INRAE

Increasing soybean production in Europe: impact on cropping systems and environment

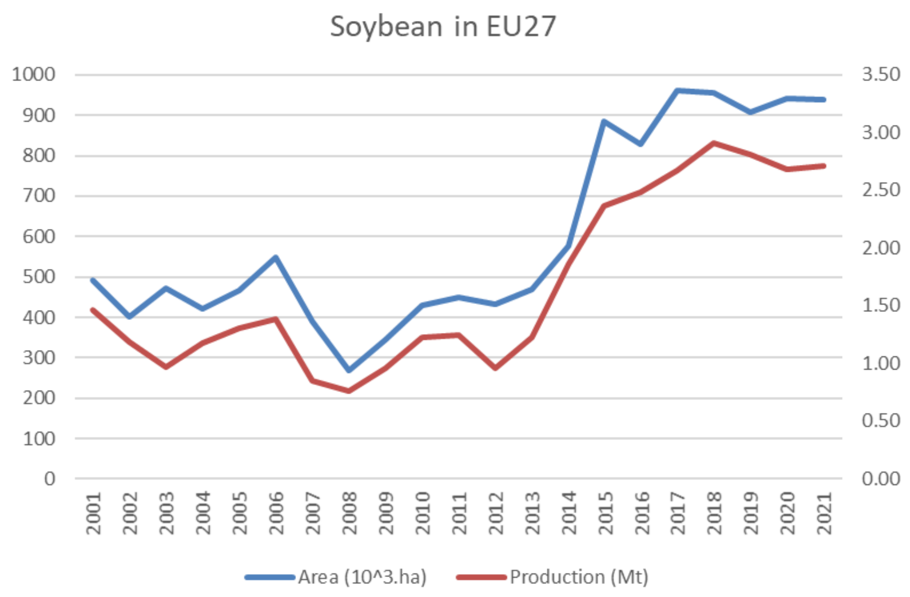
Julie Constantin[1], Hélène Tribouillois[2], Etienne-Pascal Journet[1], Philippe Debaeke[1], Hélène Raynal[1]

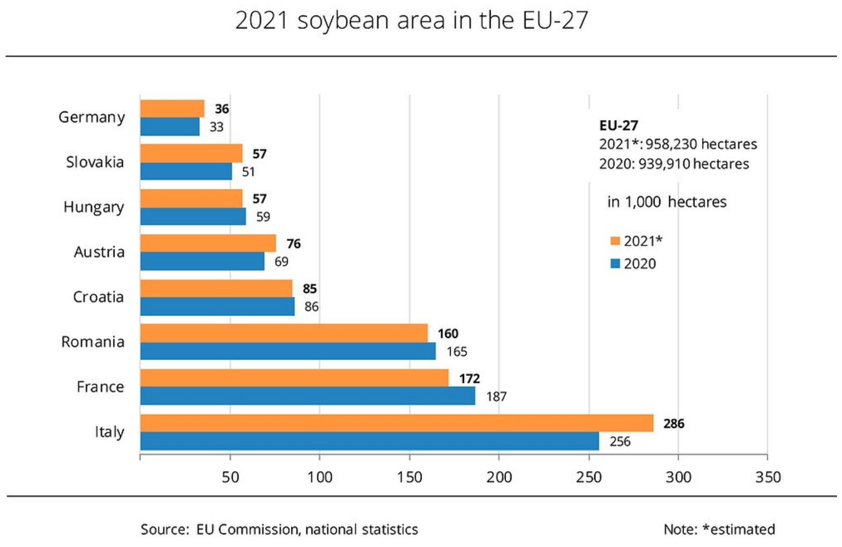
[1] University of Toulouse, INRAE, UMR AGIR, Castanet-Tolosan, France

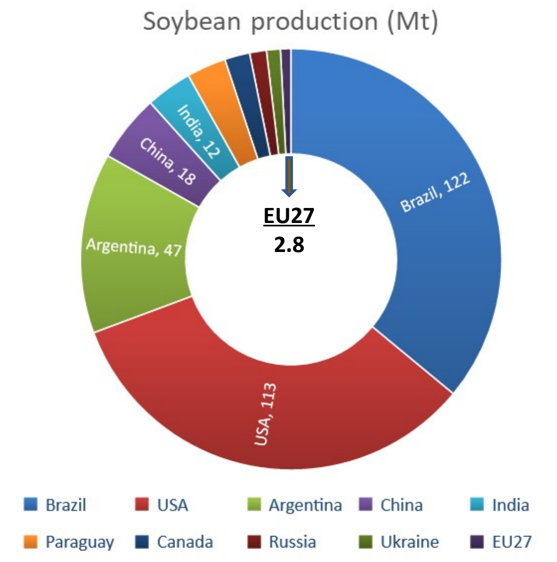
[2] Terres Inovia, Baziège, France

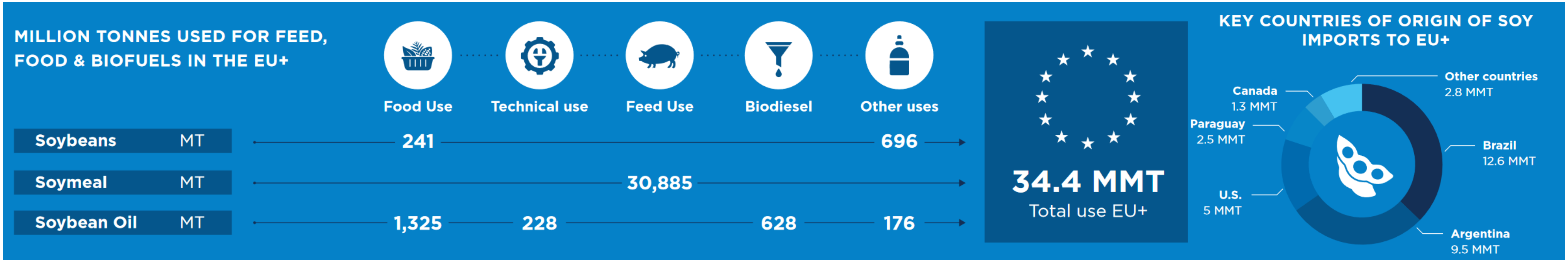
Source : FAOSTAT

Soybean in Europe and in the world









Source: IDH European-Soy-Monitor-2017

INRAE

Several programs to be more self sufficient in Europe (EraNet LegumeGAP, ANR soystainable)

Objectives of our simulation study in Europe

For soybean production :

- Analyse the potential yield for soybean in contrasted contexts (temperature, radiation and unlimited water)
- Estimate the yield gap with limited water with rainfed crop
- Evaluate the climate change impact on crop yield in potential and water-limited conditions

At the crop rotation scale :

- Analyse the impact on non legume crop to introduce soybean both in irrigated and rainfed systems
- Quantify the impact of soybean introduction on environmental components : water drainage, nitrate leaching, C storage, N_2O emissions and GHG balance.

➡ Soybean was previously calibrated in STICS v9.2 for several maturity groups (Schoving et al., 2020; Nendel et al., 2022)

INRAE

Design of the numerical experiment

8 scenarios

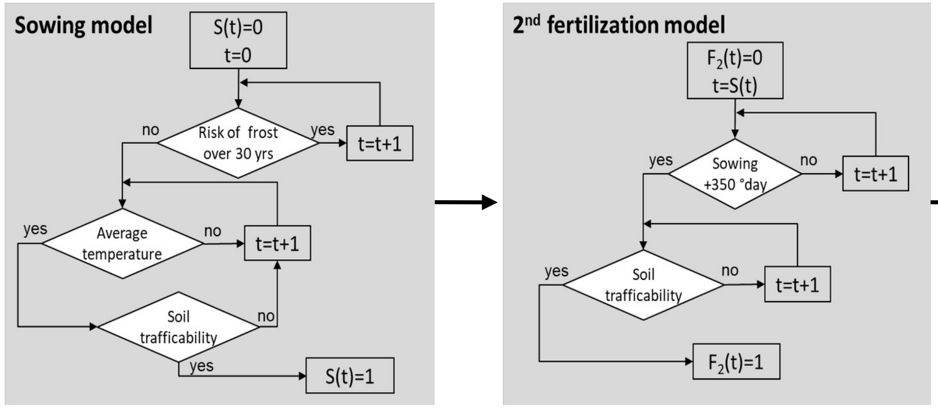
Crop rotation	Irrigation	Climate scenario
Wheat / Maize	Irrigated (fully)	Present (0.0)
Wheat / Soybean	Rainfed	Future (RCP 4.5)

Crop	Cultivar(s)	Fertilization (kgN/ha)	Water stress for irrigation	Soil tillage	Crop residues
Wheat	1	180	0.70	8 days after harvest	Straws & roots
Maize	8 (Very early to very late)	180	0.85		
Soybean	7 (0000 to II)	0	0.85		

- **100 grid cells of 25x25 km²**
- **Soils :** European Soil Database at 1 km² resolution (Hiederer, 2013)
- **Climate :** based on the dataset Webber et al. 2018.
  - Baseline (1980–2010) - JRC Agri4Cast database (version 2.0)
  - Climate Models (GCM): MPI-ESM-MR

100 sites selected to cover Europe

Modelling chain with STICS v9.2



From Constantin et al., 2019

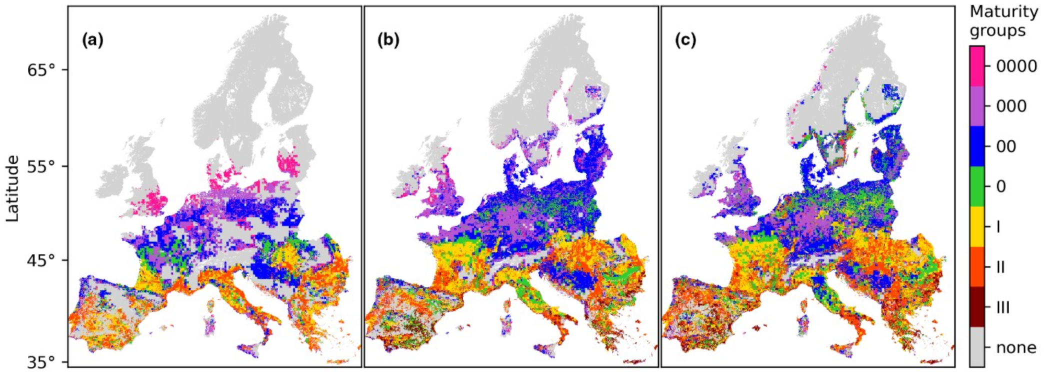
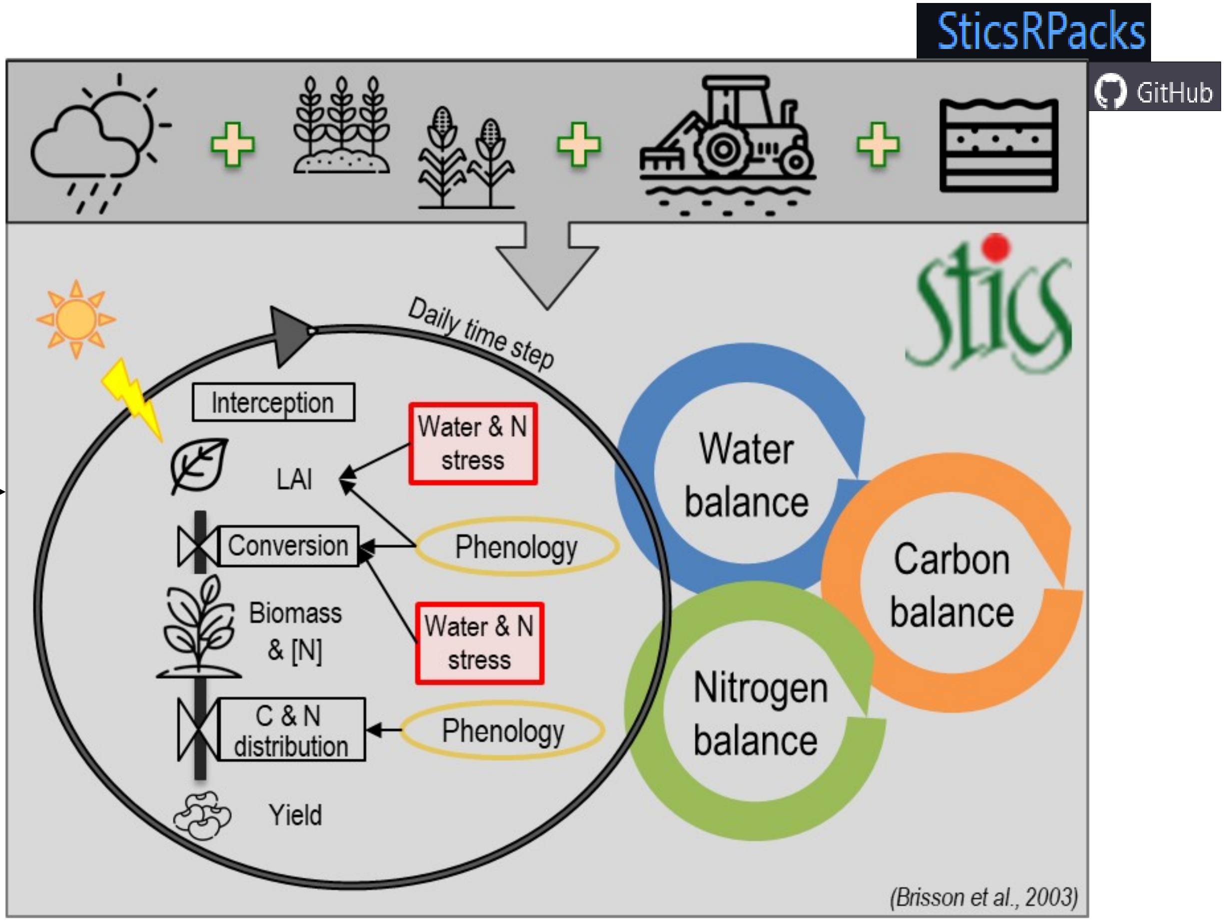


FIGURE 3 The soybean maturity group (0000—Extremely early; III—Middle) that produced the highest yield in individual pixels in a simulation of an ensemble of four crop models. 1981–2010 hindcast (a), 2040–2069 RCP 4.5 scenario ensemble mean of five global climate models (b), 2040–2069 RCP 8.5 scenario ensemble mean of five global climate models (c). Note that MG III was only introduced for the future scenarios.

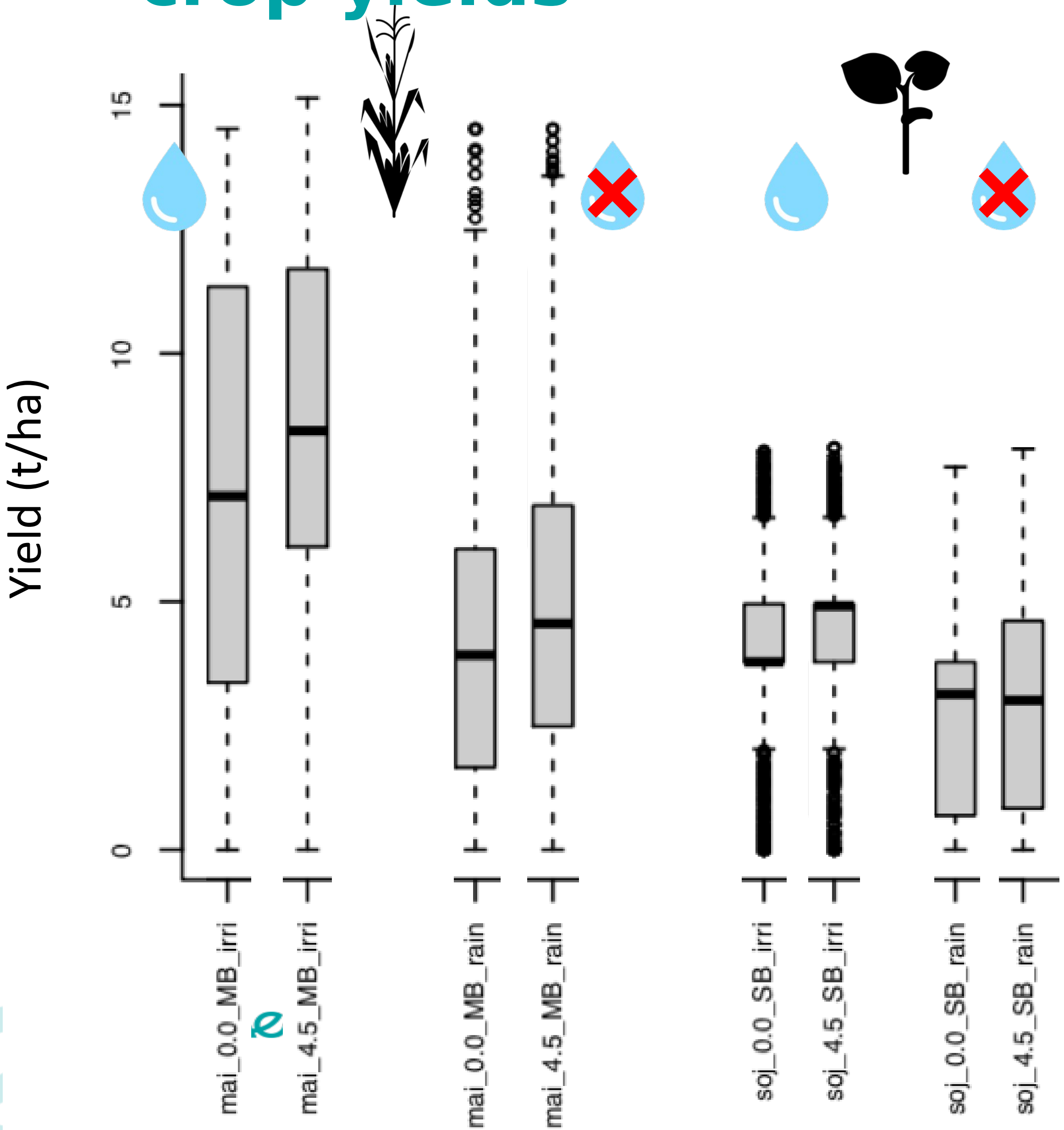
From Nendel et al., 2022



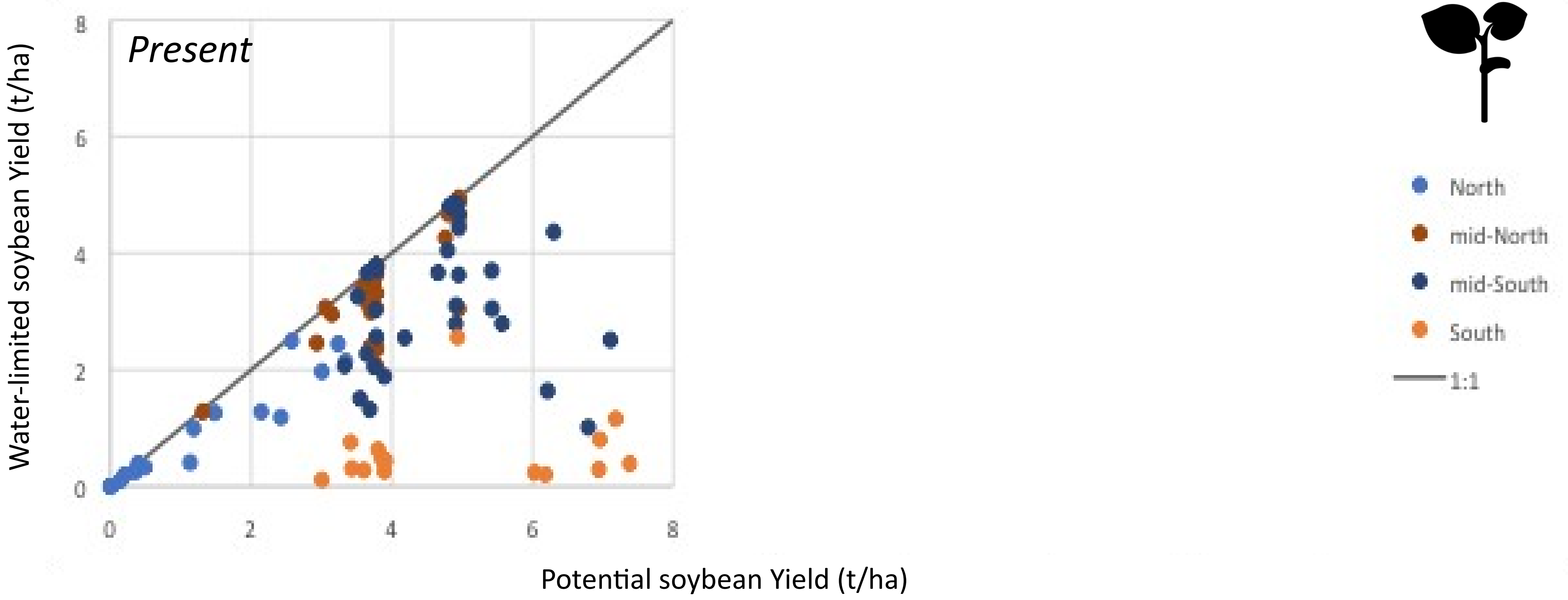
GHG balance = f(N_2O direct & indirect, C storage, N fertilizer)

INRAE

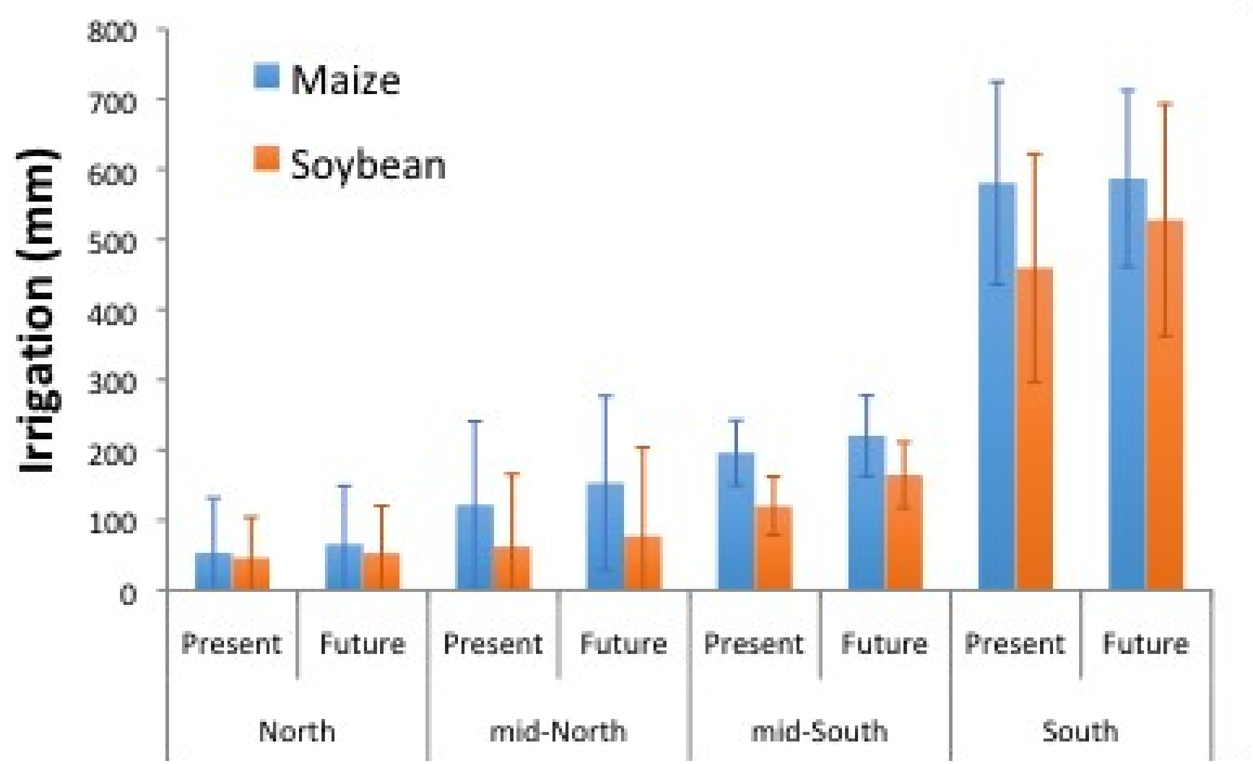
Positive effect of irrigation and CC for both crop yields

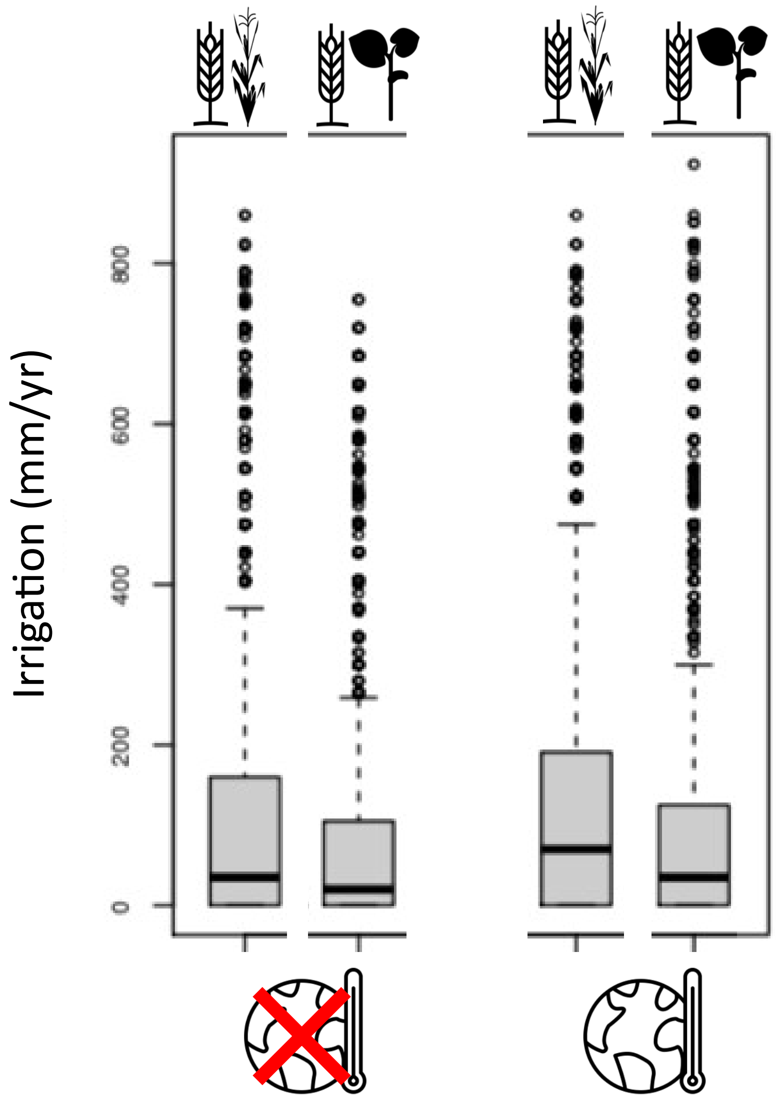


Potential and limited yield of soybean vary widely from North to South of Europe

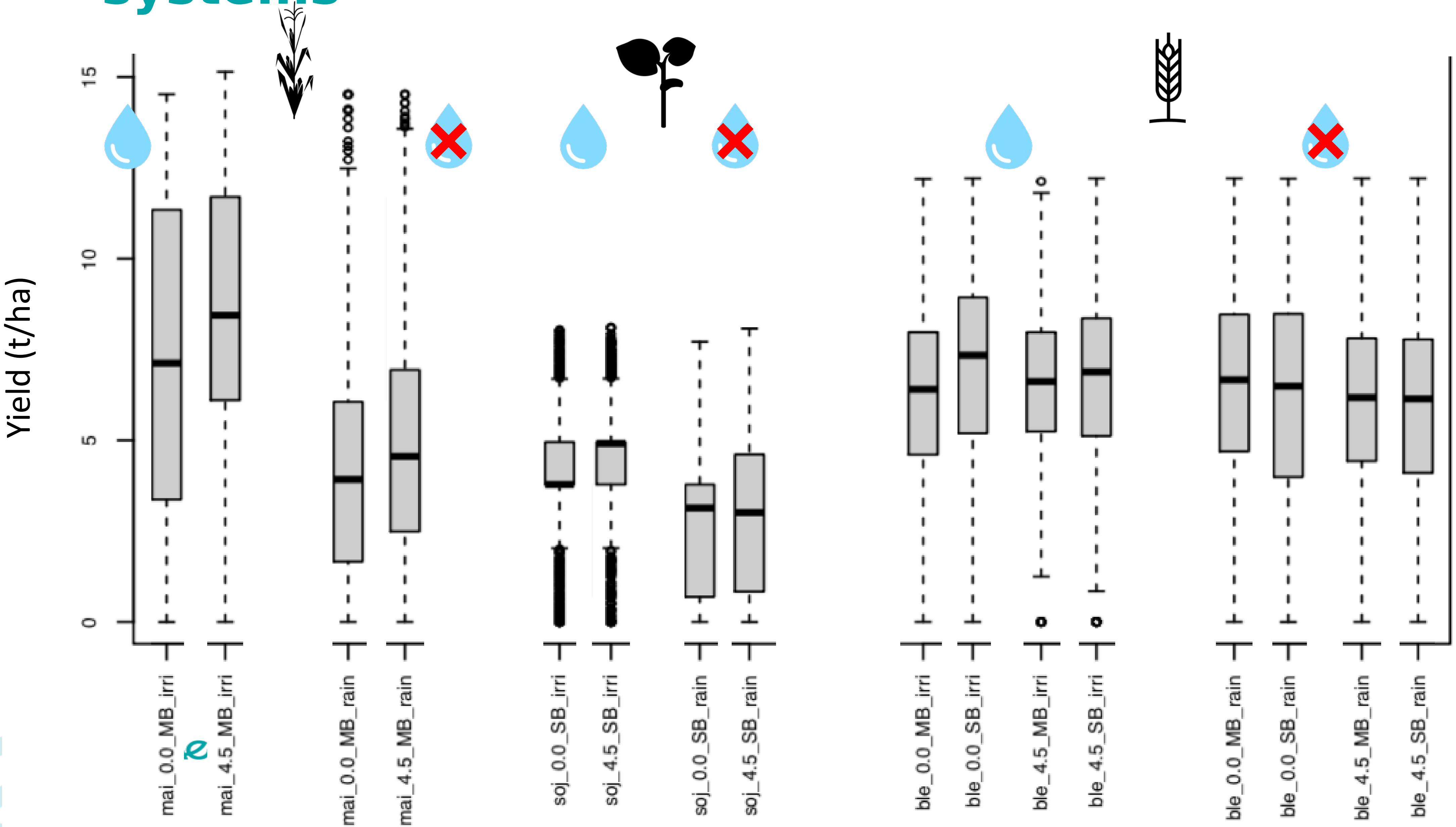


Reduced irrigation for soybean compared to maize

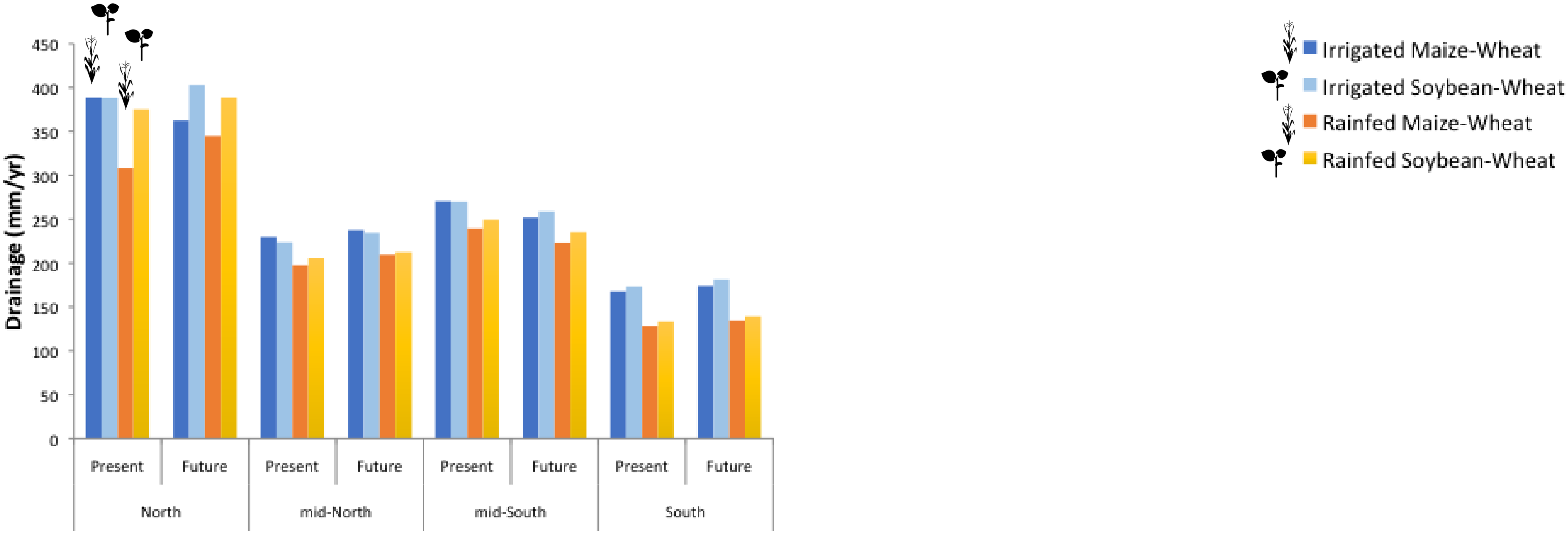




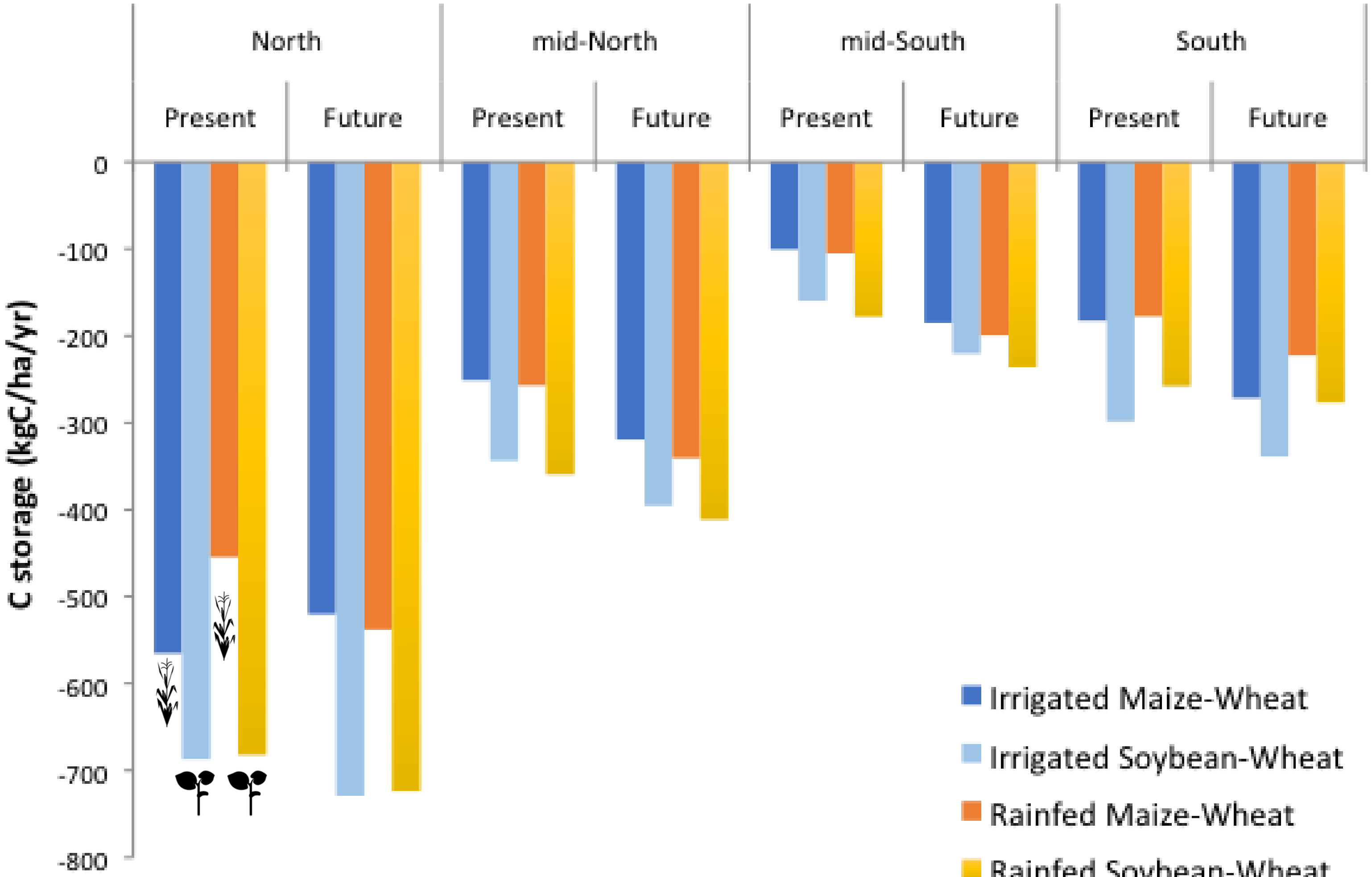
Slight increase of wheat yield in irrigated systems



Positive impact on drainage and N leaching in most cases

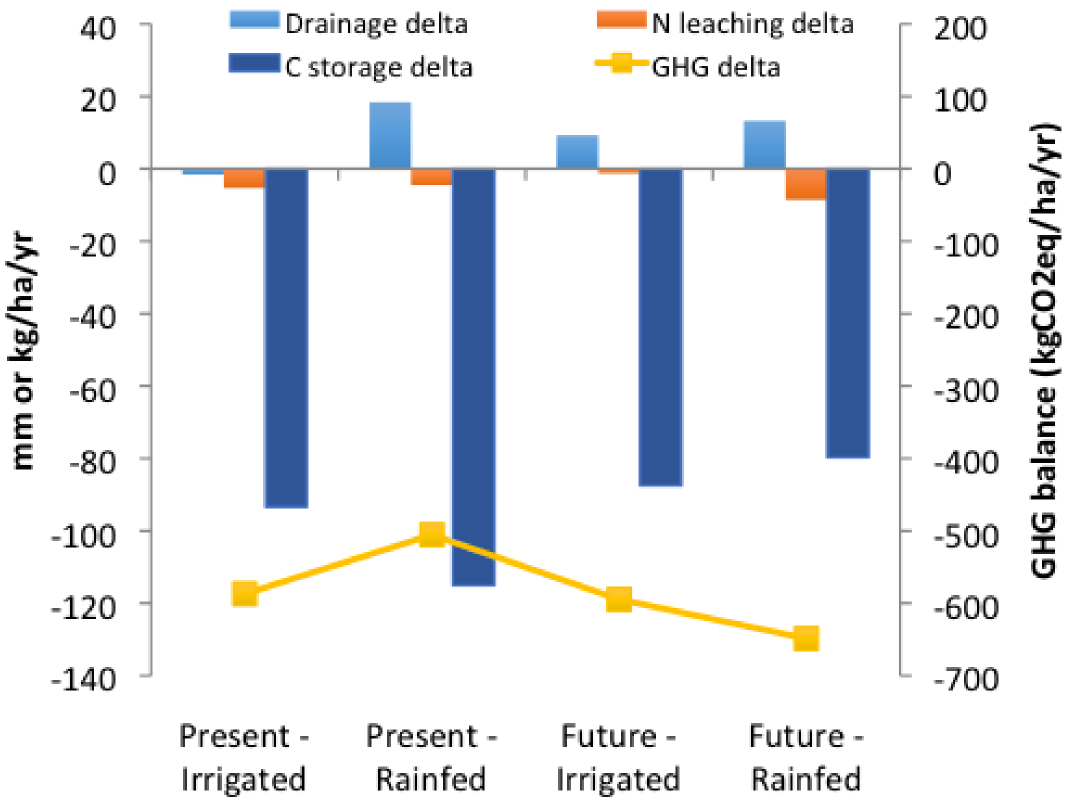


Less C storage due to lower biomass residues

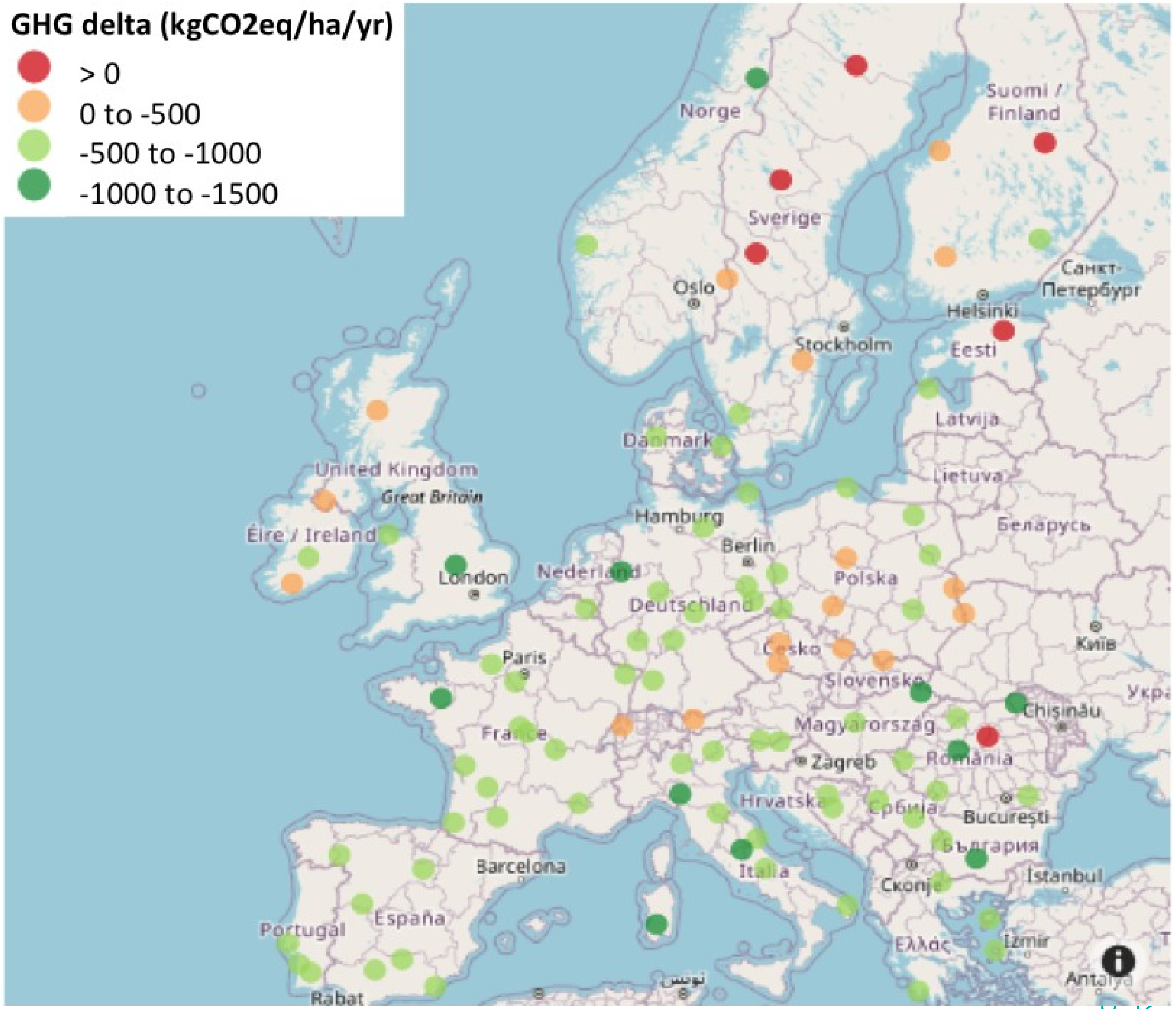


INRA

GHG balance decreases with soybean due to lower fertilization



Difference in soybean-wheat vs maize-wheat in future rainfed systems



To conclude

About soybean production in Europe :

- ✓ High potential but high yield gap in the South vs. low yield gap but low potential in the North
- ✓ Interesting potential and relatively low yield gap in the mid-North and mid-South
- ✓ Positive impact of climate change on the potential yield (but negative on YG for mid-south)
- ✓ Reduced need for irrigation with soybean than maize (lower biomass)

In both present and future climate, the introduction of soybean in rotation:

- ✓ Increased water drainage, particularly in rainfed systems
- ✓ Reduced nitrate leaching and N_2O emissions related to fertilizer
- ✓ Decreased soil C storage due to lower residue of soybean compared to maize
- ✓ Decreased GHG balance, reducing the environmental impact of agriculture

Perspectives

- Simulating more accurately mineral N fertilization with SticsTkR *(Willaume et al, this morning)*
- Simulating a wider range of grid cells to cover Europe better
- Testing more agroecological cropping systems with cover crops
- Simulating crop rotation including both soybean and maize
- Using STICS v10 with one soybean plant file including all maturity groups

Thank for your attention!