EO for Africa Symposium 2024

23 - 26 September 2024

ESA | ESRIN, Frascati (IT)

Session: Water and Food Nexus

24/09/2014

An Open-Source Earth Observation-based Composite Drought Indicator for the Borena region in Southern Ethiopia

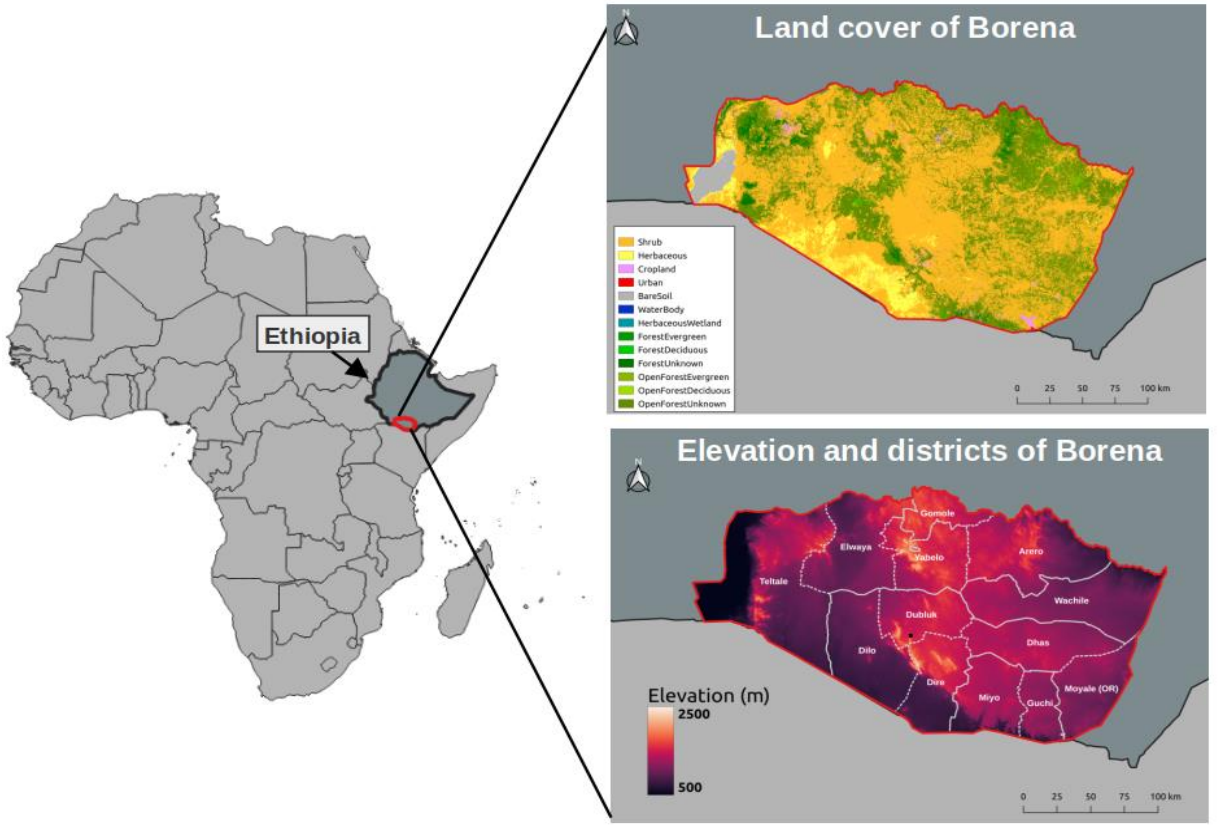
Vicente Burchard-Levine, Tinebeb Yohannes, Elias Cherenet Weldemariam, Héctor Nieto, Ana Andreu and Getachew Mehabie Mulualem

Financiado por la Unión Europea NextGenerationEU | Ministerio de Ciencia e Innovación | Plan de Recuperación, Transformación y Resiliencia | CSIC

Juan de la Cierva: FJC2021-047273-I

Borena, Ethiopia: vulnerable to droughts

Borena, Southern Ethiopia



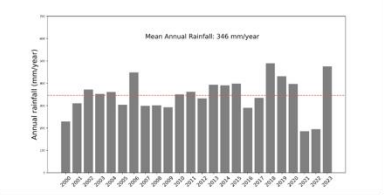
Mean Annual Precipitation ~ 350 mm/year

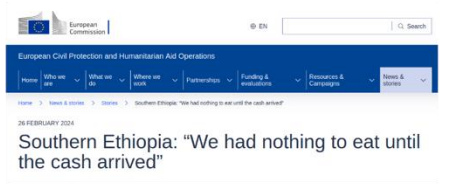
Two main rainy seasons: *March to May* and *Oct to Nov*

- **Semi-arid region** in Southern Ethiopia
- **Rangelands:** High dependence on pastoral activities
- **Recent drought events** (2019-2022) have devastated the region
  - Large impacts on **food security** and **livelihoods** of ago-pastoral communities
  - Loss of > 1.5 million livestock animals

Source: European Civil Protection and Humanitarian Aid Operations, 2024

Borena, Ethiopia: challenges and limitations





Climate change → **Food Scarcity** → **Socio-economic impacts**

Irregular Rainfall patterns

Lack of water for livestock and crops

Increased risk of malnutrition and financial losses

Challenges

Mitigation strategies?

Limitations

Data scarcity

Limited data for informed decision making and early warning system

Technological limits

Reliance on in-situ measurements (low spatio-temporal resolution)
Capacity building for implementation of new EO technologies

Models poorly suited for rangelands

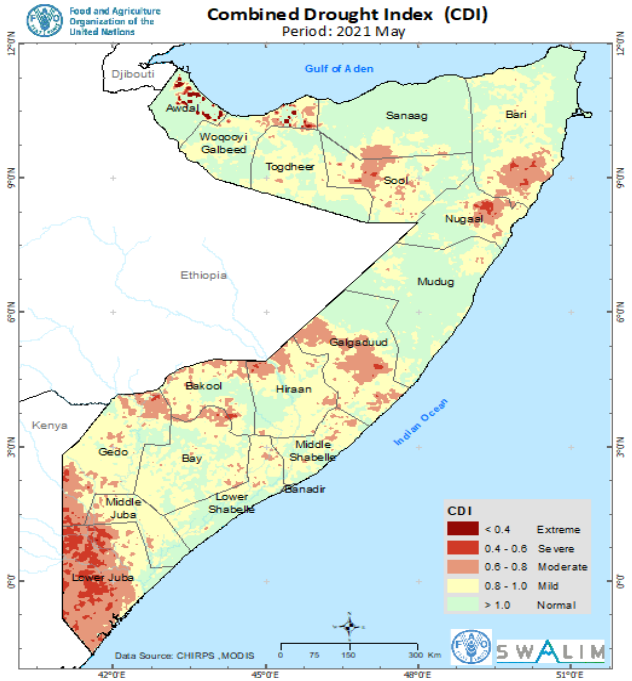
Earth Observation (EO) models often not designed nor evaluated over semi-arid conditions of rangelands

Drought monitoring

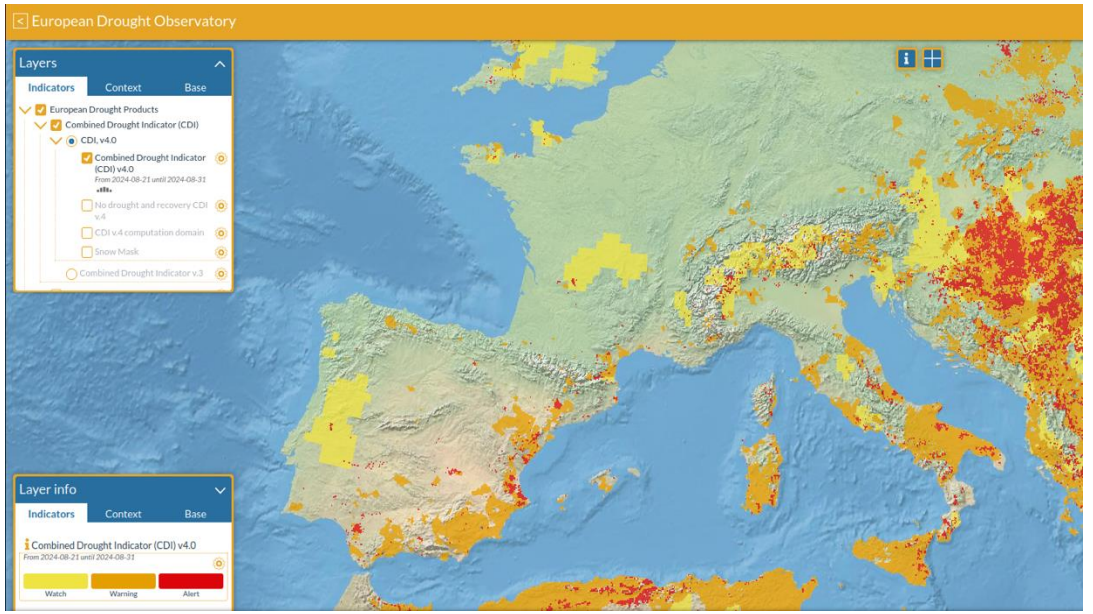
- **Drought occurrence** related to **many factors**
  - Drought are difficult to define (i.e. meteo vs agricultural vs hydrological)
  - Precipitation, temperature, soil moisture, vegetation health
- Importance to **regularly monitor** and **analyze** these factors
  - Often undetected and gradually intensify over time → need to capture early for effective response
- **Earth observation (EO) datasets** highly suitable to improve drought monitoring
  - Most drought indicators are based on meteo (i.e. SPEI)
  - EO methods especially useful to integrate vegetation response and agricultural impacts

Composite Drought Index (CDI)

- The **CDI** integrates **many variables** into one combined index
- Aims to capture **cause and effect** of **meteorological drought** and **agricultural/ecological impact**
  - **Simple to implement** and easy to communicate to policymakers and general public
- Used by **FAO-SWALIM** (in Somalia) and **European Drought Observatory (EDO)**

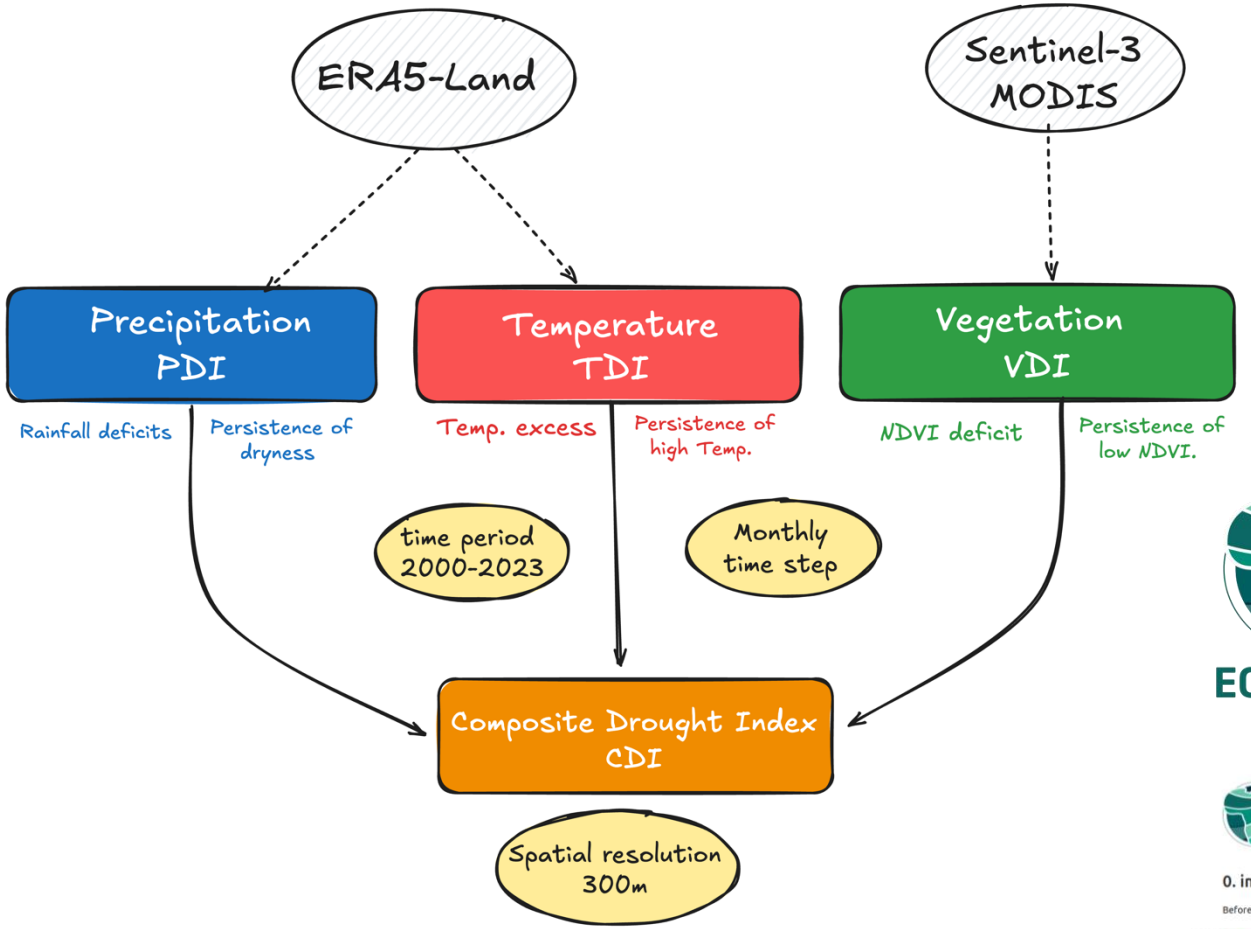


CDI = *f*(Precip, Ta, NDVI)



CDI = *f*(Precip, soil moisture, FaPAR)

CDI for Borena region

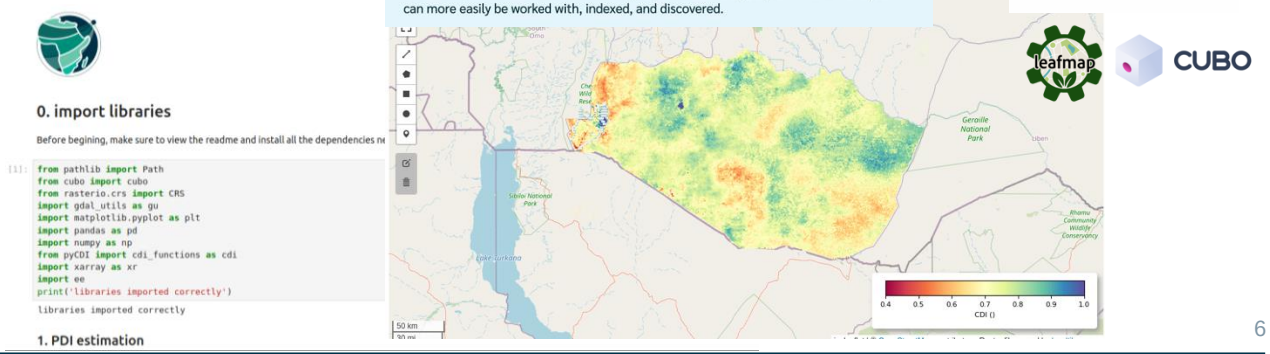


https://github.com/VicenteBurchard/pyCDI

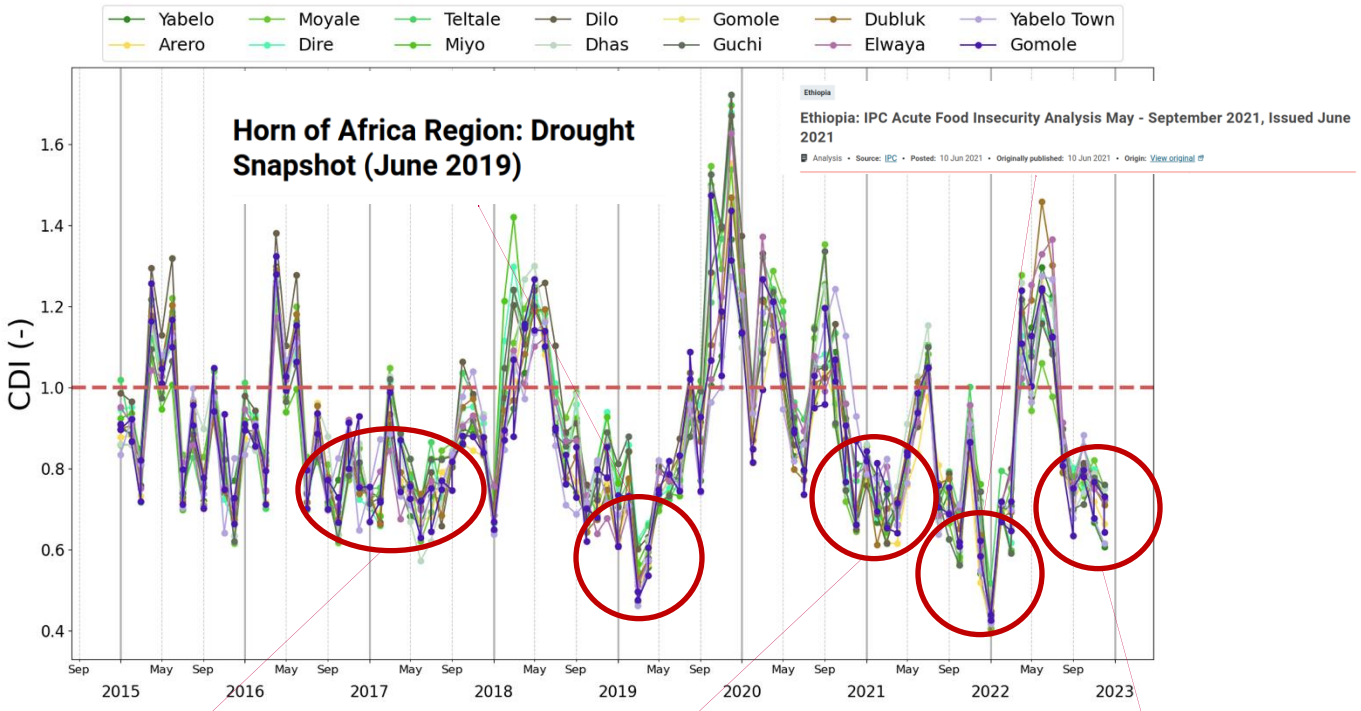
GitHub STAC

- **EO-DBE:** 1-year EO AFRICA R&D project
  - Ethiopian and Spanish collaboration
- Develop **open-source CDI** for the **Borena region** based on **Copernicus datasets**
  - ERA5 and Sentinel constellation
  - **Cloud-based satellite inputs** to easily apply and upscale to other regions
  - **Jupyter notebook** to document, disseminate and run **pyCDI**

EO AFRICA



CDI Results



Ethiopia

Mid-Year Review, Ethiopia Humanitarian Requirements Document, July 2017

Analysis • Sources: Govt. Ethiopia, OCHA • Posted: 9 Aug 2017 • Originally published: 8 Aug 2017

Ethiopia

Ethiopia: IPC Acute Food Insecurity Analysis May - September 2021, Issued June 2021

Analysis • Source: IPC • Posted: 10 Jun 2021 • Originally published: 10 Jun 2021 • Origin: View original

World + 22 more

Hunger Hotspots: FAO-WFP early warnings on acute food insecurity, March to July 2021 outlook

Analysis • Sources: FAO, WFP • Posted: 23 Mar 2021 • Originally published: 23 Mar 2021 • Origin: View original

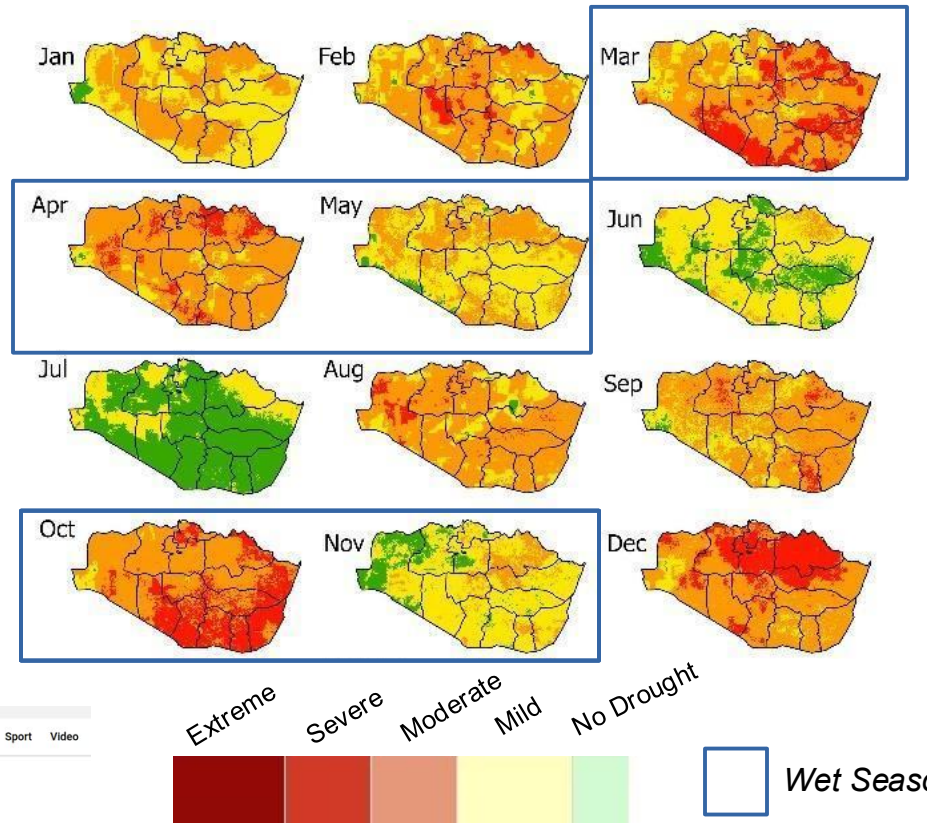
ALJAZEERA News War on Gaza US Election Opinion Sport Video

News | Drought

In southern Ethiopia, drought kills livestock and brings hunger

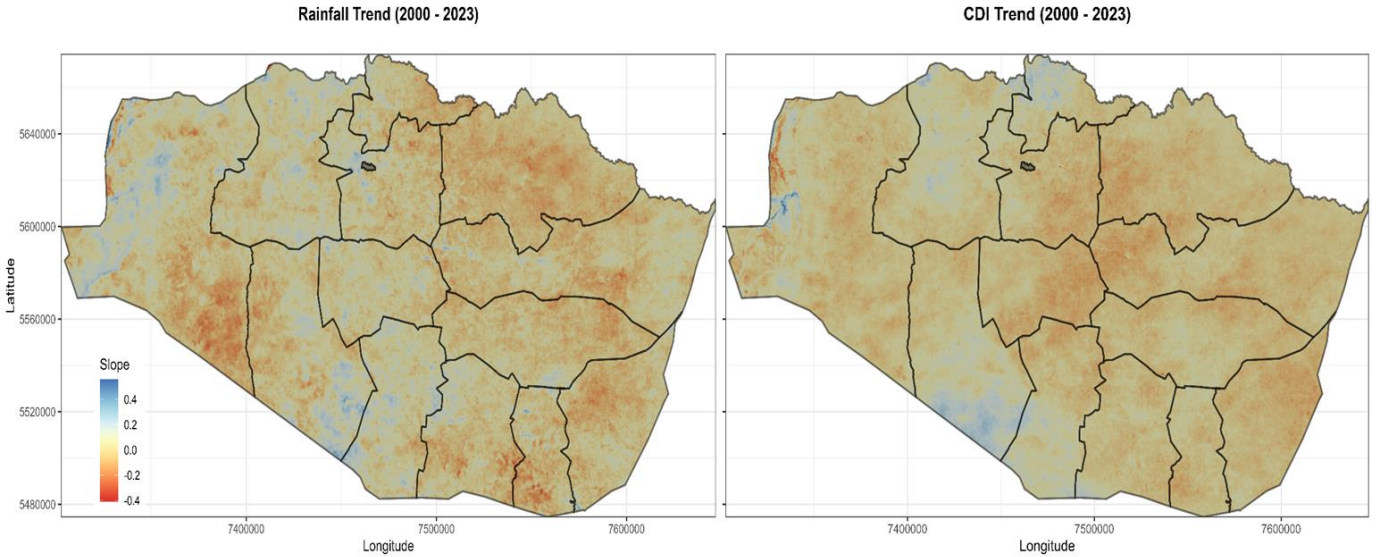
Nearly 12 million people, a 10th of the population, are at risk of famine in Ethiopia's drought-affected areas.

CDI results for 2021

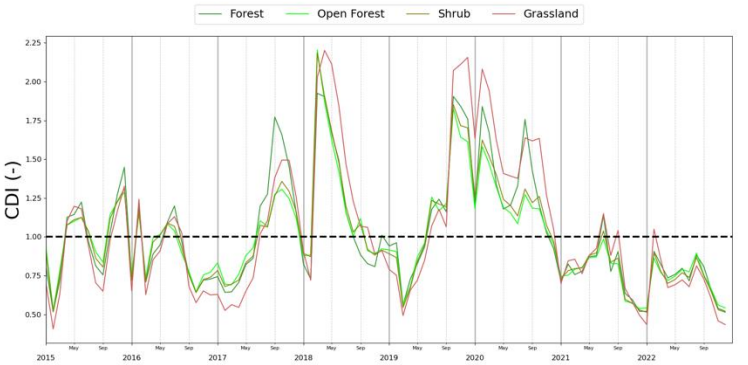


Spatio-temporal trends

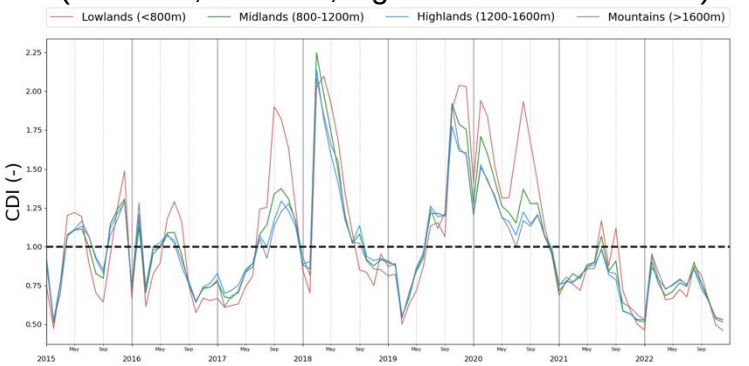
- **Mark-Kendall test** and **Sen's Slope** revealed negative trends in **P** and **CDI**
  - Non-parametric test to analyze trends
  - Most of Borena: **negative Sen's slope** (magnitude of linear trend)
  - Decreasing CDI → Increasing trend of drought occurrence and severity
- **Lowest CDI** values over **grasslands** and **lowlands** (<800m)
  - Highest drought vulnerability for these regions



Average CDI values per vegetation classes
(Forest, Open Forest, Shrub and Grasslands)

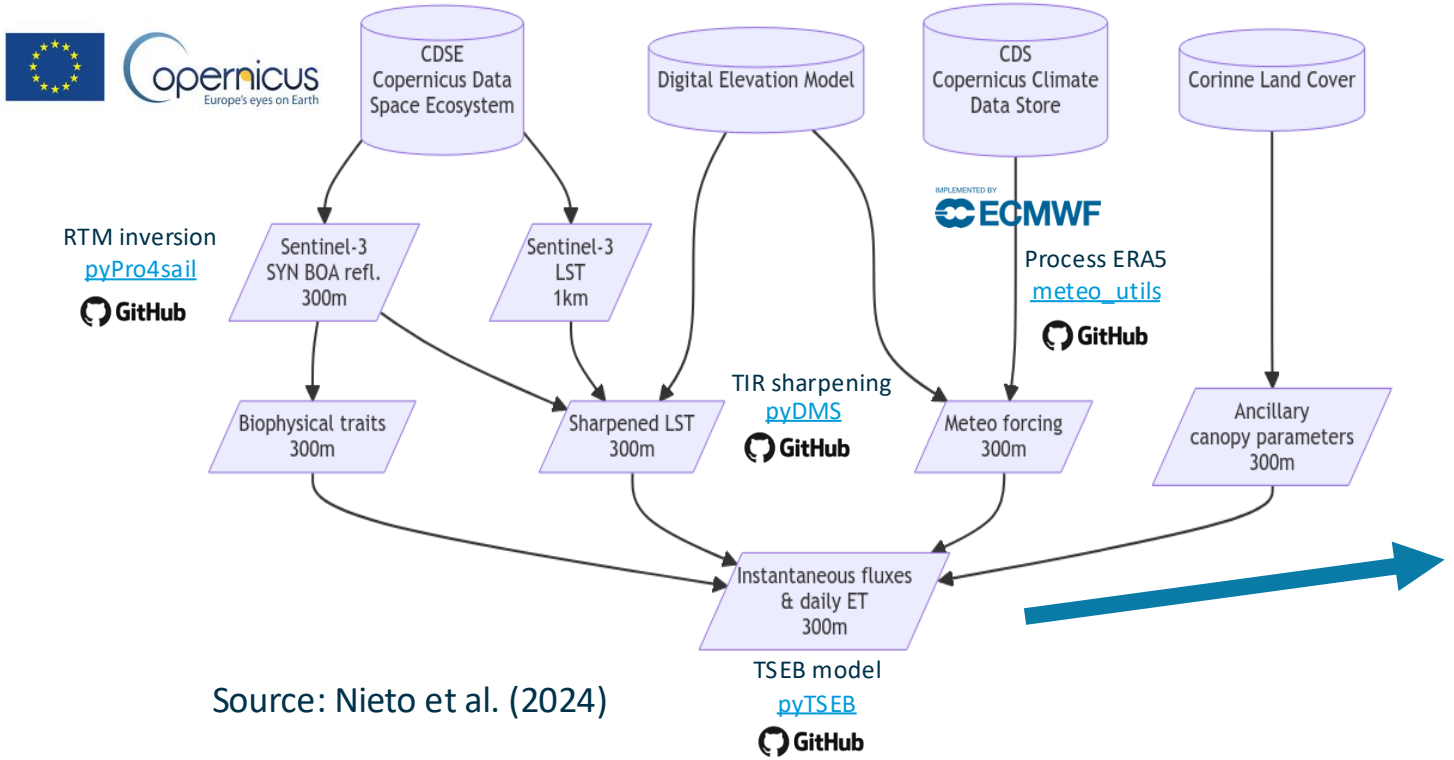


Average CDI values for elevation classes
(lowlands,midlands, highlands and mountains)

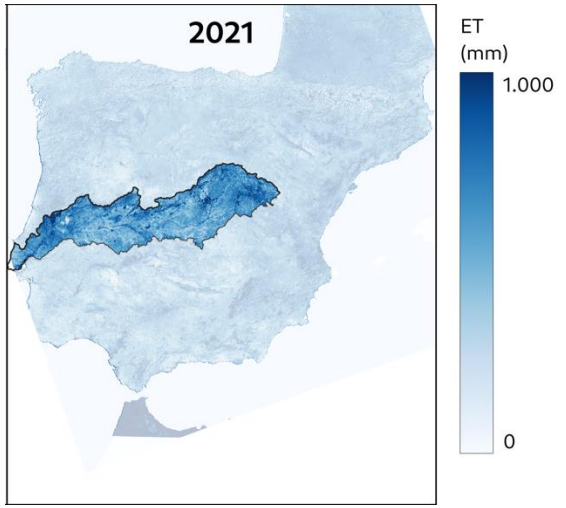


Next steps: improving CDI with ET

- Studies[1] have shown that **evapotranspiration (ET)** has faster response to water deficit compared to NDVI (especially for **semi-arid regions**)
- **Open-source processing chain** to ingest **Sentinel-3** (SYN + LST) imagery for **energy balance models**
  – building upon **Sen-ET/ET4FAO** approach



Source: Nieto et al. (2024)

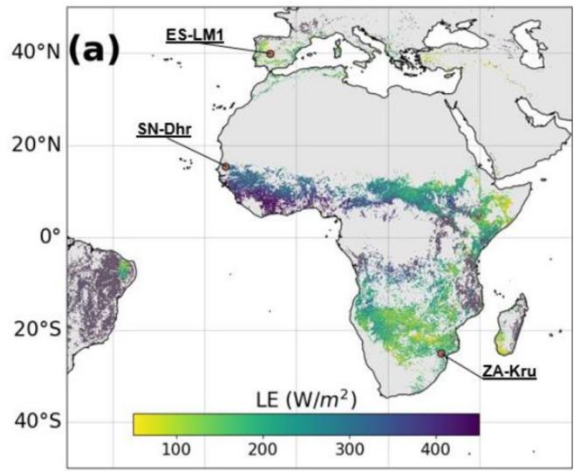


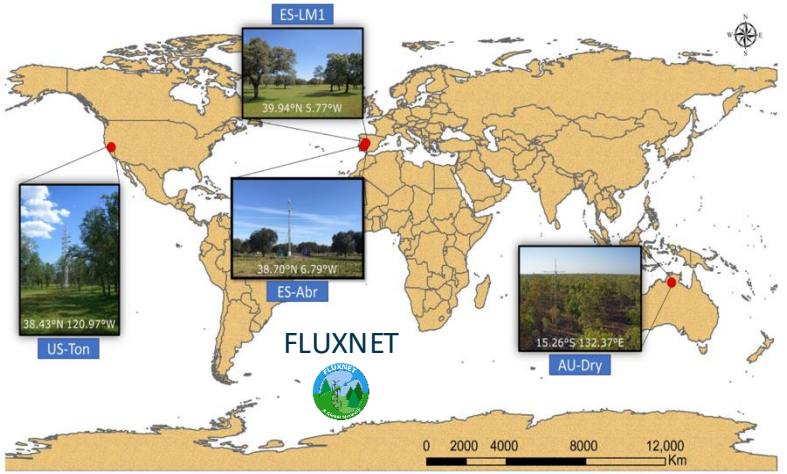
Credit: Héctor Nieto

[1]Joiner, J., Yoshida, Y., Anderson, M., Holmes, T., Hain, C., Reichle, R., Koster, R., Middleton, E., & Zeng, F.-W. (2018). Global relationships among traditional reflectance vegetation indices (NDVI and NDII), evapotranspiration (ET), and soil moisture variability on weekly timescales. Remote Sensing of Environment, 219, 339–352. https://doi.org/10.1016/j.rse.2018.10.020

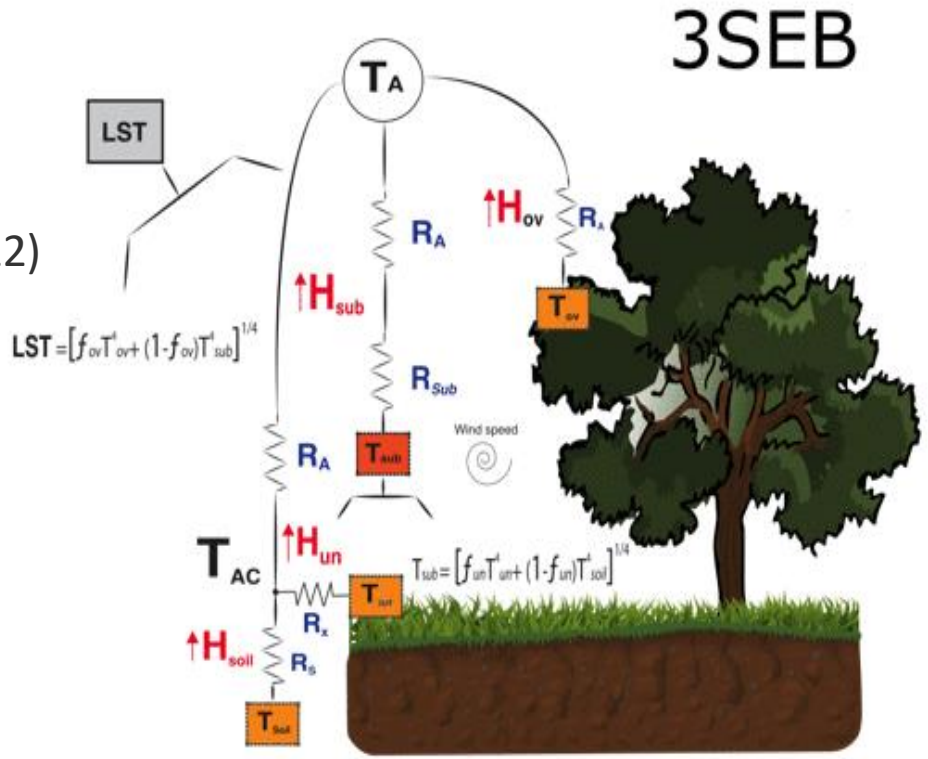
Three-Source Energy Balance Model (3SEB)

- **3SEB**, an adapted TSEB, more suited for complex **rangeland** and **agro-forested ecosytems**
- Applied at both in-situ **tower footprint** and **geostationary scales** (MSG-SEVIRI ~5 km)
  - Improved over state-of-the-art models (Burchard-Levine et al. 2022)
- Developing **Sentinel/Copernicus**-based processing chain with 3SEB (20/300 m)





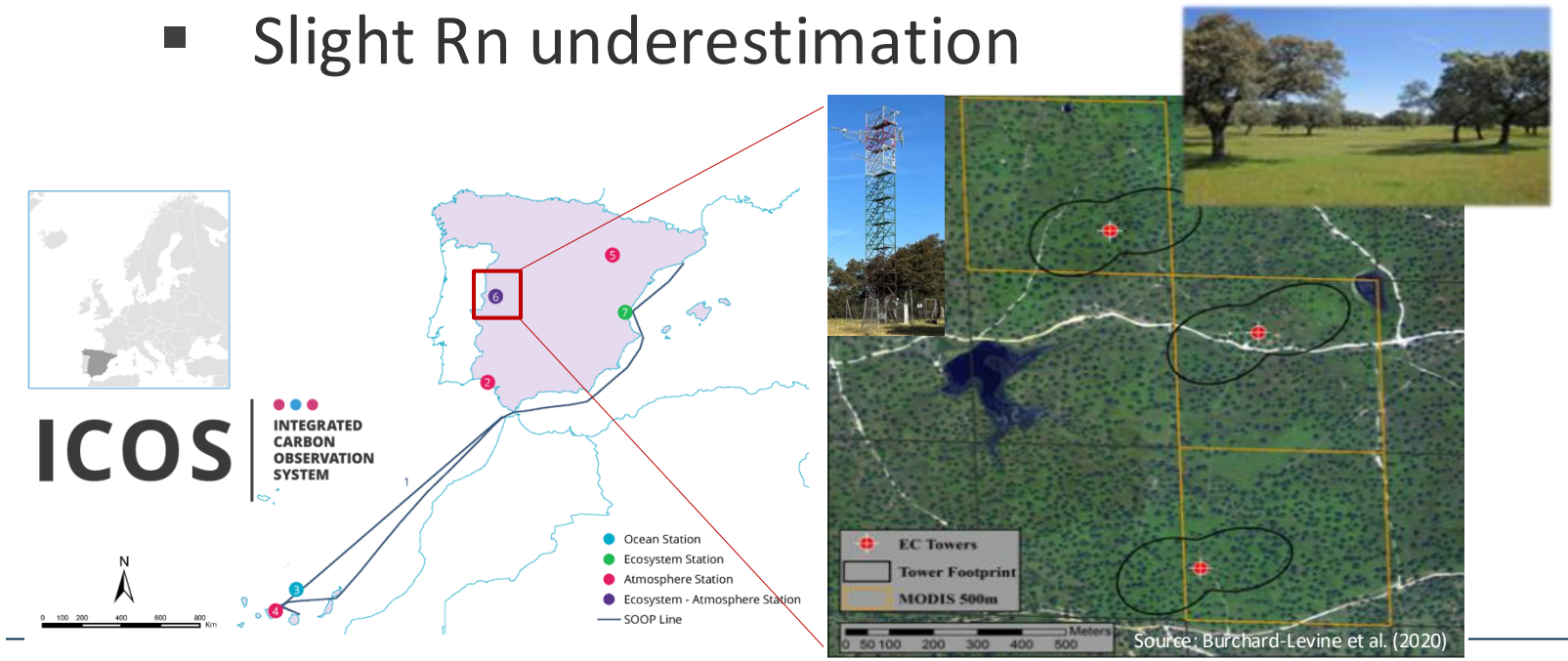
Source: Burchard-Levine et al. (2022)



Python code available at:
https://github.com/VicenteBurchard/py3SEB

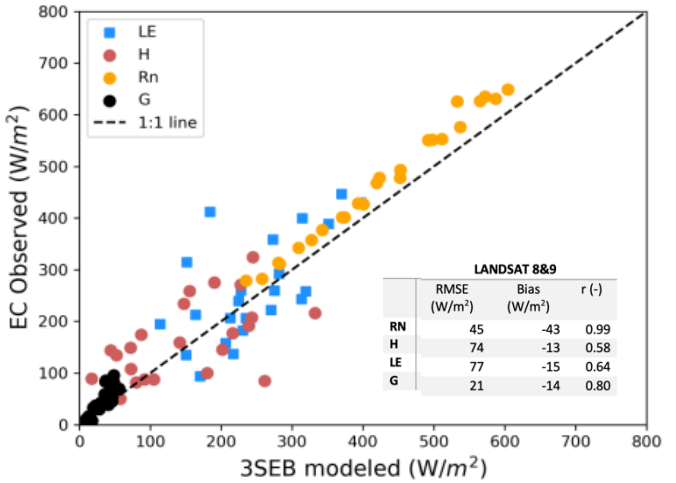
Preliminary evaluation: Copernicus-based 3SEB

- **Majadas de Tiétar (ES-LMa)** site
  - Tree-grass ecosystem (savanna-like)
- **Sharpened Sentinel-3** (SYN+SLSTR) and **Landsat 8/9**
- Overall **good performance** for all energy balance fluxes
  - Slight Rn underestimation

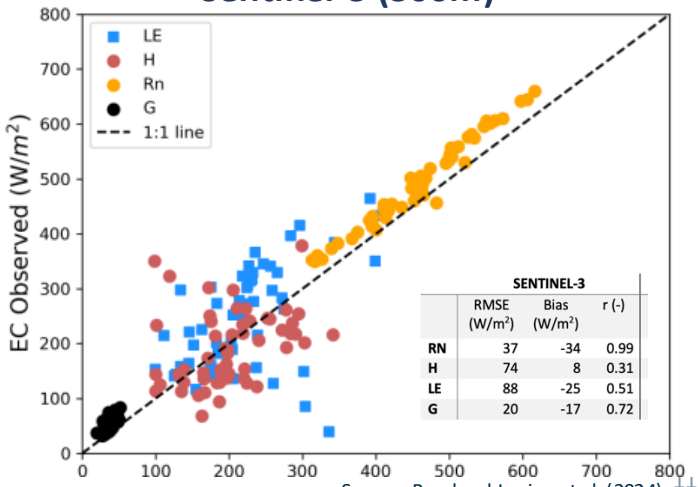


Source: Burchard-Levine et al. (2020)

Landsat 8/9 (100m)



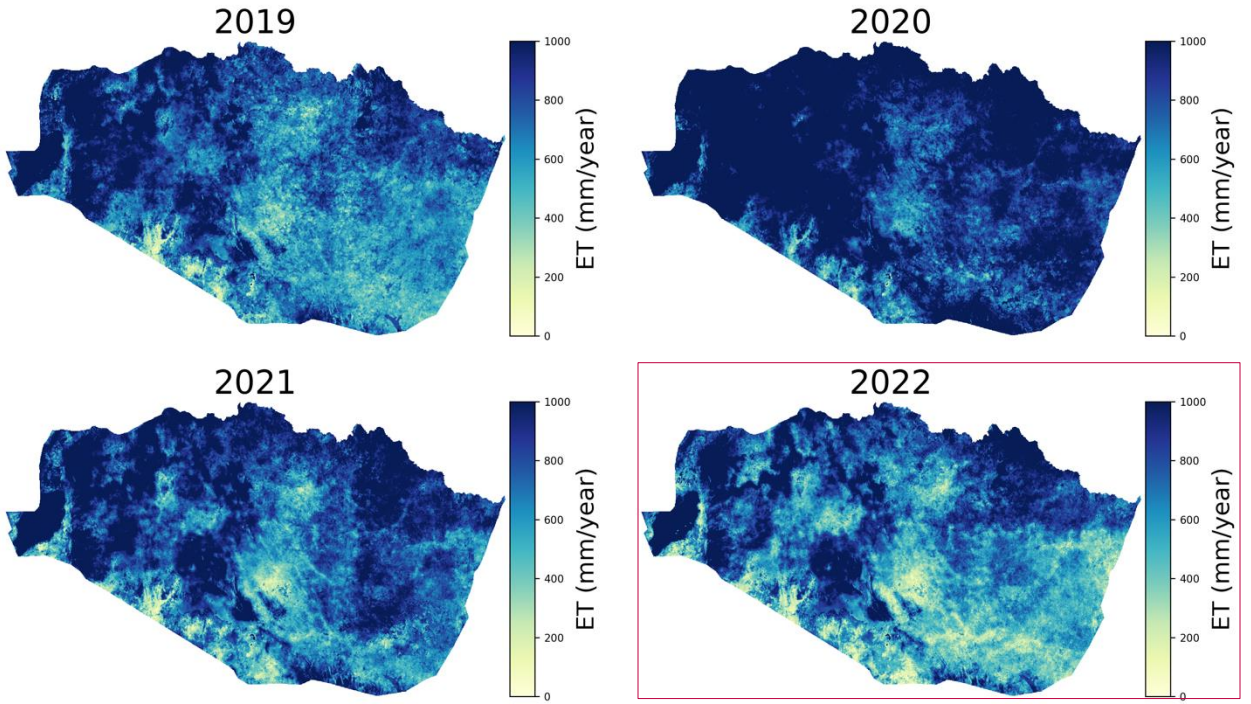
Sentinel-3 (300m)



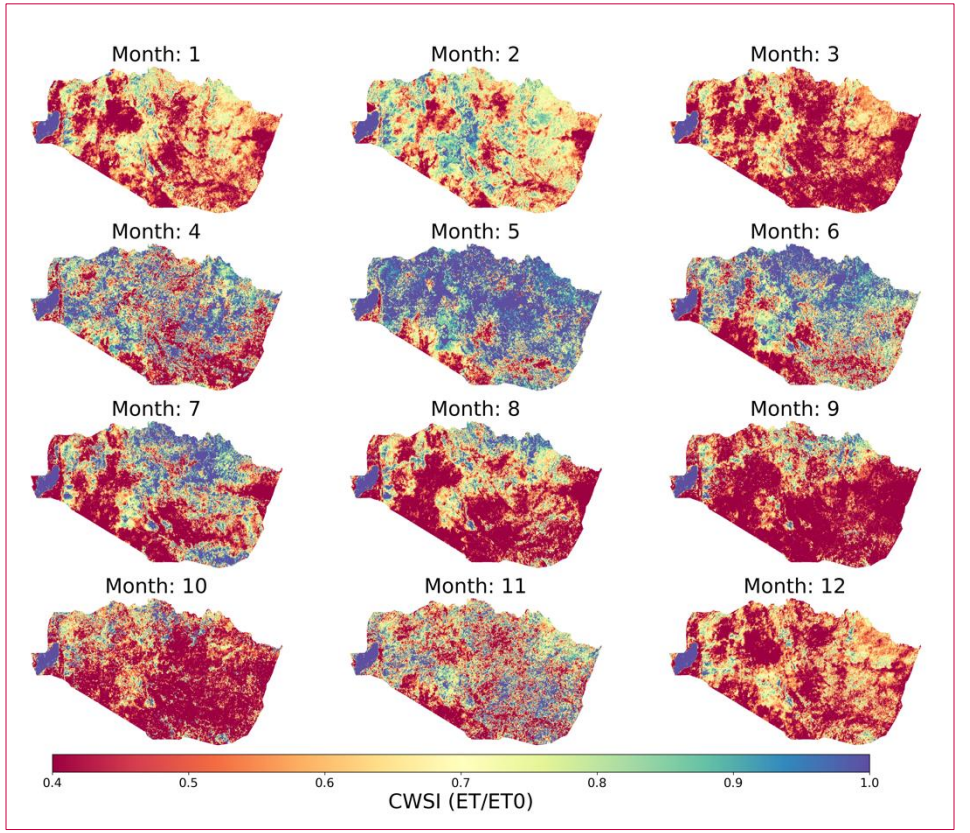
Source: Burchard-Levine et al. (2024)

3SEB ET over Borena

Annual ET (mm/year)



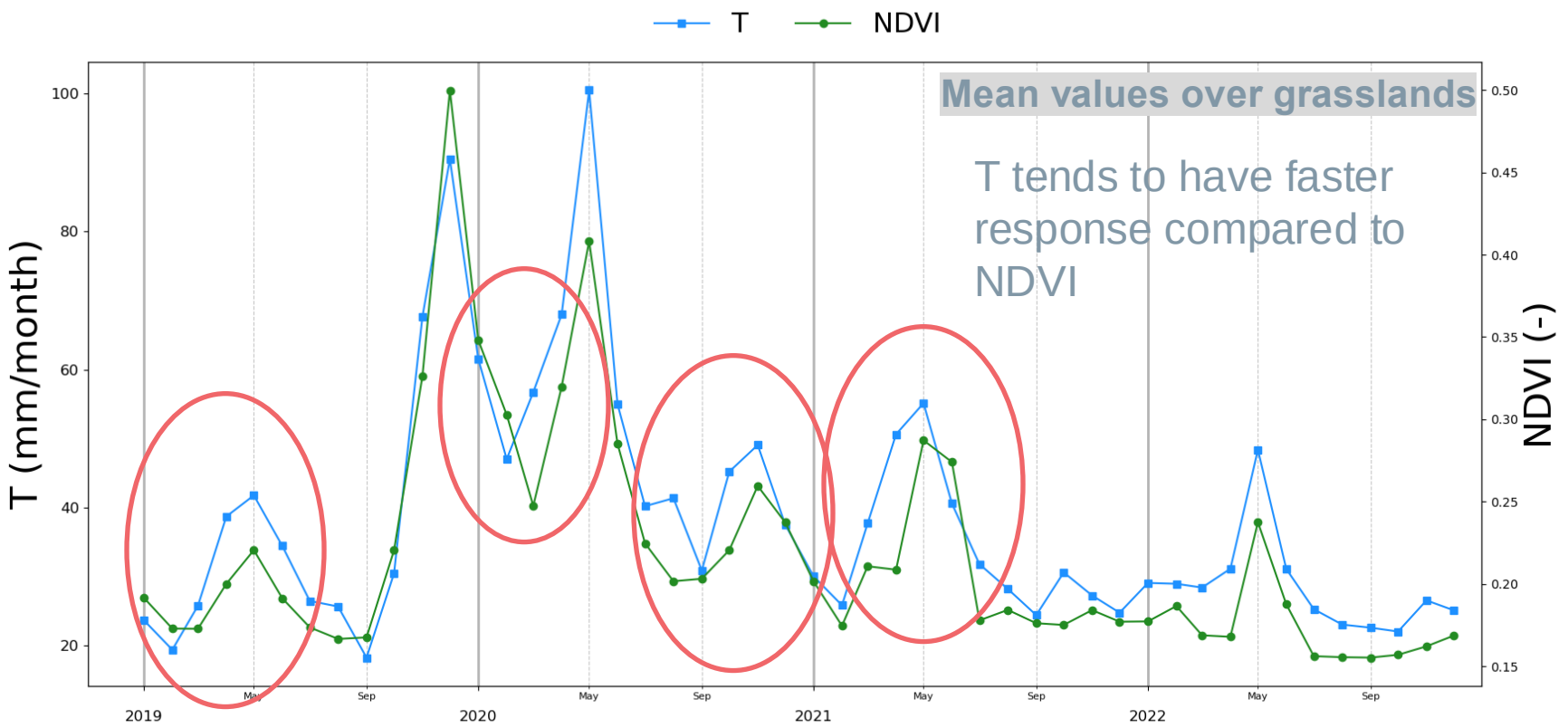
Monthly Crop Water Stress Index (ET/ET0) during 2022



3SEB Sentinel-3 results (300m)

ET partitioning

- TSEB/3SEB partition between **vegetation transpiration (T)** and **surface evaporation (E)** → better capture **vegetation response** and **functioning**



ET for drought monitoring

- **ET** highly relevant variable for drought monitoring
  - Accounts for **atmospheric conditions**, **water availability** and **vegetation functioning**
  - However, ET models tend to have **greater uncertainty** in semi-arid and **sparsely vegetated ecosystems**
  - Need for adapted **modeling schemes** for complex semi-arid rangeland conditions prevalent in African continent
- **Next steps:** evaluate 3SEB ET in African EC sites
  - ZA-Kru, SN-Dhr, Sn-Nkr
- **Next steps:** Develop and compare **novel EO drought indicators**
  - CDI-NDVI
  - CDI-Bio [biophysical traits such as LAI, Cab or CWC]
  - CDI-ET
  - Compared against food security and socio-economic datasets

FEWS NET
Famine Early Warning Systems Network

EO for Africa Symposium 2024

ESA-ESRIN, Frascati (Rome), IT
24/09/2024

Thanks!

Vicente Burchard-Levine (CSIC)
Email: vburchard@ica.csic.es

Financiado por la Unión Europea NextGenerationEU
Plan de Recuperación, Transformación y Resiliencia
Juan de la Cierva: FJC2021-047273-I