CASCA 2026
The First China-Australia Symposium on Crop Stress and Climate Adaptation

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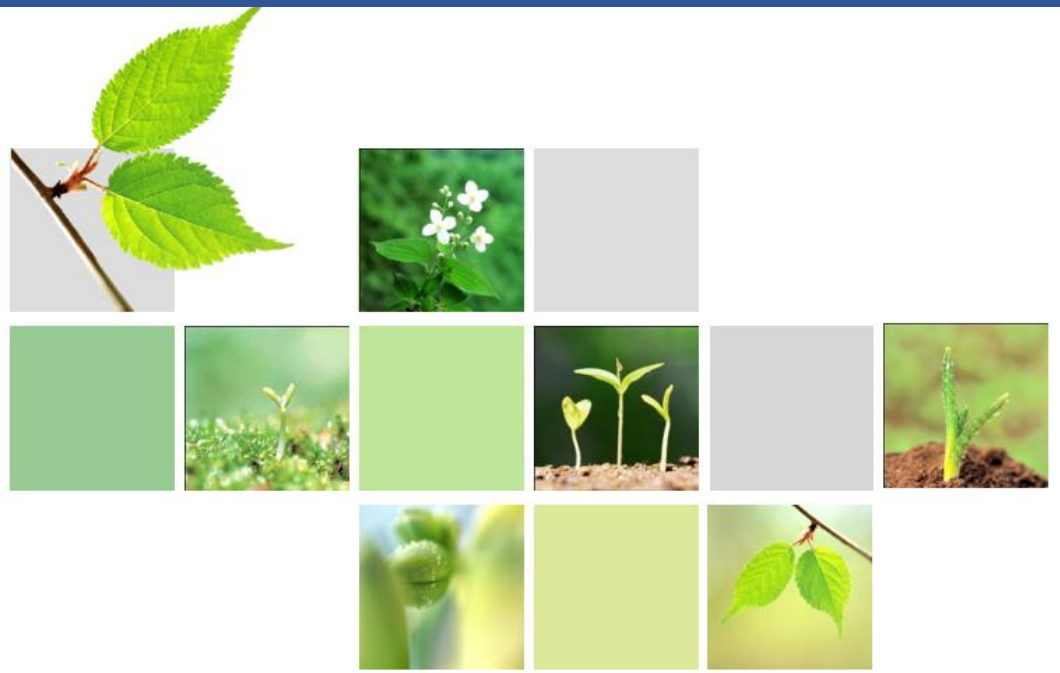
Improving APSIM Predictions under Waterlogging Stress through Physiological Mechanisms



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Prof. Matthew Harrison

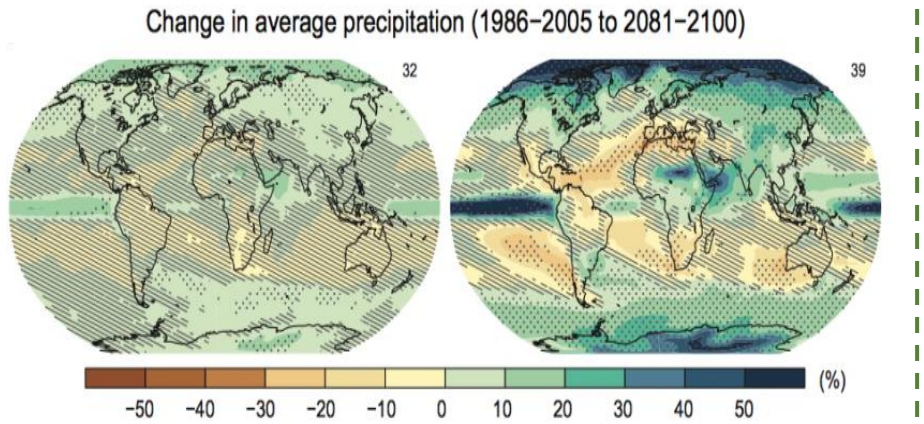
Prof. Meixue Zhou

13 March 2026 Launceston

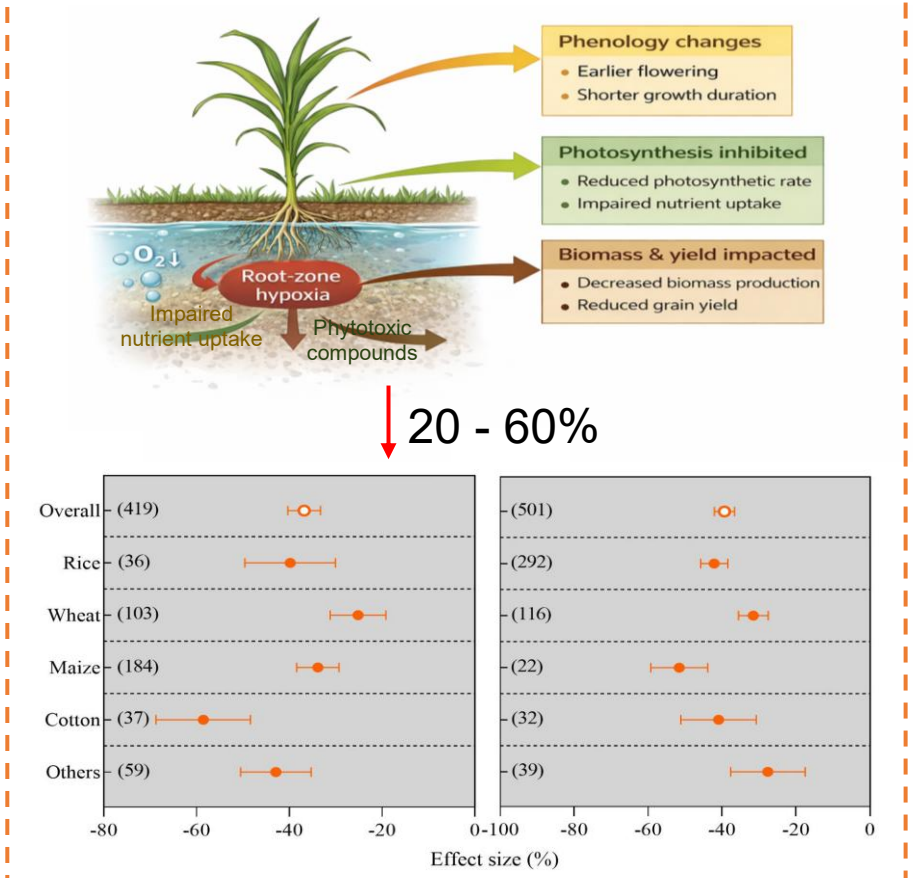
Background

- Extreme rainfall events are increasing under climate change, raising the risk of soil waterlogging and crop yield loss

Climate risk



Yield loss



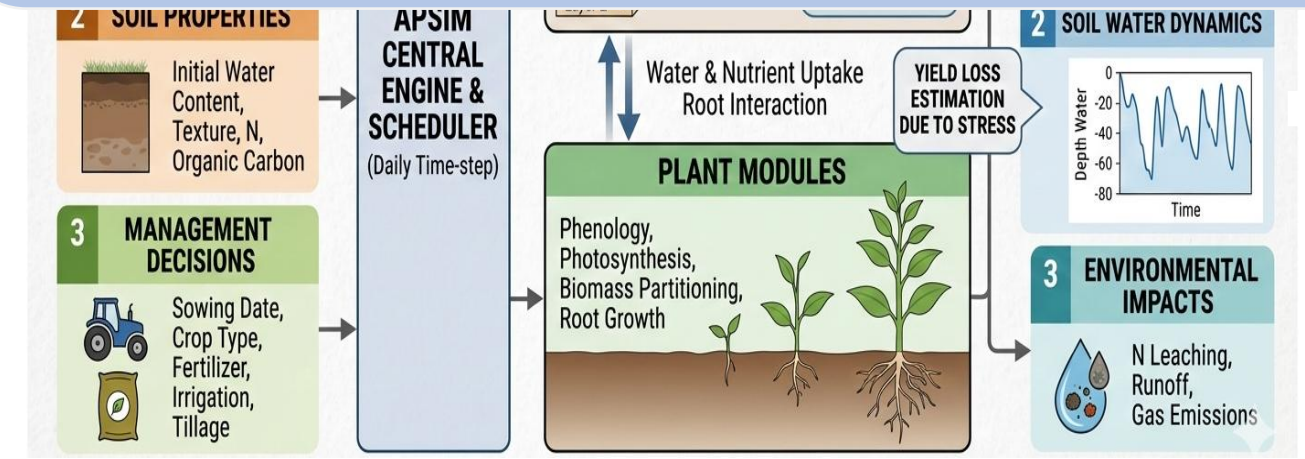
(Tian et al, 2021) (EPA, 2022) (Hossein Tabari, 2020)

Background

- Crop models are essential tools for evaluating agricultural adaptation strategies
- APSIM (Agricultural Production Systems Simulator) is a widely used process-based crop model integrating climate, soil and crop processes

Research gap:

How to identify and represent key waterlogging processes in crop models to improve predictive capacity?



- Missed interactions between soil hypoxia and plant growth
- Inaccurate yield prediction in extreme rainfall scenarios

Objectives

Field trial

1

- Identify key processes affected by waterlogging
- Quantify the physiological and yield responses of barley genotypes to waterlogging

Modelling

2

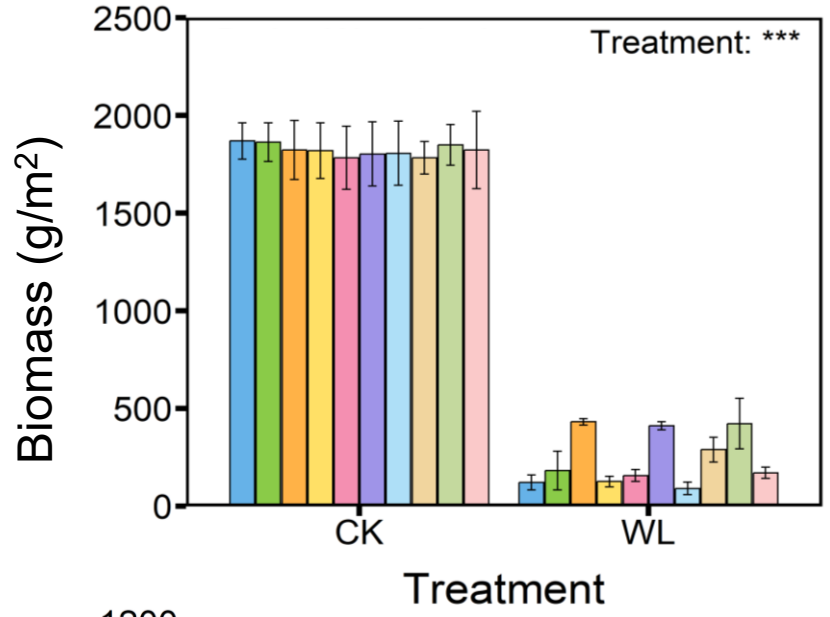
- Incorporate key waterlogging processes into APSIM
- Improve model performance in simulating biomass and yield under waterlogging stress

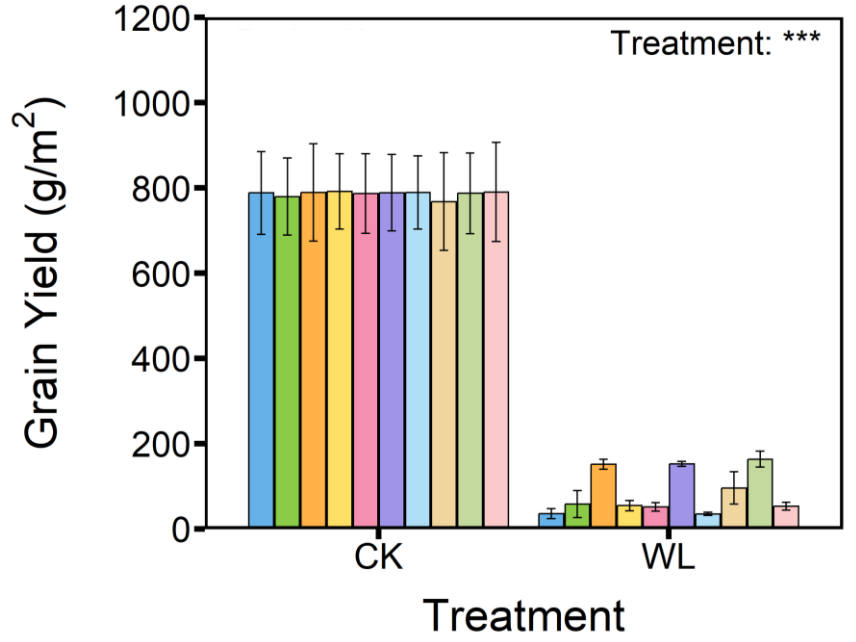
Experimental evidence of waterlogging effects

Part 1 : Field experiment

Experimental design

- **Location:** Mt Pleasant, Tasmania
- **Design:** 10 barley genotypes × 2 treatments (WL vs CK), 4 replicates (randomized block design)
- **Waterlogging stage:** three-leaf stage
- **Waterlogging period:** 28 May–31 Aug





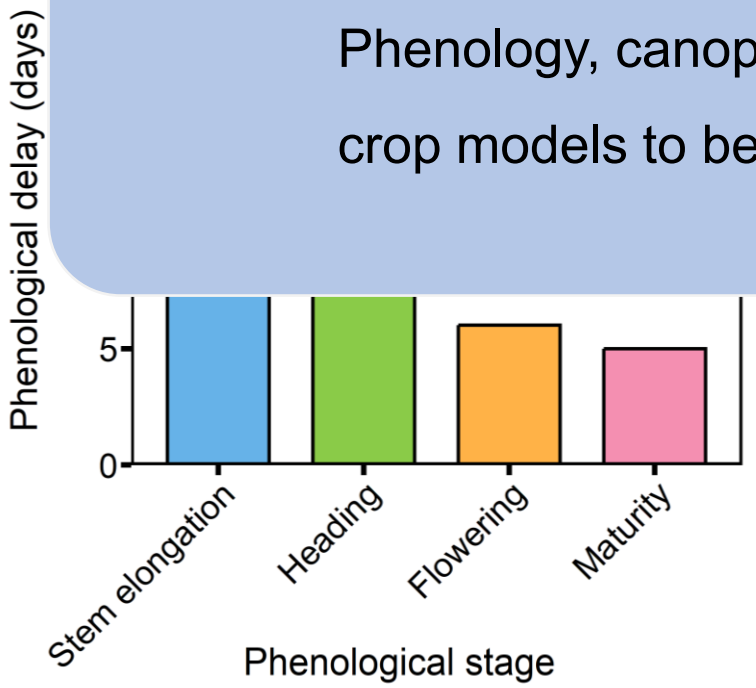
Experimental evidence of waterlogging effects

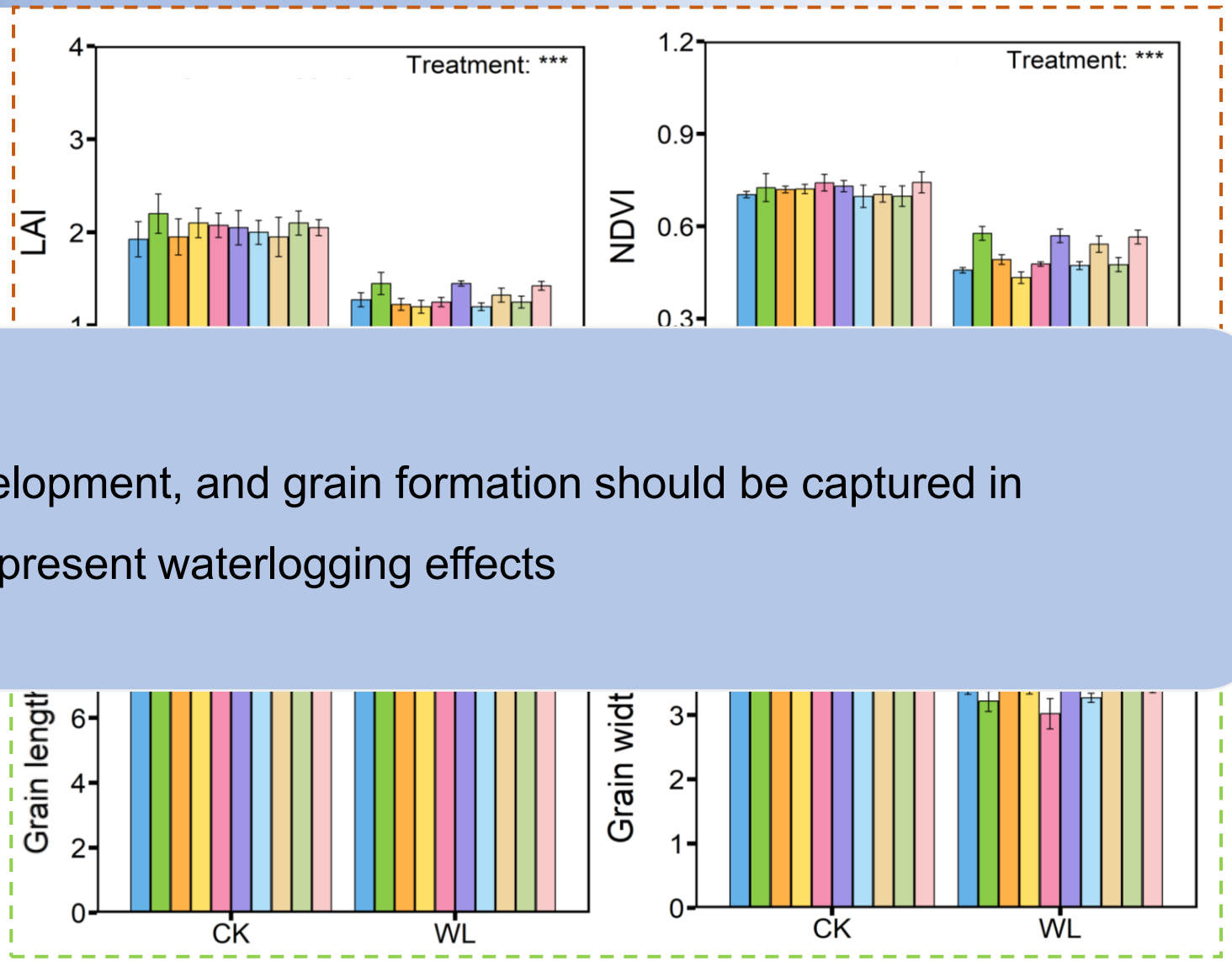
Field experiment

- Delayed phenological development
- Reduced Canopy development
- Re

Summary:

Phenology, canopy development, and grain formation should be captured in crop models to better represent waterlogging effects



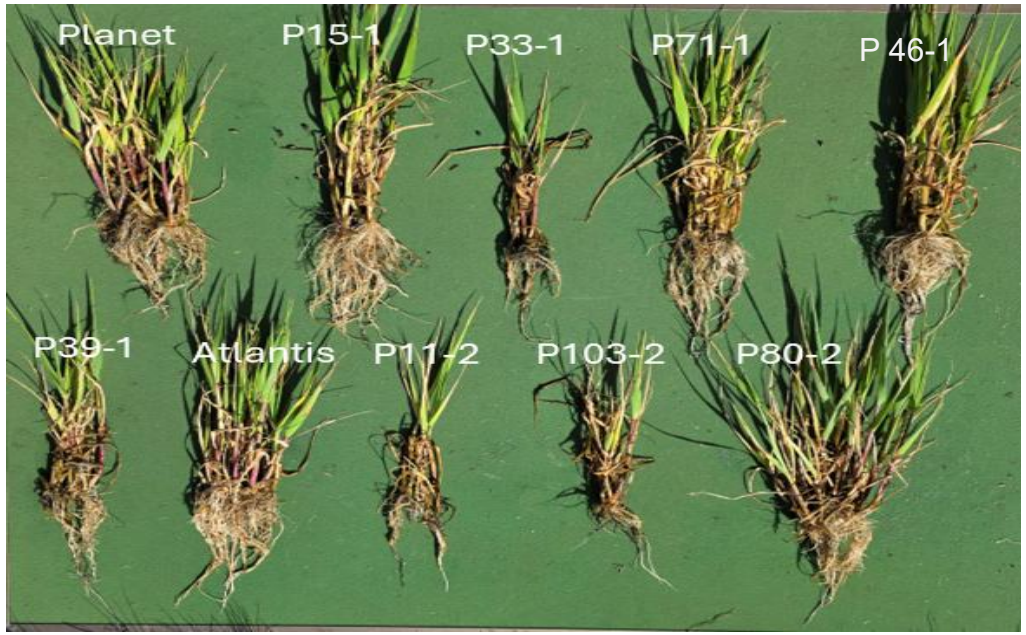


The definition of soil waterlogging in APSIMX - *Wet root fraction*

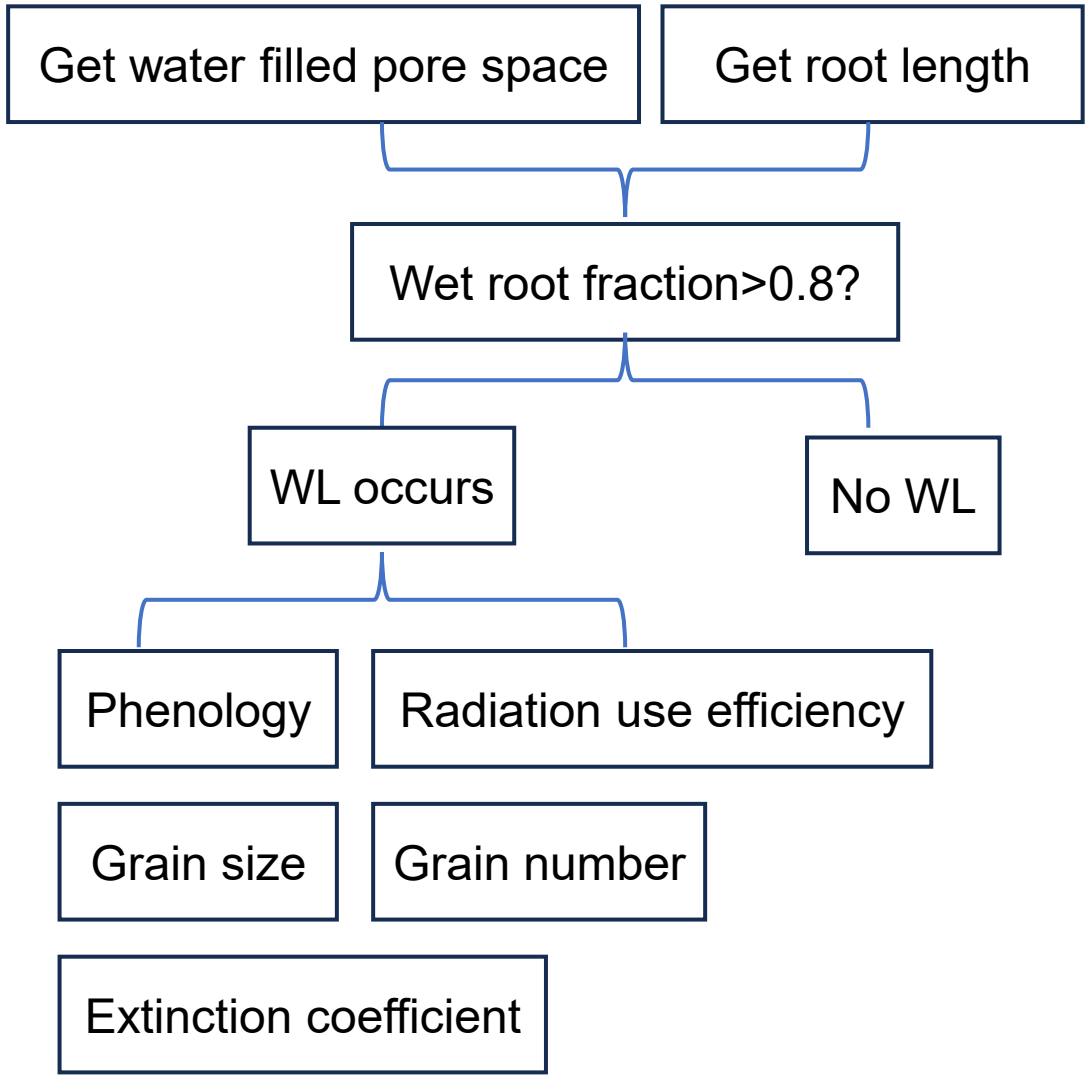
$$Wet\ root\ fraction = \sum_{i=1}^{n}\left(\frac{WFPS_i \times root\ length_i}{\sum_{j-1}^{n} root\ length_j}\right) \quad \text{(Eq.1)}$$

$$WFPS = \frac{(SW-DUL)}{(SAT-DUL)} \times 100\% \quad \text{(Eq.2)}$$

- Wet root fraction (0–1):
- Stress triggered at wet root fraction > 0.8



(Holzworth et al., 2018)

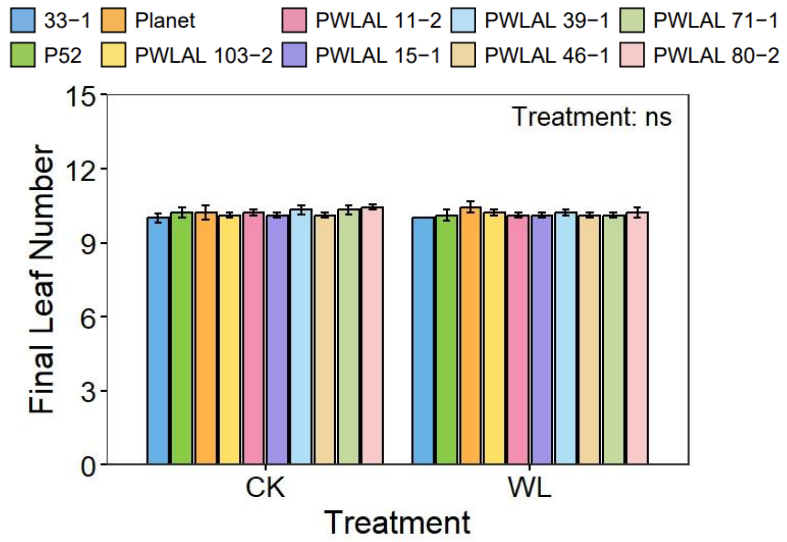


Phenology modification - *Phyllochron*

- In APSIM, flowering timing depends on final leaf number (FLN) and leaf appearance rate (phyllochron)
- Waterlogging does not change final leaf number
- Phyllochron is the thermal time between the appearance of successive leaves

$$\text{Phyllochron} = \text{Leaf stage factor} \times \text{Base Phyllochron} \times \text{Photoperiod Effect} \quad \text{(Eq.3)}$$

$$\text{BP} = \begin{cases} \text{BP} * FOXphyllo & 0.8 < \text{wet root fraction} \leq 1 (\text{ between emergence to flowering}) \\ \text{BP} & \textit{wet} \text{ root fraction} \leq 0.8 \end{cases} \quad \text{(Eq.4)}$$



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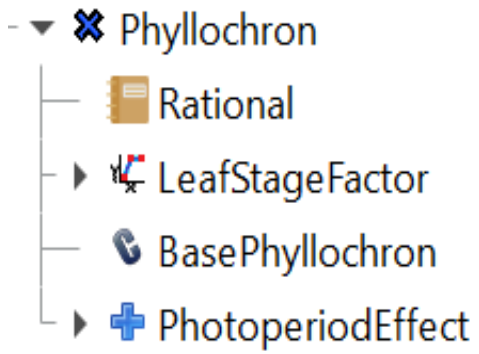

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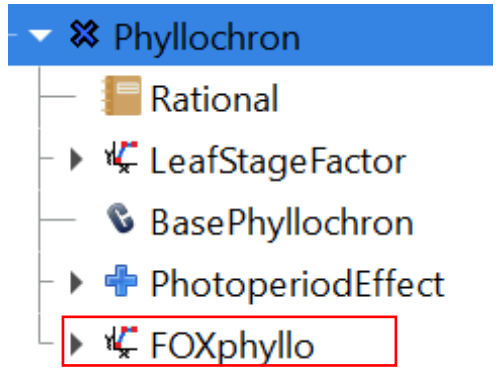


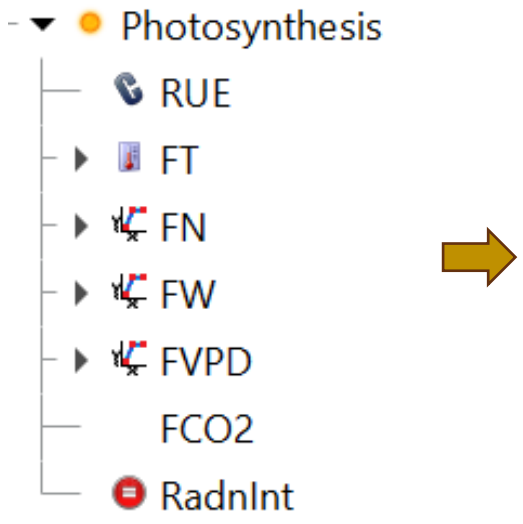
Radiation use efficiency modification - *FOX*

- Default APSIM does not explicitly represent waterlogging effects on RUE
- A waterlogging stress factor (FOX) was introduced to reduce RUE

$$\text{RueReductionFactor} = \min(\text{FT}, \text{FN}, \text{FVPD}) \times \boxed{\text{FW}} \times \text{F}CO_2 \quad \text{(Eq.5)}$$

$$\text{RueReductionFactor} = \min(\text{FT}, \text{FN}, \text{FVPD}) \times \boxed{\min(\text{FW}, \text{FOX})} \times \text{F}CO_2 \quad \text{(Eq.6)}$$

Default



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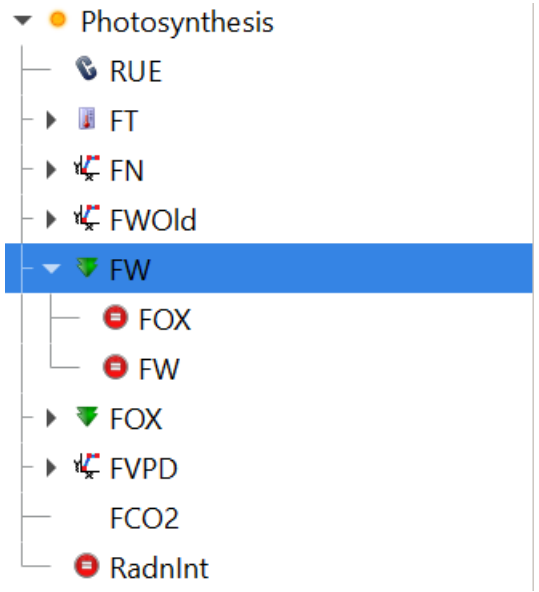
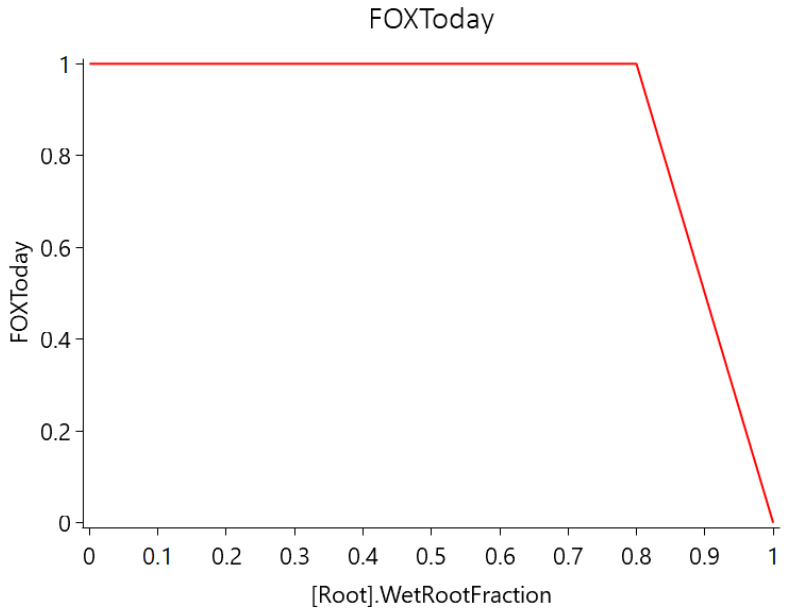
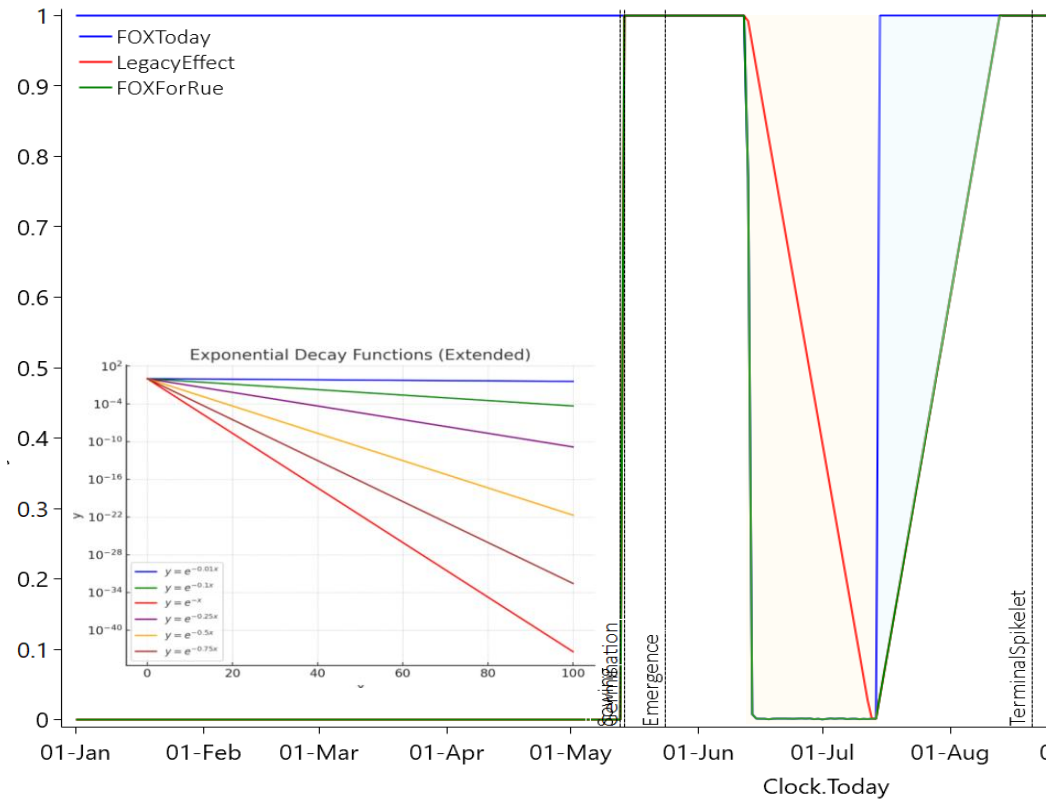
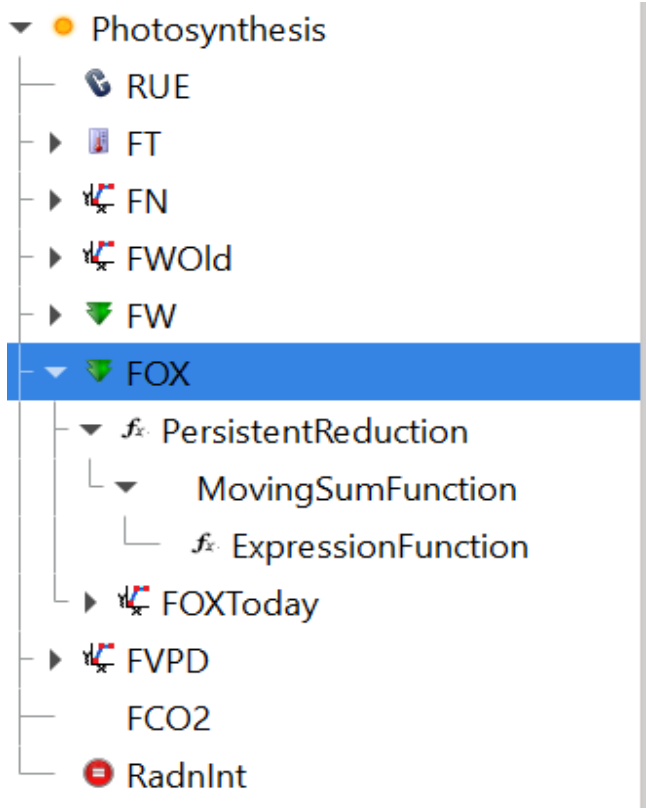




Radiation use efficiency modification – *FOX legacy effect*

- The negative impact of WL extended beyond the WL period
- Persistent reduction implemented using exponential decay and moving accumulation
- The final FOX value is derived by taking the minimum of PersistentReduction and FOXToday





PersistentReduction:
This uses Y = exp (-0.01x) to calculate a reduction factor.

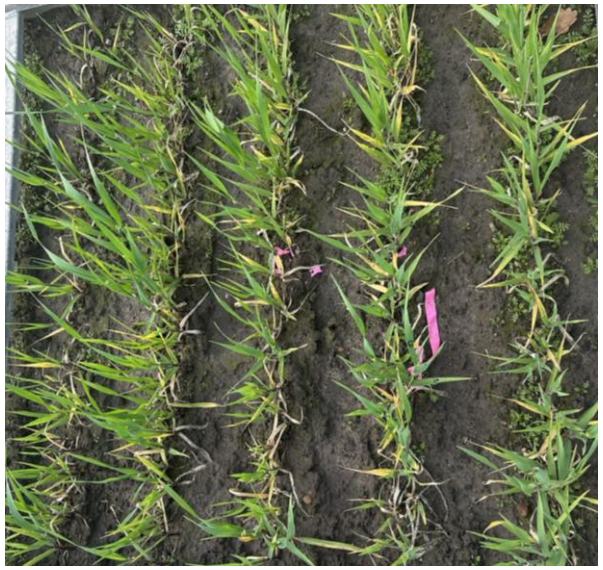
Moving Sum Function:
This function accumulates values over a moving sum of 30 days. It relies on the **ExpressionFunction**, which is calculated as:

1-[Photosynthesis].FOX.FOXToday

FOXToday: This value is determined through linear interpolation based on an XY matrix.

Extinction coefficient modification

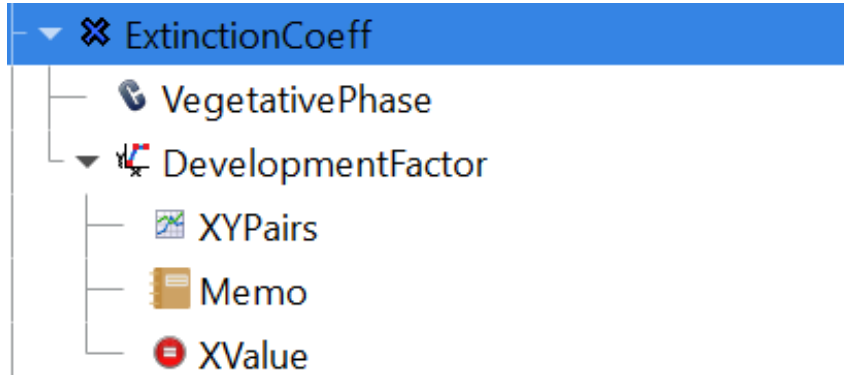
- Waterlogging reduced canopy density, requiring adjustment of the extinction coefficient in the model



two months waterlogging

control

Default



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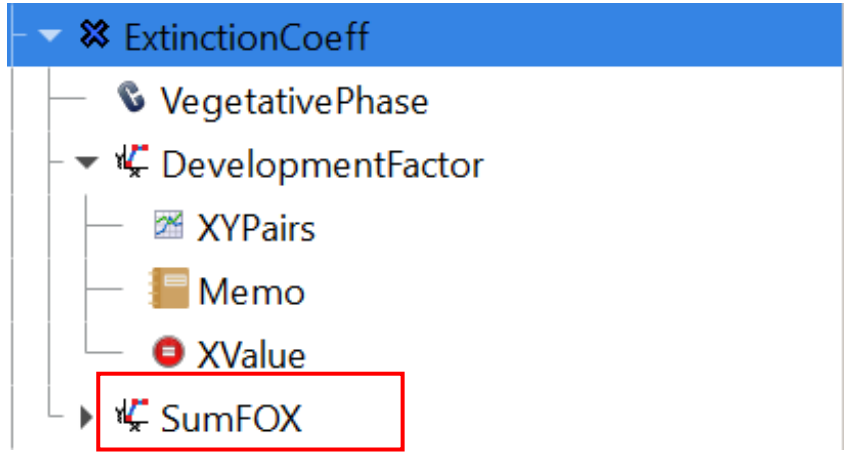
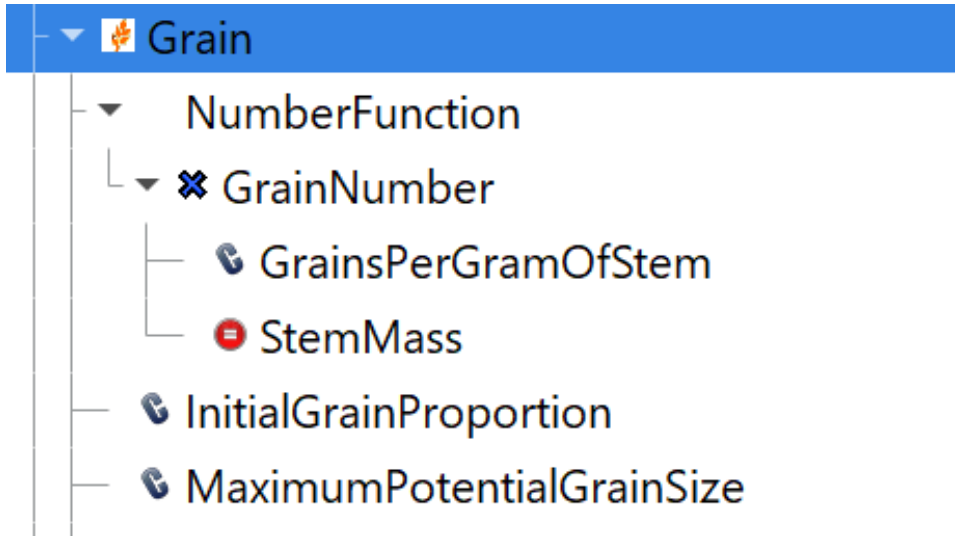
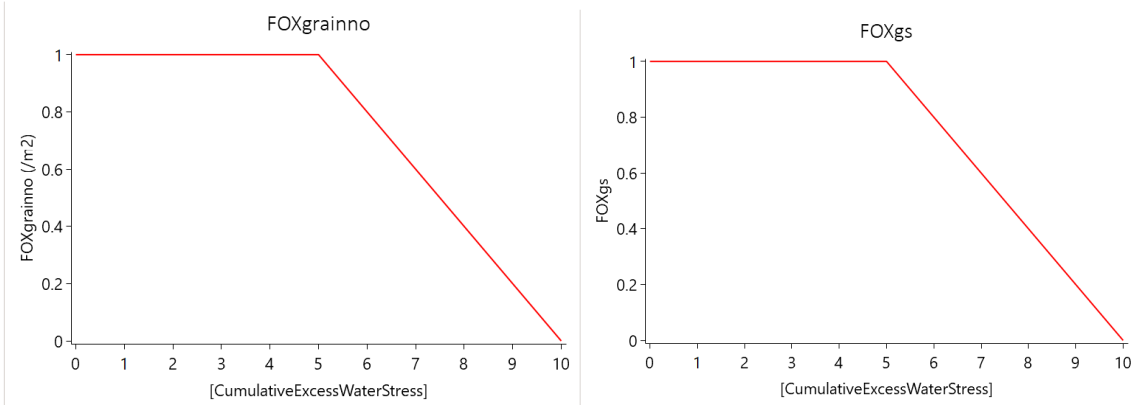


Grain number and grain size modification

- SumFOX dynamically adjusted grain number and maximum grain size

Default





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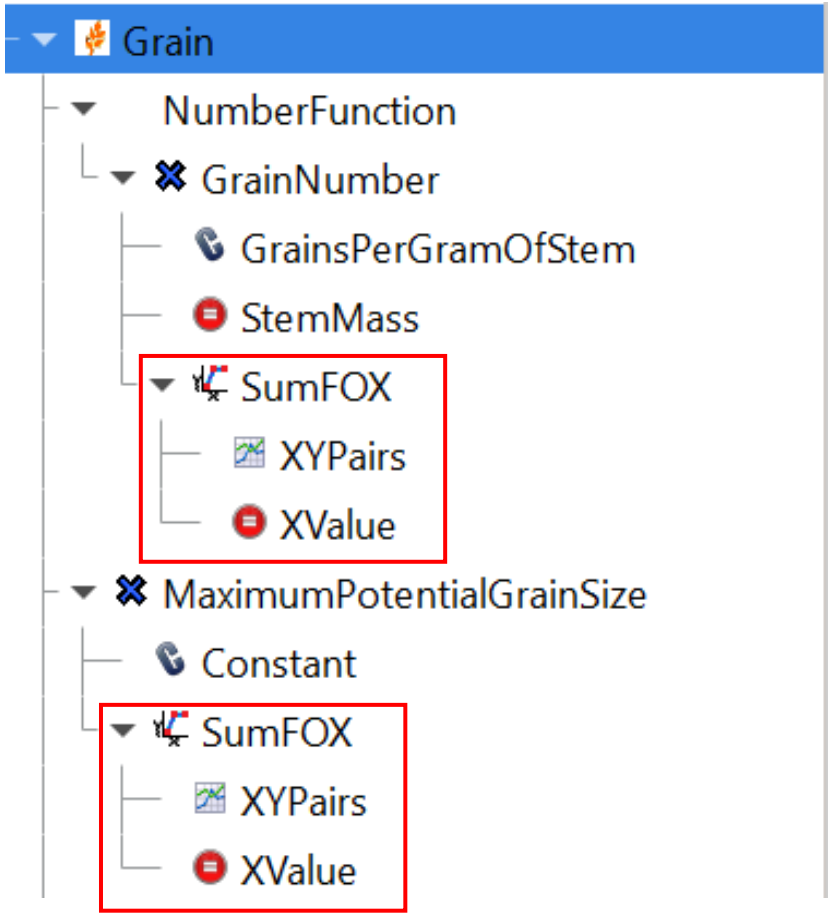


Validation of the improved model

Validation dataset：

Ploschuk et al., 2021, *J. Agron. Crop Sci.*

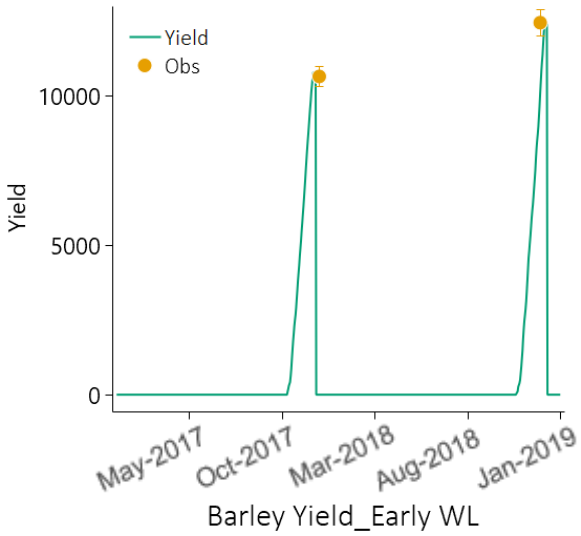
Measured:

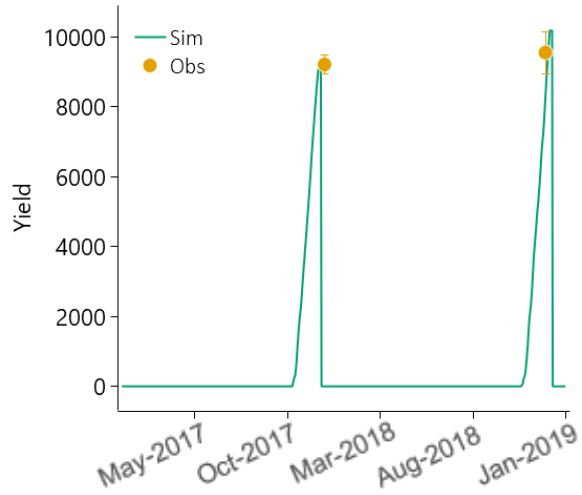
- Climate conditions
- Waterlogging timing and duration
- LAI, biomass, grain number and yield

Treatments:

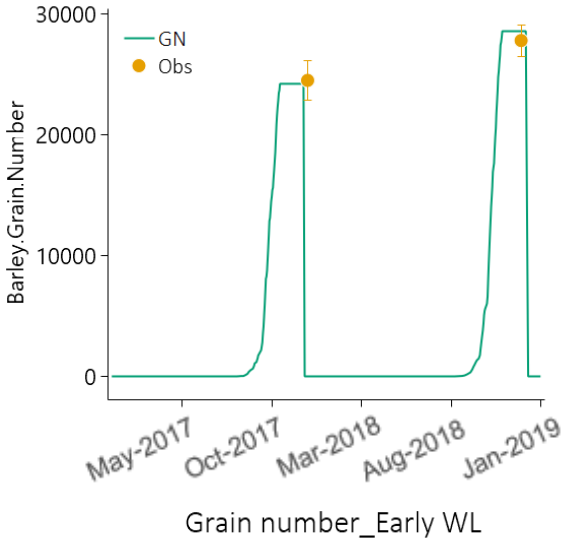
- Control – well-drained conditions
- Early waterlogging – vegetative stage
- Late waterlogging – reproductive stage

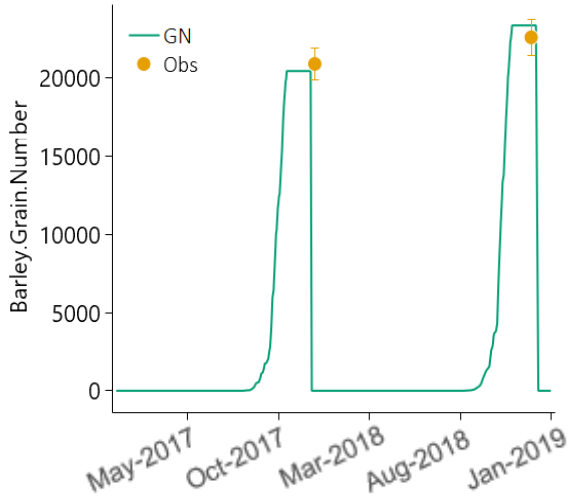
➢ **Grain yield**





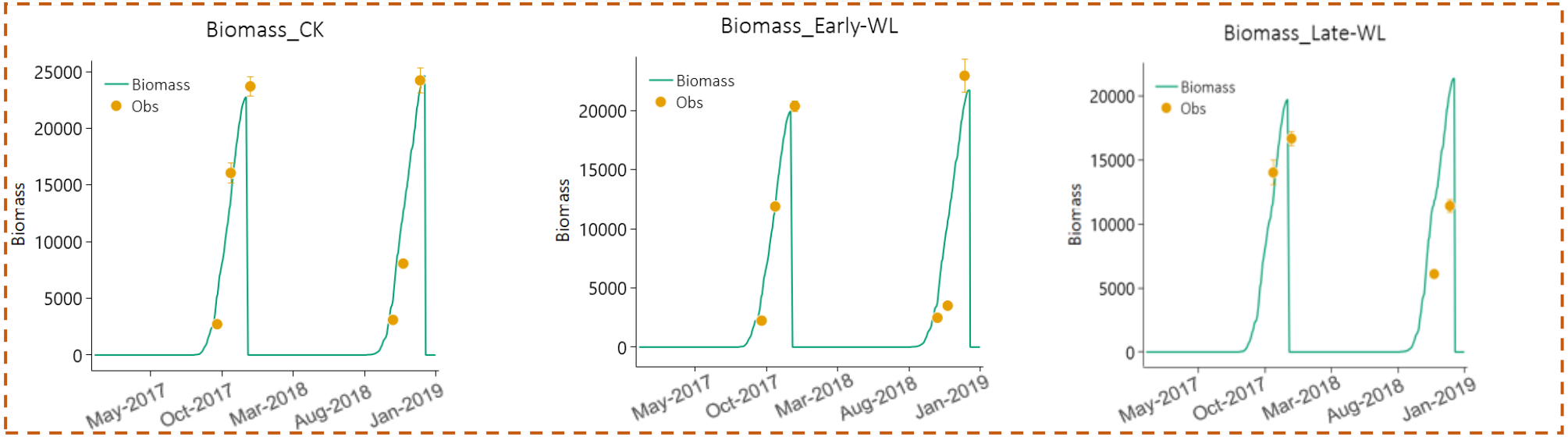
➢ **Grain number**



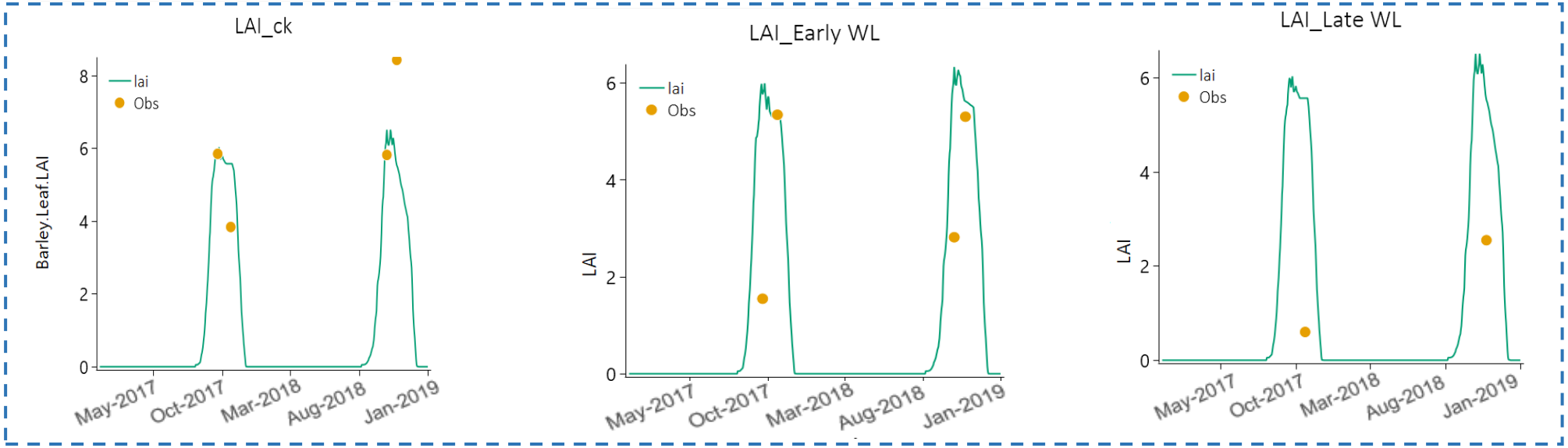


Validation of the improved model

➢ Biomass



➢ LAI



Implications and future applications

Future risk

02

Integration with future climate projections to evaluate long-term resilience

Scaling up

Transferable framework for other crops

01

Decision Support

03

Enabling mitigation strategies and precise quantification of yield and economic loss

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Thanks for your attention

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