EGF 31st General Meeting 2026
ÉVORA-PORTUGAL

Évora, Portugal
13–16 April 2026

Challenges and innovations for grasslands resilience

Edited by

H. Trindade
J.P.F. Almeida
J.P. Carneiro
D. Fangueiro
M. Castro
M.C. D'Abreu
B. Maçãs
J. Madruga
O. Moreira
J.S. Silva
M.B. Freitas
C. Cruz

EGF

Volume 31
Grassland Science in Europe

Protein efficiency and grassland performance on Northwest European dairy farms

Clausecker F.[1], Komainda M.[1], Pustilnik N.[2], Holmström K.[3], Schockemöhle V.[4], Rops J.[5], Kayser M.[1,6] and Isselstein J.[1,7]

[1] Department of Crop Sciences, Grassland Science, Georg-August-University Göttingen, Göttingen, Germany; [2] Copernicus Institute of Sustainable Development, Utrecht University, Utrecht, The Netherlands; [3] Rural Economy and Agricultural Society Sjuhärad, Länghem, Sweden; [4] Center of Sustainability Transformation in Areas of Intensive Agriculture, University of Vechta, Vechta, Germany; [5] VZW Boerennatuur Vlaanderen, Limburg, Leuven, Belgium; [6] Geo-Lab, University of Vechta, Vechta, Germany; [7] Centre of Biodiversity and Sustainable Land Use, Göttingen, Germany

Abstract

Ruminants can convert grassland biomass into valuable human-edible protein and other nutrients through milk and meat. In this context, grassland-based dairy systems can play a key role in improving protein self-sufficiency. The European North Sea region as an important area of permanent grassland and intensive dairy farming offers considerable potential for sustainable protein production. This study evaluates the protein conversion efficiency of grassland-based dairy farms. A total of 49 dairy farms across five countries in Northwest Europe (Belgium, France, Germany, The Netherlands, and Sweden) were investigated. Data were collected via interviews with farm managers covering farm structure, grassland management, animal performance, and feed composition. From this, human-edible protein conversion ratios (hePCR) were calculated. Biomass samples were collected and botanical assessments of up to five grasslands per farm conducted to evaluate forage nutritive value and plant species diversity on the farm-level. Farms were categorized based on their hePCR (<1.0 for low, >1.0 for high) and relationships derived with environmental, biodiversity and farm-performance data. The study highlights that there is no trade-off between net protein production from dairy milk and dairy farm performance measures.

Keywords: dairy farming, feed, food competition, protein conversion efficiency

Introduction

Ruminants are able to transform grassland biomass into high-value, human-edible protein in the form of milk and meat (Wilkinson, 2011). Consequently, grassland-based dairy systems have the potential to play a key role in improving protein self-sufficiency. A key advantage of such systems is their capacity to reduce reliance on food-competing feed by making use of resources that cannot be consumed directly by humans, such as grassland biomass. In this context, the food efficiency of livestock systems and the broader issue of feed–food competition have gained increasing attention (Barbieri *et al.*, 2022). One promising indicator for evaluating this efficiency is the human-edible protein conversion ratio (hePCR), which quantifies the balance between human-edible protein input and output within the system (Wild *et al.*, 2025). The European dairy sector accounts for approximately one-fifth of global milk production (Eurostat, 2025), with the North Sea region distinguished by large proportions of permanent grasslands and highly specialized dairy farming systems (Huyghe *et al.*, 2014). Despite this high potential for sustainable protein production, little is known about the protein efficiency at farm level in this region.

Materials and methods

A total of 49 dairy farms located in five Northwestern European countries (Belgium, France, Germany, The Netherlands, and Sweden) were included in this study. These farms are characterized by high milk production intensity, with milk contributing, on average, 84.2 ± 14.0% to total farm income. The average herd size was 119 ± 77 dairy cows, and 43 of the farms kept Holstein–Friesian breeds. The study consisted of two components: First, a structured interview with the farm manager, which covered topics including farm structure, grassland management practices, animal performance and feed rations. Second, a field-based grassland survey on up to five grassland fields per farm. In one or two 2 × 2 m subplots per field, the number of different plant species was counted. This species richness (SR) was then averaged over all investigated fields per farm. Species richness therefore is given per 4 m^2. Hand-plucked biomass samples were collected from these subplots by cutting the upper third of the vegetation from ten hand-grabs, which together formed a composite sample. These samples were dried at 60°C for 48 hours and ground to 1 mm. Crude protein (CP), acid detergent fibre (ADF), crude ash (CA) and crude fat (CL) and the enzyme-soluble organic matter (ESOM) were analysed by Near-Infrared Reflectance Spectroscopy (Phoenix 5000, Bluesun Sci, USA), with each sample scanned twice. Metabolisable energy (ME, MJ kg^{-1} DM) was calculated as follows: ME = 5.51+0.00828×ESOM−0.00511×CA+0.02507×CL−0.00392×ADF. The coefficient of variation (CV) of ME served as indicator for production stability per farm. Annual feed qualities offered to dairy cows (kg DM $year^{-1}$) during lactation (305 days) and the dry period (60 days) were multiplied by their crude protein (g (kg DM)$^{-1}$) and the corresponding human-edible protein fraction. CP values came from feed analyses and standard feed tables (LfL, 2021). The human-edible protein conversion ratio (hePCR) was calculated per farm using feed ration data according to the following formula: hePCR = Σ_n(kg CP feedstuff×human-edible proportion of the CP from feedstuff$_i$)/(kg CP milk×human-edible proportion of the CP from milk), where n is the number of feedstuffs used per farm per year, CP is the crude protein concentration, and i represents each feed type, following the methodology of Wild *et al.* (2025). Farms were categorised based on hePCR into two groups (low, high), with thresholds of <1.0 considered net protein production (n = 22) and >1.0 as net protein loss (n = 27). To characterise milk production performance, the total amount of energy corrected milk (ECM) per cow and year was calculated, along with the amount of ECM per cow and year produced from grass using a residual method. ECM per hectare of grassland was then determined. Also, the proportion of milk produced from concentrates, maize silage, and arable land (including all fed crops growing on arable land, except ley-grass) have been calculated accounting for energy requirements of maintenance and performance similar to Wild *et al.* (2025). An analysis of variance (ANOVA) was conducted with hePCR category (low vs. high) as the influencing variable on milk production performance, concentrate feed, SR and CV ME. Post hoc comparisons of means using t-tests were then applied to compare group means.

Results and discussion

ANOVA showed that higher inputs of human-edible concentrate feed were linked to increased total energy-corrected milk (ECM) yields (Table 1). However, the common practice of evaluating dairy system productivity solely based on annual milk yield per cow is increasingly criticised due to concerns related to environmental impact, animal welfare, food security, and the economic dependence of smallholder farmers on the feed industry (Knaus, 2016; Peyraud and Peeters, 2020). Consequently, some studies advocate prioritizing milk production per hectare of grassland—referred to as grassland performance—over per-cow productivity. This approach is typical in pasture-based dairy systems such

Table 1. Estimated means±SE of parameters of interest as affected by the hePCR categories (low: <1; high: >1).

Parameter	low hePCR (<1)	high hePCR (>1)
ECMtot (kg cow^{-1} year^{-1})	8982± 519a	9942 ± 469a
ECMgr (kg cow^{-1} year^{-1})	4210 ± 315a	2867 ± 336b
ECMgr (kg ha^{-1} GL)	8655 ± 1410a	7123± 1323a
Concentrate feed (g kg^{-1} ECM)	1289 ± 19a	230± 17b
Proportion milk from concentrates (%)	23 ± 4a	39 ± 3b
Proportion milk from maize (%)	11 ± 4a	27 ± 3b
Proportion milk from arable land (%)	39 ± 4a	68 ± 4b
Species richness (4 m^2)	7.1 ± 0.4a	6.9 ± 0.4b
CV ME	0.03 ± 0.01a	0.03 ± 0.01a

Superscript lowercase letters indicate significant differences within a row (p<0.05). hePCR: human-edible protein conversion ratio, ECMtot: total energy-corrected milk per cow, ECMgr: energy-corrected milk from grassland, GL, grassland; ECM, energy corrected milk; CV ME, coefficient of variation of ME.

as those in New Zealand and Ireland (Peyraud and Peeters, 2020; Knaus, 2016). Consistent with this, farms with lower inputs of human-edible concentrate feed in our study exhibited higher milk yields from grass per cow and per hectare (Table 1); even though the latter could not be statistically confirmed, a trend has been observed. In addition, high hePCR farms not only use more concentrates but also show greater share of milk produced from maize and arable land (Table 1). Overall, the biodiversity level was generally rather low, but SR was slightly higher for low than high hePCR farms in the North Sea region. This might be due to overall lower regional biodiversity in coastal lowlands; Wild *et al.* (2025) also reported lower mean Shannon diversity on farms in northern Germany compared to other regions. No significant difference in the CV of ME was observed between low and high hePCR farms (Table 1) which suggests that grassland herbage was stable irrespective of farm type.

Conclusion

Higher hePCR increased total ECM per cow but lowered the proportion of milk derived from grass, thereby intensifying feed-food competition. Farms with low concentrate inputs moreover produce milk from slightly more diverse grasslands. The sustainability of grass-based dairy farms is therefore highly dependent on external feed resources produced on arable land.

Acknowledgement

This study was funded by the EU and Interreg under the DivGrass project 41-2-52-22.

References

Barbieri, P., Dumont, B., Benoit, M., Nesme, T. (2022). Opinion paper: Livestock is at heart of interacting levers to reduce feed-food competition in agroecological food systems. *Animal*, 16, 100436.

Eurostat (2025). Key figures on the EU in the world. 2025 edition.

Huyghe, C., De Vliegher, A., van Gils, B., Peeters, A. (2014). Grasslands and herbivore production in Europe and effects of common policies. Édition Quae.

Knaus, W., 2016. Perspectives on pasture versus indoor feeding of dairy cows. *Journal of the Science of Food and Agriculture* 96 (1), 9–17.

LfL (2021). Gruber Tabelle zur Fütterung der Milchkühe, Zuchtrinder, Schafe, Ziegen. Bavarian research center for Agriculture LfL-Information, 47th ed.

Peyraud, J.-L., Peeters, A., 2020. The role of grassland based production system in the protein security. *Grassland Science in Europe* 21, 29–43.

Wild, M., Komainda, M., Bettin, K., Jürgens, K., Isselstein, J. (2025). Feed the green for a sustainable and protein-efficient dairy production. Agricultural Systems, 223, 104216.

Wilkinson, J.M. (2011). Re defining efficiency of feed use by livestock. Animal, 5 (7), 1014 1022.