



Sustainable intensification in European agriculture – The role of maize nutrient management

Friedhelm Taube

President of the German Maize Committee

Institute of Crop Science and Plant Breeding, Kiel University (Germany)

Special Professor in Grass based Dairy System, WUR (Netherlands)

The challenge: Resilience of agricultural systems

Planetary boundary concept > ,Thresholds‘ and ,tipping points‘

The challenge:

- Maintaining high production level
- Maintaining highest quality level
- Enhancing eco-efficiency =

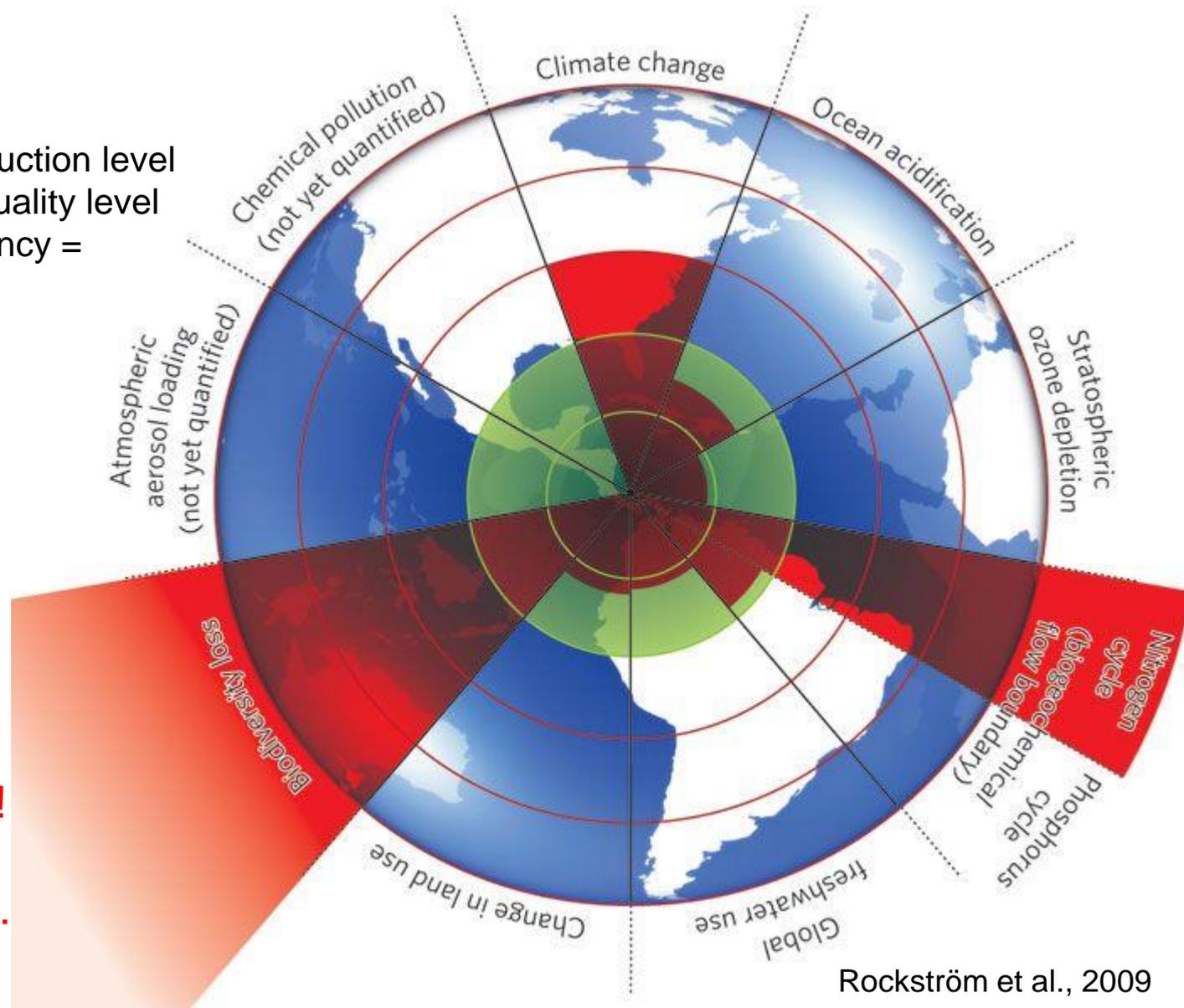
- Milk +
- Blue Water +
- Climate friendly +
- Biodiversity+

- towards

**Ecological
Intensification!**

**Also in forage
Production systems!**

Three approaches...



Rockström et al., 2009

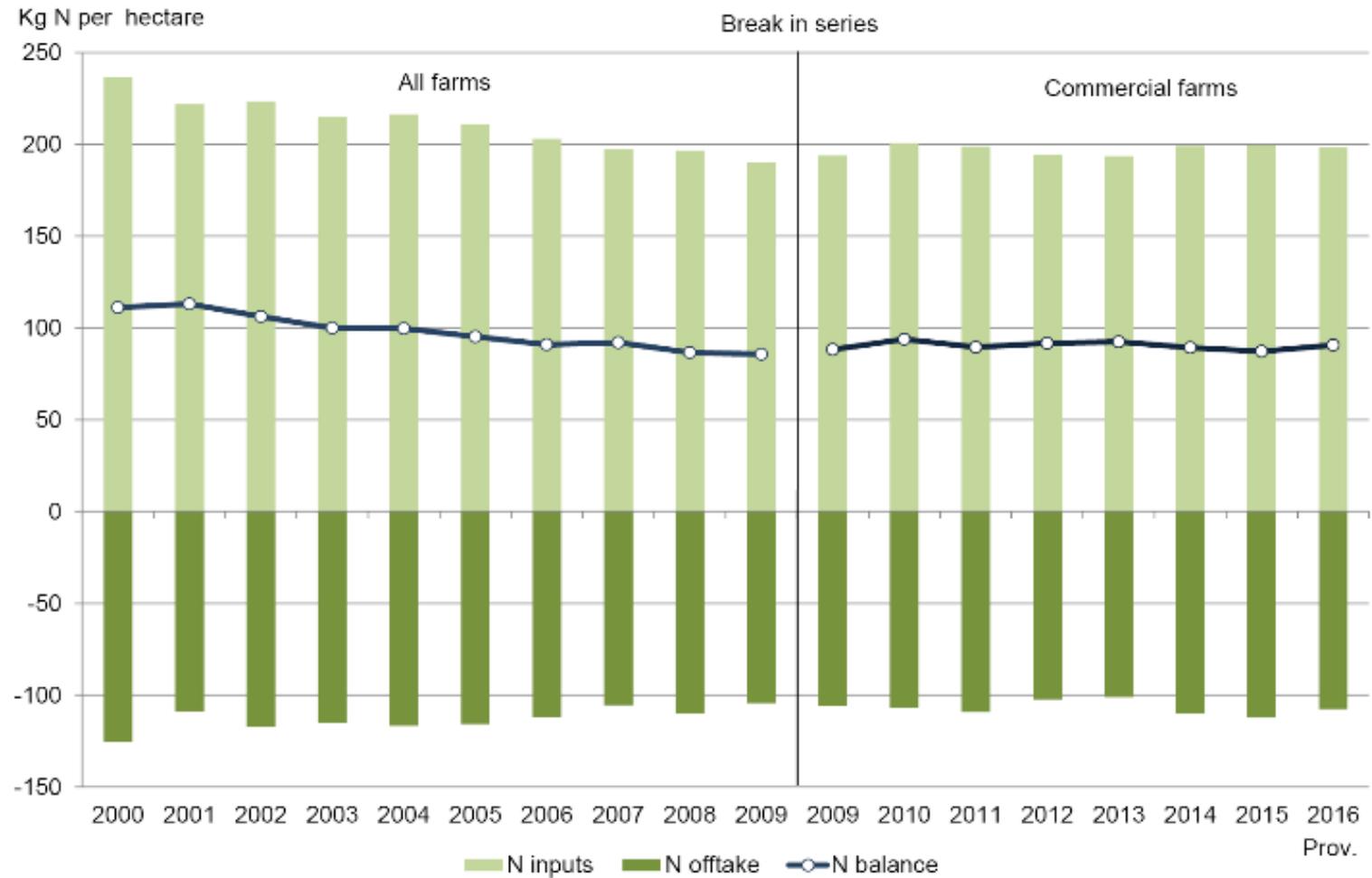


Research towards ecological intensification in grass & forage science

- **Reduced N footprint:** ‚Critical Nitrogen‘ concept maize
- **Reduced carbon footprint:** ‚no till maize‘
- **More with less:** breeding progress forage maize
- **Conclusions**

What do we have to deal with?

Chart 1: Summary of nitrogen balance for UK, 2000 to 2016 (kg N per hectare)



Pathways of reactive nitrogen derived from N farmgate figures for NW Germany (~1,2 LU/ha)

Calculations from different sources from the literature

Lit. u.a.: Wachendorf et al., 2004; Lampe et al., 2006; Rotz et al., 2005; Kelm et al., 2007, Svoboda et al., 2013; Dittert et al., 2005; Taube et al., 2013; Quackernack et al., 2014; Herrmann et al., 2015; Poyda et al., 2016)

N-surplus (kg/ha)	+ 100
N-losses leaching (NO ₃ ;NH ₄ ; DON)	- 37
N-losses ammonia emissions (NH ₃)	- 30
N- losses N ₂ O and/or NO _x	- 8
N- losses denitrification > N ₂	- 20
N- sequestration soils (net)	- 5
balance:	0

... ~ 75% of surplus directly linked to negative environmental effects

How much nitrogen you can apply to your crops

There's a limit on the average amount of manufactured fertiliser and crop-available nitrogen from organic manure that you can apply to most crops each year – this is known as the N-max limit.

These are shown in the following table:

Crop	N-max limit (kilograms of nitrogen per hectare)	Standard crop yield (tonnes per hectare)
Autumn or early winter-sown wheat	220	8
Spring-sown wheat	180	7
Winter barley	180	6.5
Spring barley	150	5.5
Winter oilseed rape	250	3.5
Sugar beet	120	-
Potatoes	270	-
Forage maize	150	

How to prove the reliability of these figures for maize?

...how to use CP analysis from silage maize for good N management of maize crops?

Critical N concentration of forage maize

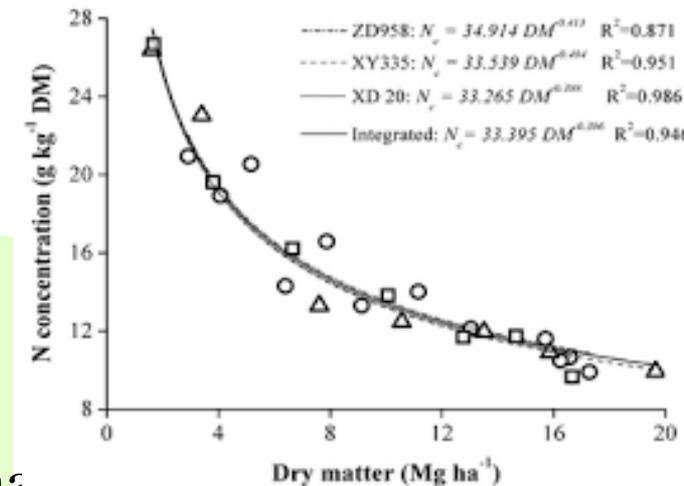
„minimum N concentration in plants needed for maximum growth rate of the crop at a given time“ (Ulrich, 1952)

Plénet & Lemaire (1999):

$$\%N_c = \begin{cases} 3.40 & < 1 \text{ t ha}^{-1} \\ 3.40 \cdot W^{-0.37} & 1 \text{ t ha}^{-1} \leq W \leq 22 \text{ t ha}^{-1} \end{cases}$$

%N_c: crit. N conc. [g kg⁻¹] W: biomass [t ha⁻¹]

Validity: biomass > 1 t ha⁻¹ up to silking plus 25 days



Hypotheses:

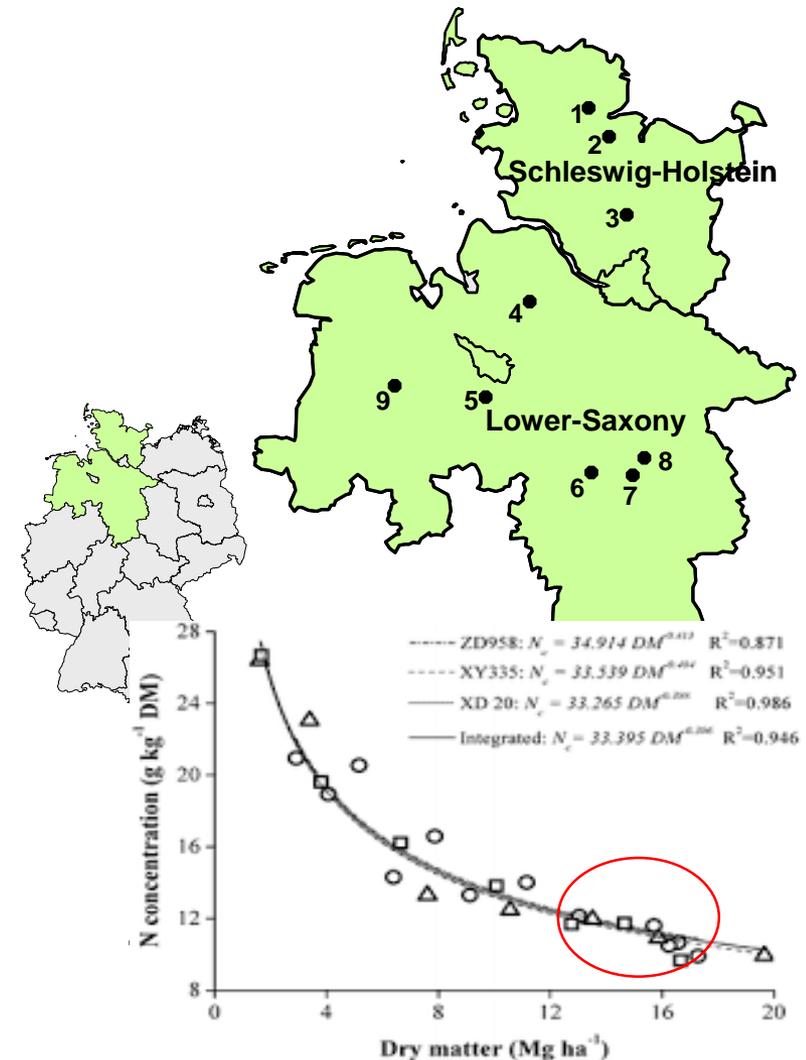
1. Relationship between relative dry matter yield and N concentration at silage maturity provides suitable tool for ex post analysis of N status of forage maize, and allows derivation of critical N concentration (CNC)
2. Compliance with CNC at silage maturity results in balanced N input/output and nitrate concentrations in leachate below the EU drinking water threshold



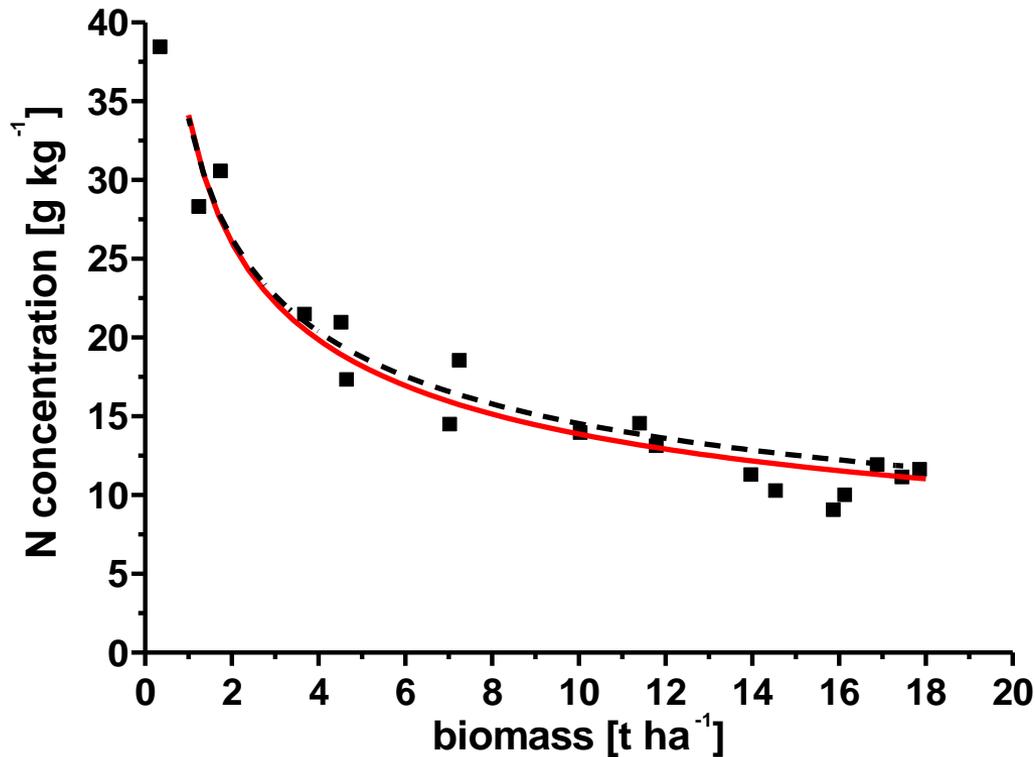
Relationship between relative DM yield and N concentration at silage maturity as ex-post indicator of N status

Data base:

- 9 multi-year field trials from 5 independent projects on sandy soils, in total 29 site-year combinations
- Conducted by University of Kiel, University of Applied Sciences Kiel, and Agricultural Chambers of Hannover, Schleswig-Holstein and Weser-Ems
- Maize grown in monoculture or crop rotation
- Mineral and organic N fertilization
- Sampling at 30 to 35% DM content



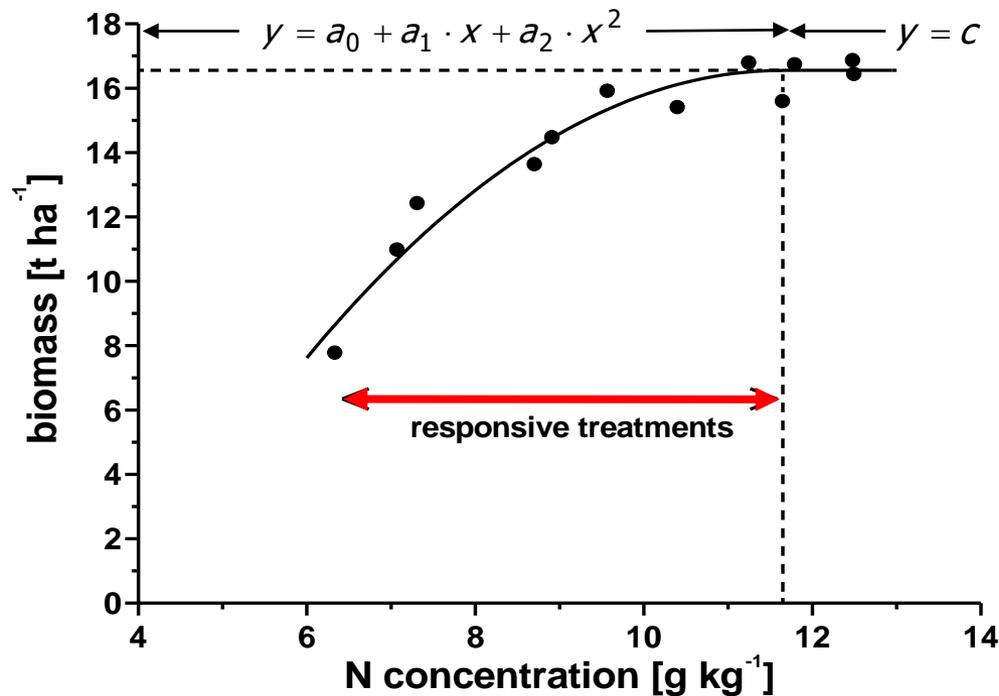
In advance: Verification of critical N concept including organic N fertilization



— $\%Nc = 34.12 \cdot W^{-0.391}$ (Herrmann & Taube, 2004)
 - - $\%Nc = 33.90 \cdot W^{-0.368}$ (Plénet & Lemaire, 1999)

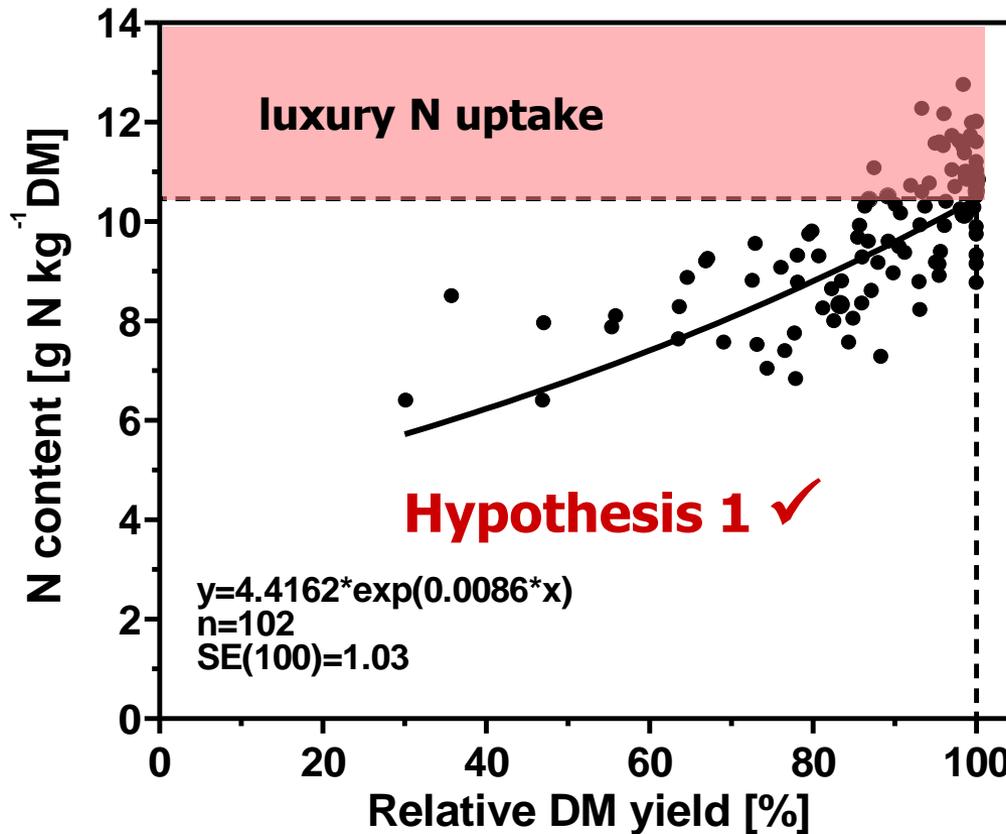


Separating informative from non-informative data sets



15 (out of 29) informative site-year combinations remaining
⇒ pooled set of 102 data points

Derivation of critical N concentration (CNC) at silage maturity

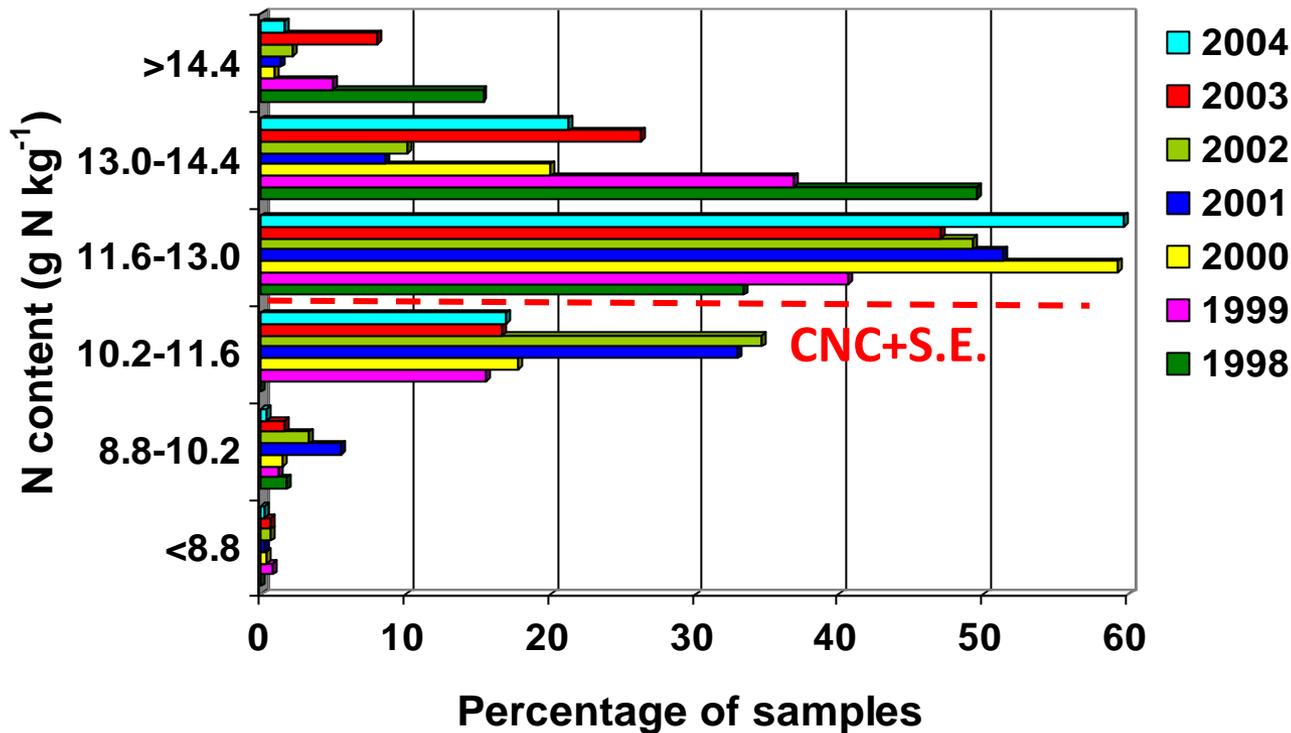


⇒ **Crit. N concentration (CNC): 10.5 g N kg⁻¹ DM**

(Herrmann & Taube, 2005)



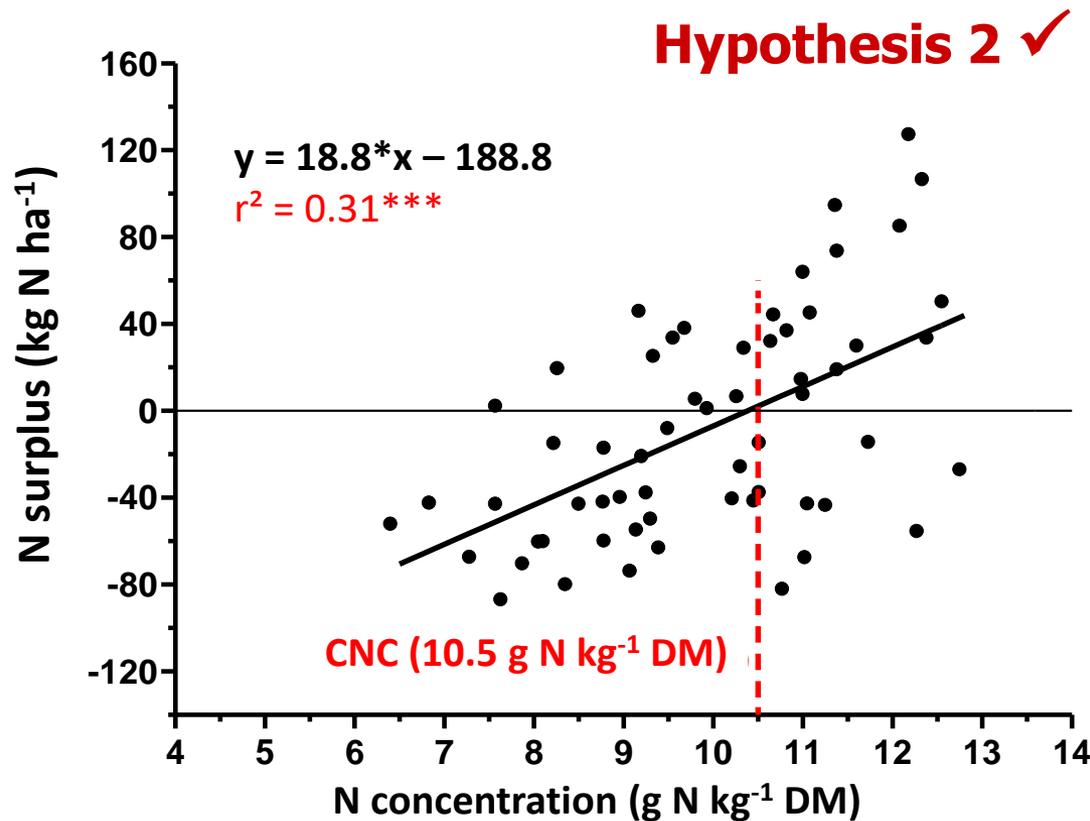
Monitoring N status of forage maize (data: LUFA agricultural lab, Kassel)



Ratio of samples > CNC+S.E.	1998: 98.2%	2002: 61.4%
	1999: 82.4%	2003: 81.1%
	2000: 80.3%	2004: 82.5%
	2001: 61.3%	...'16: ~70%



Relationship between N content at silage maturity and N surplus



Data base: Karkendamm project 1997-2001 including treatments with grass understorey



Maize N concentration at harvest as indicator of N loss potential by leaching

Data base

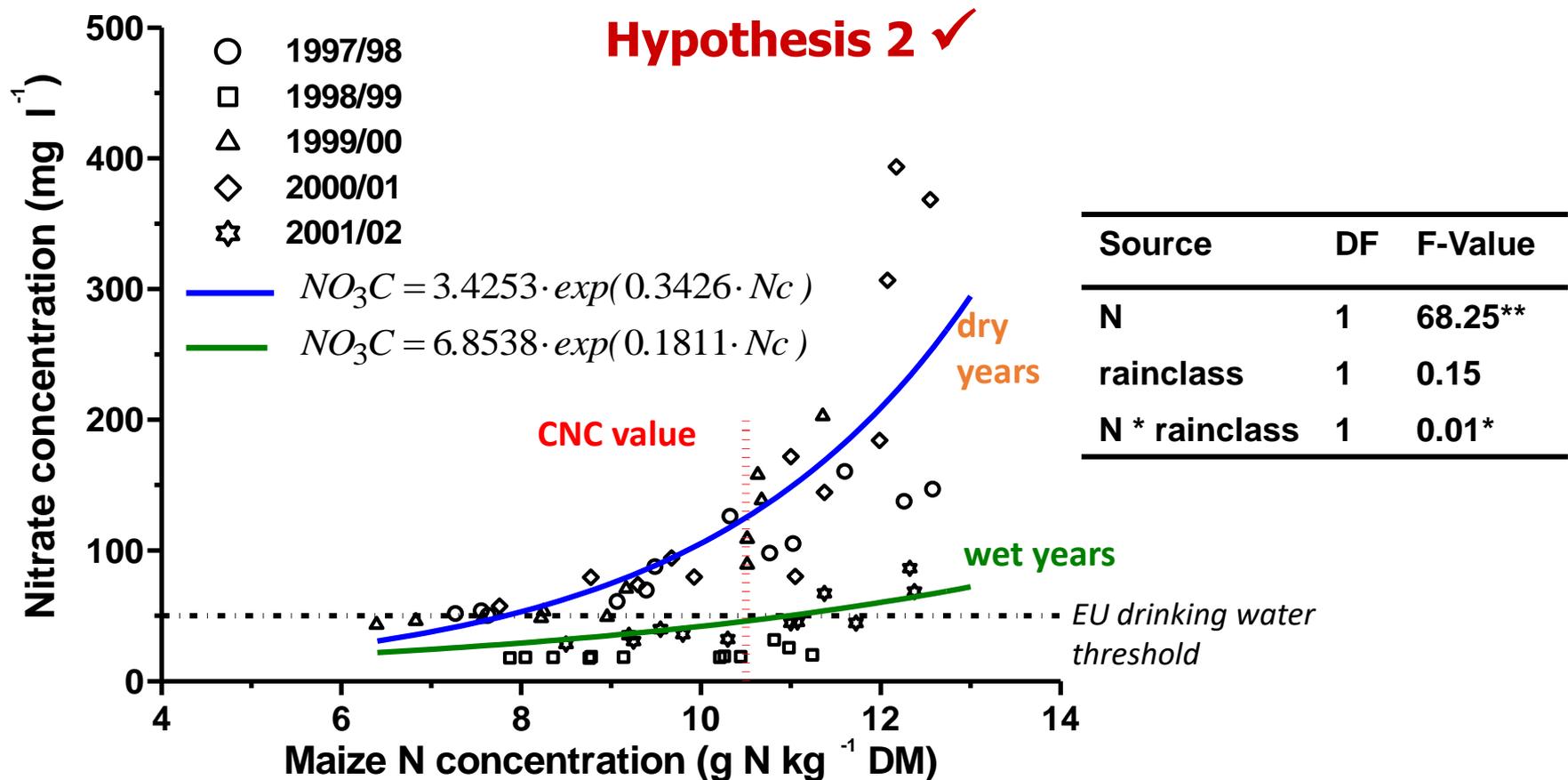
- Maize monoculture experiment of the N-project Karkendamm (1997-2001)
- N fertilization
 - Mineral: 0, 50, 100, 150 kg N ha⁻¹
 - Slurry: 0, 20, 40 m⁻³ ha⁻¹ } 0-298 kg N ha⁻¹
- Leachate sampling by suction cups (60 cm depth) from October to end of March
- Estimation of leaching water from climatic water balance and field capacity

Modeling of water and N fluxes

- HERMES model (Kersebaum, 1995)
- Adaptation of model algorithms to forage maize



Relationship between crop N concentration at silage maturity and simulated mean NO₃ concentration of the soil solution (0-60 cm) of the subsequent leaching period (Oct.-March)



(Herrmann et al., 2005)

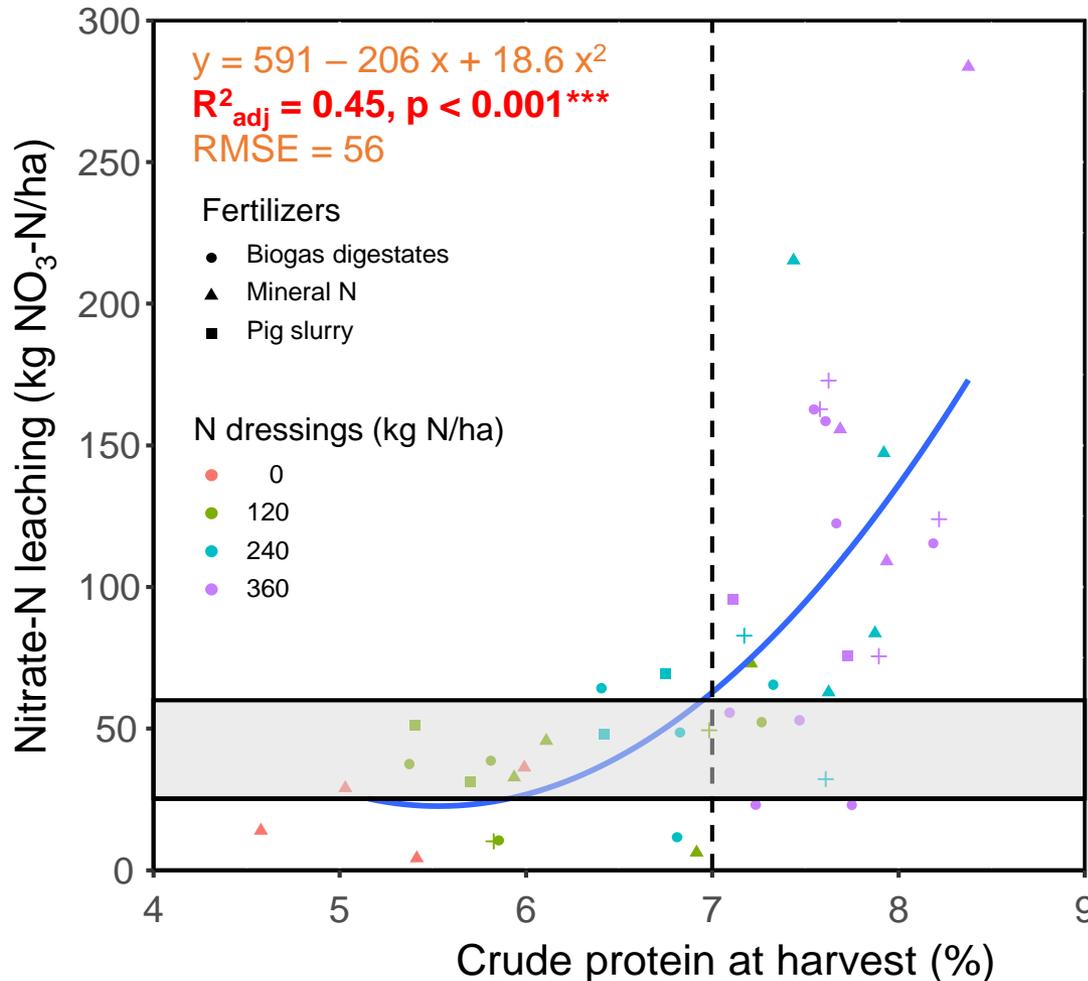
Critical N content and leaching

- ...recent validation data (cv Ronaldino)

Experimental sites: Hohenschulen (loam) und Karkendamm (sand)

Leaching periods: 2007/08 und 2008/09

Grey: range of critical load (50 ppm nitrate in the leachate)



Crude protein maize silage beyond ~7,2% = enhanced N leaching losses

1. Conclusion



- **Maize is a well performing crop in NVZ's due to highest NUE, but...**
 - **N fertilization has to be managed carefully (poor rooting system)**
 - **Crude protein data (%) from maize silage**
 - > **valid tool for ex post analysis of best N management**
 - **6,5 – 7,0 > perfect**
 - **7,0 – 7,5 > reduce N input by 20 kg/ha**
 - **7,5 – 8,0 > reduce N input by 40 kg/ha**
 - **8,0 - 8,5 > reduce N input by 60 kg/ha**
- ...a lot of money for fertilisation can be saved without any yield losses**

No-till silage maize in a grass – maize system

Effects on GHG emissions and
soil organic carbon storage

Struck et al., 2019: Yield potential and
nitrogen dynamics of no till silage maize
European J of Agron.



A project supported by:
**Stiftung Schleswig-Holsteinische
Landschaft**



M.Sc. agr. Inger Julia Struck et al.
istruck@gfo.uni-kiel.de

Christian-Albrechts-Universität zu Kiel
Grass and Forage Science/Organic Agriculture



Ecoefficient production system for forage and substrates:

(temporary grassland + maize via direct drilling)



+



- Comparison with conventional tillage and original grassland

Goal: Conserving SOC stocks – Carbon dynamics

Hypotheses:

- Biomass production (above-/belowground):
seeding technology has no negative impact on dry matter yields and root growth
- CO₂-fluxes & SOC-stocks:
reduced CO₂-losses and lower SOC degradation via no-till

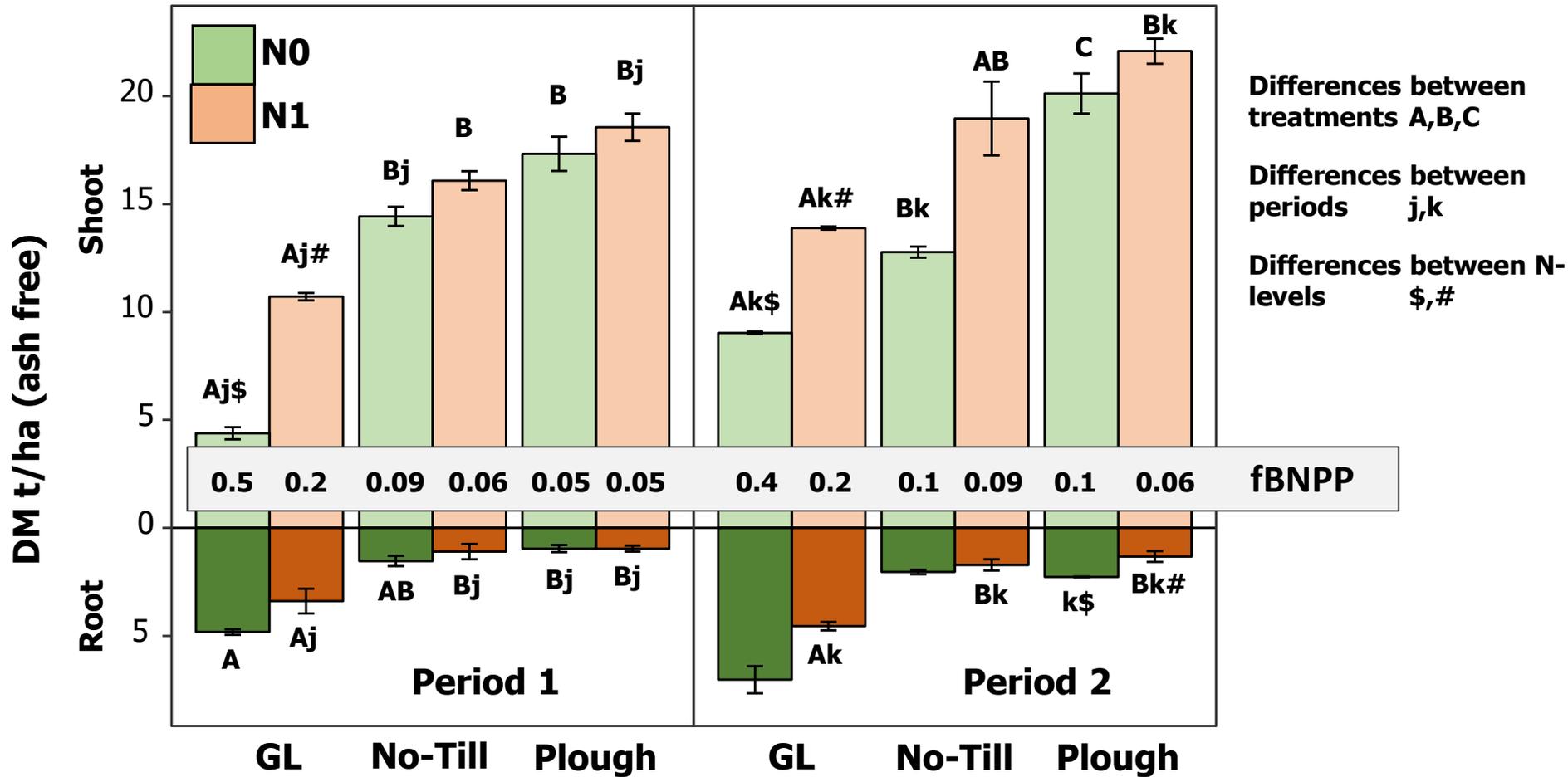
- April 2015 – March 2017
- Sandy-loam texture
- Split plot design, 24 plots
- three rep's for intensive measurement campaigns

- ❖ Mean annual temperature 8.9°C
- ❖ Mean annual precipitation 847mm



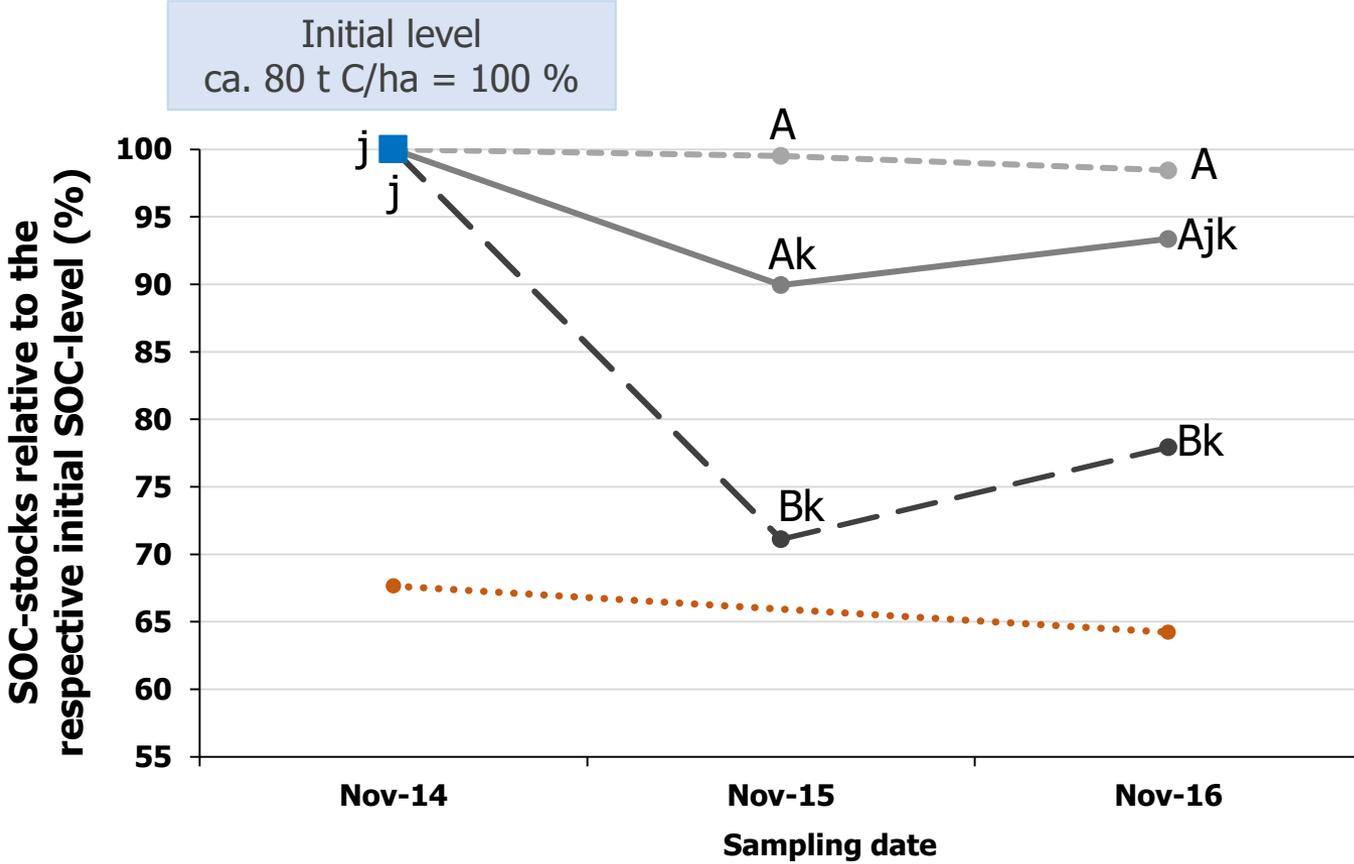
Factor	Factor level
Production system	Control – Grassland (GL), 4-cut Maize following ploughing (Plough) Mais via direct drilling (No-Till)
N-fertilization (CAN)	0 kg N ha ⁻¹ (NO) 380 kg N ha ⁻¹ Grassland (N1) 90 kg N ha ⁻¹ Maize (N1)
Year (for Maize)	Conversion 2015 (preceding crop grassland) Succeeding Year 2016 (preceding crop maize)

Maize variety: **Ronaldinio**
medium early S 240/K 240



Ingrowth core-root biomass in no-till and plough without significant differences
 &
No significant differences in DM-yields in N1 between no-till und plough

Soil organic C stocks - changes



- Grassland
- No-Till
- Plough
- Arable land relative to GL

Different treatments A,B
Different periods j,k

Production system	Δ SOC t/ha (0-30 cm) 2014 – 2016
Grassland	-1.23
No-Till	-5.57
Plough	-19.01

SOC-stocks after 2 years maize in no-till are at a comparable level with those of GL > Hypothesis verified...

II. Conclusion



- **Maize-grass rotations are offering energy & protein for dairy cows**
- **„No till“ maize cropping saves GHG emissions and reduces PCF of milk production**
- **Re-evaluation on glyphosate ban (more with less)?**



Carbomaize project: Which functional traits explain the yield progress of silage maize?

F. Taube, K. Budde, A. Herrmann

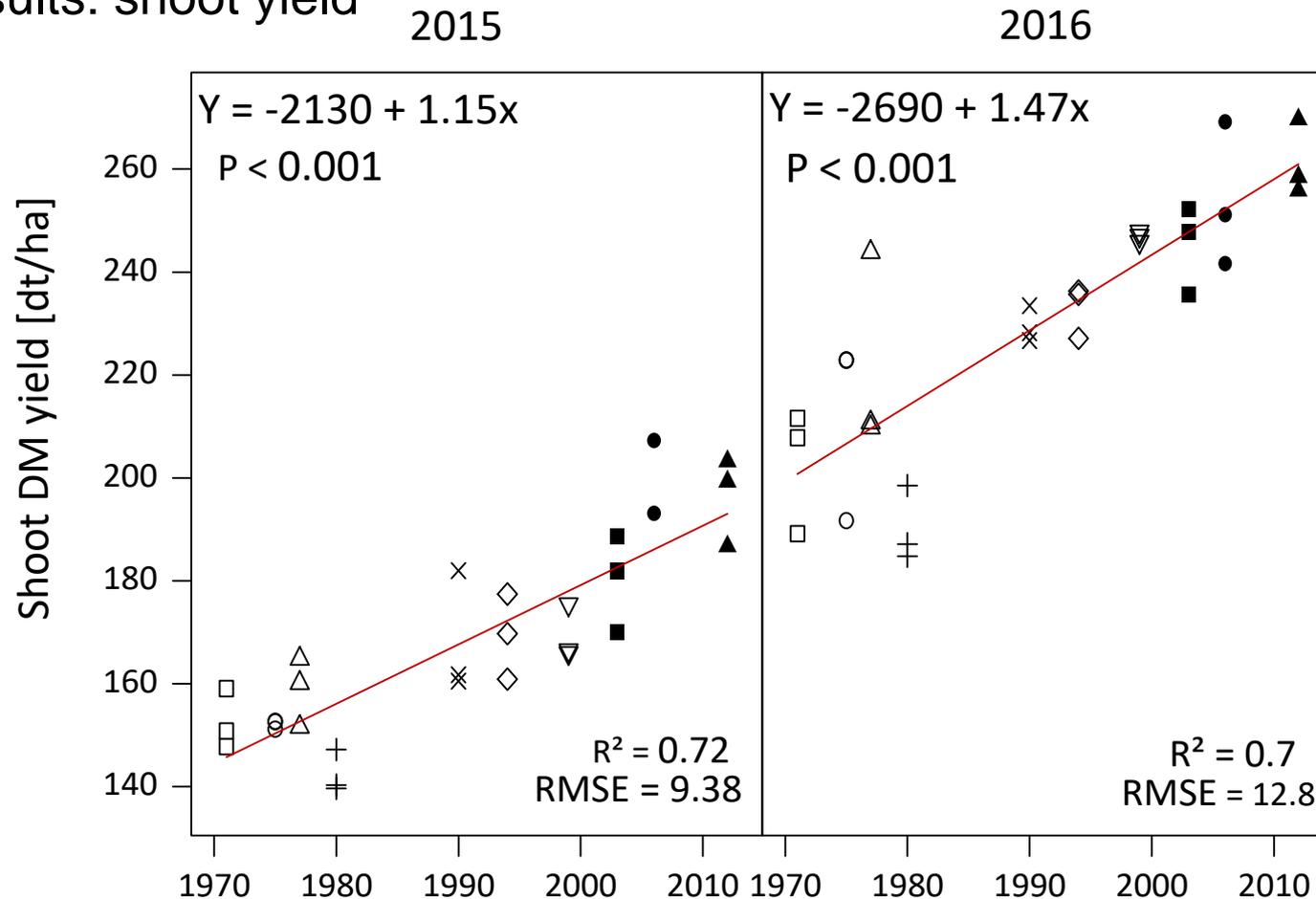
**Grass and Forage Science/Organic Farming
Christian-Albrechts-Universität zu Kiel**

- 2-year field trial (2015-2016), northern Germany
- Randomized block design, 3 replicates

hybrid	release	hybrid form	endosperm type
Brilliant	1971	double	intermediate
Blizzard	1975	three-way	(flint)/intermediate
Tau	1977	three-way	flintlike intermediate
Mutin	1980	three-way	intermediate(flint)/intermed.
Beketrio	1990	three-way	intermediate
Helix	1994	single	intermediate
Oldham	1999	single	intermediate
LG 3232 (Lupus)	2003	three-way	flint-like
Ronaldinio	2006	three-way	flint-like
LG 30224	2012	single	flint-like

- Early/mid-early assortment
- Criteria for selection: importance/yield

Results: shoot yield



New hybrids > higher yields > 1,15 – 1.47 dt/ha/year

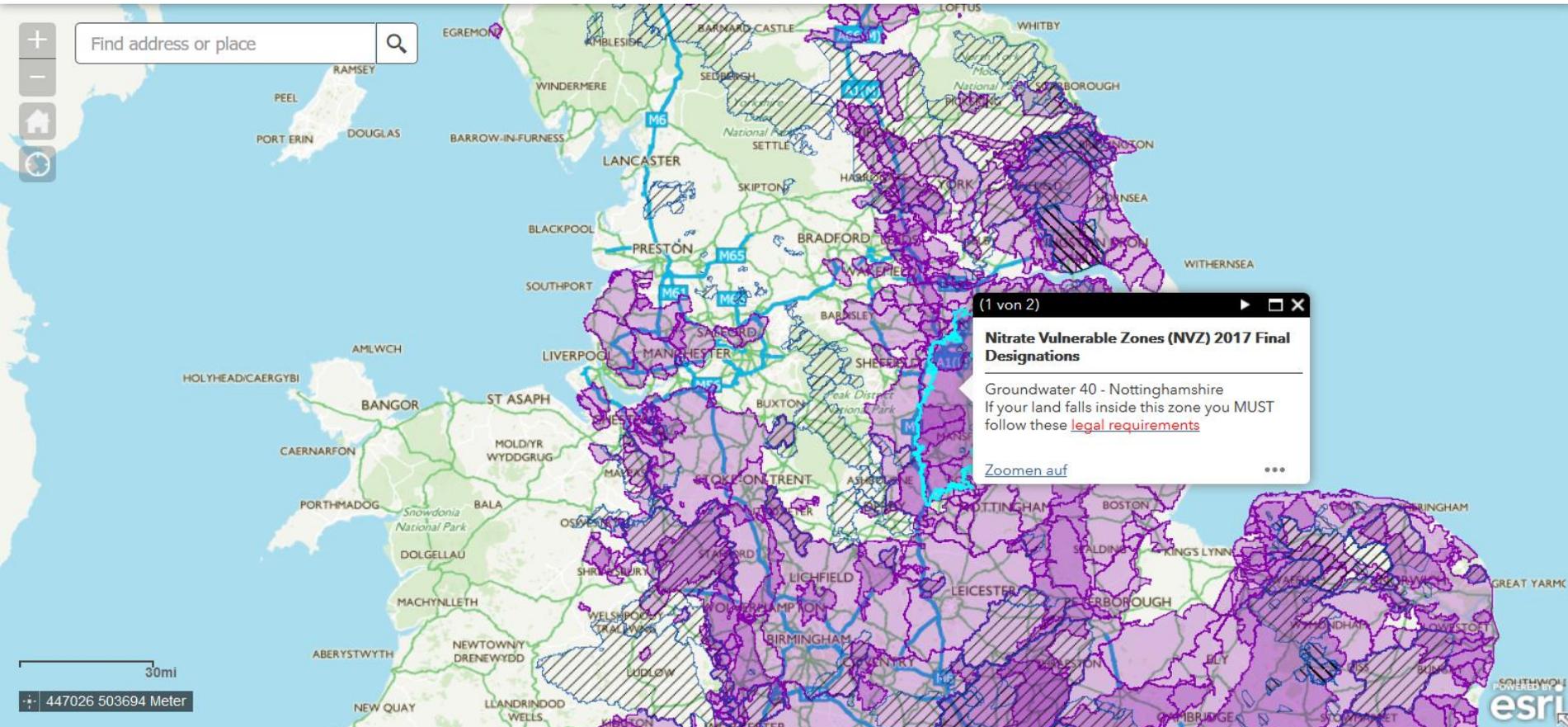
- New hybrids have improved shoot yield ✓
 - Higher yield is (mostly) attributed to modified leaf architecture ✓
Leaf length + 10cm; two additional leaves in 40 years; leaf angle > effective LAI ✓
 - New hybrids have improved photosynthesis per LA ✗
 - Yield progress resulted in proportional increase of root biomass ✗
 - Yield progress is related to higher proportion of roots in subsoil ✗
- Results indicate a trend towards delayed root senescence of newer hybrids ($P < 0.10$), but not higher root biomass
- New hybrids have improved NUE ✓
 - New hybrids have higher ME per kg DM (sink limitation > + WSC in the corn) ✗

A photograph of a cornfield with green leaves in the foreground and a clear blue sky in the background. A white contrail from an aircraft is visible in the sky.

Thanks for your attention

More information: ftaube@email.uni-kiel.de
or www.grassland-organicfarming.uni-kiel.de

Nitrate vulnerable zones in England



58% of land area in England > NVZ or drinking water saveguard zone..., same situation in Many regions in Germany, e.g. Schleswig-Holstein...

Extension of critical N concept over vegetation period of forage maize

Calibration data base

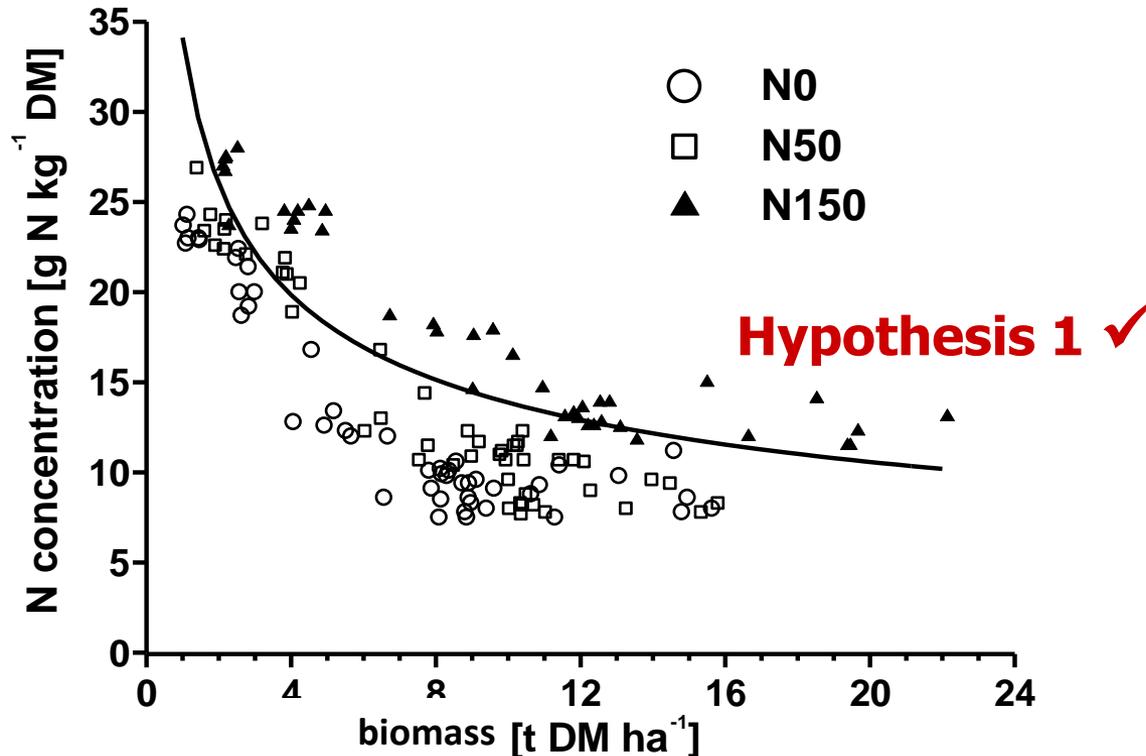
- Continuous maize experiment of the N-project Karkendamm, 1997-1999
 - Humous sand
 - N fertilization
 - Mineral: 0, 50, 100, 150 kg N ha⁻¹
 - Slurry: 0, 20, 40 m⁻³ ha⁻¹
- } 0-298 kg N ha⁻¹
- Biweekly sampling

Validation data base

- Ostenfeld site, 1996-1997
- Loamy sand
- Mineral N fertilization: 0, 50, 150 kg N ha⁻¹
- Seven cultivars, 3-weekly sampling



Validation of critical N-to-biomass relationship (other years, site)



Critical N dilutes curve discriminates well between N-limited (0, 50 kg N ha⁻¹) and non-N-limited (150 kg N ha⁻¹) treatments



Determination of critical N concentrations for each sampling date

