NEU.rind - Digital farm assistant for assessing sustainability, efficiency and environmental impact on the dairy farm

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Abstract

In order to reduce the environmental impact of Austrian cattle farming and to improve sustainability, farm-specific recommendations for action are essential. However, these can only be provided if meaningful key figures and information on the potential of farm-specific measures are known for individual farms. Representative and comparable key figures with benchmarking are essential for this. In collaboration with representatives from research, farmer representatives, recording organisations, consultancies, dairy processing and marketing organisations, needs and requirements were elaborated. We use as much pre-collected data as possible to assess highly important sustainability aspects on a dairy farm-specific but internationally comparable level by aiming at reducing the workload for data recording. These data come from the central cattle database and interfaces to other official and relevant data, e.g. farms' land use (from the Integrated Administration and Control System, IACS) or economic parameters. Existing data are supplemented with on-farm primary data to calculate eight aggregated indicators based on life cycle assessment methods in the environmental dimension. Indicators cover global warming, food-feed-competition, ammonia emissions, cumulative energy demand, biodiversity aspects and are complemented by animal health aspects and economic key figures. Functional units are kg milk, hectare and farm. Sensitivity analyses have been conducted to assess the most important data and changes in accuracy due to minimised additional farm data records. Currently, we use a prototype for data collection to analyse 200 dairy farms representing different environmental conditions and production systems. Based on that information, we will elaborate a final user-friendly version of the digital farm assistant for routine use.

Keywords: greenhouse gas emissions, carbon footprint, online tool.

Introduction

Emissions from cattle farming are under critical discussion and there is a need for an increase in sustainability, especially regarding greenhouse gas (GHG) emissions (Twine *et al.*, 2019, Leip *et al.*, 2021). Cattle farming is in the area of conflict between food security and securing ecosystem services while maintaining sustainable and competitive agricultural production (Mottet *et al.*, 2018). Consumers expect transparency and high standards in production like sustainable products with low environmental footprint, good animal health and welfare, but also favourable pricing (Schiano *et al.*, 2020).

In order to reduce the environmental impact of Austrian cattle farming and to improve sustainability, farm-specific recommendations for action are essential, which sufficiently take into account the complexity of milk production (Schils *et al.*, 2007). These can only be provided if meaningful key figures and information on the potential of possible measures are known for the individual farm (Robling *et al.*, 2023). Representative and comparable key figures with benchmarking are essential for this. FarmLife is an already existing LCA tool in Austria in this area, which is very precise but not broadly used, as it requires a time effort of around two days for farmers to complete data entry (Herndl *et al.*, 2016). To establish key figures and enable benchmarking, a broader use is necessary. This shall be achieved by developing a user-friendly simplified but scientifically sound tool with minimized effort for data entry.

NEU.rind digital farm assistant

The EIP AGRI Project NEU.rind aims to develop a digital farm assistant for assessing sustainability, efficiency and environmental impact on Austrian dairy farms. The goal is to generate a broad data basis and provide current facts and key figures for representative Austrian farms. A benchmarking with farm comparisons for the estimation of improvement potentials and recommendations for farm-specific measures for improvements are the goal of NEU.rind.

In the first step, the needs and requirements for such a tool were elaborated in collaboration with representatives from research, farmer representatives, recording organisations, consultancies, dairy processing and marketing organisations. Important aspects are, that the application is user-friendly with little effort for additional data collection for the farmers and with meaningful and easily understandable key figures for the practice. Broad use can only be expected if these requirements are met.

Selection of indicators and methods used by the NEU.rind tool

While some of the standard impact categories in the Product Environmental Footprint Category Rules (PEFCR) or in the Eco-Score do not have a high relevancy in dairy production, the important issue of biodiversity is not covered by this life cycle assessment (LCA)-based assessment (EDA 2018, Curran *et al.*, 2016). Moreover, the Eco-Score does not consider all dimensions of sustainability, but only product-related assessments on efficiency in ecology. In addition, some of the PEFCR-LCA impact indicators have large uncertainty ranges (ADEME and INRAE, 2020). Given the large problem areas highlighted in the planetary boundaries (Steffen *et al.*, 2015) and the dairy-specific issues, stakeholders within our project defined a new set of indicators. Calculation and definitions consider international standards like IDF (2023) and ICAR (2023). Furthermore, most of the indicators in the NEU.rind-tool link impacts of dairy farming on two functional units, per kg milk and per hectare of farmland, e.g. for global warming. These indicators are primarily intended to provide valid and practical results to farmers, which are also used for on-farm recommendations (Table 1).

Table 1. The final set of indicators in the NEU.rind-tool as defined by the stakeholders within the NEU.rind-consortium. Impacts of dairy farming on two functional units, per kg milk and per hectare of farmland; the second biodiversity indicator is based on farm-level, animal health aspects are based on herd level.

Indicator	Per kg milk[1]	Per ha utilized area or per farm	
Global warming	kg CO_2-eq	kg CO_2-eq	LCA[2]
Human edible feed conversion efficiency / Protein production	heFCE factor	kg CP / ha	SUS[3]
Biodiversity	Potentially disappeared fractions of species	% HNVF[4]; rare / endangered crops / breeds	LCA[2]/ SUS[3]
Fossil energy demand	MJ	GJ	LCA[2]
Ammonia emissions	kg NH_3	kg NH_3	LCA[2]
Nitrate emissions	kg NO_3	kg NO_3	LCA[2]
Animal health aspects	Scores	Scores	SUS[3]
Contribution margin	€	€	SUS[3]

[1]Consideration of co-products, allocation
[2] Typical LCA-based methods, which are evaluated over the life cycle from cradle to farm-gate
[3]Supplementing sustainability indicators
[4]High nature value farmland

GHG emissions are also reported on a single basis (CO_2, CH_4 and N_2O) for on-farm recommendation, and in CO_2-eq (GWP_{100} and GTP_{100}; IPCC, 2021). The human-edible feed conversion efficiency (heFCE) is calculated for protein, including the protein quality (DIAAS; see Ertl *et al.*, 2015, 2016) in addition to the amount of protein, which is produced on a hectare-basis. Firstly, biodiversity conservation is assessed according to the potentially disappeared fraction of species method developed by Chaudhary and Brooks (2018), taking into account aspects such as feed conversion efficiency and imported feed. Secondly, for another perspective on biodiversity, the on-farm status is evaluated by the proportion of high nature value farmland (% HNVF) and whether rare or endangered livestock breeds and crop varieties are used. Fossil energy consumption is inter alia an important driver for GHG emissions and also a finite resource and thus assessed within the NEU.rind-tool. Moreover, ammonia and nitrate emissions are evaluated for both functional units. The same applies to farms' economic results as gross margins. Animal health aspects are assessed based on recorded data on animal or herd level. A specific goal with regard to user-friendliness is, that the defined indicators and evaluation methods are based as far as possible on data already collected (Central Cattle Database, CCD; IACS) and require as little additional data as possible to be collected on the farms.

Sensitivity analyses by Tornado plots (Figure 1) and by diverse runs of the LCA method with default data have been conducted to assess the most important farm data and changes of accuracy due to reduced farm-specific data records. For example, in the sensitivity analysis for GHG emissions, the kg energy corrected milk per cow and year, feeding and fossil energy parameters have the greatest influence on results and are therefore most important for data collection (Figure 1).

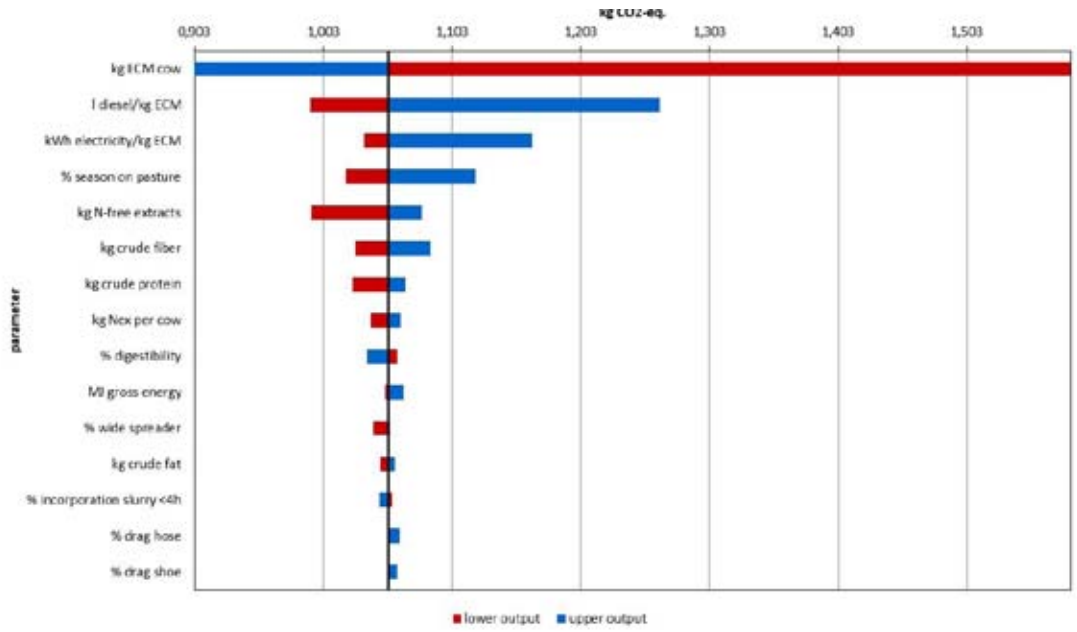

Figure 1. A Tornado plot for GHG emissions, presenting the magnitude of the influence of individual parameters (keeping the other parameters constant) on overall results.

Data demand for the NEU.rind tool

For the NEU.rind tool, data on farm characteristics, land use, animals, housing, manure management, milk yield, milk quantities, diet composition, feeding, energy consumption, buildings and machinery and on farm management are used. Data integration is a central point in order to generate a simple tool with reduced data entry effort, but also meaningful results. Already existing data are used to keep the time required for data recording to a minimum. For those data that nevertheless need to be collected additionally, a user-friendly solution, the NEU.rind tool, was developed.

Some data are well available from already existing sources, like animal and housing data from the CCD. Other data that are already partly available are: data on feeding (also in the CCD for farms using the CCD tool “efficiency check”) and on land management from IACS (the Ministry of Agriculture) or economic data by the Federal Institute of Agricultural Economics (BABF). In general, economic data should be collected specifically on-farm. Already available date are collected through online interfaces (Figure 2).

Data collection with app prototype

Data is collected online with an Oracle APEX App in 40 acquisition steps with more than 170 individual parameters as well as several other parameter complexes (e.g. ration composition and feeding period, degree of mechanisation and work processes). For each parameter there is an input field, a detailed description of the parameter and, if available, a default value from already available data sources and information on the origin of the default value.

Data entry is mainly done by employees of the milk recording associations and by farmers themselves under supervision by recording associations. Data collection on farms started in 2023 and is planned to be carried out on 200 farms that are selected to cover different production conditions and systems as base for representative and comparable figures. Evaluation routines are gradually added in the APEX application.

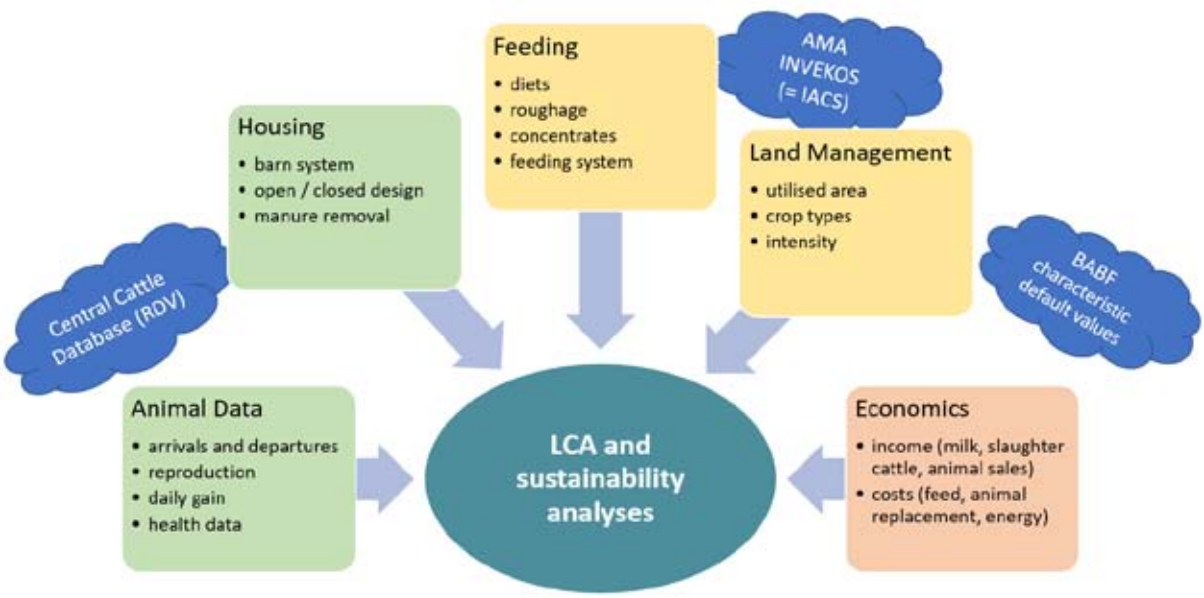

Figure 2. Data demand for the NEU.rind-tool. Data well available from already existing sources are shown in green, data already partly available in yellow and data hardly available that need farm-specific additional collection in red.

The NEU.rind app can be continuously developed and adapted based on practical experience (evolutionary prototyping) by implementing the app as an APEX application. In addition to the possibility of data collection, analysis and result feedback as well as graphical preparation will also be developed in APEX as the project progresses.

Since ongoing adjustments to the calculation methods are to be expected even after the project has been completed in order to always correspond to the current state of knowledge and international standards, all recordings and analyses are always assigned to the current version of the analysis routines at the time of recording. This means that analyses that have already been carried out remain reproducible at any time. This is the basis for a possible annual certification of farms based on the NEU.rind tool in the future.

Results, discussion and conclusion

Farm-specific results show the status quo for environmental impacts and supplementing sustainability aspects as presented above and measures for improvement. On the basis of first representative results, a system for farm comparisons (benchmarking) will be developed to further illustrate the strengths and weaknesses of the individual farms (within groups of comparable farms) and show improvement potentials. Additionally, recommendations for farm optimization can be provided on the basis of the results. If the system is broadly used in practice, current key figures on the sustainability of Austrian dairy farms will be extracted and used for the information of consumers, agricultural policy, etc.

Internationally, different tools to assess sustainability are in use. The approach used in NEU.rind is comparable to tools like ANCA in the Netherlands (De Haan, 2021), or Arla's Climate Check tool (Arla, 2022). Approaches used by ICAR (ICAR, 2023) with the list of the parameters to describe sustainability, or Lactanet's Sustainability Index (Warner *et al.*, 2022), are based on data routinely recorded by milk recording organizations. However, this is not comparable to a direct and comprehensive sustainability analysis, as such indices do not assess a carbon footprint (kg CO_2-eq) or other quantitative environmental impacts of a LCA. For a comprehensive analysis, it is inevitable to include input parameters that dominate LCA results, such as the feed composition and the feed production including the origin of the feed (with inter alia parameters on yields in relation to the efforts of cultivation and fertilizer use, emissions from land use and land use changes, transport distances, etc.). These are not included in routinely recorded input parameters and therefore their significance regarding overall sustainability is limited. Moreover, dairy production (agriculture in general) is connected to many social and economic aspects of a local community, including farmers, farm workers, and consumers. Regarding resource use it is for instance important to evaluate human edible feed conversion efficiency and (net-) protein production. All of these important sustainability aspects can be assessed using quantitative methods, such as those listed in Robling *et al.* (2023). Of course, this needs a lot of farm-specific data, which can be collected efficiently by using data from the CCD, IACS, farm questionnaires and supplemented by economic default data.

In conclusion, our NEU.rind- sustainability analysis is an up-to-date tool that meets the requirements of dairy LCAs (IDF, 2022) and addresses further economic and social sustainability aspects.

The assessment of sustainability, efficiency and environmental impact on Austrian dairy farms based on routine data (CCD, IACS data and interfaces to other official and relevant data) is possible, but some additional manual data collection is needed. The working time requirement is approximately 1 to 2 hours per farm per year.

Oracle APEX is a suitable tool to develop such a web application using a prototype approach with continuous further development. A user-friendly data recording and recommendations for improvement are essential for broad use. Participation of the relevant stakeholders in the development ensures acceptance and practicability.

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References

ADEME, INRAE, 2020. Agribalyse Version 3. In. France. https://agribalyse.ademe.fr (accessed 2022-01-05).

Arla, 2022. Arla´s climate check tool. https://www.arla.com/sustainability/sustainable-dairy-farming/how-we-measure-dairy-farmings-carbon-footprint/ (accessed 2023-09-15)

Chaudhary, A., and Brooks, T. M., 2018. Land Use Intensity-Specific Global Characterization Factors to Assess Product Biodiversity Footprints. Environmental Science and Technology, 52(9): 5094–5104. https://doi.org/10.1021/acs.est.7b05570

Curran, M., de Souza, D.M., Antón, A., *et al.***,** 2016. How Well Does LCA Model Land Use Impacts on Biodiversity? – A Comparison with Approaches from Ecology and Conservation. Environ Sci Technol. 50(6): 2782-2795. https://doi.org/10.1021/acs.est.5b04681

De Haan, M., 2021. Reducing environmental impact in the Dutch dairy sector with ANCA-tool. ICAR-Conference 2021. https://www.icar.org/wp-content/uploads/2021/06/15.1-Michel-de-Haan.pdf

EDA (European Dairy Association, 2018) Product Environmental Footprint Category Rules for Dairy Products. https://ec.europa.eu/environment/eussd/smgp/pdf/PEFCR-DairyProducts_Feb%202020.pdf (accessed 2022-01-13)

Ertl, P., Klocker, H., Hörtenhuber, S., Knaus, W., and Zollitsch, W., 2015. The net contribution of dairy production to human food supply: The case of Austrian dairy farms. Agricultural Systems, 137: 119–125. https://doi.org/10.1016/j.agsy.2015.04.004

Ertl, P., Steinwidder, A., Schönauer, M., Krimberger, K., Knaus, W., Zollitsch, W., 2016. Net food production of different livestock: A national analysis for Austria including relative occupation of different land categories / Netto-Lebensmittelproduktion der Nutztierhaltung: Eine nationale Analyse für Österreich inklusive relativer Flächenbeanspruchung. Die Bodenkultur: Journal of Land Management, Food and Environment, 67(2): 91–103. https://doi.org/https://doi.org/10.1515/boku-2016-0009

Herndl, M., D.U. Baumgartner, T. Guggenberger, M. Bystricky, G. Gaillard, J. Lansche, C. Fasching, C., A. Steinwidder, und T. Nemecek, 2016. Einzelbetriebliche Ökobilanzierung landwirtschaftlicher Betriebe in Österreich. Abschlussbericht, BMLFUW, 99 S.

ICAR, 2023. List of sustainability traits. https://www.icar.org/wp-content/uploads/2023/05/ICAR-sustainability-traits-v3.pdf (accessed 2023-09-15)

IDF (International Dairy Federation), 2022. The IDF global Carbon Footprint standard for the dairy sector. Bulletin of the IDF No. 520/2022. https://shop.fil-idf.org/products/the-idf-global-carbon-footprint-standard-for-the-dairy-sector (accessed 2023-09-15)

IPCC (Intergovernmental Panel On Climate Change), 2021. Climate Change 2021 – The Physical Science Basis: Working Group I Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press; [accessed 2023 08-24]. https://doi.org/10.1017/9781009157896

Leip, A., Weiss, F., Wassenaar, T., Perez, I., Fellmann, T., Loudjani, P., Tubiello, F., Grandgirard, D., Monni, S., Biala, K., 2010. Evaluation of the livestock sector's contribution to the EU greenhouse gas emissions (GGELS). European Commission, Joint Research Centre. https://agritrop.cirad.fr/558780/1/document_558780.pdf

Mottet, A., Teillard, F., Boettcher, P., De' Besi, G., Besbes, B., 2018. Review: Domestic herbivores and food security: current contribution, trends and challenges for a sustainable development. Animal 12: 188-198. https://doi.org/10.1017/S1751731118002215

Robling, H., Abu Hatab, A., Säll, S., Hansson, H., 2023. Measuring sustainability at farm level – A critical view on data and indicators. Environmental and Sustainability Indicators 18,100258. https://doi.org/10.1016/j.indic.2023.100258

Schils, R. L., Olesen, J. E., del Prado, A., and Soussana, J. F., 2007. A review of farm level modelling approaches for mitigating greenhouse gas emissions from ruminant livestock systems. Livestock Science, 112(3), 240-251. https://doi.org/10.1016/j.livsci.2007.09.005

Schiano, A.N., Harwood, W.S., Gerard, P.D., Drake, M.A., 2020. Consumer perception of the sustainability of dairy products and plant-based dairy alternatives. Journal of Dairy Science 103 (12), 11228-11243. https://doi.org/10.3168/jds.2020-18406

Steffen, W., Richardson, K., Rockstrom, J., Cornell, S. E., Fetzer, I., Bennett, E. M., Biggs, R., Carpenter, S. R., de Vries, W., de Wit, C. A., Folke, C., Gerten, D., Heinke, J., Mace, G. M., Persson, L. M., Ramanathan, V., Reyers, B., Sorlin, S., 2015. Planetary boundaries: Guiding human development on a changing planet. Science, 347(6223): 1259855–1259855. https://doi.org/10.1126/science.1259855

Twine, R., 2021. Emissions from Animal Agriculture—16.5% Is the New Minimum Figure. Sustainability, 13(11): 6276. https://doi.org/10.3390/su13116276

Warner, D., Vasseur, E., Villettaz Robichaud, M., Adam, S., Pellerin, D., Lefebvre, D.M., Lacroix, R., 2020. Development of a benchmarking tool for dairy herd management using routinely collected herd records. Animals 10 (9): 1689. https://doi.org/10.3390/ani10091689