Modelling non-CO_2 greenhouse gas emissions and mitigation potentials of Austrian farms

Verena Kröner, Katharina Falkner, Bernadette Lienhart, Erwin Schmid and Hermine Mitter

University of Natural Resources and Life Sciences, Vienna, Department of Economics and Social Sciences, Institute of Sustainable Economic Development, Feistmantelstrasse 4, 1180 Vienna, Austria
verena.kroener@boku.ac.at

Introduction

Agriculture is responsible for a large share of the non-CO_2 greenhouse gas (GHG) emissions, both globally and in Austria. Non-CO_2 GHG emissions include methane (CH_4) and nitrous oxide (N_2O) as well as reactive trace gases such as ammonia (NH_3) [1]. CH_4 originates primarily from enteric fermentation of ruminants and during manure storage. N_2O and NH_3 are produced in microbial processes of soils and manure [2].
The literature proposes a variety of mitigation measures while farm specific calculations of marginal abatement costs (MACs) are still limited. We have extended and applied the Farm Optimization Model FAMOS [3] to account for non-CO_2 GHG emissions and to compute MACs for selected mitigation measures at the farm level, including alternative manure storage systems, feeding rations, crop rotations, tillage, and fertilization intensities.

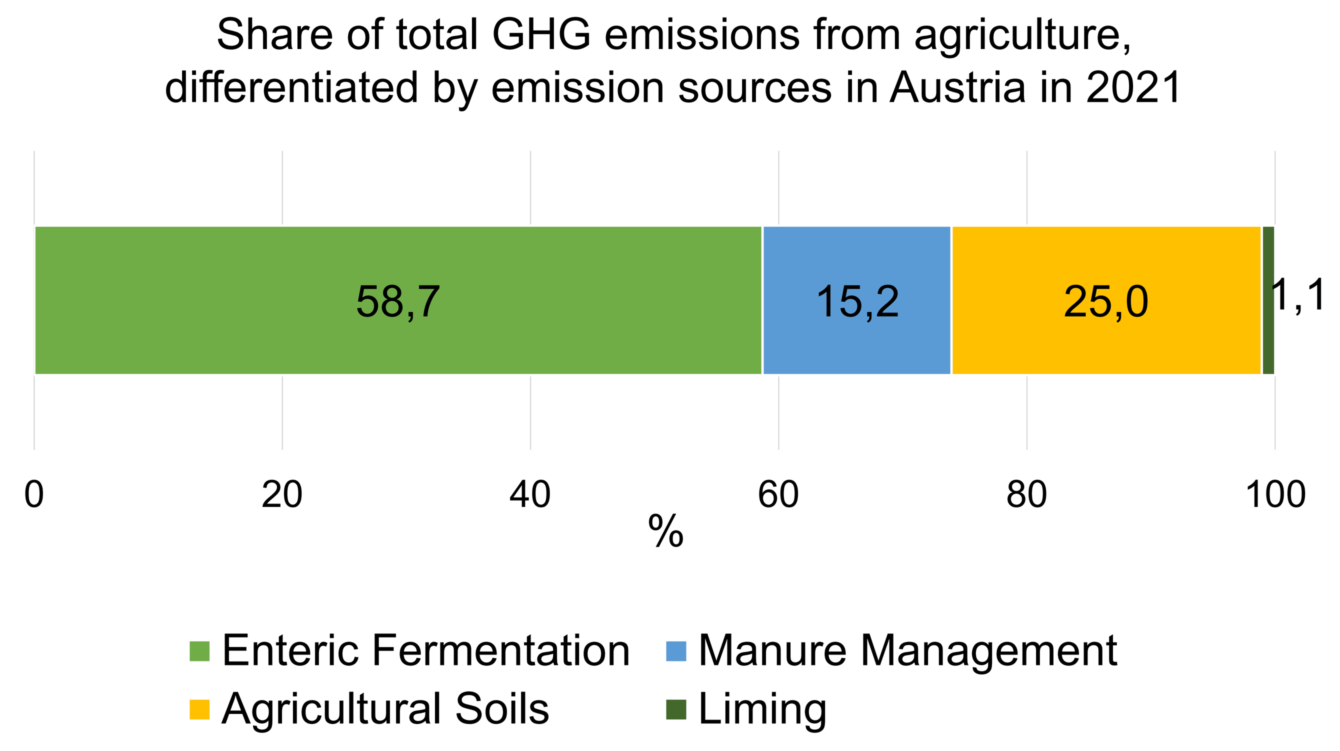

Figure 1: Own illustration based on [4]

Data and Methods

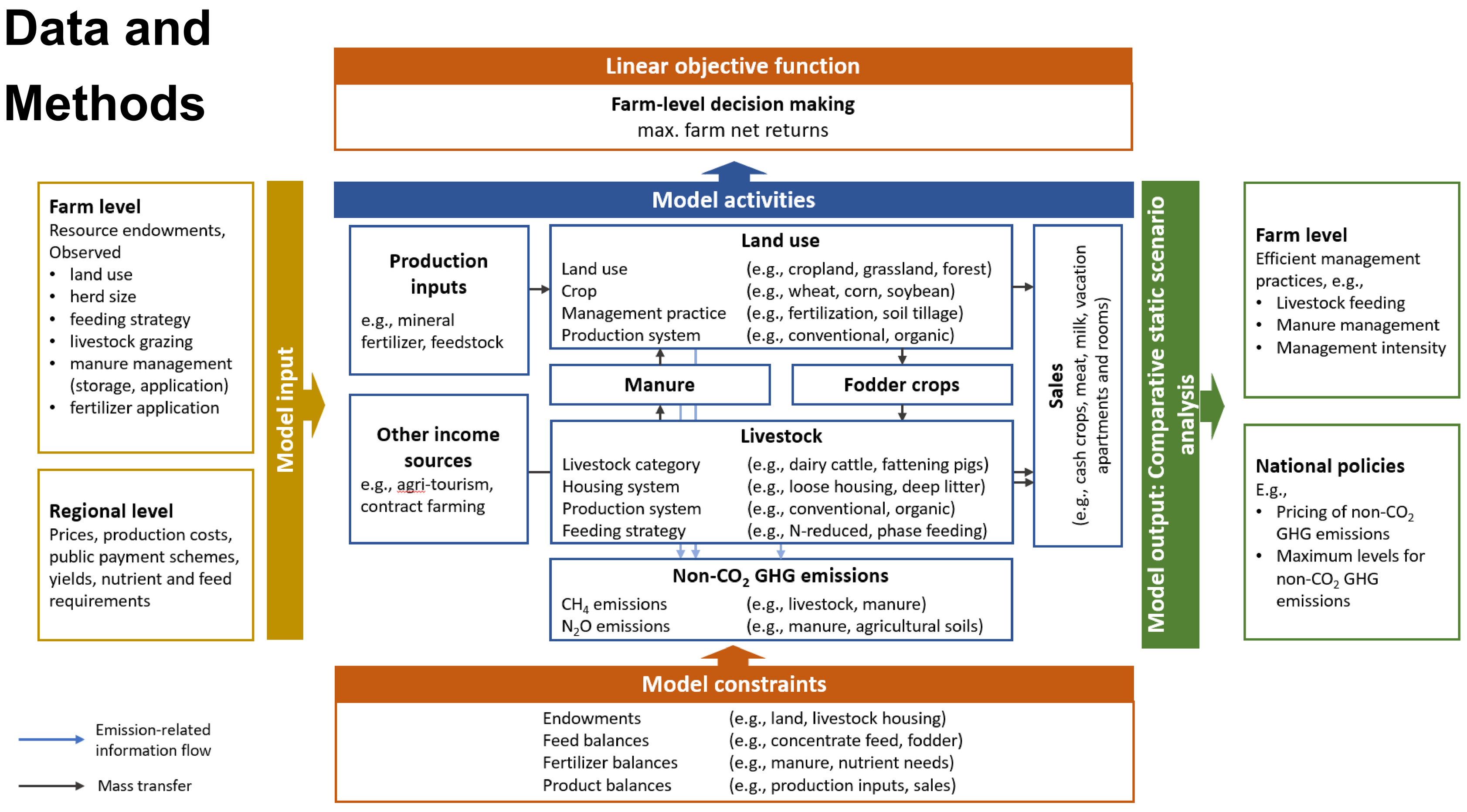

Figure 2: Own illustration of Farm Optimization model (FAMOS) based on [3]

- FAMOS is a mixed-integer linear **farm optimization model** implemented in GAMS for the Austrian farms [5].
- FAMOS **maximizes farm net returns** and operates within the constraints of the farm's resource endowments.
- Agronomic **production relationships** (e.g., fertilizer and feed balances, crop rotations) and **legal compliances** (e.g., CAP measures and payments) are taken into account.
- The **non-CO_2 GHG emission accounting module** follows the guidelines for national GHG inventories, as provided by the Intergovernmental Panel on Climate Change [2,6]. Emissions beyond the farm gate are not quantified.

Results: Non-CO_2 emissions of alternative feeding rations in dairy farming

- The nutritional content of feeding rations (FR; such as crude protein (CP), crude ash (CA) and feed digestibility) affects non-CO_2 emissions from livestock and manure management.
- The non-CO_2 emissions are caused along the chain of emission sources.
- CH_4 emissions from manure management are higher for a feeding strategy without grazing compared to a feeding strategy with grazing and with higher shares of concentrate feed in the feeding ration (FR 2A, FR 2B).
- Direct and indirect N_2O emissions from manure management are lower for feed rations consisting of higher shares of concentrate feed (FR 2A, FR 2B).
- Feeding rations affect the availability of nitrogen for its application to the soil.

Emission source	Unit	A: Feeding strategy with grazing		B: Feeding strategy without grazing	
		Grass silage-based with hay		Total mixed ration with grass and maize silage	
		FR 1A: Moderate share of grazing	FR 2A: Reduced share of grazing	FR 1B: Concentrate feed with wheat, soja extraction meal	FR 2B: CCM, dried distillers grains
CH_4 emissions from enteric fermentation	kg CH_4 head^{-1} year^{-1}	126.0	126.0	126.0	126.0
CH_4 emissions from manure management	kg CH_4 head^{-1} year^{-1}	22.4	24.4	25.2	26.1
Direct N_2O emissions from manure management	kg N_2O year^{-1}	1.2	0.9	1.7	0.8
Indirect N_2O emissions from manure management	kg N_2O year^{-1}	0.4	0.3	0.5	0.3
Manure N available for application to soil	kg N year^{-1}	129.4	95.8	173.3	87.9

Table 1: Non-CO_2 emissions from different feeding rations of a dairy cow (assumption: average annual milk production of 7,000 kg; 115 pasture days per year; moderate share of grazing = 8 hours per day, reduced share of grazing = 4 hours per day)

Conclusions and outlook

- Feeding rations need to be adjusted based on livestock performance and resource endowments of a farm in order to reduce non-CO_2 emissions.
- Data on livestock characteristics and performance is needed to formulate feed rations for their application in the farm optimization model.
- The reduction of non-CO_2 emissions at the farm level requires a holistic approach due to the dependencies of emission sources.
- Data on e.g., the composition of feeding rations are necessary for an accurate representation of non-CO2 emissions of alternative farm management practices in FAMOS.

References
[1] Nabuurs, G-J., Mrabet, R., Abu Hatab, A., Busta-mante, M., Clark, H., Havlík, P., House, J., Mbow C., Ninan, K. N., Popp, A., Roe, S., Sohngen, B., Towprayoon S. (2022). Agriculture, Forestry and Other Land Uses (AFOLU). In IPCC, 2022: Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth As-sessment Report of the IPCC Cambridge University Press, Cambridge, UK and New York, NY, USA.
[2] IPCC. (2019). 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. IPCC, Switzerland.
[3] Schmid, E. (2004). Das Betriebsoptimierungssys-tem FAMOS. FArM Optimization System. Diskussionspapier. Institut für nachhaltige Wirtschaftsentwicklung.
[4] UBA. (2022). Austria's National Inventory Report 2023 – Submission under the United Nations Framework Convention on Climate Change and under the Kyoto Protocol. Wien, Österreich.
[5] General Algebraic Modeling Systems; https://www.gams.com/
[6] IPCC. (2006). IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme (No. Volume 4 Agriculture, Forestry and Other Land Use). IGES, Japan.