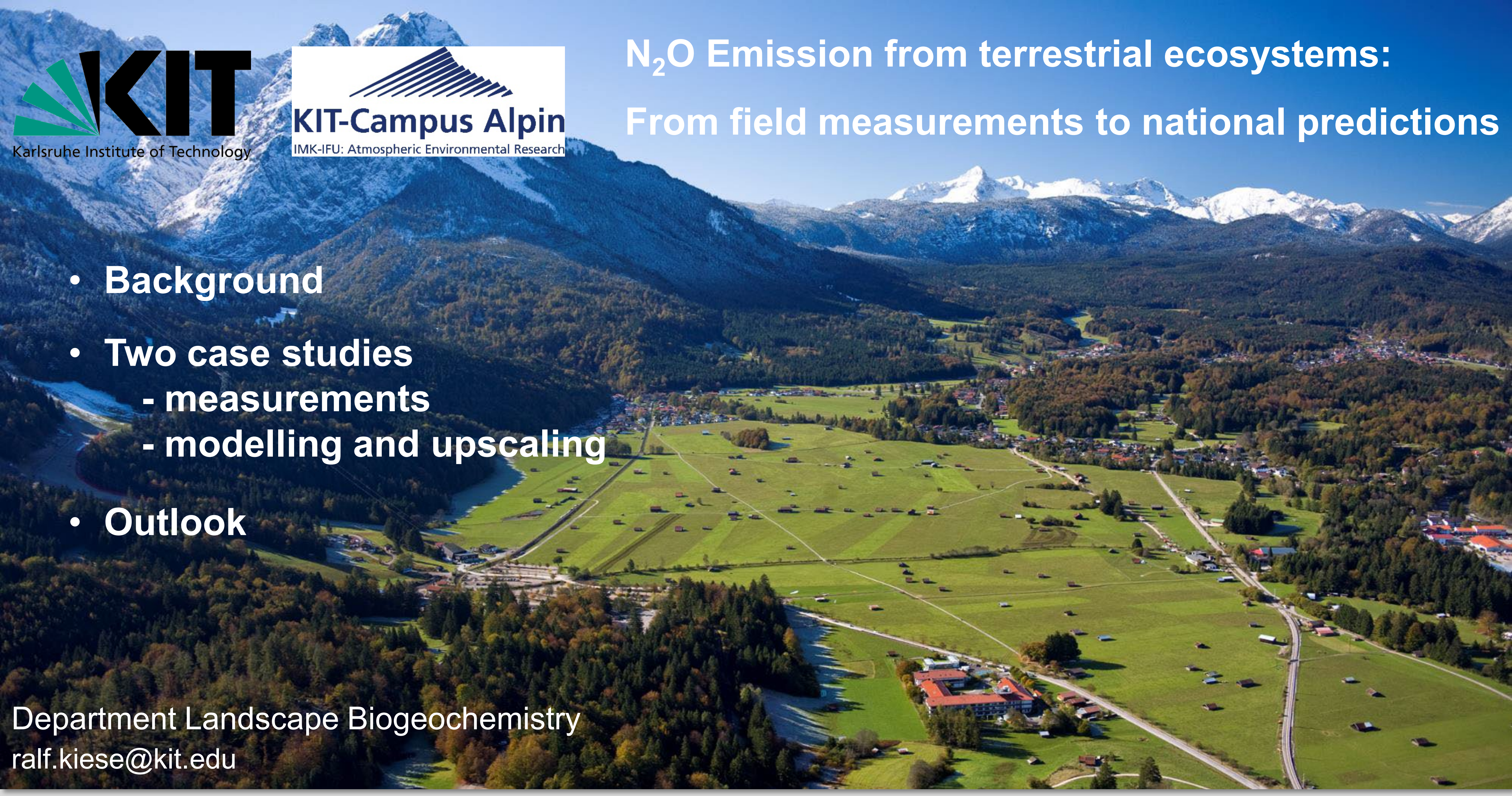

Karlsruhe Institute of Technology

KIT-Campus Alpin
IMK-IFU: Atmospheric Environmental Research

N_2O Emission from terrestrial ecosystems:

From field measurements to national predictions

- Background
- Two case studies
  - measurements
  - modelling and upscaling
- Outlook

Department Landscape Biogeochemistry
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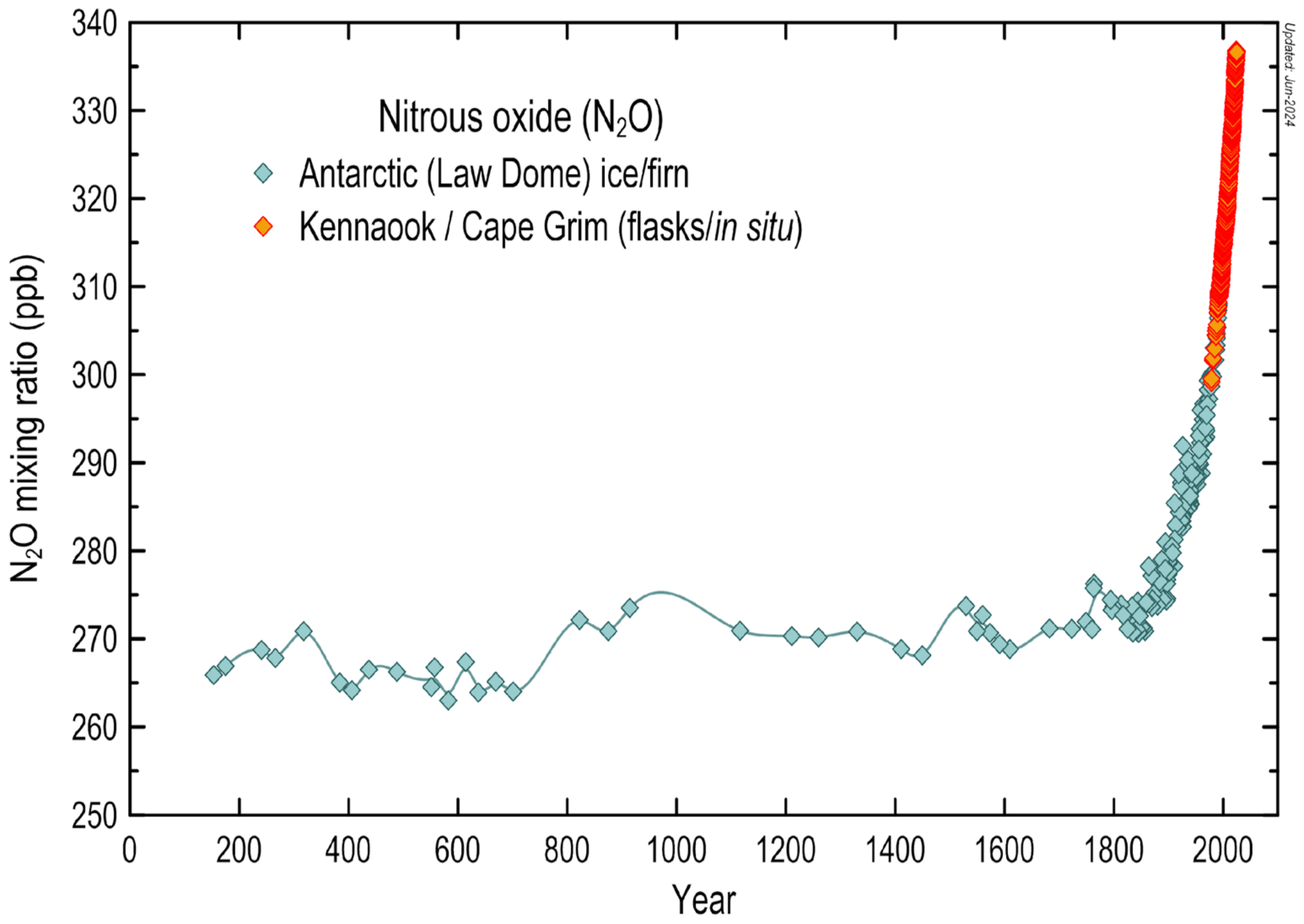
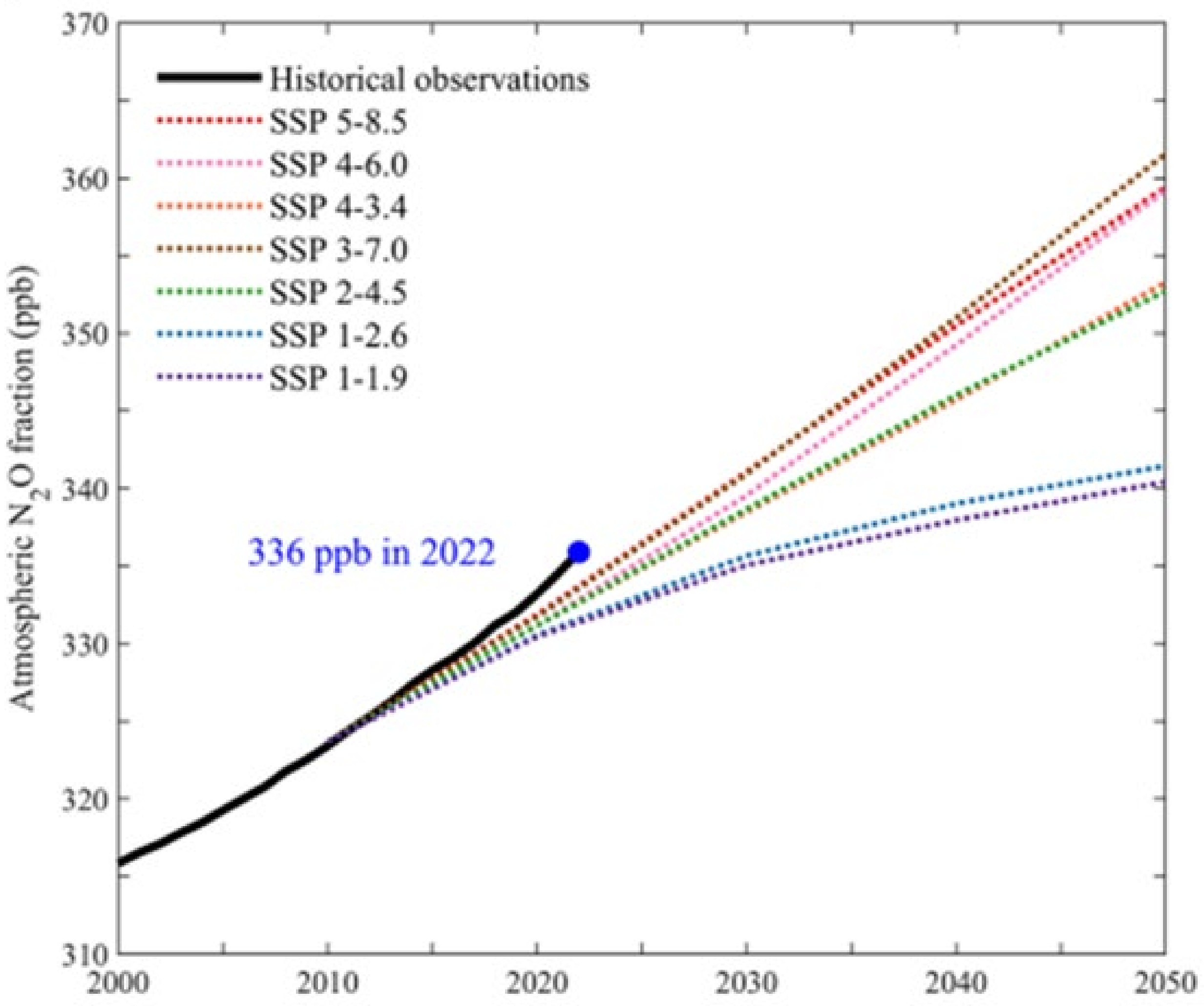
Atmospheric N_2O Concentrations Over The Last Two Millennia



- N_2O concentration reached 336 ppb in 2022
- 25% above before industrial era levels (1750)
- N_2O molecule is a 273 times higher radiative forcing than CO_2 (GWP100)
- After CO_2 CH_4, it is the third most important GHG
- Responsible for 6.5% of the global warming
- N_2O is the most significant ozone-depleting substance in the stratosphere

BoM/CSIRO/AAD

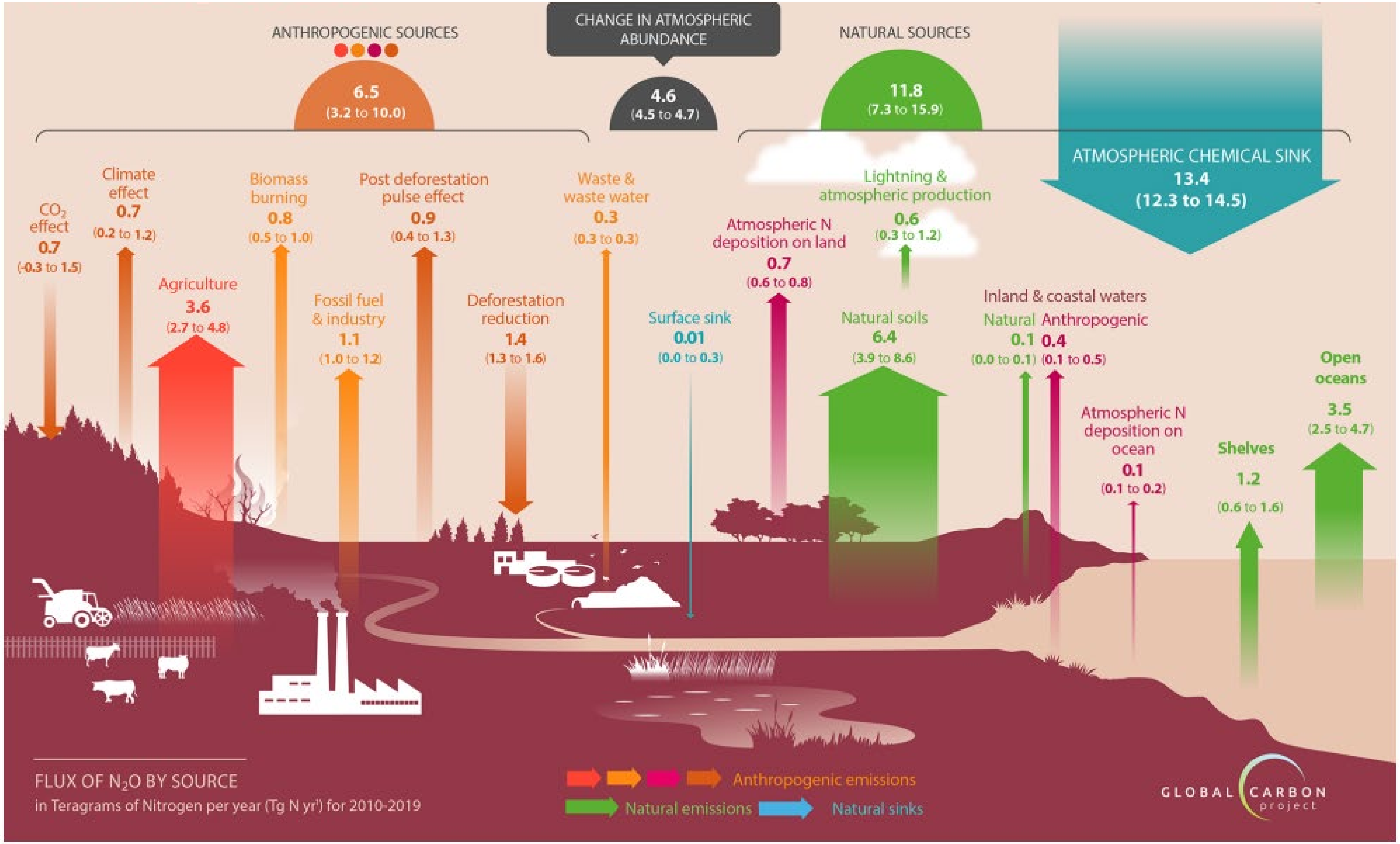
Historical Atmospheric N_2O Concentrations and future projections



- Global anthropogenic emissions increased by 40% from 1980 to 2020.
- N_2O accumulation in the atmosphere has accelerated
- Growth rates over 2020-2022 are higher than any previous observed year since 1980
- Increase exceeds the projections of the least optimistic IPCC AR5 and AR6 scenarios
- Urgent need to mitigate N_2O emissions
- Anthropogenic emissions were almost exclusively responsible for the increase

Tian et al., 2024

Global N_2O Budget



Agricultural production by use of nitrogen fertilizers and animal manure contribute

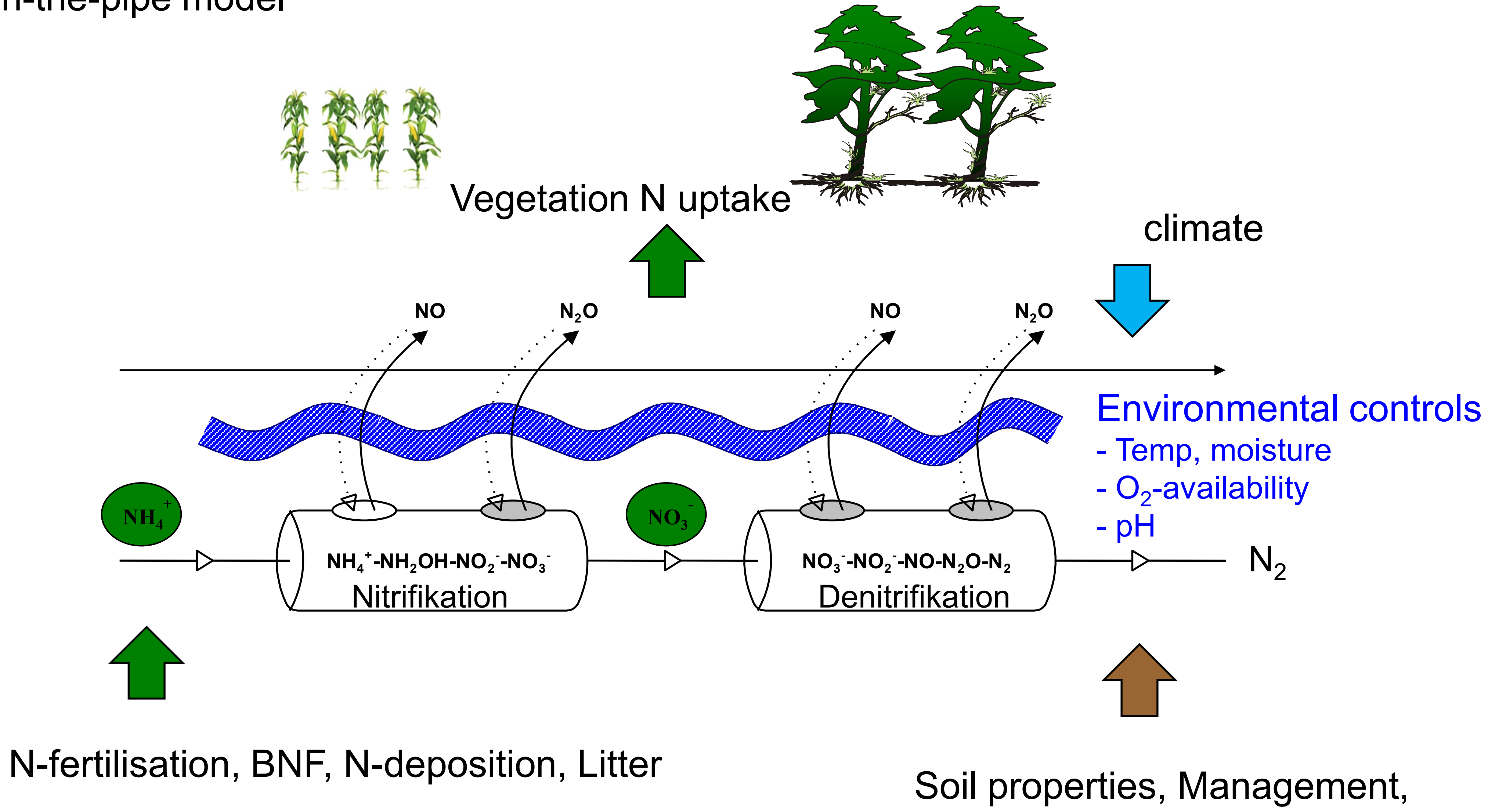
74% of the total anthropogenic N_2O emissions

Tropical rainforests are major source of N_2O emissions from natural soils

Tian et al., 2024

Conceptual model of N_2O production and consumption processes

„Whole-in-the-pipe model“



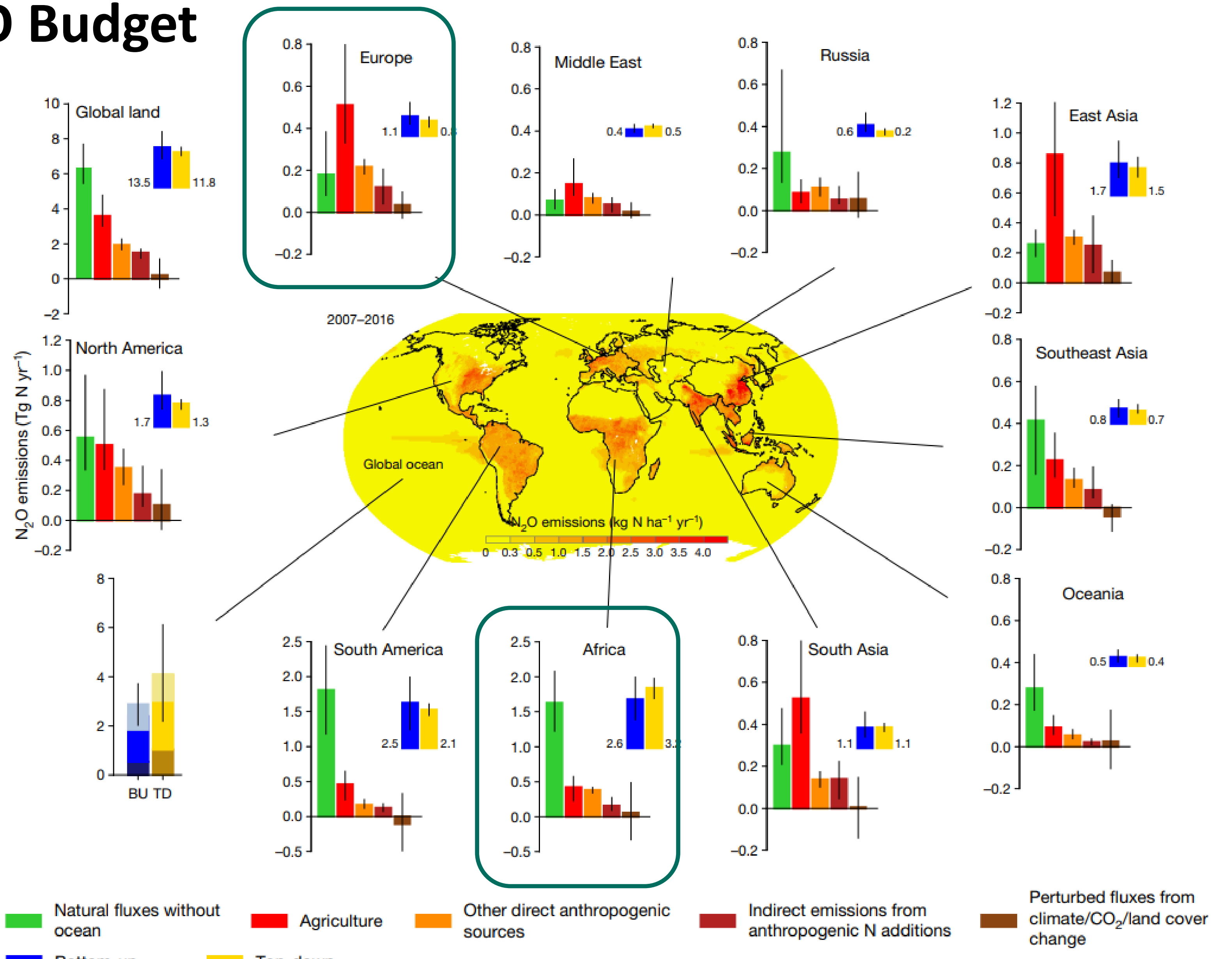
modified after Davidson, 1991

Regional difference in N_2O Budget

Two case studies:

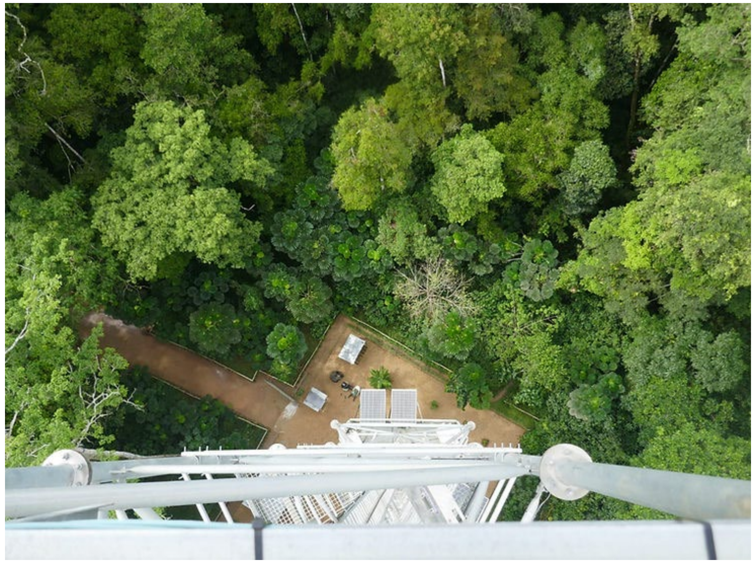
- Agricultural use soils
  focus on national upscaling
  (UNFCCC reporting)

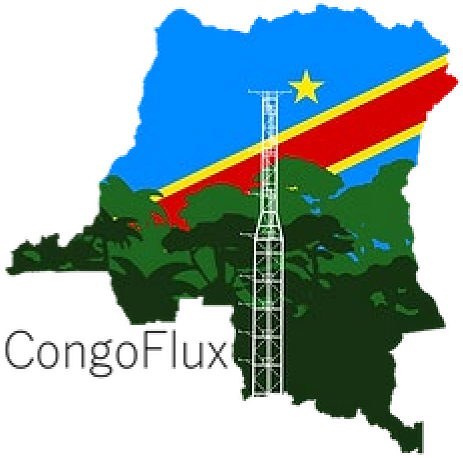
- Tropical rainforest Africa (DRC)
  focus on measurements

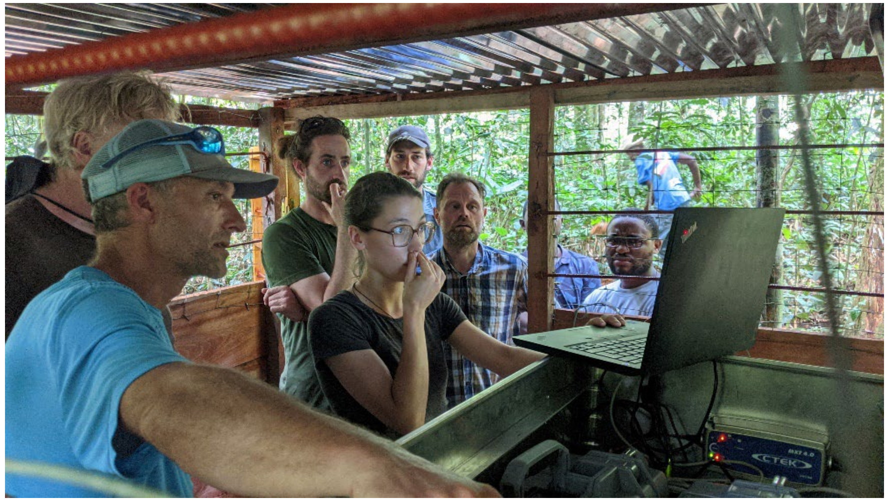


Tian et al., 2024

Field measurements: Tropical rainforest Yangambi, DRC







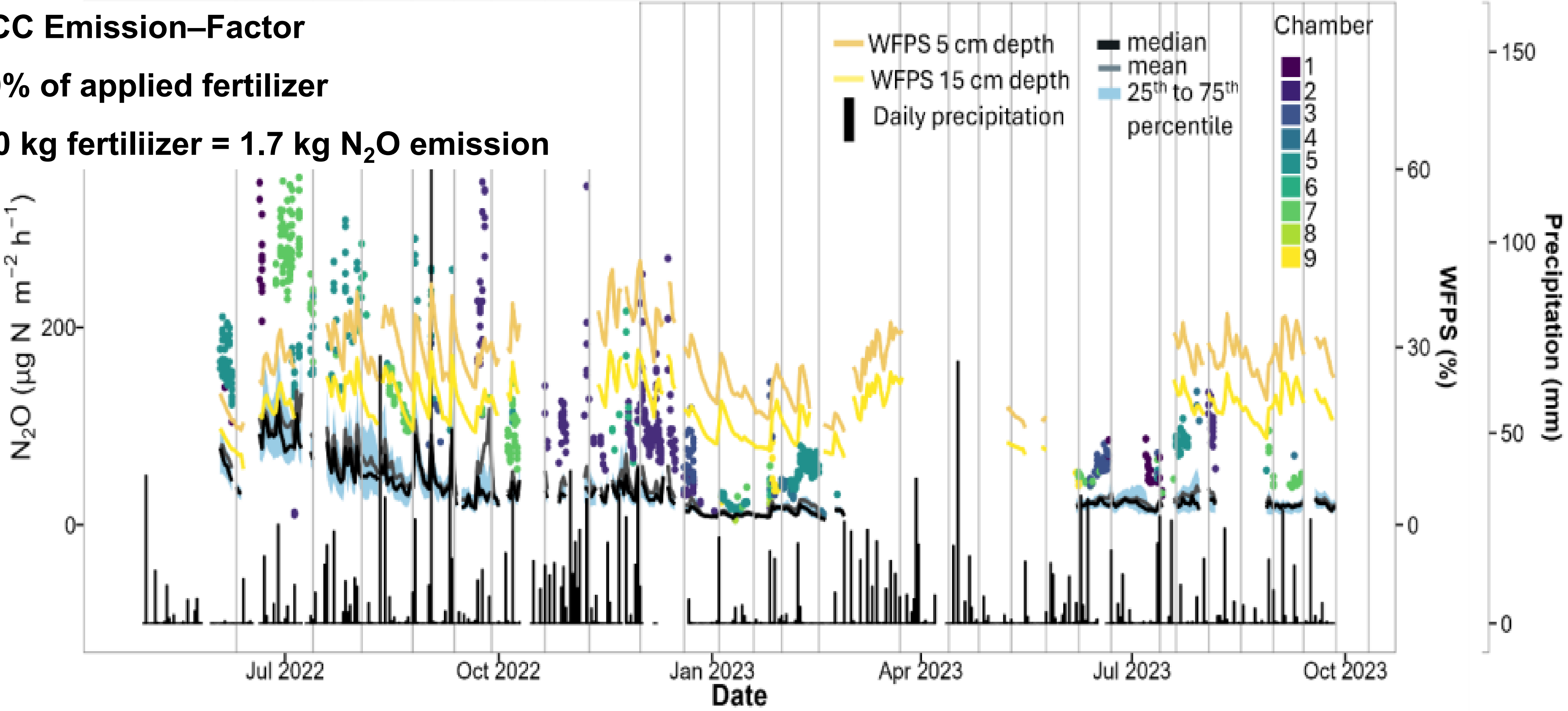
Automatic field measurements: Tropical rainforest Yangambi, DRC

annual Emission **3.6 kg N_2O-N ha^{-1} yr^{-1}**

IPCC Emission–Factor

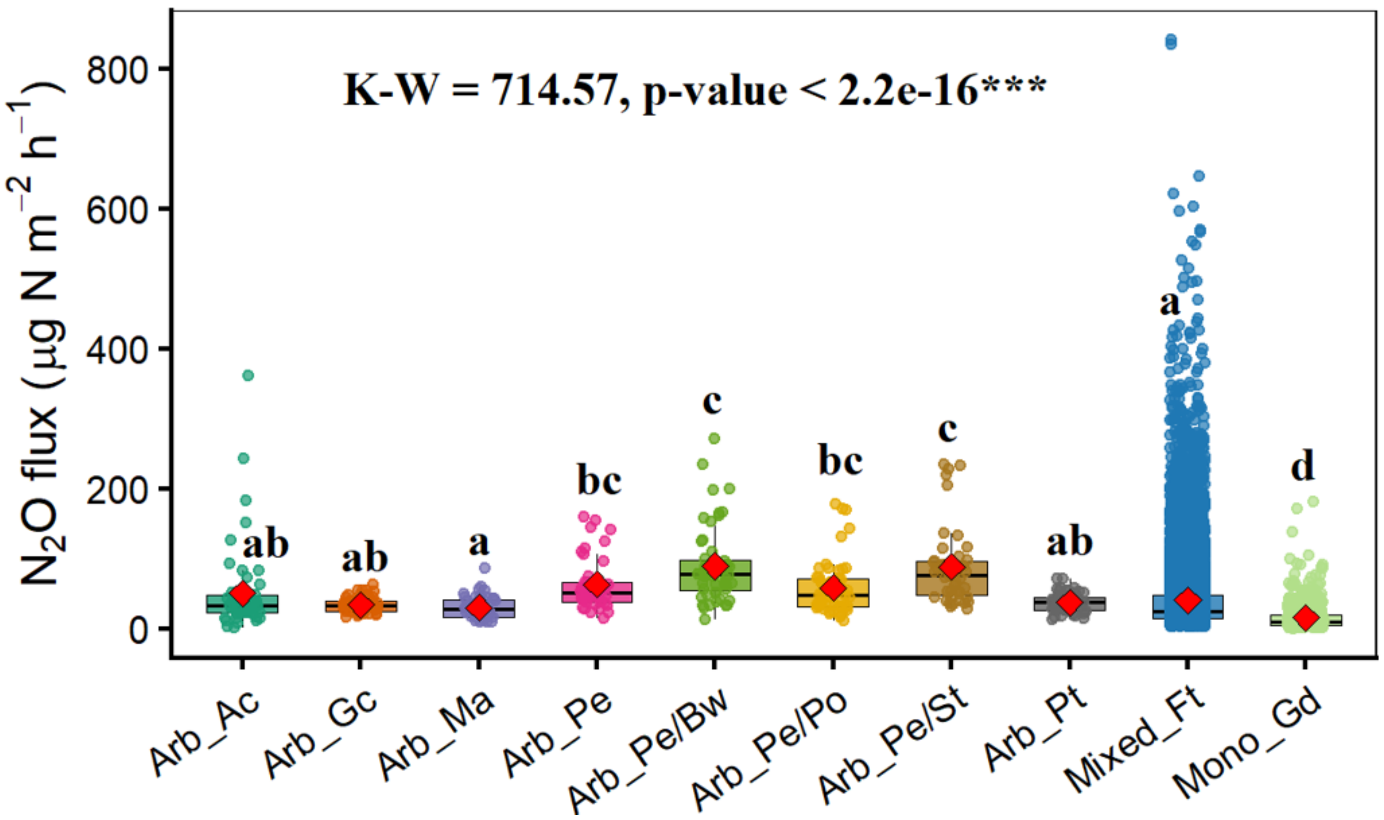
1.0% of applied fertilizer

170 kg fertiliizer = 1.7 kg N_2O emission



Daelman et al., 2025

Manual field measurements: Tropical rainforest Yangambi, DRC

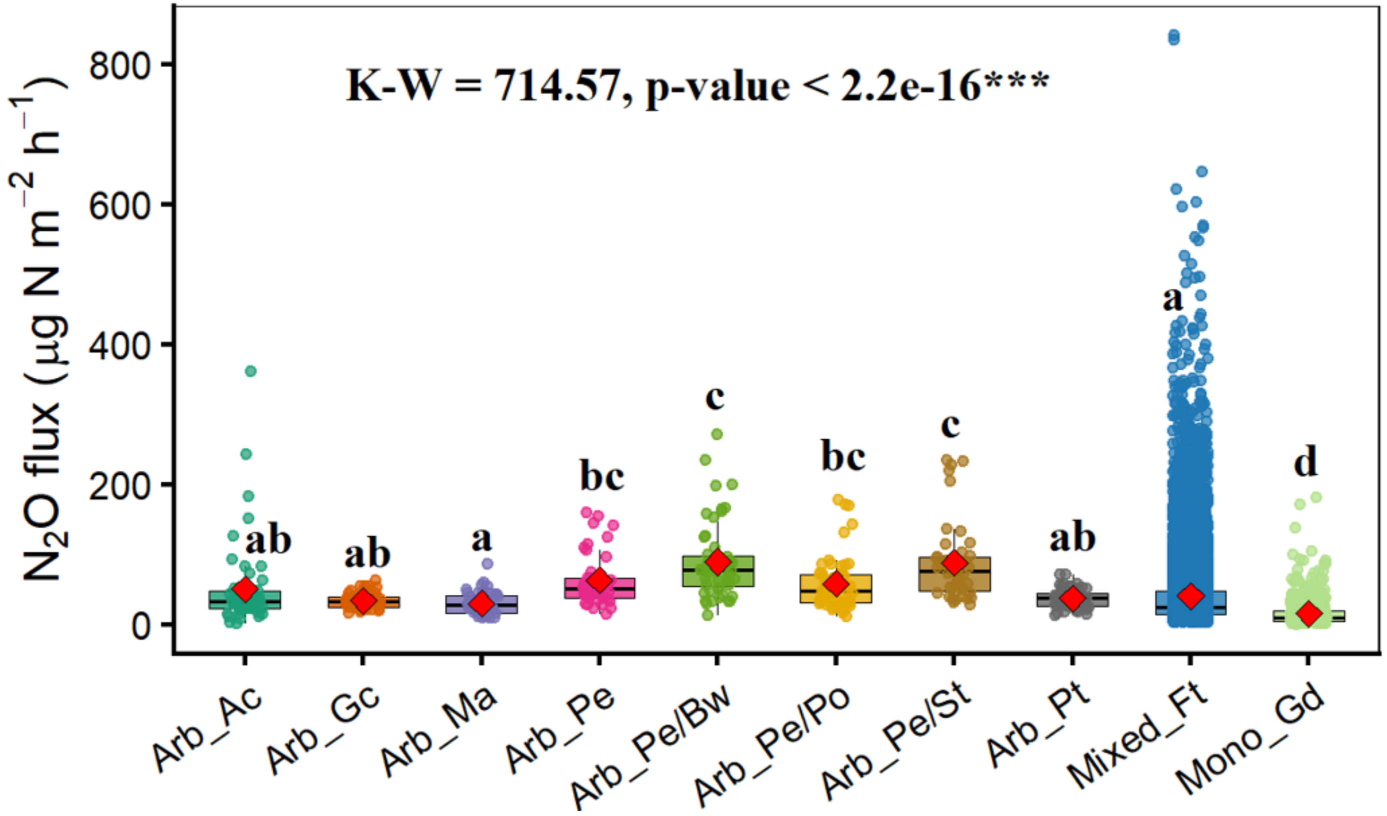


Emission **0.97 to > 4 kg N_2O-N ha^{-1} yr^{-1}**

EC tower site **3.6 kg N_2O-N ha^{-1} yr^{-1}** → **0.425 Mg CO_2-C ha^{-1} yr^{-1}**

Alebadwa et al., 2025 in prep, Barthel et al., 2022, Galarotti et al., 2021

Manual field measurements: Tropical rainforest Yangambi, DRC



AGB biomass C sink (Mg CO_2-C ha^{-1} yr^{-1})

	Africa	Amazon	Africa	Amazon
1980–1990	45	73	**0.33** (0.06–0.63)	**0.35** (0.06–0.59)
1990–2000	96	172	**0.67** (0.43–0.89)	**0.53** (0.42–0.65)
2000–2010	194	291	**0.70** (0.55–0.84)	**0.38** (0.26–0.48)
2010–2015[c]	184	172	**0.66** (0.40–0.91)	**0.24** (0.00–0.47)
2010–2020[d]	–	–	***0.63*** *(0.36–0.89)*	***0.23*** *(–0.05–0.50)*
2020–2030[d]	–	–	***0.59*** *(0.24–0.93)*	***0.12*** *(–0.29–0.51)*
2030–2040[d]	–	–	***0.55*** *(0.08–0.99)*	***0.00*** *(–0.54–0.49)*

Emission **0.97 to > 4 kg N_2O-N ha^{-1} yr^{-1}**

EC tower site **3.6 kg N_2O-N ha^{-1} yr^{-1}**

0.425 Mg CO_2-C ha^{-1} yr^{-1}

Alebadwa et al., 2025 in prep, Barthel et al., 2022, Galarotti et al., 2021, Hubau et al., 2020

Field measurements: Tropical rainforest Yangambi, DRC

2023-2024

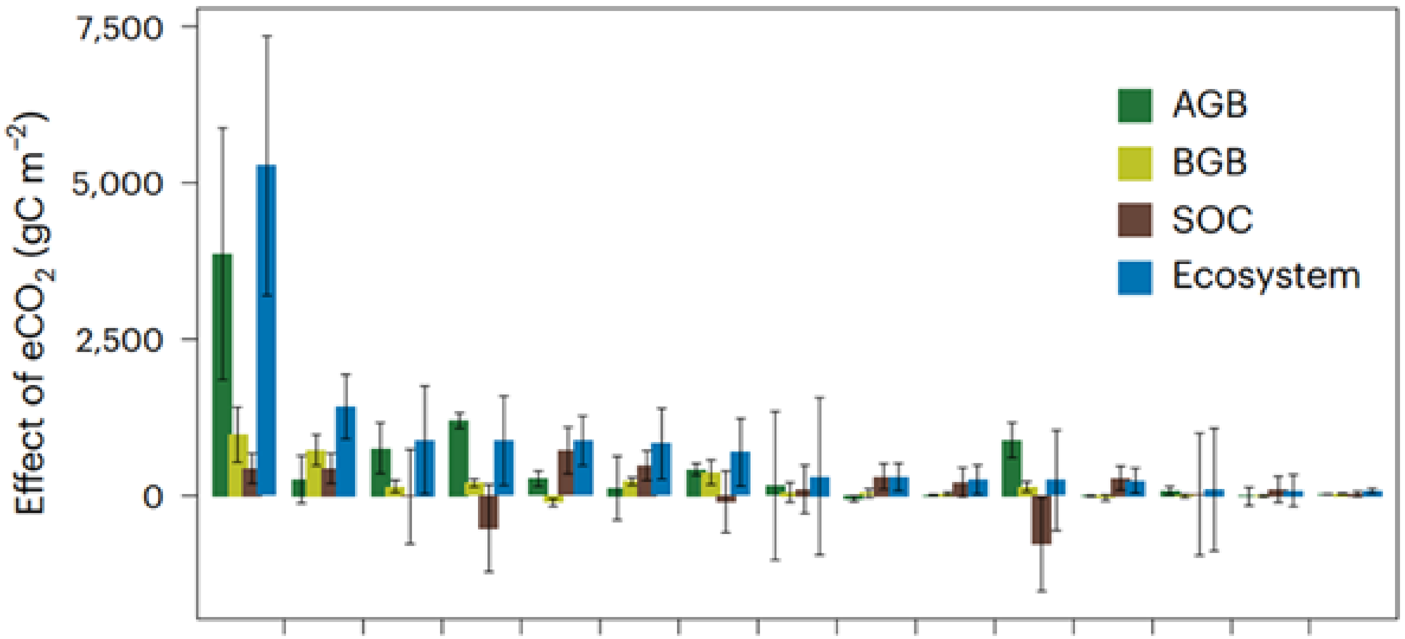
GPP: -34 Mg C ha^{-1} yr^{-1} (30-39)

Reco: +37 Mg C ha^{-1} yr^{-1} (32-42)

NEE: +1.6 Mg C ha^{-1} yr^{-1} (+0.5 - +3)

El Niño years
with increased Reco as a result of
higher temperature levels

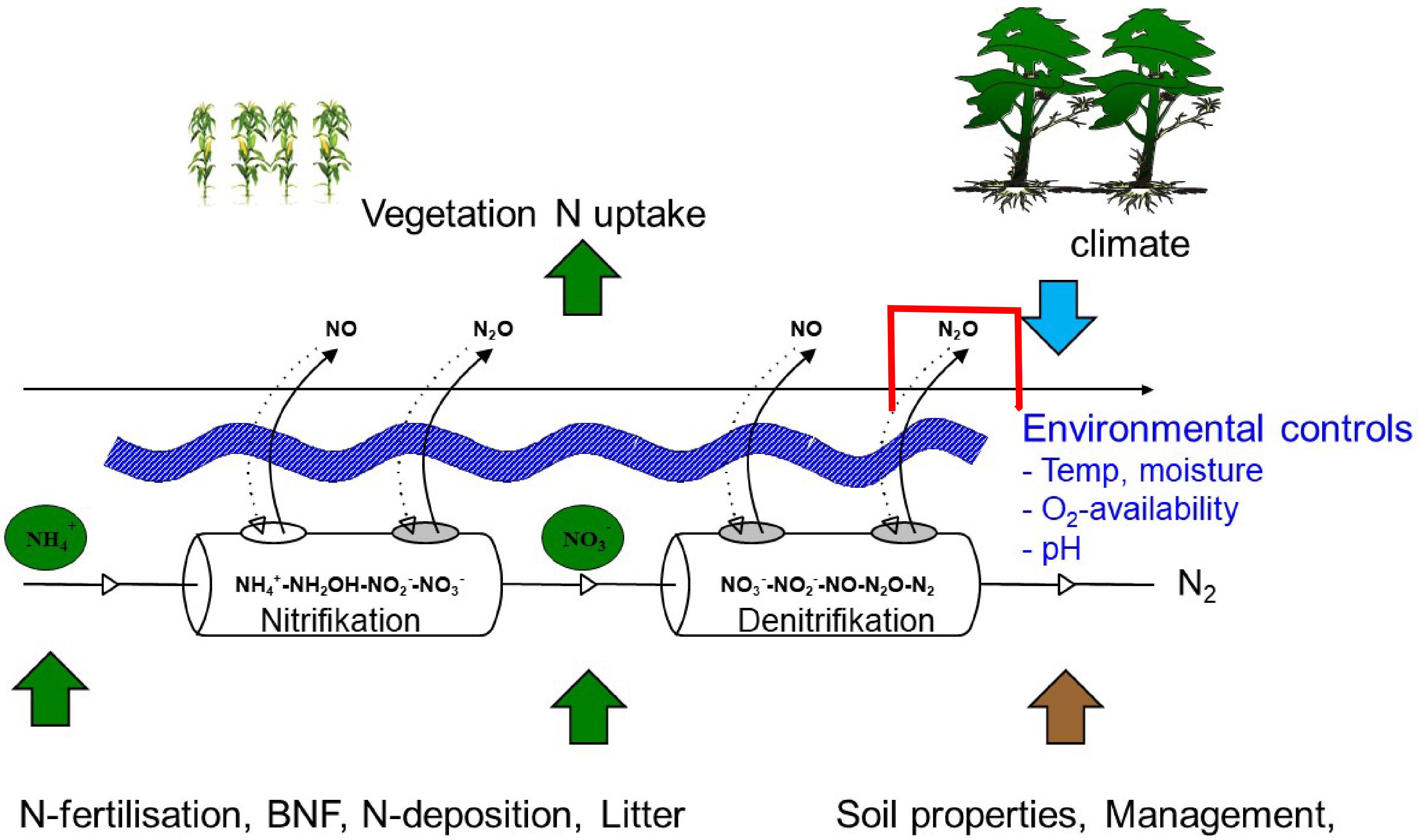
mobilisation of SON may also increased N_2O ?



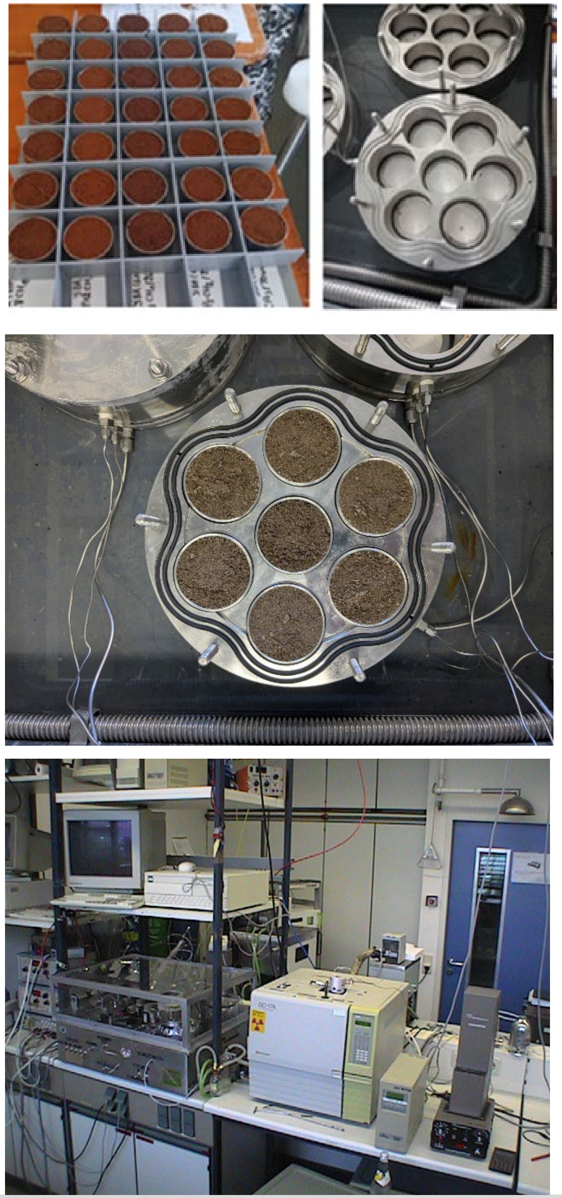
eCO_2: increases in BGB/ SOC were same or larger than AGB

N_2O and N_2 emissions

„Whole-in-the-pipe model“

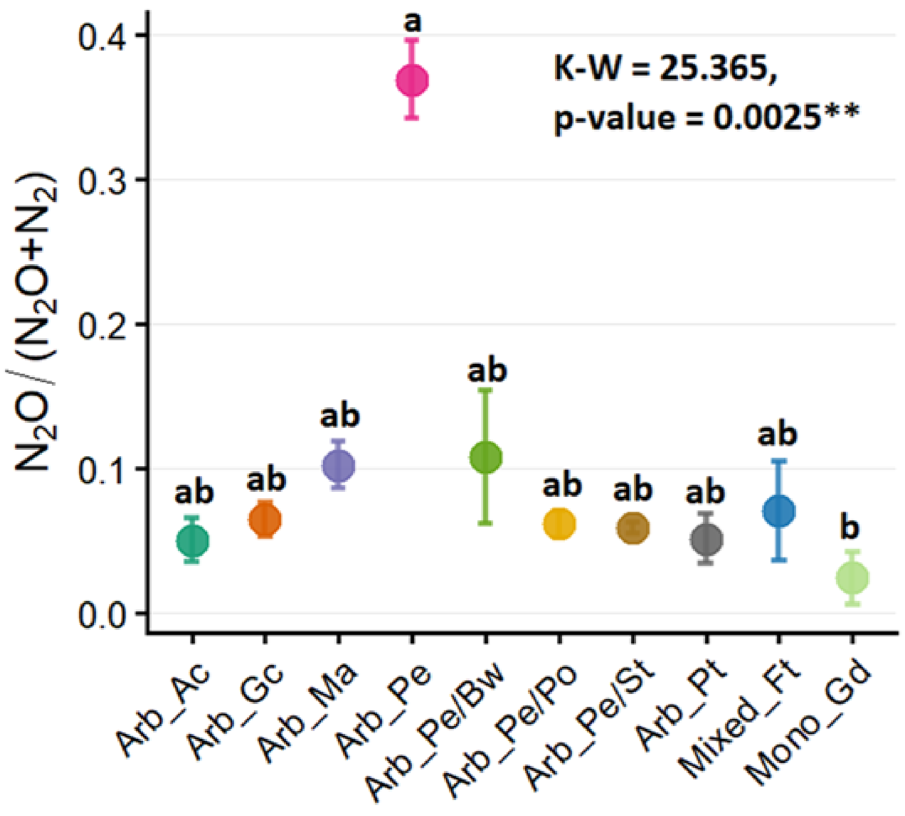


Soil incubation system



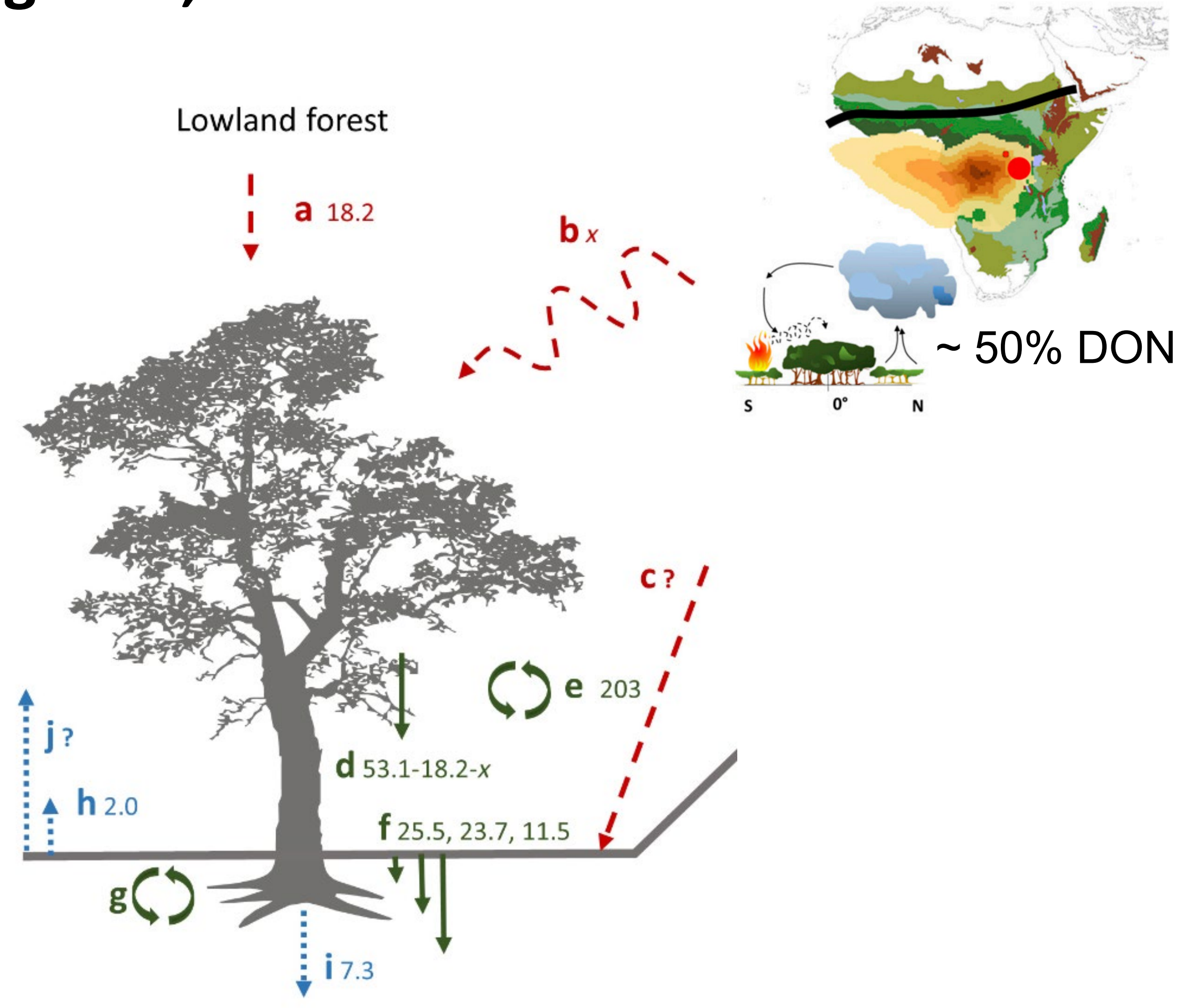
modified after Davidson, 1991

N_2O – N_2 ratio: Tropical rainforest Yangambi, DRC



Emission **0.97 to > 4 kg N_2O-N ha^{-1}**

N_2O/ N_2 ratio → **10 – 40 kg N_2-N ha^{-1}**



N_2 Emission closing the N budget

From point measurements to national upscaling – case study modelling

Estimating GHG emissions from cropland and grasslands is inherently complex and of high uncertainty due to variability in

- weather and soil characteristics
- management options
- interaction of management with environmental variables

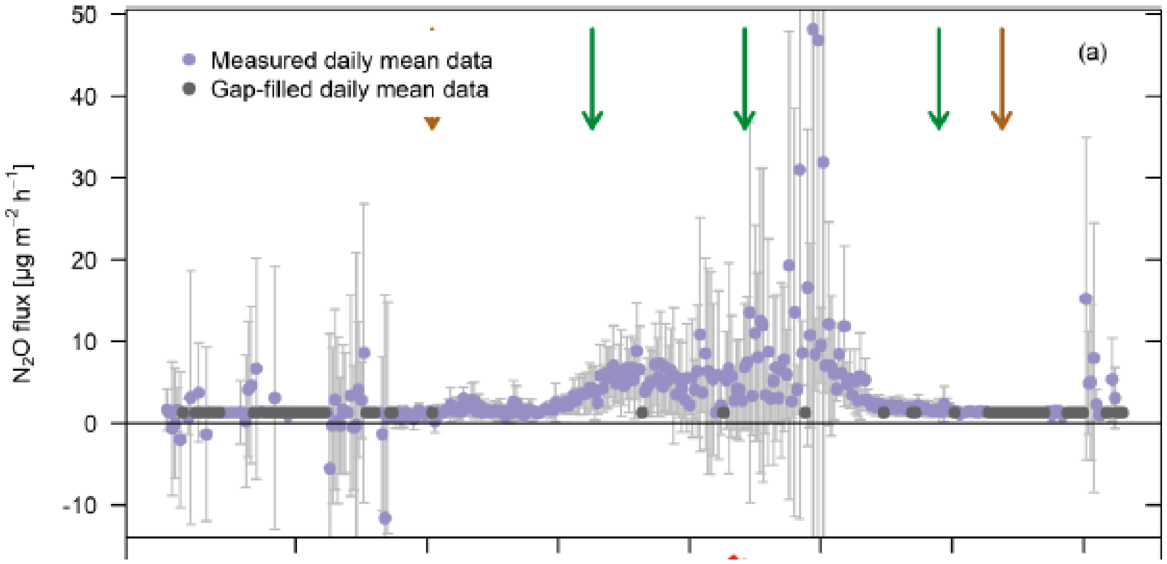
IPCC methods for GHG reporting of agricultural soils

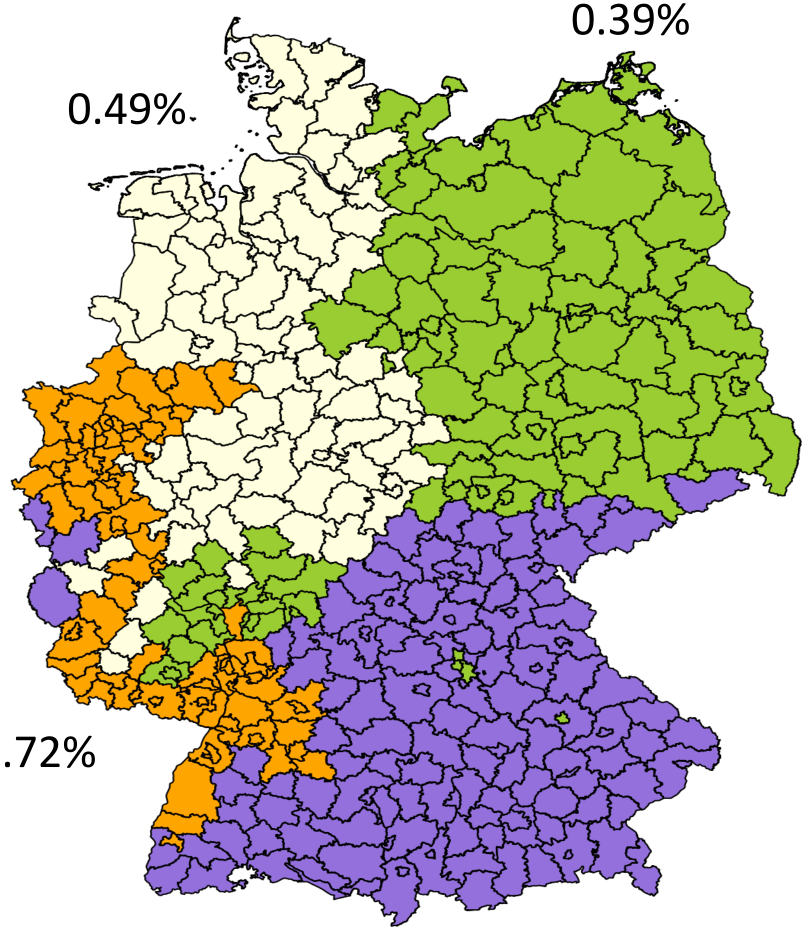
Tier 1: N_2O emissions calculated as 1% (EF) of N fertilizer application

Tier 2: Country or region-specific emission factors

Tier 3: Process-based models informed by geographically specific activity soil, vegetation and climate data

From point measurements to regional/ national upscaling: Tier 2





N_{fert} * EF = N_2O emission

Mathivanan et al. 2021

From point measurements to regional/ national upscaling: Tier 3

Site scale

INPUTS

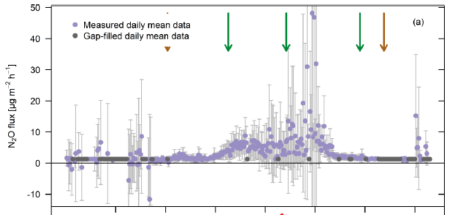
Climate
Soil
Vegetation
Management

PARAMETER OPTIMIZATION

- Uncertainty

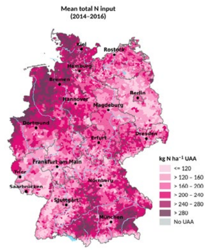
SITE VALIDATION

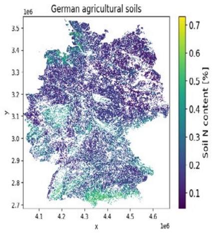
Eddy covariance
Chamber fluxes
Field data



LandscapeDNDC

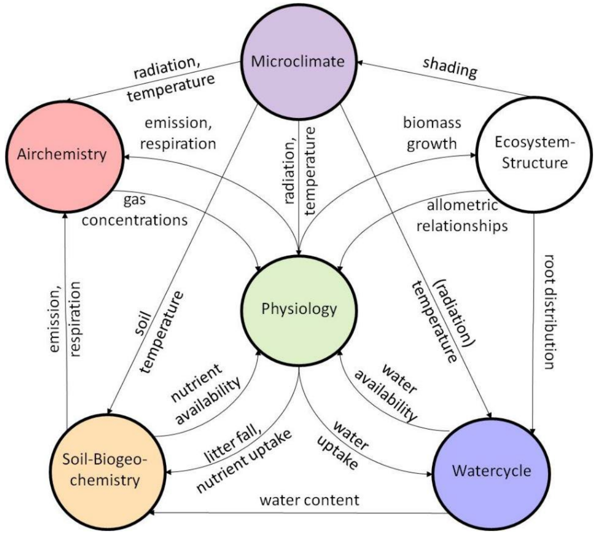
National scale





INPUTS

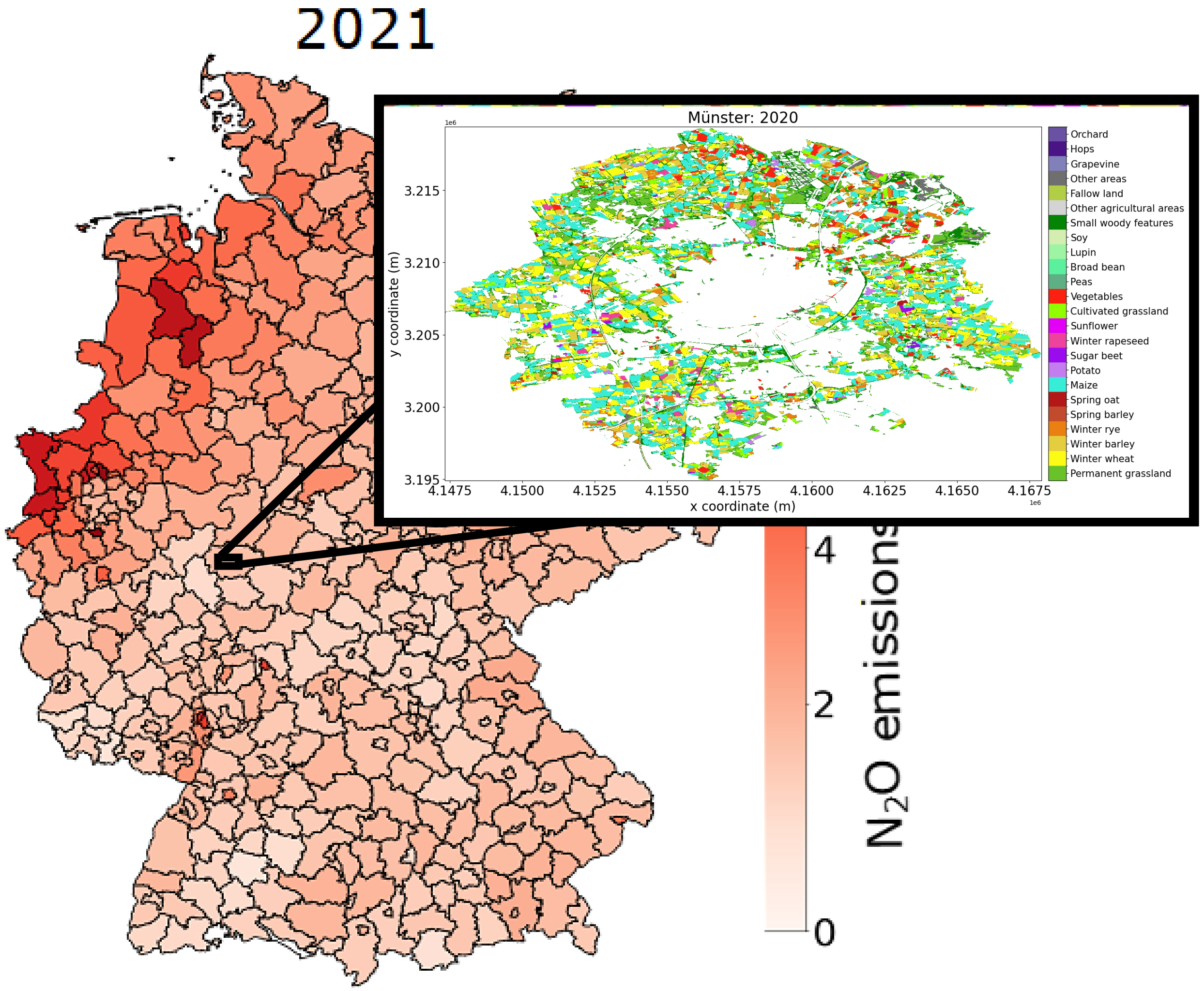
Climate
Soil
Vegetation
Management



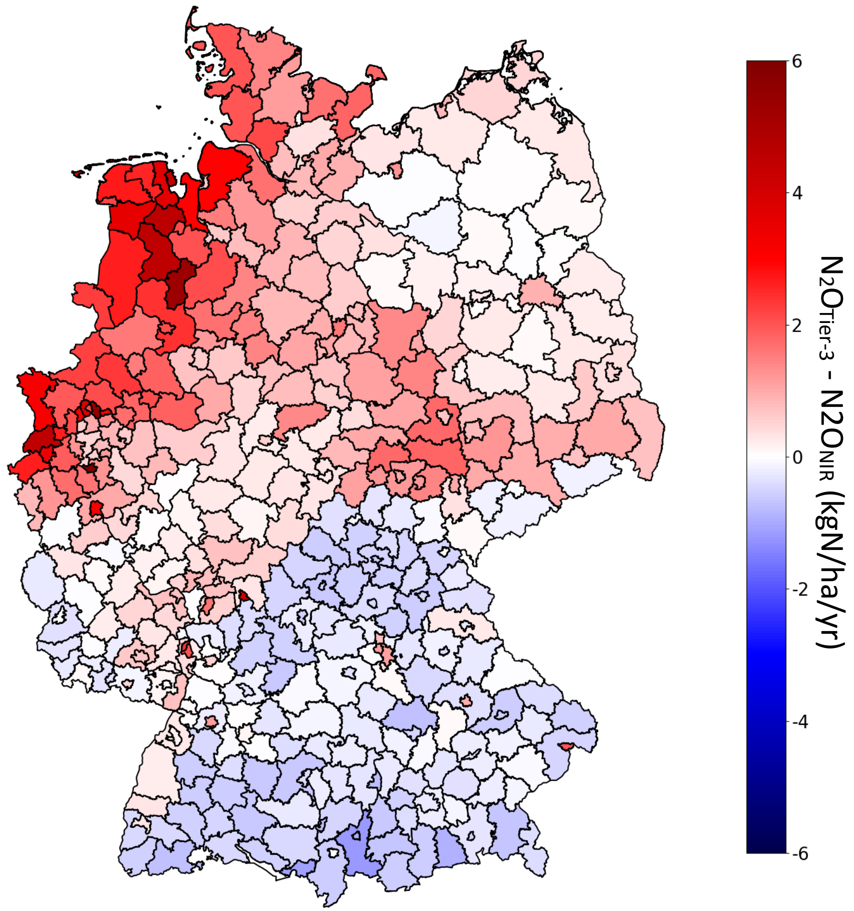
OUTPUTS

Regional/ national GHG flux maps
Uncertainty estimates
Inventory-ready data

National N_2O Emission inventory croplands and grasslands: Tier 3

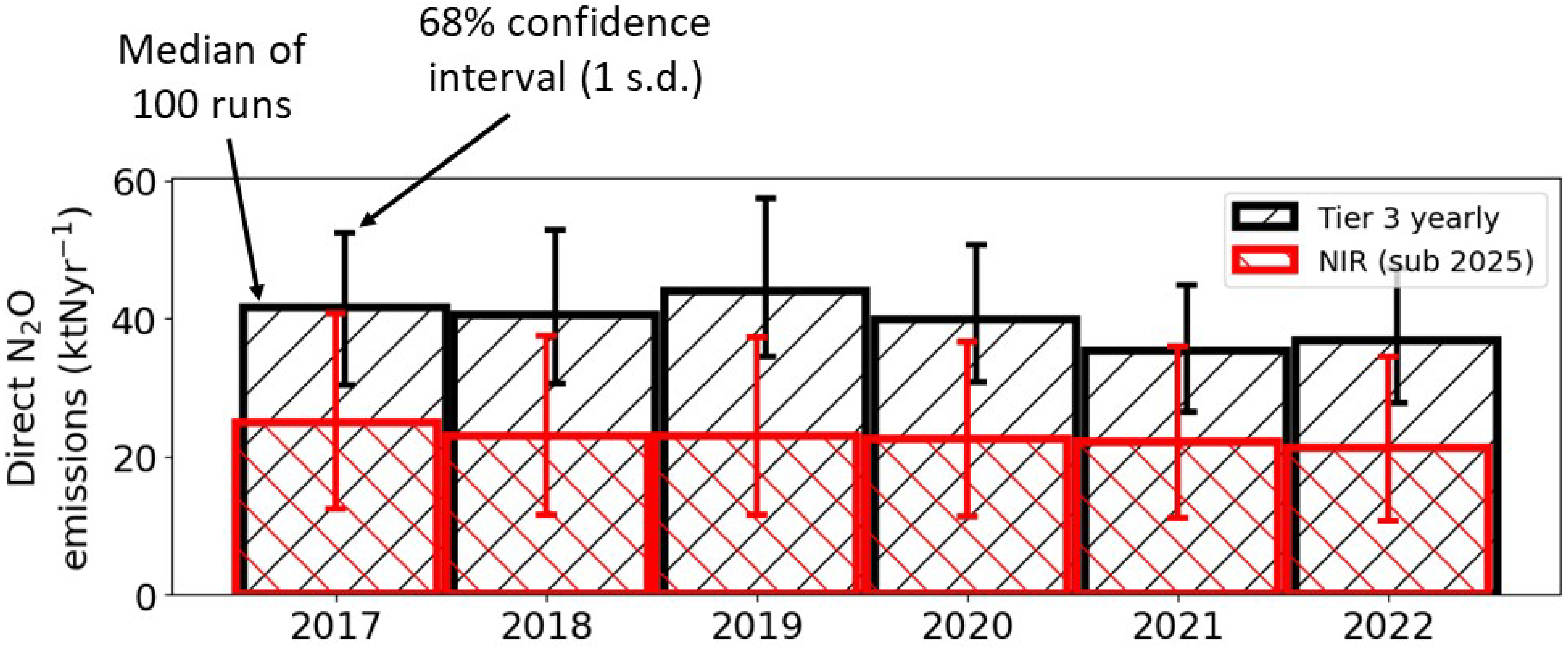


Difference Tier 3-Tier 2



Smerald et al., in prep;

Comparison of Tier 3 N_2O emission and uncertainties with NIR

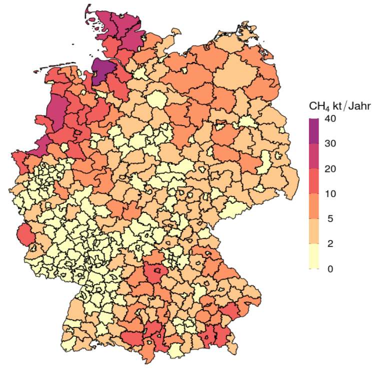


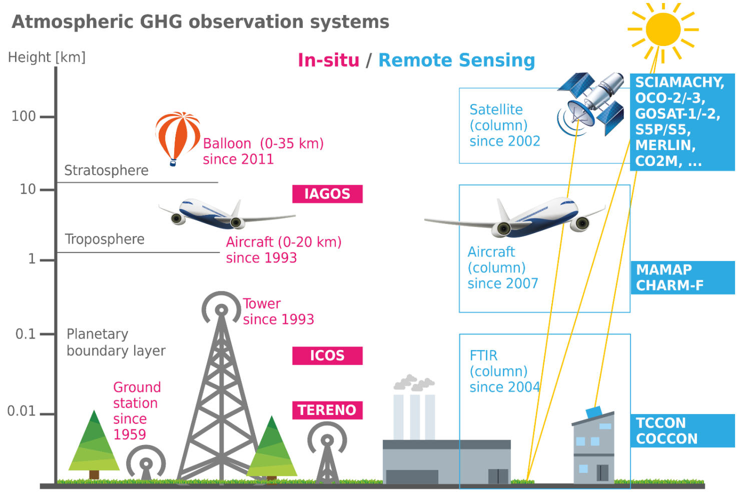
Smerald et al., in prep

The Integrated Greenhouse Gas Monitoring System for Germany (ITMS)

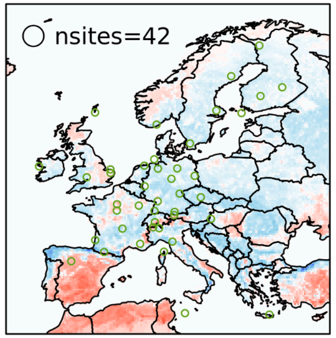
NATIONAL INVENTORIES ✚ **ATMOSPHERIC OBSERVATIONS** ✚ **MODELS** = **EMISSION ESTIMATES**

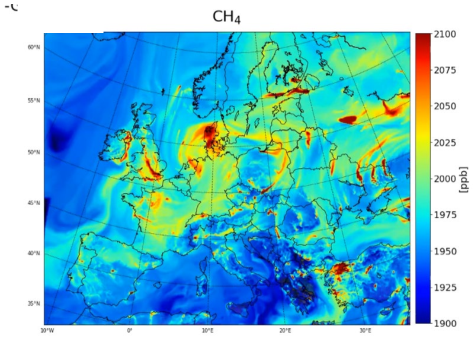
Spatially and Temporally Resolved,
Observation Based,
For all relevant emission sectors / types





Credits: Uni Bremen/DWD





Credits: MPI-BGC

ESTABLISH AN OPERATIONAL SERVICE

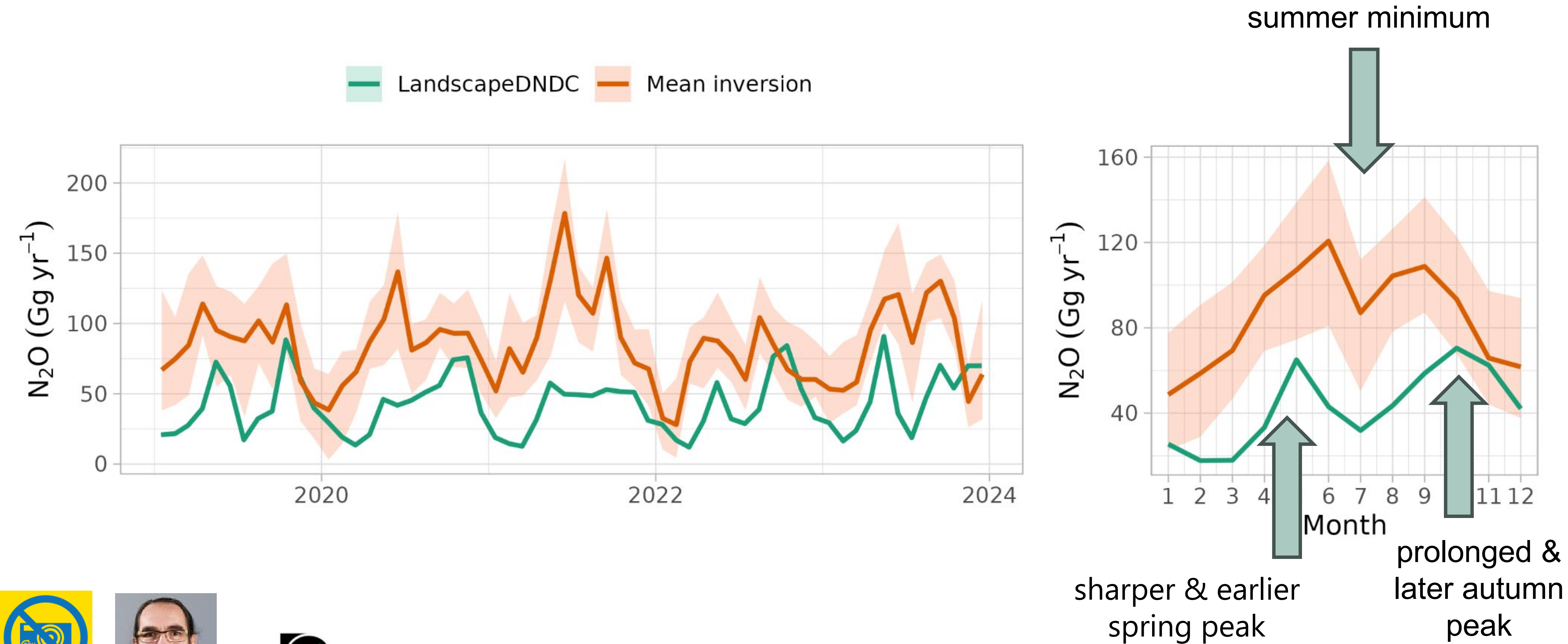
DWD

Umwelt Bundesamt

THÜNEN

Sources and Sinks | Observations | Atmospheric and Inverse Models

Comparison of Tier 3 N_2O emission with atmospheric inversions



PARIS | DATA MODELS INVENTORIES

Slide of Stefan Henne

Summary

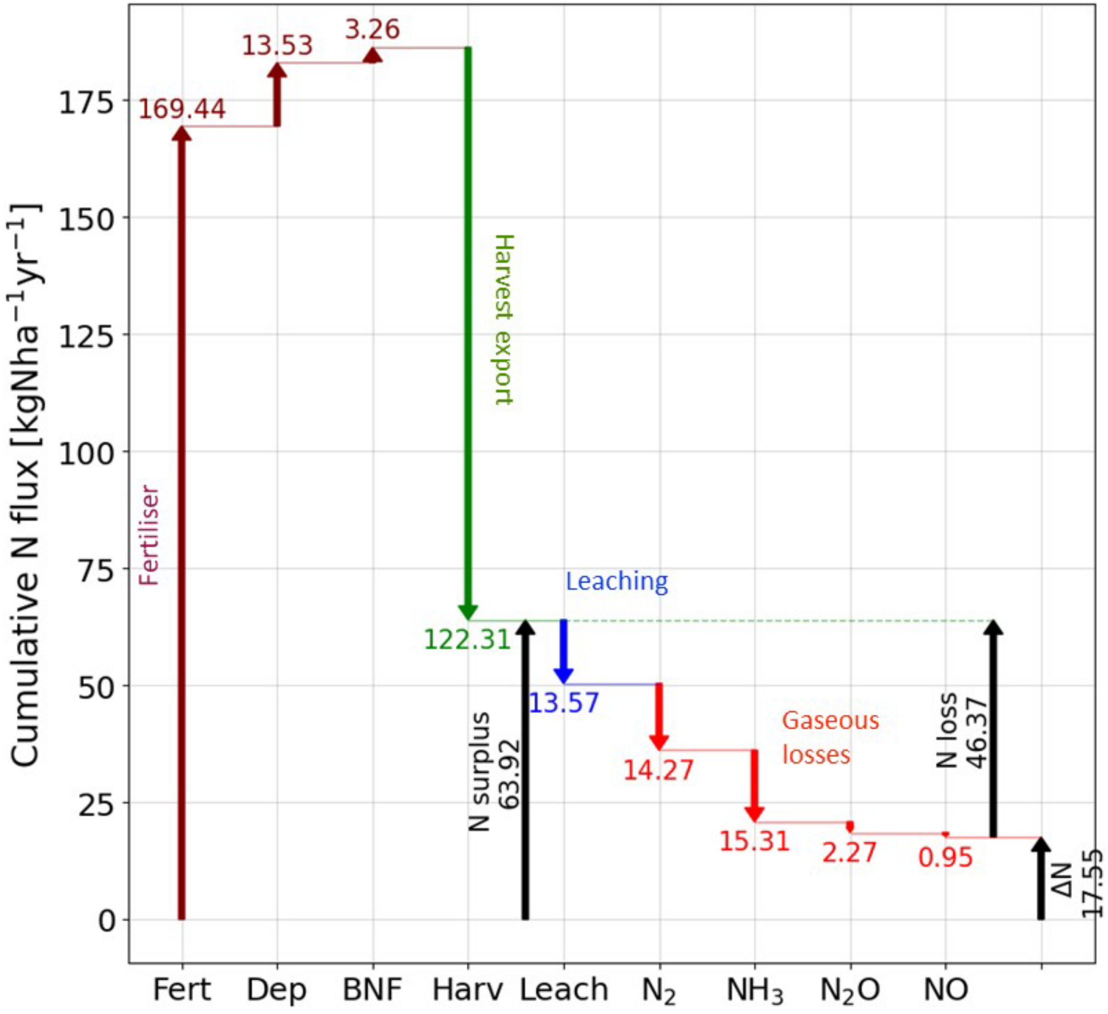
Absolute proportion of N_2O in the atmosphere and its impact on the climate will continue to rise in the coming decades

Trend can be reversed if the technical and political measures that reduce nitrous oxide emissions are consistently implemented

Need for more accurate (input) data both

- for improved calculation of nitrous oxide emissions and their potential reduction as well as
- for future developments within the context of scenario analyses

More and increasingly permanent measurements under quite different conditions for improved understanding of the causes and quantites of N_2O emission



Thanks for your attention

Cropland N Balance field setup