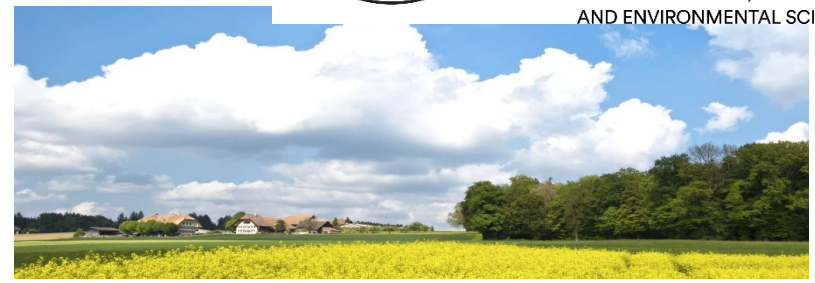
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Modelling soil N2O emissions from agricultural soils in LCA under different climates, soils and application rates

Thomas Nemecek
Agroscope
Life Cycle Assessment research group
Zurich, Switzerland
www.agroscope.ch I good food, healthy environment

Pietro Goglio
University of Perugia
Department of Agricultural, Food, and Environmental Sciences
Italy

LCA food 2026

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Challenges

- N_2O is a major contributor to climate change from agriculture
- High spatial and temporal variability
- Review of N_2O emission models in LCA (Goglio *et al*. 2024) → recommend DNDC or IPCC Tier 1/2 models
- DNDC often not applicable in LCA, IPCC factors ignore many driving parameters and have large uncertainties for site specific assessment.

Objectives

develop an empirical model:

- considering the main driving parameters,
- applicable with data readily accessible in LCA studies,
- modelling the individual factors independently
- avoiding step changes.

Modified model for direct N_2O soil emissions

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$$N_2O_{emf} = 44/28 \cdot ((EF1_m\,(N_{min} + TAN_{org}) + EF1_o\,(N_{org} - TAN_{org})) \cdot SF_{fert} \cdot SF_{prec} \cdot SF_{temp} \cdot SF_{text} \cdot SF_{soc} \cdot SF_{pH} + EF1_{cr} \cdot N_{cr} + EF1_o \cdot N_{som}))$$

N_2O_{emf} = direct emissions of N_2O from agricultural soil [kg N_2O ha^{-1}]

N_{min} = total N in mineral fertilisers [kg N ha^{-1}]

TAN_{org} = NH_4-N in organic fertilisers [kg N ha^{-1}] (TAN = Total Ammonia Nitrogen)

N_{org} = total N in organic fertilisers [kg N ha^{-1}]

SF_{fert} = scaling factor for N application rate (Eq. 2)

SF_{prec} = scaling factor for growing season precipitation (Eq. 3)

SF_{temp} = scaling factor for mean annual temperature (Eq. 4)

SF_{text} = scaling factor for soil texture (Eq. 5) and (Eq. 6)

SF_{soc} = scaling factor for soil organic C (Eq. 7)

SF_{pH} = scaling factor for soil pH (Eq. 8)

N_{cr} = nitrogen contained in the crop residues [kg N ha^{-1}]

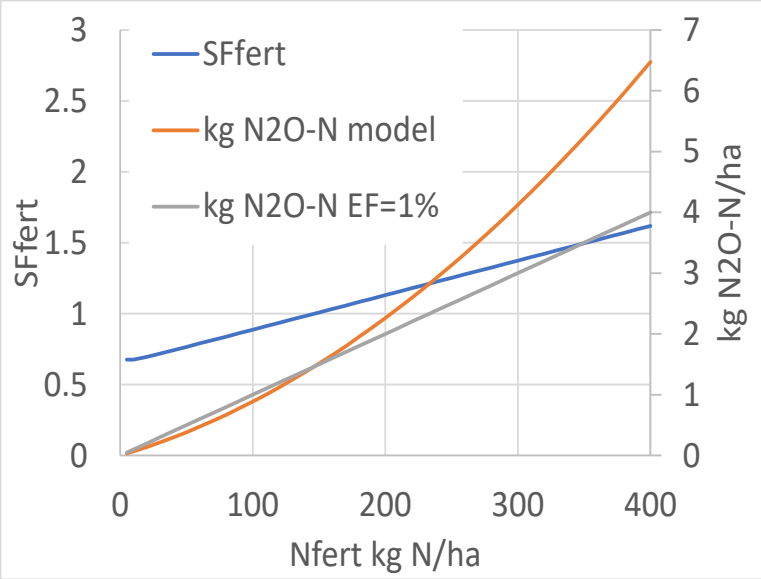
N_{som} = nitrogen from mineralisation of soil organic matter [kg N ha^{-1}]

Emission source	Variable	EF kg N_2O-N/kg N	Source
Mineral N fertilisers and mineral N in organic fertilisers, N in excreted urine	EF1m	1.0%	IPCC (2019) default EF1; SALCA (Nemecek et
Non-mineral N in organic fertilisers, N in excreted dung	EF1o	0.25%	SALCA (Nemecek et al., 2024)
Crop residues	EF1cr	0.25%	Following Liang et al. (2020), but adjusting to th value as organic N in fertilisers
Rice, continuous flooding	EF1FRc	0.3%	IPCC 2019
Rice, single and multiple drainage	EF1FRd	0.5%	IPCC 2019

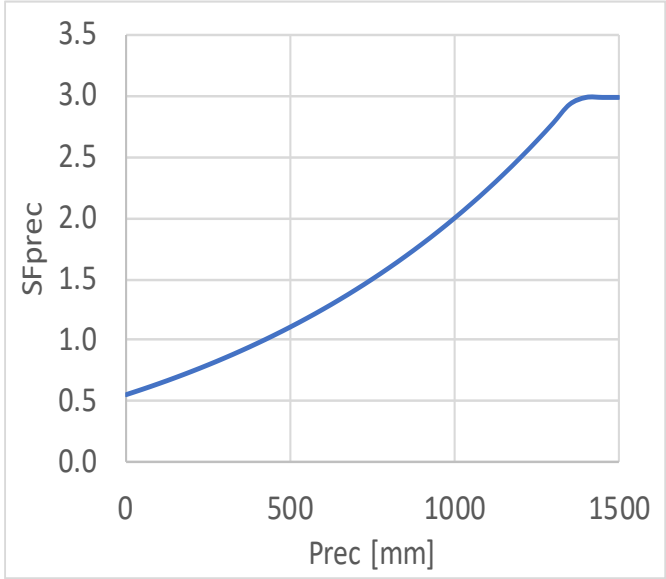
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Scaling factors

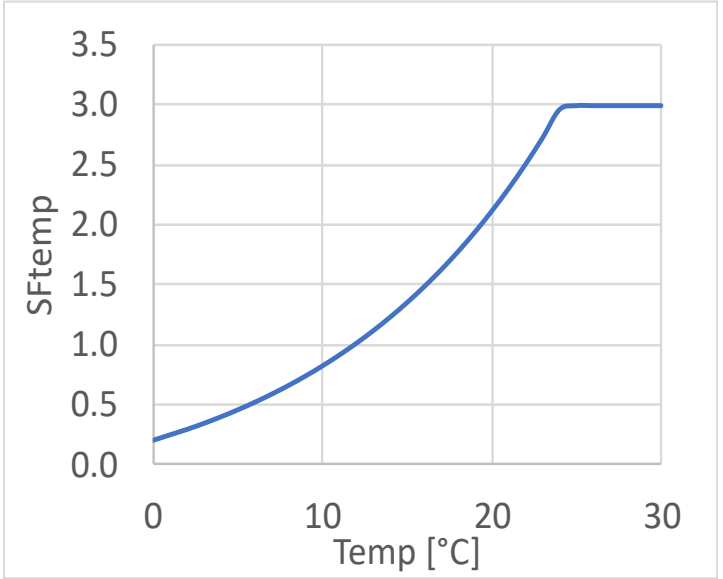
N fertilisation



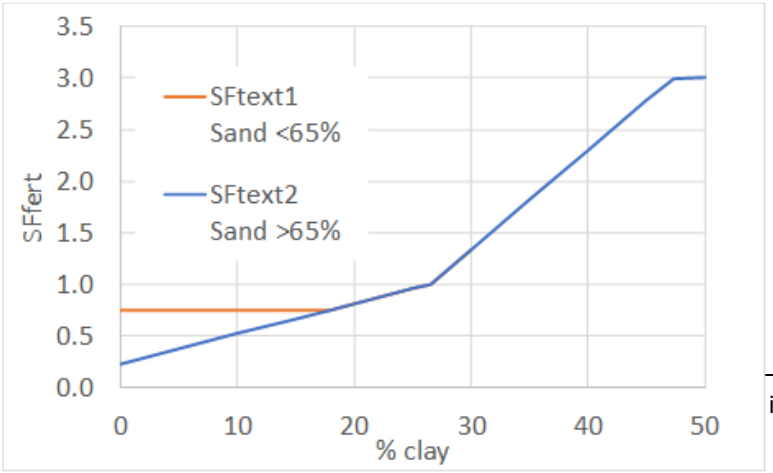
Precipitation May-Oct



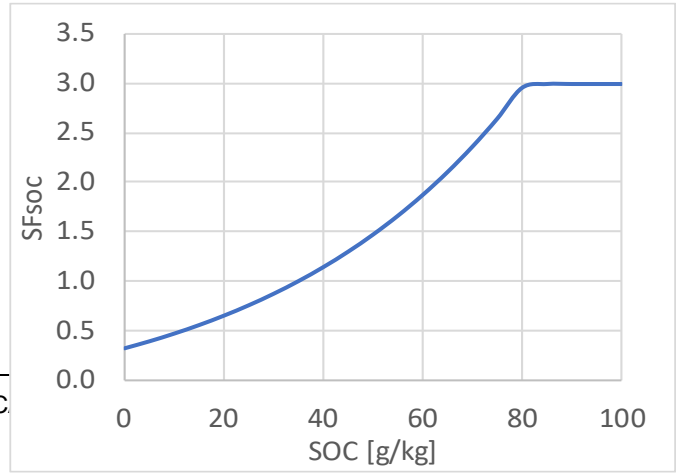
Temperature



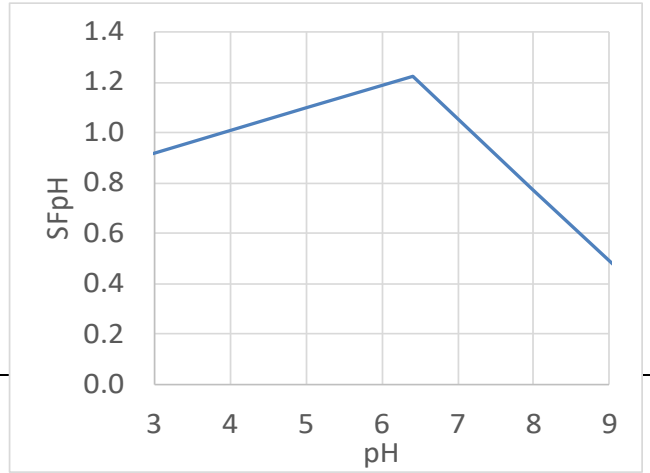
Soil texture



Soil organic C

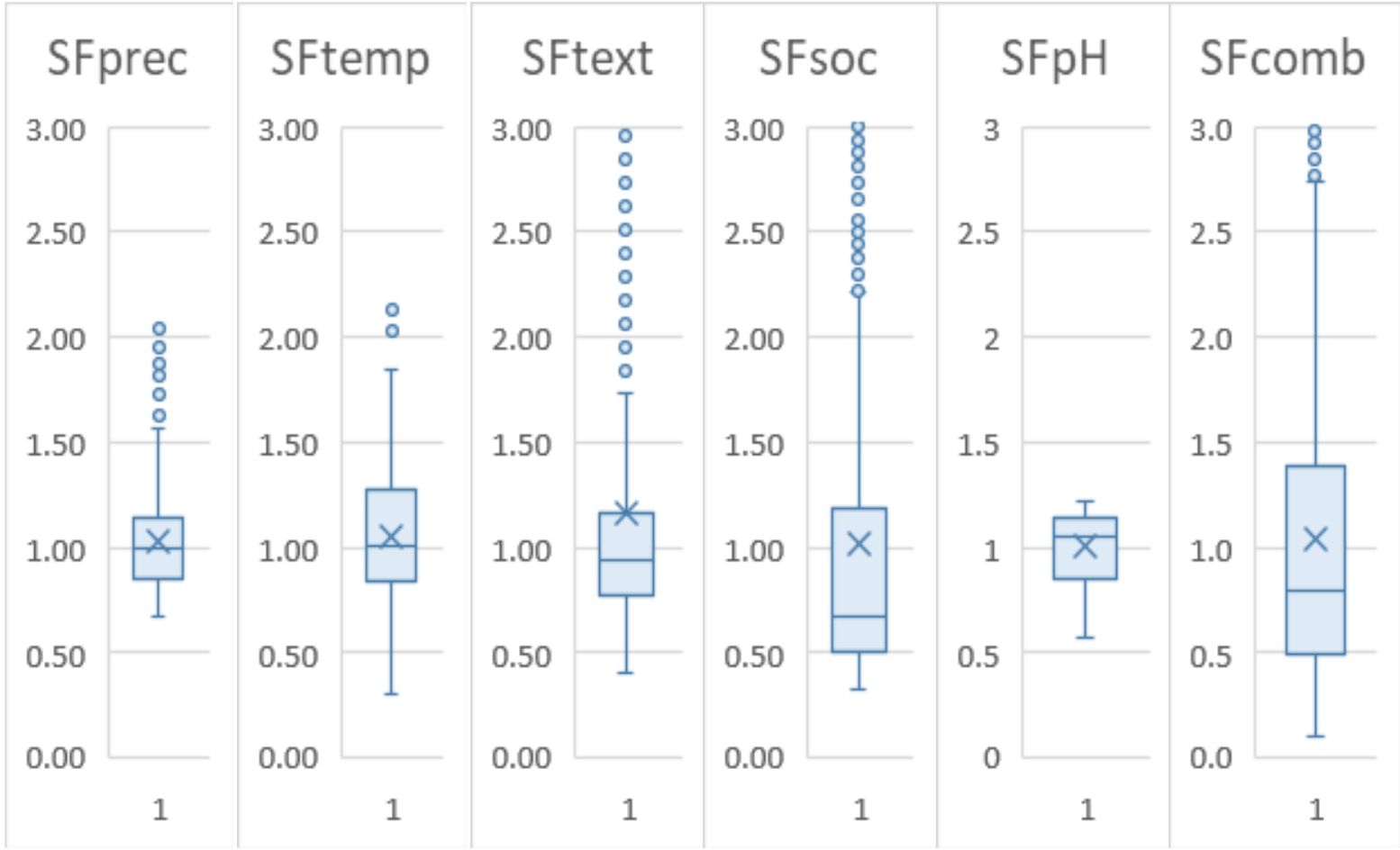


Soil pH



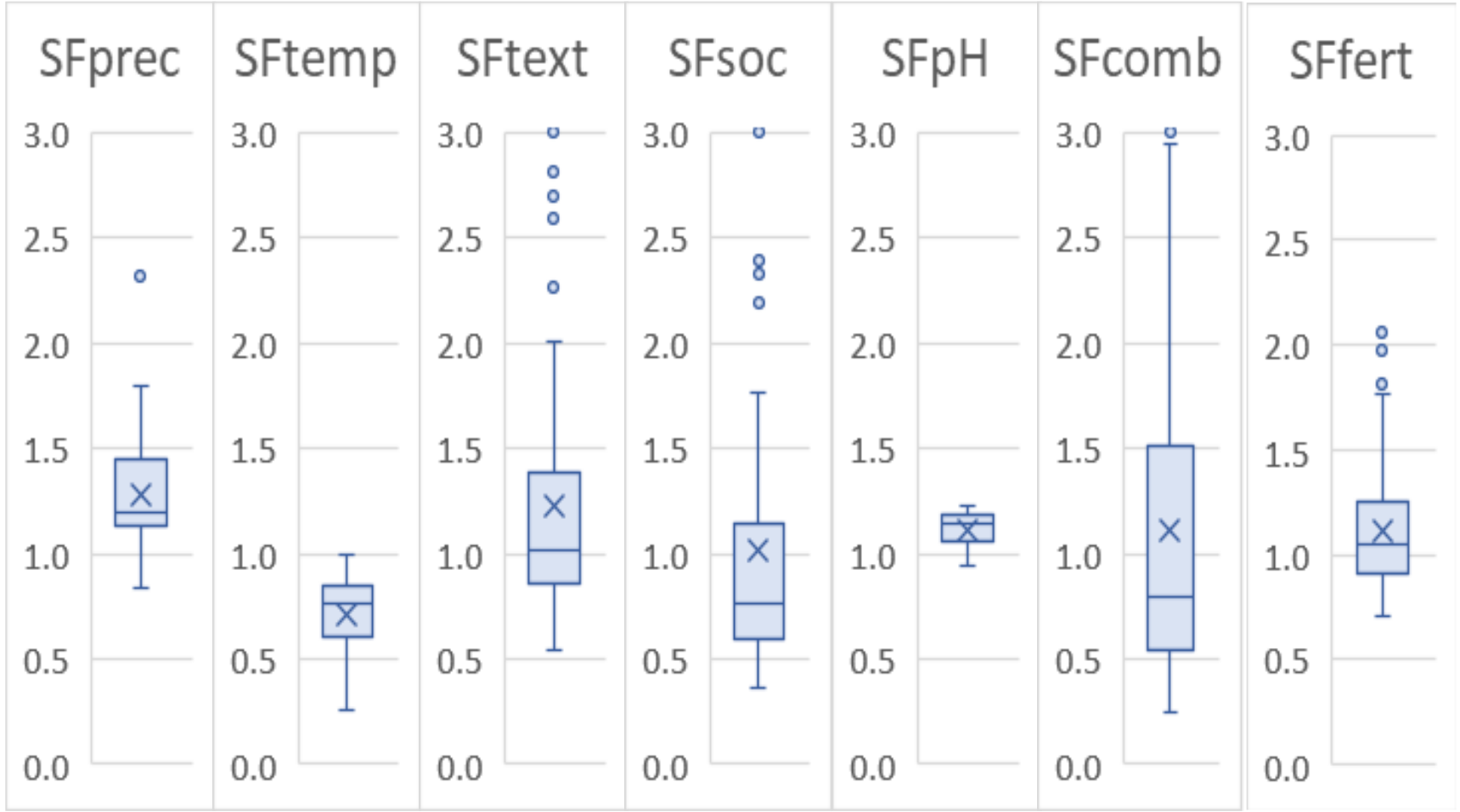
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Plausibility testing with a European soil database



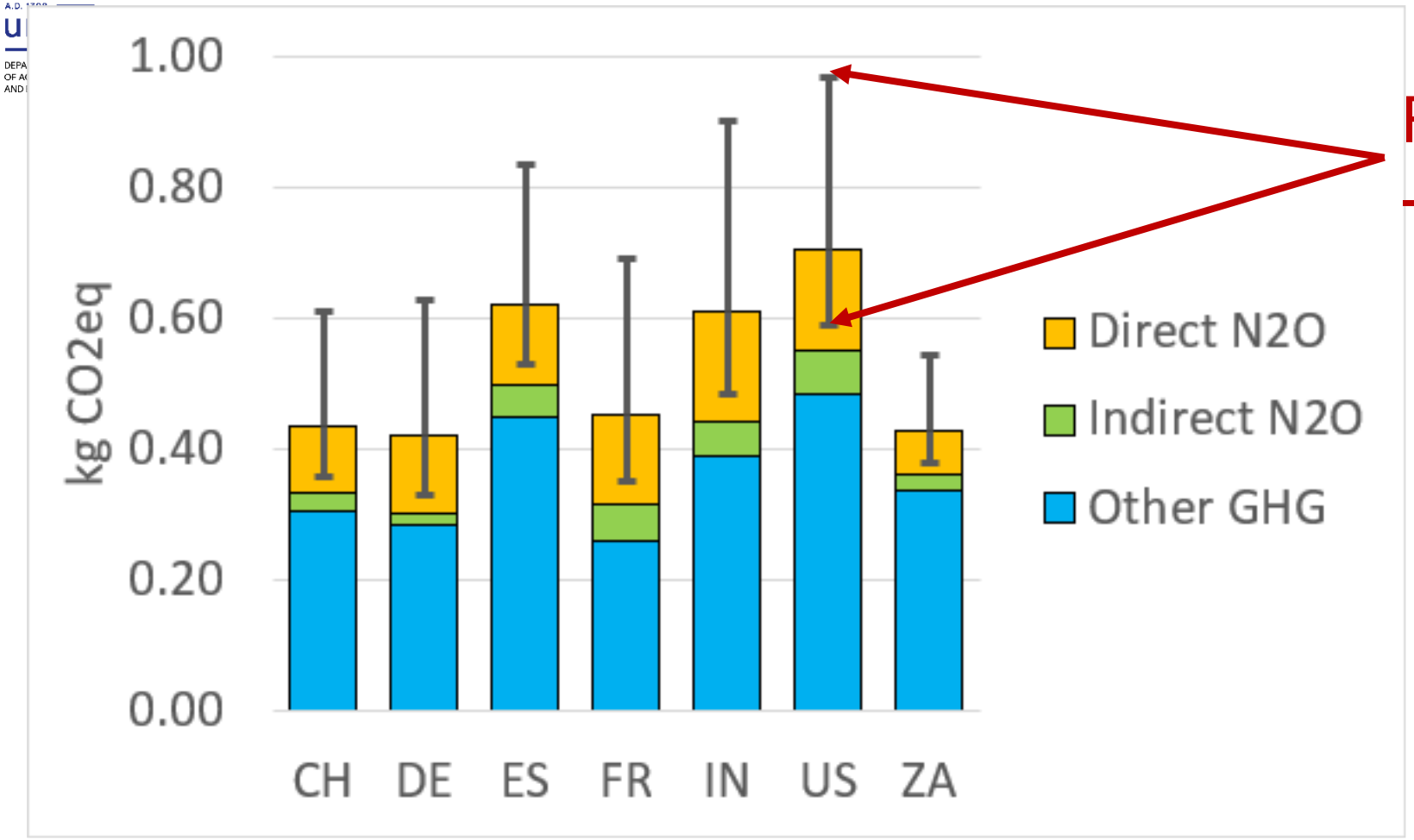
Results for the scaling factors applied to the LUCAS dataset (Jones et al., 2020), combined with climate from Copernicus Climate Change Service (2021) (N=1730).

Plausibility testing with Swiss soil monitoring data



Results for the scaling factors applied to the Swiss soil monitoring network dataset (Gross et al., 2024) (N=240 for SF_{fert}, N=80 for all other parameters).

Effect on total climate impacts for wheat



Range 5th-95th perc.:
-20% to +40%

Variability of GWP100 in wheat grain production datasets for Switzerland (CH), Germany (DE), Spain (ES), France (FR), USA (US), India (IN), and South Africa (ZA) from ecoinvent V3.11. The error bars indicate the 5th and 95th percentile of the recalculated direct N_2O emissions from agricultural soils.

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Discussion

- Compromise between complex mechanistic models and Tier 1 and 2 emission factors
- Independent modelling of driving factors (modularity) → in case of missing data, the effect of the available parameters can still be calculated
- Distinguishing between mineral and organic C
- WFPS
- Step changes avoided
- Truncation avoids unrealistic values

Limitations

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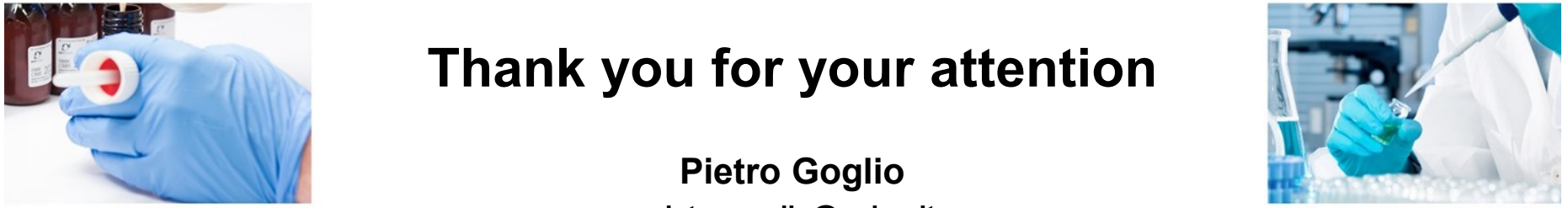
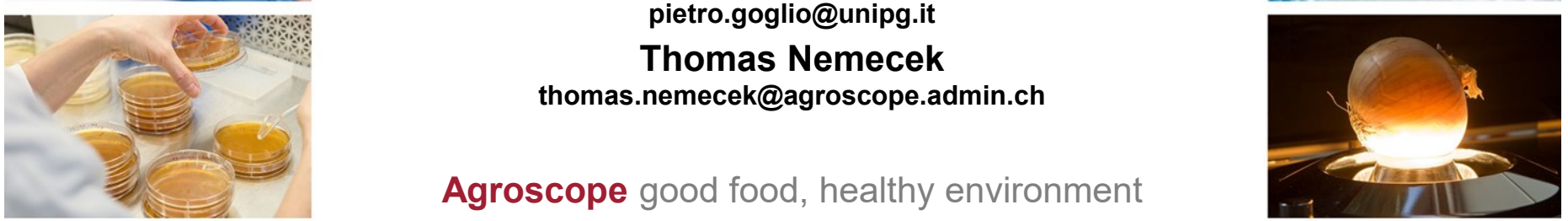
- No validation with measured field data → further research
- Interactions between parameters cannot be considered
- Limited to temperate zones
- High uncertainty of estimates remains: WFPS

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Conclusions

- Six driving factors considered: N fertilisation, precipitation, temperature, soil texture, SOC, pH
- Considerable variability of direct soil N2O emissions propagates into total climate impacts (90% of values between -20% and +40%)
- Different relevance of factors:
  - High: SOC, clay content
  - Medium: temperature, precipitation, N application rates
  - Low: soil pH, sand content
- Model can be easily integrated in LCA studies and LCI databases





Thank you for your attention

Pietro Goglio

pietro.goglio@unipg.it

Thomas Nemecek

thomas.nemecek@agroscope.admin.ch

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