



**INTERNAL DOCUMENT**

# **Environmental assessment of dairy cattle farms from San Vicente, Caquetá by using the CLEANED model**

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# Environmental assessment of dairy cattle farms from San Vicente, Caquetá by using the CLEANED model

### Key Messages

- Dual-purpose cattle farms in San Vicente, Caquetá primarily utilize forages in their feed basket and exhibit extensive grazing practices.
- Milk production per cow in these farms ranges from 3 to 5 kg FPCM cow<sup>-1</sup> day<sup>-1</sup>, with corresponding milk production per unit area varying between 1238 to 3521 kg FPCM<sup>ha-1</sup> yr<sup>-1</sup>.
- Greenhouse gas emissions primarily result from animal activities, with enteric fermentation and manure deposited on pastures contributing 88.6% and 6.9% of total emissions, respectively.
- Emission intensities for milk ranged from 2.7 to 8.3 kg CO<sub>2</sub>eq kg FPCM<sup>-1</sup>, and for meat, the range was 109.8 to 312.8 kg CO<sub>2</sub>eq kg LWG<sup>-1</sup>.
- The studied farms exhibit a negative N surplus per hectare, attributed to the low-input nature of dual-purpose systems.
- All land use is dedicated to pasture production, with on-farm water usage predominantly contributing to feed production, aligned with pasture cultivation.
- Enhancing the composition of the feed basket, emphasizing higher digestibility and crude protein, holds promise for increasing milk yields and mitigating environmental impacts.

The information was collected through semi-structured surveys conducted across 18 farms in San Vicente, Caquetá, Colombia.



## Methodology

### *CLEANED tool*

To assess the environmental footprints of 18 dual-purpose dairy cattle farms located in the municipality of San Vicente, Caquetá the CLEANED tool was used. CLEANED is an indicator framework for ex-ante environmental impact assessment, that allows users to explore multiple impacts of developing livestock value chains). Based on baseline data about the dual-purpose farms (agroecology; herd size, composition, and productive performance; feed crop management and performance), CLEANED calculates land requirement, land productivity, economic feasibility, water use, greenhouse gas emissions, and soil health. Its concepts and guidelines are well described by Notenbaert et al. (2014). This tool assesses the possible environmental impacts arising from the cattle enterprise only, and not those associated with the whole farm (Notenbaert et al., 2020)

In this assessment, some of the environmental indicators were estimated, and the economic indicators were excluded. Dimensions of interest included land requirements, water use, and greenhouse gas emissions (GHGe). Under land requirements, the tool estimates the total land required to grow the feed items prerequisite for the animals present in the livestock enterprise. The soil health indicator refers to the nitrogen balance, considering the N inputs and outputs from the livestock enterprise. In terms of water impacts, the tool estimates the amount of water used for feed production, which accounts for most of the water consumption in livestock production (Descheemaeker et al., 2010), and is presented by feed crop evapotranspiration. The GHG emissions are calculated using 2006 IPCC guidelines and included methane (CH<sub>4</sub>) from enteric fermentation and manure management, and direct and indirect nitrous oxide (N<sub>2</sub>O) from manure and managed soils. CH<sub>4</sub> and N<sub>2</sub>O emissions were converted into CO<sub>2</sub> equivalents by using the global warming potentials for a period of 100 years: 28 kg CO<sub>2</sub>/kg CH<sub>4</sub> and 265 kg CO<sub>2</sub>/kg N<sub>2</sub>O (IPCC, 2014). All environmental indicators are expressed as absolute values as well as intensities, on a per area basis, as well as per product basis by using a functional unit of kg Fat and Protein Corrected Milk (FPCM). FPCM is the total cow milk adjusted for or corrected on the basis of its fat and protein content.

### *Sources of information*

The data utilized in this comprehensive evaluation (CLEANED) were gathered in 2023 via semi-structured surveys conducted across 18 farms situated in the municipality of San Vicente, within the department of Caquetá, Colombia. Farmers contributed both quantitative and qualitative information based on their knowledge of the farms or available farm records. The survey instrument employed encompassed inquiries covering (1) general farm information, (2) herd composition and management, (3) pasture management practices, and (4) data related to livestock production and reproduction.

## Results

### *Milk production*

The dietary composition of the examined dual-purpose farms predominantly consisted of forages, underscoring a year-round practice of animals grazing. Milk productivity per cow in the studied Colombian dual-purpose cattle systems ranges from 3 to 5 kg FPCM cow<sup>-1</sup> day<sup>-1</sup> (Figure 1), with corresponding milk production per unit area varying between 1238 to 3521 kg FPCM ha<sup>-1</sup> yr<sup>-1</sup> (Figure 1). These findings align with the reported daily milk production rates of 3.2 to 3.7 cow<sup>-1</sup> day<sup>-1</sup> in dual-purpose cattle systems in Colombia (González-Quintero et al., 2021b). Outstanding Colombian dual-purpose cattle farms, as



highlighted by Gonzalez-Quintero et al. (2022), exhibit remarkable productivity due to effective cattle and pasture management practices (Mazzetto et al., 2015). These farms achieve a notable 82% increase in milk yields compared to average farms. While the specific outstanding farms were not identified in the studied cases, the research suggests that adopting improved cattle and pasture management practices, along with enhancing feed composition in terms of higher digestibility and crude protein, holds the potential to further elevate milk yields per cow (González-Quintero et al., 2022).

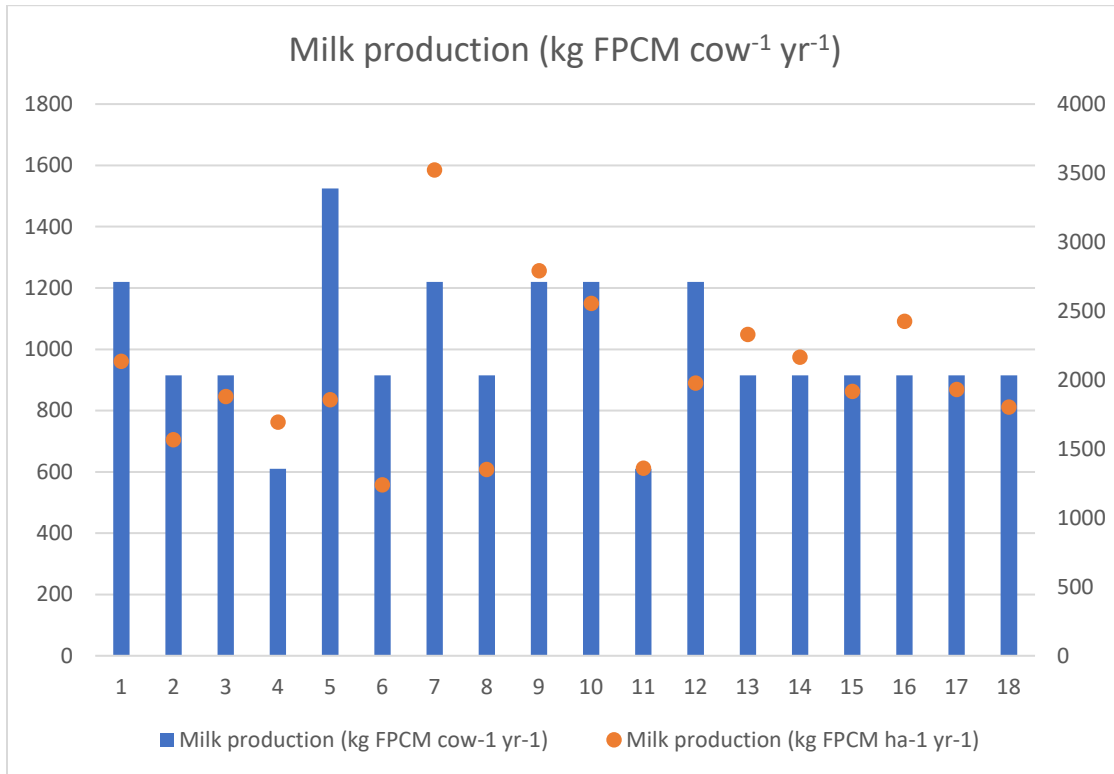


Figure 1. Milk production per cow and per hectare for dual-purpose dairy cattle farms San Vicente, Caquetá.

### Greenhouse gas emissions

GHG emissions in all farms primarily result from animal activities, with enteric fermentation and manure deposited on pastures contributing 88.6% and 6.9% of total emissions, respectively (Figure 2). The absence of manure management practices underscores the significance of these sources. Notably, the lack of agrochemical use, such as chemical fertilizers or soil amendments, eliminates on-farm N<sub>2</sub>O and CO<sub>2</sub> emissions from their use and field application. This pattern aligns with observations in low-input dairy cattle systems in Latin America, where enteric fermentation dominates GHG emissions followed by emissions from manure left pastures (González-Quintero et al., 2021b; Mazzetto et al., 2020). Considering the prevalence of these emission sources, there is a need for mitigation strategies. Proposals should address enteric fermentation and pasture-deposited manure, emphasizing scalable solutions. The identified emission patterns underscore the importance of tailoring mitigation efforts to the specific practices and challenges prevalent in low-input dairy systems in Latin America.



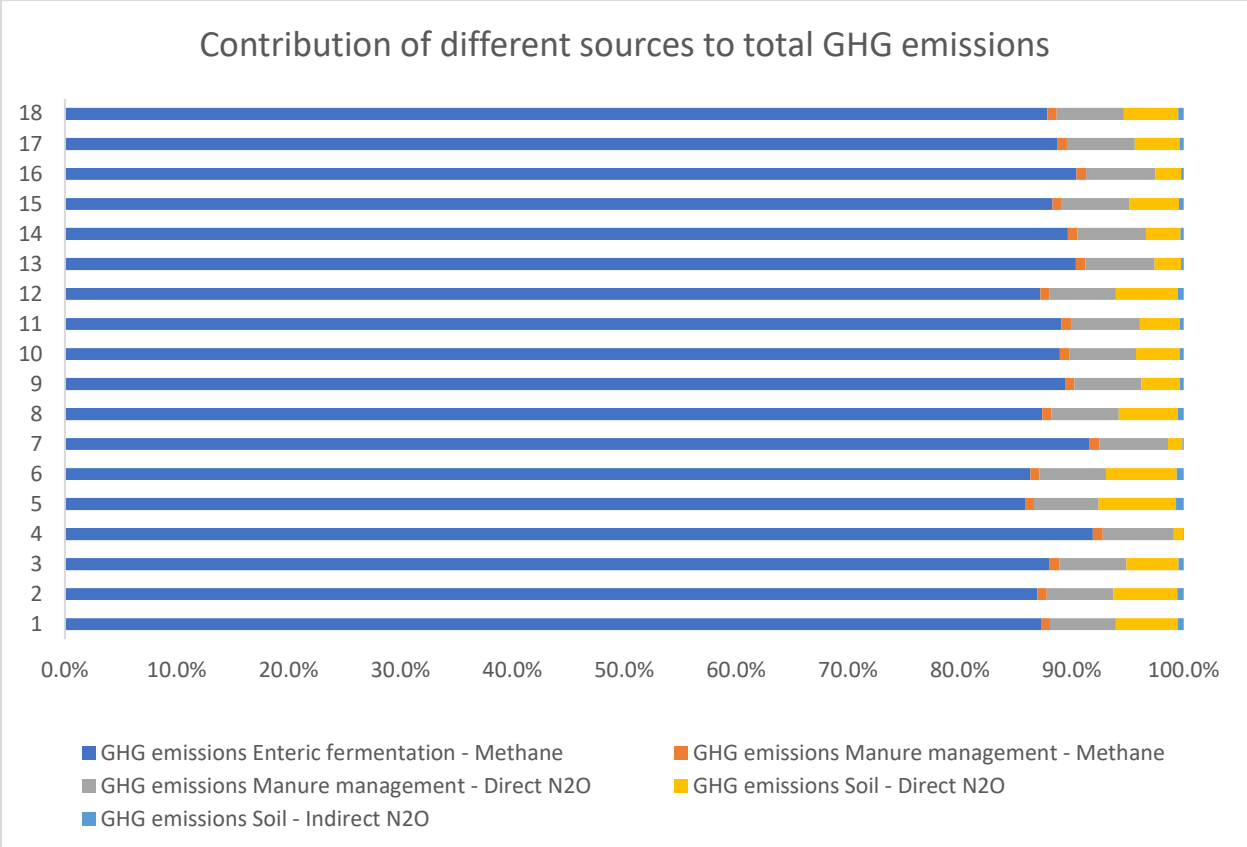


Figure 2. Contributions of different processes to total GHG emissions from 18 dual-purpose cattle farms

Emission intensities for milk ranged from 2.7 to 8.3 kg CO<sub>2</sub>eq kg FPCM<sup>-1</sup>, and for meat, the range was 109.8 to 312.8 kg CO<sub>2</sub>eq kg LWG<sup>-1</sup> (Table 1). In Colombian dual-purpose systems, a reported carbon footprint varied from 2.1 to 4.2 kg CO<sub>2</sub>eq kg FPCM<sup>-1</sup> (González-Quintero et al., 2021b). Notably, only 5 of the examined farms fell within this range, while the others exhibited higher GHG emissions intensity values. This indicates a significant potential for reducing GHG emission intensities on the studied farms, necessitating the identification of suitable strategies. As mentioned earlier, one promising mitigation strategy involves enhancing milk productivity by improving the feed basket composition with high-quality feeds. By implementing such measures, the farms can effectively contribute to mitigating GHG emissions, aligning with sustainability goals.

Table 1. Milk productivity and GHG emissions intensities for dual-purpose dairy cattle farms in San Vicente, Caquetá.

Farm Number	Milk production (kg FPCM cow <sup>-1</sup> yr <sup>-1</sup> )	GHG emissions (kg CO <sub>2</sub> eq kgFPCM <sup>-1</sup> )	GHG emissions (kg CO <sub>2</sub> eq kg meat <sup>-1</sup> )
1	1220	4.9	138.4
2	915	6.5	129.9
3	915	5.3	160.1
4	610	5.6	157.6
5	1525	5.6	109.8
6	915	8.3	124.4



7	1220	2.7	312.8
8	915	7.5	138.5
9	1220	3.5	178.6
10	1220	3.9	160.2
11	610	7.2	142.9
12	1220	5.1	130.1
13	915	4.1	193.4
14	915	4.5	181.7
15	915	5.2	156.3
16	915	4.0	214.8
17	915	5.1	145.0
18	915	5.5	145.4

### Nitrogen balances

N surpluses at the farm gate are typically ascribed to various forms of N loss, including gaseous emissions ( $\text{NH}_3$ ,  $\text{N}_2\text{O}$  and  $\text{NO}_x$ ), leaching, runoff of nitrate to surface or groundwater, and changes in soil N stocks (Penati et al., 2011). In the context of dual-purpose dairy cattle farms characterized by minimal inputs a unique pattern emerges. Studied farms exhibit a negative N surplus per hectare, with an average value of  $-237.2 \text{ kg N ha}^{-1} \text{ year}^{-1}$  across all farms (Figure 3). Such low-input cattle systems often maintain a very low or negative N balance, indicating insufficient nitrogen for leaching and runoff (González-Quintero et al., 2021a). Consequently, this limitation restricts indirect nitrous oxide ( $\text{N}_2\text{O}$ ) emissions originating from N leaching and runoff.

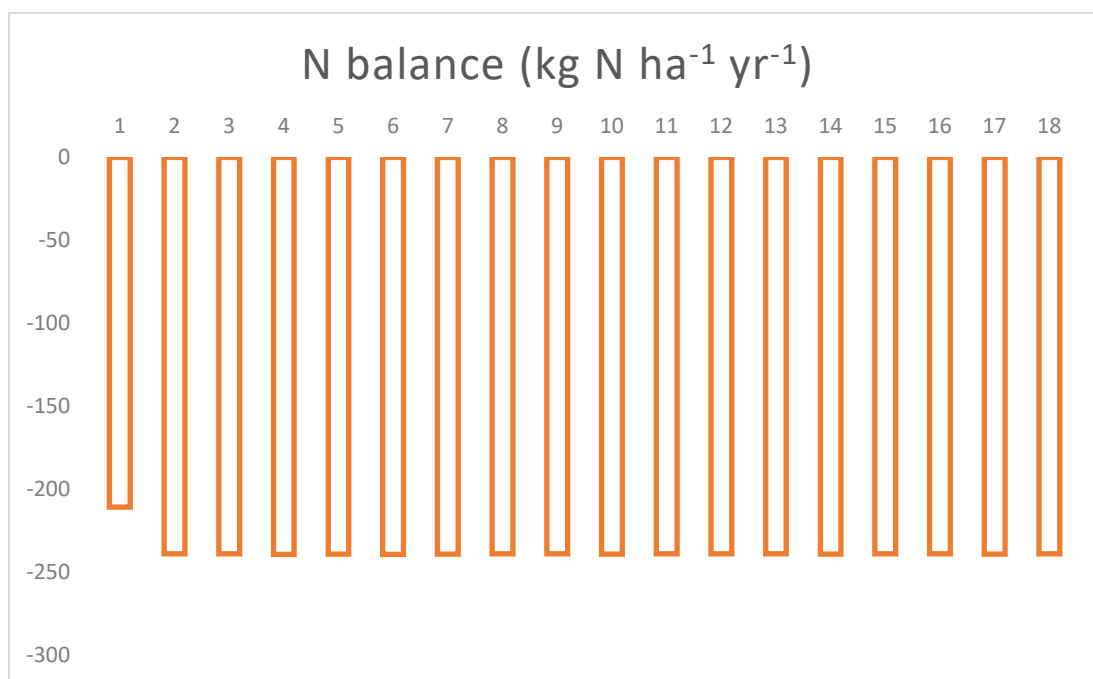


Figure 3. N balances for 18 dual-purpose dairy cattle farms from San Vicente, Caquetá.



## Land requirements

The total land required by farms for feed production exhibits variability based on the size of the animal inventory; farms with larger animal numbers necessitate more land to produce the feed to meet the energy requirements of the animals (Figure 4). When evaluating the land required to produce 1 MT of FPCM, the values ranged from 0.3 to 0.8 hectares. This observation underscores the extensive nature of the studied farms and highlights the low quality of the implemented grasses. A comparative analysis with smallholder dairy farms employing high-quality grasses reveals higher land requirements in the studied farms (Notenbaert et al., 2023). Our observations align with the data documented for extensive dual-purpose cattle systems in Colombia, as reported by González-Quintero (2021b).

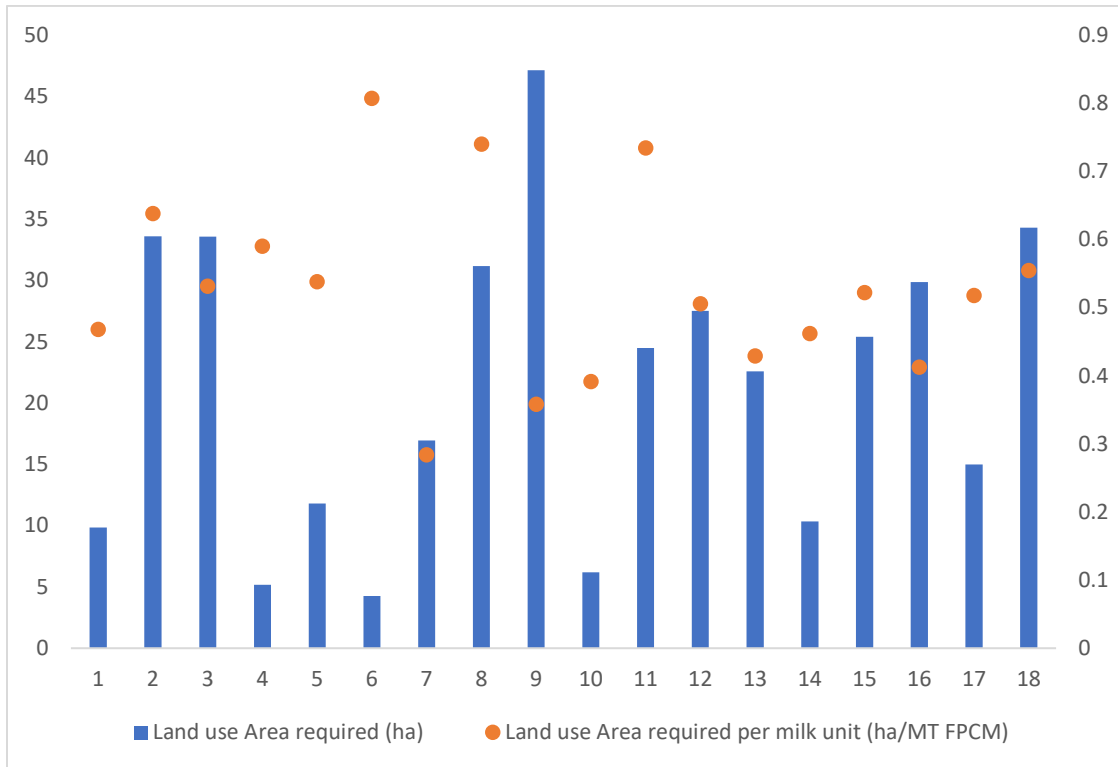


Figure 4. Total land required, and land use per MT of milk produced for 18 dual-purpose cattle farms in San Vicente, Caquetá.

## Water impacts

Across all 18 farms studied, approximately 96% of water usage is attributed to feed production, specifically the water required for pasture cultivation. The remaining 4% accounts for the water necessary for the animals, aligning with a recurring pattern observed in pasture-based cattle systems (Gerbens-Leenes et al., 2013). Furthermore, the water footprint values for milk (refer to Figure 5) are consistent with reported ranges for grazing systems in different global regions (Bosire et al., 2015; Gerbens-Leenes et al., 2013).



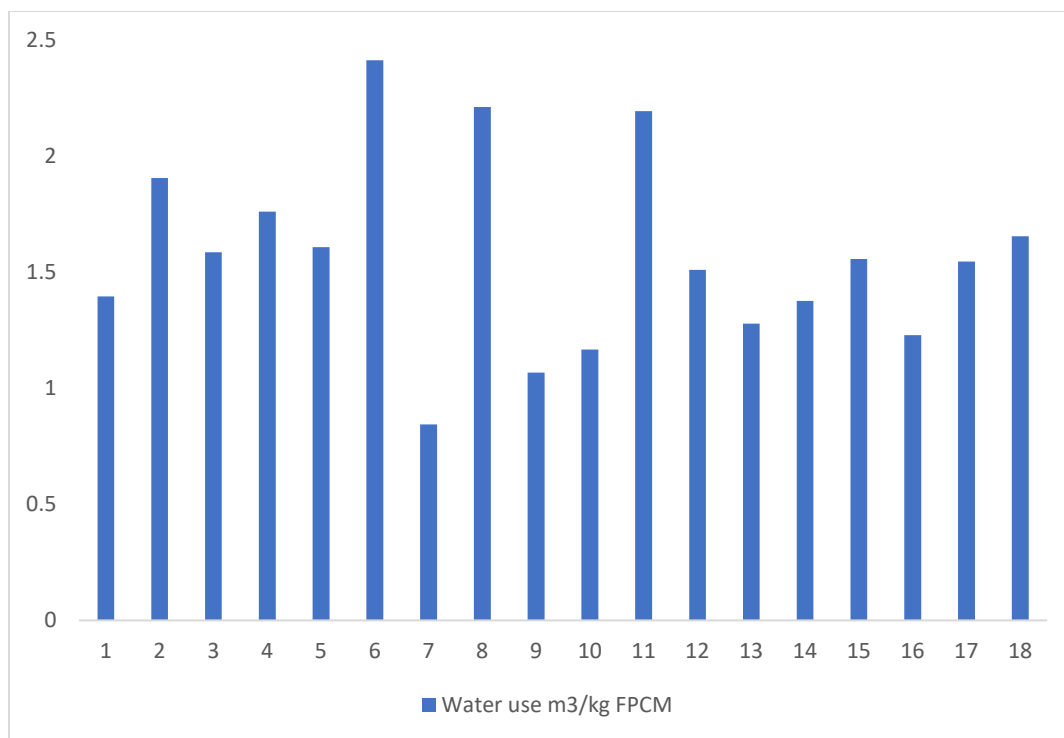


Figure 5. Water footprint for 18 dual-purpose cattle farms in San Vicente, Caquetá.

## Conclusions

The primary contributors to greenhouse gas (GHG) emissions in dual-purpose systems in San Vicente, Caquetá, stem from cattle herds, with methane generated through enteric fermentation and nitrous oxide released from excretions deposited on pastures. The resulting carbon footprint of farm products is intricately linked to the quantities of enteric methane and nitrous oxide emanating from pastures relative to the production of milk and meat.

The investigated farms display a negative nitrogen (N) surplus per hectare, attributed to the low-input nature of dual-purpose systems. Notably, the assessment excludes indirect nitrous oxide (N<sub>2</sub>O) emissions from N leaching and runoff.

All land use is dedicated to pasture production, corresponding to the grazing area for animals, as the feed basket primarily consists of forages. On-farm water usage predominantly contributes to feed production, aligned with pasture cultivation, while water demands for animal consumption represent a minor fraction of the total water usage on the farms.

Enhancing the composition of the feed basket, emphasizing higher digestibility and crude protein, holds promise for increasing milk yields. This has the potential to mitigate total environmental impacts and environmental impact intensities. The subsequent phase of the CLEANED assessment should involve modeling various scenarios, incorporating feasible mitigation options that farmers can adopt in the near future.



## References

- Bosire, C.K., Ogotu, J.O., Said, M.Y., Krol, M.S., Leeuw, J. de, Hoekstra, A.Y., 2015. Trends and spatial variation in water and land footprints of meat and milk production systems in Kenya. *Agric Ecosyst Environ* 205, 36–47. <https://doi.org/10.1016/J.AGEE.2015.02.015>
- Descheemaeker, K., Amede, T., Hailelassie, A., 2010. Improving water productivity in mixed crop–livestock farming systems of sub-Saharan Africa. *Agric Water Manag* 97, 579–586. <https://doi.org/10.1016/J.AGWAT.2009.11.012>
- Gerbens-Leenes, P.W., Mekonnen, M.M., Hoekstra, A.Y., 2013. The water footprint of poultry, pork and beef: A comparative study in different countries and production systems. *Water Resour Ind* 1–2, 25–36. <https://doi.org/10.1016/J.WRI.2013.03.001>
- González-Quintero, R., Bolívar-Vergara, D.M., Chirinda, N., Arango, J., Pantevez, H., Barahona-Rosales, R., Sánchez-Pinzón, M.S., 2021a. Environmental impact of primary beef production chain in Colombia: Carbon footprint, non-renewable energy and land use using Life Cycle Assessment. *Science of The Total Environment* 773, 145573. <https://doi.org/10.1016/j.scitotenv.2021.145573>
- González-Quintero, R., Kristensen, T., Sánchez-Pinzón, M.S., Bolívar-Vergara, D.M., Chirinda, N., Arango, J., Pantevez, H., Barahona-Rosales, R., Knudsen, M.T., 2021b. Carbon footprint, non-renewable energy and land use of dual-purpose cattle systems in Colombia using a life cycle assessment approach. *Livest Sci* 244, 104330. <https://doi.org/10.1016/j.livsci.2020.104330>
- González-Quintero, R., van Wijk, M.T., Ruden, A., Gómez, M., Pantevez, H., Castro-Llanos, F., Notenbaert, A., Arango, J., 2022. Yield gap analysis to identify attainable milk and meat productivities and the potential for greenhouse gas emissions mitigation in cattle systems of Colombia. *Agric Syst* 195, 103303. <https://doi.org/10.1016/J.AGSY.2021.103303>
- IPCC, 2014. Fifth Assessment Report (AR5). Synthesis Report (SYR), Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. <https://doi.org/10.1017/CBO9781107415324>
- Mazzetto, A.M., Bishop, G., Styles, D., Arndt, C., Brook, R., Chadwick, D., 2020. Comparing the environmental efficiency of milk and beef production through life cycle assessment of interconnected cattle systems. *J Clean Prod* 277, 124108. <https://doi.org/10.1016/j.jclepro.2020.124108>
- Mazzetto, A.M., Feigl, B.J., Schils, R.L.M., Cerri, C.E.P., Cerri, C.C., 2015. Improved pasture and herd management to reduce greenhouse gas emissions from a Brazilian beef production system. *Livest Sci* 175, 101–112. <https://doi.org/10.1016/j.livsci.2015.02.014>
- Notenbaert, A., Groot, J.C.J., Herrero, M., Birnholz, C., Paul, B.K., Pfeifer, C., Fraval, S., Lannerstad, M., McFadzean, J.N., Dungait, J.A.J., Morris, J., Ran, Y., Barron, J., Tiftonell, P., 2020. Towards environmentally sound intensification pathways for dairy development in the Tanga region of Tanzania. *Reg Environ Change* 20, 1–14. <https://doi.org/10.1007/S10113-020-01723-5/FIGURES/2>
- Notenbaert, A.M.O., Lannerstad, M., Herrero, M.T., Fraval, S., Ran, Y., Paul, B.K., Mugatha, S.M., Barron, J., Morris, J., 2014. A framework for environmental ex-ante impact assessment of livestock value



chains, in: 6th All Africa Conference of Animal Agriculture. International Center for Tropical Agriculture, Nairobi.

Notenbaert, A.M.O., Mwendia, S.W., Burkart, S., Karimi, P., Musau, E.M., 2023. Environmental co-benefits of improved forages in smallholder dairy systems of Kenya. International Grassland Congress.

Penati, C., Berentsen, P.B.M., Tamburini, A., Sandrucci, A., de Boer, I.J.M., 2011. Effect of abandoning highland grazing on nutrient balances and economic performance of Italian Alpine dairy farms. *Livest Sci* 139, 142–149. <https://doi.org/10.1016/J.LIVSCI.2011.03.008>





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