LEUPHANA
UNIVERSITÄT LÜNEBURG

MEASURING AMMONIA LOSSES FROM MANURE SPREADING – WHAT FACTORS DETERMINE LOSSES AND NEED FOR MEASURING PLOT SIZE

Andreas Pacholski
Leuphana University Lüneburg
Faculty of Sutainability; Institute of Ecology

EUROPÄISCHE UNION
Europäischer Fonds für regionale Entwicklung
Europa fördert Niedersachsen

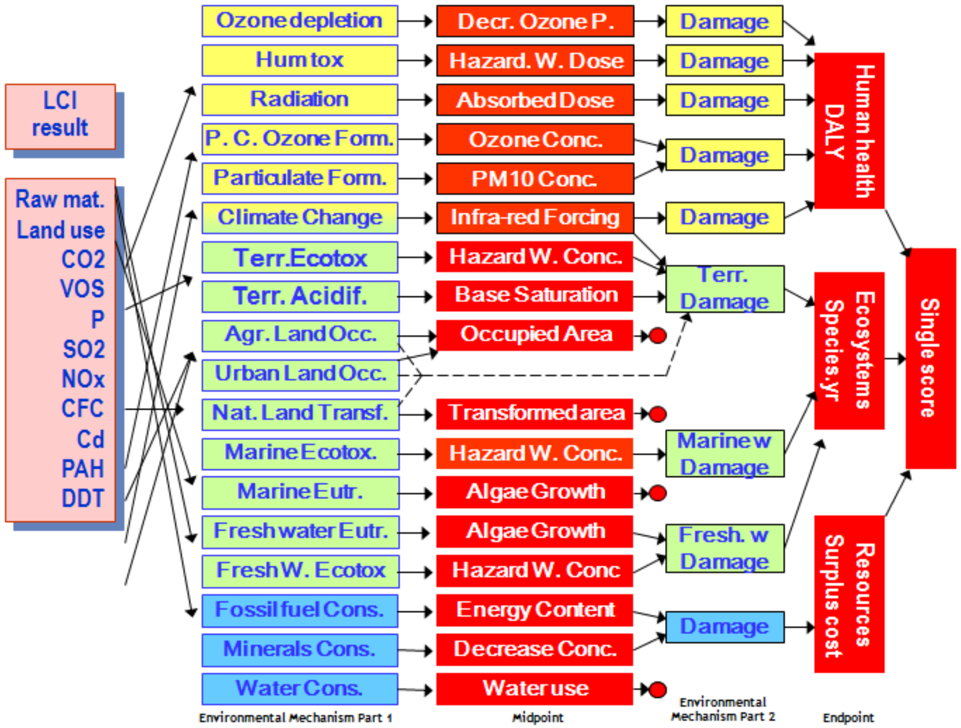
Agenda:

1. **Relevance of ammonia emissions as driving force of agriultural sustainability**
2. **The need and a recent approach to measure plot size**
3. **Factors affecting ammonia emissions from field applied manures**
4. **Conclusions**

Importance of manure spreading

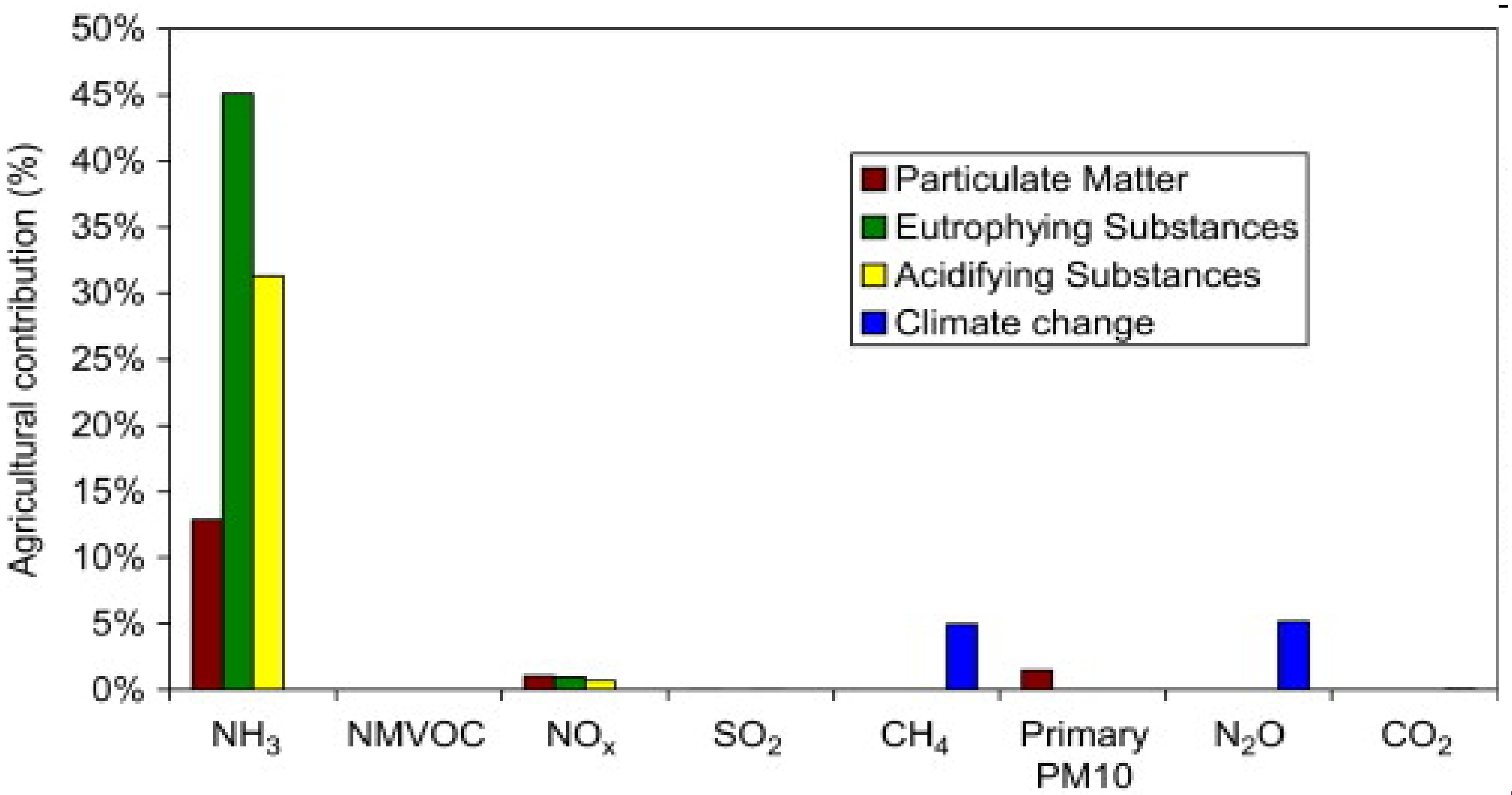
Ammonia emissions as major variable affecting main impact factors of sustainability accounting in agriculture

- *Climate Change (Greenhouse gases)*
- Fossil fuel depletion
- Eutrophication
- Acidification
- Particulate matter
- *Resource depletion*



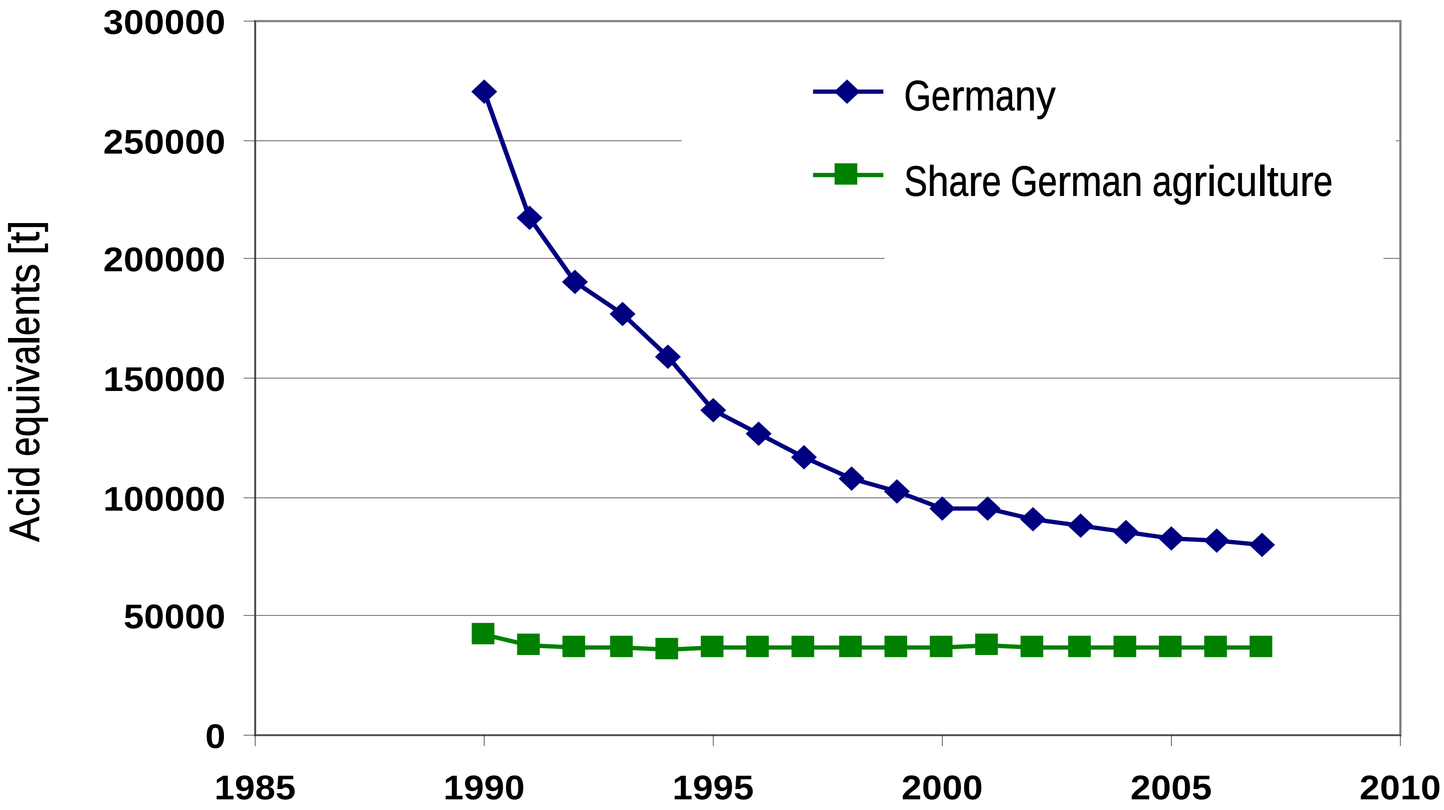
(Factors according ReCiPe, Goedkoop et al. 2009)

Contribution of the agricultural sector to environmental effects caused by gaseous emissions in the EU (15)



Erisman et al. 2008

Contribution of agriculture (NH_3-losses) to air borne acid deposition in Germany



UBA 2010

About 40% of NH_3 emissions from field applied manure

(Hähnel et al. 2014)

Why measure on a plot scale?

1. Key scale of agronomic experimentation → yields, nutrient balances, GHG emissions etc.
2. Measurements from large scale plots are often not replicated and not all treatment of interests can be covered
3. Effects of several different treatments under the same conditions → hard to reconstruct from large scale emissions
4. To analyze treatment effects under varying condition → robustness of treatment effect

Why measure on a plot scale?

Êxample: strong institutional effects on multi-institutional data base

Term	Effect (%)	Estimate	*SE*	*P* value
Broadcast	0.0	0.00	-	-
Band application	**-54.2**	**-0.99**	**0.203**	**<0.0001**
Open slot	**-81.6**	**-1.99**	**0.326**	**<0.0001**
Air temperature (°C)	3.0	0.04	0.0076	<0.0001
Wind speed (m s^{-1})	14.8	0.20	0.0259	<0.0001
Dry matter (broadcast) (%)	**7.9**	**0.11**	**0.012**	**<0.0001**
Application rate (broadcast) (t ha^{-1})	-1.0	-0.01	0.00413	0.0006

Adjusted R^2 0.67,

Partial R^2 value for institute effect is 0.077, partial eta^2 is 0.19 (in both cases institute is the largest term, for comparison application method values are 0.03 and 0.08).

Plot based measurements: Standard comparison method

(Vandré & Kaupenjohann 1998)

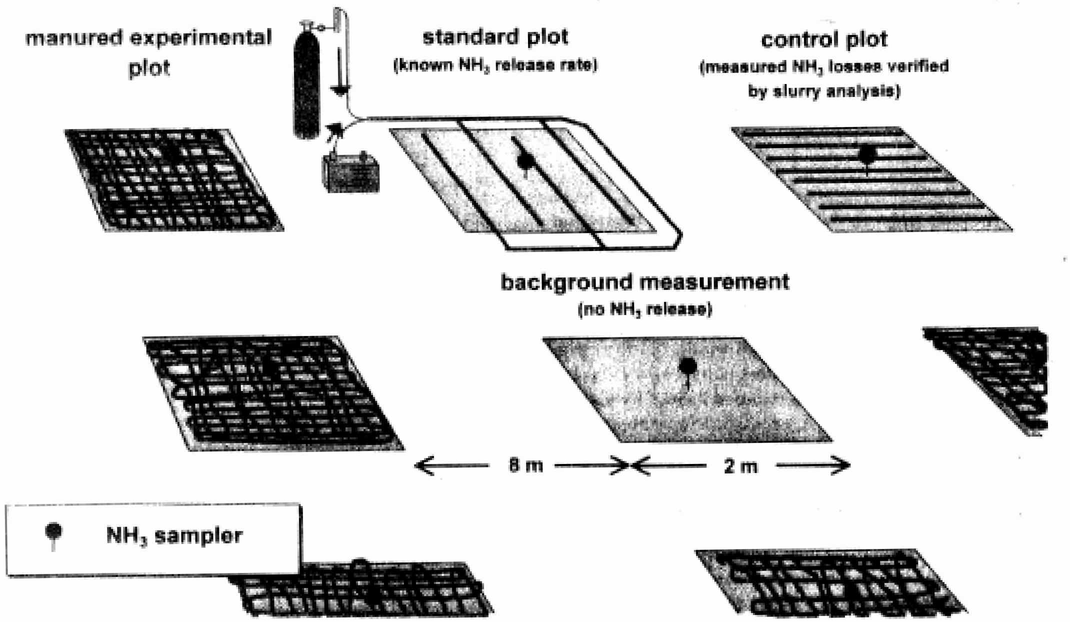


Fig. 1. Sketch of the experimental design of the field study.

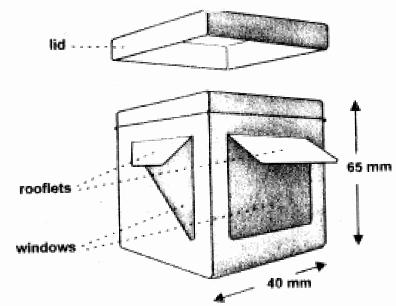


Fig. 2. Sketch of the passive samplers collecting NH_3.

Acid traps filled with 20 ml 0.05 M H_2SO_4

Standard comparison method - validation

compared to residual ammonium concentrations on plots without soil (plastic base)
(Vandré & Kaupenjohann SSAJ 1998)

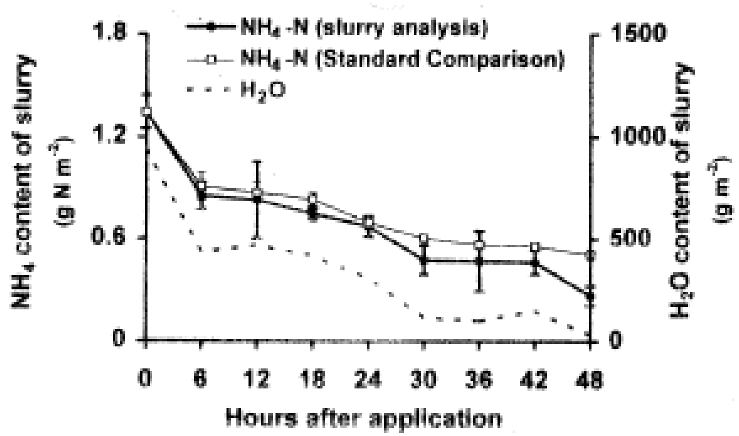


Fig. 6. Ammonium-N and H_2O contents of slurry after application to gutters on the control plots in the spring experiment. The NH_4–N content was determined from slurry samples by steam distillation on a dry-matter basis (slurry analysis) and calculated from NH_3 losses measured by the standard comparison (SC) technique. Error bars indicate standard deviations.

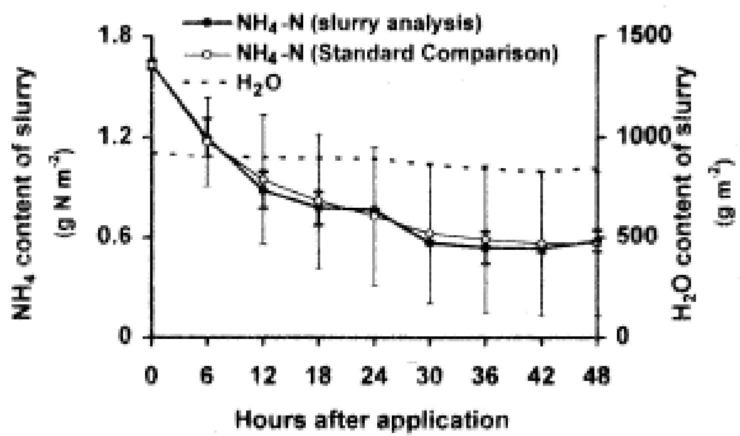
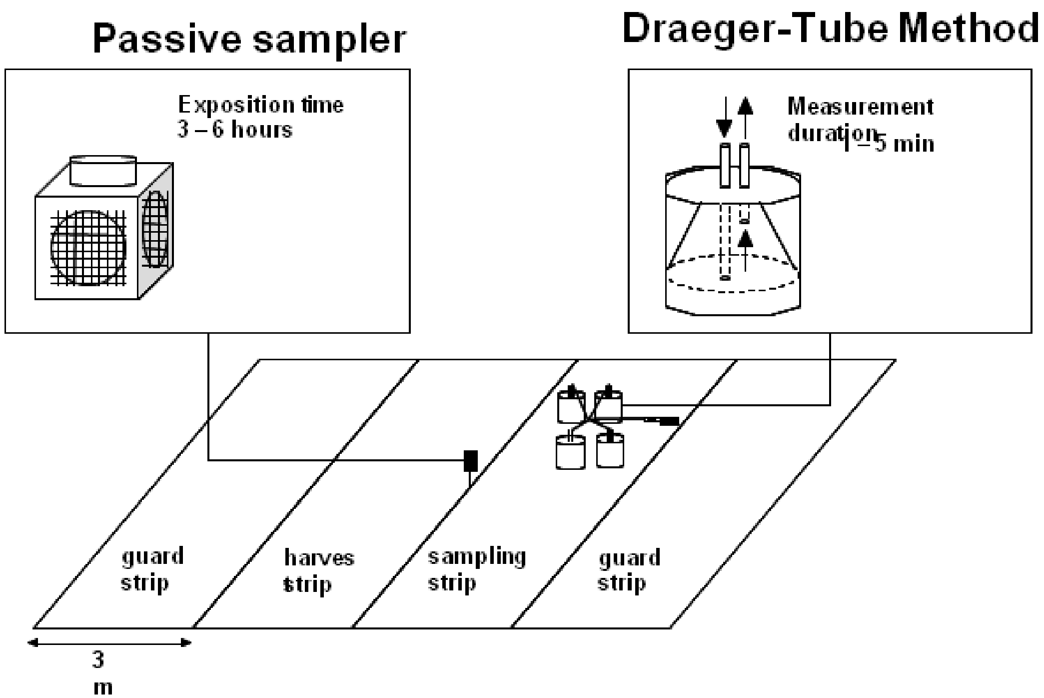
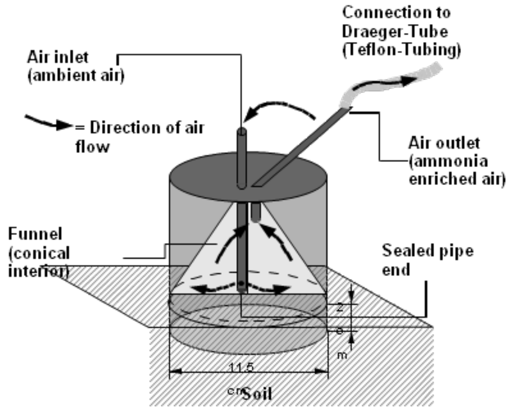


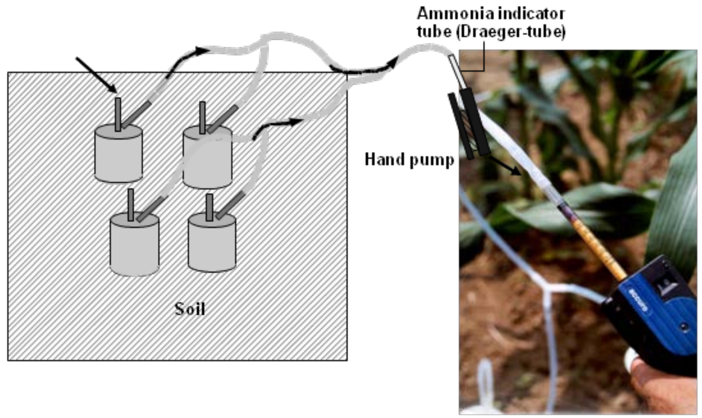
Fig. 7. Ammonium-N and H_2O contents of slurry after application to gutters in the replication of the control measurement in the summer during ripening of the wheat. The NH_4–N content was determined from slurry samples by steam distillation on a dry-matter basis (slurry analysis) and calculated from NH_3 losses measured by the standard comparison (SC) technique. Error bars indicate standard deviations.

Standard comparison method - new approach

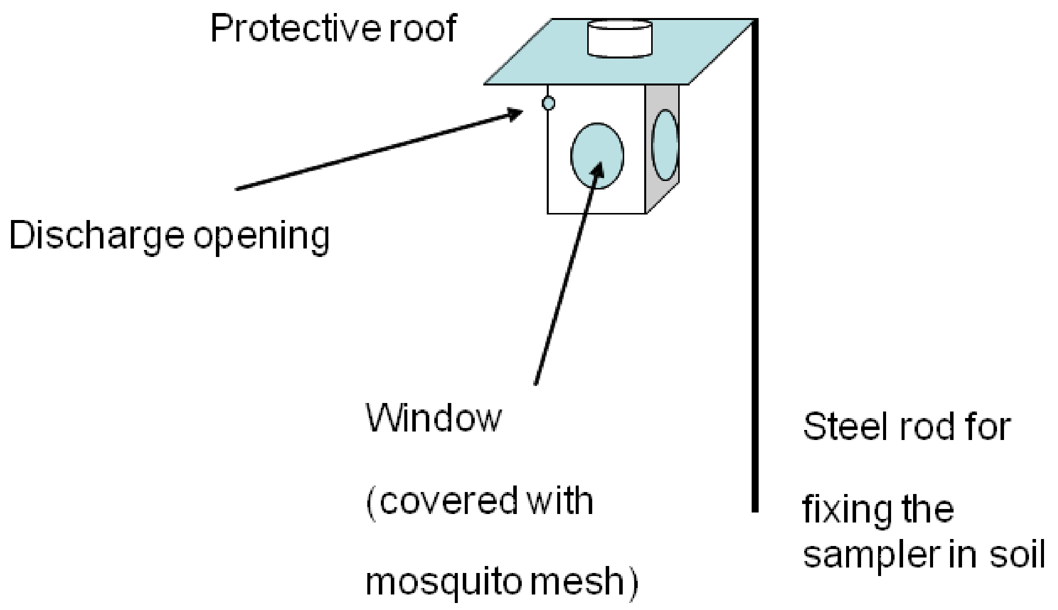
(Pacholski et al. 2006, Gericke et al. 2011)





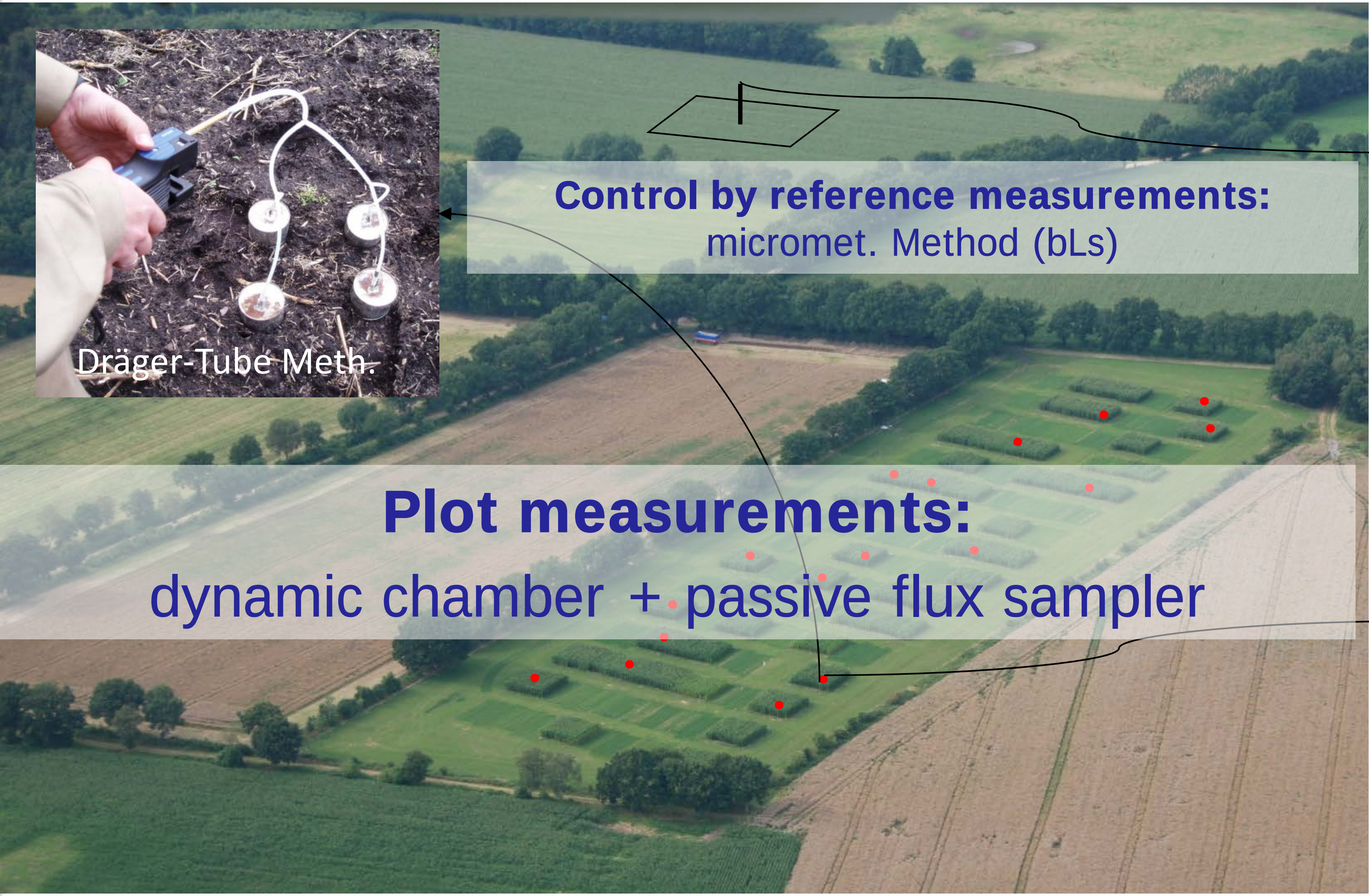


New design of passive sampler



Testing the new plot based NH_3-loss measurement approach

(Gericke et al., Biosys. Eng. 2011)



micromet. method (bLs)

Recommended experimental design – ‚chess board'

Ni et al. 2014

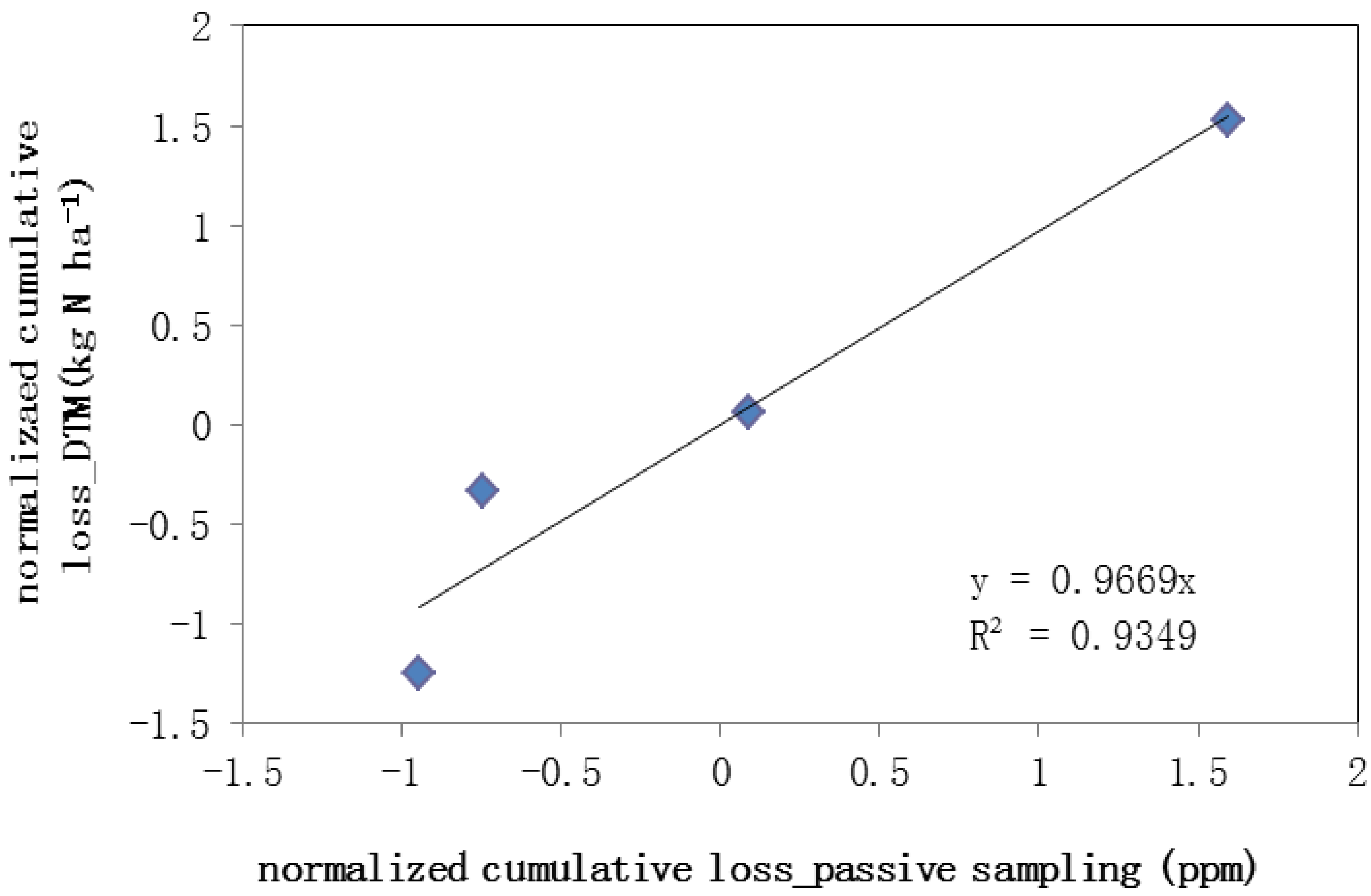
Large, quadratic plots ~ 100 m² → avoid effect of uneven manure distribution

Large distances between plots → minimize transfer of ammoinia between plots

Fertilize areas between treatment plots with nitrate fertilizer to avoid edge effects

Tranfer between plots taken into account by control plots

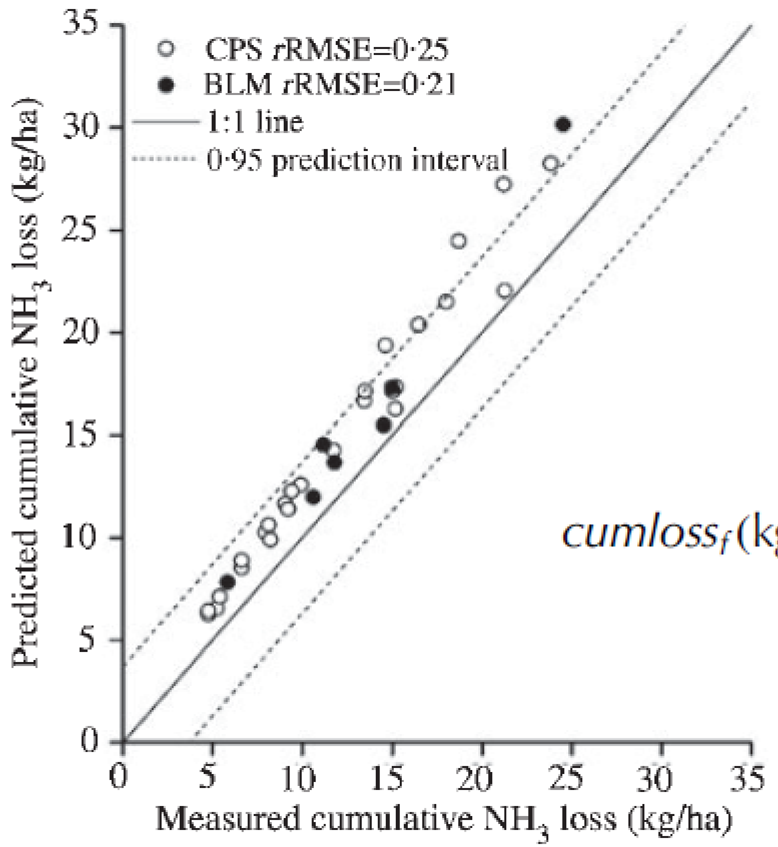
Linearity of passive samplers



comparison of cumulated losses by DTM and passive sampling after normalization to the mean

Temporal dynamics of emissions of passive samplers compared to bLs

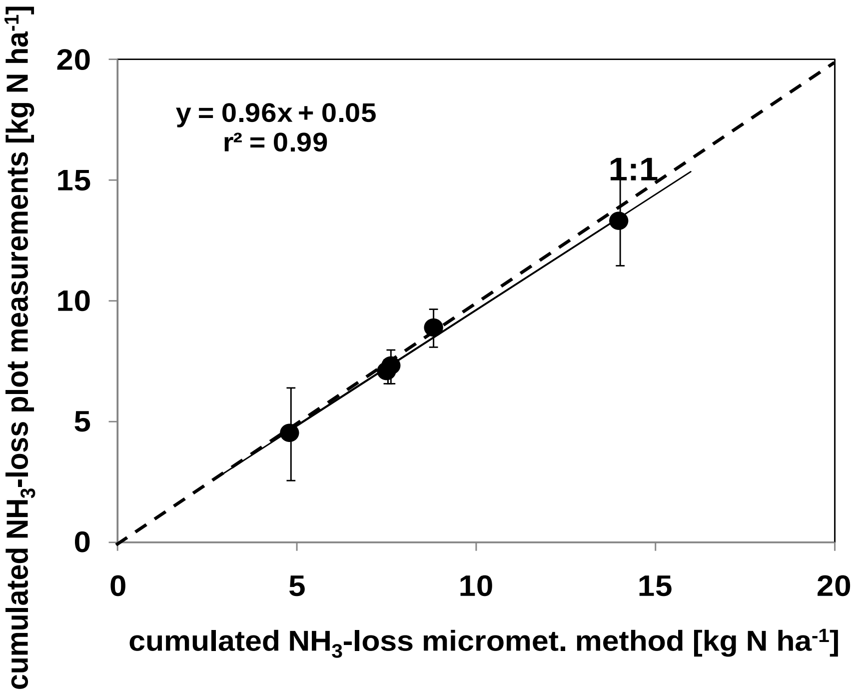
(Ni et al. 2012)

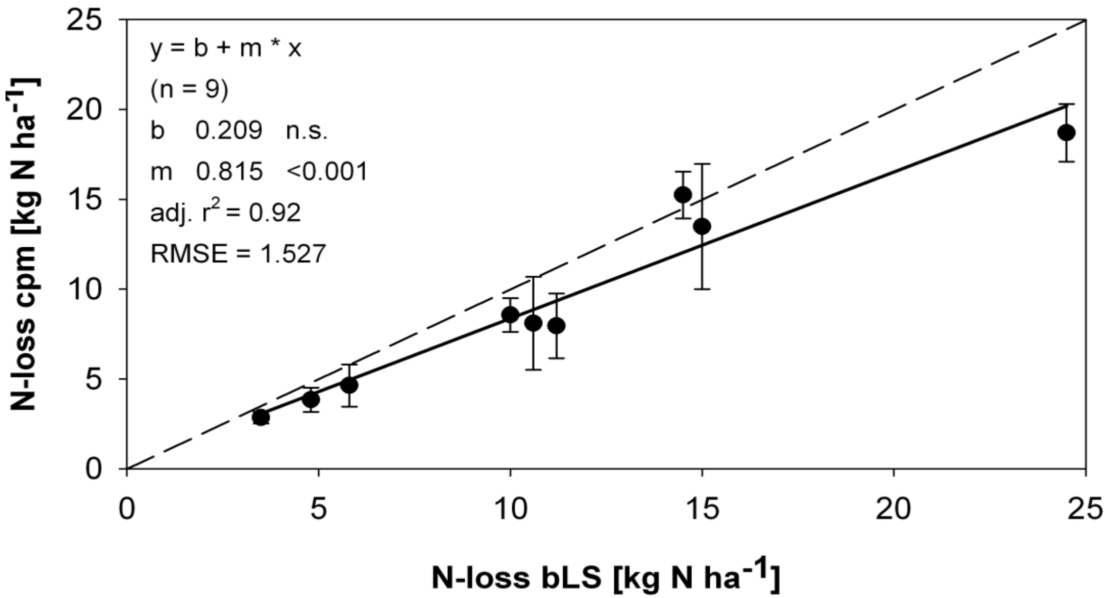


$$cumloss_f(\mathrm{kg/ha}) = 1{\cdot}34 \times cumloss_{24} \times (R^2 = 0{\cdot}98, P < 0{\cdot}001)$$

Validation of NH_3-methods

tested against simultaneous micrometeorological measurement

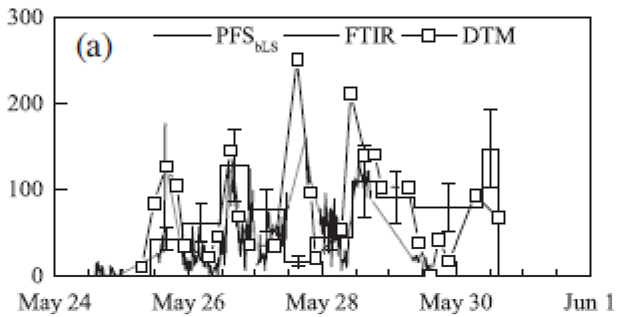


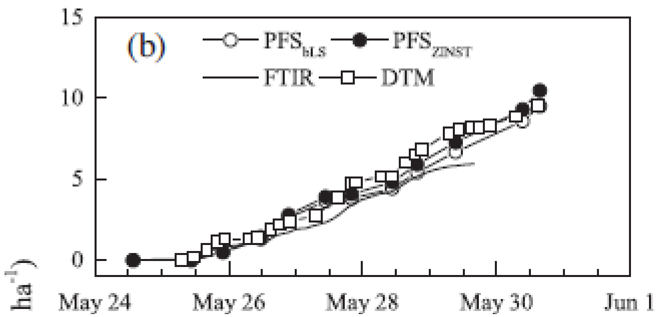


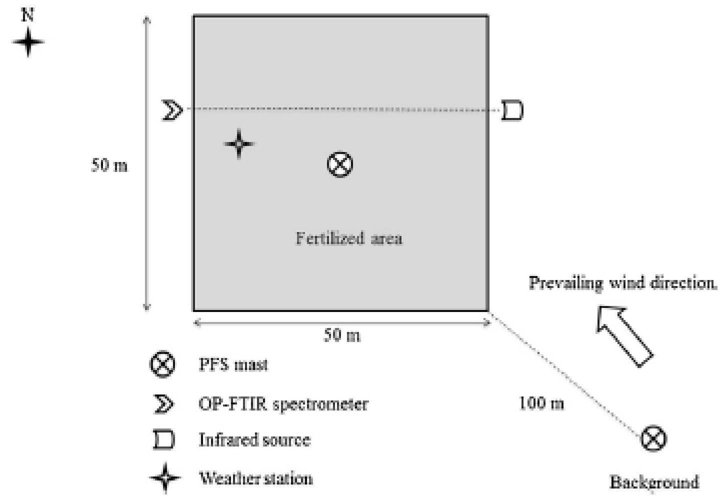
(Gericke et al. 2011, Quakernack et al. 2012)

Comparison with micromet under high canopies (urea) and after slurry incorporation

(Ni et al. 2015)







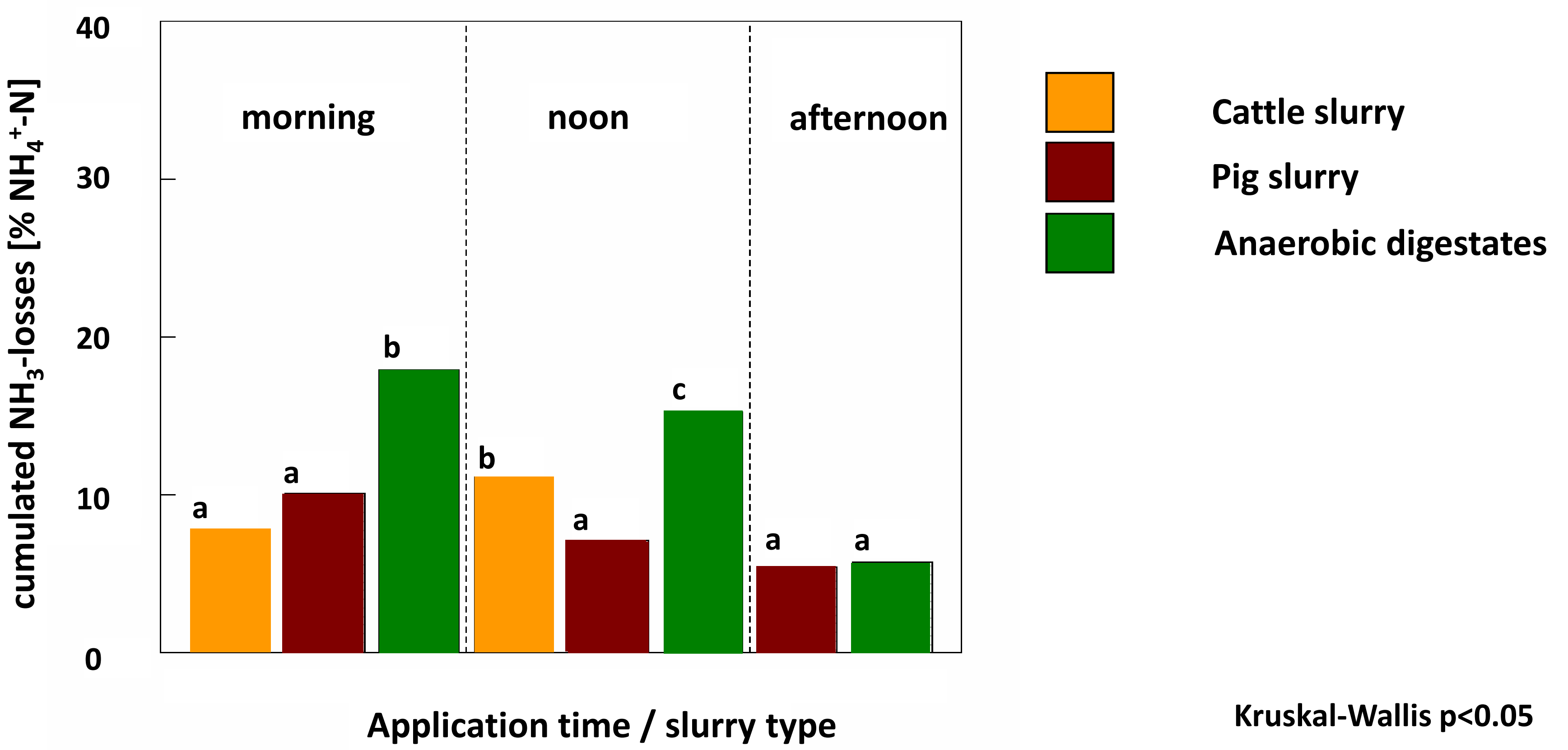
First example:
NH_3 emissions of digestates from co-fermentation of slurries and energy crops (Ni et al. 2012)

- Earlier studies on digestates: organic residues without energy crops → no effect of fermentation on ammonia emissions compared to animal slurries
- Typical slurries from co-fermentation with energy crops: - high pH-values, high viscosities

→ ammonia emissions from field applied energy crops based slurries still uncertain

Test of cofermented digestates: measured losses

(analysis of results of 15 multi-plot field trials)



Kruskal-Wallis $p<0.05$

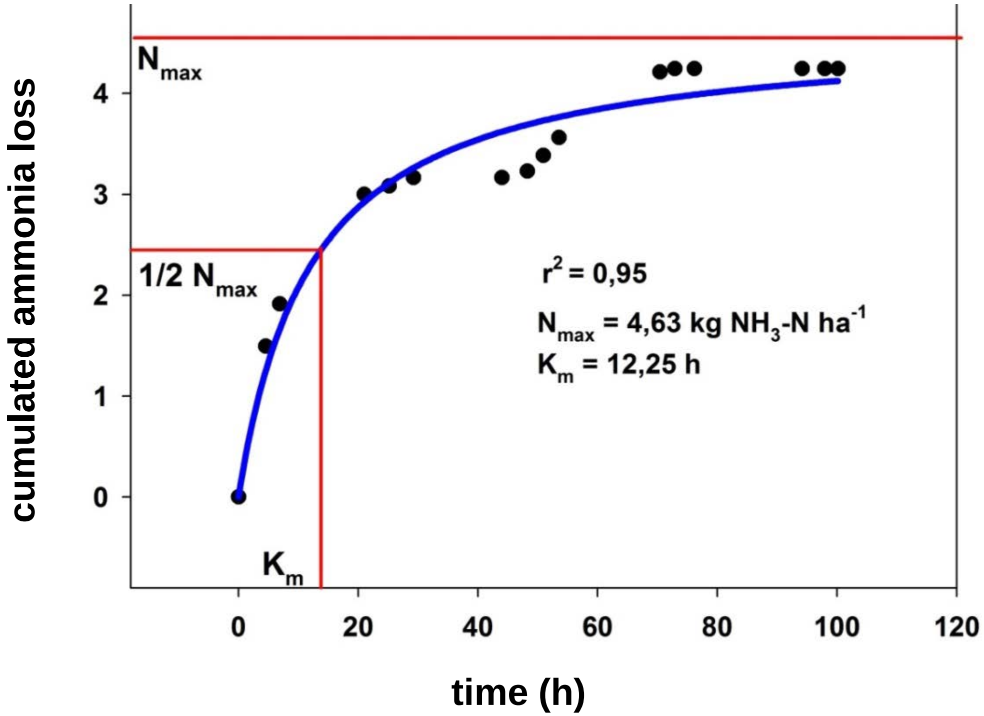
Analyisis of data with empirical model

Ni et al., in 2012

a. Calculation of total emissions based on Michaelis-Menten type equation

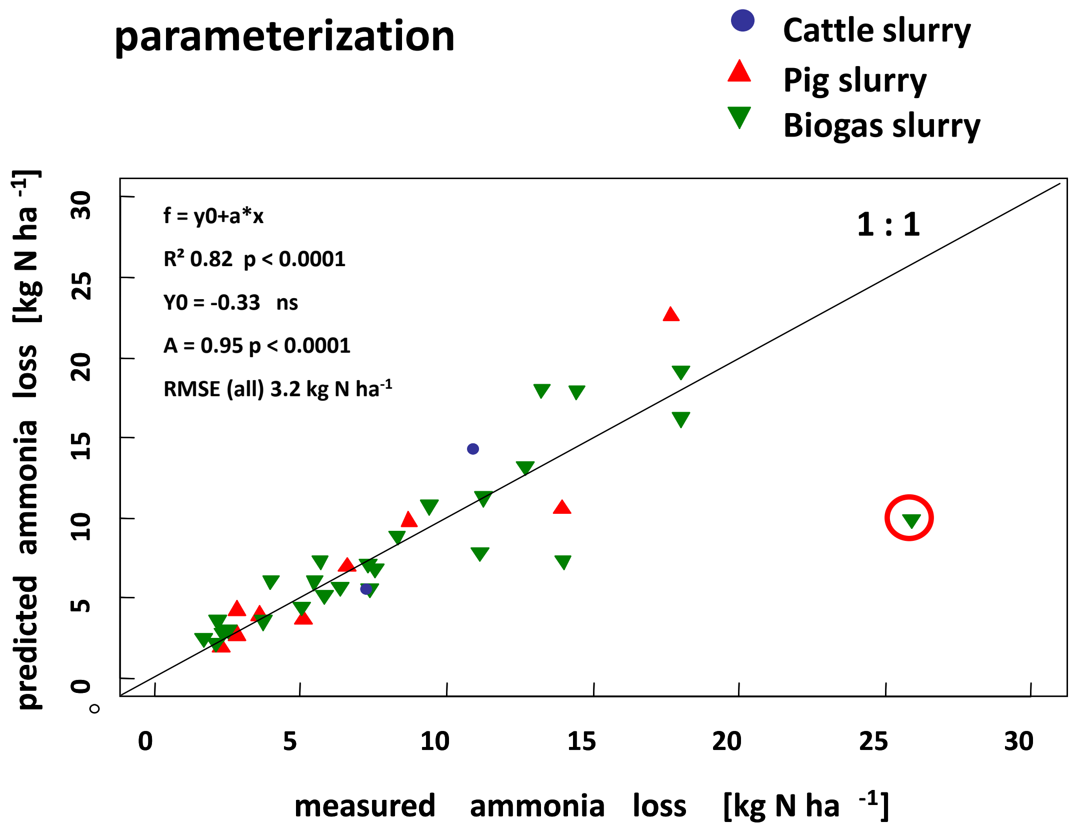
$$N(t) = N_{max} \frac{t}{t + K_m}$$

N(t)	**cumulative emission at time (t)**
N_{max}	**asymptotic maximum loss**
K_m	**point in time where N(t)=0.5 * N_{max}**
t	**time**



acc. Sogaard et al. 2002 (ALFAM model)

Empirical model: performance



Ni et al. 2012

Empirical model: factors affecting NH_3 losses

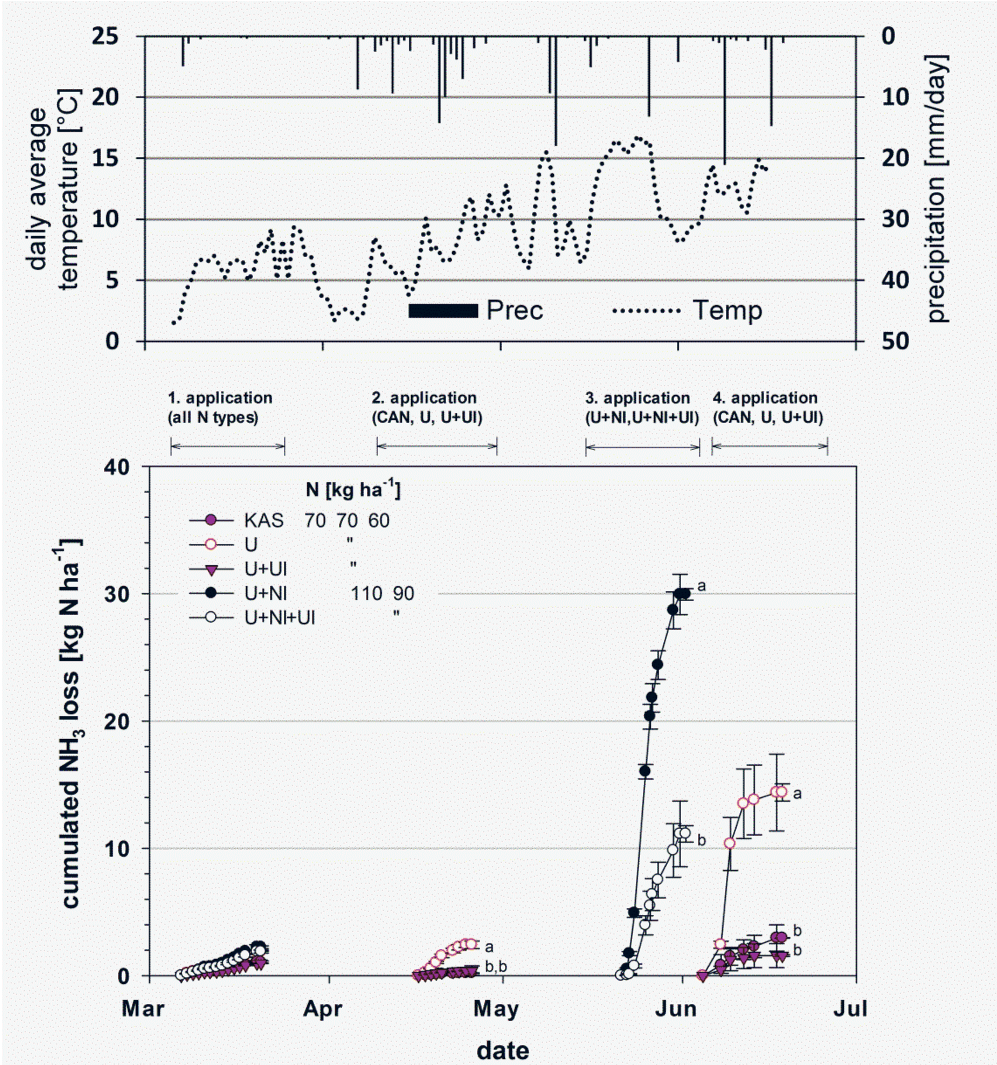
varibale	**Nmax**	**Km**
Slurry type	Biogas>pig≥cattle	
pH		↓
Dry matter [%]		↑
Total ammoniacal N applied [kg N ha^{-1}]	↑	↑
Crop type	wheat/grass>maize	Wheat/grass ↓
LAI	↓	↑
Air temperature [°C]	↑	↓
Wind speed 2 m [m s^{-1}]	↑	
Precipitation [mm]	↓	↓
Global radiation [W m^{-2}]	↓	↓

↑ **increasing** ↓ **decreasing**

Second example: NH_3 emissions after urea fertilization as affected by urease and nitrification inhibitors (Ni et al. 2014)

Treatment	Year	Applications	Dates	Application rates
Unit				
		number	EC-stage	kg N/ha
Ck	2011/12/13	0	~20/28/49	0
CAN	2011/12/13	3	~20/28/49	70/70/60
Urea U	2011/12/13	3	~20/28/49	70/70/60
U + urease inhibitor Ui	2011/12/13	3	~20/28/49	70/70/60
U+nitrification inhibitor NI	2011/12/13	2	~20/39	110/90
U+UI+NI	2011/12/13	2	~20/39	110/90
U+NI	2012/13	3	~20/28/49	70/70/60
U+UI+NI	2012/13	3	~20/28/49	70/70/60

Cumulated ammonia emissions after urea fertilization in 2012



ANCOVA results (2011-2013, n =4)

	Estimates		ANOVA	
	Parameter	P-value	% of total explained variance	P-value
U	7.76	<0.001	17.52	<0.001
UI	-7.28	<0.001	28.08	<0.001
Temperature	1.05	<0.001	33.88	<0.001
Precipitation	-2.06	<0.001	11.91	<0.001
Initial soil moisture	-8.19	<0.001	8.62	<0.001
Ajusted R^2 = 0.71, $P<0.0001$				

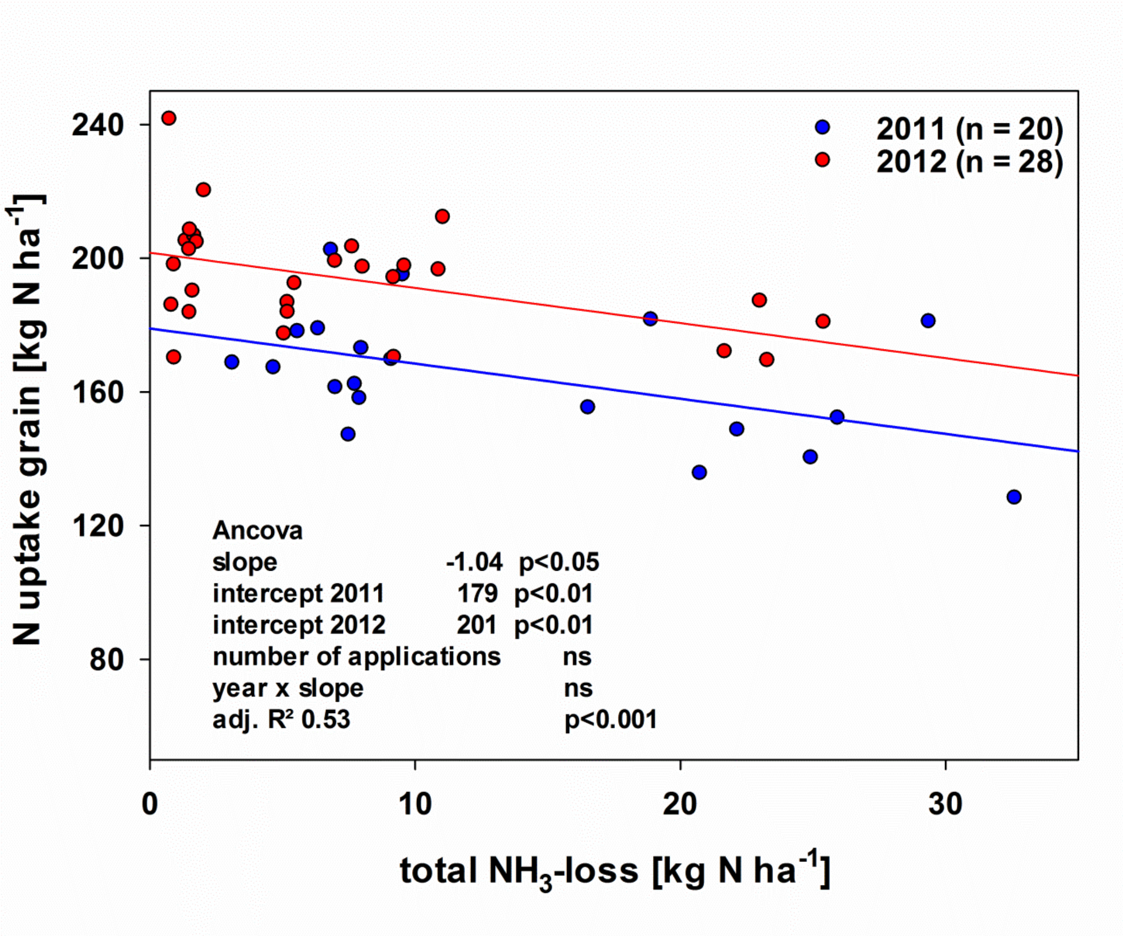
ANCOVA results (2011-2013, n =4): which factors affect reduction of ammonia emissions by UI

	Estimates		ANOVA	
	Parameter	P-value	% of total explained variance	P-value
Application rate	0.62	<0.001	25	<0.001
NI	-30.77	<0.001	24	<0.001
Temperature	3.24	<0.001	17	<0.001
Precipitation*	-9.02	<0.001	18	0.06
Initial soil moisture	-24.77	<0.06	3	<0.001
T:P	-0.165	0.05		

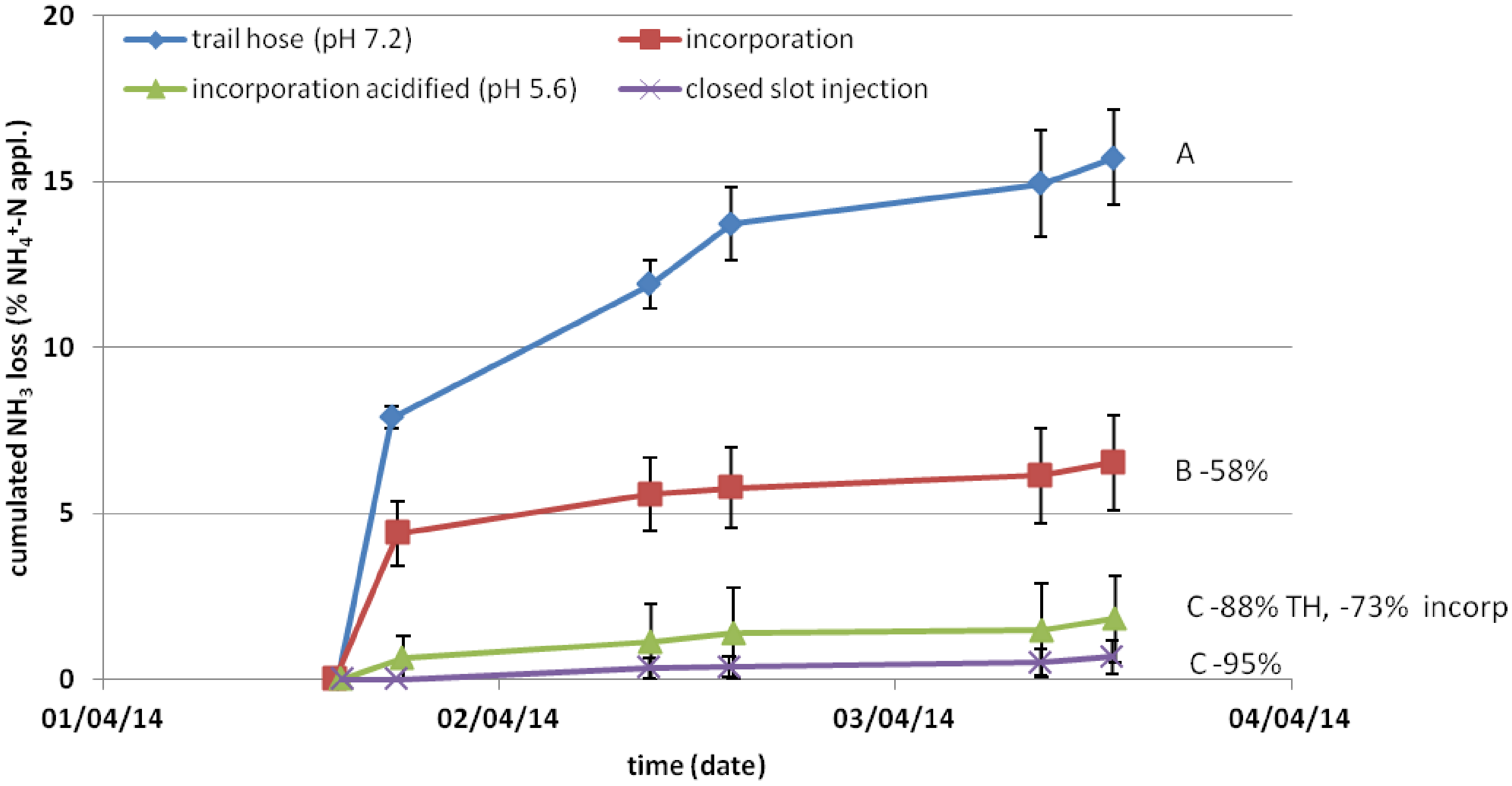
Ajusted R^2 = 0.81, P<0.0001, *sum of first 3 days

Relationship between ammonia loss and wheat grain N uptake

(Pacholski 2015 – in press)



Actual slurry trials – application techniques



Factors affecting ammonia emissions from field applied slurries

- Application method
- Soil conditions
- Slurry characteristics/type (DM, pH)
- Weather conditions (temperature, precipitation)
- Canopy characteristics (LAI, canopy type)

→ Multi plot field trials may help to elucidate the detailed differences (quantitiy, conditions)

Plot based ammonia measuerements

Advantages

— Comparison of large number of treatments at the same time

— Creation of large data sets for statistical and model analysis → management + environmental effects

— Cheap + independent of electrical power

Critical points

- Applicability of plot approach still under debate ← effects showed close agreement to effects observed in other studies
- Quantitative validity of statistical chamber measurements still under debate ← may be exchanged by other method (e.g. wind tunnel)
- Chamber not applicable under all application conditions (e.g. slurry incorporation)
- Not known precision of passive samplers + exchange of acid solution → use of other passive samplers, e.g. Alpha samplers
- Effects of drifting ammonia emissions on neighbouring plots ← enlarge guard area

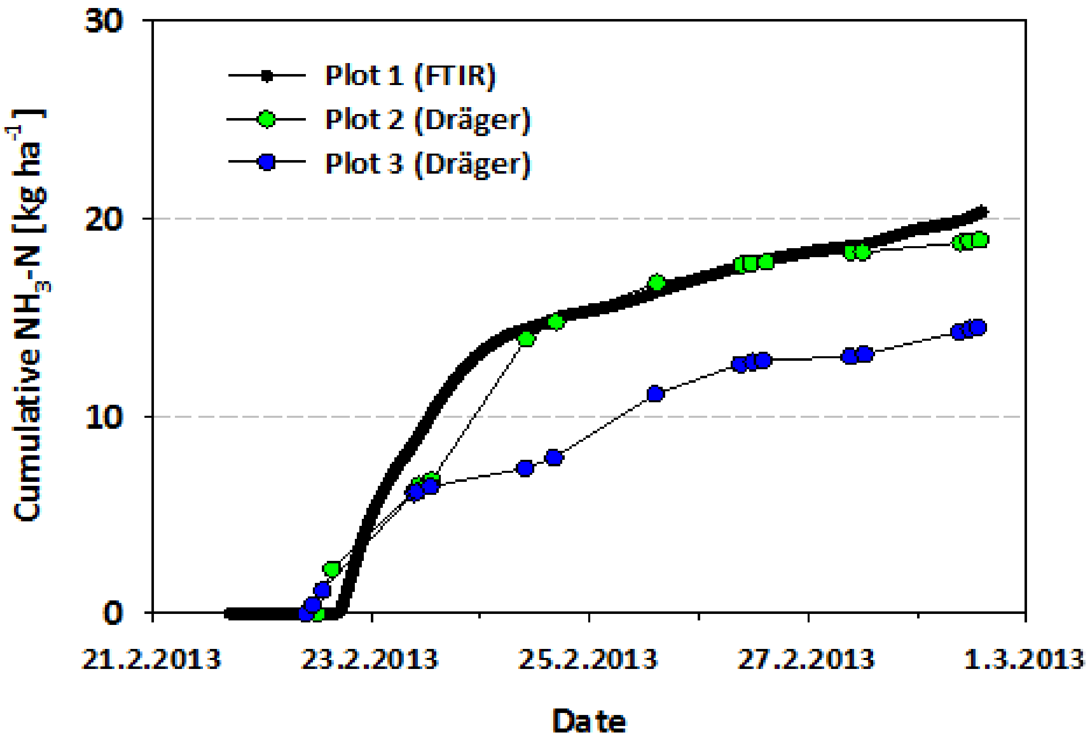
Thanks to:

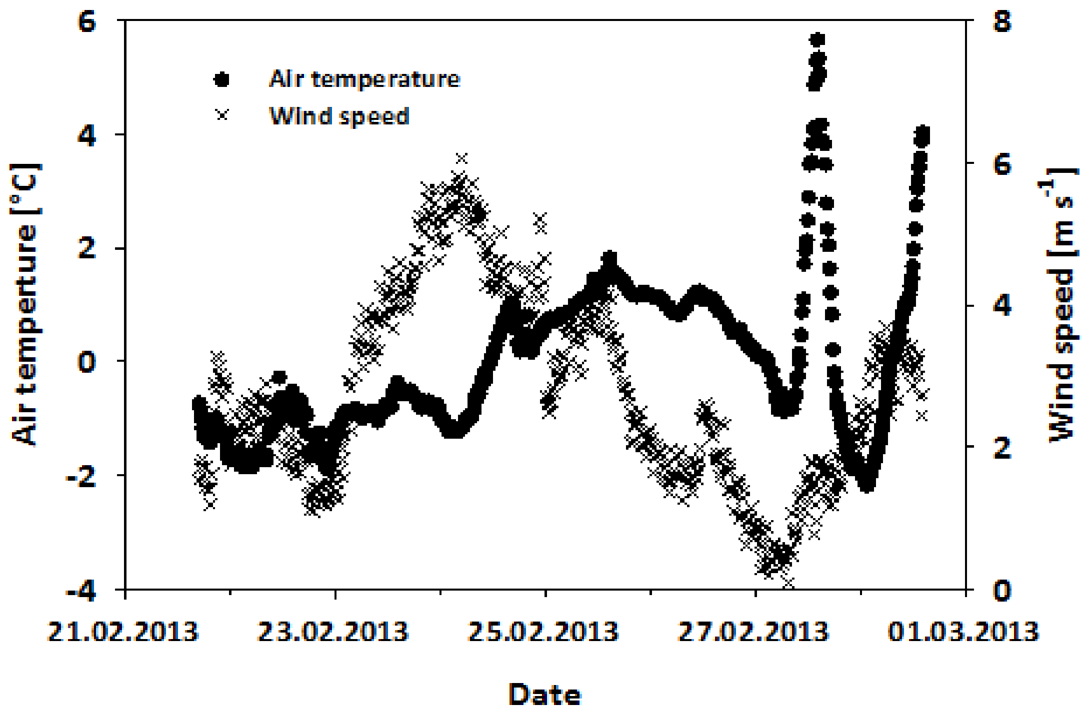
Robert Quakernack
Achim Seidel
Kang Ni
Dirk Gericke
Sasha Hafner

Comparison of methods 2013

1. opFTIR with micrometeorological flux calculation
2. dynamic chamber (Draeger Tube method)

Koester & Seidel in prep.



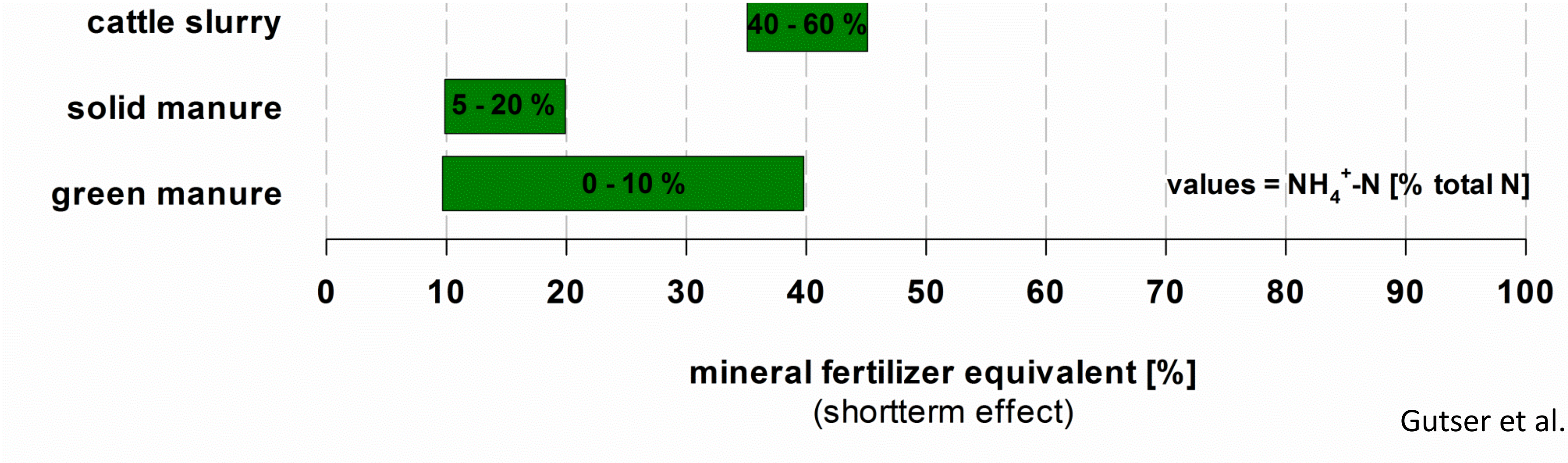


- Anaerobic digestates applied to frozen soil

Ammonia emissions reduce fertilizer value of field applied manure:

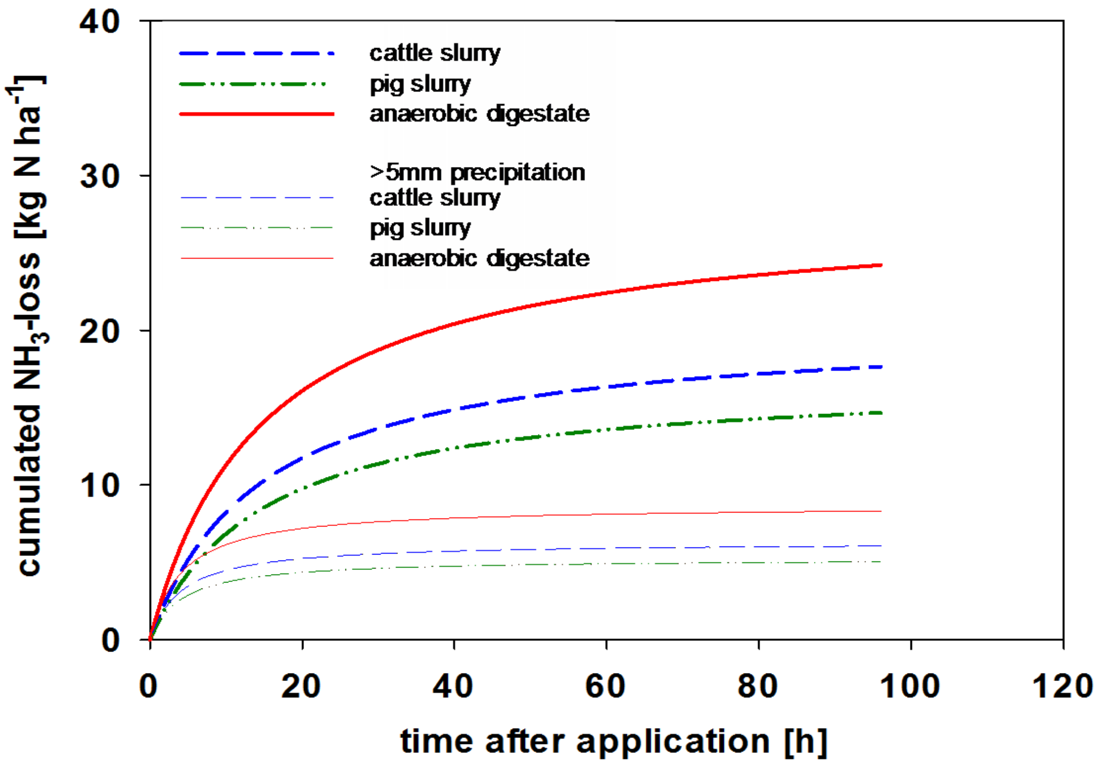
fertilizing effect mainly depends on ammonium content

→ Reduction of N fertilzer value by ammonia (NH_3-)losses



Gutser et al. 2005

Ammonia emissions from Anaerobic Digestates



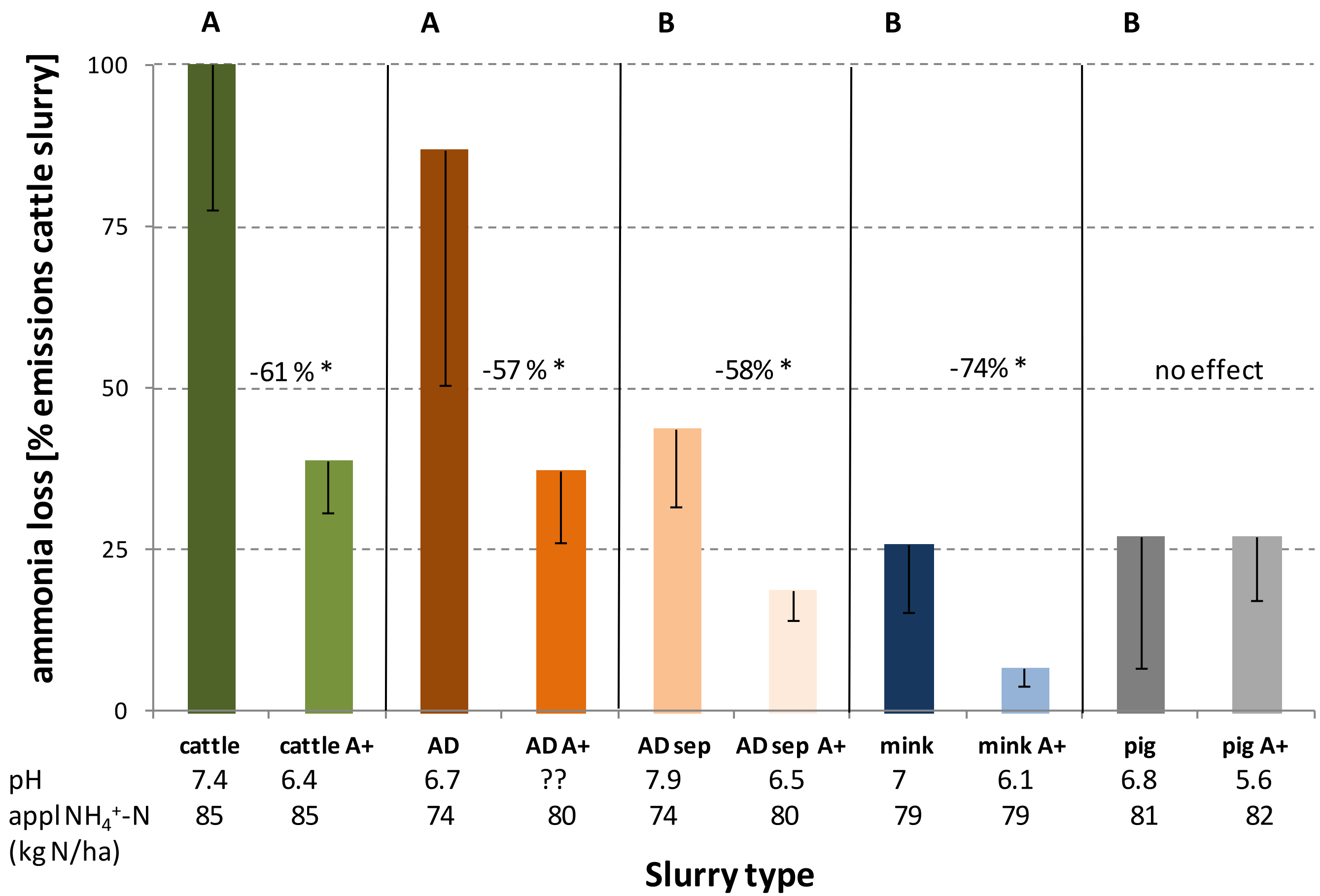
Animal slurries and AD applied at same N application rates under identical canopy and weather conditons calculated with an empirical model (Ni et al. 2012)

- Typical AD (high pH, TAN)

→ higher relative ammonia losses as compared to typical animal slurries

(Ni et al. 2012)

Ammonia emissions first application to winter wheat (target Ammonium-N level 80 kg NH_4^+-N/ha)



AD = digested cattle slurry

* significant t-test with and without acid

Letters = sig level ANOVA slurry type