Assessing the potential of crop model to reproduce *Thinopyrum intermedium* agro-ecosystems functioning and support knowledge acquisition about perennial grain crops.

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Context

Context

- Soils are at risk all around the world and agriculture needs to shift toward agro-ecological practices

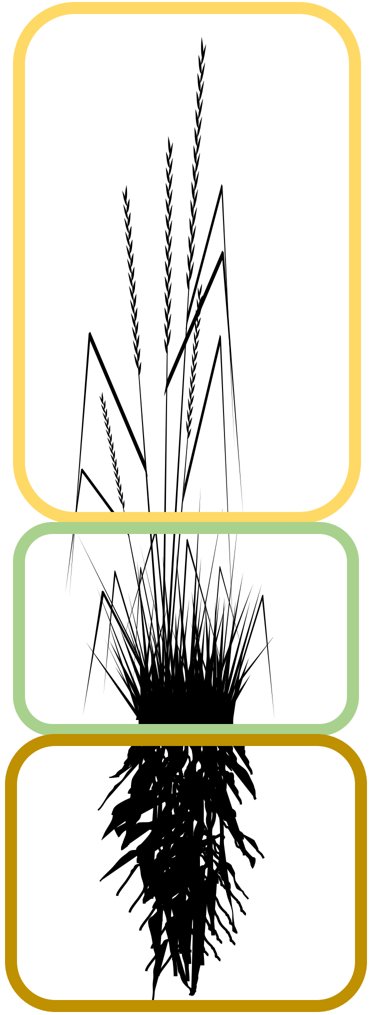
- One solution ➔ perennial grain crops

- Perennial wheat candidate : *Thinopyrum intermedium* (Host) Barkworth & D.R. Dewey

- Grain producing variety : Kernza®

What is Kernza® ?

- Dual purpose forage/grain production during the same year
- Soil carbon storage, permanent ground cover
- Selection by The Land institute since 20 years to improve grain yield



Grain production

Forage production

Ecosystem services

New crop, New questions

- Eco-physiology ? Nutrient dynamics, resources allocation, long term development, yield components ...

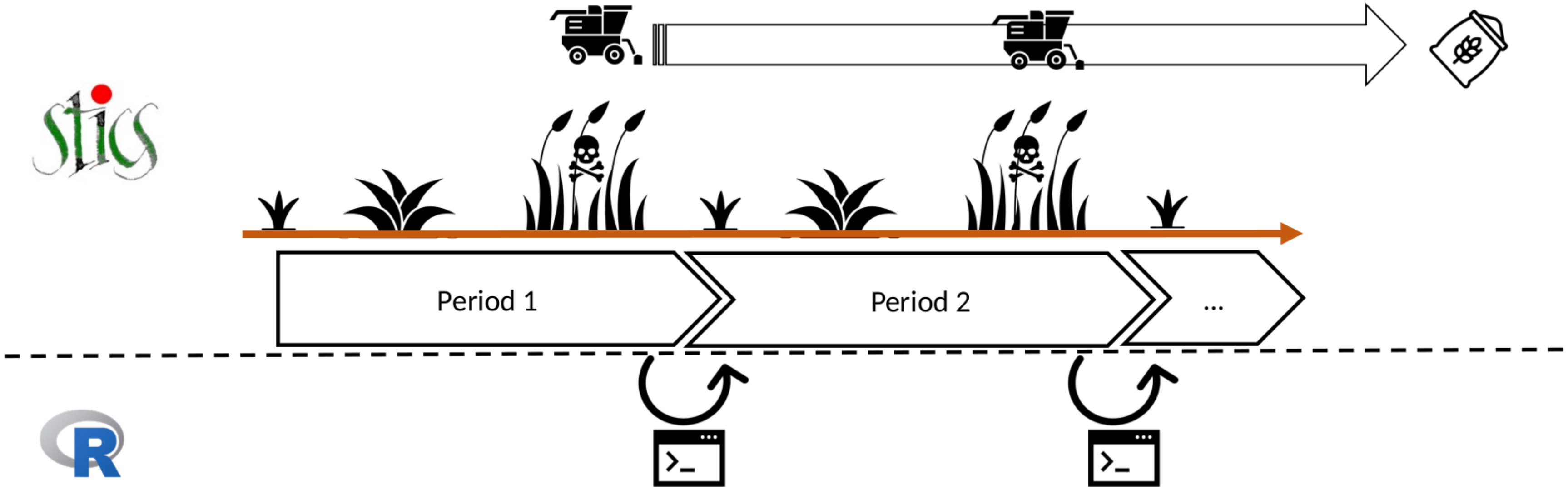
- Technical management ? Sowing, fertilization, weeding, agronomic potentials, climate change adaptation ...

➔ Crop modeling can support knowledge acquisition about this new crop in addition to traditional field experiments

Crop modeling

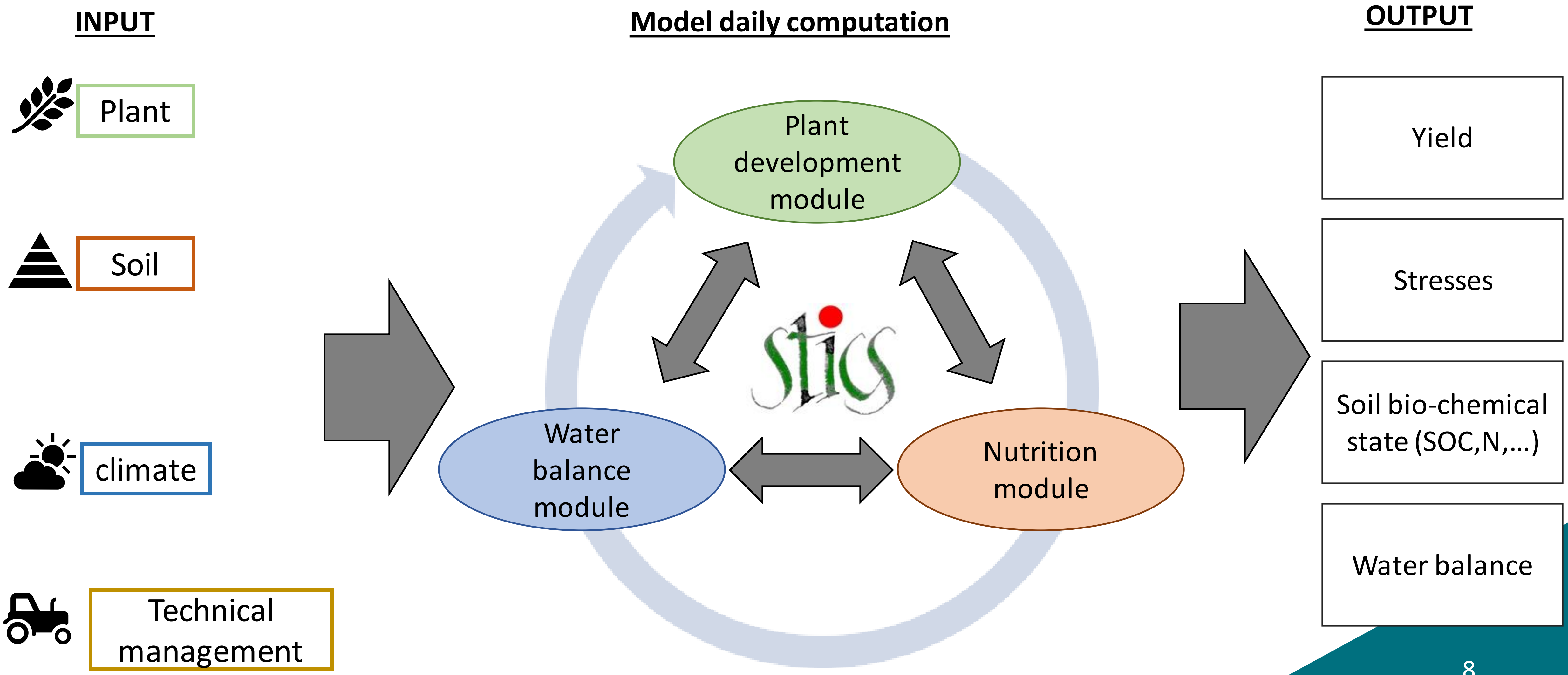
Crop modeling

- The Process based STICS crop model was used
- Can simulate annual grain crops and pasture but cannot do both at the same time



➔ Perenniality is simulated with an external algorithm

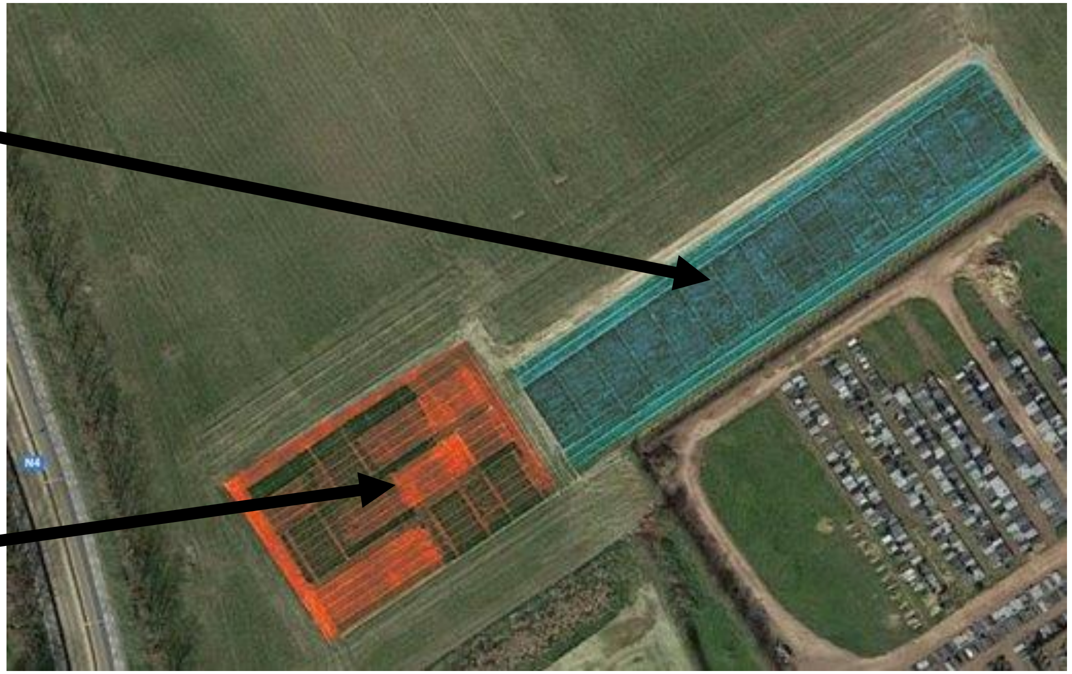
The STICS crop model



Modeling Kernza – Data set

- Calibration data set:
  - 4 years of data (2017 – 2021)
  - 7 different fertilization management x mowed or not

- Validation data set:
  - 2 years of data (2019 – 2021)
  - 3 sowing dates x 2 inter row



➔ 2 Independent and contrasted data set

Modeling Kernza - first step : parametrization

- STICS uses a set of approximately 200 plant parameters
- Some parameters are shared by plants in the same family and other are specific to the specie

➔ Parameters from various grass plants have been evaluated to identify the shared ones among poaceae species

Phenology parameters : Duchene et *al.* (2021)

NNI parameters : Fagnant et *al.* (Under review)

Modeling Kernza – Model evaluation

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\left(Y_i - \hat{Y}_i\right)^2}$$

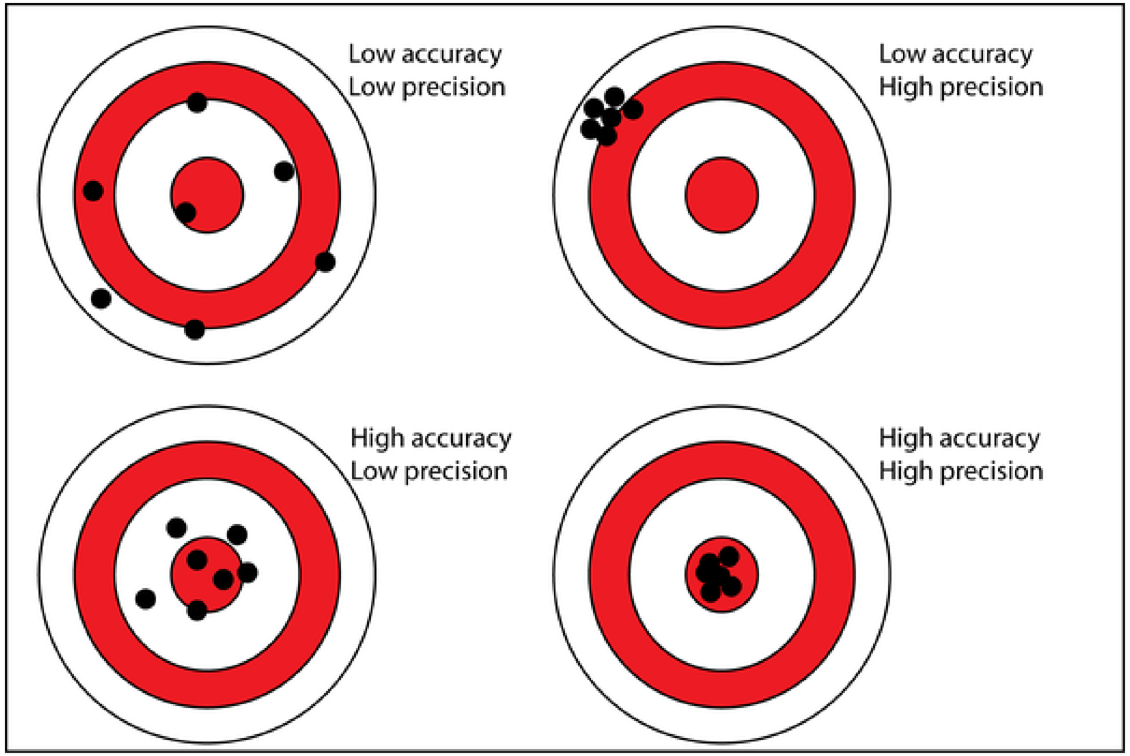
➔ Precision

$$ND = \frac{\sum_{i=1}^{N}\left(\widehat{Y}_i\right) - \sum_{i=1}^{N}\left(Y_i\right)}{\sum_{i=1}^{N}\left(Y_i\right)}$$

➔ Accuracy (<0,1)

$$EF = 1 - \frac{\sum_{i=1}^{N}\left(Y_i - \widehat{Y}_i\right)^2}{\sum_{i=1}^{N}\left(Y_i - \bar{Y}\right)^2}$$

➔ Exactness (>0,5)

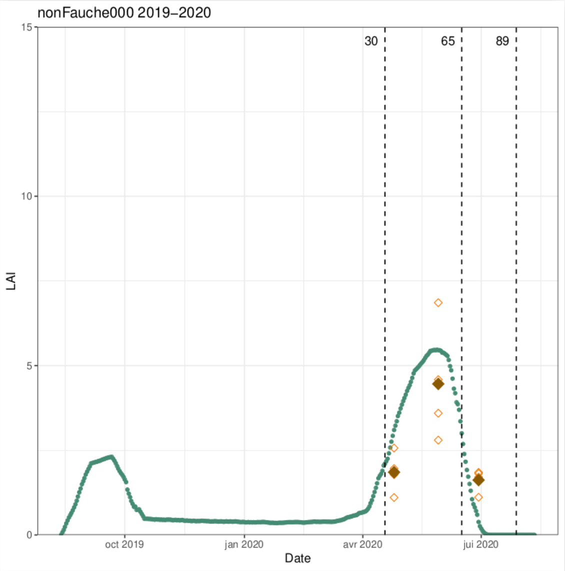


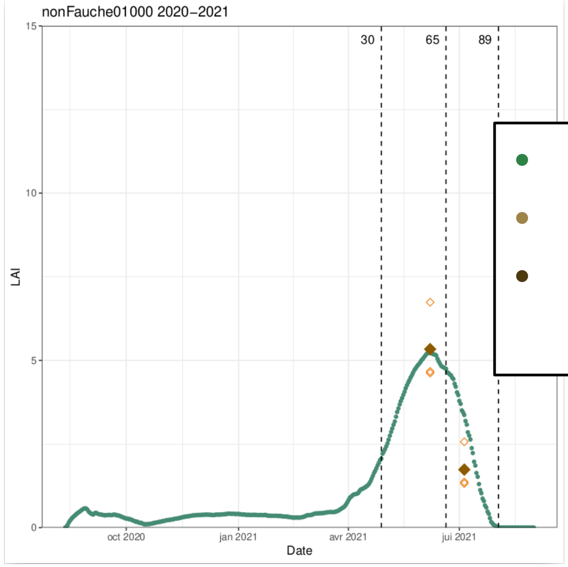
Calibration and Validation

Results

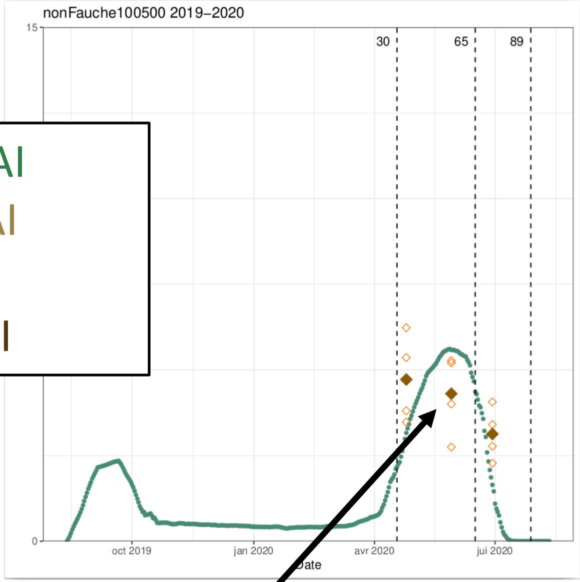
	Calibration			Validation		
	RMSE	EF	ND	RMSE	EF	ND
Phenology	9,6	0,94	0,015	7,6	0,96	0,011
Leaf Area Index	1,5	0,32	0,057	2,4	-0,213	0,31
Biomass production	1,6	0,80	0,034	3,1	0,64	0,126
Grain yield	0,077	0,74	0,033	0,51	0,27	0,186
N uptake	13,74	0,55	0,08	11,52	0,79	0,031
Root biomass	4,52	-15,5	1,6	2,3	-0,42	0,39

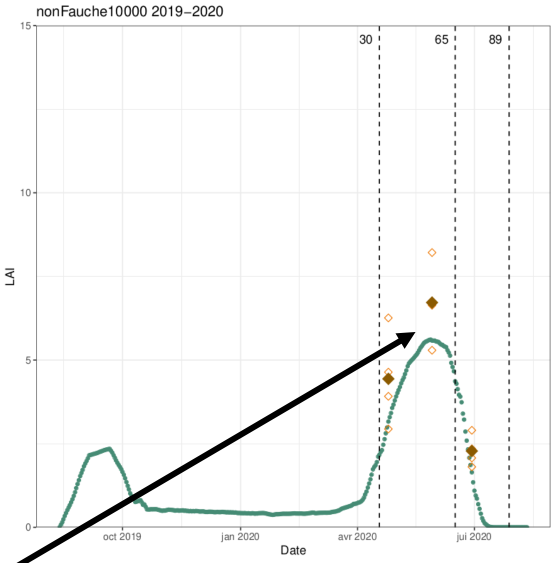
Results : Main issues - LAI

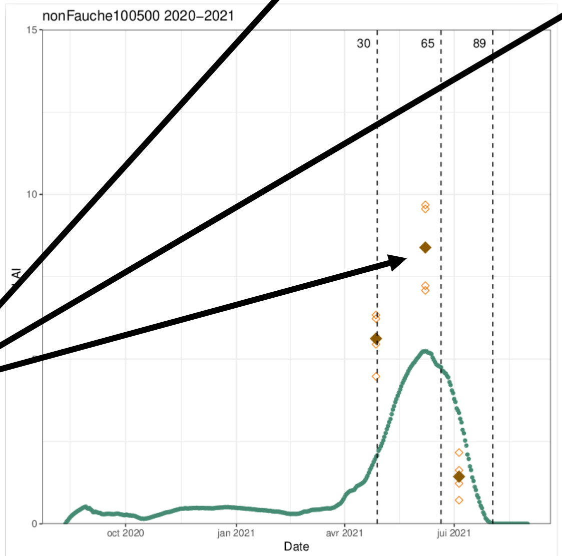




- Simulated LAI
- Observed LAI
- Means of observed LAI



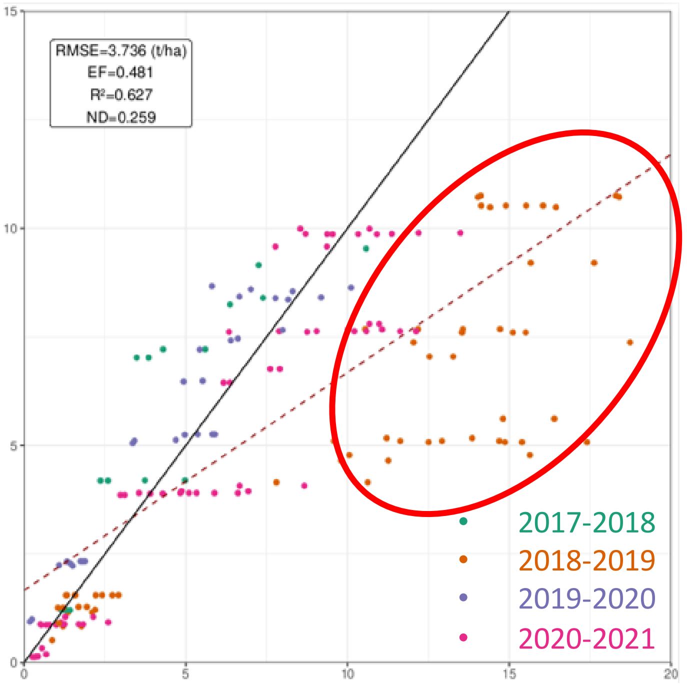




- Dynamic graphs (LAI over time) show good trends simulations
- Some heavily and early fertilized crops show poor fit
- STICS "one leaf" formalism is not perfectly adapted for this crop

Results : Main issues – production peak

- Second growth period is always underestimated



Results : Main issues – production peak

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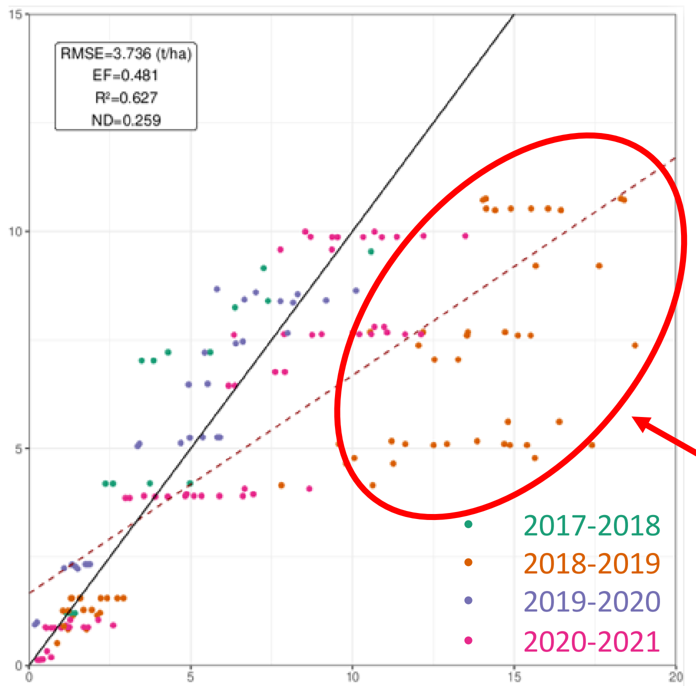
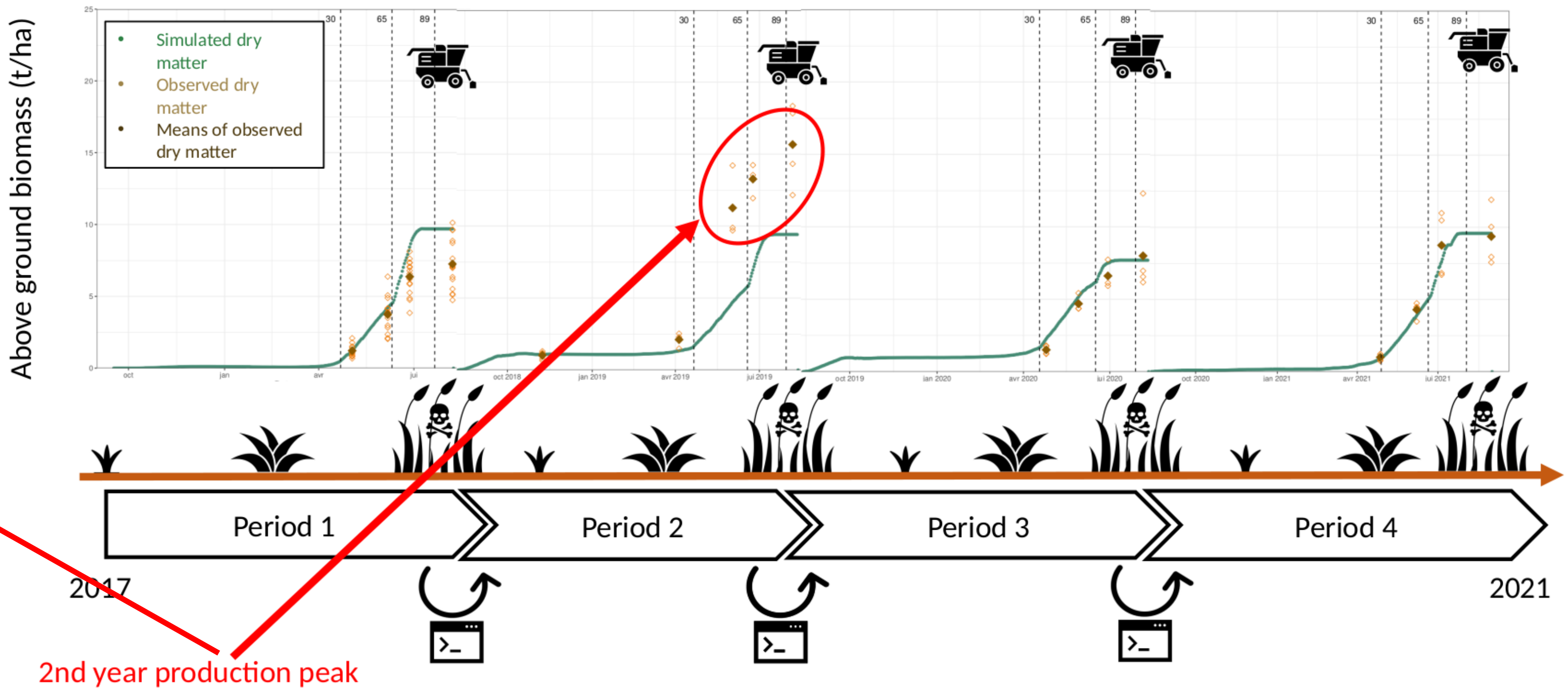
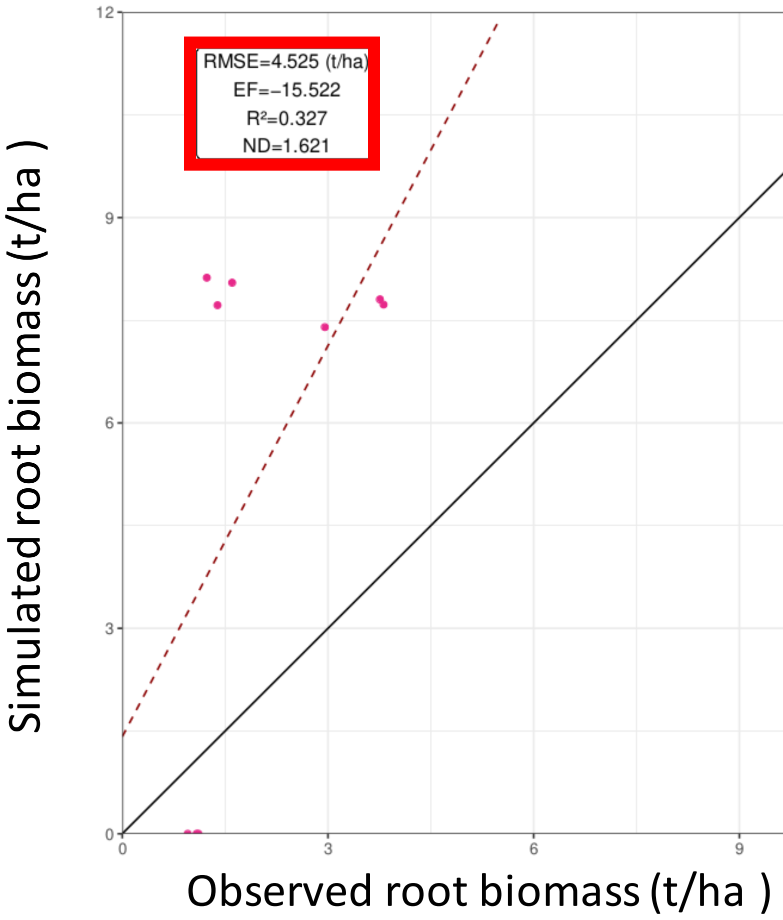




Results : Main issues – Roots



- Only limited calibration dataset (3 stages, 3 technical management)
- Bad results, the V 9.2 of the model is limited regarding belowground biomass
- New equations will be added in V 10 to improve the model ability to simulate roots (initially developed for miscanthus)

Developing new knowledge

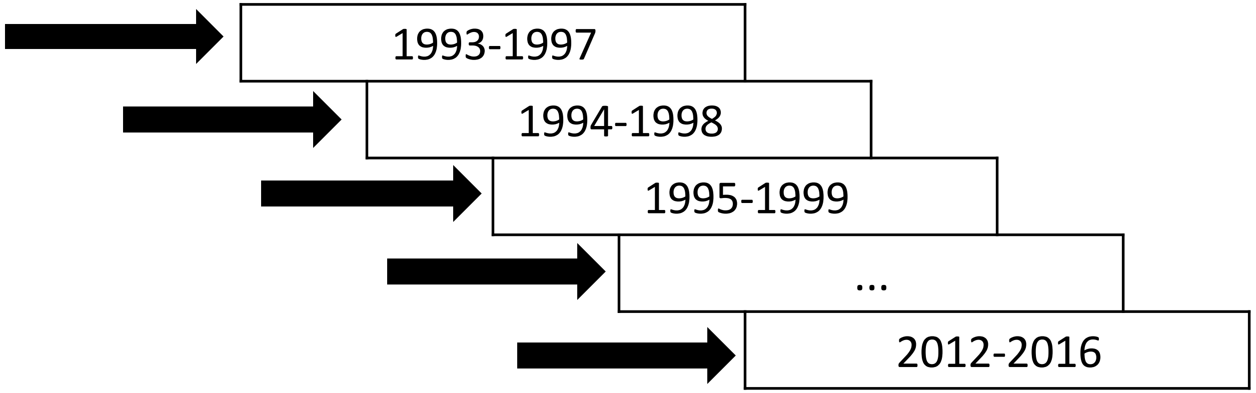
N fertilization optimization

Which fertilization management, if applied systematically every year, gives the best chances to obtain high grain yield ?

➔ Multi-simulation approach

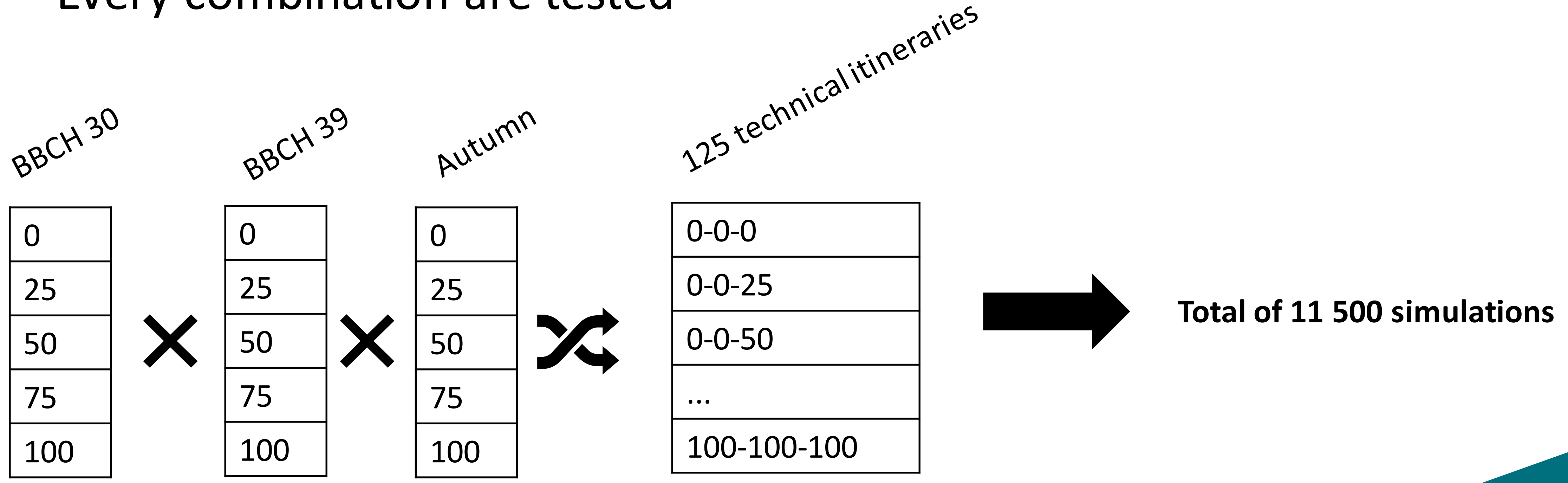
N fertilization optimization

- The model is run on past climate dataset (1993-2016 = 23 years)
- Simulations are chained during 4 years
- The first simulation year is shifted by one year to cover the all range



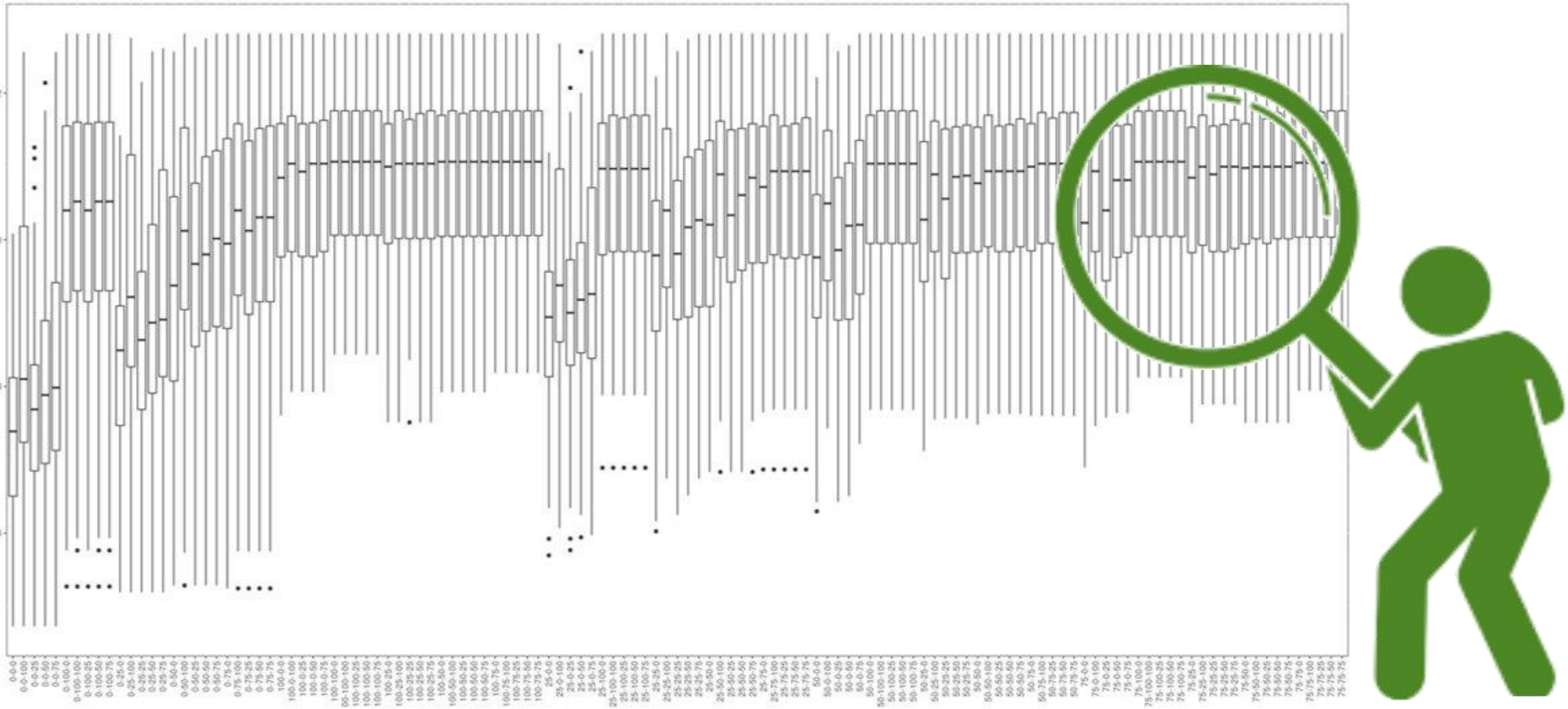
N fertilization optimization

- 125 different N fertilization rate have been created with 3 fractions
- Ranging from 0-0-0 kgN/ha to 100-100-100 kgN/ha
- Every combination are tested



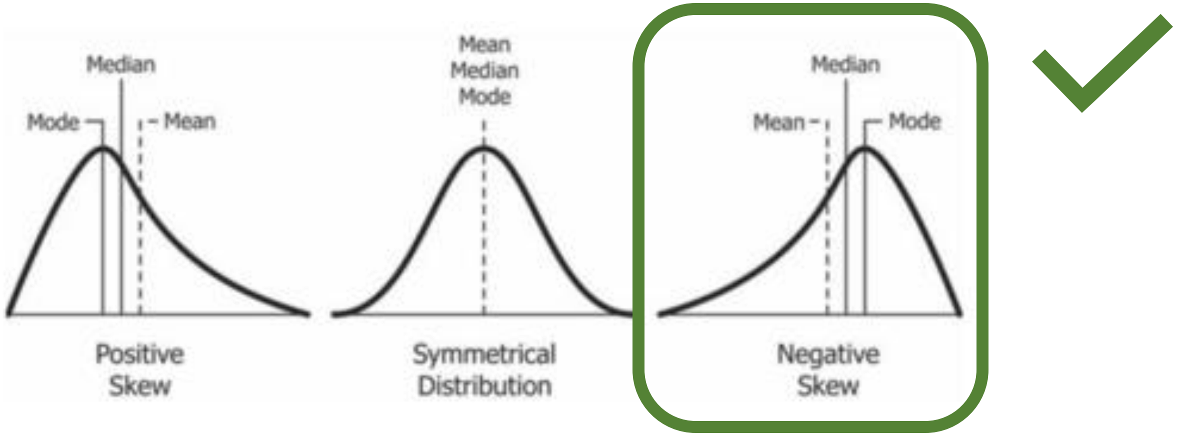
Results : Grain yield

grain yield (t/ha)



Fertilization fractions

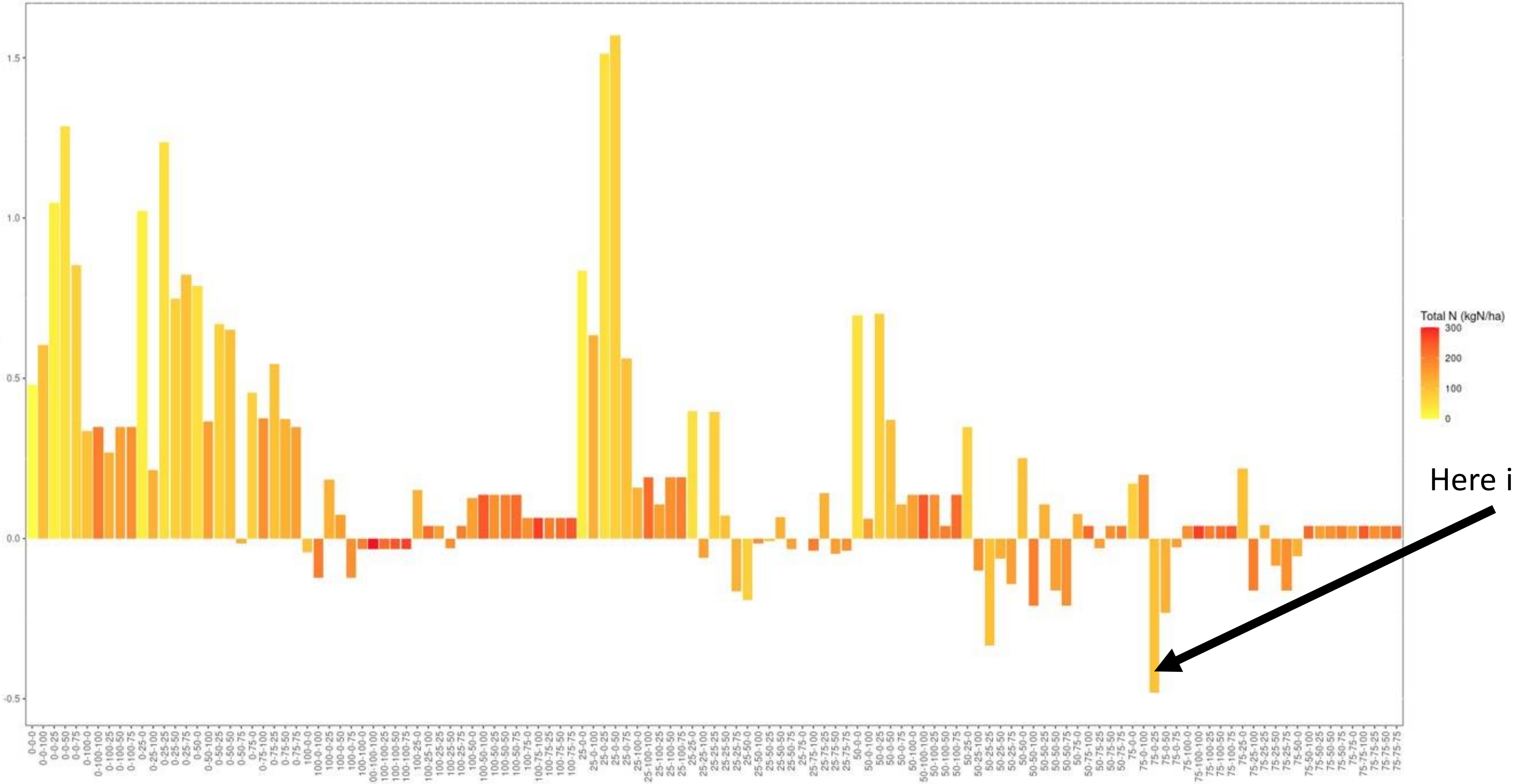
Finding the best N management strategy



Identifying the fertilization management that allows the ***greatest mean grain yield*** and a ***high probability*** to get yields greater than the mean.

➔ Looking for a PDF of yield with a high negative skewness coefficient
➔ Ensuring that the corresponding fertilization allows for a great mean yield

Finding the best N management strategy

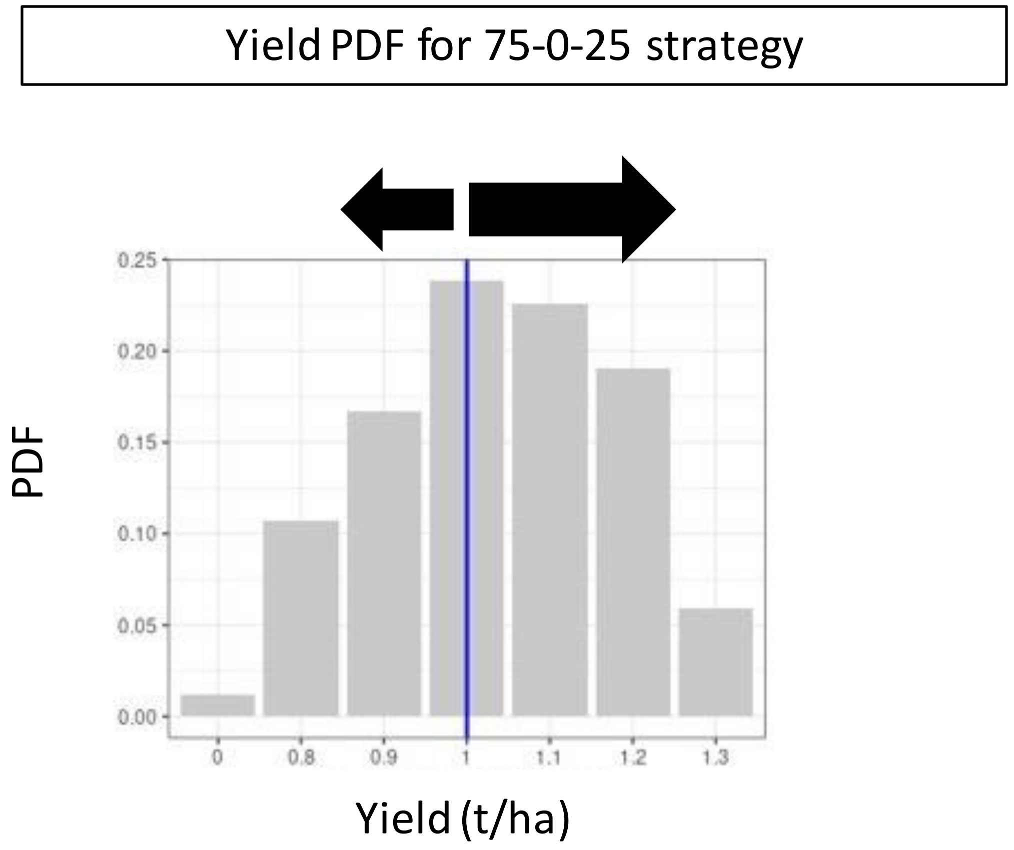


skewness

Fertilization strategies

Here is our candidate

Finding the best N management strategy



- Probability distribution of yields is oriented to the right of the mean (blue line)

- The average yield obtained with this strategy is:
  - Statistically equivalent to the highest yields
  - only 47 kg lower than the yield obtained when 300 kgN/ha are applied (3x more N)

- This fertilization strategy thus maximizes the chances to obtain yields above the average if applied systematically

➔ Result in line with Jungers et al. (2017) and fields experiments who recommended amount between 60 kgN/ha and 100 kgN/ha in total

➔ Model-based approach brought new insights and allow to fill the gaps with experimental-based knowledge

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Thank you for your attention !

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