Analysing the impact of calibrating a low-cost soil moisture sensor on crop model (FAO Aquacrop) performance


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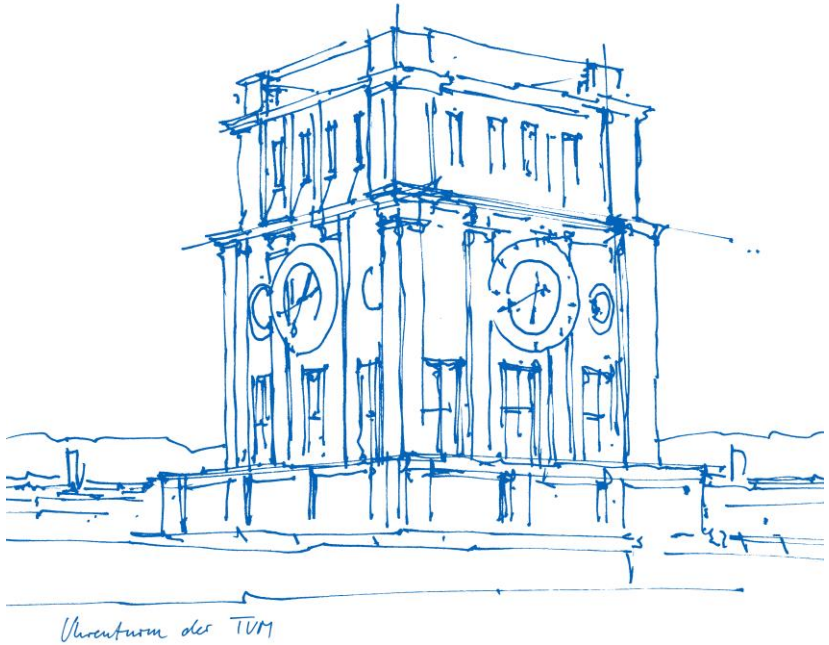

Collaborators:

- Felix Bruckmaier (Technical University of Munich)
- Leonardo F. Arias-Rodriguez (Technical University of Munich)
- Prof. Shivam Tripathi (Indian Institute of Technology Kanpur)
- Prof. Saket Pande (Delft University of Technology)
- Prof. Dr.-Ing Markus Disse (Technical University of Munich)

a) https://pin.it/1NRrO19

Background

- **Overall goal:** increasing water related input efficiency in agriculture
- **Tools:**
  - Soil moisture measurements: Unless they are cost-effective, they won't be adopted[a-b]
  - Crop modelling: Less data intense, parsimonious is necessary because of many data scarce regions and crops[c]

a) Srbinovska et al. (2015): https://doi.org/10.1016/j.jclepro.2014.04.036
b) Pramanik et al. (2022): https://doi.org/10.1016/j.atech.2021.100032
c) Vanuytrecht et al. (2014): https://doi.org/10.1016/j.envsoft.2014.08.005

The Plan

Low-cost soil moisture sensor (capacitance)
Spectrum SM100
USD 90

a-b

+

AQUACROP-OS

c

→

Improved Water Productivity

d

$$WP_{ET} = \frac{yield}{ET_a} \text{ (kg/m}^3\text{)}$$

a) https://www.specmeters.com/weather-monitoring/sensors-and-accessories/sensors/soil-moisture-sensors/sm100/
b) Adla et al. (2020): https://doi.org/10.3390/s20020363
c) Foster et al., (2017): https://doi.org/10.1016/j.agwat.2016.11.015, Steduto et al. (2009): https://doi.org/10.2134/agronj2008.0139s
d) Van Halsema and Vincent (2012): 10.1016/j.agwat.2011.05.016

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AQUACROP-OS

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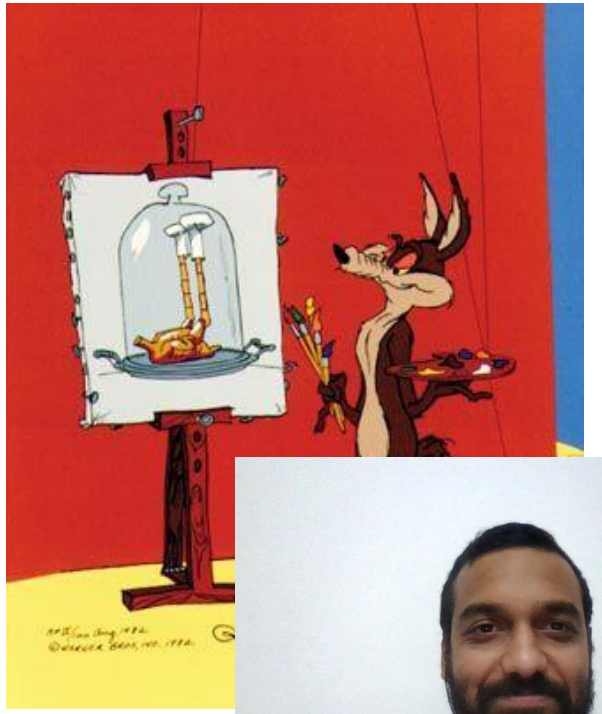
Improved Water Productivity

a

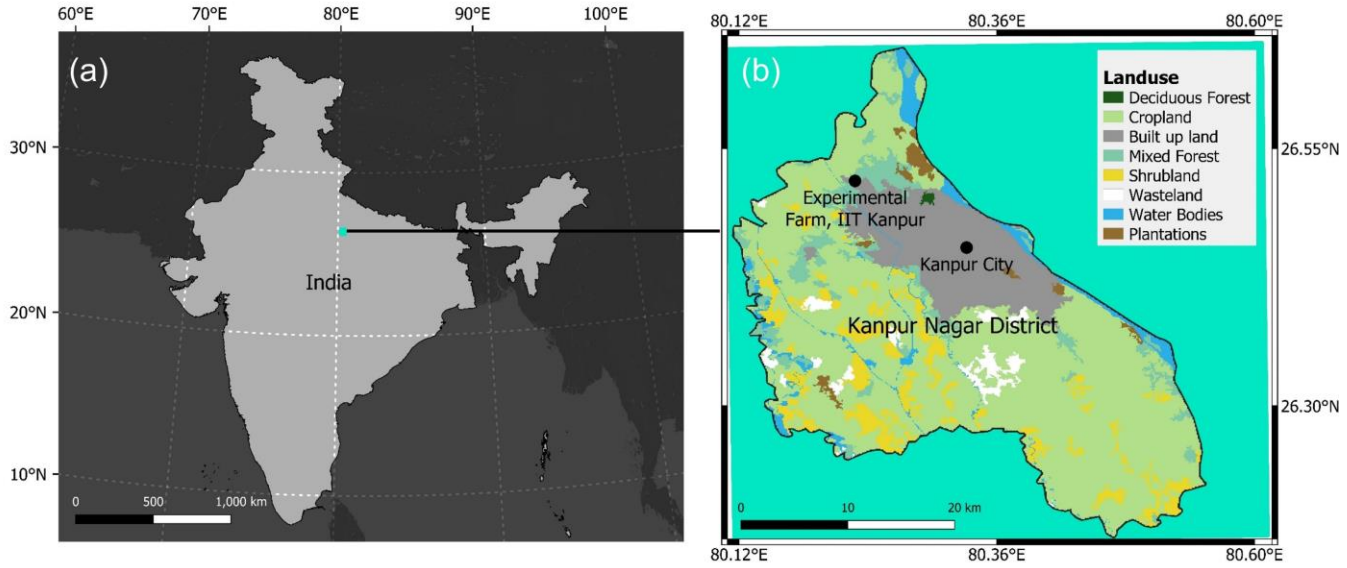
b

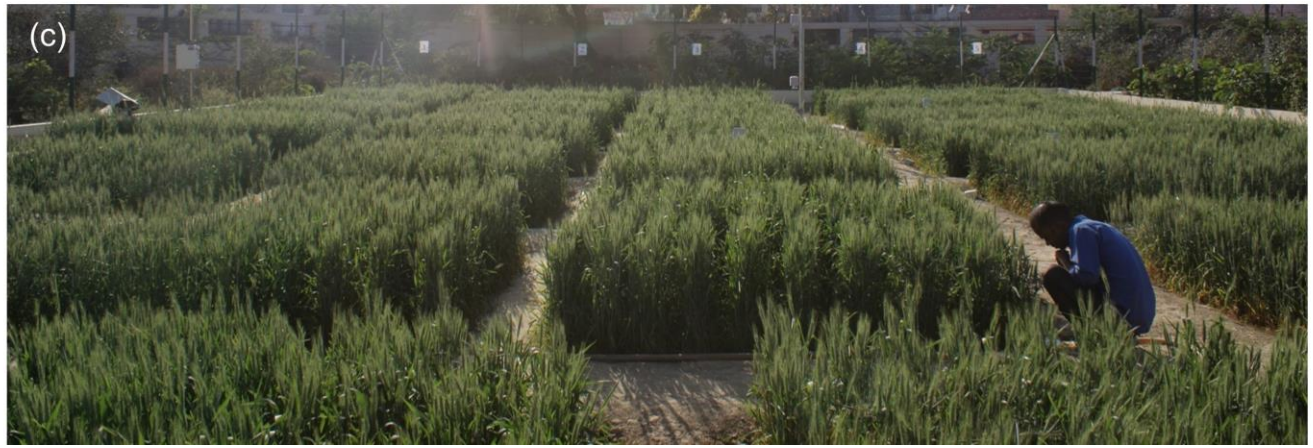


c

a) https://pin.it/7KB3DoRsd
b) https://wall.alphacoders.com/big.php?i=434080
c) https://pin.it/4uesano

Methodology





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Methodology

a

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a) https://pin.it/5FMqRtm

Methodology

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- Phenology (e.g., days to emergence, flowering, senescence)
- Initial canopy cover (CC_o)
- Canopy growth coefficient (CGC)
- Maximum canopy cover (CC_x)

- Irrigation application efficiency

- Saturated water content (θ_s)
- Water content at field capacity (θ_{FC})
- Water content at permanent wilting point (θ_{WP})
- Saturated hydraulic conductivity (K_{sat})

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Raes et al. (2018): https://www.fao.org/aquacrop/resources/referencemanuals/en/

Methodology

“Default”

SHP cal. using the literature[a-b]

“Raw” SHPs calibrated using **raw** LC sensor data

“Calibrated” SHPs calibrated using **calibrated** LC sensor data

Effect of calibrating Aquacrop’s soil hydraulic parameters (SHPs) using **raw** LC soil moisture data

Effect of calibrating Aquacrop’s soil hydraulic parameters (SHPs) using **calibrated** LC soil moisture data

a) Rawls and Brakensiek (1989): https://doi.org/10.1007/978-94-009-2352-2_10
b) Gupta et al. (2021): https://doi.org/10.5194/essd-13-1593-2021

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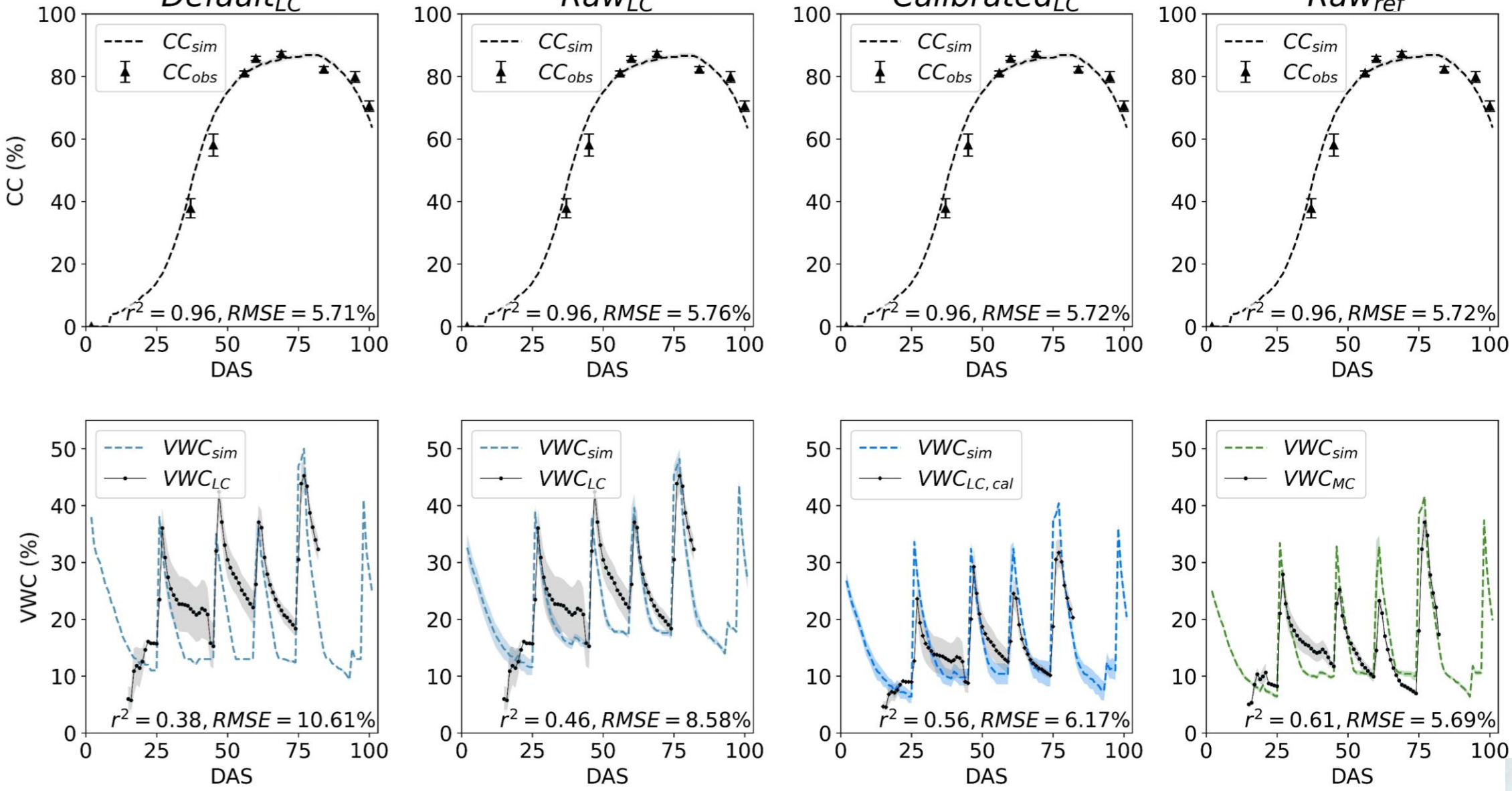
Results



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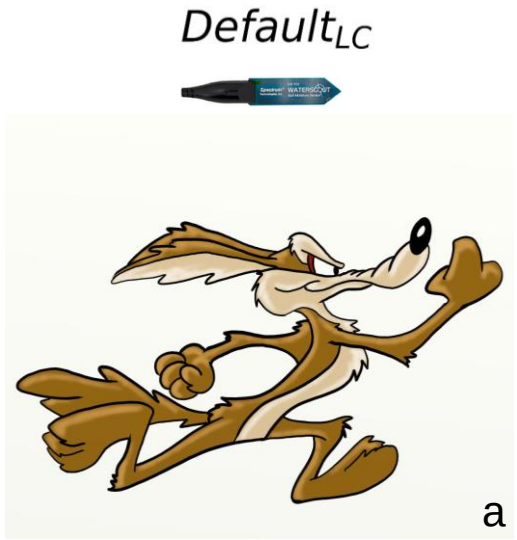
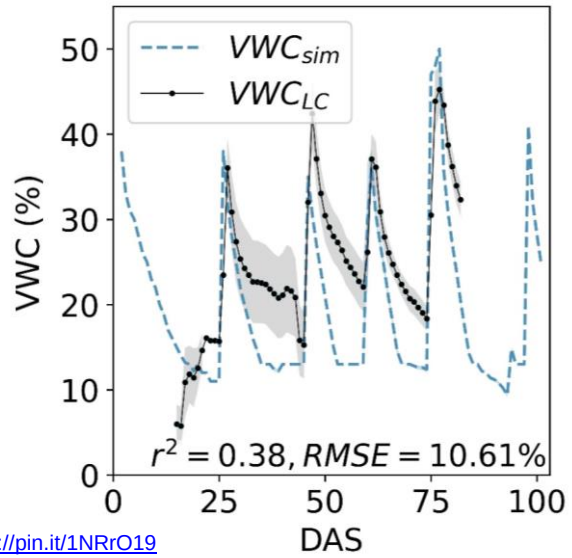
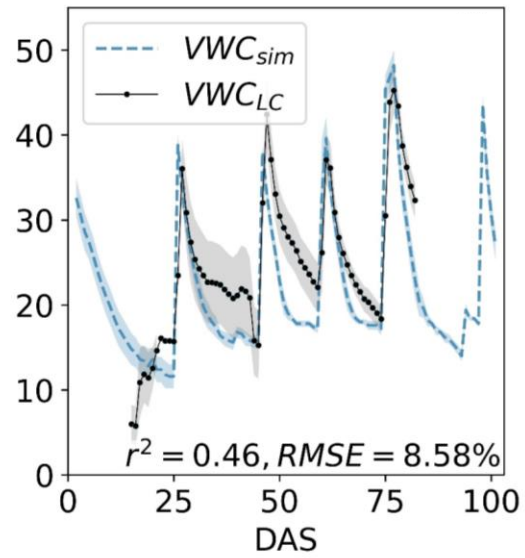
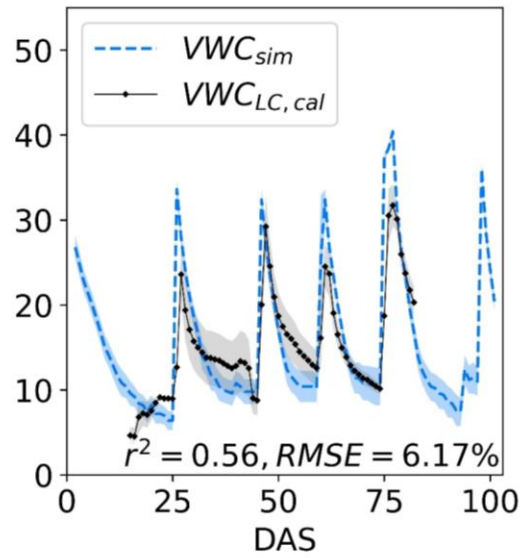
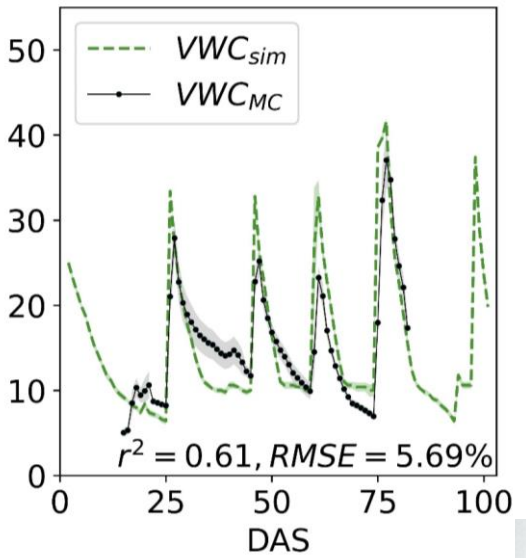
Results





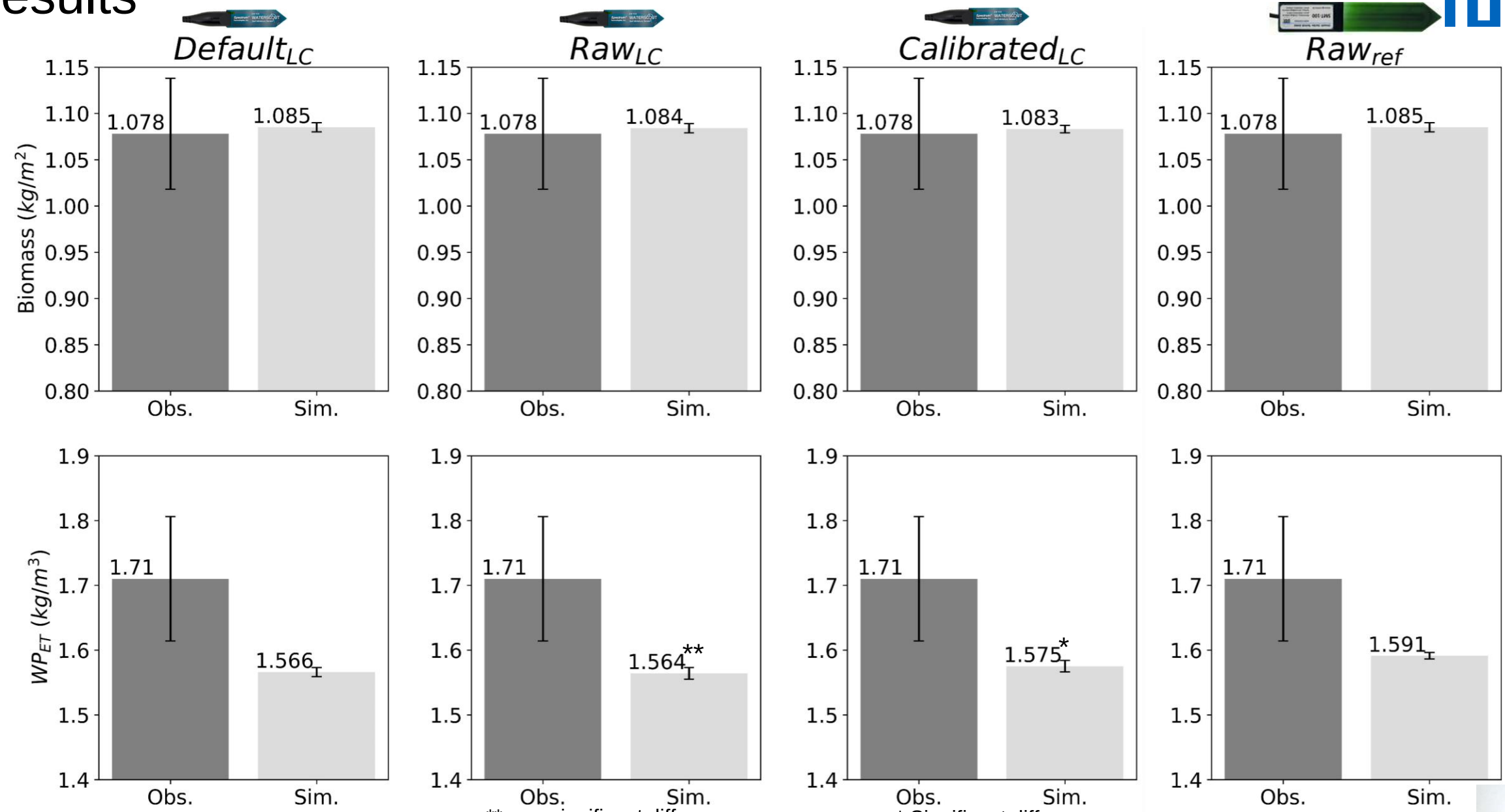




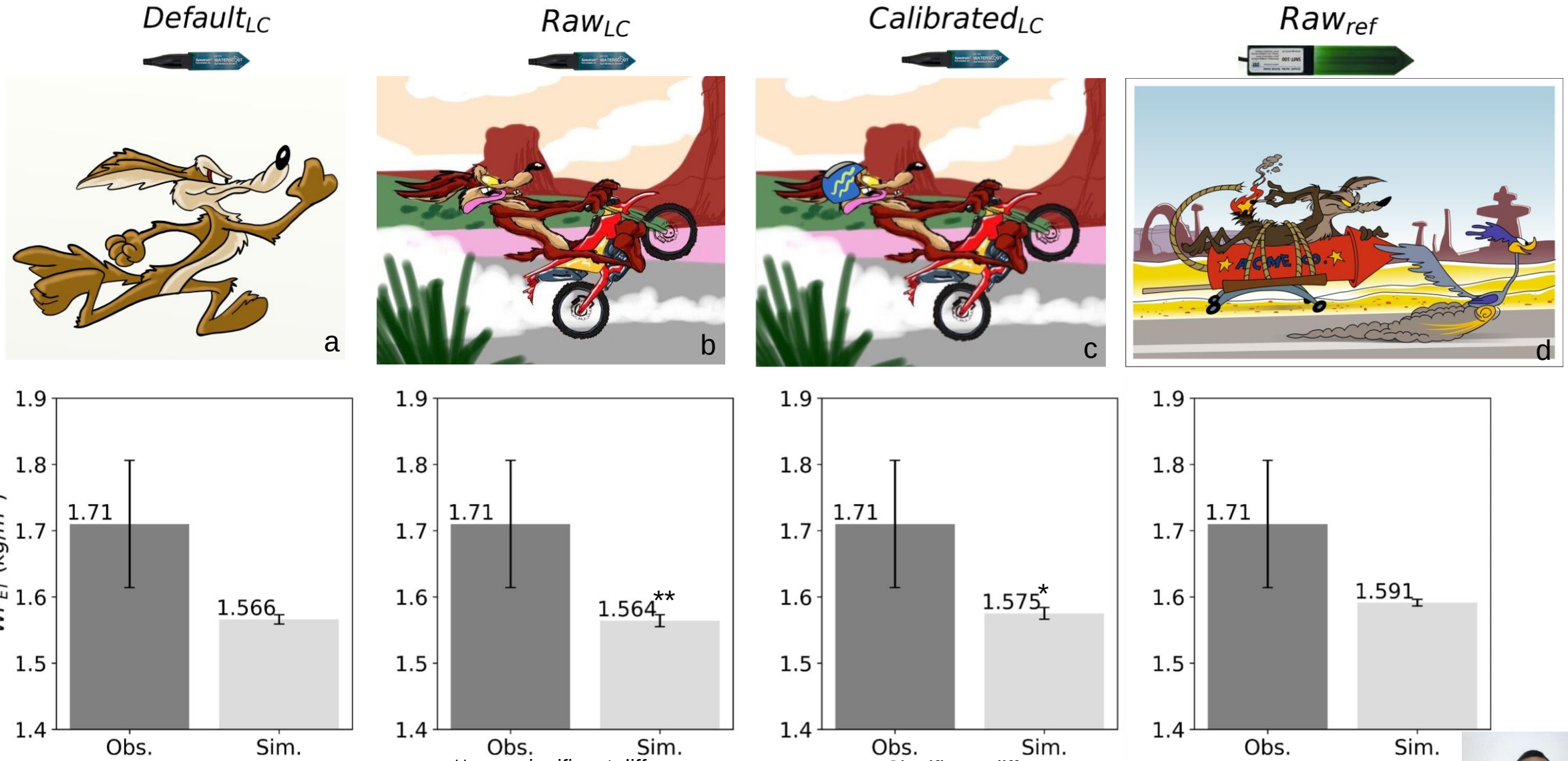


a) https://pin.it/1NRrO19
b) https://pin.it/5FMqRtm
c) Helmet artwork by Dr. Ashwini Bidnurmath
d) https://devan.codes/blog/2015/9/16/why-do-most-people-give-up-after-one-try-i-blame-wile-e-coyote

Results


Default$_{LC}$
Raw$_{LC}$
Calibrated$_{LC}$
Raw$_{ref}$
Biomass (kg/m^2)
WP_{ET} (kg/m^3)
1.078
1.085
1.084
1.083
1.71
1.566
1.564**
1.575*
1.591
Obs.
Sim.
** non-significant difference compared to Default$_{LC}$
* Significant difference compared to Default$_{LC}$

Results


Default$_{LC}$
Raw$_{LC}$
Calibrated$_{LC}$
Raw$_{ref}$
a
b
c
d
WP_{ET} (kg/m^3)
1.9
1.8
1.7
1.6
1.5
1.4
1.71
1.566
1.564**
1.575*
1.591
Obs.
Sim.
** non-significant difference compared to Default$_{LC}$
* Significant difference compared to Default$_{LC}$

Conclusion

LC_{raw}

+

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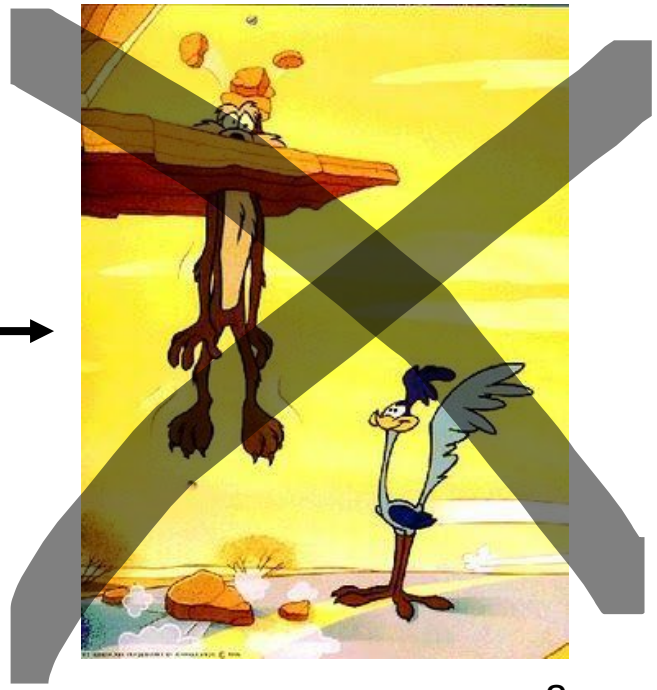

a

If you want to use the low-cost SM100 sensor with FAO Aquacrop and CAN'T calibrate it, don't use it.
Use soil hydraulic parameters from the literature and save instrument cost!

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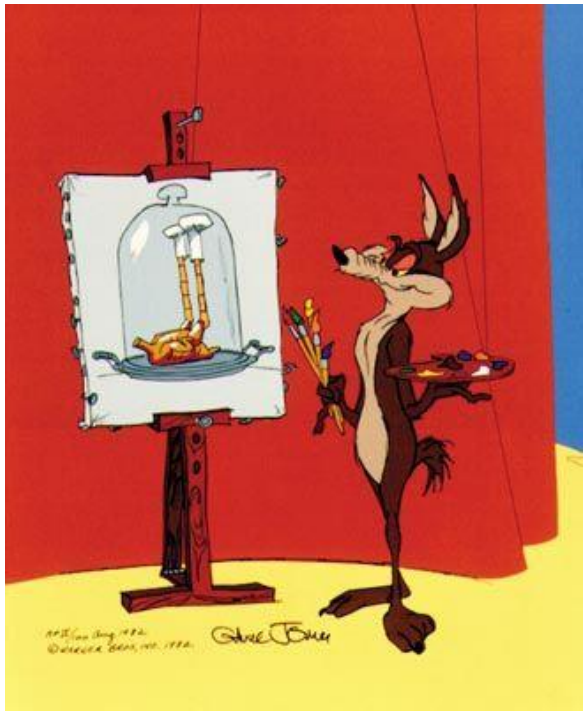
a) https://pin.it/1EmfdIC

Conclusion

LC_{cal}

+

AQUACROP-OS



If you can calibrate the low-cost soil moisture sensor,
the data and experiments from this study lead to improved simulations of soil moisture and WP_{ET}.

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