TEKNOLOGISK INSTITUT

Crop Simulation Models in Field Trials

Svend Vendelbo Nielsen,

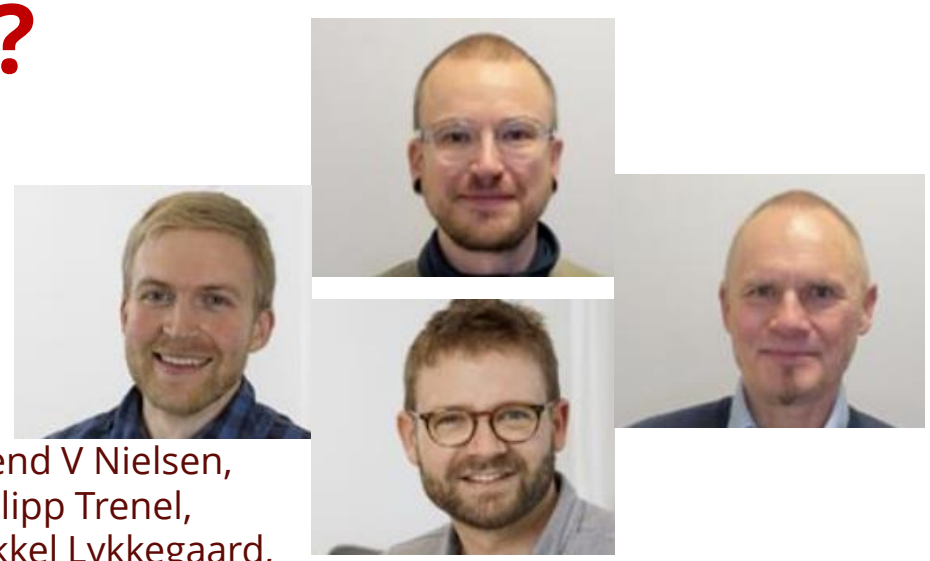
04-03-2025

Outline

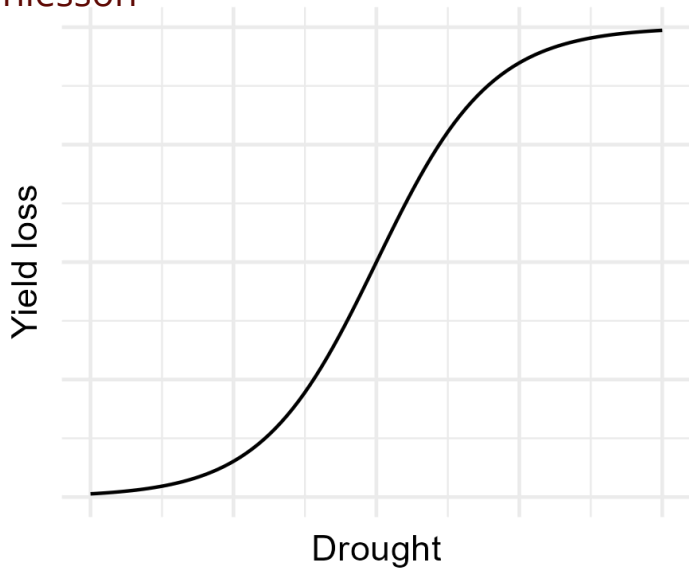
- Who are we?
- Sales-pitch
- What is a crop simulation model?
- Why use crop simulation models?

Who are we?

- In the Agriculture and Digitalization centre of Danish Technological Institute, we have a data modeling team
- We oversee the analyses of hundreds of field trials every year and make the statistics in Nordic Field Trial System.
- In our research projects, crop simulation are used to
  - Predict yield in future climate
  - Explain nitrous oxide emission
- Crop simulation models can be used in field trials as well!



Svend V Nielsen, Philipp Trenel, Mikkel Lykkegaard, Bo Thiesson

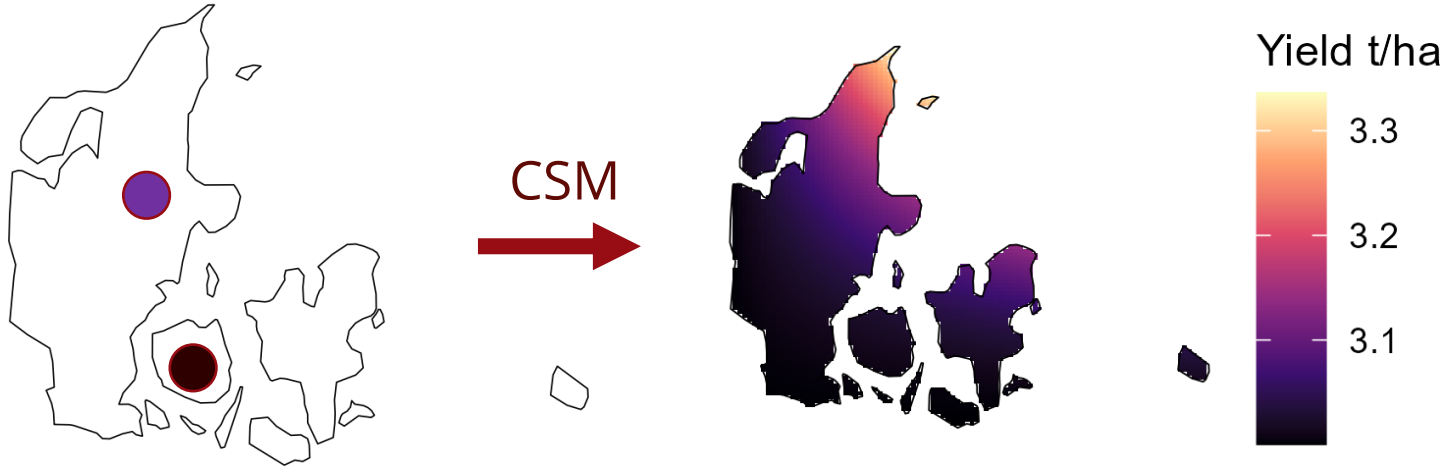


Sales-pitch for Crop Simulation Models (CSM)

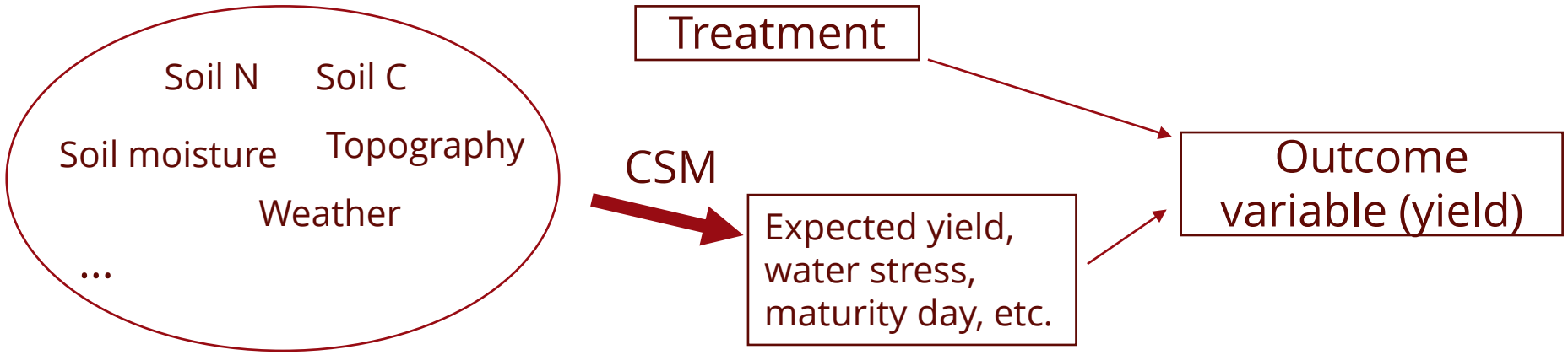
Extrapolate results*:

2024	2025	2026
3.2 t/ha	3.5 t/ha	2.8 t/ha

CSM

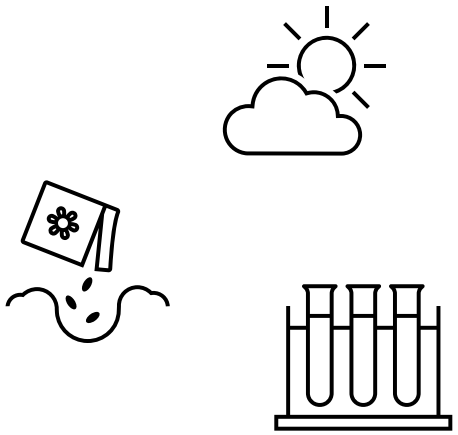


Better usage of sensors:



***Hypothetical numbers**

What is a crop simulation model?



Daily weather for the full growing season,
Soil sample data,
Planting days,
Irrigation,
Fertilization

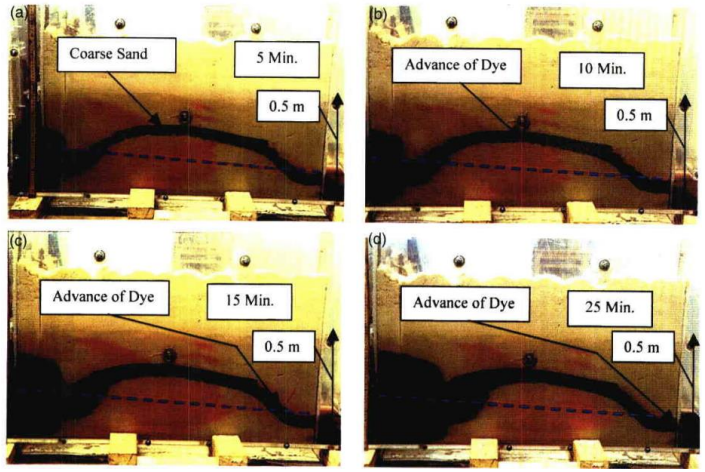
Yield parameters,
Maturity day,
...

What is a crop simulation model?

- Most crop simulation models compute the daily growth of each plant component:

$$\text{Growth of grain during one day} = \begin{cases} 0 & \text{if crop has not reached grain filling stage} \\ f(\text{leaf area, available water, temperature, nutrients, } \ldots) & \\ 0 & \text{if crop is no longer in grain filling stage} \end{cases}$$

- The formulas come from experiments rather than inferred from big data:



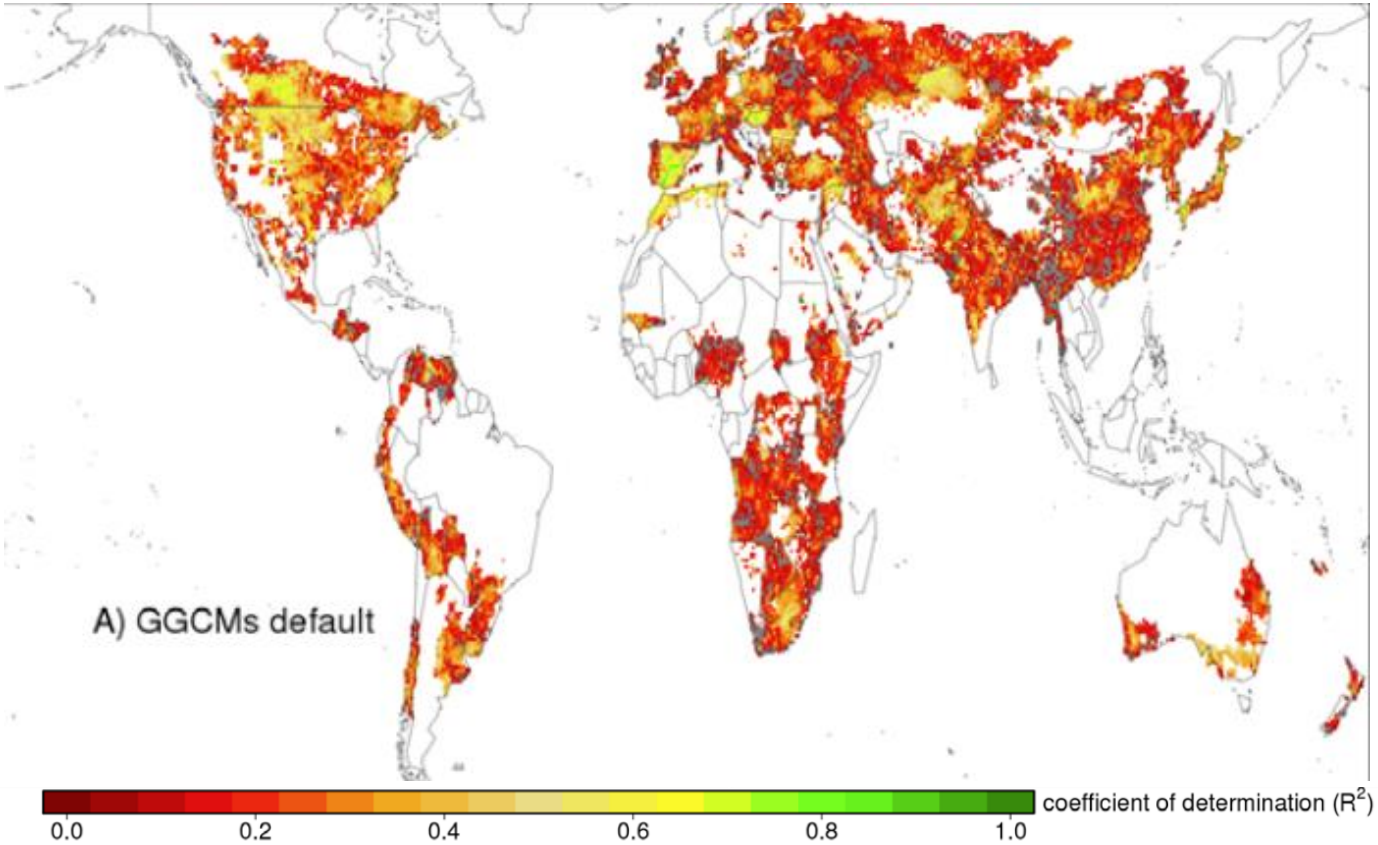
→ $$\theta(\psi) = \theta_r + \frac{\theta_s - \theta_r}{[1 + (\alpha|\psi|)^n]^{1-1/n}}$$ →

Crop Simulation Model

Silliman SE, Berkowitz B, Simunek J, van Genuchten MT. Fluid flow and solute migration within the capillary fringe. Ground Water. 2002 Jan-Feb;40(1):76-84. doi: 10.1111/j.1745-6584.2002.tb02493.x. PMID: 11803946.

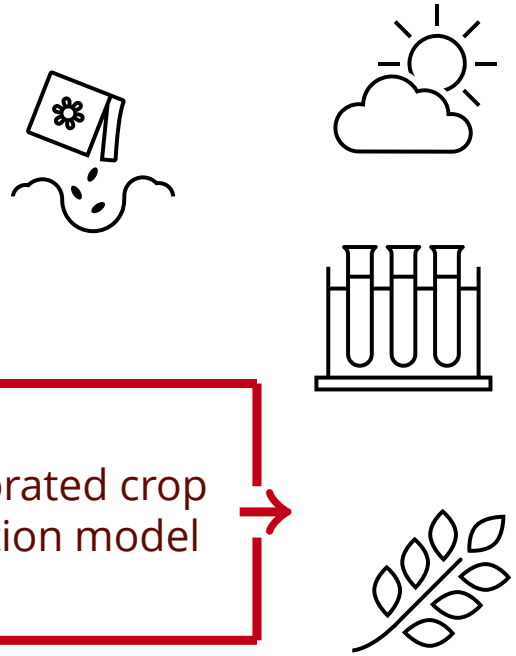
How good are crop simulation models?

- The models are better than randomly guessing the between-year variation, but not much better (Müller et al. 2017), because:
  - Difficult to get site-specific data
  - The computations are **not calibrated** to their specific area



Müller, Christoph, et al. "Global gridded crop model evaluation: benchmarking, skills, deficiencies and implications." *Geoscientific Model Development* 10.4 (2017): 1403-1422.

Calibrated crop simulation models



Uncalibrated crop simulation model

Calibration procedure

Calibrated crop simulation model

Daily weather,
Soil sample data,
Planting days,
Irrigation,
Fertilization,
Yield data

CERES calibrated wheat model

Days required to vernalization=5
Photoperiod response (%redu./10h)=75
Grain phase duration (Tdays)=450
Kernel number per canopy weight=30
Kernel weight(mg)=35
Standard tiller weight=1
Tdays between leaf appearances=60
Duration phase 1=200
Duration phase 2=200
Duration phase 3=15
....
Minimum grain N=0

Days required to vernalization=9.3
Photoperiod response (%redu./10h)=13.2
Grain phase duration (Tdays)=331.4
Kernel number per canopy weight=12.11
Kernel weight(mg)=63.48
Standard tiller weight=2.2
Tdays between leaf appearances=86
Duration phase 1=362
Duration phase 2=258
Duration phase 3=13
....
Minimum grain N=2

Calibrated model results

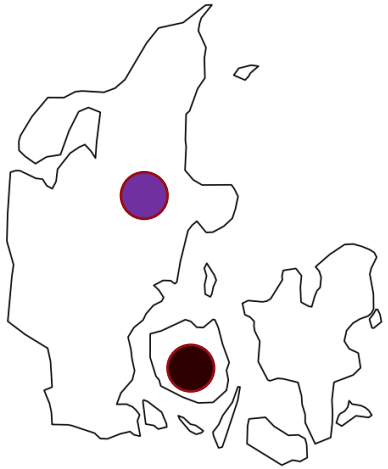
- There have been very high accuracy for well-calibrated crop simulation models, when predicting between-variety yields (Mukhtar, et al. 2016).
  - One field trial repeated 3 years,
  - Wheat, APSIM and CERES models,
  - **R^2=0.85**

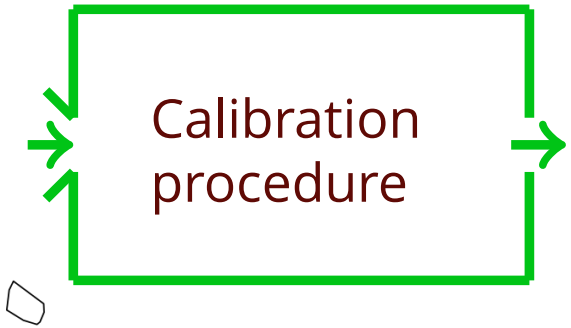
2009	2010	2011
Calibration data	Test data	Test data

Ahmed, Mukhtar, et al. "Calibration and validation of APSIM-Wheat and CERES-Wheat for spring wheat under rainfed conditions: Models evaluation and application." *Computers and Electronics in Agriculture* 123 (2016): 384-401.

Use for field trials

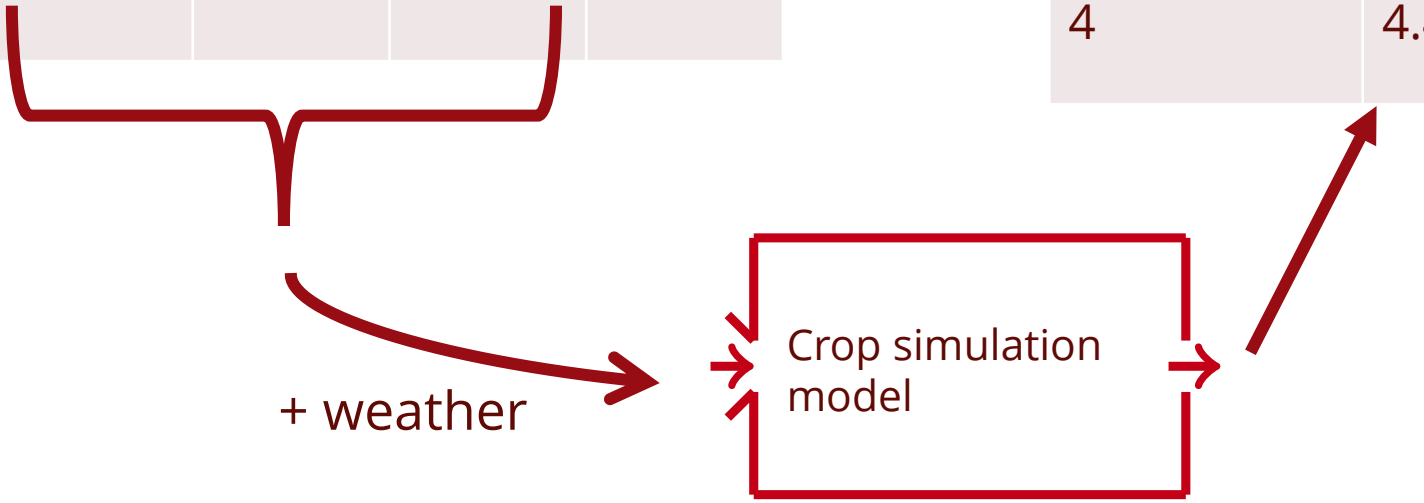
- It is possible to calibrate a crop simulation model to one or more field trials, and then predict yields in related situations.
- One can explore different locations, different weather, different sowing dates, different fertilization schemes, etc.





Use Crop simulation model (CSM) to make better analysis

Treat-ment	Mois-ture	Clay %	SOM %	Yield
1	40	6	2.5	4.5
1	45	6.5	2.5	4.2
…				
4	32	8	2	5.5

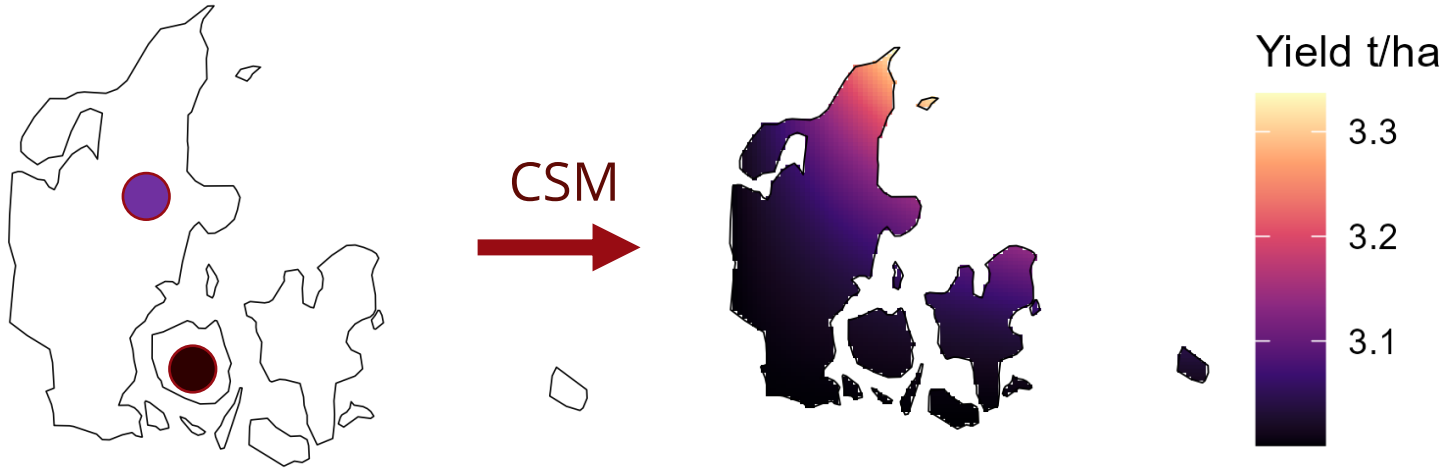


Treatment	CSM-simulated yield	Yield
1	4.4	4.5
1	4.0	4.2
…		
4	4.4	5.5

Conclusion

- Crop Simulation models work best when the data quality is high, and it has been calibrated to a similar system.
- They have potential to improve the analysis of field trials and extrapolate field trial results
- I hope to find valuable uses for these methods in field trials.

Treatment	CSM-estimated yield	Yield
1	4.4	4.5
1	4.0	4.2
…		
4	4.4	5.5

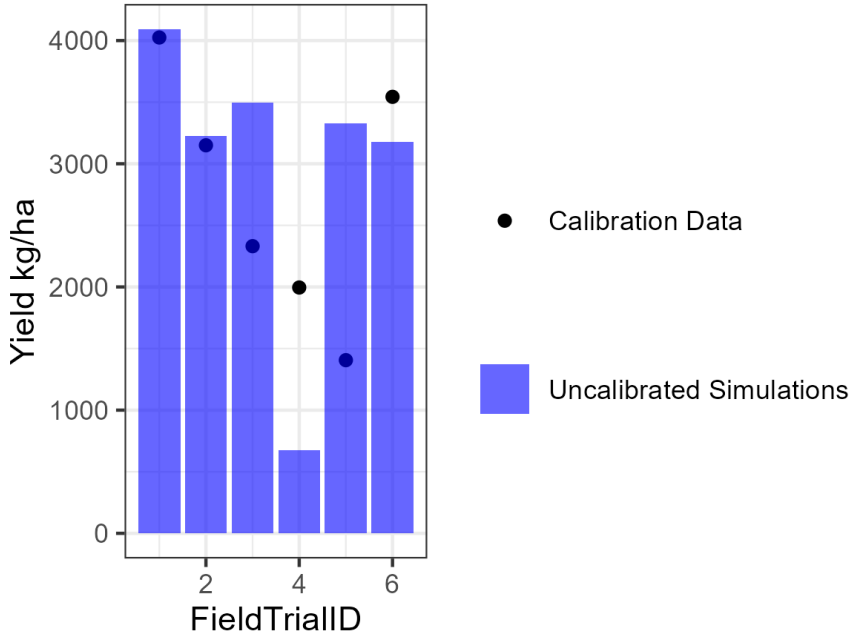


Thank you

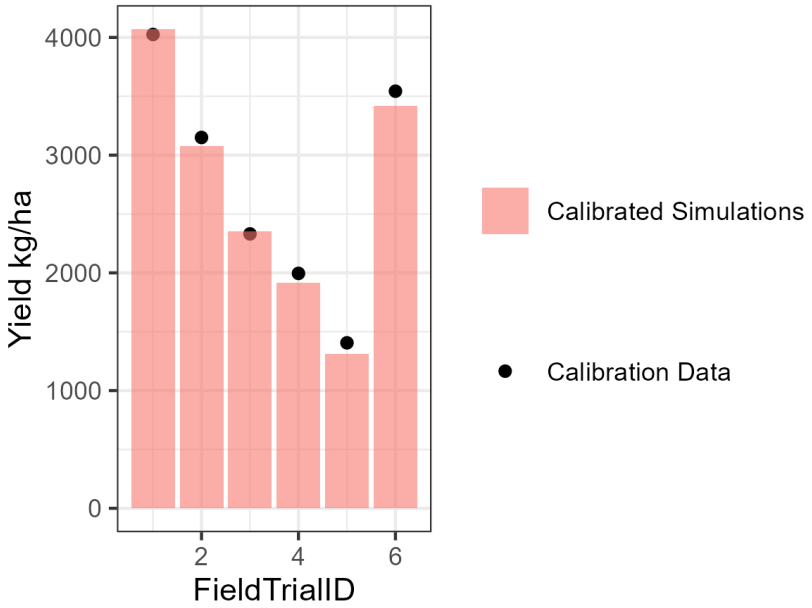
Questions, past experiences, ideas?

Calibrated crop simulation models

Uncalibrated crop simulation model



Calibrated crop simulation model

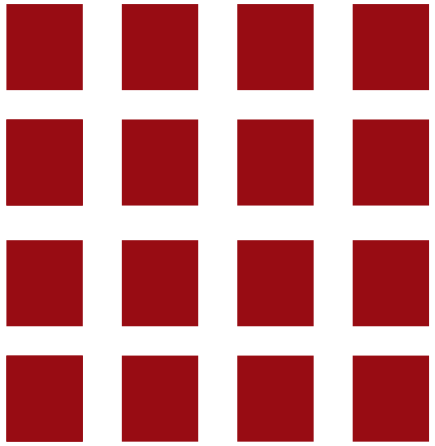


Use in analysis of field trials

- In data-intensive field trials, the number of variables can be high compared to the number of plots

Effect	Degrees of freedom
Treatment	4
Block	4
Soil moisture	1
Clay percentage	1
Residual variance	6
Total degrees of freedom	**16**

4 treatments, 4 Blocks/Repetitions

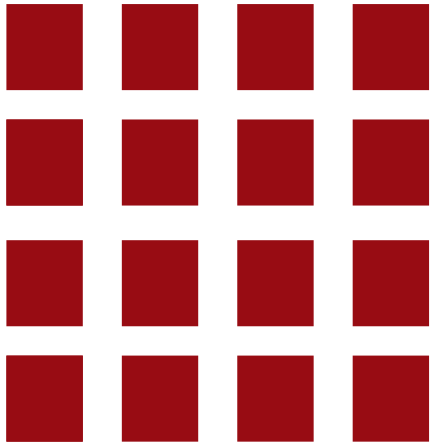


Use in analysis of field trials

- In data-intensive field trials, the number of variables can be high compared to the number of plots

Effect	Degrees of freedom
Treatment	4
Block	4
Soil moisture, Clay Percentage, SOM, and their interactions	6
Residual variance	2
Total degrees of freedom	**16**

4 treatments, 4 Blocks/Repetitions

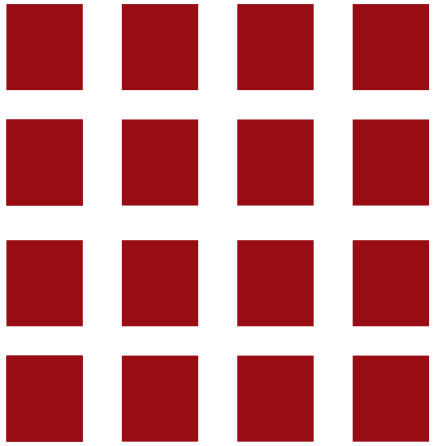


Use in analysis of field trials

- In data-intensive field trials, the number of variables can be high compared to the number of plots

Effect	Degrees of freedom
Treatment	4
Block	4
Effect of Soil moisture, Clay Percentage, SOM estimated by Crop Simulation Model	1
Residual variance	7
Total degrees of freedom	**16**

4 treatments, 4 Blocks/Repetitions



This gives higher power and smaller confidence intervals and puts all the data to use!