Methodology for target-oriented water, N and P fertilizer requirements in crop production

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  - Program SSFS, project A1, wp 1
- Hypothesis and general approach
- Basic methodology
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  - Water, N and P requirements
- Interactions between water, N and P
- Data requirements
  - Crop, soil, weather
- Discussion & options for cooperation

Background: a global challenge

Globally we need:

- More food production to satisfy growing demands;
- More efficiency e.g. to minimize biodiversity losses;
- More inputs to sustain higher production (?)

Program Sustainable and Smart Food Supply:

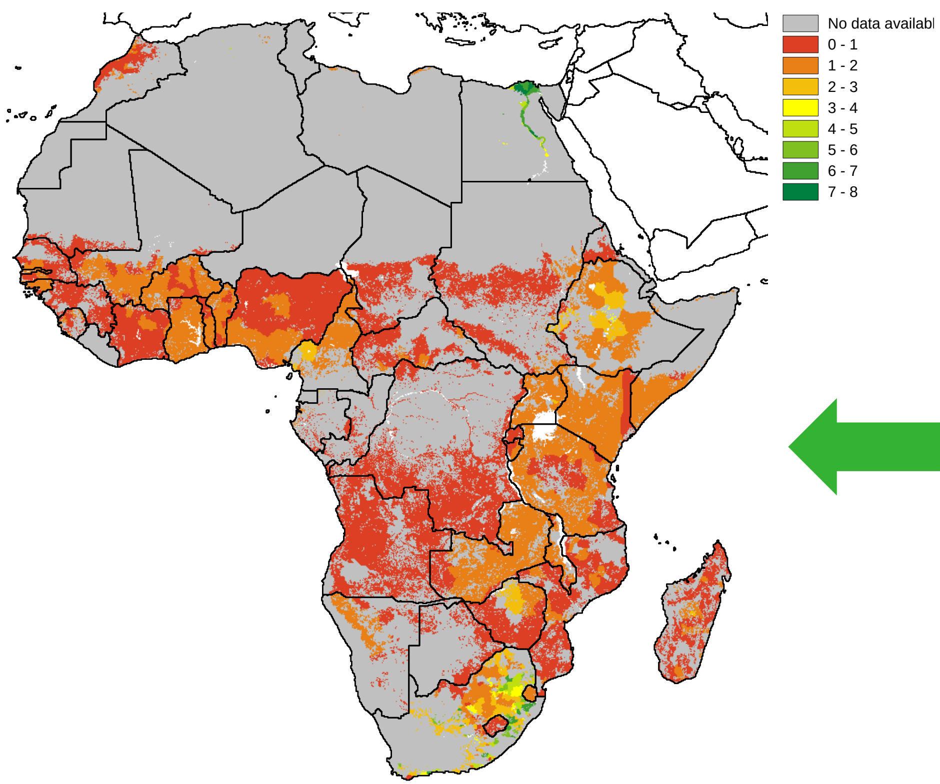
Develop benchmarking atlas to reveal options for sustainable intensification (where and how)

Project A1: *... to benchmark N, P and water use and use efficiencies against theoretical limits ...*

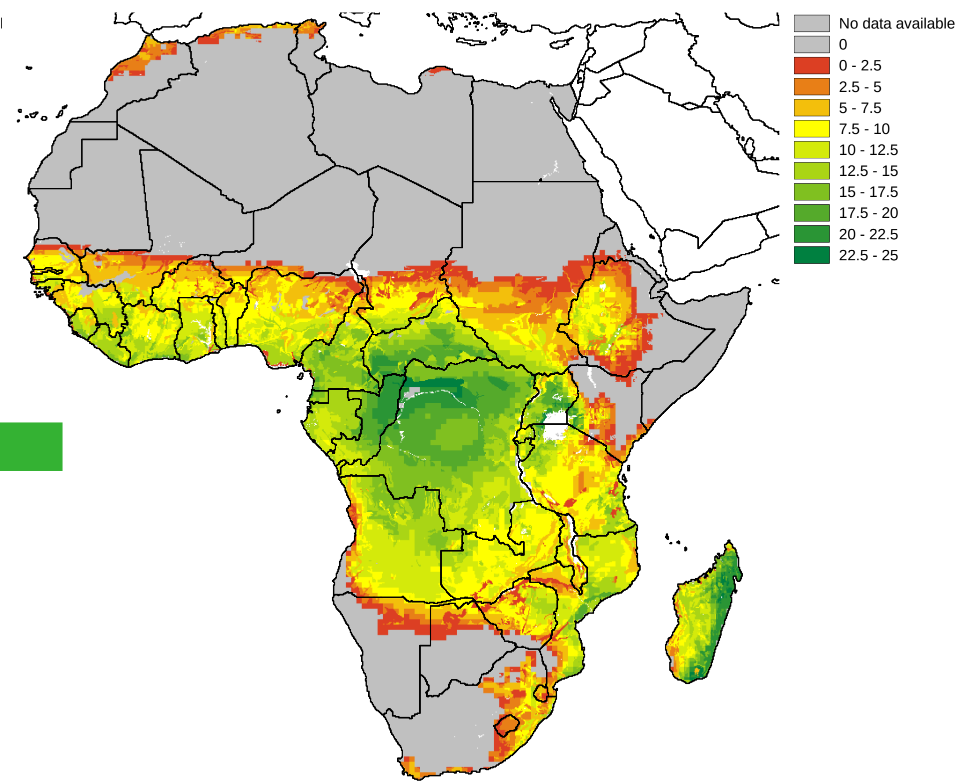
(... in analogy to using potential and water-limited production levels in a yield gap analysis ➔ *nutrient gap analysis*)

How to use potential production estimates to improve actual yields ?

Avg maize yld around the year 2000 (tonnes dm per ha per harvest)



Calculated rain-fed cereal yield (tonnes DM per ha per year)



Actual maize grain yield (2000)

Monfreda et al. (2008)

Rain fed cereal grain yield (calc)

Conijn et al. (2011)

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Project A1: overview of whole project plan

Project A1
wp 1 (methodology development) linking sub-models additional modelling and parameterisation study N loss equation and soil P supply publication **wp 2 (test cases)** searching for exp. datasets comparing model results with data publication **wp 3 (up-scaling)** development of methodology application for crops/countries database for benchmark Atlas

Work package 1 of project A1

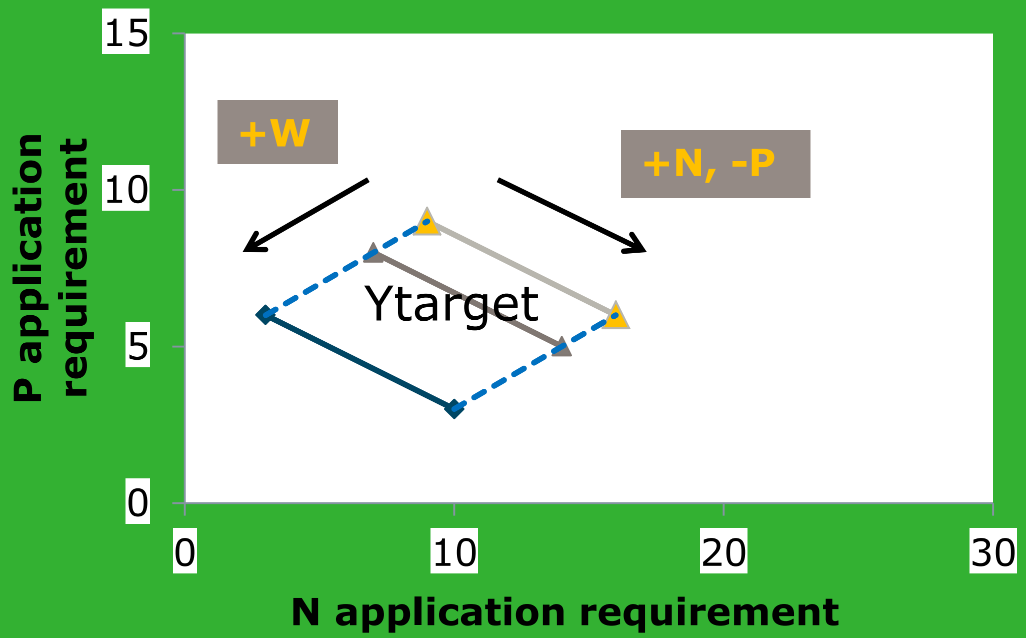
➔ *Methodology for determining the "theoretical limits"*

N, P and water use (efficiencies) depend on interactions, local conditions and target yields, and actual input use can be above or below theoretical limits (e.g. over- and under-fertilisation).

Main research question: how to calculate the minimum N, P and water input requirements for a target yield while improving or maintaining soil fertility.

De Wit (1994): *... what fertiliser rates are needed to realise a given yield target in such a way that the fertility of the soil is brought to or maintained at its corresponding equilibrium level.*

Hypothesis: realising a specific target yield has multiple solutions



Sustainable boundary conditions:

- Soil N in equilibrium (N mineralization = organic N input)
- Soil P in equilibrium or increasing towards equilibrium

General approach

QUADMOD:

A flexible tool to evaluate crop responses to nutrient input

Characteristics:

Static, empirical, seven parameters, three-quadrant approach (3rd: Biomass Yield as function of N dose)

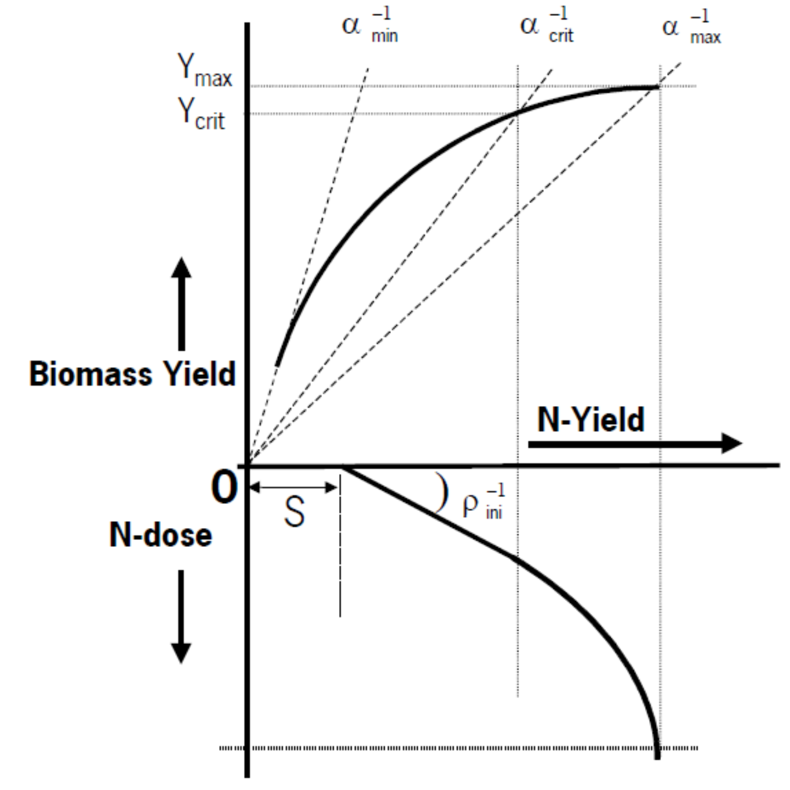


Figure 2.1. Graphical representation of the QUADMOD core model.

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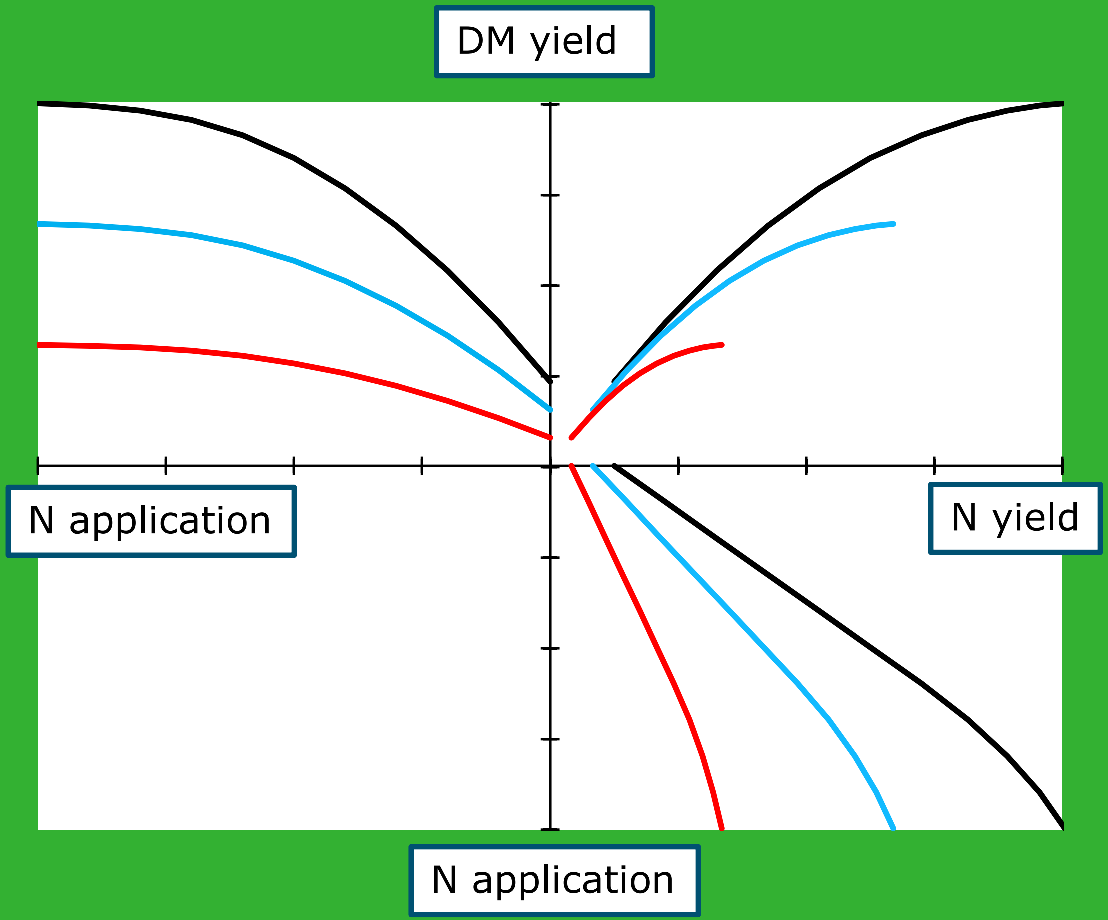
Ten Berge et al. (2000)

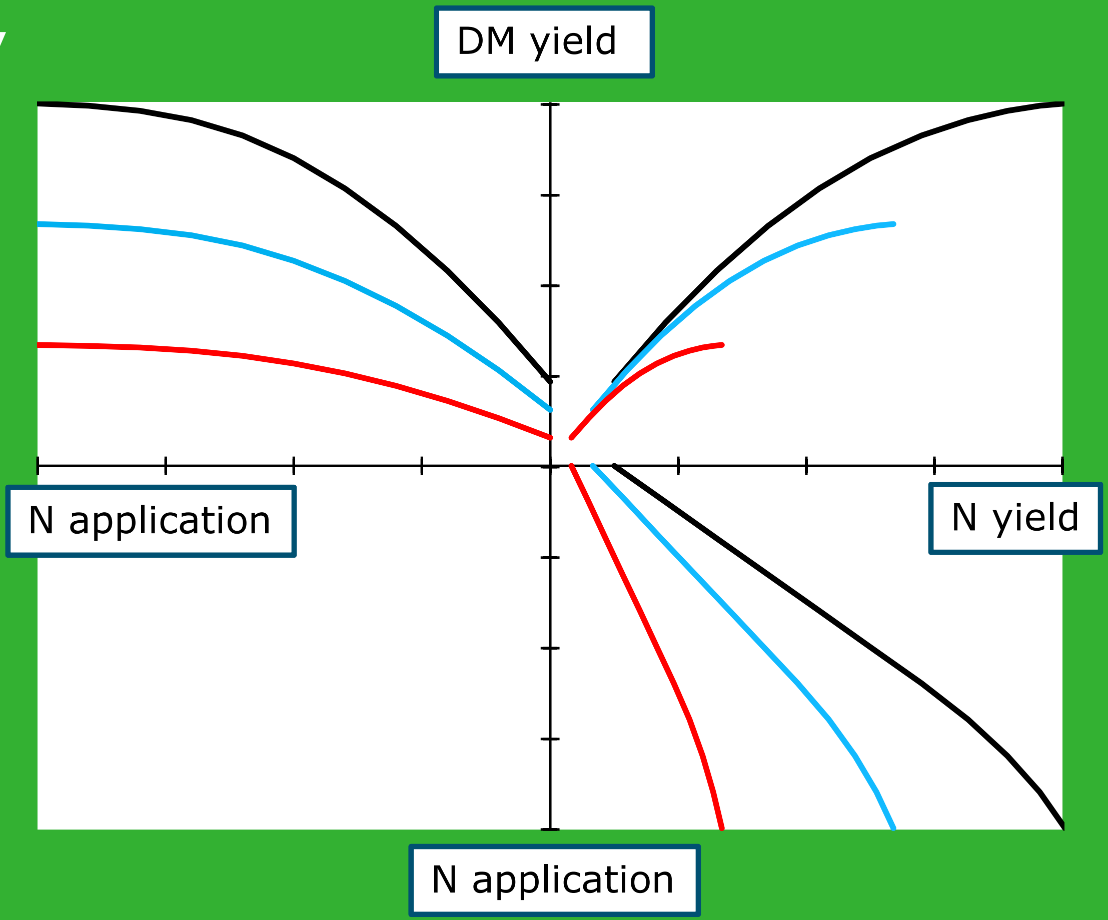
Three QUADMOD examples

Input parameters (e.g. grain maize and N)		
Ymax	9	3
Nzero	20	6.7
Rini	0.4	0.13
Fcrit	0.9	0.9
N%max	0.019	0.019
N%crit	0.014	0.014
N%min	0.009	0.009



Interactions (1): effects of water availability

Assumed: no P limitation, different Ymax refer to different water availab.



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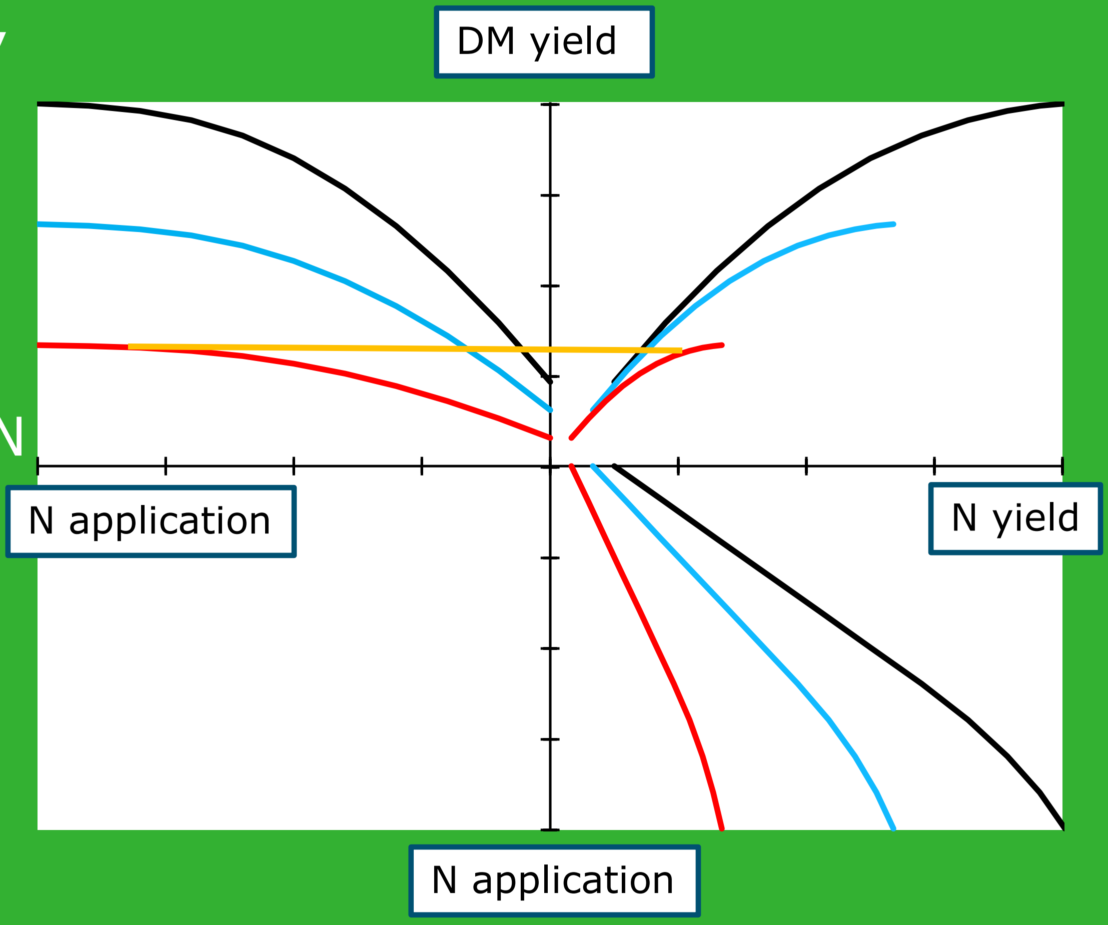
Horizontal line (Ytarget): improved water availability causes lower N requirement



Interactions (1): effects of water availability

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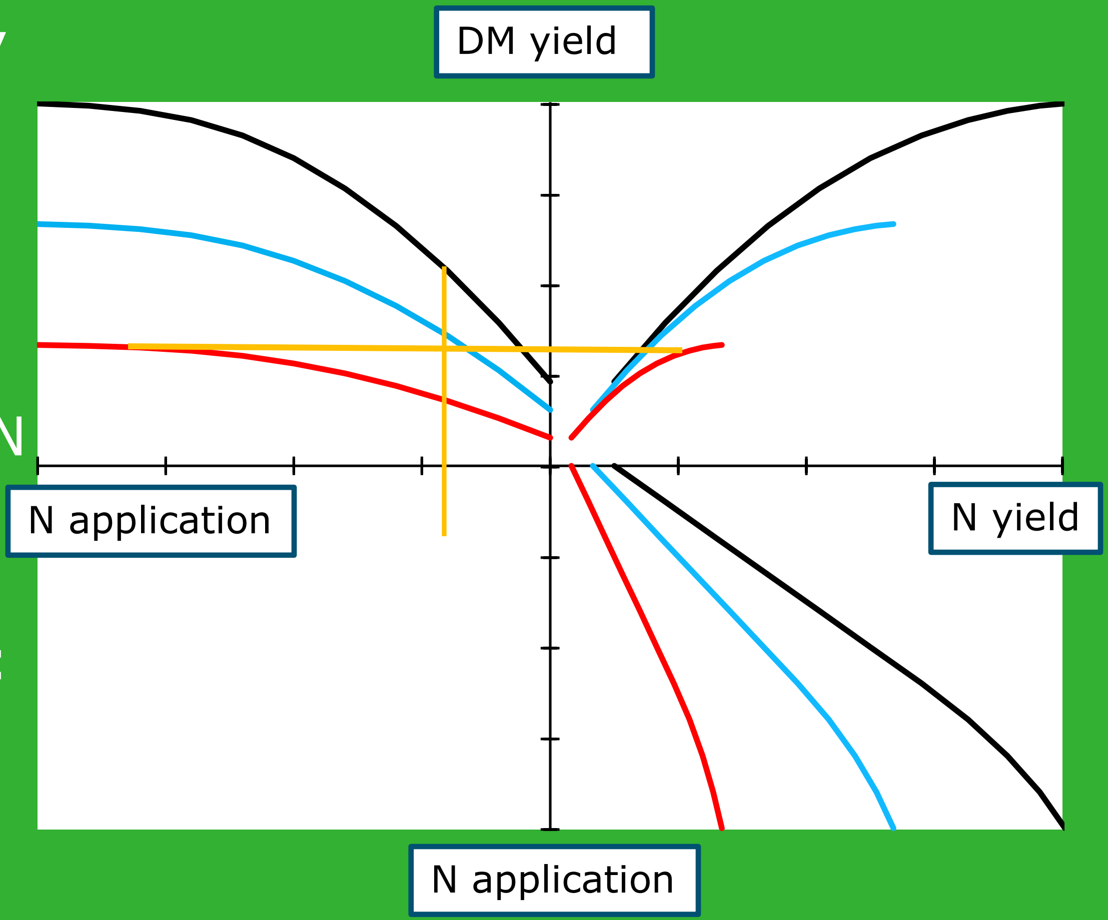
Horizontal line (Ytarget): improved water availability causes lower N requirement

Vertical line (N applicat.): improved water availability causes higher DM yield



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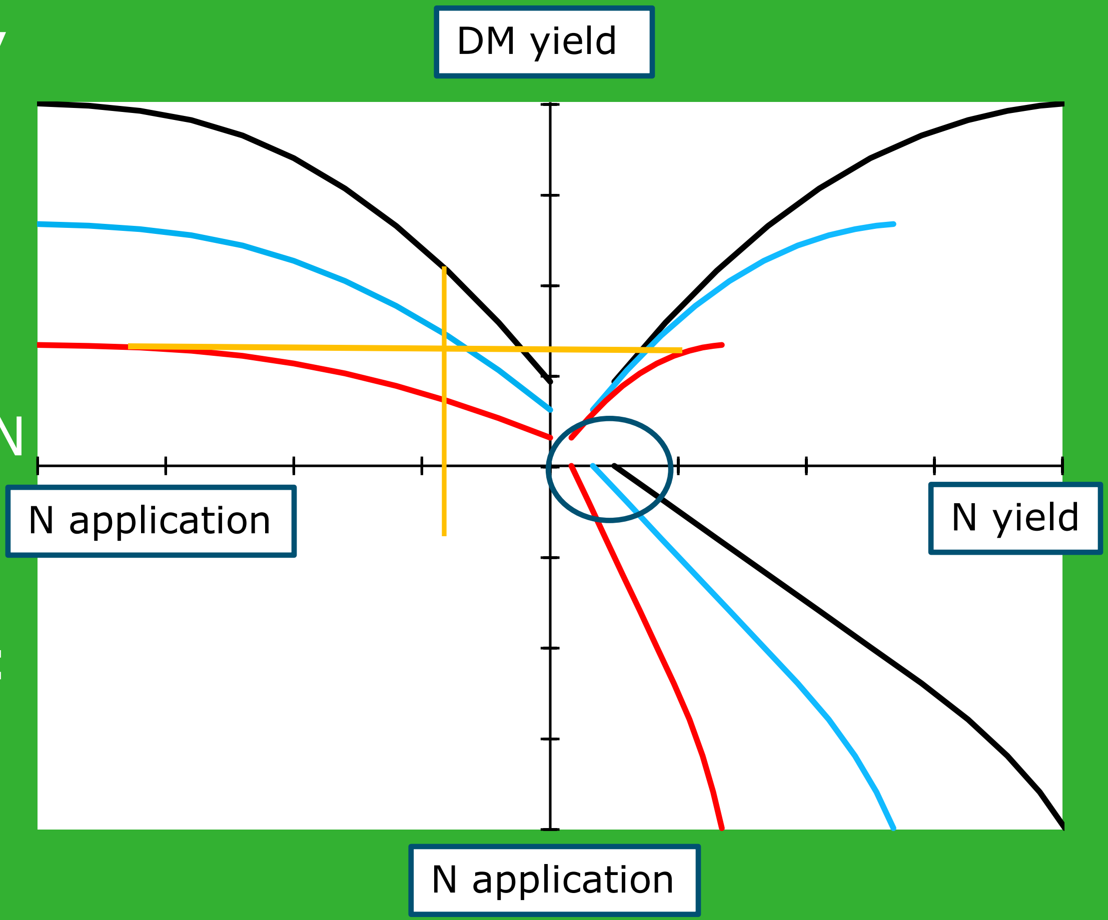
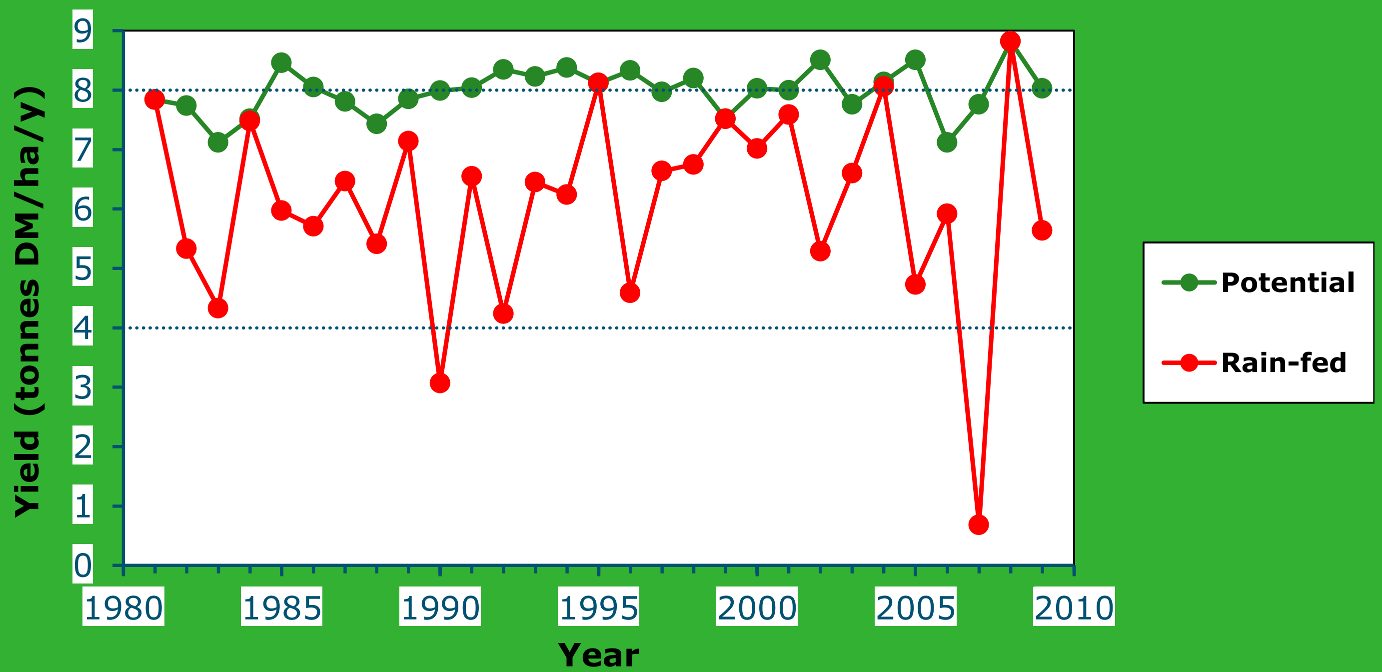


Nzero & Rini also affected by the water balance

Example: Ymax variability (grain maize)

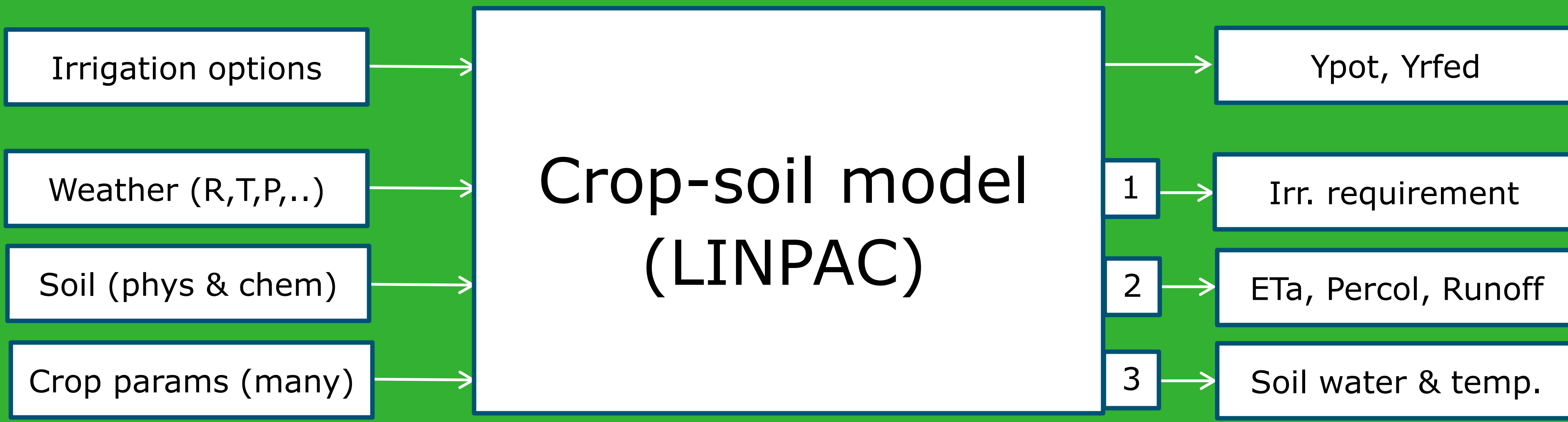


Case 1 (green), irrigated: low variability

Case 2 (red) , no irrigation: high variability

Source: LINPAC model

Calculating Ymax for different water availability conditions



Ad. 1: in calculating Ypot (irrigated) and Yrfed (not-irrigated), availability of nutrients is assumed to be non-limiting

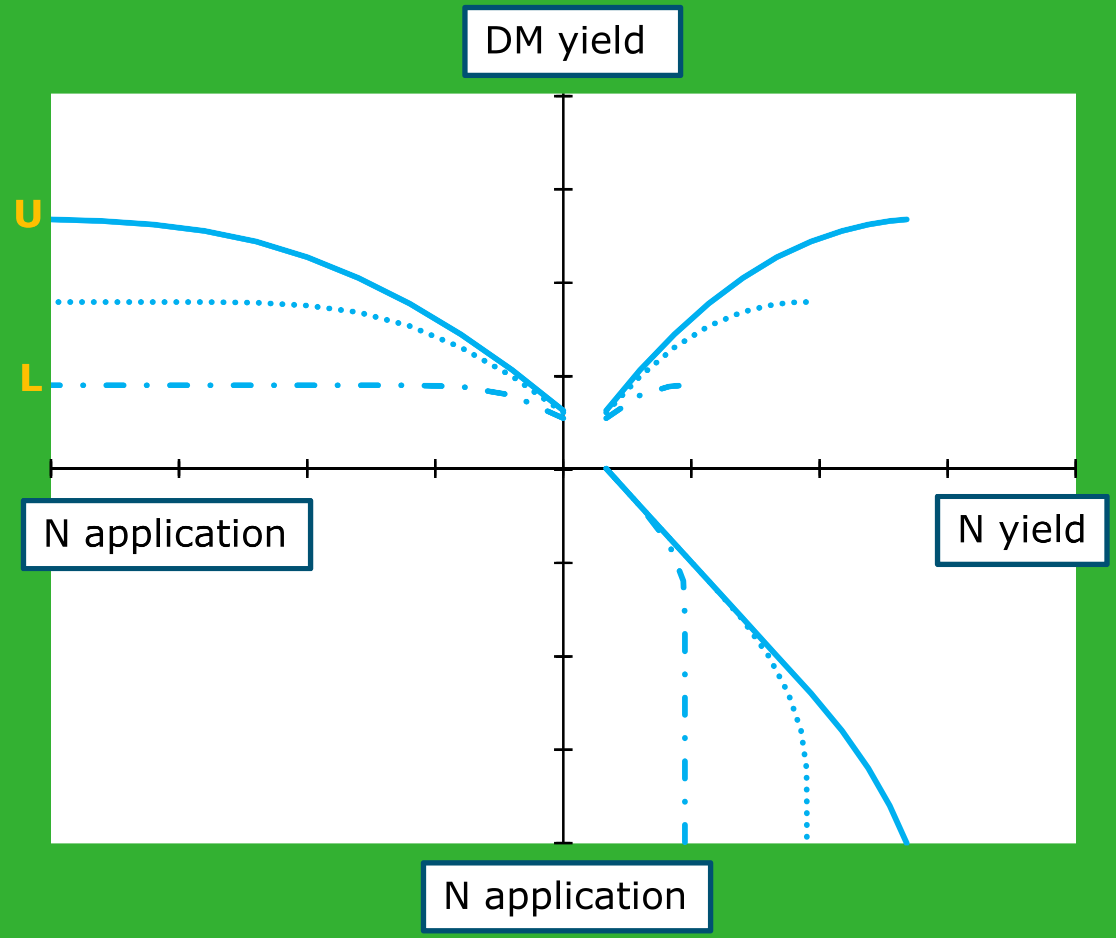
Ad. 2: a relation between yield and the related water balance will be established to find variables of 1, 2 and 3, consistent with Ytarget

Interactions (2): effects of P availability

Assumed: water supply equal, but high, medium and low P supply cause different Ymax values

YmaxU = Yrfed or Ypot

YmaxL = Ytarget



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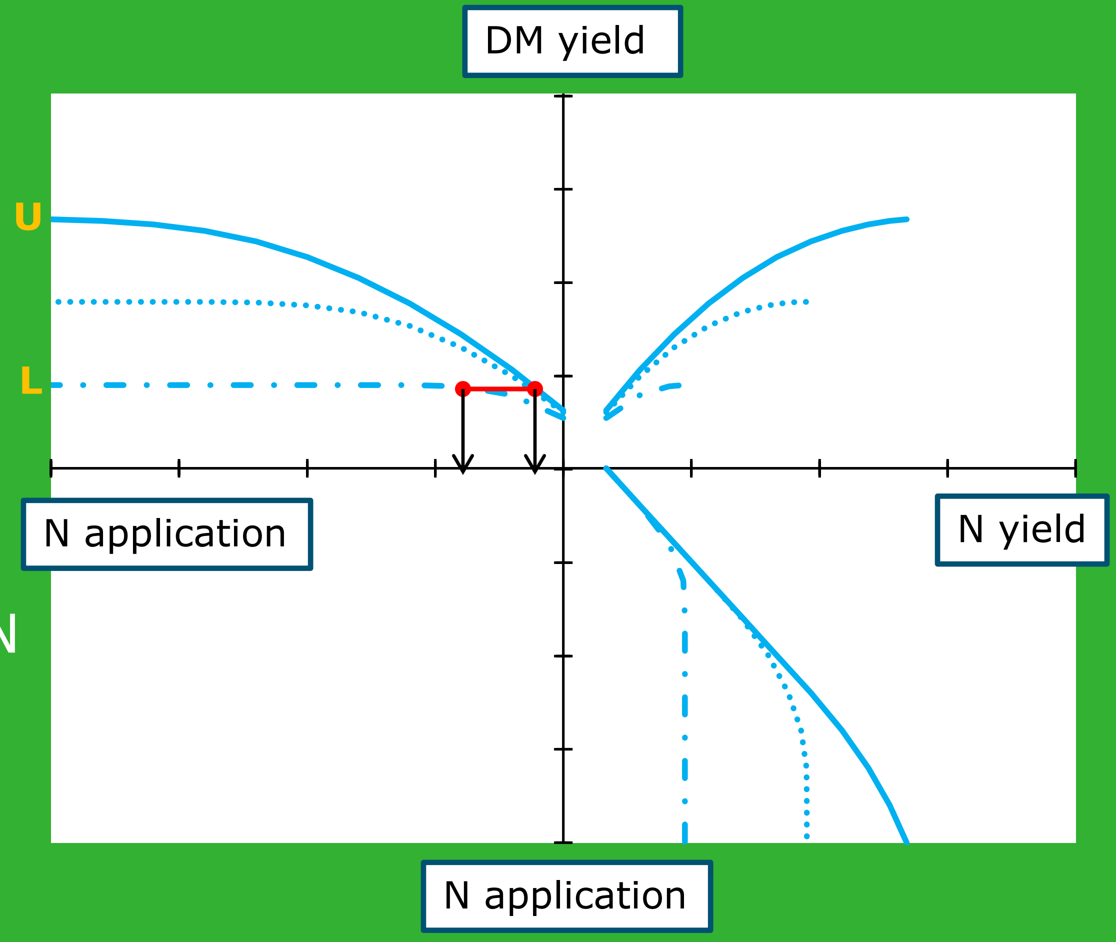
Interactions (2): effects of P availability

Assumed: water supply equal, but high, medium and low P supply cause different Ymax values

YmaxU = Yrfed or Ypot

YmaxL = Ytarget

High P (U) gives lowest N requirement and low P (L) gives highest N requirement



Determining P application consistent with N concentrations and target yield

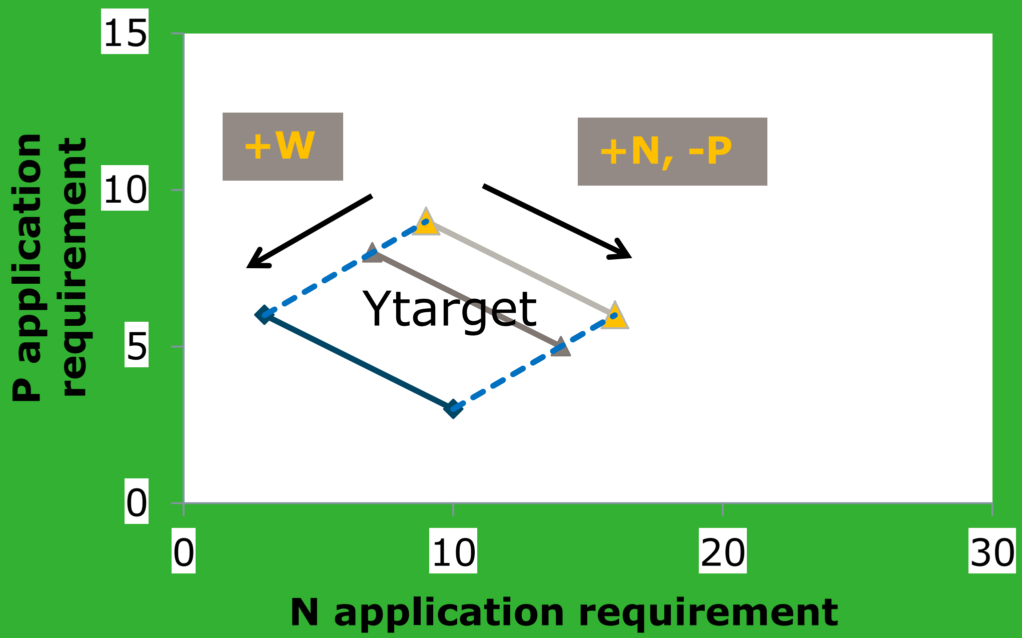
1. Find the P concentrations corresponding with the low and high N concentrations (as function of Ytarget; min. and max. P concentrations and min. and max. N:P ratios)

2. Two points of the total range of possible crop nutrient contents to realise Ytarget, i.e. : lower N% with upper P% and upper N% with lower P%

3. Calculate P application rates as function of P yields and soil P availability (two values: lower and upper value) by using a crop soil P model

Crop soil P model

Summary of the methodology



Ad 1. Two N and P levels calculated; a lower N and a higher P and vice versa. This can be done for different irrigation options ("solution space").

Ad 2. Solution spaces can also be drawn for e.g. N and P concentrations or N and P losses and give different optimisation options

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Challenges of the methodology

- To find data sets on yield, water, N and P use on selected crops (maize (varieties?), wheat, other crops)
- To determine crop N & P distribution (e.g. ratio Nyield / Nplant)
- To calculate the fraction of N lost as function of soil moisture (denitrification) + percolation (leaching)
- To estimate the soil P pools and recovery of P from soil and fertilizers

Data requirements (1): crop experiments

Crop characteristics/management are key factors

1) dates of sowing, emerging, flowering and harvesting, maximum LAI and date, LAI at harvest, light extinction coefficient, light use efficiency, rooting depth, ...

2) Crop response to fertilization and irrigation: DM yield, N and P concentrations, fertilizer application rates of N and P *(from zero application to ample availability levels)* and irrigation treatment (net applied amounts and dates)

3) Internal DM, N & P distribution (e.g. among (a) roots, (b) aboveground biomass and (c) grain) as function of DM yield

Data requirements (2): weather & soil

Local conditions are very important

1) radiation or cloud cover, temperature (min/max), vapour pressure & wind speed, daily precipitation or monthly precipitation and # of wet days per month

2) Soil texture, plant available water holding capacity (FC–WP), porosity, soil depth, slope and a number of soil characteristics (pH, Al-saturation, salt concentration, ...)

3) Soil characteristics that determine P recovery/fixation and soil (in)organic P pools

Data requirements (3): losses

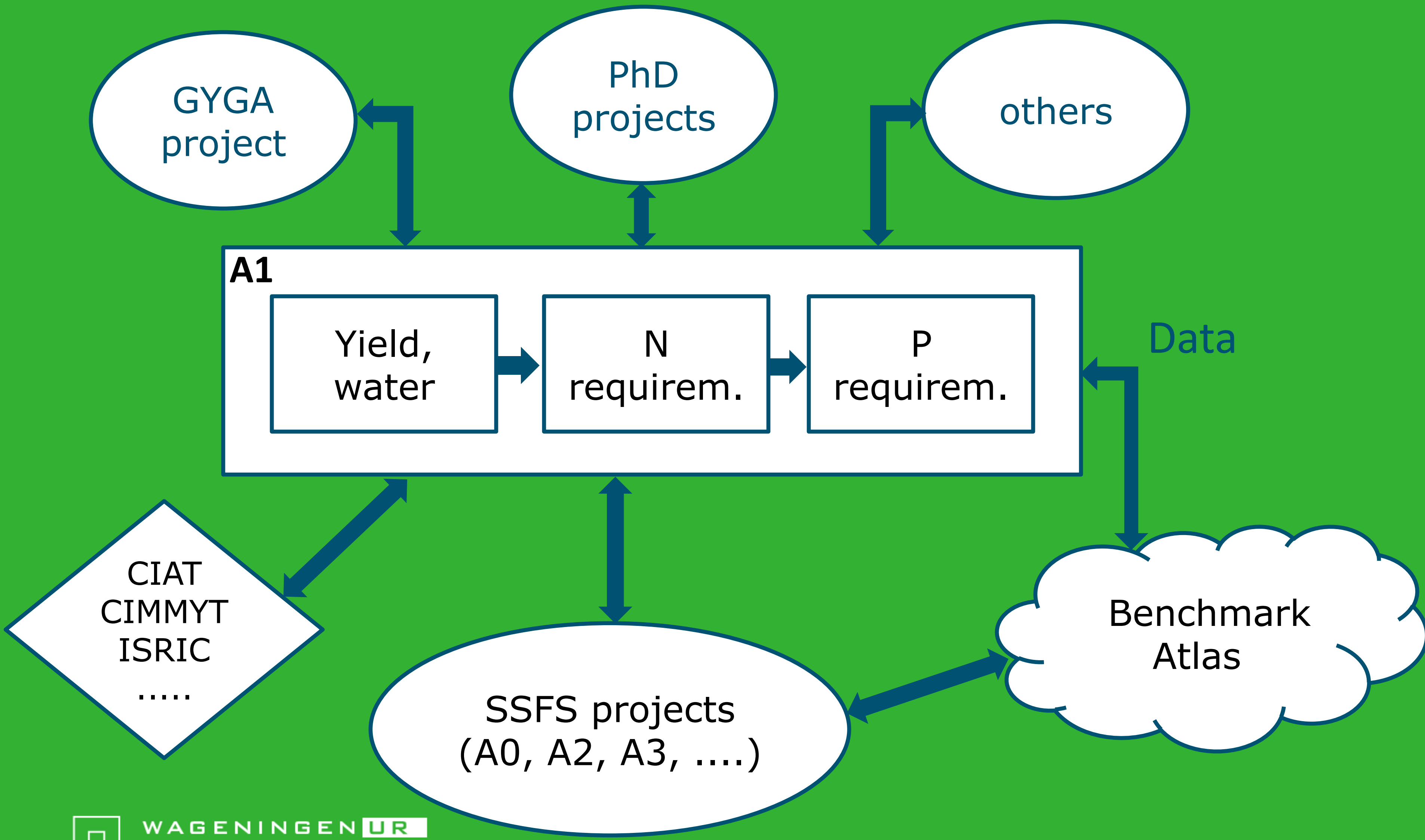
Losses affect input efficiencies/requirements

1) Estimate for runoff (e.g. for net infiltration rate)

2) Losses due to (a) runoff (N & P), (b) volatilization (N), (c) denitrification (N) and (d) leaching (N & P)

3) Estimate for harvest losses

Links of project A1 with other initiatives



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Discussion and options for cooperation

- Discussion
  - The floor is yours, ...

- Options for cooperation
  - Experimental data
  - Crop modelling

The end

Thank you for your contribution

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