Improved large-scale crop water requirement estimation through new high-resolution reanalysis dataset

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Introduction and motivation

Why water requirement?

- ✓ Agriculture is the highest water-demanding sector.
- ✓ Food production in an increasingly populated world is strictly depending on the correct management of withdrawn freshwater.
- ✓ Important role of agriculture in the water balance modeling at various scales, for water management purposes and for the fulfilling of water-related environmental regulations.

New possibilities

- ✓ Using new space-time high-resolution data, obtained combining satellite and ground-based acquisitions, in numerical models driven by climate forcing.
- ✓ Availability of re-analysis climate data to explore the dynamics in water requirement over decades-long periods.

Our Goals

- ✓ Describing the spatial and temporal distribution of **global irrigation requirement**.
- ✓ Analyze the **crop-specific** irrigation requirements.

Data

Agricultural data

Global 5' high-resolution distribution of 26 crops for the year 2000:

- Multicropping practices;
- Irrigated areas;
- Sowing and harvesting calendars;

Climate data

Crop water requirement is mainly driven by **Precipitation** and **Evapotranspiration**. In this work high time-space resolution data from C3S ERA5 dataset have been used.

Reference Evapotranspiration (**ET_0**) is required for the evaluation of crop-Evapotranspiration with FAO's approach.
ET_0 has been evaluated using ERA5 temperature and top-of-atmosphere radiation data, following the Hargreaves-Samani equation:

$$ET_0 = 0.0023 \cdot R_a \cdot (T_{mean} + 17.8) \cdot \sqrt{T_{max} - T_{min}} \cdot$$

ET_0 = reference evapotranspiration (mm/day)
T_{max} and T_{min} = maximum and minimum daily temperature (°C)
T_{mean} = daily mean temperature (C°)
R_a= Radiation on top-of-atmosphere (mm/day)

Crops

Barley	Groundnuts	Rice
Cassava	Maize	Rye
Cocoa	Millet	Sorghum
Coffee	Oil palm	Soybean
Cotton	Others annual	Sugar beets
Cytrus	Others perennial	Sugar cane
Date palm	Potato	Sunflower
Fodder grasses	Pulses	Wheat
Grapes	Rape seed	

ERA5 Dataset

ERA5 is a **climate reanalysis dataset** available from October 2017, covering the period 1979-present (only data from 1979 are currently available) and is being developed by ECMWF through the *Copernicus Climate Change Service (C3S):*

- **Global** scale;
- Spatial resolution: **0.25°**;
- Temporal resolution: **hourly**;

Methods

Irrigated scenario

$$\Delta S = ET_c - I - P_{eff}$$

$$ET_c = ET_0 \cdot k_c$$

Daily soil water balance components

ΔS: soil moisture variation [mm/day]

P_{eff}: effective precipitation [mm/day]

I: irrigation requirement [mm/day]

k_c = crop coefficient [-]

k_s = water-stress coefficient [-]

ET_c = crop-potential evapotranspiration [mm/day]

ET_a = crop-actual evapotranspiration [mm/day]

ET_0 = reference evapotranspiration [mm/day]

Rainfed scenario

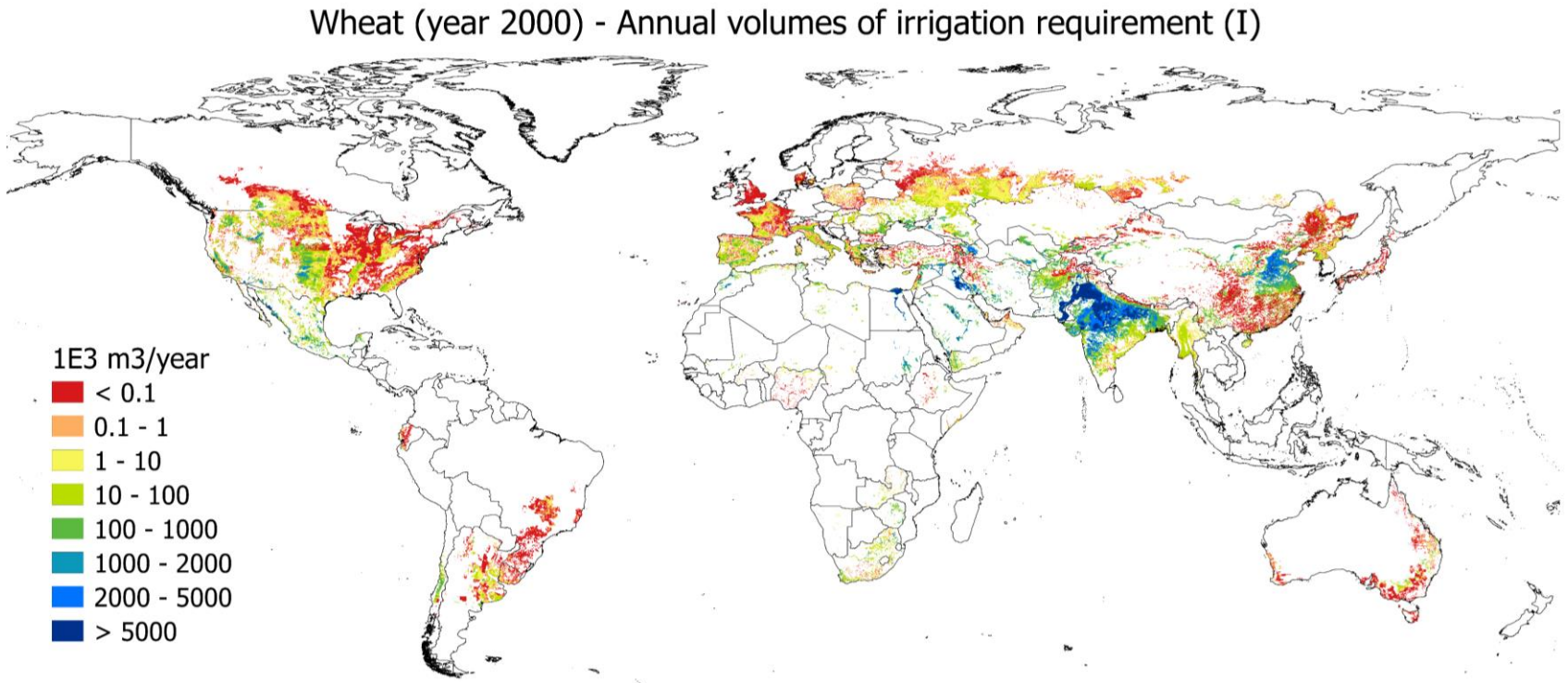
$$\Delta S = ET_a - P_{eff}$$

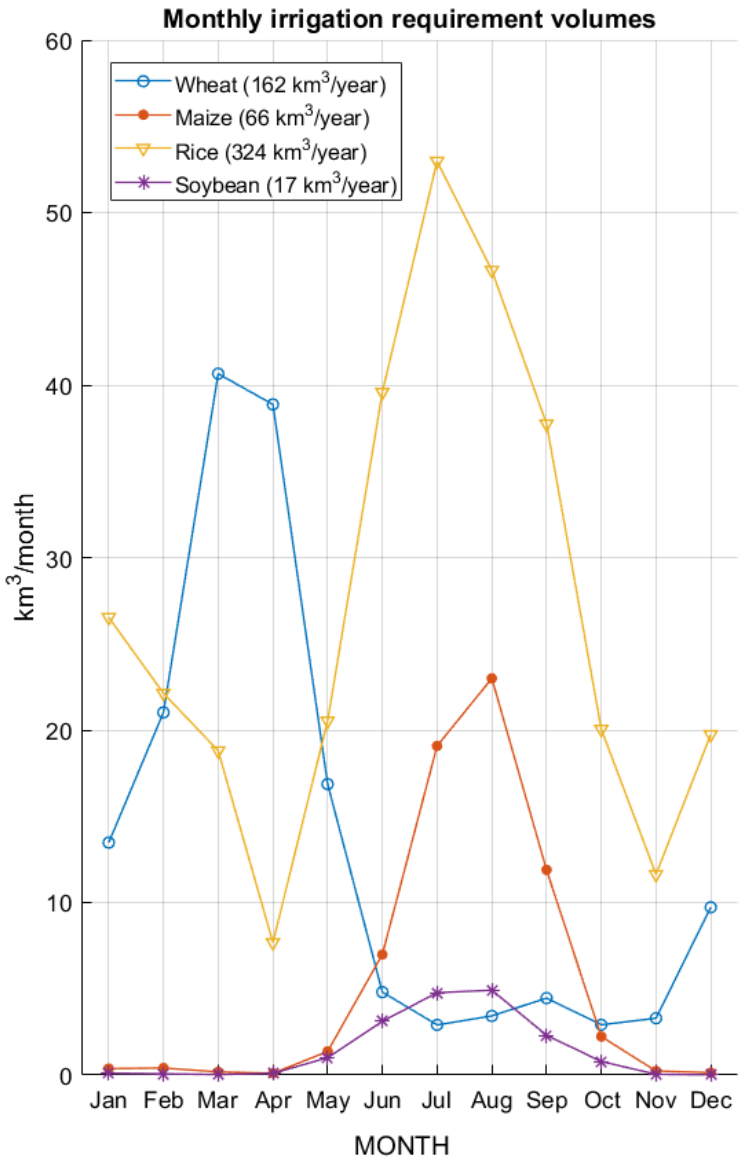
$$ET_a = ET_0 \cdot k_c \cdot k_s$$

$$I = ET_c - ET_a$$

Irrigation requirement: I is the amount of water required to keep the crop evapotranspiration at the highest potential value (ET_c → k_s=1), avoiding water-stress condition.

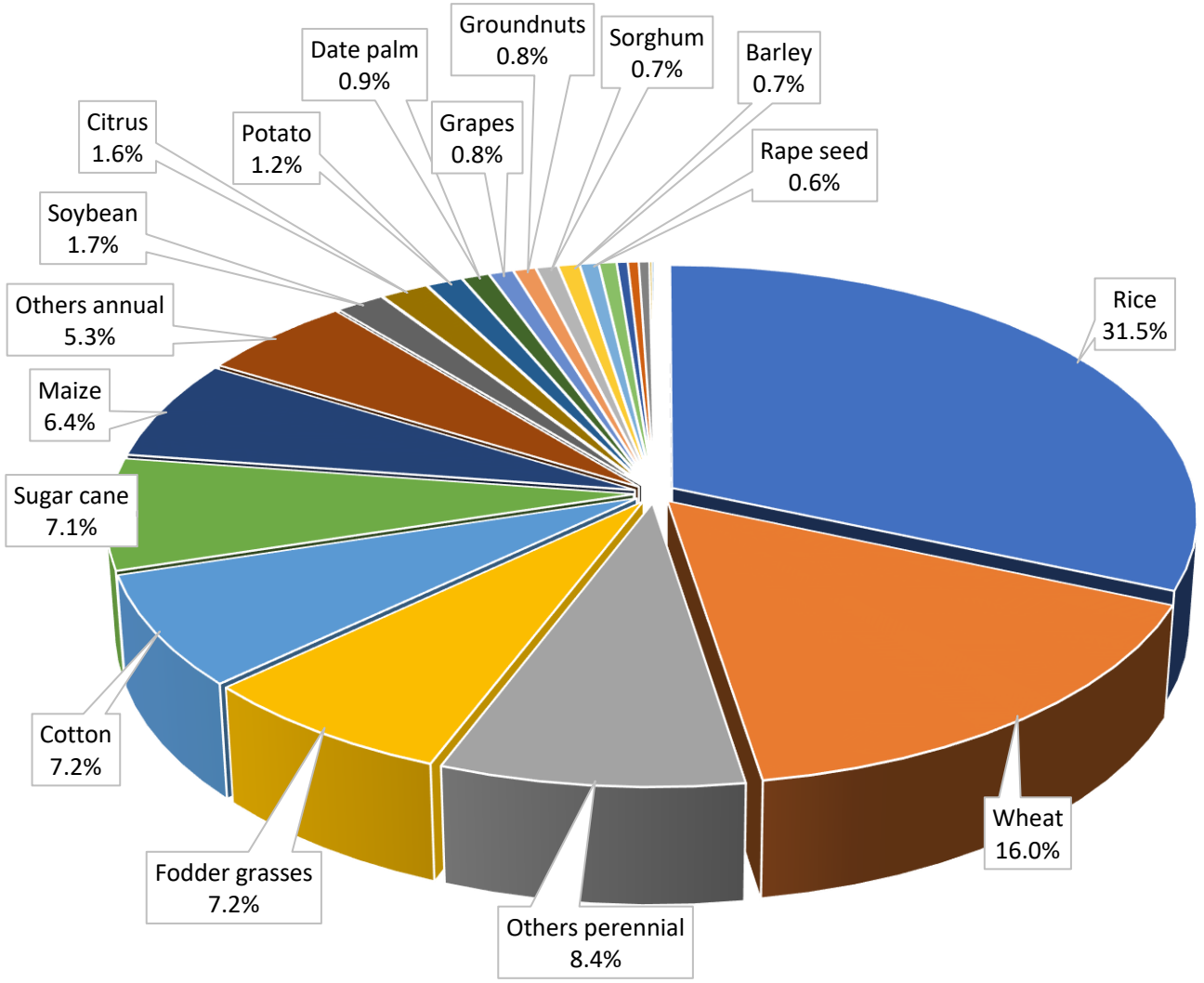
Findings





The monthly irrigation requirement's trend depends on the spatial distribution of the cultivated areas and on the sowing calendars. Wheat appears to be more water-demanding in early spring, when "winter wheat" grows in the northern hemisphere.
In the map, huge volumes may depend on high rates of irrigation requirement and on the massive presence of wheat fields.

Findings



The total modeled irrigation requirement for the year 2000 is **1027 km^3**.

More than 50% of this water is used by **rice**, **wheat** and **maize**, which are respectively the 2nd, 3rd and 4th biggest crop yearly productions, and the three most consumed cereals in the world.

Conclusions and recommendations

The new high-resolution climate data available today allow to estimate the water requirement through the knowledge of the actual daily conditions, partially avoiding the uncertainties deriving from monthly means. Furthermore, re-analysis data allows to work with a uniform reliability on a global scale.

A deep knowledge of the irrigation requirement distribution is essential in a world where the food demand will grow together with the population and the availability of local water resources could massively change soon.

The irrigation requirement assessment is a critical step for the development of a model for the evaluation of actual irrigation, for which there are currently few tools.