

Modelling to Support the Observations of Surface Temperatures and Soil Water Content in Agrivoltaics

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Introduction

- Climate change tends to increase the frequency of intense droughts and periods of abnormal temperatures.
- Initial studies show that Agrivoltaics (AV) can reduce diurnal surface temperatures [1, 2, 3] and improve water balance [4, 5] but there is still a lack of available data.
- This work presents soil t° and water content data acquired during 2 years in a vertical AV pilot on spring wheat (Fig. 1).
- Experimental trials often have many limitations in terms of resources.
- This study is an initial attempt to supplement the understanding of soil t° and water content data through modelling.



Fig. 1: Aerial view of the vertical AgriPVplus demonstrator of Wallhausen in 2024: $\times$ 2 depth (8 and 25 cm) and $\times$ 3 depth (8, 25 and 50 cm) of TOMST buriable unit.

Material and methods

1. Field trials

- Spring wheat was monitored in 2023 within the vertical AgriPVplus pilot of Wallhausen, Germany (51.458, 11.175).
- Among other variables, soil temperature (t°) and water content (WC) were measured with buriable TMS TOMST units composed of a TDT sensor and digital thermometers.
- These were installed at 2 or 3 depths along the AV transect with 2 repetitions for measurements at 8 and 25 cm and 1 at 50 cm (Fig. 1).
- 2 repetitions of TMS units at 3 depths were placed in the reference zone with full sunlight conditions.
- Soil t° and water content data were averaged on repetitions and on the AV transect to highlight the main effects of the AV pilot.
- A weather station in the reference zone collected weather data during both year.

2. Modelling with PASE

- Weather data, soil analysis, crop management data and AV pilot geometric parameters were used to reproduce both years of spring wheat growth.
- The Python Agrivoltaic Simulation Environment (PASE) was used in co-simulation with the JavaStics crop model.
- Simulated soil t° and water content were compared to field data.

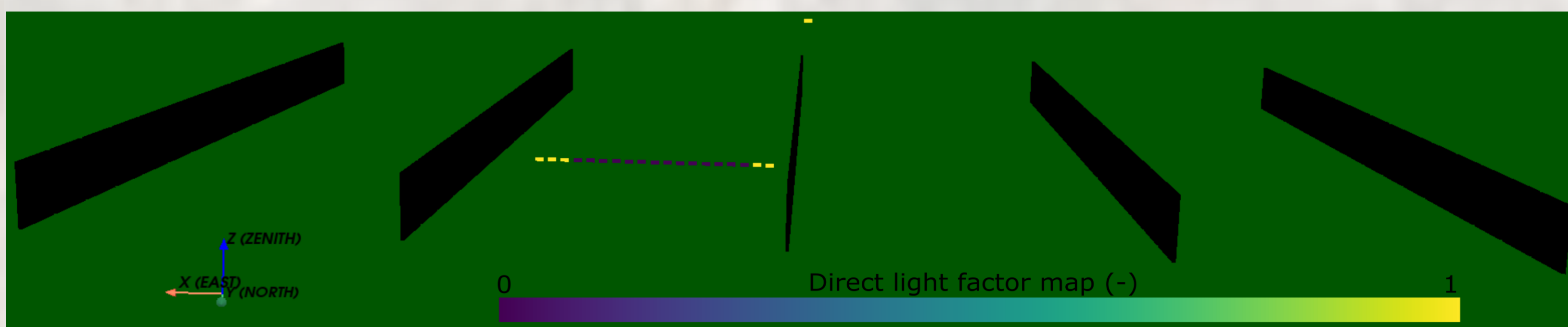


Fig. 2: AgriPVplus demonstrator of Wallhausen reproduced in PASE with a transect of point of interest.

Results and discussion

- Fig. 3 shows soil water content and temperature simulated and observed during the year 2023. Observations are averaged over the repetitions.
- Experimental data shows a depths-averaged temperature reduction of 1.9 °C induced by the PV modules with a maximal average reduction of 2.3±1.0 °C at a depth of 8 cm and 1.5±0.6 °C at 50 cm.

- WC in the AV zone is slightly higher than in the reference zone at 25 and 50 cm depths and on average 0.15±0.03 higher at 8 cm depth.
- RMSEs written on the graphs indicate how accurately the model matched the experimental data.
- Overall, the model provides a reasonably accurate simulation of the temporal dynamics of soil t° and WC.
- In general, STICS underestimates the potential soil t° reduction offered by PV modules compared to observations.
- As STICS computes soil t° based on crop t° , it would be interesting to monitor also canopy temperature.
- STICS underestimates the difference of WC between the AV and the reference zone at 8 cm and slightly overestimates it at 25 and 50 cm.
- Due to the limited data replications and the presence of surface agglomerates, field WC results should be interpreted with caution.
- Instead of fixing WC at field capacity at simulation initialization, further analysis should explore the simulation using first observed data to initialize WC.
- Because of soil heterogeneities, a greater number of repeated measurements using TDT sensors, or alternatively the use of lysimeters, should be prioritized to obtain high-quality soil WC data.
- In addition to high-quality data, hydric and energy balance crop model formalisms should be improved regarding AV conditions.
- The pySTICS initiative will provide access to high-spatial resolution soil data, enhancing comparison quality and allow refinement of surfaces temperature and water balance formalisms to better account for AV conditions.

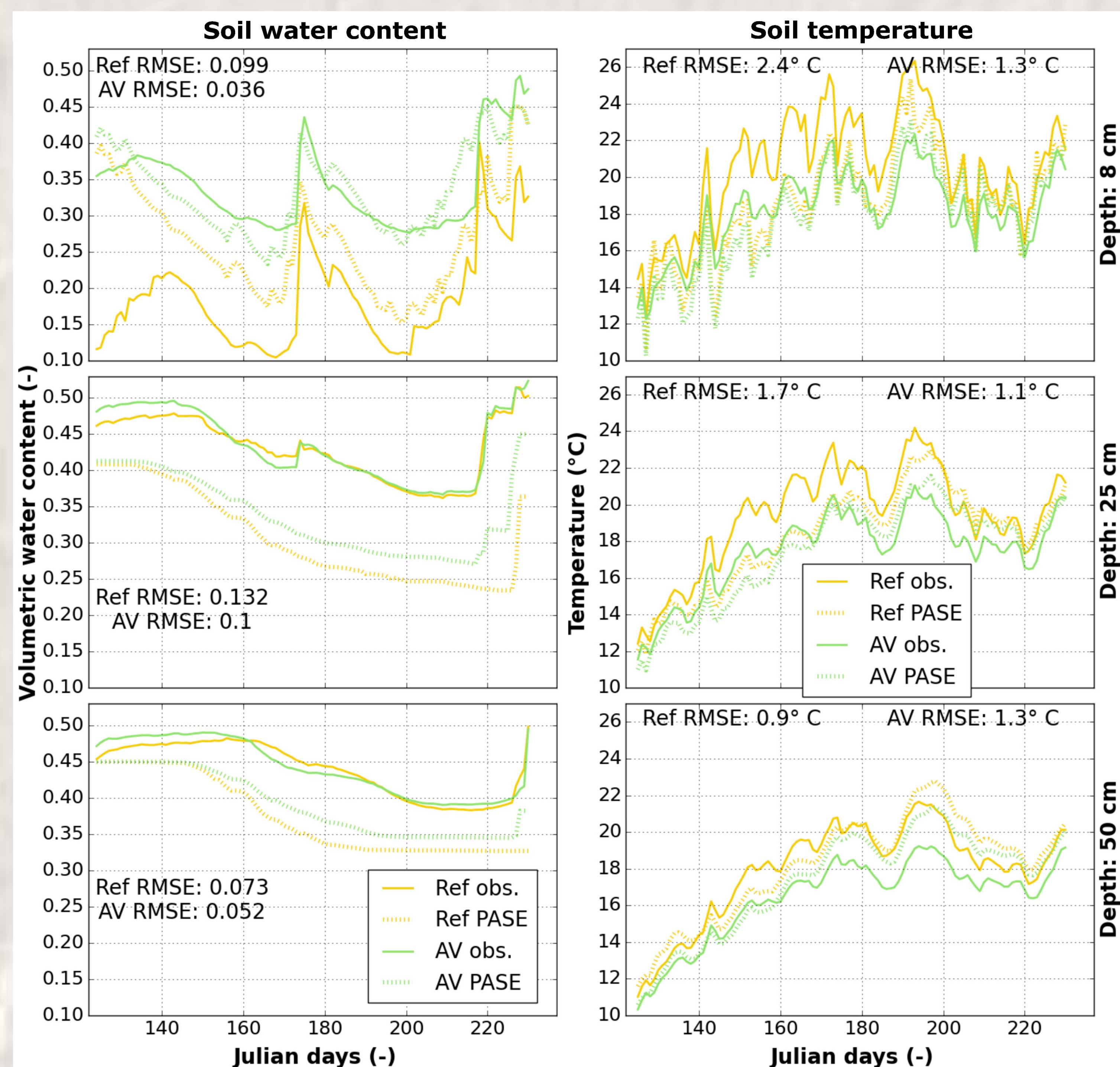


Fig. 3: Simulated and observed soil water content and temperature at 3 depths in 2023.

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