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Evaluation of On-Farm Field Trials

the Example of Site-Specific Nitrogen Fertilization Trials

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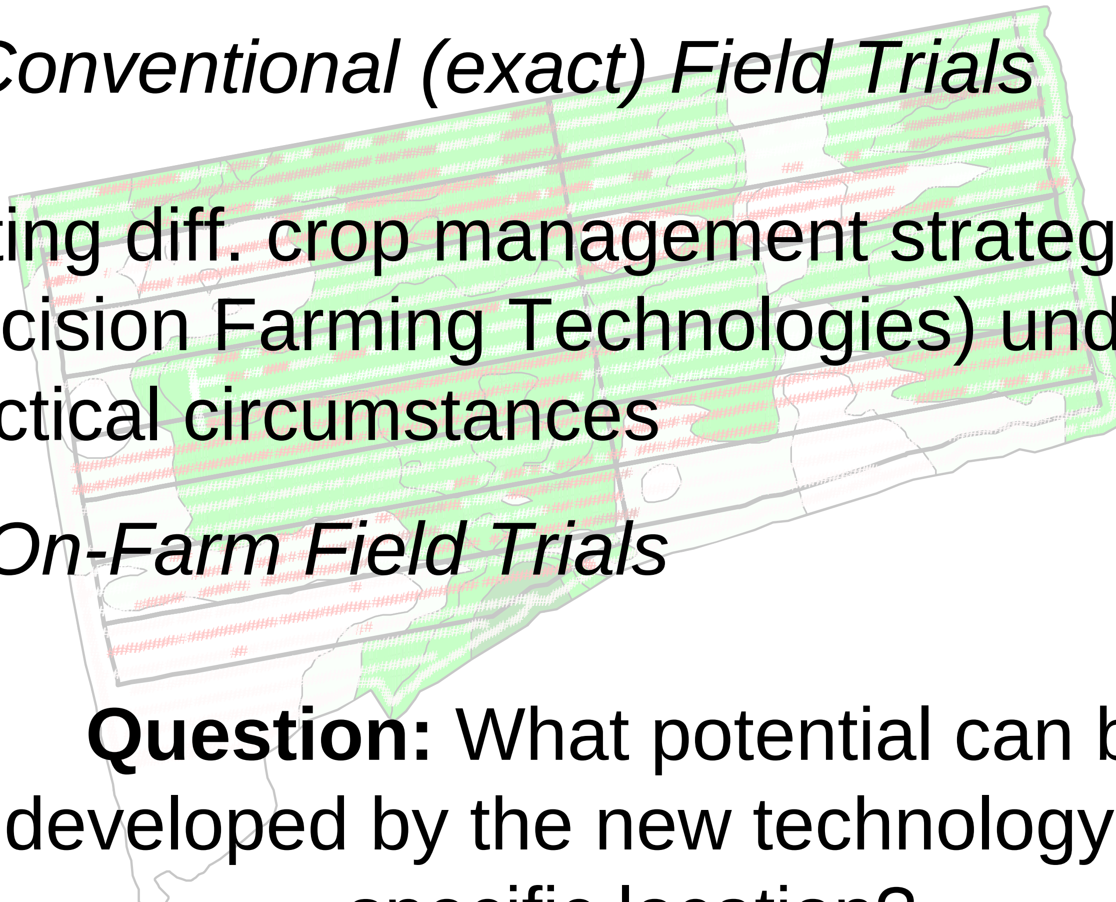
Why On-Farm Field Trials?

- testing diff. crop varieties, fertilizers, etc.

→ *Conventional (exact) Field Trials*



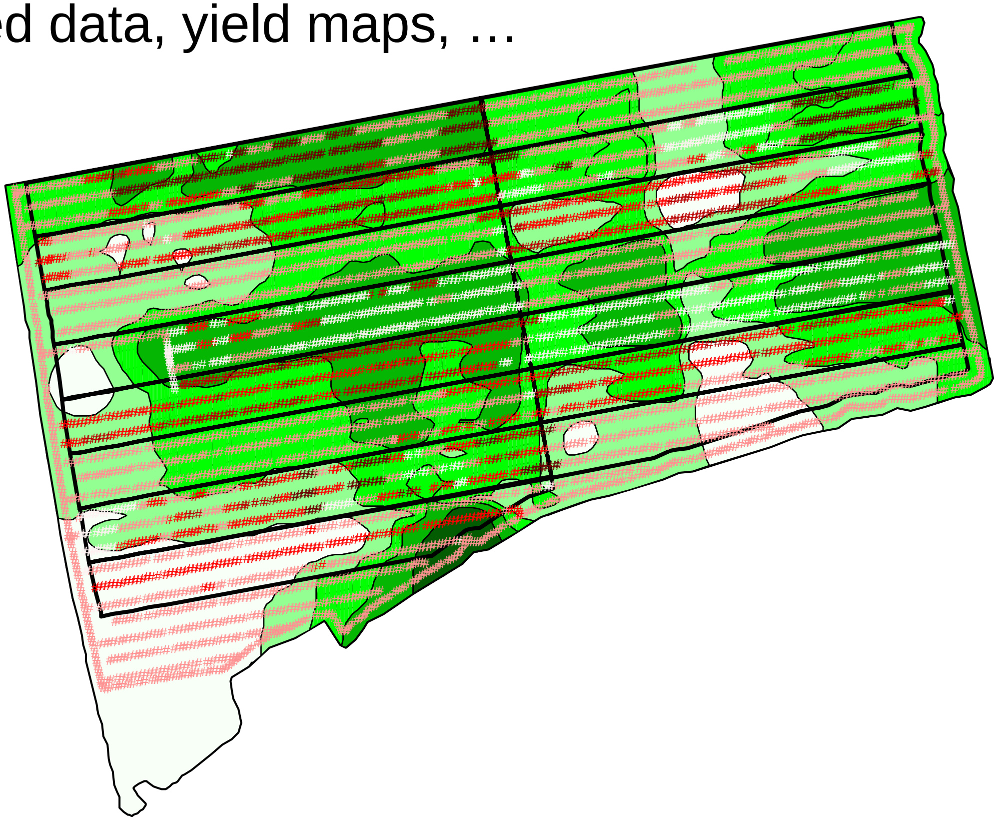
- testing diff. crop management strategies (e.g. Precision Farming Technologies) under practical circumstances

→ *On-Farm Field Trials*

Question: What potential can be developed by the new technology at a specific location?

On-Farm Field Trials – How does it look like?

- virtual division of a field into different strips
- realization of the different management strategies with replications within the strips
- application of all decisive management measures with GPS to get as-applied data, yield maps, …

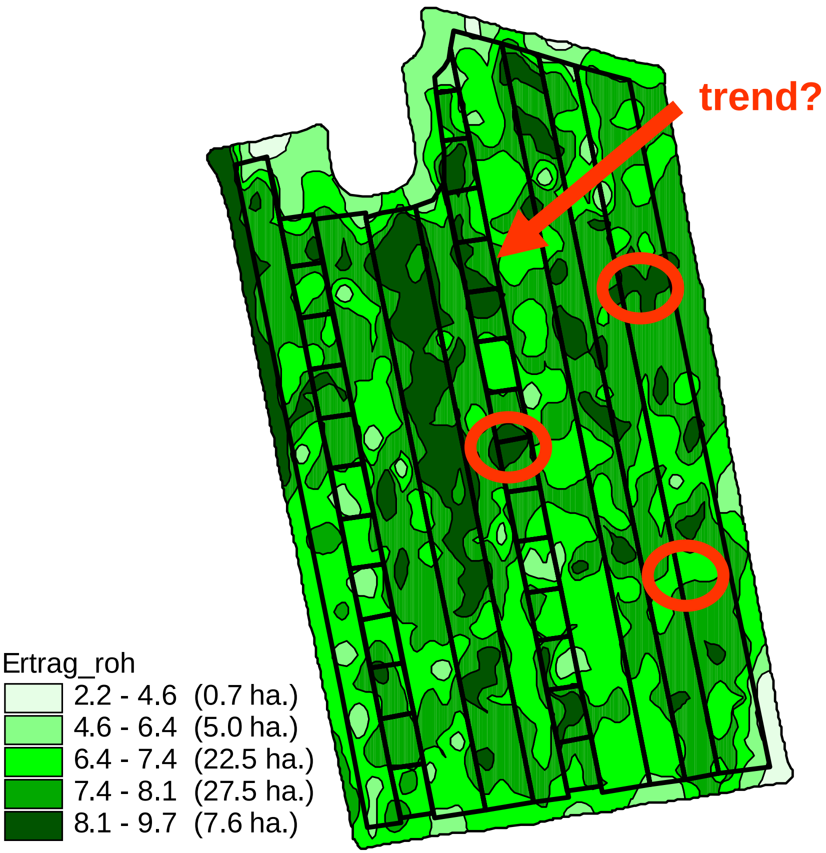


Challenges by the evaluation of On-Farm Field Trials

"… the most relevant sources of variation in wheat production might not be ascribed to management intervention in soil fertilization, but might be ascribed to soil intrinsic variation …"

Castrignanò et al. (2005)

Uniform distribution of heterogeneity over all strategies?



No!

Other (unintentional) influences to On-Farm Field trials…

Natural Effects

- “large-scale“ dependency:
    - soil trend (quantifiable by the coordinates X, Y)
    - yield potential (quantifiable by potential zones, EC, altitude, …)
- “small scale“ dependency:
    - quantifiable through the spatial covariance

Management Effects

- **management strategy**
- several harvest combines
- several harvest times

Model selection – part 1

1. optimization of the expectation structure

$$y = X\beta + e$$

with $e \sim N(0, R)$

$$R = \begin{bmatrix} \sigma^2 & & & & & 0 \\ & \sigma^2 & & & & \\ & & \ddots & & & \\ & & & \sigma^2 & & \\ & & & & \ddots & \\ & 0 & & & \sigma^2 & \\ & & & & & \sigma^2 \end{bmatrix}$$

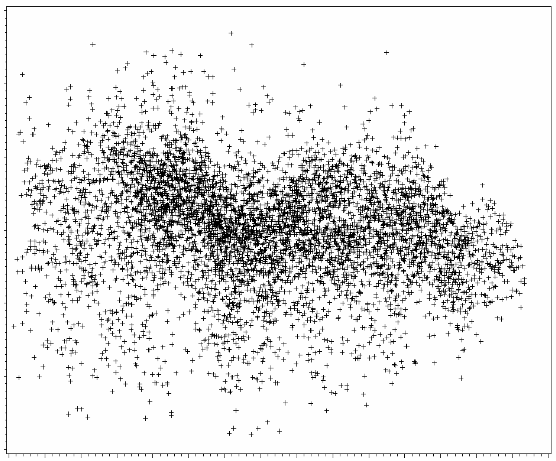
Model Selection — **Mod. 1** — **Mod. 2** — **...**

β = vector of the unknown fixed effects X = known design matrix for fixed effects

e = unknown random residual effects

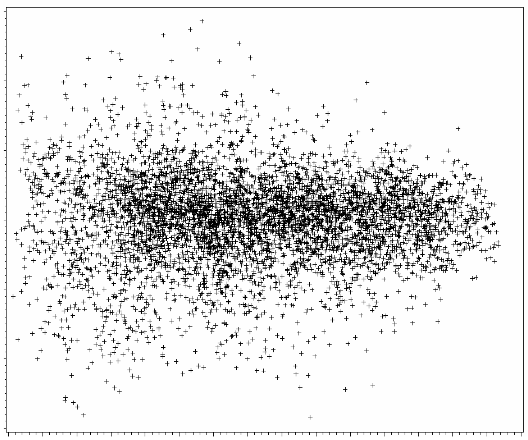
Model selection

$e \sim N(0, R)$ → **Plot of the residuals to the X axis**



yield = strategy

yield = *total model*



Analytical Criteria:

AIC or AICC „Akaike Information Criteria“

→ evaluation of the goodness of fit AND the model’s complexity

… the smaller, the better…

Model selection – part 2

1. optimization of the expectation structure

model selection

Mod. 1   **Mod. 2**   **…**

2. optimization of the covariance structure

$$y = X\beta + e$$

with $e \sim N(0, R)$

$$R = \begin{bmatrix} \sigma^2 & \sigma_{12} & \cdots & \sigma_{1j} & \cdots & \sigma_{1\,n-1} & \sigma_{1n} \\ \sigma_{21} & \sigma^2 & & & & & \sigma_{2n} \\ \vdots & & \ddots & & & & \vdots \\ \sigma_{i1} & & & \sigma^2 & & & \sigma_{in} \\ \vdots & & & & \ddots & & \vdots \\ \sigma_{n-1\,1} & & & & & \sigma^2 & \sigma_{n-1\,n} \\ \sigma_{n1} & \sigma_{n2} & \cdots & \sigma_{nj} & \cdots & \sigma_{n\,n-1} & \sigma^2 \end{bmatrix}$$

Optimization of the covariance structure

$$y = X\beta + e \qquad \text{with} \qquad e \sim N(0, R)$$

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$$\sigma^2 = \sigma_R^2 + \sigma_0^2$$

σ_R^2: nugget; σ_0^2: partial sill

$$\sigma_{ij} = \sigma_0^2 f(d_{ij})$$

$f(d_{ij})$ depending on the spatial model:

- Exponential
- Spherical
- Gaussian ...

Model selection – part 2

1. optimization of the expectation structure

model selection: **Mod. 1** | **Mod. 2** | **…**

2. optimization of the covariance structure

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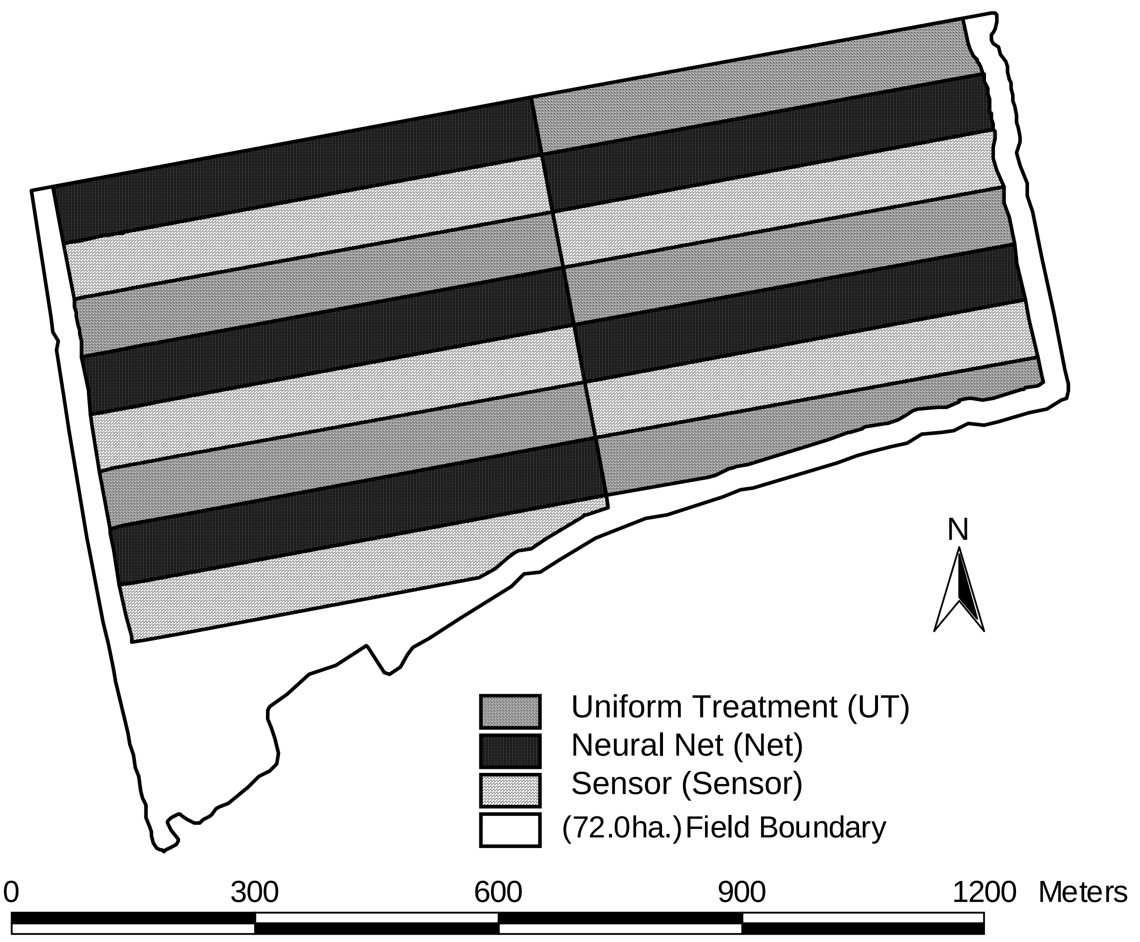
model selection: **exp. Mod.** | **sph. Mod.** | **…**

An example: nitrogen fertilization field-trial



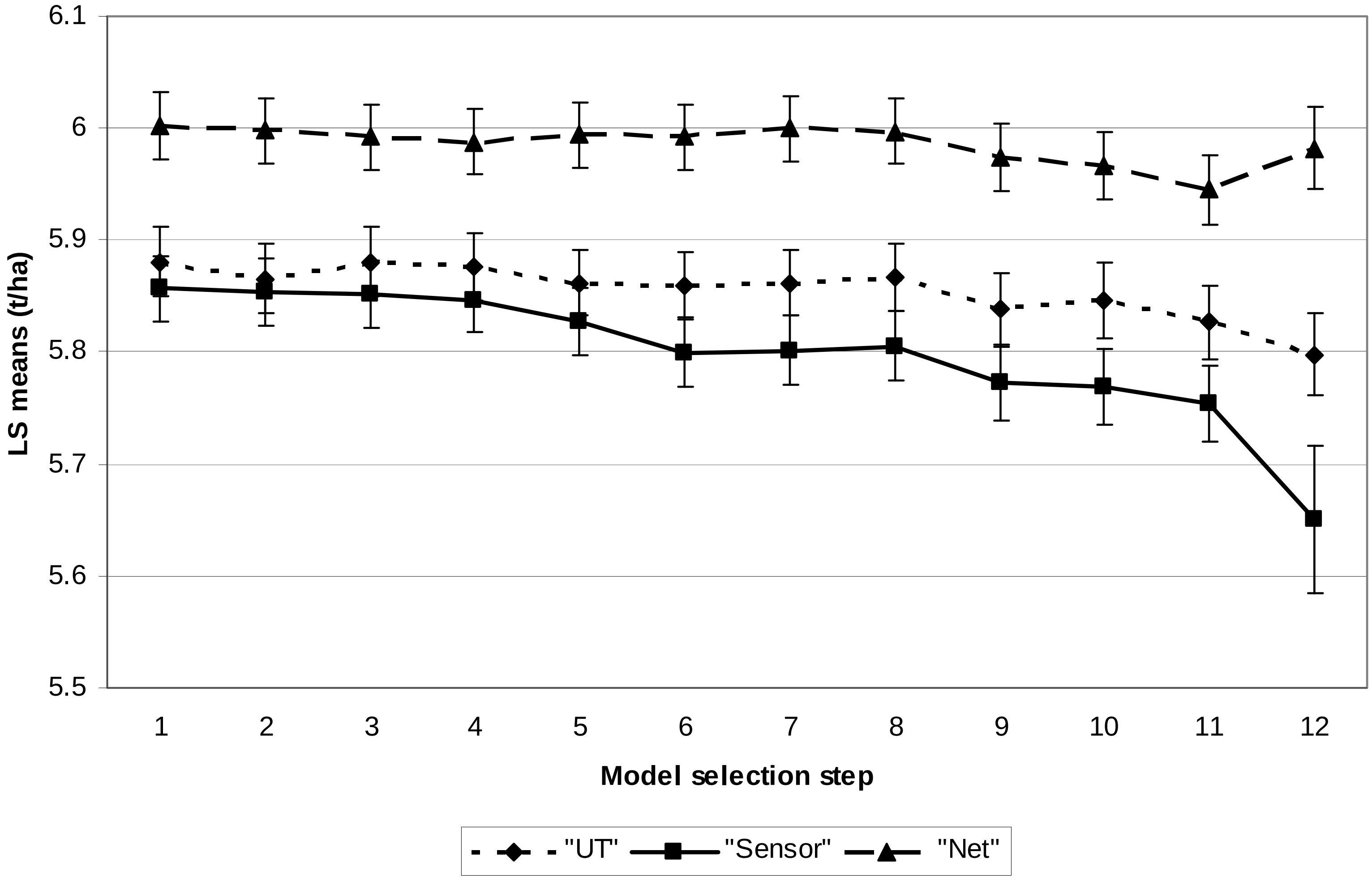
Model selection – expectation structure

Model selection Step		Model (*Yield = …*)	AICC
optimization of the expectation structure (ML)	1	VG	10728.6
	2	VG, WDH	10679.4
	3	VG, WDH, Block5	10555.0
	4	VG, WDH, Block10	10370.9
	5	VG, WDH, Block10, EC	10302.1
	6	VG, WDH, Block10, EC, Z	10265.7
	7	VG, WDH, Block10, EC, Z, Z^2	10231.0
	8	VG, WDH, Block10, EC, Z, Z^2, Z^3	10221.0
	9	VG, WDH, Block10, EC, Z, Z^2, Z^3, X	10203.9
	10	VG, WDH, Block10, EC, Z, Z^2, Z^3, X, X^2	10159.9
	11	VG, WDH, Block10, EC, Z, Z^2, Z^3, X, X^2, X^3	10135.1
	12	VG, WDH, Block10, EC, Z, Z^2, Z^3, X, X^2, X^3, X*Y	10124.4

With: VG = fertilization strategy; WDH = repetition; Block5 and Block10 = division of the field into 5 or 10 blocks along the tram lines; EC = electrical conductivity measurements; Z = altitude; X and Y = X and Y coordinate of the yield point; EXP = exponential model; SPH = spherical model

Development of the LS Means

with confidence intervals: p=0.95



Model selection – covariance structure

Model selection Step		Model (*Yield = …*)	AICC
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	12	VG, WDH, Block10, EC, Z, Z^2, Z^3, X, X^2, X^3, X*Y	10124.4
optimization of the covariance structure (REML)	*13*	*EXP with nugget*	*8695.4*
	14	EXP without nugget	8748.3
	15	SPH with nugget	9206.1
	16	SPH without nugget	9206.1

With: VG = fertilization strategy; WDH = repetition; Block5 and Block10 = division of the field into 5 or 10 blocks along the tram lines; EC = electrical conductivity measurements; Z = altitude; X and Y = X and Y coordinate of the yield point; EXP = exponential model; SPH = spherical model

Results of the on-farm field trial

	"UT"	"Sensor"	"Net"
	Yield [t/ha], (SE)		
	5.83 (0.05)	5.67 (0.07)	5.99 (0.05)
	p > |t|		
"UT"		0.02	0.02
"Sensor"			0.001

Covariance structure: nugget = 0.09; sill = 0.31; range = 16.53m

Comparison of the "means of yield-points": "UT" = 5.88; "Sensor" = 5.85; "Net" = 6.00

Discussion/Conclusions I

- Comparing different strategies by means of yields “as they are” may lead to misleading results because of unknown spatial influences
- Spatial models based on additional information are powerful to achieve more reliable results
- The power of the introduced approach is strongly depending on the quality of the selected models.

→ best model of all analyzed models…

Discussion/Conclusions II

- The more additional information about the site is available, the better the model can be adjusted
- The approach delivers the possibility to get “home-grown” results for farmers.
- Question of transferability: results are location dependent and a product of the year’s weather conditions…

Thank you for your attention!

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