20th Nitrogen Workshop

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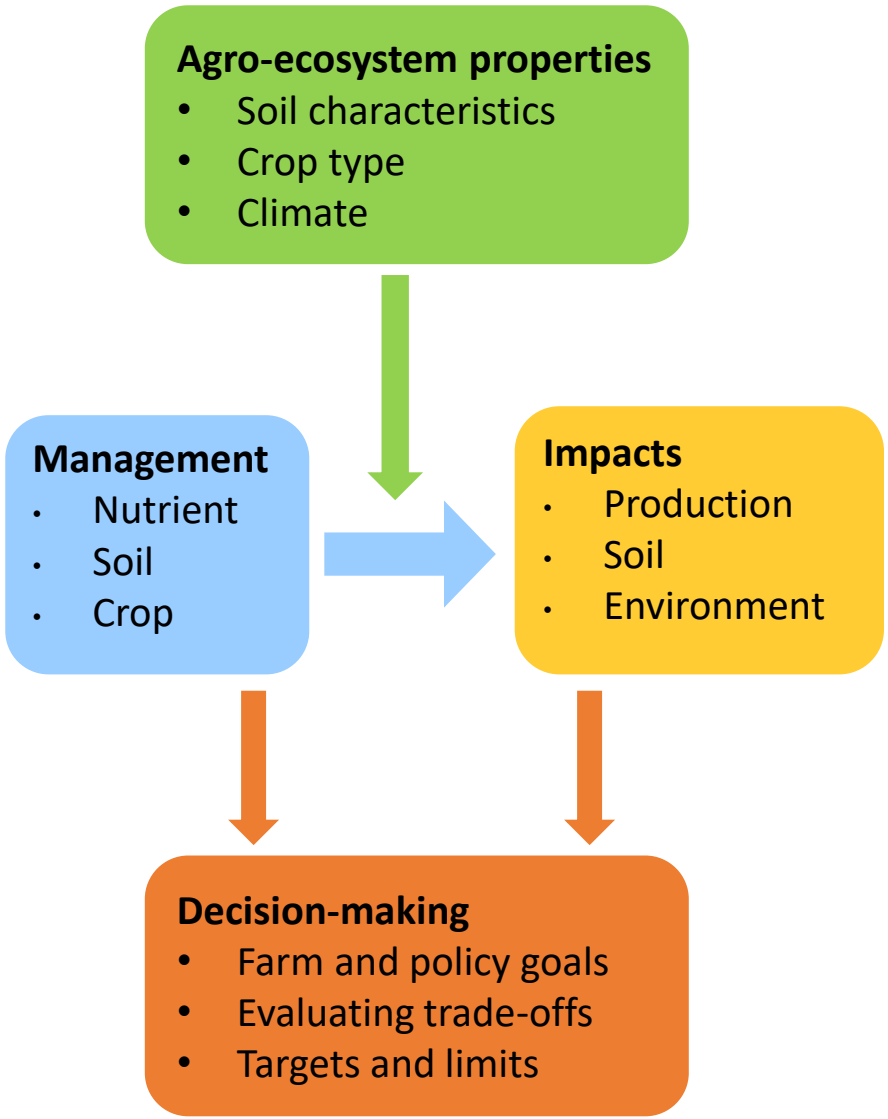
A decision support framework to evaluate the impacts of agricultural management on crop yield, soil quality, and environment

Madaline Young, Wim de Vries, Gerard Ros

Wageningen University

Introduction



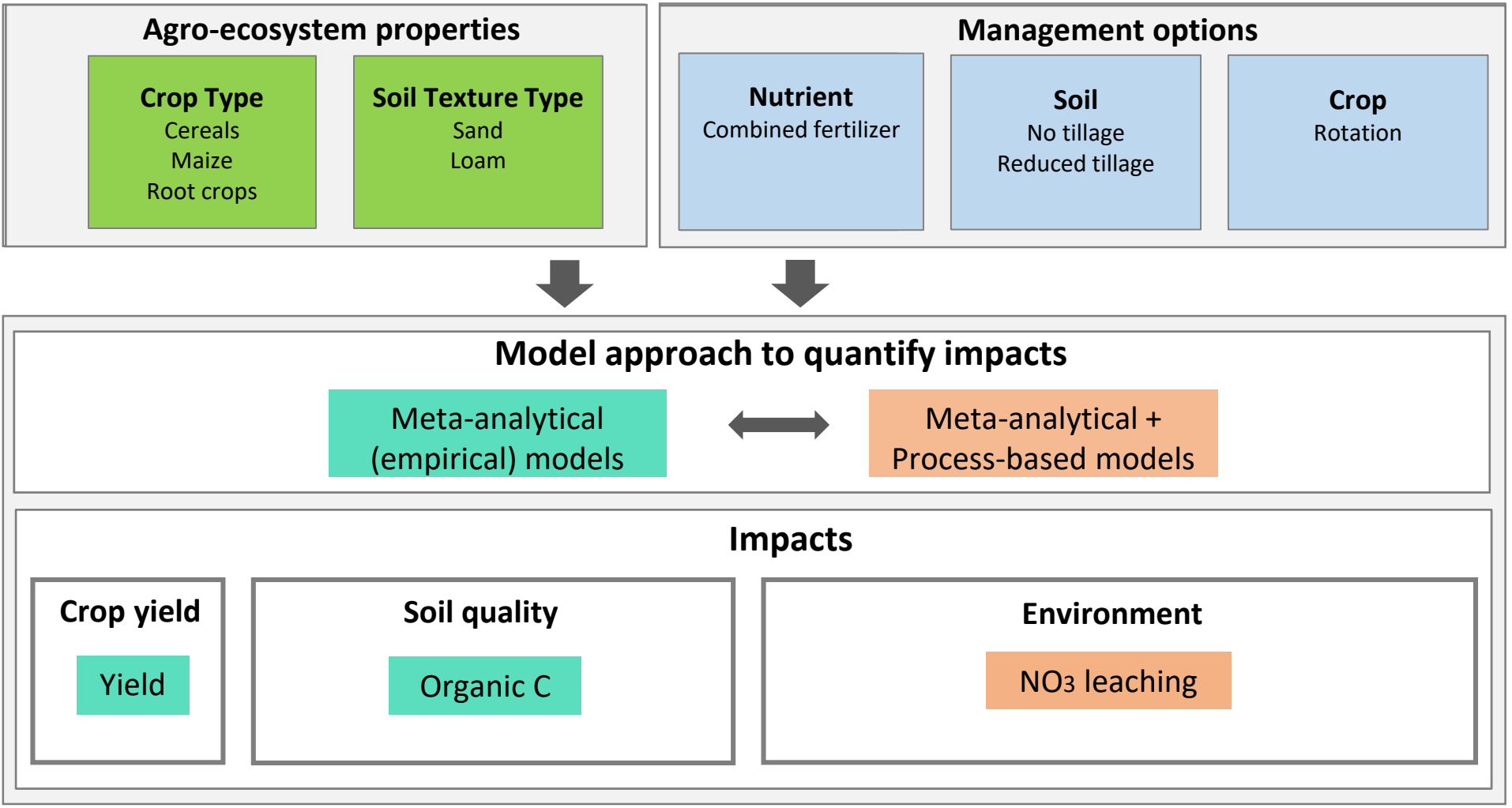
- Need for a decision support tool (DST) that:

  1. Quantifies impacts of management on yield, soil quality and environment

  2. Assesses the influence of agro-ecosystem properties (AEPs)

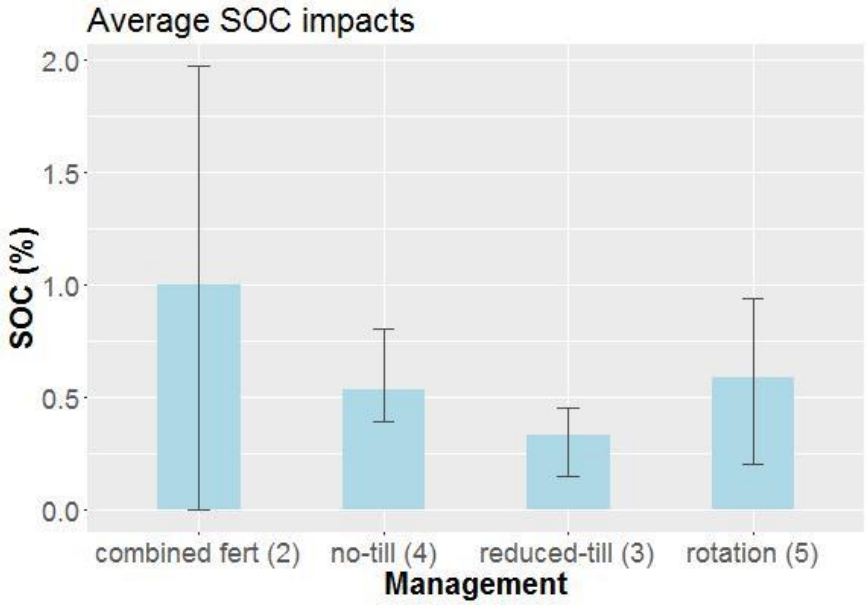
  3. Assesses the tradeoffs among the various indicators and management practices

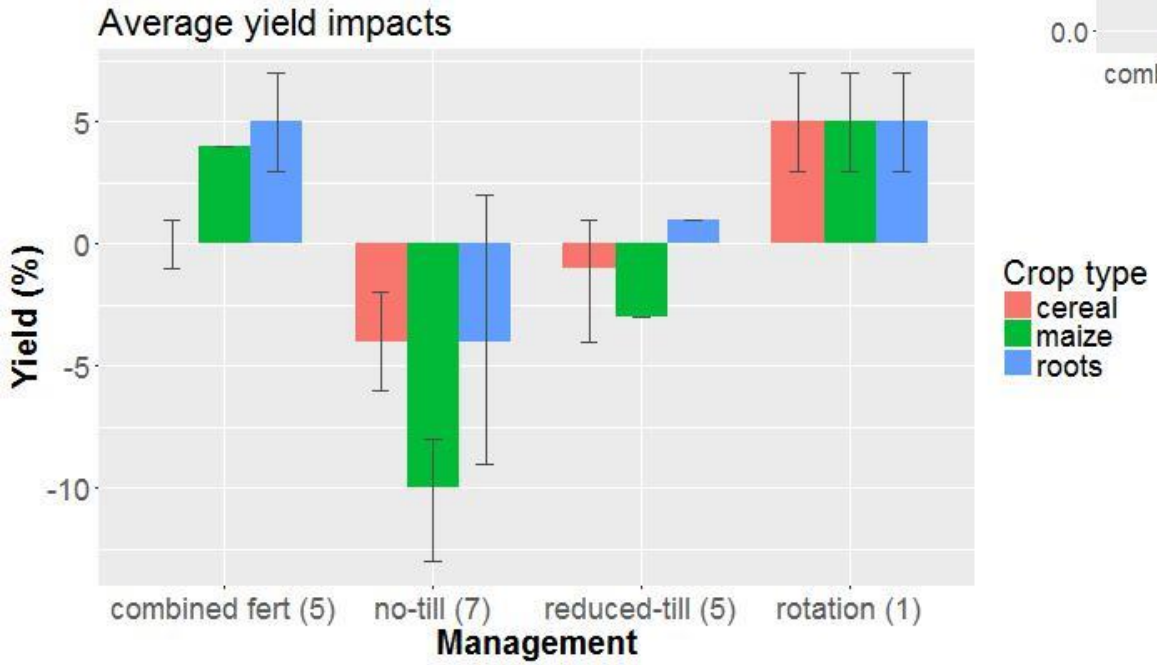
- Simple → improved DST


Agro-ecosystem properties
Crop Type
Cereals
Maize
Root crops
Soil Texture Type
Sand
Loam
Management options
Nutrient
Combined fertilizer
Soil
No tillage
Reduced tillage
Crop
Rotation
Model approach to quantify impacts
Meta-analytical (empirical) models
Meta-analytical + Process-based models
Impacts
Crop yield
Yield
Soil quality
Organic C
Environment
NO3 leaching

“A meta-analysis of meta-analyses”

- Average global effect size data from literature
- Response ratio → % change





Process-based calculations

- From **relative** yield and SOC changes, estimate N losses
  - Adapted equations from MITERRA/INTEGRATOR model approach

Δ Yield (meta-analysis)

Δ SOC (meta-analysis)

Δ N Uptake = **ΔYield** x N content crop

Δ N immobilization = **ΔSOC** x N/C

Δ N surplus = N input – **Δ N Uptake** – N emissions – **Δ N immobilization**

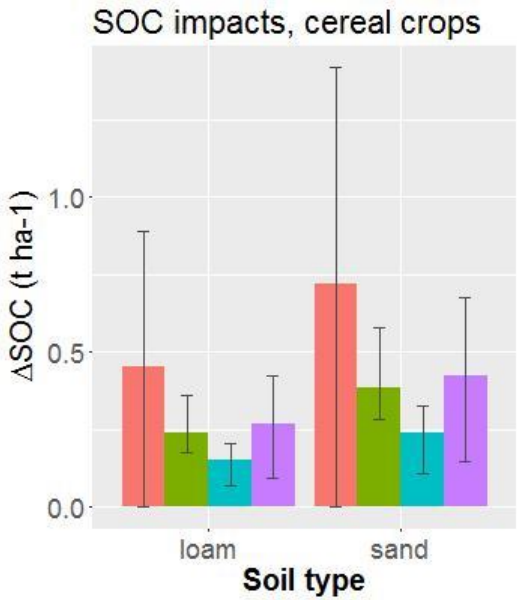
Δ N leaching = leaching fraction x **Δ N surplus**

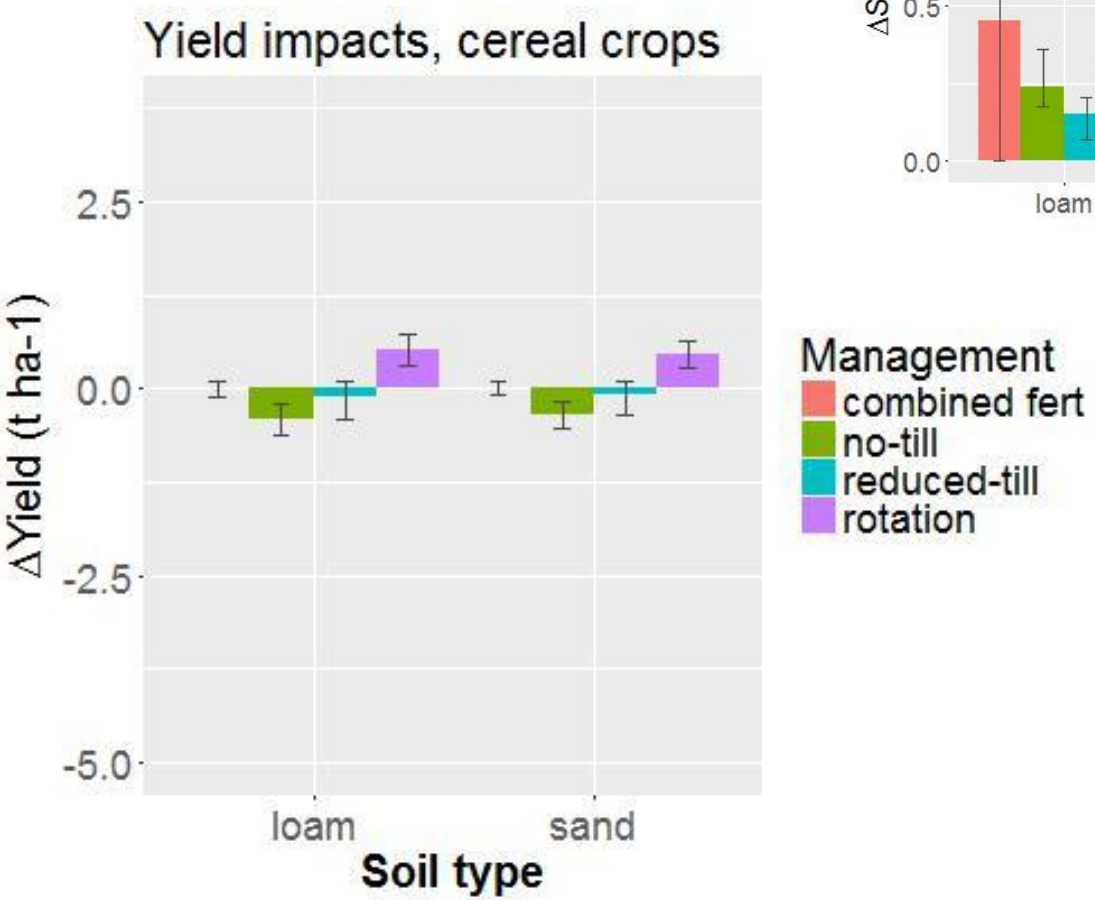
Regional input data

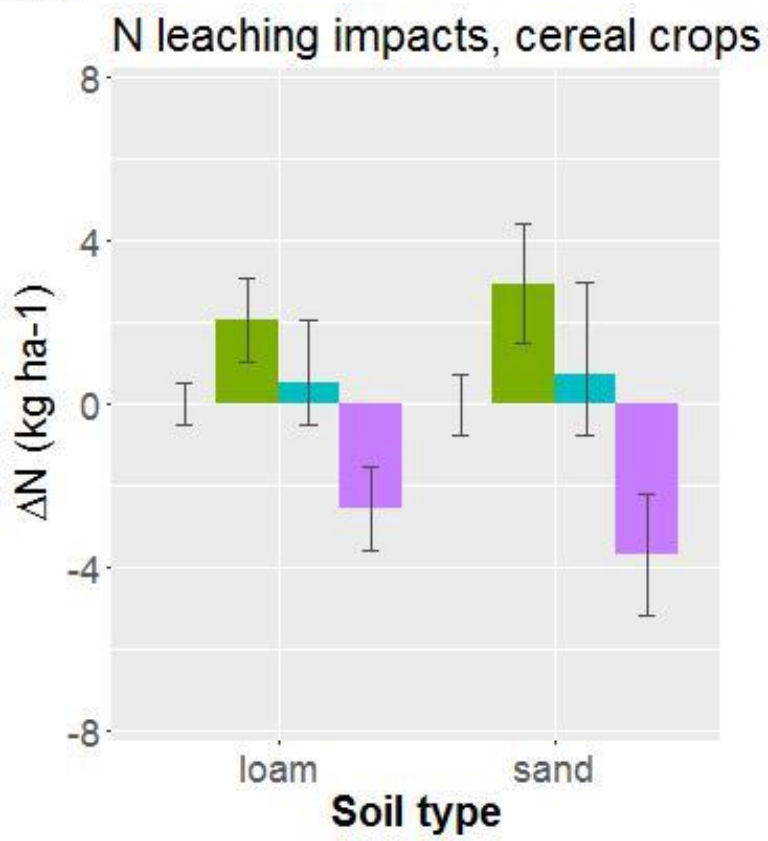
- Typical inputs and soil properties (INTEGRATOR)
- East Groningen arable land
- Selected properties (6 combinations):
  - 2 Soil types: loam, sand
  - 3 Crop types: cereal crops, maize, root crops

Agro-ecosystem				Crop		Soil		N inputs				Fractions N		
Farm type	climate	soil	crop	Yield (t ha-1)	N content (g kg-1)	SOC (g kg-1)	C/N	Fertilizer (kg ha-1)	Manure (kg ha-1)	Fixation (kg ha-1)	Deposition (kg ha-1)	Emissions manure	Emissions fertilizer	Leaching
1	northern	sand	wheat	9	19.6	21.0	20.8	225	80	5	20	0.112	0.024	0.42
2	northern	loam	wheat	10.5	19.6	13.4	20.5	225	80	5	20	0.101	0.024	0.25
3	northern	sand	maize	12	15.0	21.0	20.8	25	250	5	20	0.128	0.024	0.32
4	northern	loam	maize	15	15.0	13.4	20.5	25	250	5	20	0.125	0.024	0.18
5	northern	sand	potato	45	3.4	21.0	20.8	200	80	5	20	0.112	0.024	0.42
6	northern	loam	potato	52	3.4	13.4	20.5	200	80	5	20	0.101	0.024	0.25

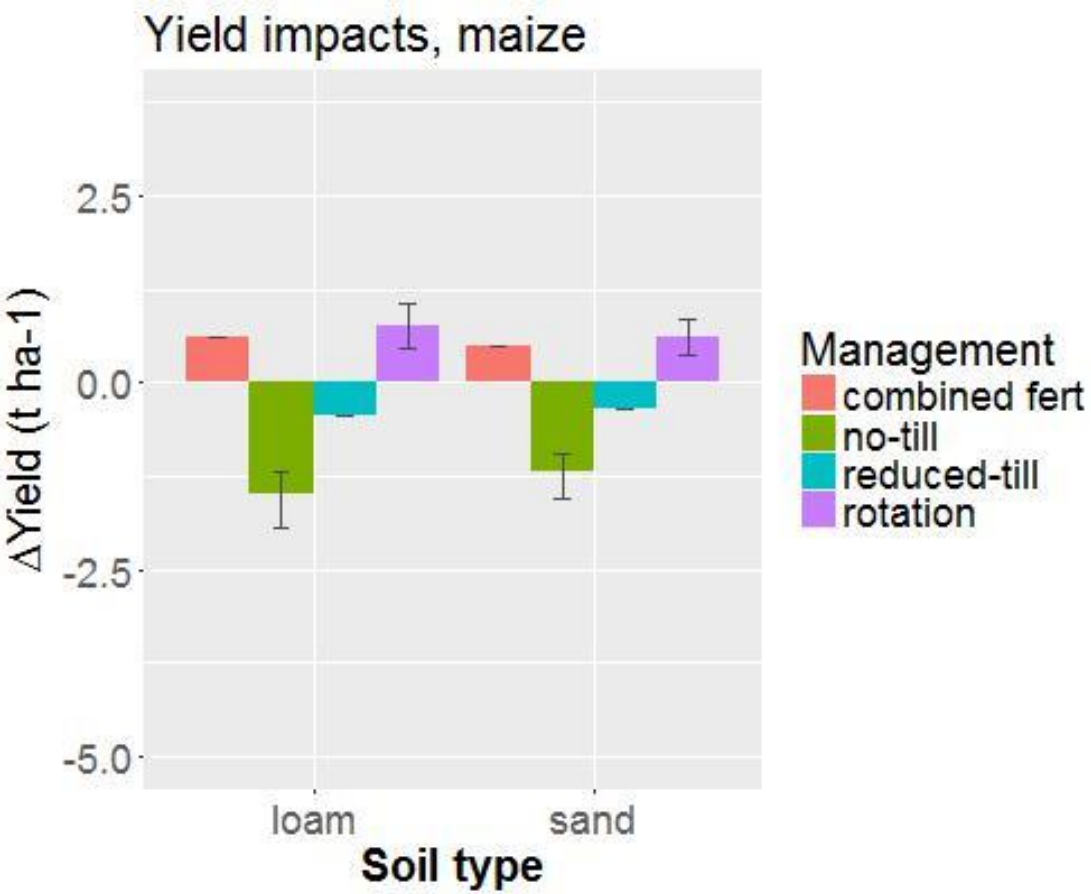
Annual changes: CEREAL CROPS (wheat)

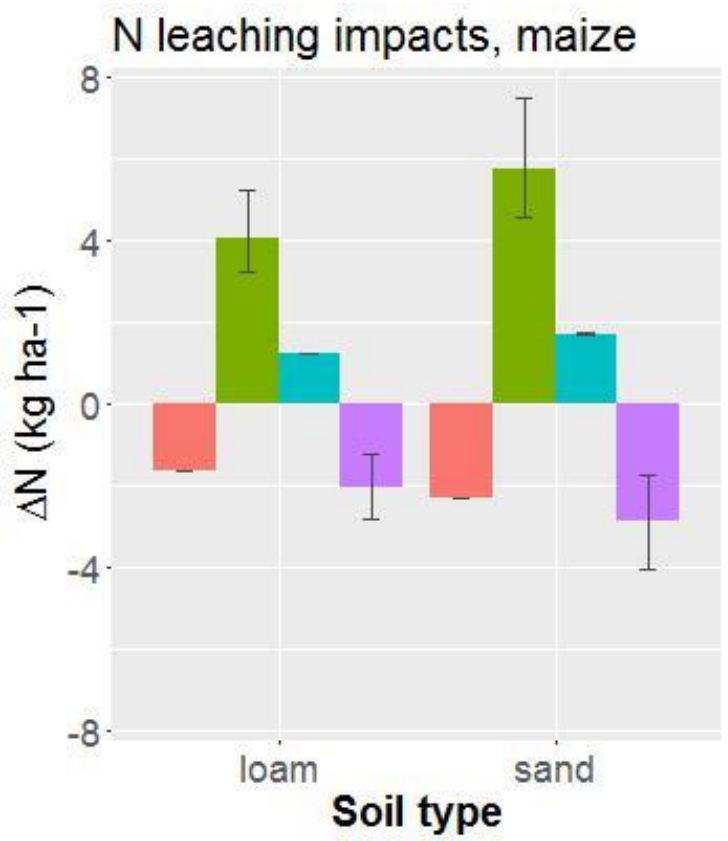




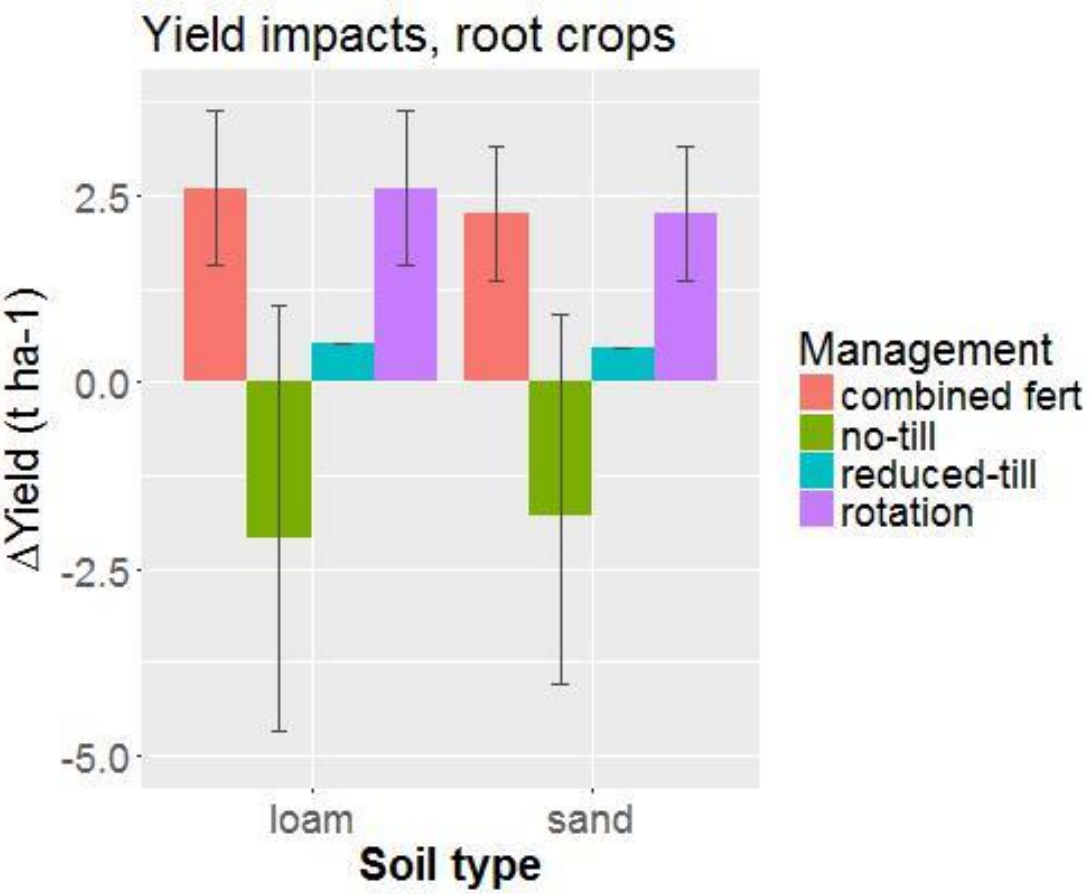


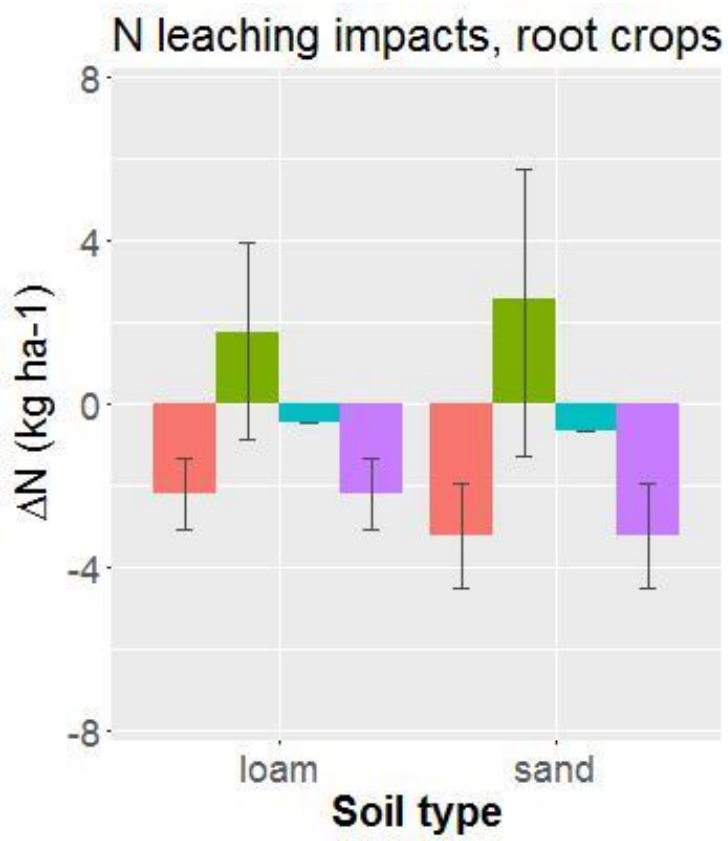
Annual changes: MAIZE



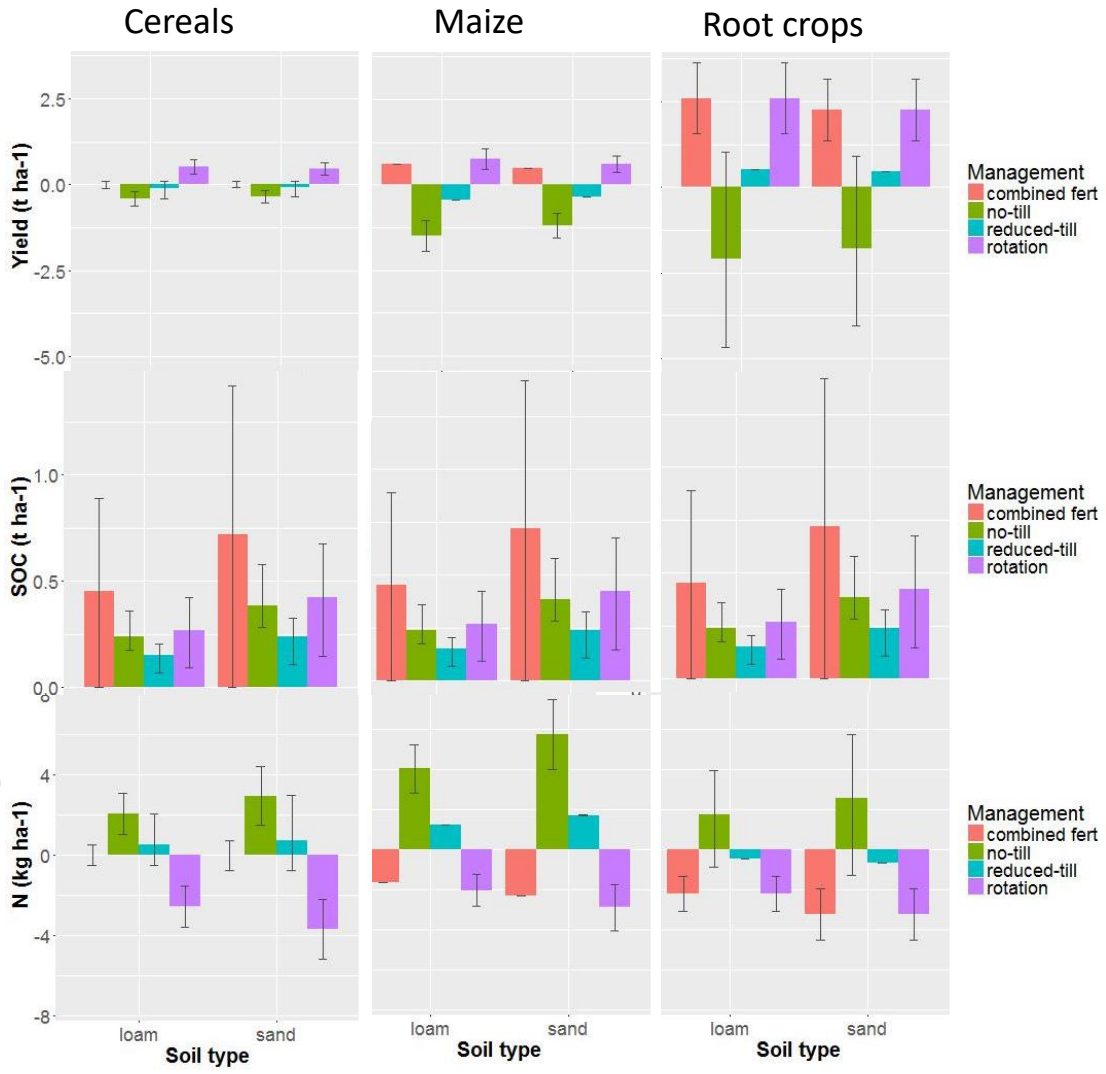


Annual changes:
ROOT CROPS (potato)





Problem of global data

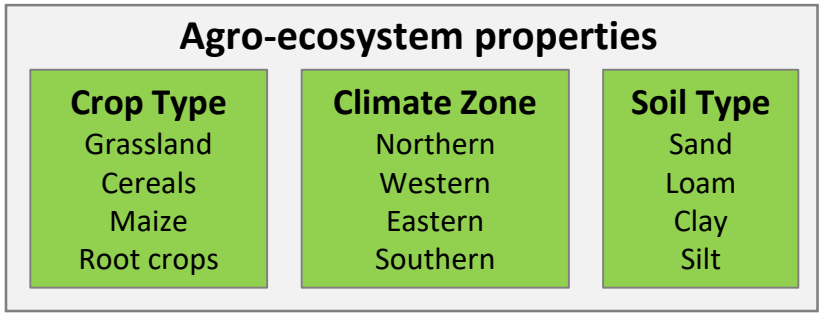


SOC is not differentiated by crop type

Soil type not differentiated in meta-analysis results

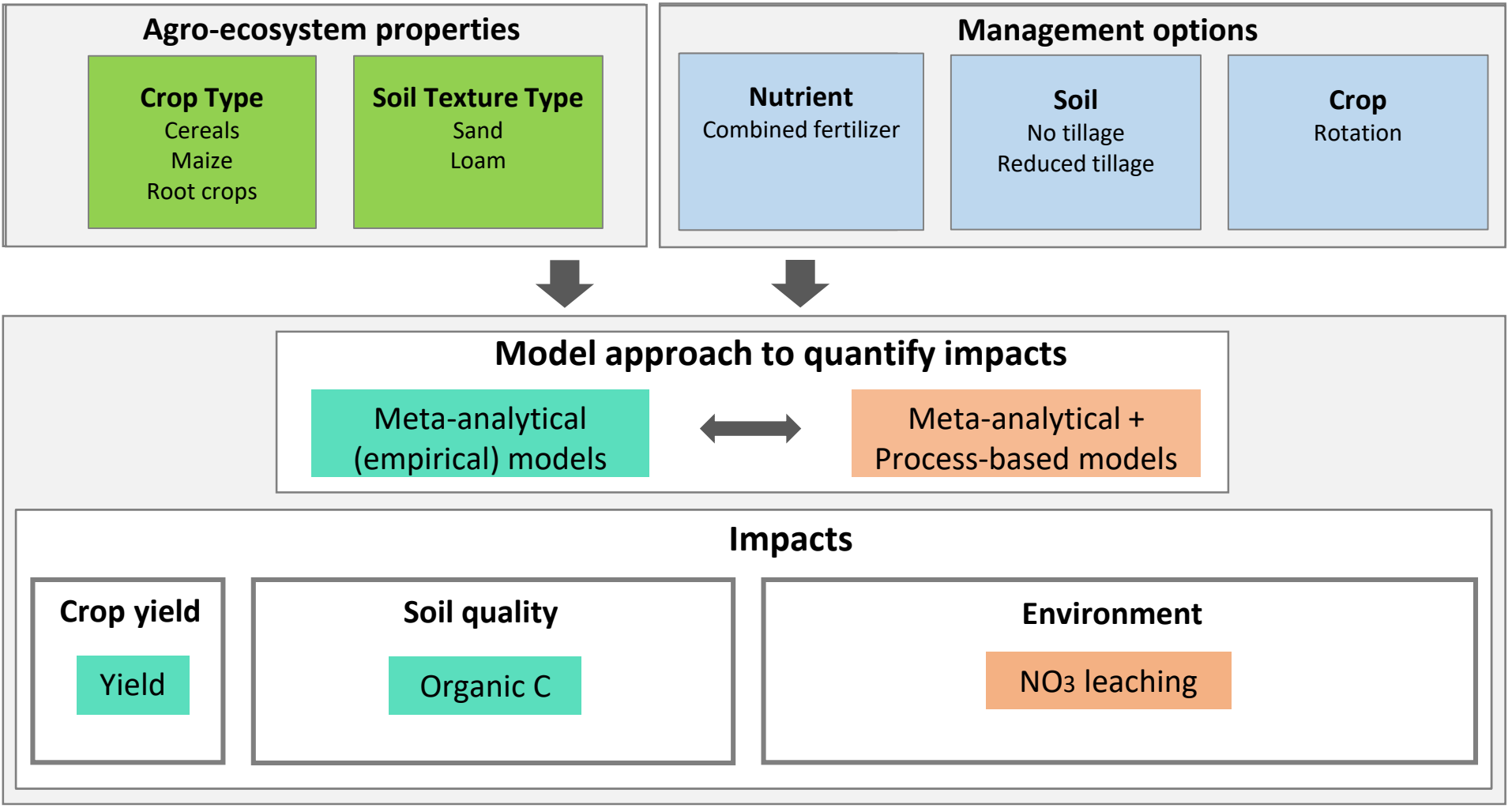
Multiple meta-regression approach

- Assess influence of “moderator variables” → outputs tailored to specific climate/soil/crop
- Assessing all factors together + interactions



$$Y = a * MP + b * soil + c * climate + d * crop + interactions$$

Where ***Y*** = value of soil index (e.g. yield, C, NUE, PUE, ...)
MP = independent variable management practice
soil = independent variable soil type
climate = independent variable climate zone
crop = independent variable crop type
a, b, c, d = estimated coefficients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Agro-ecosystem properties

Crop Type
Grassland
Cereals
Maize
Root crops

Climate Zone
Northern
Western
Eastern
Southern

Soil Type
Sand
Loam
Clay
Silt

Management options

4R Nutrient
Right source
Right rate
Right timing
Right placement

Soil
Tillage
Mechanical operations
Leaching/runoff control
...

Crop
Crop rotation
Inter/Multi-cropping
Residue management
...

Model approach to quantify impacts

Meta-analytical (empirical) models ⟷ Meta-analytical + Process-based models

Response variable outputs (changes in impacts)

Crop yield
Yield

Soil quality
Organic C
P Use Efficiency
Compaction
N Use Efficiency

Environment: emissions
CO_2
N_2O
NH_3

Environment: leaching
P
NO_3

Adaptable weighting procedure

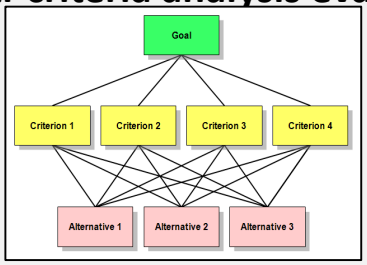
User goals

Target values

Critical limits

Multi-criteria analysis evaluation

Multiple objectives →

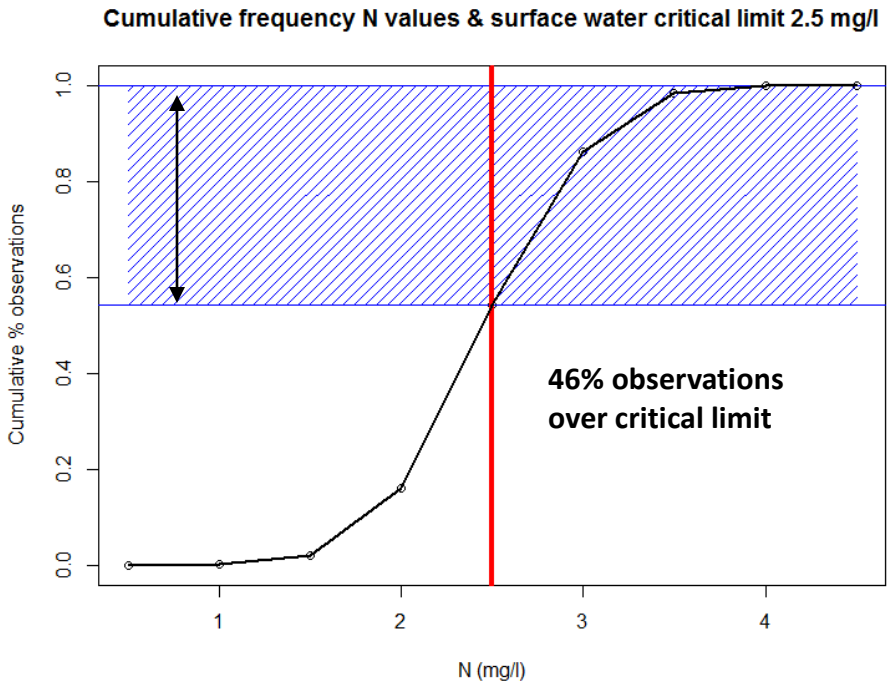


→ Rankings of management options

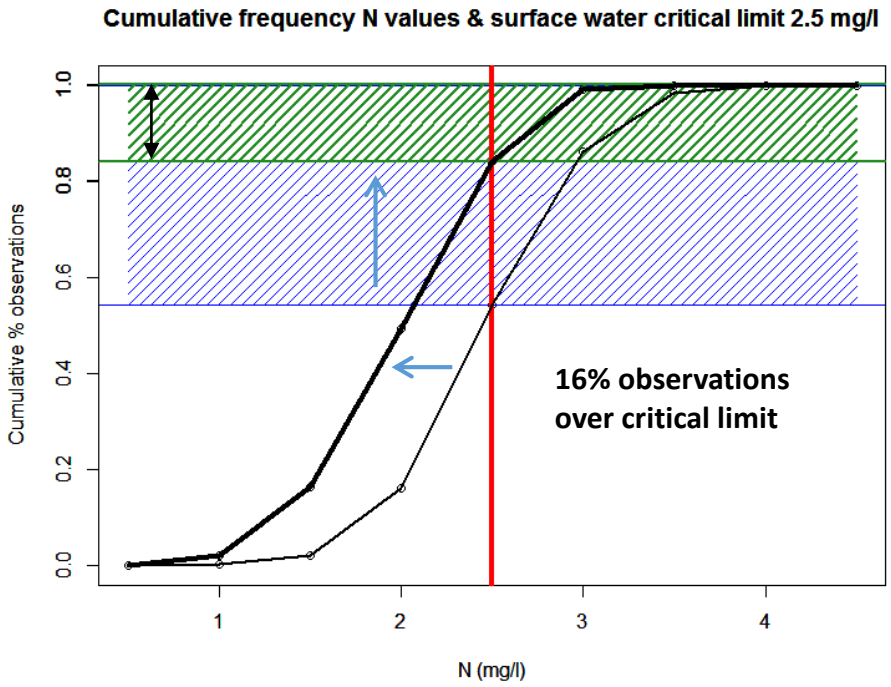
Weighting

- Frequency distributions based on ranges of input data

Control



Control plus management measure



Conclusion

- Local decision based on:
  - Agro-ecosystem properties
  - Integrated recommendations

- Next steps: improving the model!
  - Meta-analysis: NUE/PUE, compaction
  - Process-based / long-term

Meta-analysis publications

Aguilera et al. (2013)
McDaniel et al. (2014)
King & Blesh (2018)
Zavaratto et al. (2017)
Virto et al. (2012)
Ogle et al. (2005)
Meurer et al. (2018)
Spiegel et al. (2014)
Hijbeek et al. (2017)
Pittelkow et al. (2015)
Van den Putte (2010)