

Ecological-Planetary Deep-Dive

Purpose. This text works through the ecological-planetary strand of the FORSCH-0090 bundle in full and deepens the environmental balance of industrial animal production, treated only summarily in Layer 8 (industry) and Layer 13 (aquaculture). It draws on the largest available life-cycle datasets and keeps three things honestly apart: global aggregate figures, product-specific intensities, and regional differentiation. Every claim is graded by strength of evidence at the end (§9).

Methodological frame — the denominator decides. Environmental balances depend strongly on the functional unit: per kilogram, per kilocalorie, or per gram of protein yields different rankings. The data backbone is the most comprehensive meta-analysis to date: **Poore & Nemecek 2018** (*Science* 360(6392):987–992, doi:10.1126/science.aag0216) consolidates ~38,700 farms in 119 countries across 40 products and covers land, greenhouse gases, water, acidification and eutrophication along the whole supply chain. “Causal” is rarely the right word in ecology; what counts here is the robustness of the balance across independent datasets.

1. Greenhouse gases — three interlocking numbers

1.1 Food systems overall. Crippa et al. 2021 (*Nature Food* 2:198–209, doi:10.1038/s43016-021-00225-9, EDGAR-FOOD): in 2015 the global food system caused about **18 Gt CO₂-equivalent — roughly 34% of all anthropogenic greenhouse gases** (from production through processing, transport, packaging to consumption and waste).

1.2 Animal vs. plant. Xu et al. 2021 (*Nature Food* 2(9):724–732, doi:10.1038/s43016-021-00358-x): of food emissions, **57% come from animal-based foods (including feed), 29% from plant-based, 14% from other uses** — animal food emits about twice as much globally as plant food.

1.3 The livestock sector. Gerber et al. 2013 (FAO, *Tackling climate change through livestock*): livestock supply chains emit **~7.1 Gt CO₂-eq/year ≈ 14.5% of anthropogenic greenhouse gases**; main sources: feed production (45%), enteric fermentation/methane (39%), manure decomposition (10%). **Honestly:** the 14.5% figure is methodologically contested (boundary and GWP questions; some re-analyses come out lower). The *direction* — livestock as a large single item — is robust across all datasets; the *exact percentage* is not.

1.4 Product spread and methane. Within animal products the spread is enormous: beef is about an order of magnitude more emission-intensive per gram of protein than legumes (Poore & Nemecek 2018). Part of ruminant emissions is **methane** (enteric fermentation) — short-lived but very potent in the short term (GWP-100 vs. GWP-20 changes the balance; a genuine methodological debate, not a free pass).

2. Land use — the largest lever

Poore & Nemecek 2018: agriculture uses about **43% of ice- and desert-free land**; of that, around **83% serves animal-based foods — which provide only ~18% of calories and ~37% of protein**. This is the central inefficiency: a large share of global farmland produces a small share of food energy.

Hence the concept of **carbon opportunity cost**: land tied up for animal production (including feed cropping) could partly be restored and sequester CO₂. A global shift to plant-forward eating would, per Poore & Nemecek, cut **farmland by ~76% and food greenhouse gases by ~49%** — the single largest environmental lever on the demand side. **Status: robust modelling over the largest LCA dataset.**

3. Water

Mekonnen & Hoekstra 2012 (*Ecosystems* 15(3):401–415, doi:10.1007/s10021-011-9517-8): about **one-third of agriculture's water footprint** is animal products; the water footprint **per calorie is ~20× larger for beef than for cereals**, and per gram of protein ~1.5× larger for milk/eggs/chicken than for pulses.

Honest differentiation: most of it is “green” water (rain that falls anyway); scarcity-relevant is mainly “blue” water (irrigation/groundwater). The ecological salience thus depends on region — beef from rain-fed pasture stresses scarce water less than irrigated feed cropping in dry areas. The aggregate figure holds; the local impact varies.

4. Nitrogen and phosphorus — the transgressed boundary

Industrial animal production is, via feed cropping (fertiliser) and manure, a major driver of **re-active nitrogen**. The Haber-Bosch process has altered the global nitrogen cycle so strongly that the **planetary boundary for biogeochemical flows (N and P) is considered substantially transgressed** (Steffen et al. 2015, *Science*, doi:10.1126/science.1259855). Consequences: eutrophication of waters, dead zones (e.g. Gulf of Mexico), acidification, nitrous oxide (N₂O, a potent greenhouse gas). Poore & Nemecek account for eutrophication explicitly — animal products dominate here too. **Status: robust balance + transgressed planetary boundary.**

5. Biodiversity and deforestation

Land-use change is globally the **single most important driver of biodiversity loss** (IPBES 2019). Pendrill et al. 2019 (*Global Environmental Change* 56:1–10, doi:10.1016/j.gloenvcha.2019.03.002): tropical deforestation 2010–2014 ≈ 2.6 Gt CO₂/year, of which **cattle and oilseeds (especially soy, palm oil) more than half**; in 2005–2013, 62% of forest loss was attributable to commercial land expansion, with cattle meat, forestry products, oil palm, cereals and soy as the leading drivers. A substantial part of globally traded **soy is feed** — so deforestation is indirectly embedded in European meat too. **Status: strong.**

6. Aquaculture and the oceans (link to Layer 13)

Aquaculture reproduces environmental burdens underwater: eutrophication from feed and faecal load, antibiotics and pesticides (Lozano-Muñoz et al. 2018, *Front. Microbiol.* 9:1284, doi:10.3389/fmicb.2018.01284), mangrove destruction for shrimp farms (Hamilton & Casey 2016, doi:10.1111/geb.12449). Wild capture: ~38% of stocks overfished (FAO 2024); subsidies ~35 bn USD/year sustain overcapacity (Sumaila et al. 2019, doi:10.1016/j.marpol.2019.103695). Detail in Layer 13 and the aquaculture section of the science spin-off.

7. Planetary boundaries — the overall picture

The EAT-Lancet Commission (Willett et al. 2019, *Lancet* 393:447–492, doi:10.1016/S0140-6736(18)31788-4) anchors the food question in the **planetary boundaries** (Steffen et al. 2015): the food system is a major driver of climate change, land-system change, freshwater use, N/P flows and biodiversity loss — for several of these boundaries animal production is the dominant item. The “Planetary Health Diet” is strongly plant-forward. **Affordability caveat:** ~1.58 billion people cannot afford it (Hirvonen et al. 2020, doi:10.1016/S2214-109X(19)30447-4) — a hard class and Global-South limit that constrains any simple “eat plants” message.

8. Honest differentiation — what the aggregates do not say

Three objections are legitimate and are not waved away here:

8.1 Extensive grazing on non-arable land. Ruminants on marginal grassland that cannot be cropped convert biomass inedible to humans into food. This is to be judged differently from irrigated soy-maize feed cropping for CAFOs — and it is exactly the bundle’s subsistence/pastoralism caveat. But: extensive grazing has low land efficiency and cannot carry world meat consumption; it is a niche, not a scaling model.

8.2 “Grass-fed is climate-neutral.” Partly misleading: grass-fed cattle often have *higher* methane emissions per kg (slower growth), and the land’s carbon opportunity cost remains. Soil-carbon sequestration through grazing is real but limited and saturates — it does not fully offset life-cycle emissions.

8.3 LCA limits. System boundaries, allocation rules (meat vs. by-products), GWP time horizon and regional data gaps create real uncertainties. Hence: *direction robust, single percentage uncertain*.

9. Evidence grading

Finding	Best source	Status
Food system ~34% of global GHG	Crippa 2021 (EDGAR-FOOD)	Robust
Animal food ~2× GHG of plant	Xu 2021	Robust
Livestock sector ~14.5% GHG	Gerber/FAO 2013	Direction robust; % contested
83% farmland for 18% calories	Poore & Nemecek 2018	Robust
Plant shift: –76% land, –49% GHG	Poore & Nemecek 2018	Robust modelling
Beef water ~20× cereals/kcal	Mekonnen & Hoekstra 2012	Robust (green/blue distinction)
N/P boundary transgressed	Steffen 2015	Robust
Cattle/soy >½ tropical-deforestation emissions	Pendrill 2019	Strong
Extensive grazing ecologically distinct	LCA differentiation	Valid, but niche
Grass-fed “climate-neutral”	LCA	Not supported

10. Synthesis

First: at the aggregate level the direction is robust across all large independent datasets — industrial animal production is a dominant item in greenhouse gases, land use, water, nitrogen/phosphorus, deforestation and biodiversity loss; shifting demand toward plant-forward eating is the single largest environmental lever.

Second: at the detail level exact percentages (14.5%; GWP horizon) are methodologically contested, and regional differentiation is mandatory — extensive grazing on non-arable land and smallholder mixed farming are to be judged differently from irrigated feed-CAFO chains.

Third — the caveat stays firm and coincides with the nutritional-medical finding: the ecological critique targets *industrial* animal production in industrial societies, not subsistence pastoralism or indigenous practice; and the EAT-Lancet affordability limit (~1.58 billion people) forbids any simple universalisation.

Track: FORSCHUNG · ORCID 0009-0003-9799-6747 · forschung@tschueller.com · CC BY 4.0 **As of:** 2026-06-16 · Extension to Layer 8 and Layer 13; all key sources web-verified 2026-06.