Bettina Schäppi, Jürg Heldstab, Thomas Kupper

Modeling uncertainty in ammonia emissions from agriculture: Regional upscaling by Monte Carlo analysis

Kraków, 7.10.2015

4th International Workshop on Uncertainty in Atmospheric Emissions

Introduction

NH_3-Emissions

- In Switzerland, critical loads of nitrogen are exceeded for a large part of natural ecosystems.
- Lead to increased nitrogen deposition, which results in indirect N_2O emissions.

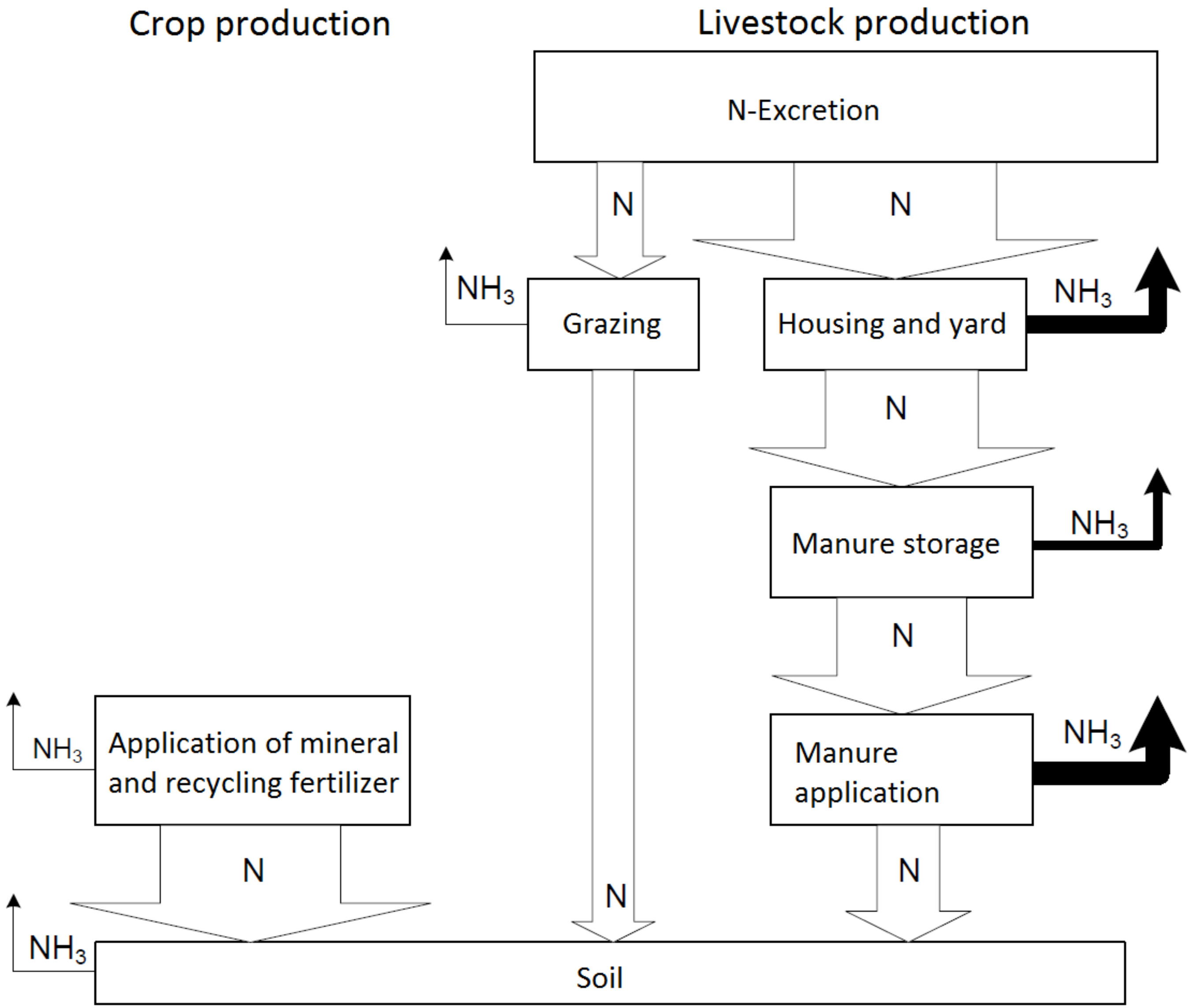
$\Rightarrow$ **Assessment of underlying uncertainties is required for both air pollutant and greenhouse gas inventories**

Introduction

NH_3 emission modelling
A nitrogen mass flow model (Agrammon) has bee developed in order to assess emissions of single farms as well as for the regional scale.

- In Switzerland estimates of NH_3 uncertainties relied solely on expert judgement
- Based on the present work they were updated for submission 2014

NH_3 emission modelling I: Model Structure



NH_3 emission modelling II: Input data

Data sample from a survey of 2957 farms in 2010

Input data

- Number of animals
- Housing type
- Manure handling
- Grazing duration and time
- ….

Technical parameters

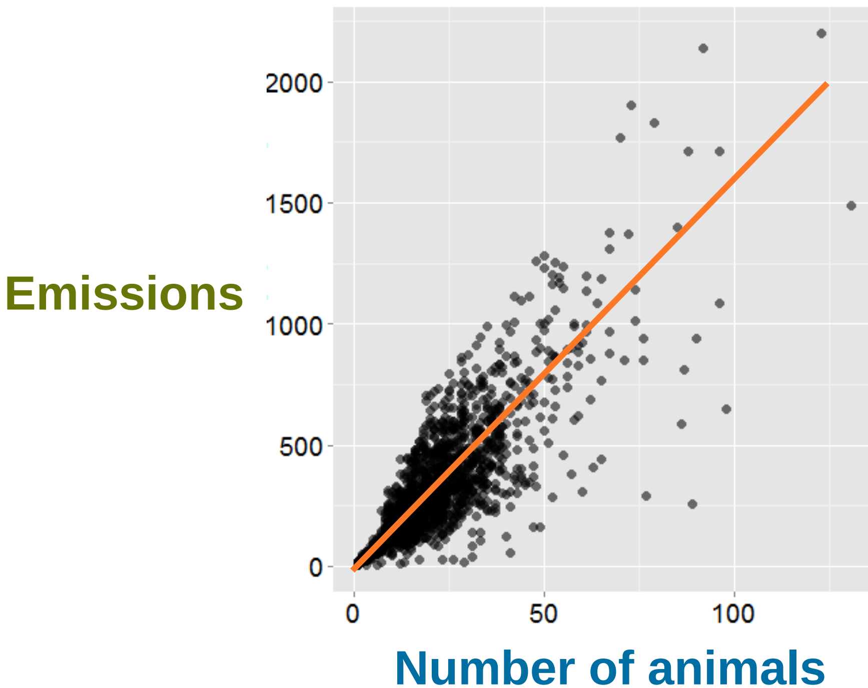
- N excretion
- Share of soluble nitrogen in excretion
- Emission factors of manure management processes
- Adjustment factors
  - Composition of animal feed
  - Manure application techniques
  - Cover of manure storage

NH_3 emission modelling III: Emission factors

Farm classes (32)
(Region, altitude, farm type)

Animal Categories (24)
- **Diary cows**
- **Fattening pigs**
- Laying hens
- …

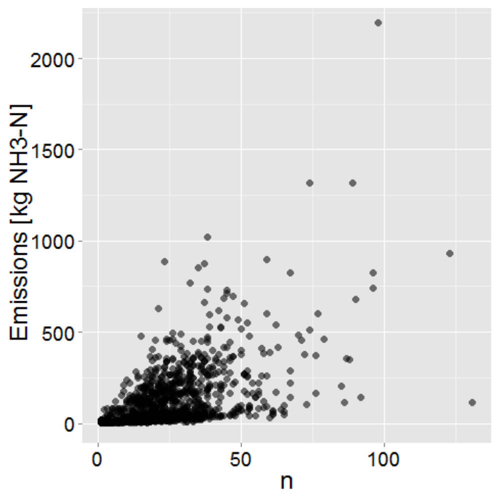
Emission stages (7)
- **Manure storage**
- Manure application
- Grazing
- Housing and yard

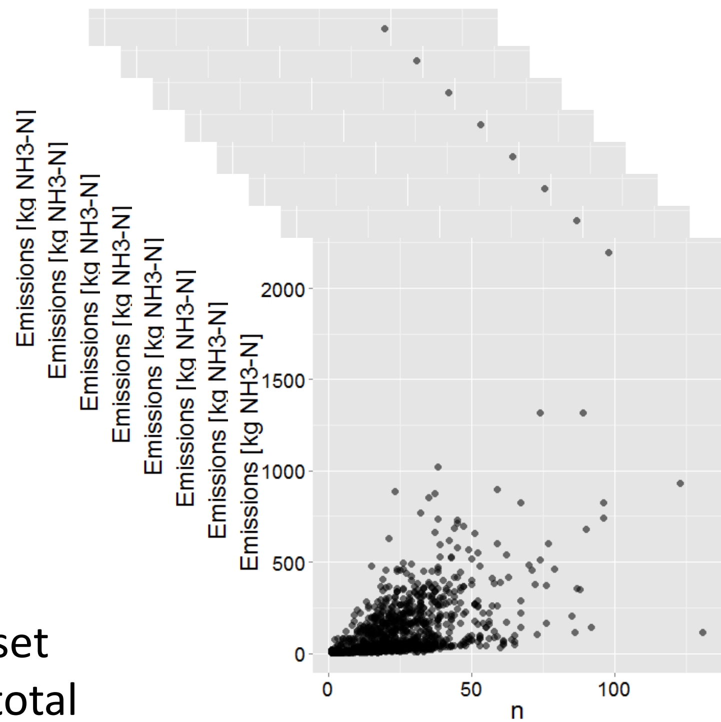


Estimation of emission factor based on linear regression:

Em = **EF** x **N**

NH$_3$ emission modelling IV: Total emissions





1. Emission factor of 1 subset
2. Extrapolation based on total number of animals of a subset:

Em = **EF** x **N**$_{tot}$

Total emissions
=
Sum of emissions from each subset

Assessment and aggregation of related uncertainties needs to account for:

- Correlated error terms
- non-constant variance

Uncertainty assessment

1. Uncertainty in simulated emissions

- Sensitivity analysis for selected farm classes

2 .Uncertainty in estimated emission factors

- Linear regression Em vs. N
- Uncertainty assessment based on Monte Carlo simulations

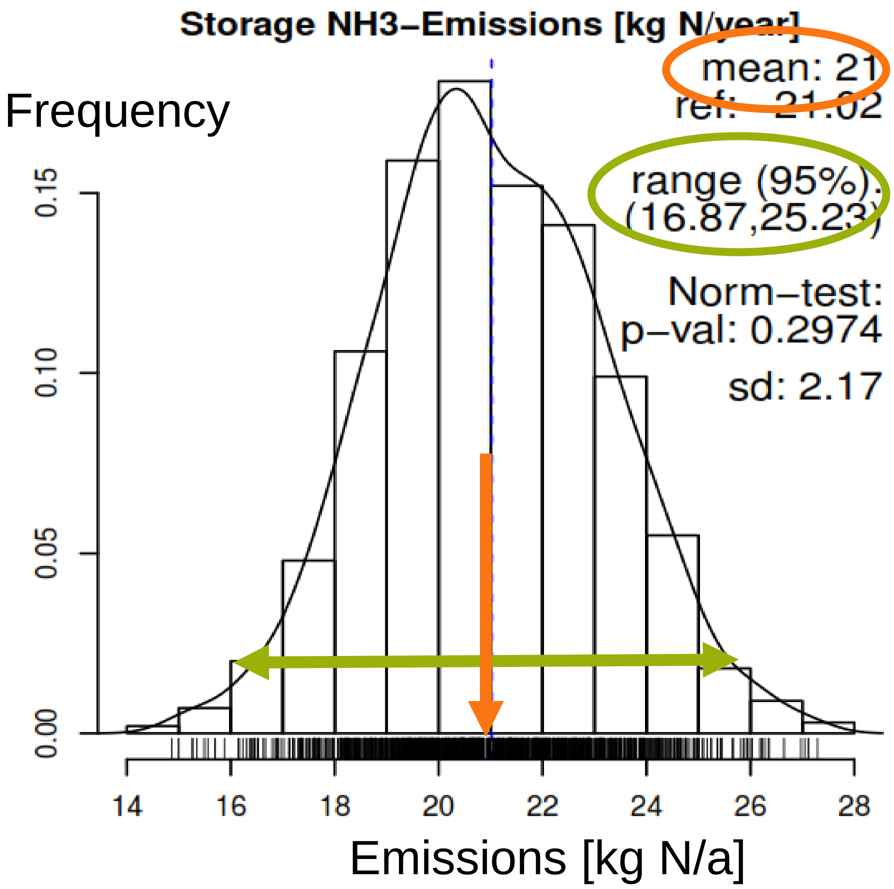
3. Upscaling to the national scale

- Based on total number of animals
- Aggregation of related uncertainties based on Monte Carlo simulation and Gaussian error propagation

Uncertainty I: Sensitivity analysis

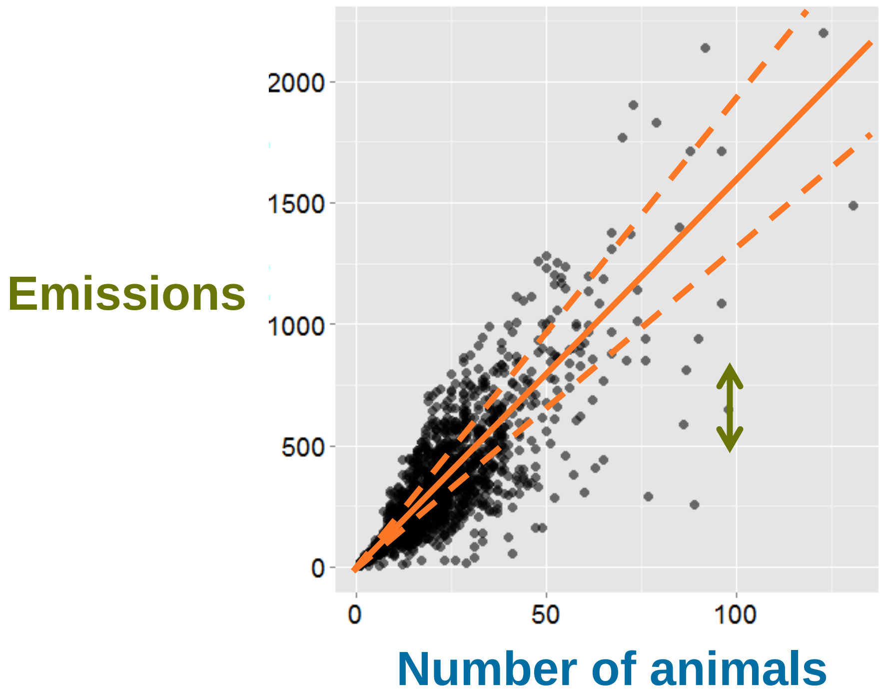
Sensitivity analysis of simulated emissions for selected farm classes

Variation of model parameters by ± 20%
→ Monte Carlo Analysis



relative standard deviation in simulated emissions

Uncertainty II: Monte Carlo Simulation



Em_{sim} = EF x N

n= 1000 Simulations

95% Interval of EF

↕ Uncertainty in emissions

Correlated error: $\varepsilon_{corr} \sim N(0, \sigma_{corr})$

Uncorrelated error: $\varepsilon_i \sim N(0, \sigma)$

$Em_{sim} = Em\ (1 + \varepsilon_i + \varepsilon_{corr})$

Uncertainty III: Aggregation

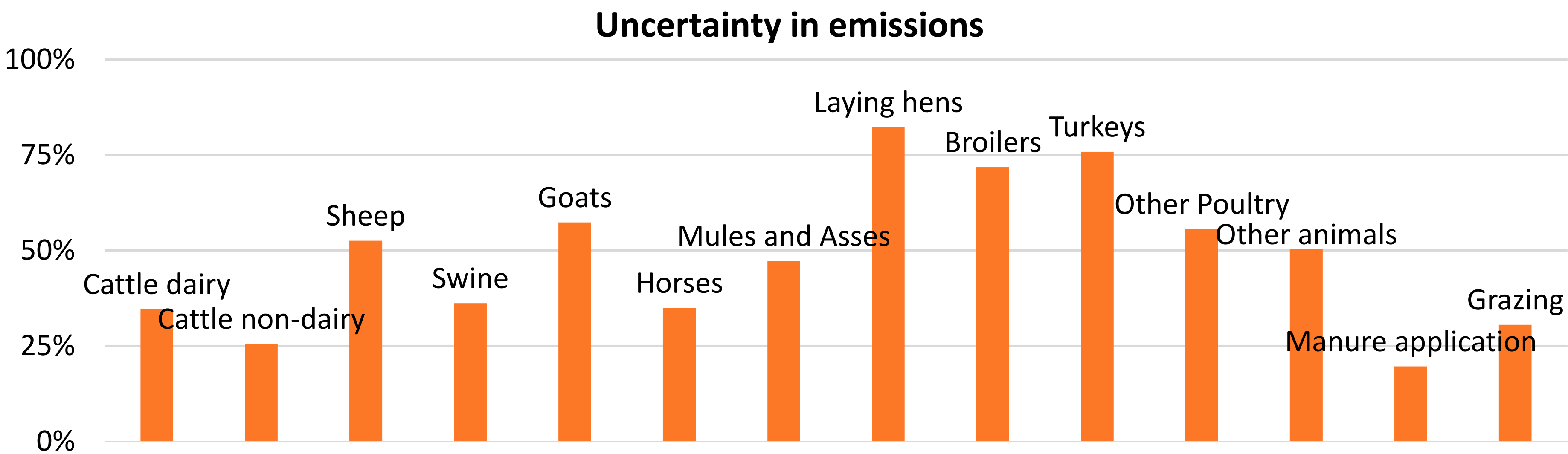
Upscaling to the national scale based on total number of animals according to categories required for emission reporting

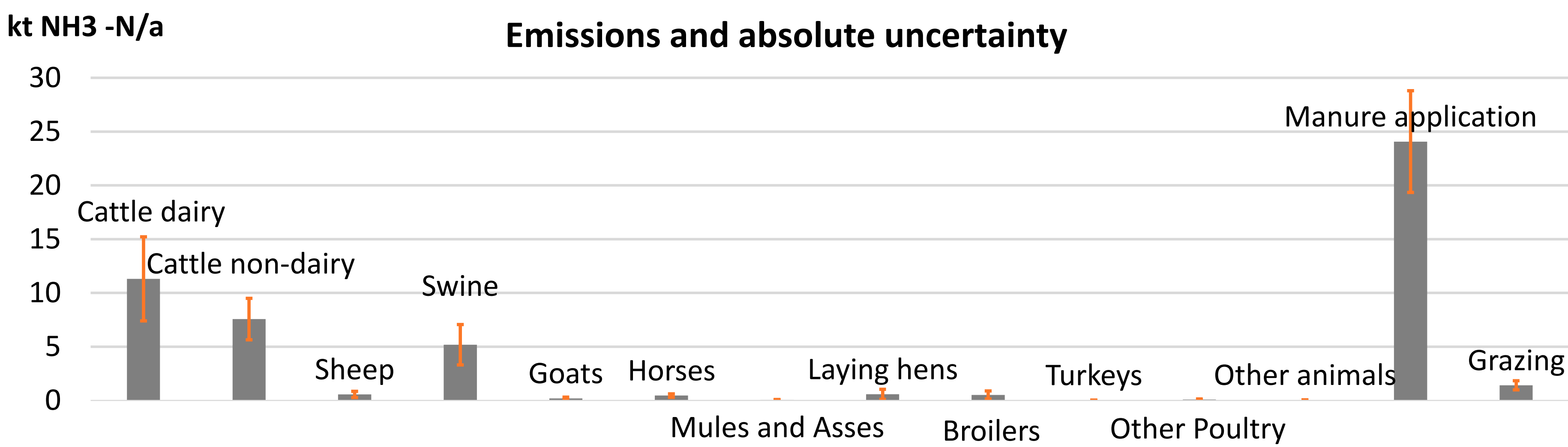
Emissions = sum of emissions of each subset
Uncertainty = ?

→ Uncertainty aggregation based on **Monte Carlo** simulation and **Gaussian error propagation**:

Aggregation step	Assumptions	Method
emission stages	correlated	Monte Carlo simulation
animal categories	uncorrelated	Gaussian error propagation
farm classes	correlated	Monte Carlo simulation

Results I

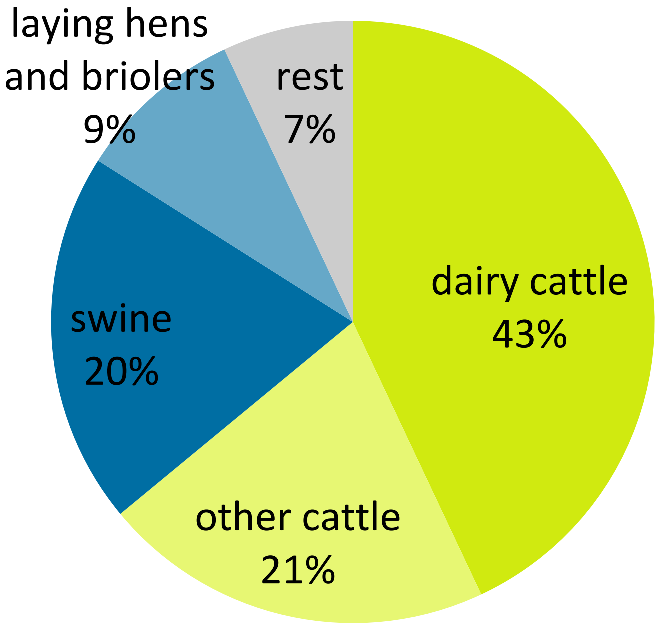

Uncertainty in emissions
100%
75%
50%
25%
0%
Cattle dairy
Cattle non-dairy
Sheep
Swine
Goats
Horses
Mules and Asses
Laying hens
Broilers
Turkeys
Other Poultry
Other animals
Manure application
Grazing


kt NH3 -N/a
Emissions and absolute uncertainty
30
25
20
15
10
5
0
Cattle dairy
Cattle non-dairy
Sheep
Swine
Goats
Horses
Mules and Asses
Laying hens
Broilers
Turkeys
Other Poultry
Other animals
Manure application
Grazing

Results I

- Uncertainty in total NH_3 emissions: 12%
- Positive correlation in partial uncertainties increases total uncertainty
- Uncorrelated partial uncertainties result in lower total uncertainty

Share of total variance in NH3 emissions



→ Assumptions on correlations are crucial

Conclusions and outlook

- The uncertainty simulation model allows a robust and standardized uncertainty assessment
- Uncertainties are implemented in the Swiss informative inventory report since 2014
- Outlook: Further refinement of assumptions on correlations is planned

Thank you for your attention!

Acknowledgements:

Swiss Federal Office of Environment

Bonjour Engineering

Bettina Schäppi

INFRAS

Research and consulting

Binzstrasse 23, 8045 Zürich

t +41 44 205 95 47

bettina.schaeppi@infras.ch

www.infras.ch

Uncertainty assessment: non-constant variance

Robust Estimated SE = $\sqrt{\sum_i w_i^2 \, e_i^2}$

Instead of

OLS Estimated SE = $\sqrt{\sum_i w_i^2 \, rmse^2}$