Using assimilation of sensor data in crop growth models

Bernardo Maestrini, Hilde Vaessen, Abel van Hoeven, Fedde Sijbrandij, Pepijn Van Oort, Corne Kempenaar, Frits van Evert

Background

A digital twin is a dynamic model which uses real time observations of the physical object to stay synchronised. In this project we use the Digital Future Farm (DFF, van Knibbe et al. 2022), a digital twin for arable crops and forages. The DFF consists of dynamic models for crop growth and a data assimilation engine. Data assimilation is implemented through a Kalman Filter that corrects model state variables (e.g. leaf area) based on observations (e.g. from drones).

Objective

The objective is to extend the DFF so that it can also assimilate topsoil moisture data. A previous model version could already correct for leaf area (LAI). Correcting for the soil moisture is important because this is a large source of uncertainty. In fact rainfall data are the most spatially heterogenous among weather data and irrigation amounts are often not recorded by farmers.

Estimation of LAI from satellite images

LAI was estimated from reflectance data using a simple but robust equation that relates LAI to WDVI, where
WDVI = NIR − g x GREEN
and g is the ratio between NIR and GREEN in bare soil.

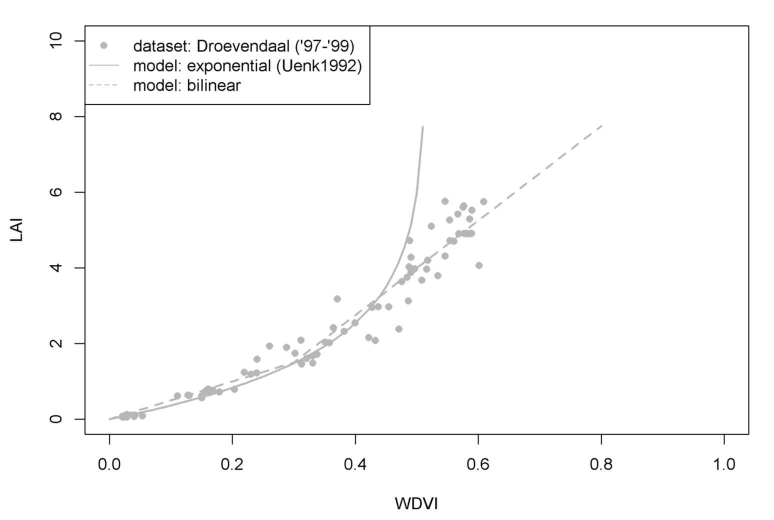

Fig 1. Relation between LAI and WDVI in potatoes (Uenk 1992, modified)

Use case from North East of the Netherlands

We present a case study where data assimilation has been applied to a potato crop field of 1 ha in the North East of Netherlands in 2021. Observations:

- LAI is estimated from canopy reflectance using Sentinel2 data (Fig 2)
- Soil moisture of top 2 cm from Planet soil moisture C band data (Fig 3).

Assimilation of LAI and topsoil moisture and its' effect on final yield estimate

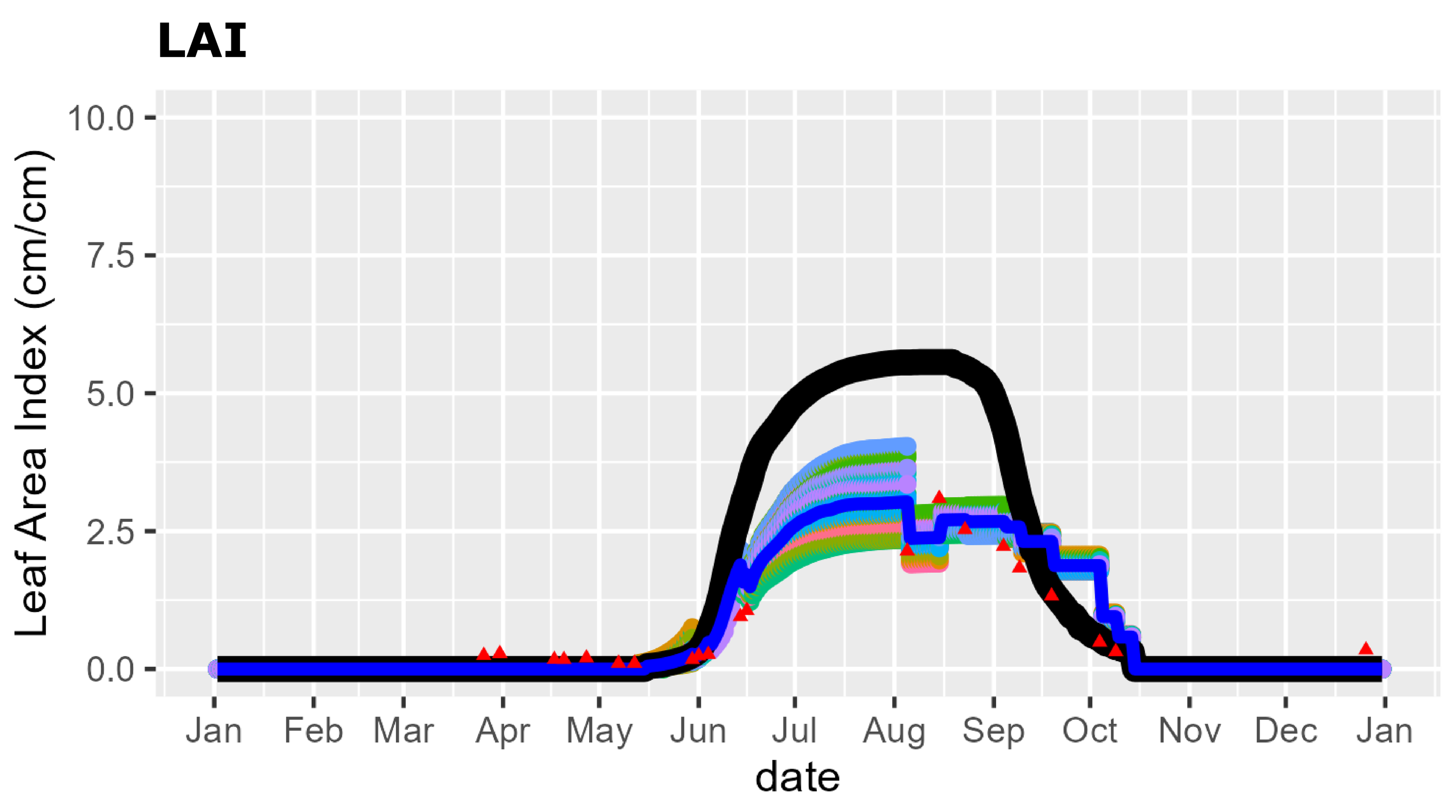

Fig 2. Data assimilation of model leaf area with observations from satellites. Black is no data assimilation, blue is median of ensemble (i.e. with assimilation), all other colours are ensemble members. Red triangles are LAI estimates from Sentinel 2.

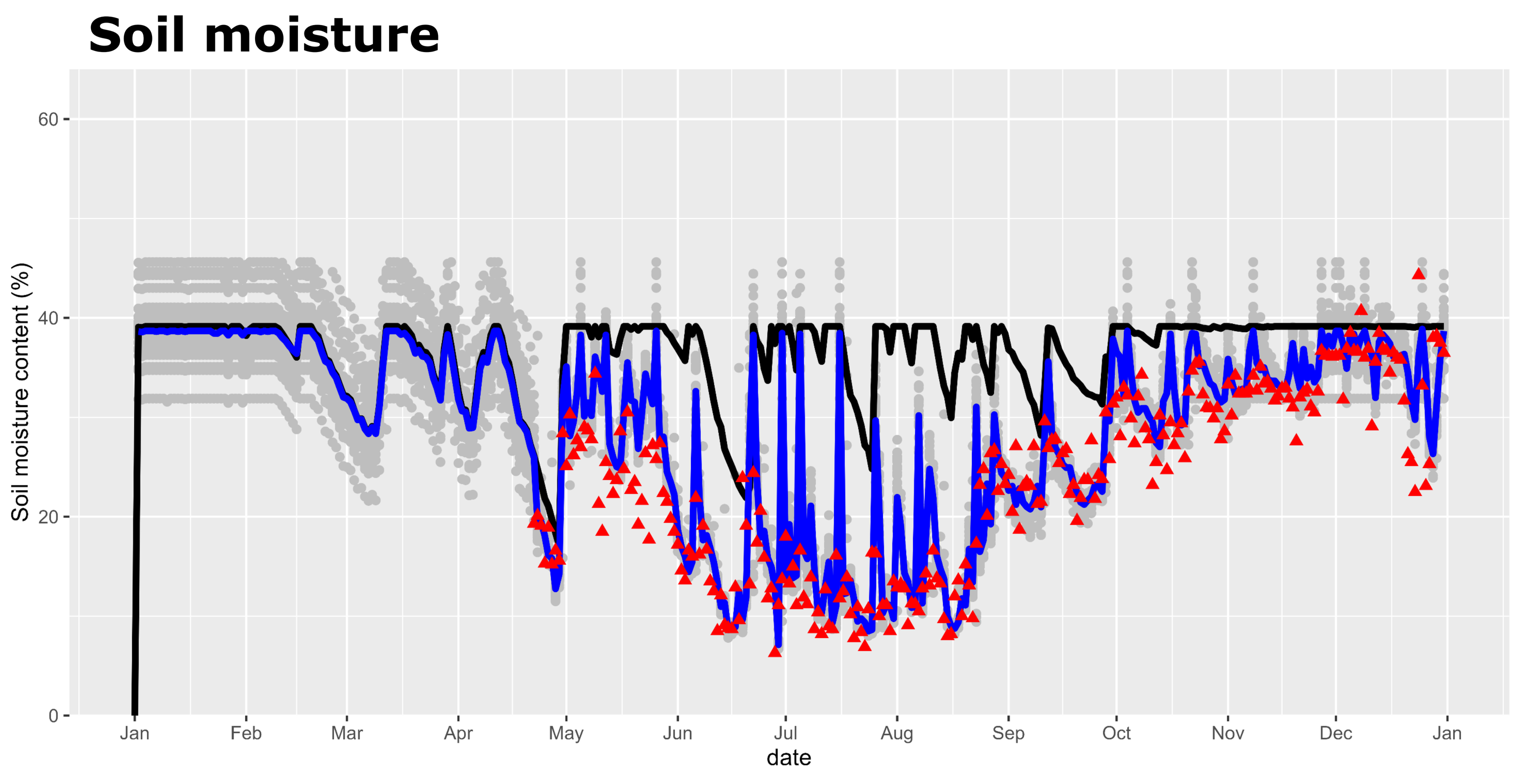

Fig 3. Data assimilation of topsoil moisture with observations from satellites. Blue is simulation with no corrections. Blue is median of ensemble (i.e. with assimilation), all other colours are ensemble members. Red triangles are estimates from Planet soil moisture data (1 ha daily resolution). .

The assimilation of data within the season corrected both LAI and topsoil moisture model estimates downward. This resulted in lower photosynthetic capacity (lowed LAI -> lower light interception), and a higher water stress (less soil water available). As a result the final yield estimate of the model + data assimilation is being corrected to a lower value, which is closer to what was measured in the field at the end of the season.

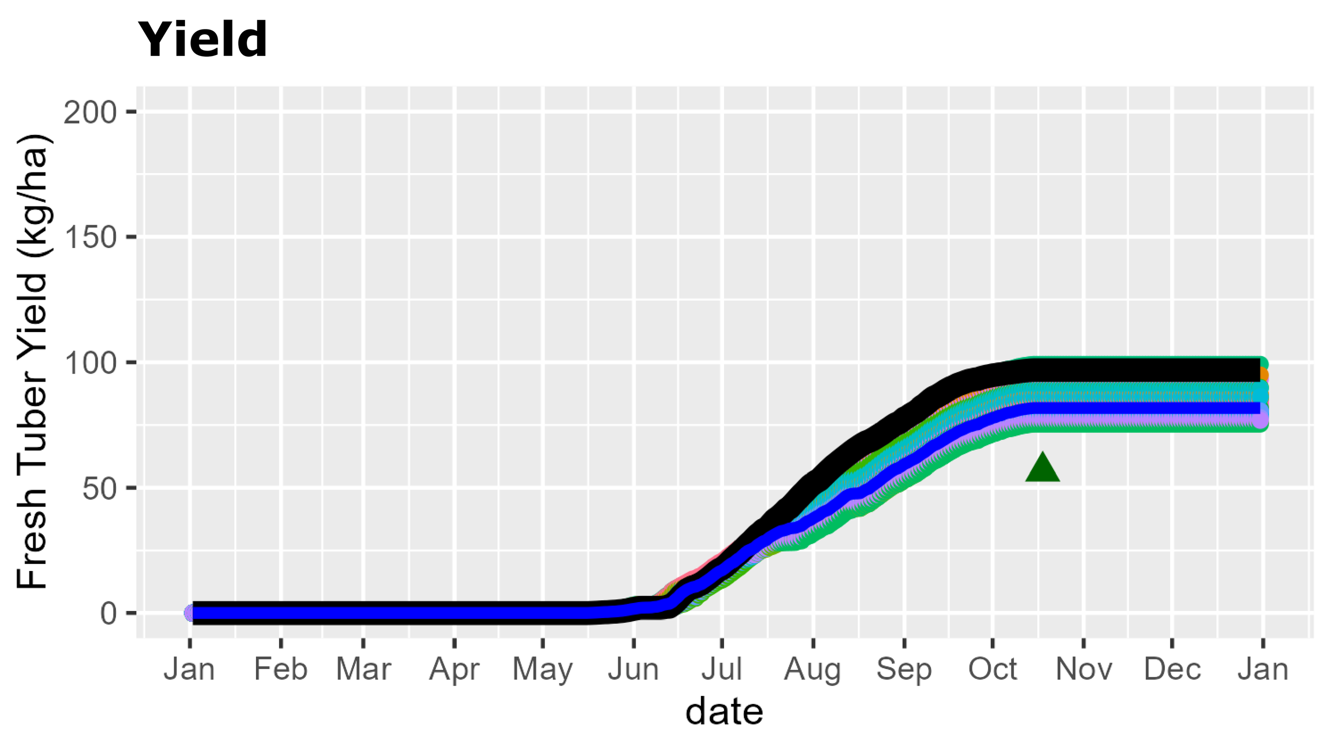

Fig 4. Simulated yield without (black) an with data assimilation (colours). Simulations with data assimilation are closer to observed final yield (green triangle)

Conclusions

Data assimilation can be used to improve yield prediction. A fully automated workflow is being developed. Better yield predictions allow for better decision support systems for farmers and lower environmental impact.

Wageningen University & Research
P.O. Box 16, 6700 AA Wagenigen
Contact: Bernardo.maestini@wur.nl
T + 31 (0)317 482392
www.wur.nl/agrosystems

Literature

Knibbe et al., 2022. Digital twins in the green life sciences. NJAS: Impact in Agricultural and Life Sciences 94:1, 249-279 https://doi.org/10.1080/27685241.2022.2150571
Uenk et al. 1992 - Reflectiemetingen aan landbouwgewassen – CABO-DLO

Acknowledgements

The project was funded through Dutch LNV ministry program KB-38-001-027