Hydro-climatic and anthropic determinants of spatio-temporal variability of crop water footprint

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Introduction and motivation

- Multidisciplinary analyses of the water-food nexus are often based on the water footprint indicator, quantified with the crop water footprint (CWF, or unit WF). CWF is an indicator of efficiency in the use of water in agriculture and it has a marked spatio-temporal variability.
- Our goal is to investigate the drivers of such variability and in particular to disentangle the role of hydro-climatic and anthropic factors
- We did so with a global-scale analysis (on a 5 arc-min grid) along the period 1961-2004 considering green (precipitation) and blue (irrigation) water in 4 crops (wheat, maize, rice, soybeans)

Data and approach

CWF in year t and cell i (in m^3/ton) is defined as $CWF_{i,t} = \frac{10 \cdot ET_{i,t}}{Y_{i,t}}$

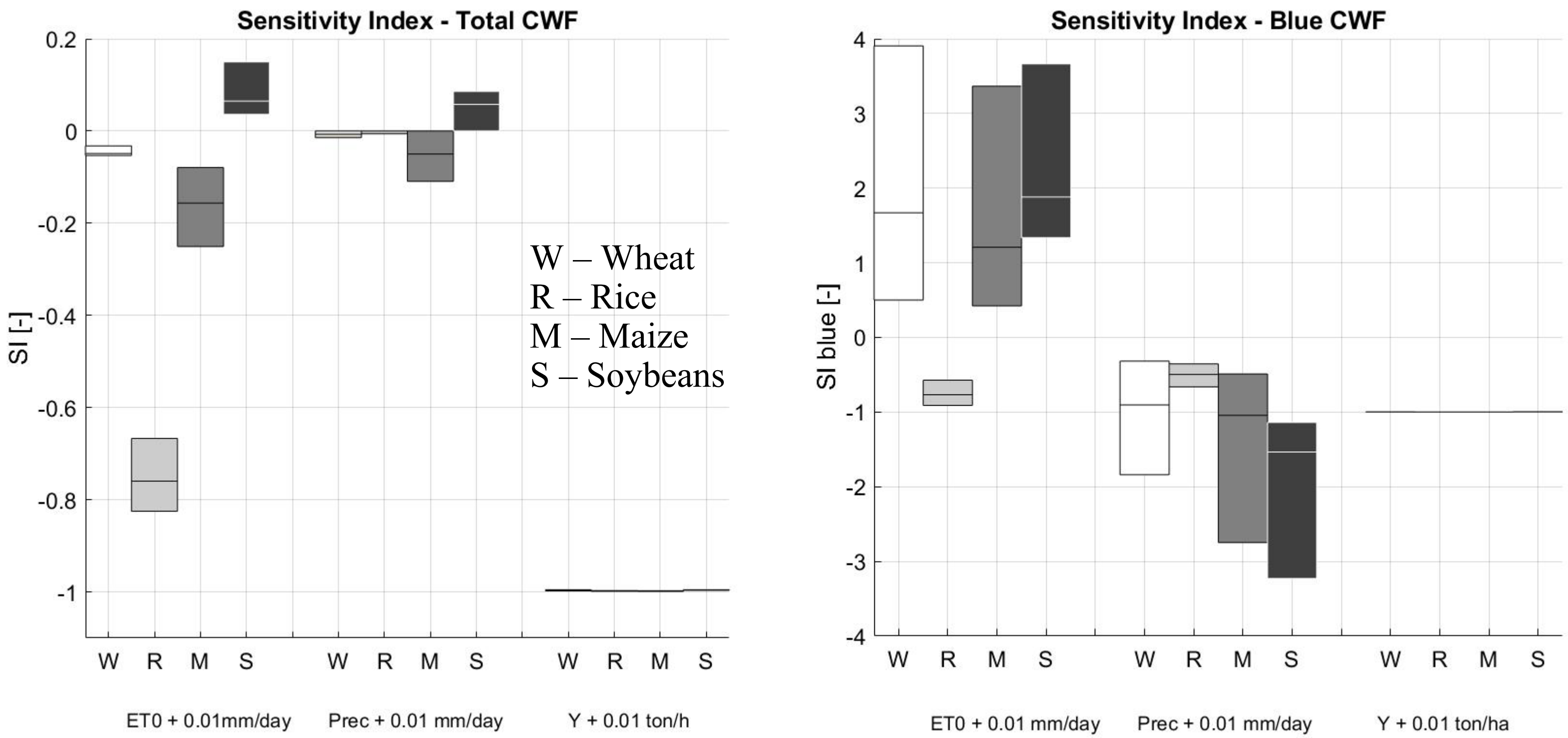
- $ET_{i,t}$ is the water depth of actual evapotranspiration of crops during the growing season (in mm) and is obtained from a gridded soil water balance model forced by year-specific precipitation (P) and reference evapotranspiration (ET0);
- $Y_{i,t}$ is the crop yield (in ton/ha), obtained from spatial and temporal yield data as $$Y_{i,t} = \alpha_{i,t}^{cl} \cdot \alpha_{c,t}^{man} \cdot Y_{i,2000}$$

where $\alpha_{i,t}^{cl}$ describes the climate-driven fluctuations of yield derived from a different actual evapotranspirations between year 2000 and year t (as from Doorenbos et al., 1979), and $\alpha_{c,t}^{man}$ accounts for changes induced by non-climate factors at the country scale, thus ascribable to the human (anthropic) role in agriculture.

Findings - Sensitivity

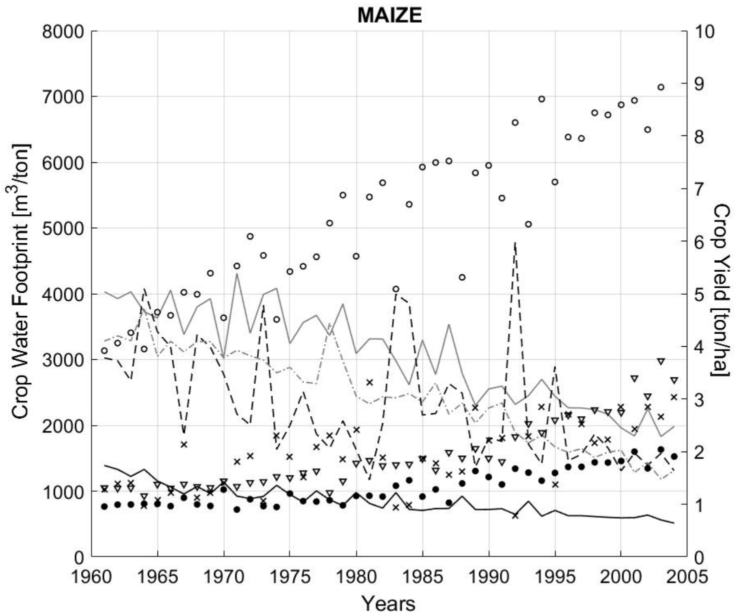
We use a normalized sensitivity index, SI_x, built perturbing one imput variable at a time (x) and dividing the variations by the reference (unperturbed) values:

$$SI_x = \frac{\Delta CWF}{CWF_0} / \frac{\Delta x}{x_{ref}}$$



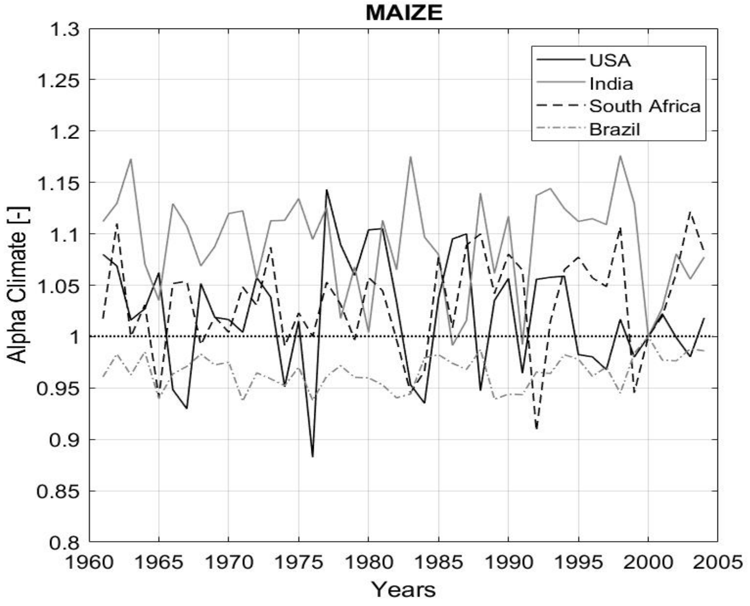
Pr and ET0 have little effect on total CWF, but a strong effect on the separation between green and blue CWF

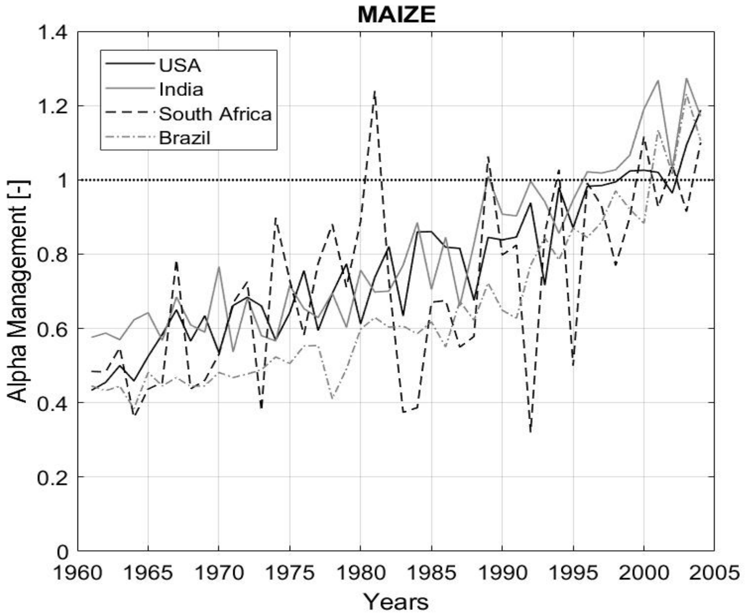
Findings – Drivers of CWF



The temporal trend in CWF is marked and tightly connected to the evolution of yield, which depends on hydro-climatic and anthropic factors

- Hydro-climatic factors only determined oscillations in CWF, without clear trends (α^{cl} above)
- Anthropic factors determined the marked trend in CWF (α^{man} below)





Conclusions and recommendations

- Hydro-climatic variables contribute to the inter-annual fluctuations of yield (and thus of CWF) but the temporal trends are dominated by anthropic determinants.

- Understanding the determinants of CWF and quantifying the human role as compared to that of climate may help triggering actions to improve a more efficient use of water in agriculture, exploiting sustainably not only blue but also green water.