

Carbon Footprint of Aquaculture vs Livestock Farming: A Brief Overview

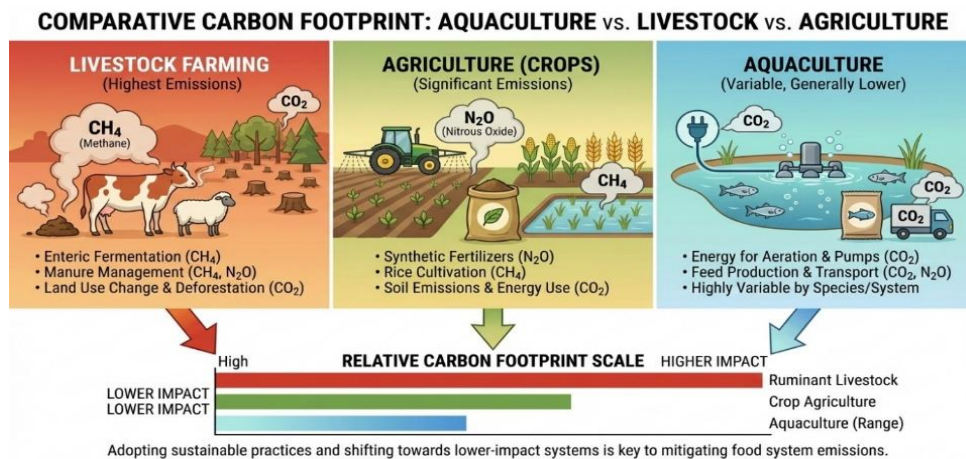
Vipul Singh Badguzar¹, Saurav Kumar^{1*} and Anjana A¹

¹ICAR – Central Institute of Fisheries Education, Mumbai, India

Corresponding Author

Saurav Kumar

Email: saurav@cife.edu.in



 **OPEN ACCESS**

Keywords

Aquaculture, Carbon footprint, Livestock, Sustainable protein, Climate change

How to cite this article:

Badguzar, V. S., Kumar, S. and Anjana, A. 2026. Carbon Footprint of Aquaculture vs Livestock Farming: A Brief Overview. *Vigyan Varta* 7 (05): 195-198.

ABSTRACT

The carbon footprint of food production plays a critical role in climate change and sustainable protein supply. This article compares aquaculture and livestock farming in terms of greenhouse gas emissions, feed efficiency, and resource use. Livestock systems, particularly ruminants, generate high emissions due to methane production, land-use change, and manure management. In contrast, aquaculture generally shows lower emissions and higher efficiency, although impacts vary by species. Shellfish and seaweed systems have the lowest environmental footprint and may contribute to carbon sequestration. Despite certain challenges, aquaculture offers a promising pathway for climate-smart protein

production.

INTRODUCTION

The concept of carbon footprint originates from the Ecological Footprint, which measures how human activities utilize natural resources (Wackernagel and Rees, 1998). It refers to total greenhouse gas emissions generated across a product's lifecycle (Williams, 2009).

Food systems are a major contributor to global emissions, making protein production a key environmental concern. While livestock farming is highly emission-intensive, aquaculture is increasingly considered a lower-impact alternative.

1. Understanding Carbon Footprint in Agriculture

The carbon footprint of food includes emissions from production, processing, transport, and waste. The primary gases involved are CO₂, methane, and nitrous oxide, expressed as CO₂-equivalents. Aquaculture contributes a relatively small share of global emissions compared to livestock systems due to lower land use and minimal methane production (Macleod *et al.*, 2020).

2. Livestock Farming: The Carbon-Heavy Protein Source

2.1 Methane Emissions from Enteric Fermentation: Ruminant livestock produce methane during digestion, which has a significantly higher warming potential than CO₂. This makes livestock, especially cattle, a major source of agricultural emissions (Putman *et al.*, 2023).

2.2 Land Use and Deforestation: Livestock farming requires large areas for grazing and

feed crops, often leading to deforestation, carbon release, and biodiversity loss.

2.3 Manure and Fertilizer Emissions:

Manure emits methane during storage and nitrous oxide when applied to soils. Fertilizer use for feed production further increases emissions.

3. Aquaculture: A Promising Yet Complex Alternative

Aquaculture is the fastest-growing food production sector and supplies over half of global seafood. Its sustainability depends on species and management practices.

3.1 Lower Greenhouse Gas Emissions

(Species Dependent): Emission levels vary by species. Freshwater fish typically have low emissions, while carnivorous species are moderately higher. Shellfish and seaweed systems have the lowest emissions and may act as carbon sinks (FAO, 2017).

3.2 Efficient Feed Conversion:

Aquatic organisms have better feed conversion efficiency than livestock due to lower energy requirements, improving overall sustainability (Fry *et al.*, 2018).

3.3 Less Land and Resource Use:

Aquaculture generally requires less land and freshwater than livestock systems. Marine systems avoid land-use change, and shellfish farming requires minimal external inputs.

4. Environmental Challenges in Aquaculture

- **Feed Sourcing:** Dependence on fish-based feed creates pressure on marine ecosystems, though alternative feeds are

increasingly being adopted (Naylor *et al.*, 2021).

- **Water Pollution and Disease:** Aquaculture waste can lead to nutrient pollution, and high-density farming increases disease risks. Improved management practices can mitigate these issues.
- **Habitat Impacts:** Aquaculture expansion has caused habitat loss in some regions, particularly mangrove ecosystems (Alongi, 2014).

5. Shellfish and Seaweed: The Climate Champions

Shellfish and seaweed require no feed or fertilizers, improve water quality, and contribute to carbon uptake. They represent some of the most sustainable food production systems (Duarte *et al.*, 2017).

6. Policy and Innovation for Sustainable Protein

Sustainable protein production requires improved feed alternatives, better farm management, and ecosystem-based approaches in aquaculture. In livestock systems, emission reductions can be achieved through improved feeding strategies, manure management, and reduced reliance on high-emission products.

Table: Side-by-side comparison between Aquaculture and Livestock Farming

Factor	Aquaculture	Livestock Farming
Methane Emissions	Minimal	High (especially from ruminants)
Feed Conversion Ratio (FCR)	1 – 2.4	6 – 10 (beef), 2.7 – 5 (pork), 1.7-2 (chicken) (Fry <i>et al.</i> , 2018)
Land Use	Low (especially marine systems)	High (grazing + feed crops)
Water Use	Moderate to low (except shrimp farms)	High
Carbon Sequestration Potential	Possible in seaweed/shellfish systems	Low

CONCLUSION

Aquaculture, particularly shellfish, seaweed, and herbivorous fish systems, has a lower carbon footprint than livestock production. While challenges remain, it offers a more efficient and climate-resilient pathway for protein production. Expanding sustainable aquaculture will be essential for future food security and climate mitigation.

REFERENCES

- Alongi, D. M. (2014). Carbon cycling and storage in mangrove ecosystems. *Annual Review of Marine Science*, 6, 195–219.
- Duarte, C. M., Wu, J., Xiao, X., Bruhn, A., & Krause-Jensen, D. (2017). Can seaweed farming play a role in climate change mitigation and adaptation? *Frontiers in Marine Science*, 4, 100.
- Food and Agriculture Organization. (2017). *The state of world fisheries and aquaculture 2017*. FAO.
- Fry, J. P., Love, D. C., MacDonald, G. K., West, P. C., Engstrom, P. M., Nachman, K. E., & Lawrence, R. S. (2018). Environmental health impacts of feeding crops to farmed fish. *Environment International*, 114, 293–303.
- MacLeod, M. J., Hasan, M. R., Robb, D. H. F., & Mamun-Ur-Rashid, M. (2020). Quantifying greenhouse gas emissions from global aquaculture. *Scientific Reports*, 10, 11679.
- Naylor, R. L., Hardy, R. W., Buschmann, A. H., Bush, S. R., Cao, L., Klinger, D. H., Little, D. C., Lubchenco, J., Shumway, S. E., & Troell, M. (2021). A 20-year retrospective review of global aquaculture. *Nature*, 591(7851), 551–563.

Putman, B., *et al.* (2023). Greenhouse gas emissions from livestock production systems.

Wackernagel, M., & Rees, W. (1998). *Our ecological footprint: Reducing human*

impact on the Earth. New Society Publishers.

Williams, A. G. (2009). Life cycle analysis and carbon footprinting of food products.