



A hierarchical robust combined index for agricultural drought detection and monitoring using EO big data

Filippo Bocchino, Sapienza University of Rome (Italy)

General context

- This work is part of the **Geomatics for Resilience Against Water scarcity (GRAW) project** (Agreement n. 2023-1-HB.0) funded by the **Italian Space Agency (ASI)** in the framework of the Innovation for Downstream Preparation for Science (I4DP SCIENCE) program
- Call for ideas: **Agriculture and Sustainable Use of Water Resources**



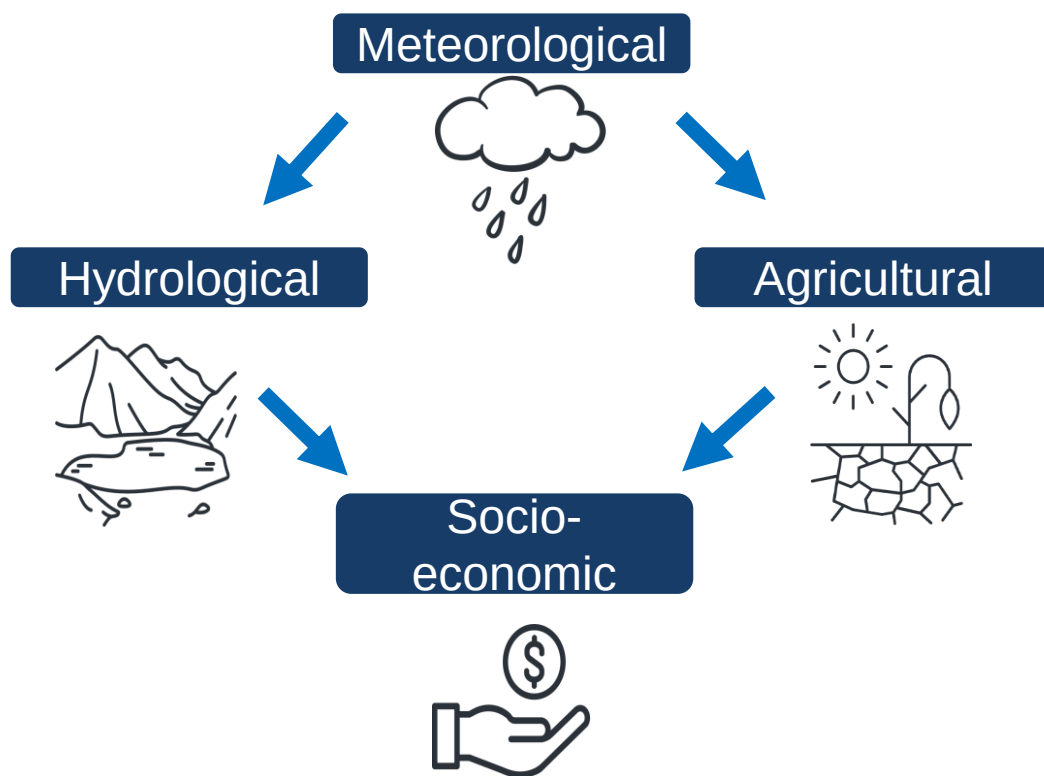
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- Final users:
 - District Basin Authority of the Central Apennines (AUBAC)
 - **Institute of Services for Agricultural and Food Market (ISMEA)**



General context

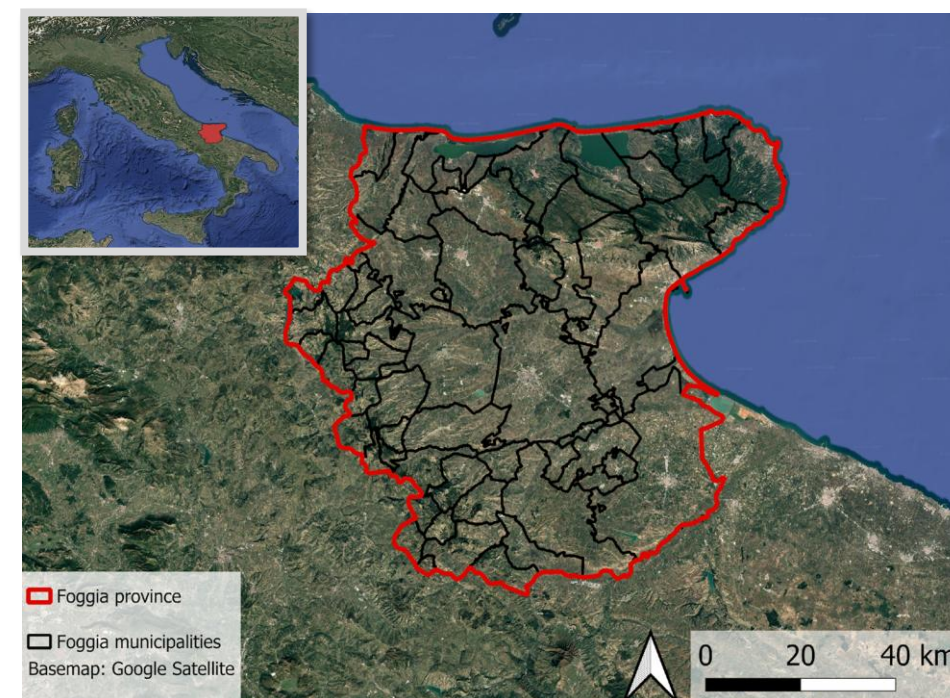
Drought is a complex phenomenon



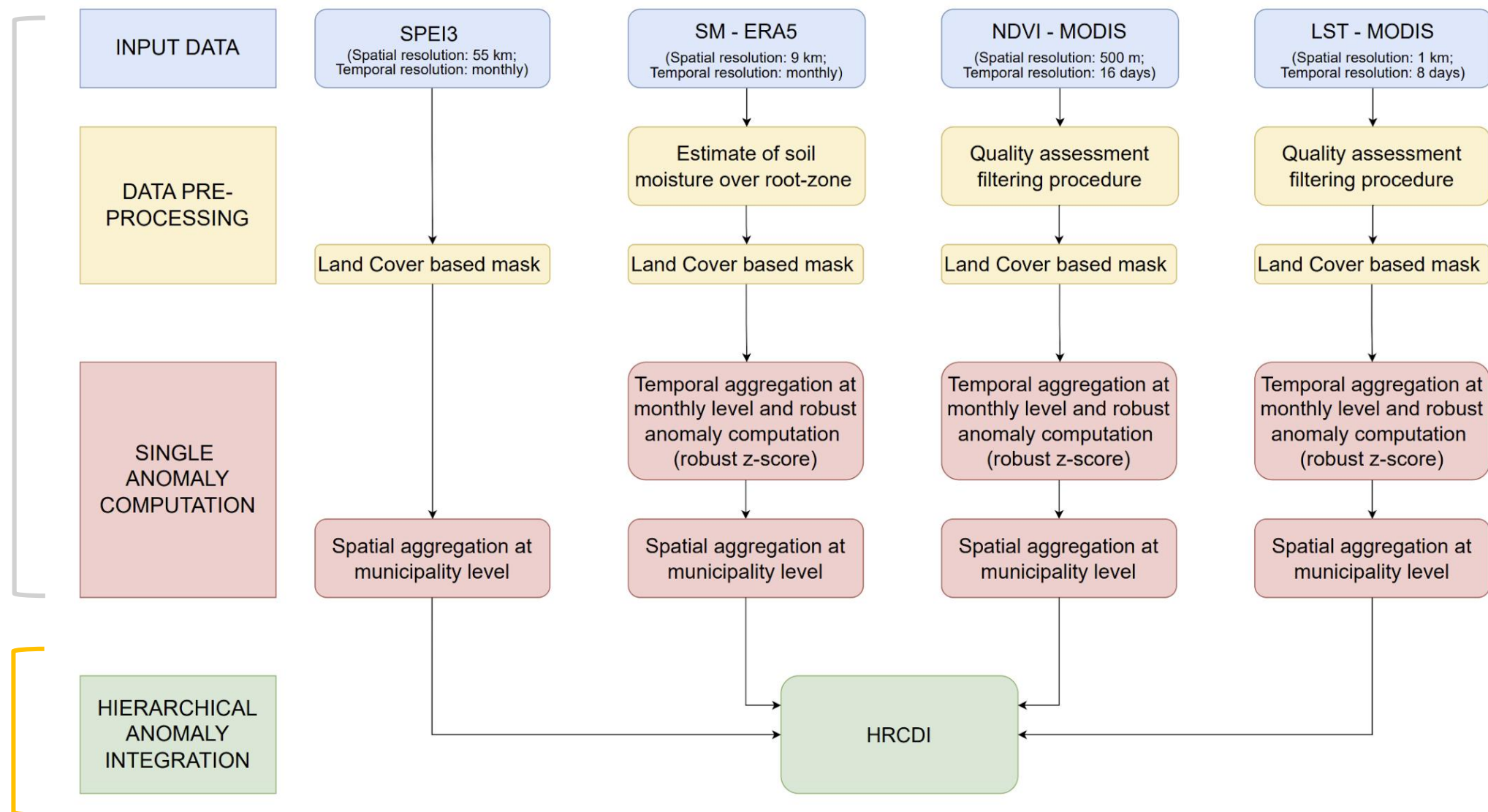
- Several studies have recently proposed **Combined Drought Indices (CDIs)**
- Multi-source integration aligns with **World Meteorological Organization** recommendations
- **Current CDIs differ in** data sources, anomaly computation methods, indicator integration strategies, and **lack** comprehensive validation
- This study proposes the **Hierarchical Robust Combined Drought Index (HRCDI)**, designed to support the operational needs of ISMEA

Case study

- **Localization:** Province of Foggia, Apulia region (Southern Italy)
- **Climate characteristics:** Typical Mediterranean climate with hot, dry summers (often $>40^{\circ}\text{C}$) and annual precipitation between 450–600 mm
- **Agricultural importance:** Foggia is known as the "*Granary of Italy*", with extensive cultivation of durum wheat
- **Drought impacts:** In 2022, severe droughts caused major agricultural losses, with durum wheat yields reduced by up to 25% in Apulia, leading to a regional natural disaster declaration

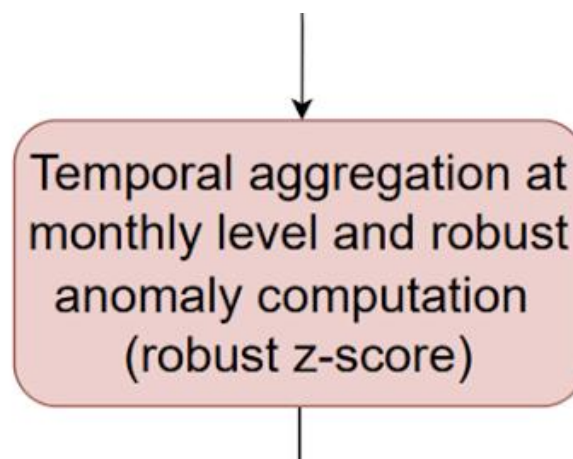


Workflow



Single anomaly computation

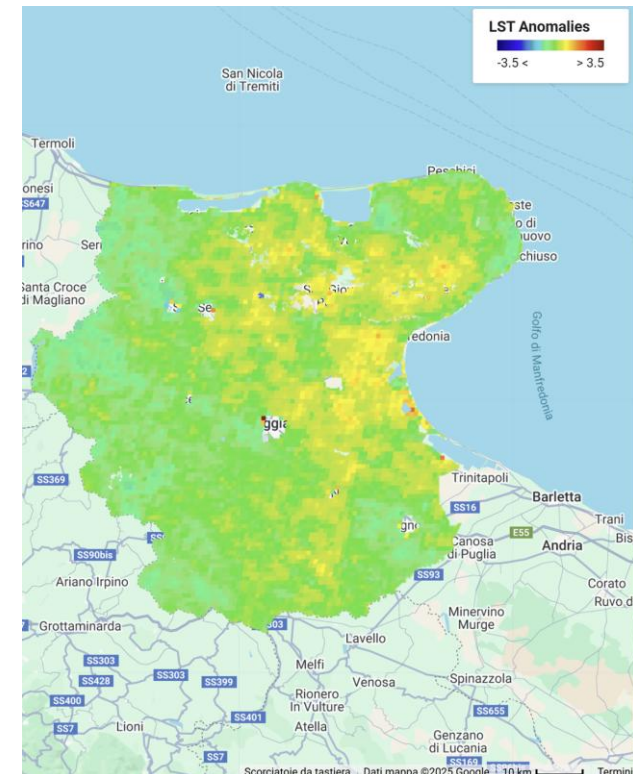
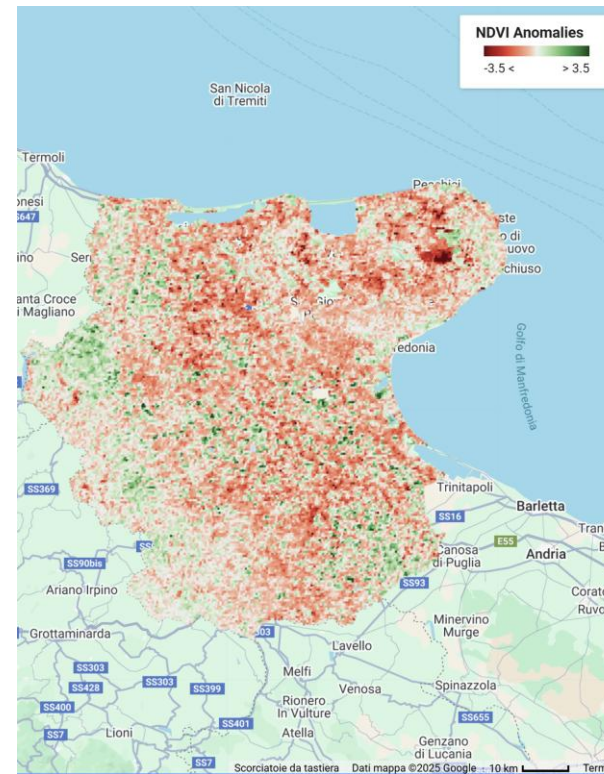
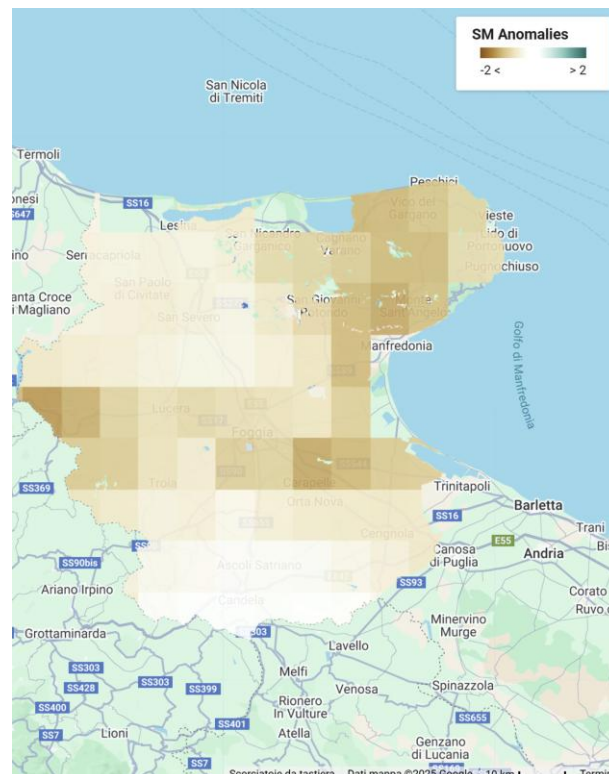
$$A_i = \frac{\text{Median}(L_i^{curr}) - \text{Median}(L_i^{ref})}{NMAD(L_i^{ref})}$$



- A_i is the robust z-score (anomaly) for the pixel i
- L_i denotes the layer (SM, LST, or NDVI) for the pixel i
- $\text{Median}(L_i^{curr})$ is the median value of the layer for pixel i during the current month of the analysed year
- $\text{Median}(L_i^{ref})$ and $NMAD(L_i^{ref})$ are the median and NMAD, respectively, of the layer for pixel i , calculated over the same calendar month within the historical reference period (2001–2016)

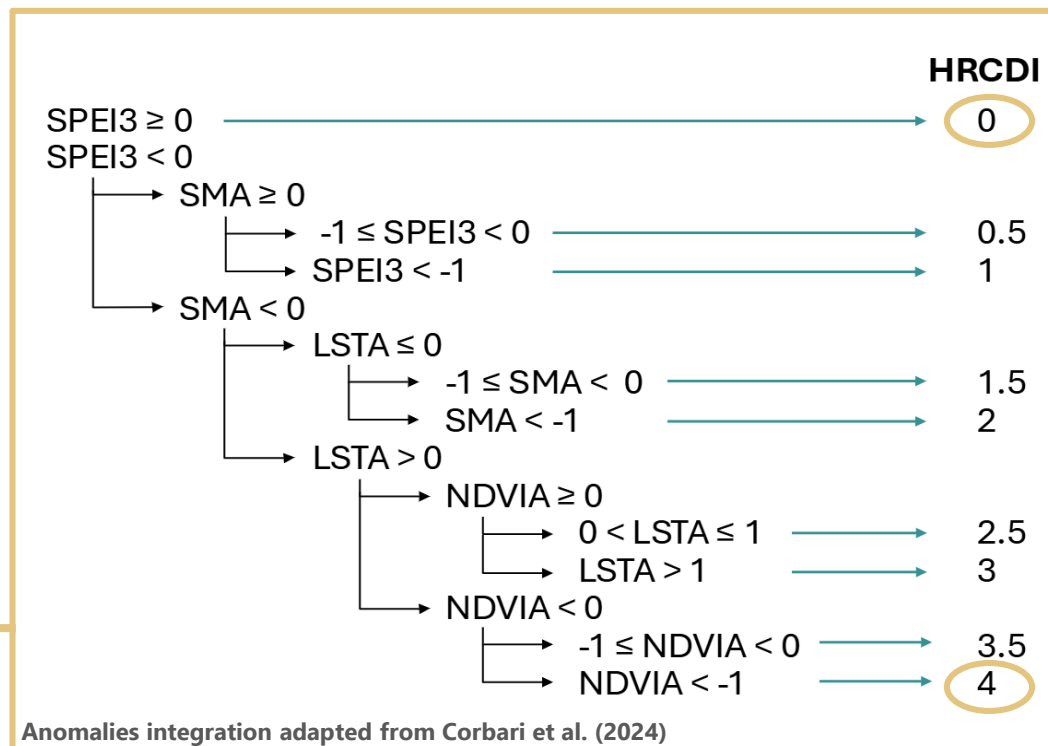
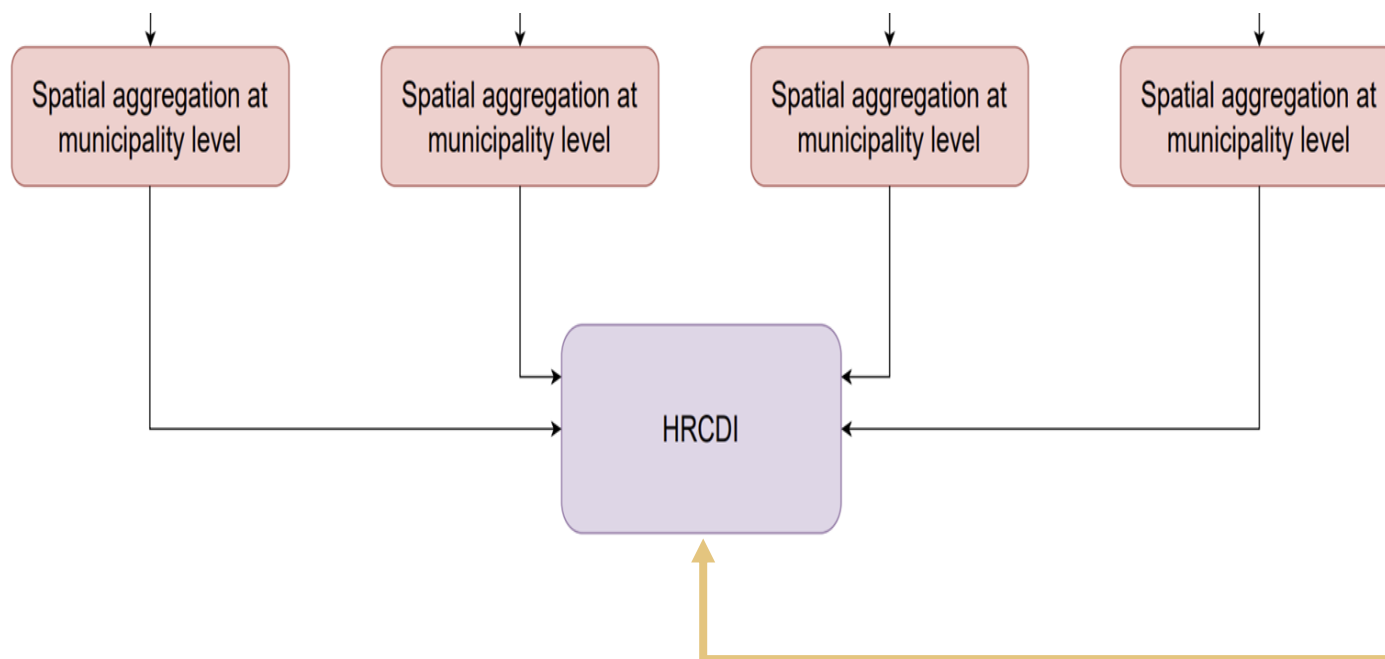
Single anomaly computation - Results

Example: single anomalies results for June 2022



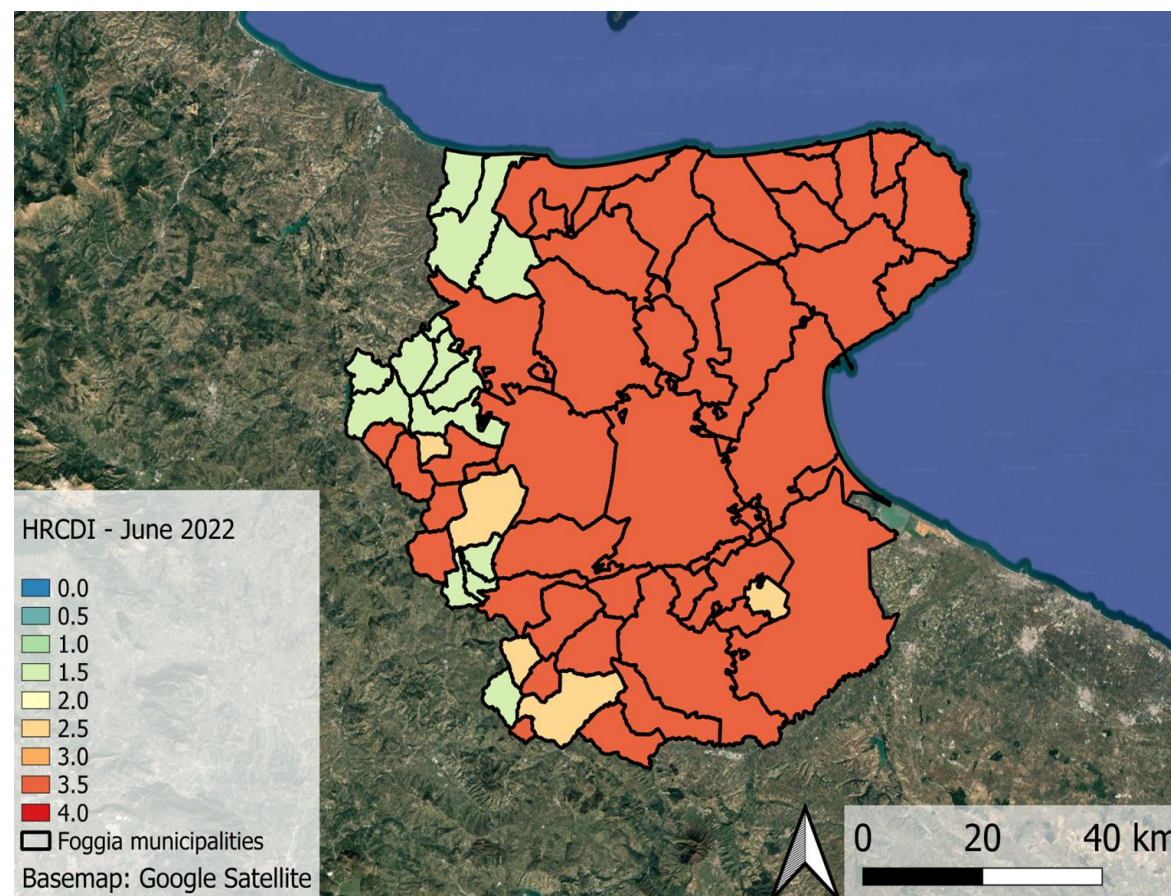
Hierarchical anomalies integration

The HRCDI is computed monthly at the **municipality level** to support ISMEA's operational drought monitoring activities, integrating all anomalies through a **hierarchical approach**



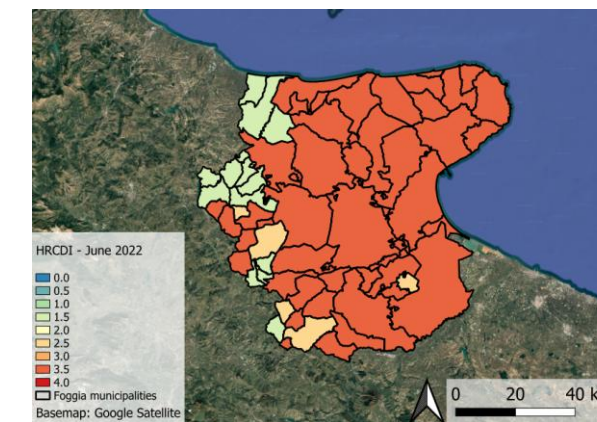
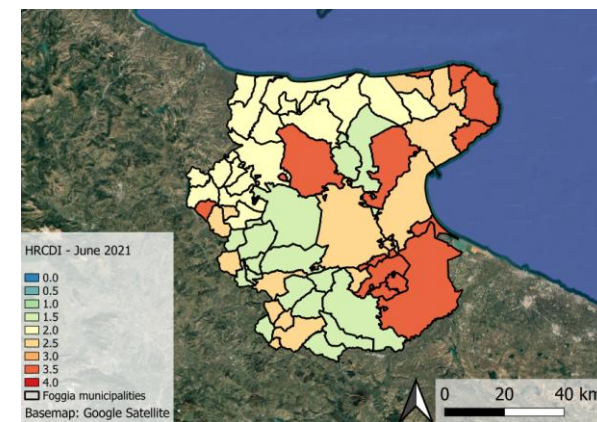
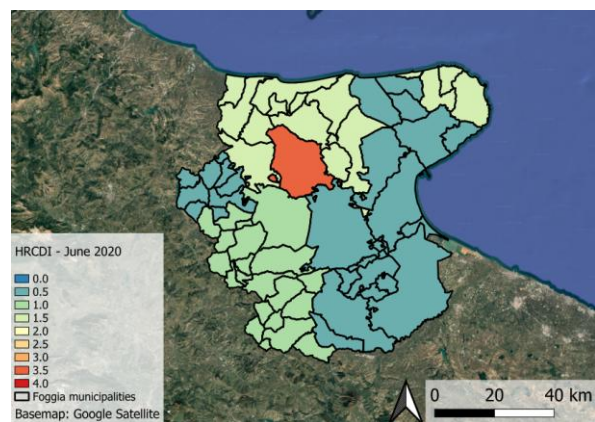
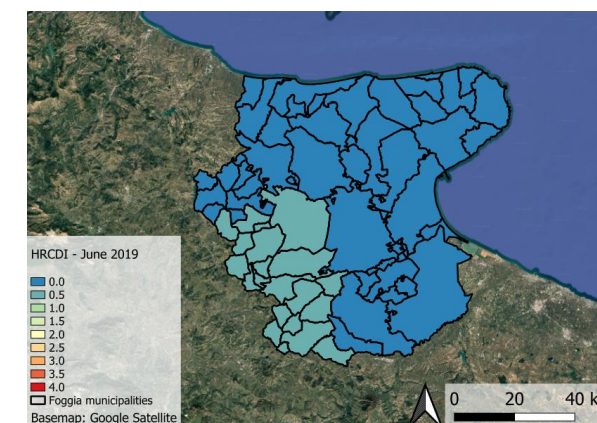
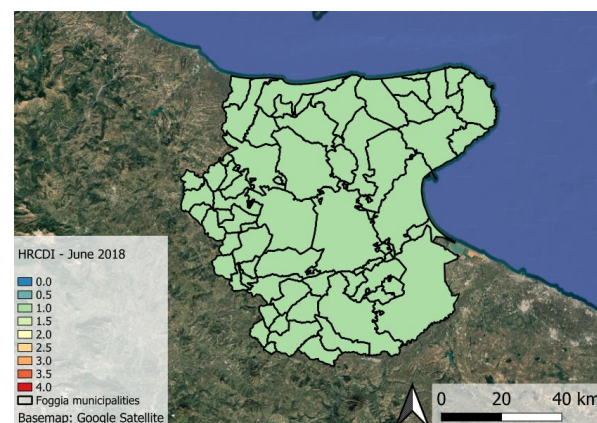
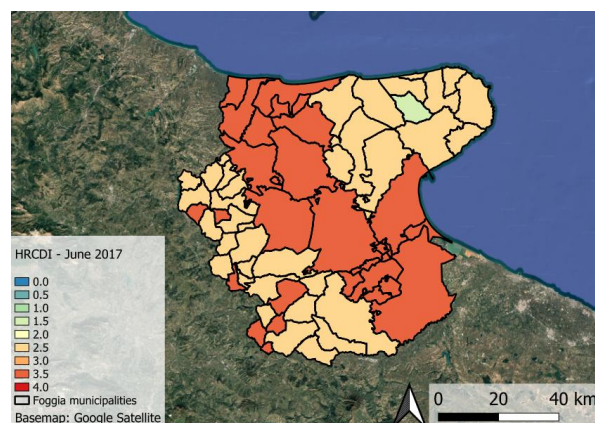
Hierarchical anomalies integration - Results

Example: HRCDI for June 2022



Hierarchical anomalies integration - Results

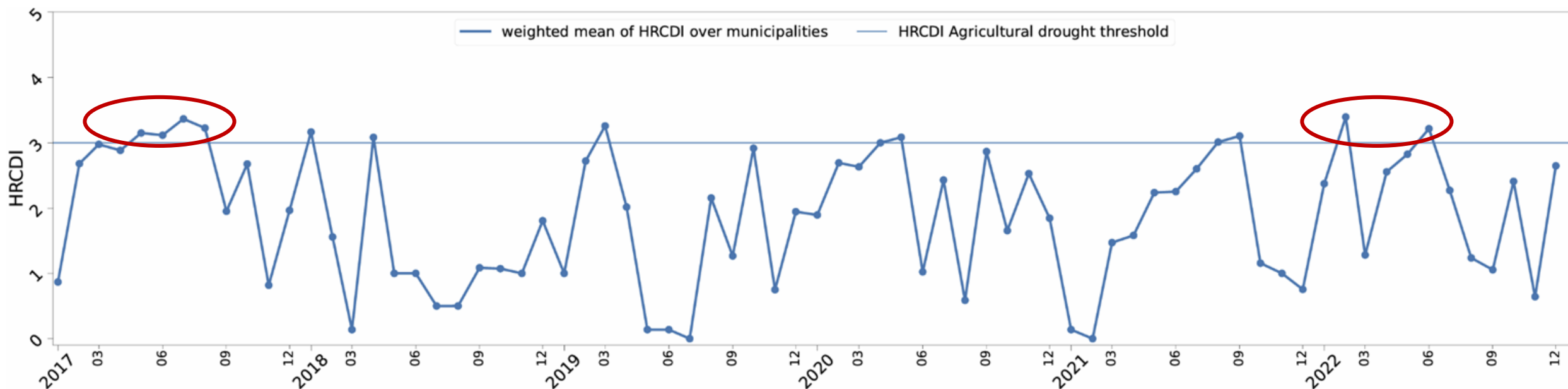
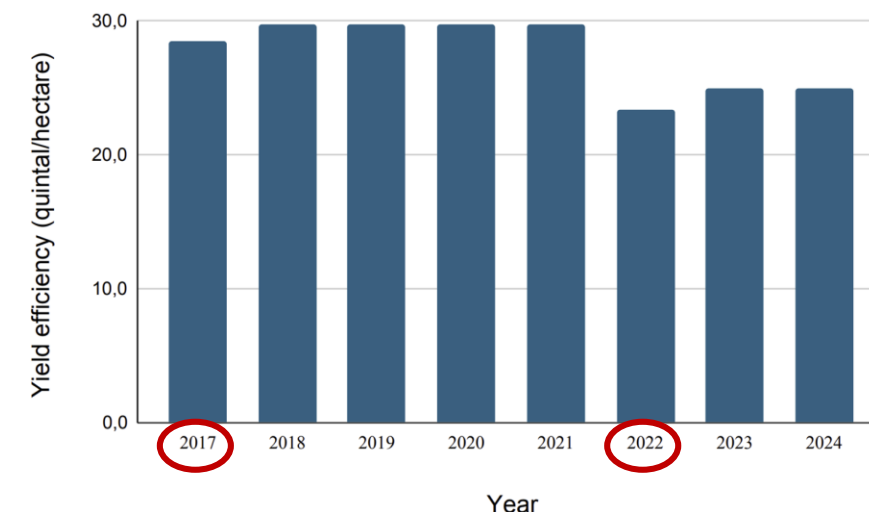
Example: HRCDI for June 2017-2022



Results

Data used for validation:

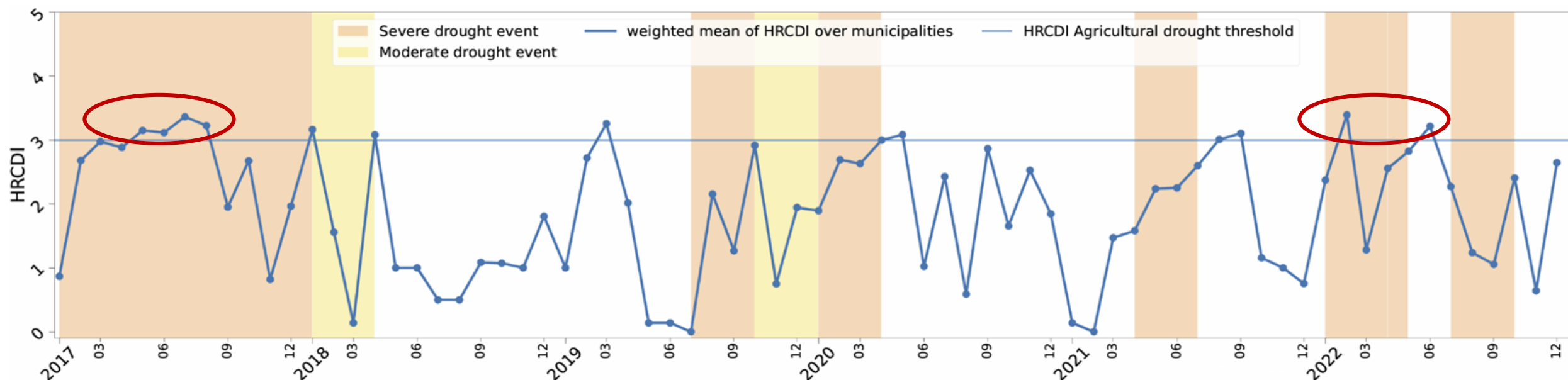
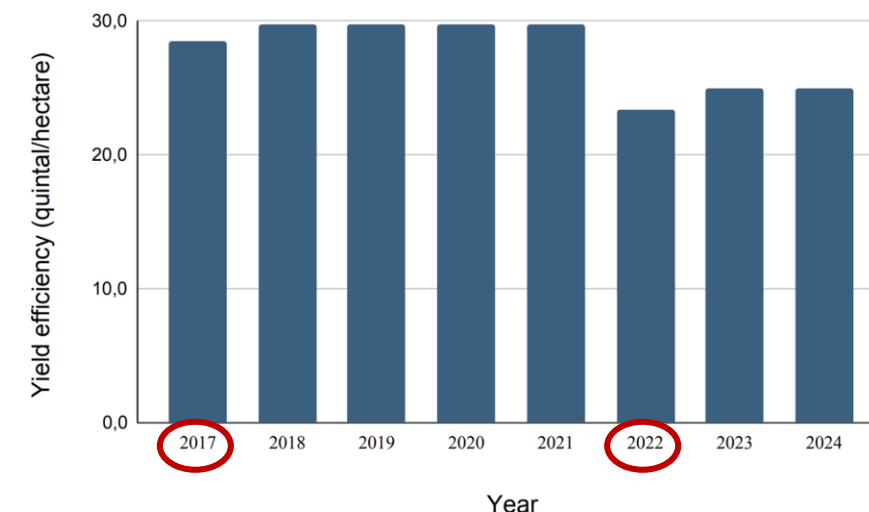
- **Agricultural production statistics for wheat** provided by the Italian National Institute of Statistics



Results

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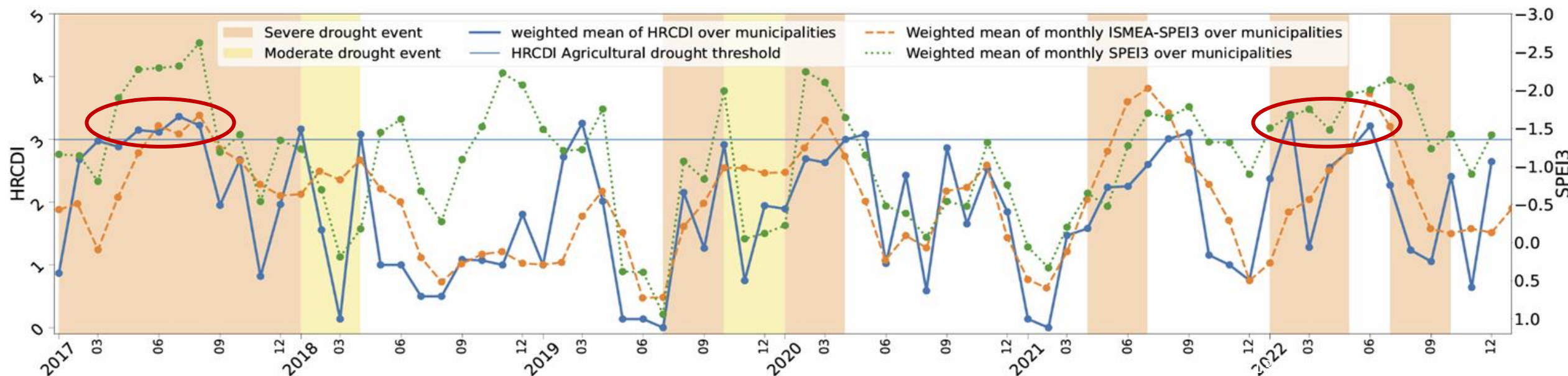
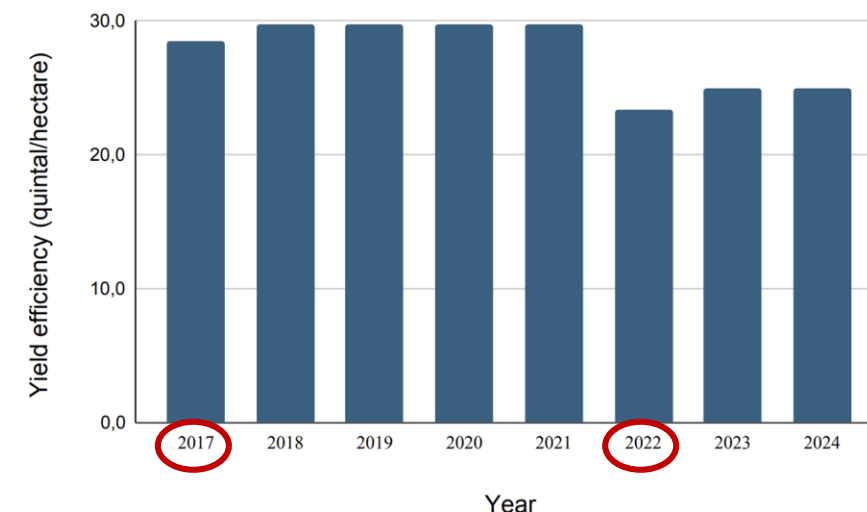
- **Agricultural production statistics for wheat** provided by the Italian National Institute of Statistics
- Drought events reported by **European Drought Impact Database** reports



Results

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- **Agricultural production statistics for wheat** provided by the Italian National Institute of Statistics
- **Drought events reported by European Drought Impact Database reports**
- **SPEI3 values** provided by ISMEA



Conclusions

- 🌾 **HRCDI values exceeded the critical threshold in 2017 and 2022, coinciding with yield anomalies** (–5% and –22%) and confirming sensitivity to major drought events
- ☐ **Good agreement with EDID records**, with slight underestimations during months characterized by important rainfall events (Nov 2017, Mar 2018)
- 📈 **Strong agreement with ISMEA–SPEI3**, with minor discrepancies likely due to the coarse spatial resolution of the freely available SPEI3 used in HRCDI
- ☐ **HRCDI detected drought earlier than ISMEA-SPEI3 in 2022**, showing strong potentiality

Future perspectives

- Near real-time HRCDI monitoring through **web dashboards and GIS platforms** for institutional users
- Crop-specific drought assessment by **integrating phenology and crop vulnerability**
- **Improved validation** using **insurance claims and field survey data**
- **Testing across different regions and climates**, especially Mediterranean and semi-arid areas
- Long-term EO continuity by **integrating next-generation satellite missions** (e.g., Sentinel-3 mission for LST and Sentinel-2 mission/IRIDE constellation for vegetation monitoring)

Bocchino et al., "A Hierarchical Robust Combined Index for Agricultural Drought Detection and Monitoring Using Earth Observation Big Data and Google Earth Engine: Application to a Case Study in Southern Italy" (IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing)



ASI-CEOS WGD International Workshop on “Earth Observation for Disaster Risk Management”

Thank you for your attention!

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