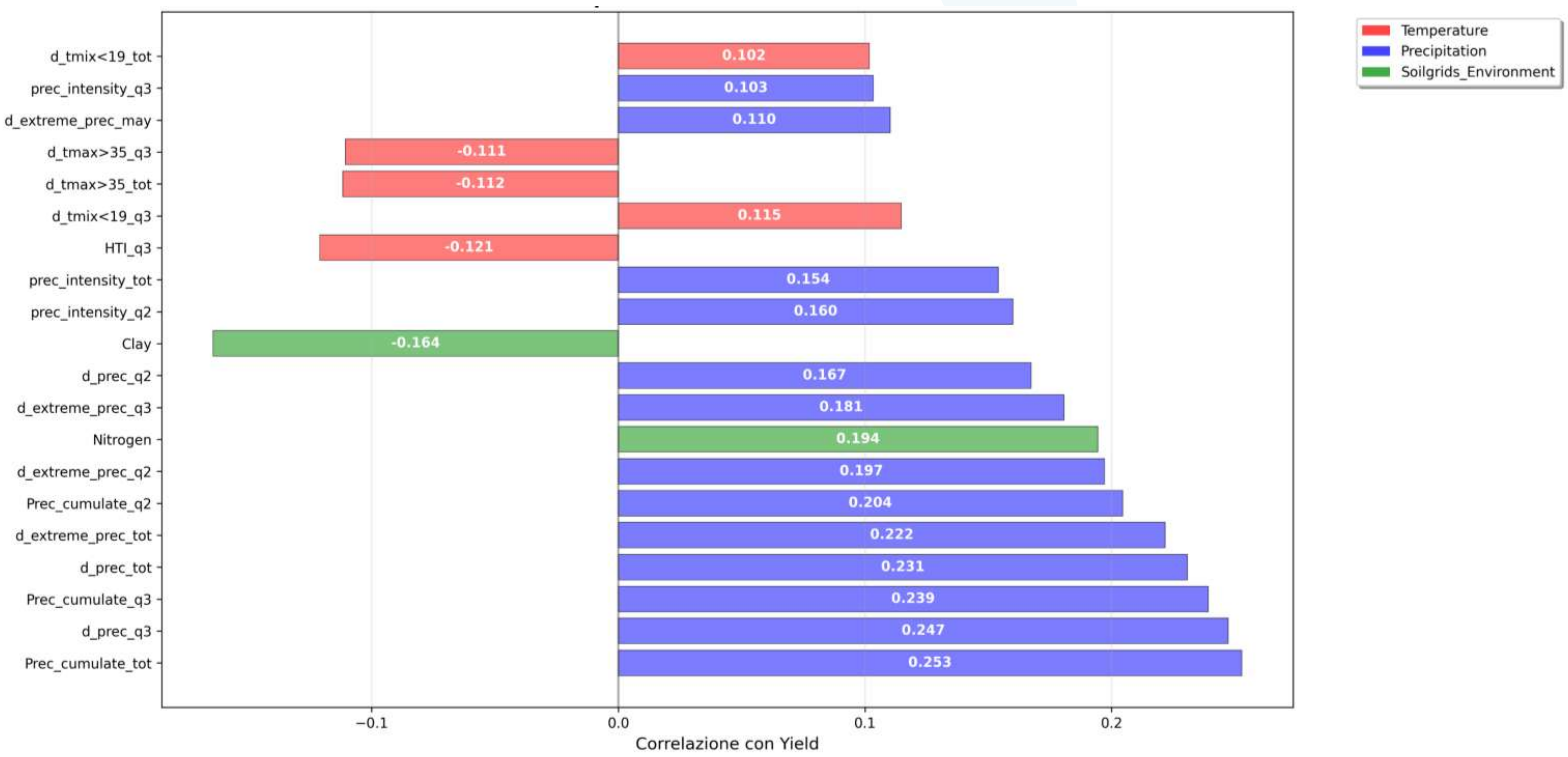
Summary of correlations



Correlation between crop yield and soil indicators



Top 20 correlations



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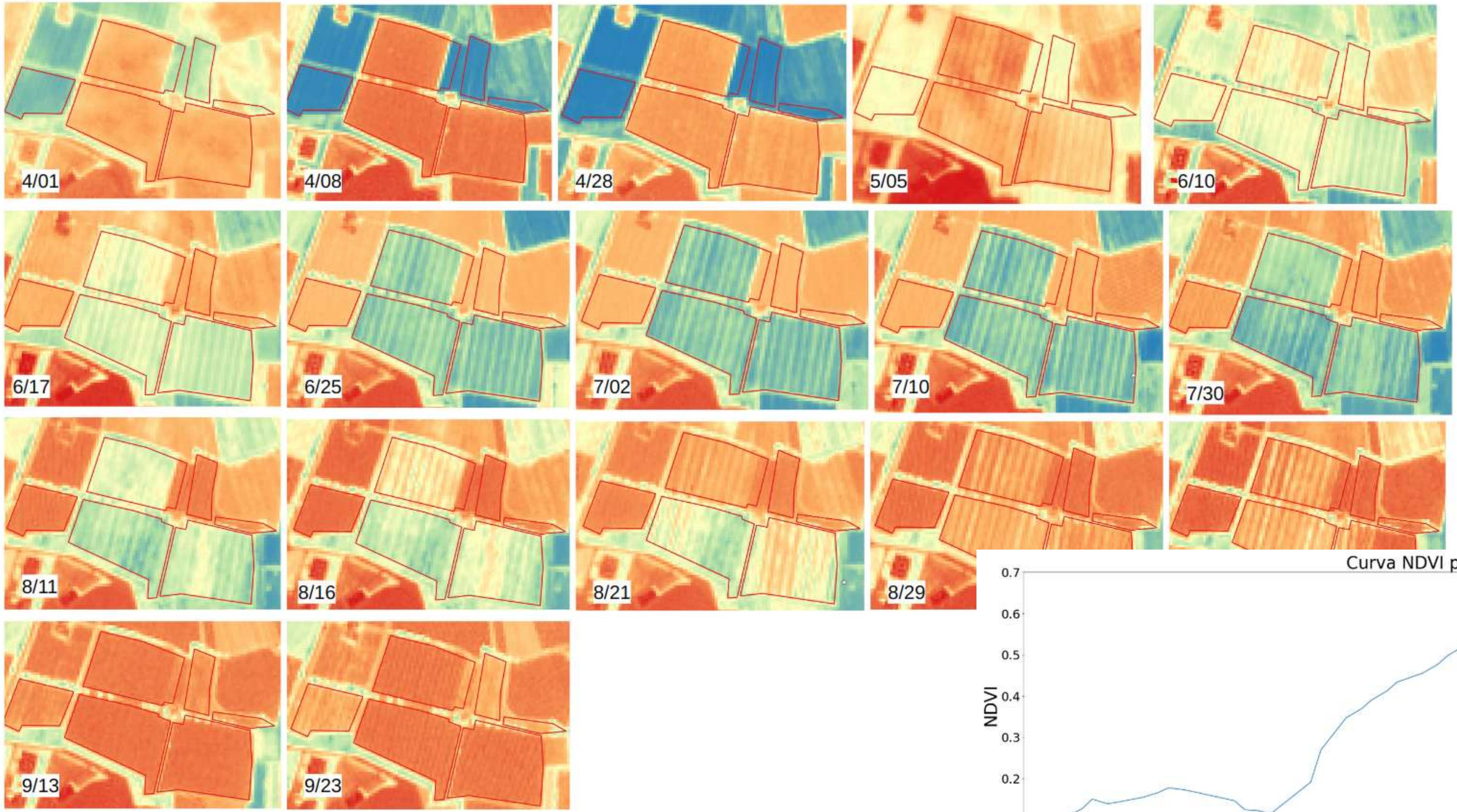
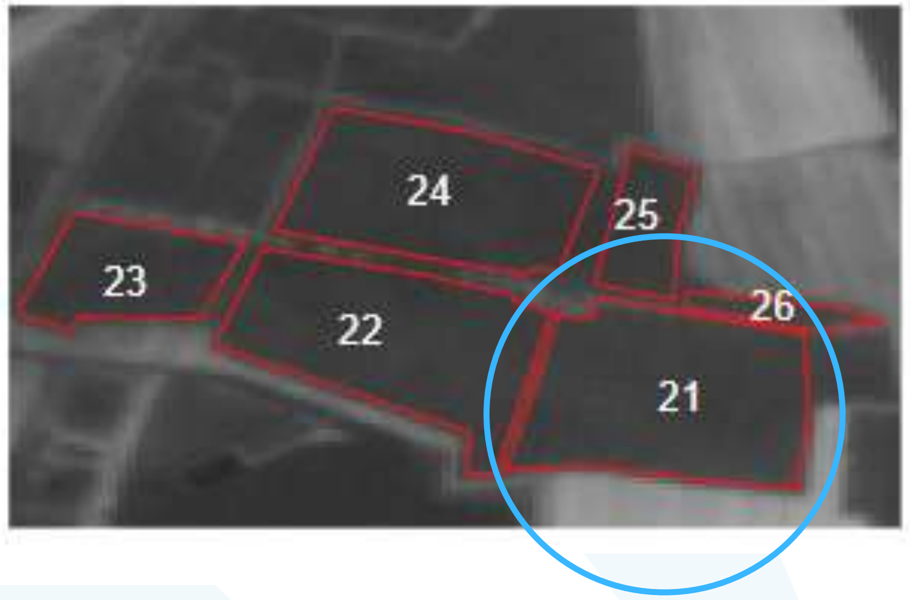
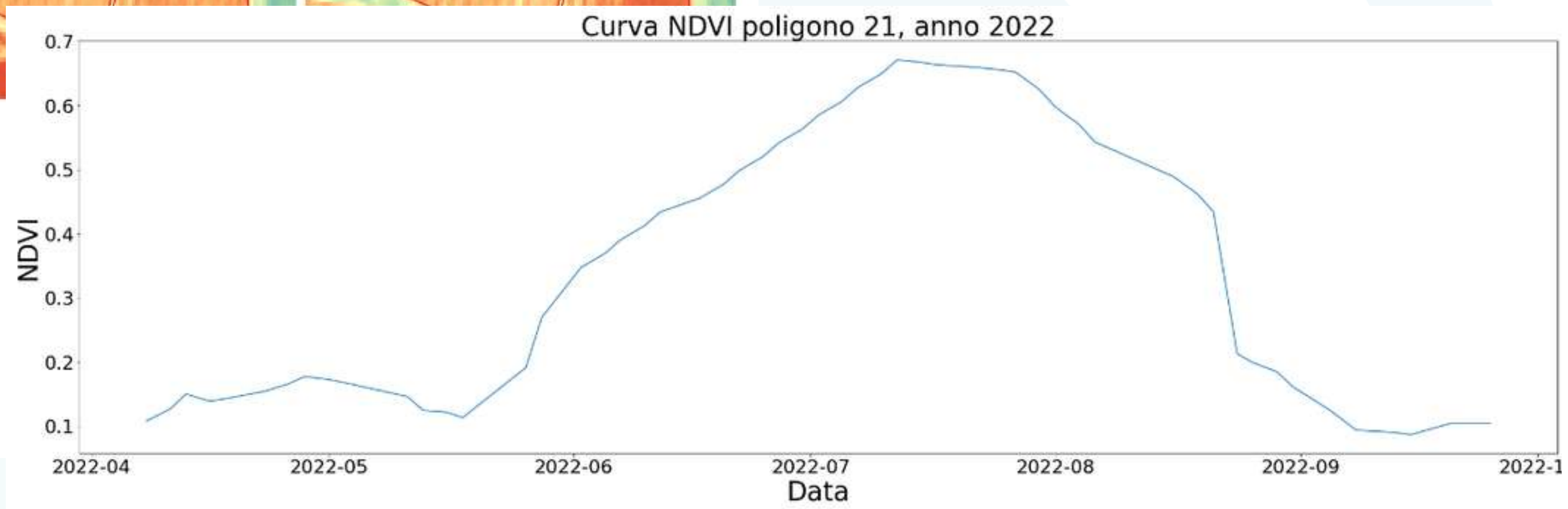
Vegetation Index (NDVI)







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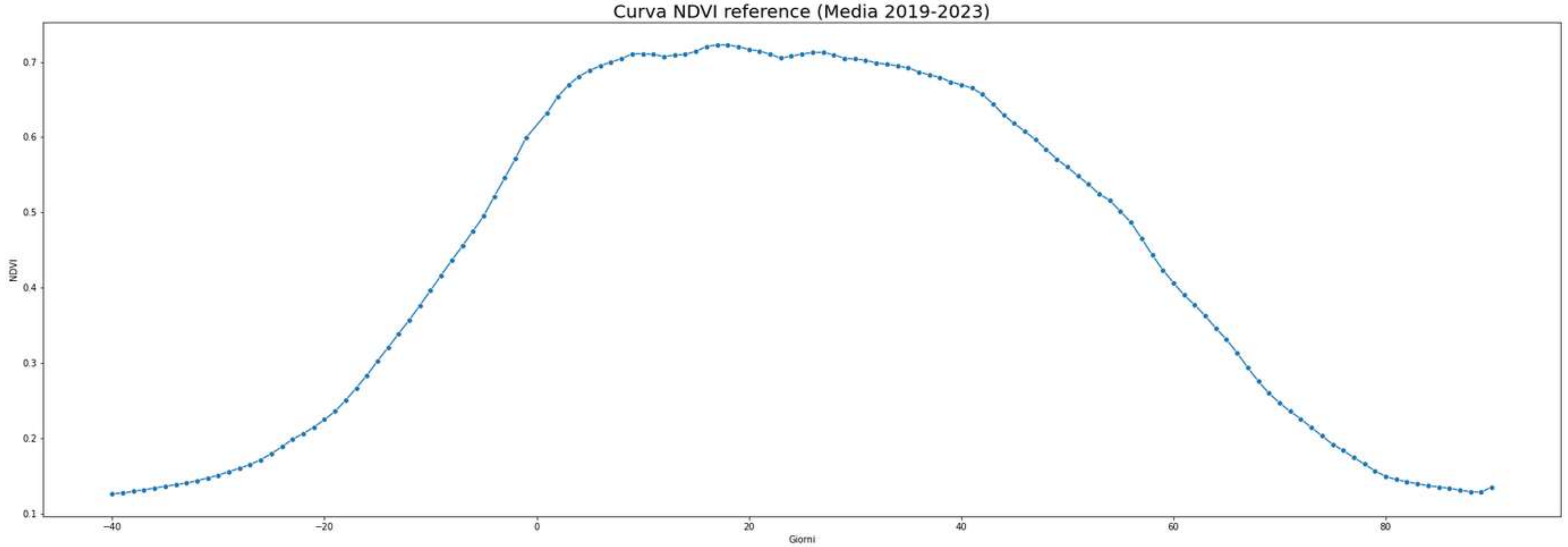

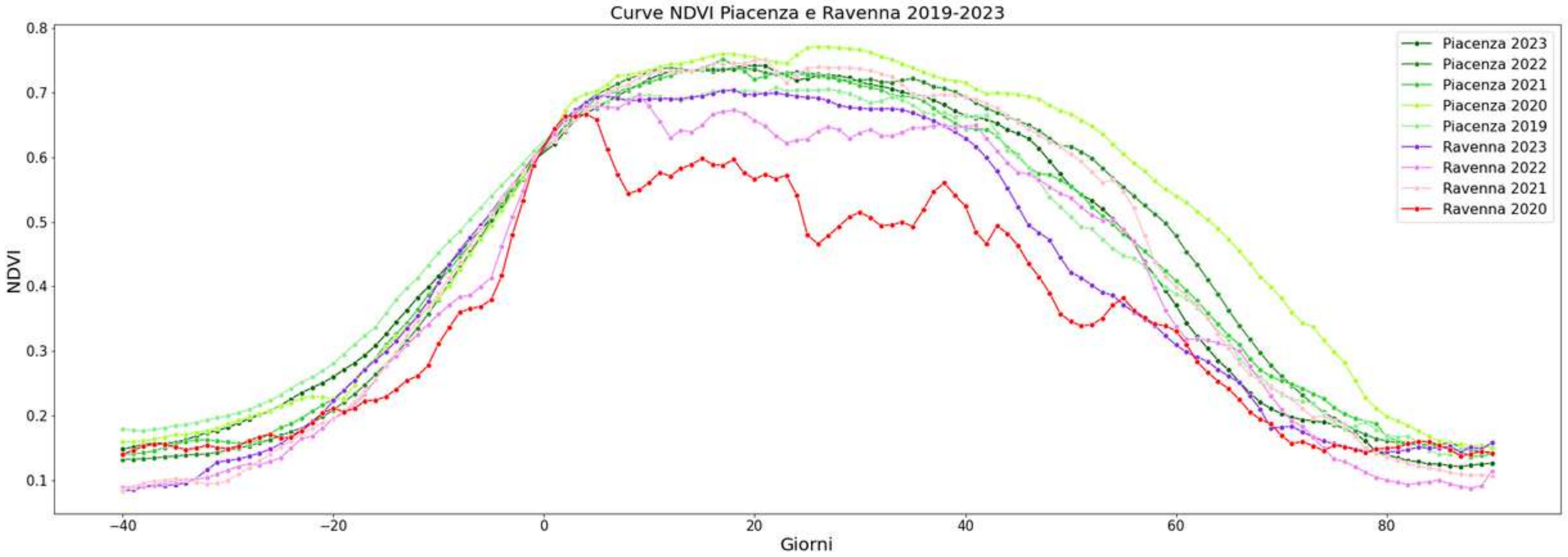

Provincia	Anno	Area NDVI	NDVI medio	NDVI massimo	NDVI std	superficie totale - ettari	produzione totale - quintali	Resa
Piacenza	2020	62.938623	0.485334	0.771263	0.230697	10183	7528954	739.365020
Piacenza	2021	56.933797	0.439024	0.751155	0.224925	10631	8085600	760.568150
Piacenza	2022	58.203509	0.448777	0.738937	0.236870	9633	8001330	830.616630
Piacenza	2023	56.713254	0.437307	0.742403	0.230245	9711	8191645	843.542890
Piacenza	2019	57.206834	0.441352	0.708020	0.210066	10418	6845160	657.051257
Ravenna	2021	56.275886	0.433624	0.752138	0.250034	2200	1804000	820.000000
Ravenna	2022	50.971388	0.392864	0.697304	0.226350	2222	1744270	785.000000
Ravenna	2023	52.063762	0.401413	0.704034	0.227078	2350	1449950	617.000000
Ravenna	2020	45.037720	0.347526	0.667023	0.173662	1890	1436400	760.000000

Machine Learning model training

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Input data

- **ISTAT** (distribution and yield of Italian crops at local scale)
- **Copernicus ERA5**
- **Copernicus Digital Elevation Model** (DEM)
- European territorial **boundaries**
- **Soil data**


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Machine Learning model inference

Model type → Artificial Neural Network for classification

- **Supervised learning**: learns from examples with known answers
- **Non-linear:** can capture complex relationships in data
- **Configurable**: allows selection of parameters (number of layers, neurons, activation functions)
- **Versatile**

Why this model?

- **Non-linear relationships**: agricultural factors involve complex, non-linear interactions
- **Multiple simultaneous factors:** better handled by classification models

Input data

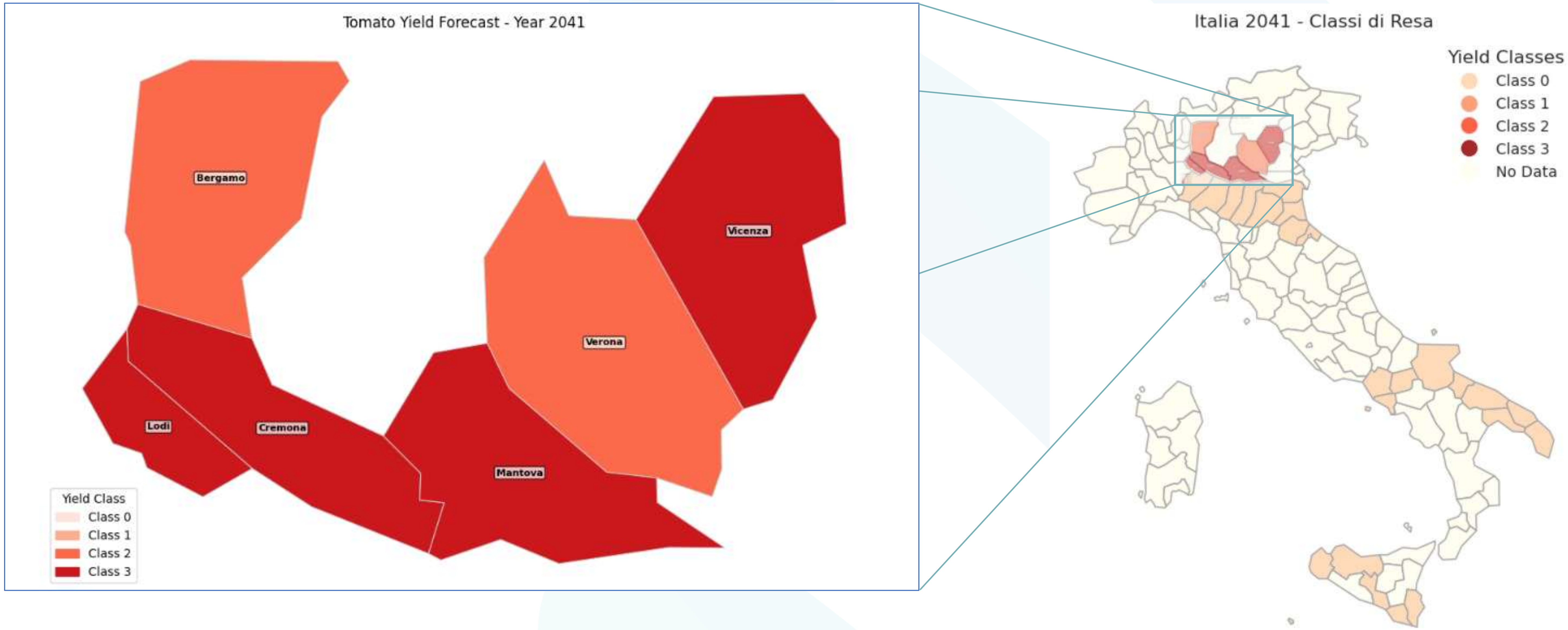
- Very high-resolution datasets from CMCC **climate projections**
- Copernicus **DEM**
- European **boundaries**
- **Soil** data

Model results

Classification of crop yield

Four yield class types:

- **Class 0**: 0–366 q/ha
- **Class 1**: 366–530 q/ha
- **Class 2**: 530–685 q/ha
- **Class 3**: >685 q/ha



Model scalability: maize crop

- Extension of the method developed for tomatoes to **maize**, a strategic crop in Italy and Europe
- Reuse of existing ML architecture with **re-training on maize-specific data**
- Training using yield, climate, and territorial indicators from **Italian and French** provinces
- Selected provinces show **high productivity and climatic diversity**
- **Confirmed scalability** of UC3 workflow to other crops by **adapting the crop calendar**

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Thank you!