Estimation of yield and water needs of maize crops combining HSTR images with a simple crop model, in the perspective of Sentinel-2 mission

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BACKGROUND

- In the **south west of France** (temperate mild climate), **maize crop** represents 60% of the irrigated area and uses up to 80% of irrigation volumes during summer. In this region, water resources are under increasing pressure as a result of global change and of rising competition among the different stakeholders. It is therefore important to develop **models** which help to optimise **irrigation schedule** while maintaining reasonable **production rates**.
- **High Spatial and Temporal Resolution (HSTR)** satellite images (like **Sentinel-2**) integrated into **crop models** has a high potential to describe main processes related to the carbon and water cycles at **local** and **regional scales**.

OBJECTIVES

- To which extent can the combination of **frequent optical remote sensing** observations (*Formosat-2, Landsat-8, SPOT4-Take5, Deimos-1*) and agronomical modeling improve the determination of maize crop **yield** and **water needs** ?
- The **Green Area Index (GAI)** is an integrative variable that can drive biomass production, but is it a good indicator of water stress ? To assess this question, we compare regional yield estimates using a crop model **without (SAFY)** and **with (SAFY-WB) water balance module**.

→ To provide an **operationaly ready** and **spatialised** maize crop yield estimates algorithm for Sentinel-2 data.

SAFY : BIOMASS & YIELD ESTIMATES

IN SITU VALIDATION :

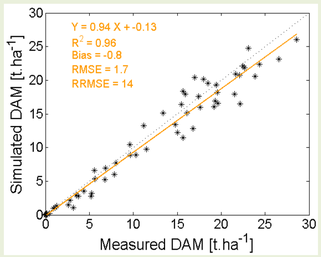


Fig : Comparison of Simulated and Measured DAM [t.ha-1] for 25 plots located in the south west of France.

✓ **SAFY model is able to reproduce accurately the *in situ* Dry Aboveground Mass (DAM) (RRMSE = 14 %)** (Battude *et al.*, submitted)

REGIONAL VALIDATION :

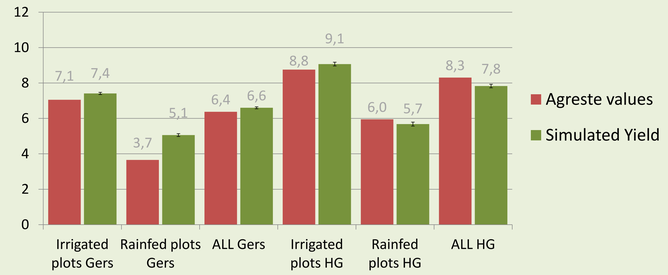
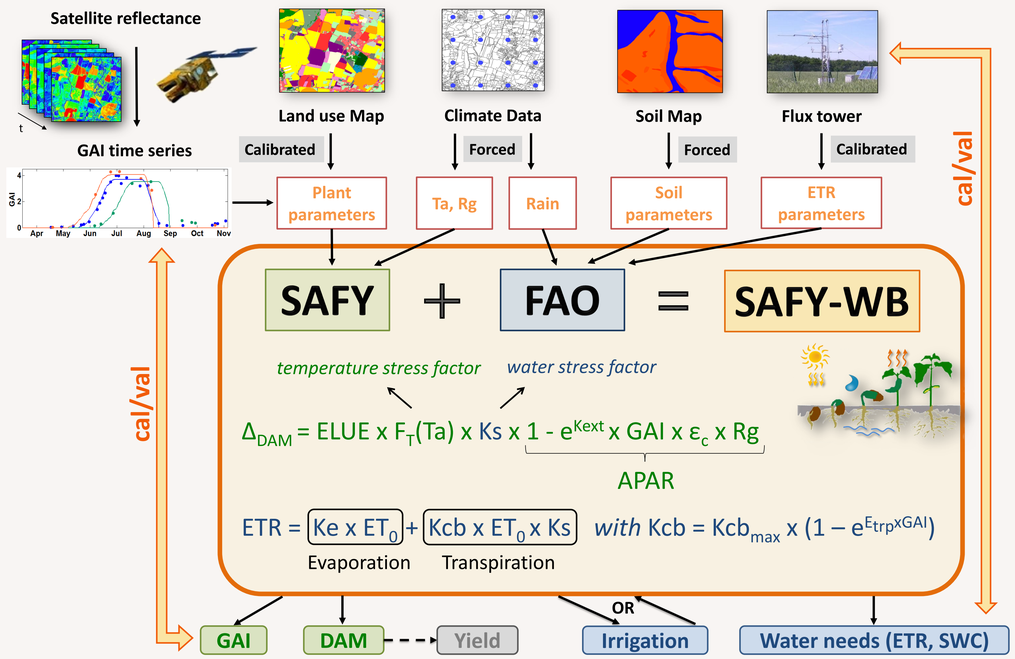


Fig : Comparison of Simulated yield and Agreste yield statistics [t.ha-1] for the Gers and Haute-Garonne (HG) departments in 2013, with the distinction of irrigated and rainfed fields. Standard errors associated to simulated values are reported.

✓ **Good adequacy of SAFY model and yield statistics without using the soil module (RRMSE = 4.6 %)**
✓ **The GAI seems to be a good indicator for yield prediction**
✓ **A need to evaluate the contribution of water balance module. May be useful in cases of high water scarcity**

MODELS AND METHODOLOGY

- The **SAFY-WB** model (Duchemin *et al.*, 2015) is tested against data collected on **maize fields** in the south west of France.
- SAFY-WB is a coupling between an adapted version of the **Water Balance (WB) FAO-56 method** (Allen *et al.*, 1998) to calculate crop actual evapotranspiration (ETR) and **SAFY** (Simple Algorithm For Yield estimates) crop model (Duchemin *et al.*, 2008) that simulates plant development based on Monteith theory (Monteith, 1972).



Ta: Air temperature; Rg: Global radiation; GAI: Green Area Index; DAM: Dry Aboveground Mass

SAFY-WB : BIOMASS, YIELD AND WATER NEEDS ESTIMATES

IN SITU VALIDATION :

With automatic irrigation

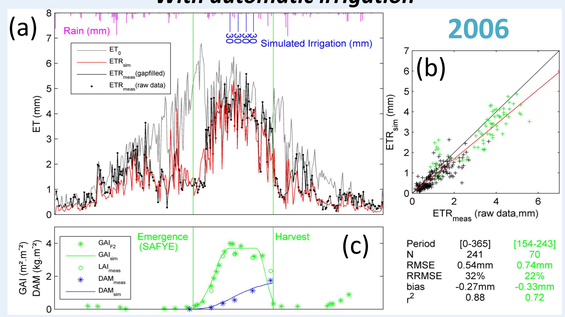


Fig : (a) & (b) Comparison of Simulated and Measured ETR in 2006 with the associated scores (vegetated period in green).
(c) Comparison of Simulated and Measured GAI and DAM time series.

✓ **Good estimates of ETR (RRMSE = 32 %) and DAM using automatic irrigation algorithm for the 4 years studied**
✓ **Automatic irrigation is close to actual irrigation with a gap of 2 mm to 35 mm depending on the year**

REGIONAL VALIDATION :

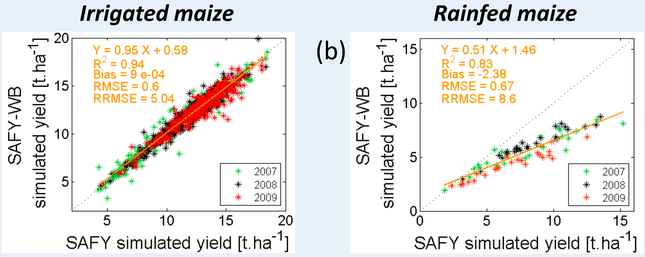


Fig : Comparison of Simulated yield [t.ha-1] with SAFY and SAFY-WB models for (a) irrigated and (b) rainfed fields in the Formosat-2 footprint (24 km²) in 2007, 2008 (rainy year) and 2009 (dry year).

✓ **SAFY-WB yield estimates are overall lower than SAFY for rainfed fields due to the impact of water stress**

CONCLUSION

- This approach, combining GAI estimated from HSRT remote sensing data with a crop model based mainly on efficiencies resulted to **good estimates** of crop biomass (RRMSE = 14 %), regional yields (RRMSE = 4.6%) and seasonal ETR ($RRMSE_{2006}$ = 32 %).

FUTURE WORK

- *In situ* validation of maize water needs is encouraging. **Regional validation** is still in progress. The model outputs will be validated using an extensive network of *in situ* sensors and water use over around 100 maize fields in the Neste watershed (southwest of France).
- This work benefits for a large remote sensing dataset and it foreshadows the future applications using **Sentinel-2**.

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