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Sunstone Institute

The Cropland Behind Norwegian Salmon Feed

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Table of contents

Executive summary 4

Method in brief 5

1. Research scope and question 5

2. National feed data 6

2.1 Crop-derived ingredients, 2020 6

3. Method 7

3.1 Alternative allocation methods 8

4. Crop yields 8

5. Guarseed: yields and allocation 9

5.1 Guarseed yields 9

5.2 Guar gum and guar meal 11

5.3 Mass allocation applied to guar 11

5.4 Economic allocation 11

6. Results 12

6.1 Result per kilogram 13

6.2 Sensitivity analysis 13

7. Comparison with published estimates 14

8. Where the land is 15

9. Limitations 15

10. Conclusion 16

Acknowledgements 17

Appendix 17

References 19

List of tables

Table 1. Headline result. 4
Table 2. National feed and production quantities, 2020 (Aas et al., 2022). 6
Table 3. Ingredients used in Norwegian salmon feed in 2020, plant-derived only (Aas et al., 2022). . 6
Table 4. Ingredient crop yields. 8
Table 5. All-India area, production and yield of guar seed. 9
Table 6. Cropland by crop group, with share of total and land use per kilogram of salmon (live weight). 12
Table 7. Effect of alternative method choices on the total. 13
Table A1. Farmed aquatic species and chicken 17
Table A2. Land use of other animal products, per kg of product (Poore & Nemecek, 2018) 18
Table A3. Illustrative extrapolation to global Atlantic salmon production. 18

Executive summary

Set in fjords, the Norwegian salmon industry gives no direct impression of a land-consuming industry. However, although not immediately apparent, this method of agriculture requires significant land use. This study set out to answer one narrow question: how much agricultural land was occupied for one year to grow the crop-derived ingredients used in Norwegian salmon feed. The amount of agricultural land this industry uses is not widely reported.

Norway publishes detailed feed-ingredient data and detailed production data; the land implied by the two together is not standard reporting. This study uses the 2020 national feed data (Aas, Åsgård et al., 2022), traces each crop-derived ingredient back to the crop and region it came from, and divides ingredient tonnage by multi-year average yields for the crops documented in the region of origin.

As a result, the crop ingredients in Norwegian salmon feed occupied about 6,100 km² of cropland for one year, or about 4.2 m²·yr per kilogram of salmon produced. Using different methodological choices, the figure falls in the range of 3.6 and 5.0 m²·yr/kg. For scale, this is roughly equivalent to three-quarters of all fully cultivated Norwegian agricultural land. However, almost none of the land used for ingredients was Norwegian; 91.7% of feed ingredients were imported (Aas et al., 2022).

The distribution of land share among ingredients proved to be one of the most striking results. Guar protein accounts for 4.3% of feed ingredients by mass and 26% of the land. This is because Indian guar yields around 0.54 tonnes per hectare, compared with 3.1 tonnes per hectare for European rapeseed and 5.6 tonnes per hectare for European wheat. Guar meal, however, is a by-product of guar seed cultivation, which is primarily done to extract guar gum (Abidi et al., 2015). This single minor ingredient, grown for an industry unrelated to aquaculture, drives more than a quarter of the result.

This study is not a life-cycle assessment, a measure of deforestation, an environmental verdict, or a critique of the Norwegian salmon farming industry. This study does not claim that salmon farming utilises more land than other animal proteins; rather, it provides a method for calculating this industry's land use. This study aims to make that component visible so consumers can use it to assess the environmental impact of their consumption habits.

Table 1.
Headline result.

Quantity	Value
Cropland occupied, 2020	6,139 km²·yr (reported as ~6,100)
Per kg of salmon, live weight	4.18 m²·yr
Plausible span across method choices	3.6 – 5.0 m²·yr/kg
Share of feed that is crop-derived	73.1% of 1,976,709 t of ingredients
Salmon produced, 2020, live weight	1,467,655 t

Method in brief

Norway's national feed data report the tonnage of each ingredient used in a year, along with the tonnage of salmon produced. Each ingredient is traced back to its crop, and cropland is calculated by dividing ingredient tonnage by the multi-year average yield for that crop in its documented region of origin. Where a crop yields more than one saleable product (rapeseed gives oil and meal, soybeans give oil and protein, guar gives gum and meal), the land is divided between them in proportion to their output mass. No feed conversion ratio is assumed: the ratio of 1.35 tonnes of ingredients per tonne of salmon follows directly from the two reported national totals.

1. Research scope and question

The research scope and question for this study are:

How much cropland was occupied for one year to grow the crop-derived ingredients used to feed Norwegian farmed Atlantic salmon in 2020?

This includes the crop ingredients consumed in Norwegian salmon feed in 2020 and the agricultural land occupied to grow the underlying crops.

Several categories that would plausibly belong in a full environmental assessment are excluded here, either because they fall outside the scope of the question or because they cannot be inferred from the national ingredient table. Each of them would add to the figure rather than reduce it:

What is excluded:

- Marine feed ingredients (22.4% of ingredients by mass), the sea area used by farms or fisheries
- Buildings, hatcheries, transport and processing facilities
- Greenhouse gas emissions, biodiversity effects
- Water use, deforestation and other land-use change
- Trout and other aquaculture species
- Micro ingredients (4.1%) and novel ingredients (0.4%) whose cropland requirements cannot be inferred from the national ingredient table.

Because the excluded categories are primarily additions to land use, the true crop-related figure is marginally higher than the reported figure. The result is to be understood as feed-related cropland occupation for Norwegian salmon, not as the footprint of aquaculture.

2. National feed data

Aas, Åsgård and Ytrestøyl (2022) at Nofima compiled feed data supplied by BioMar, Cargill, Mowi Feed and Skretting, which together covered all ingredients used in Norwegian salmon feed in 2020. The Norwegian Seafood Research Fund funded the study.

Table 2.
National feed and production quantities, 2020 (Aas et al., 2022).

Quantity	Amount
Norwegian farmed salmon produced, live weight	1,467,655 t
Feed ingredients used	1,976,709 t
Plant-derived ingredients	73.1%
Marine ingredients	22.4%
Micro-ingredients	4.1%
Novel and other ingredients	0.4%
Imported share of ingredients	91.7%

The ratio of ingredients to salmon is 1.35 kg/kg, calculated directly from the two national totals rather than assumed from a typical farm. This is the method's strongest feature: it removes the need to assume a feed conversion ratio.

2.1 Crop-derived ingredients, 2020

Table 3.
Ingredients used in Norwegian salmon feed in 2020, plant-derived only (Aas et al., 2022).

Ingredient	Tonnes	% of all ingredients
Soy protein concentrate	413,611	20.9
Rapeseed oil	356,499	18.0
Wheat gluten	193,904	9.8
Wheat	127,878	6.5
Guar protein	84,677	4.3
Faba beans	70,568	3.6
Sunflower	67,798	3.4
Pea flour	48,592	2.5
Pea protein	27,306	1.4

Ingredient	Tonnes	% of all ingredients
Linseed oil	25,874	1.3
Corn gluten	12,971	0.7
Soybean oil	7,392	0.4
Camelina oil	7,022	0.4
Coconut oil	1,006	0.1
Total crop-derived	**1,445,098**	**73.1**

Norway's national feed series covers 2010, 2012, 2016, and 2020 (Aas et al., 2022). 2020 is the most recent complete national ingredient mass balance available; therefore, this analysis uses 2020.

The composition of Norwegian salmon feed has changed substantially over three decades. Marine ingredients accounted for roughly 90% of feed in 1990 and around 40% by 2010 (Ytrestøyl et al., 2015), falling to 24.9% in 2016 and 22.4% in 2020, while plant ingredients rose correspondingly to 73.1% (Aas et al., 2022). The land requirement calculated in this study is therefore not a fixed property of salmon farming but the consequence of a deliberate substitution of marine inputs for agricultural ones. It also means that older assessments of salmon's land footprint describe a materially different diet from today's.

3. Method

Most processed crops produce more than one saleable product. This is the case with the ingredients used in fish feed, such as rapeseed, which yields oil and meal, soybeans, which yield oil and protein, and wheat, which yields starch and gluten. Under this measure, the ingredients are grouped by the crop they derive from.

This study uses mass allocation. Each ingredient carries a share of the crop's land equal to its share of the output mass. This method removes the processing step. If one tonne of a crop yields *a* tonnes of the ingredient plus co-products, then producing *X* tonnes of the ingredient requires *X/a* tonnes of crop, of which the ingredient is charged at the fraction a.

Gross land = (X / a) / yield

Mass allocated land = gross land × a

= X / yield

For each crop group:

Cropland area = crop-ingredient tonnes / representative crop yield

The benefit of mass allocation is that it requires no processing yields, only crop yields. This removes a substantial source of uncertainty and makes every figure reproducible from public data. The downside of mass allocation is that it is a simplified calculation, valid where input and output masses share compatible boundaries and moisture bases. It does not imply that processing is lossless.

3.1 Alternative allocation methods

Mass allocation is one of several calculation methods. Economic allocation, which divides land by product value, would assign less land to guar meal and more to soy protein. Section 6.2 reports the effect on these two components.

Mass allocation was chosen for its simplicity, its applicability across all regions and crops, and its stability over time. Gephart et al. (2021) gave the same reasoning for making the same choice.

4. Crop yields

Yields are calculated as aggregate multi-year values. Multi-year aggregates are used throughout, so that a single favourable or unfavourable harvest does not drive the result.

Aggregate yield = total production over the period / total harvested area

Table 4.
Ingredient crop yields.

Crop	Region	Period	Aggregate yield (t/ha)
Maize	EU-27 + Ukraine	2019–24	7.085
Coconut (in shell)	World	2019–24	5.750
Wheat	EU-27	2019–24	5.571
Wheat (for gluten)	EU-27 + Ukraine	2019–24	5.309
Soybeans	Brazil	2019-24	3.238
Rapeseed	EU-27	2019–24	3.113
Faba beans	EU-27	2019–24	2.655
Peas, dry	EU-27 + Ukraine	2019–24	2.273
Sunflower seed	EU-27 + Ukraine + Russia	2019–24	1.988
Rapeseed	Russia + Belarus	2019–24	1.858
Linseed	World	2019–24	0.897
Guarseed	India	2019–20 to 2024–25	0.537

Sources: FAO (2026) for all crops except guar seed. Government of India, Directorate of Economics and Statistics (2024), for guar seed. Camelina has no separate FAO (2026) item and is represented using the linseed yield, as both are low-yield minor oilseeds.

Two crops of importance to note: Linseed at 0.897 t/ha is the second-lowest-yielding crop of the ingredients, so linseed and camelina oils, at 1.7% of ingredients together, occupy more land than sunflower at 3.4%. Guarseed at around 0.537 t/ha is roughly one-sixth of Brazilian soybeans and one-tenth of EU wheat, which is why 4.3% of ingredients accounts for 25.7% of the land. Additionally, rapeseed is assigned two yields because its origins are documented separately. Approximately 59% of rapeseed oil came from European countries, 25% from Russia or Belarus, and the remaining 16% was undocumented. In this case, we assigned the undocumented rapeseed to the EU yield, as it was the option with the smallest area.

5. Guarseed: yields and allocation

Guarseed accounts for the largest share of land use among all measured ingredients. For this reason, it has received special attention to more thoroughly examine its impact on the study.

5.1 Guarseed yields

Guar yields have historically been volatile, as evidenced by Table 5. This volatility means that guar can disproportionately affect the study, depending on the selected averaging window. Therefore, the full published series from 1997-98 to 2024-25 is reproduced below.

Table 5.
All-India area, production and yield of guar seed.

Year	Area (000 ha)	Production (000 t)	Yield (kg/ha)
1997–98	2,301.2	962.7	418
1998–99	1,922.1	488.5	254
1999–00	2,933.9	375.1	128
2000–01	3,497.4	658.8	188
2001–02	2,903.1	1,089.9	375
2002–03	975.1	199.2	204
2003–04	2,854.0	1,513.4	530
2004–05	2,867.4	903.3	315
2005–06	2,955.5	1,059.0	358
2006–07	3,343.7	1,169.3	350

Year	Area (000 ha)	Production (000 t)	Yield (kg/ha)
2007–08	3,472.6	1,788.5	515
2008–09	3,862.5	1,935.8	501
2009–10	2,995.2	594.7	199
2010–11	3,382.2	1,965.3	581
2011–12	3,444.2	2,217.6	644
2012–13	5,151.3	2,457.6	477
2013–14	5,958.7	3,585.3	602
2014–15	5,344.8	3,275.9	613
2015–16	5,603.4	2,824.4	504
2016–17	4,103.3	1,849.5	451
2017–18	3,936.5	1,624.3	413
2018–19	3,469.1	1,312.1	378
2019–20	3,140.2	1,519.3	484
2020-21	2,707.7	1,302.0	481
2021-22	2,630.2	1,183.0	450
2022-23	3,212.9	1,786.9	556
2023-24	3,088.9	1,665.1	539
2024-25	3,221.8	2,203.9	684

The central estimate for guar uses the most recent six years, 2019-20 to 2024-25, giving an aggregate yield of 0.537 t/ha, the same window length applied to every other crop. The full 28-year series above is used to show volatility in crop yields.

Guar is a drought-tolerant legume grown in the kharif season in arid conditions, predominantly in Rajasthan and Haryana. Indian guar is largely rainfed (Haryana receives some supplementary irrigation), in contrast to Pakistan, where around 80% of the guar area is irrigated, and production fluctuates with monsoon rainfall intensity and pattern (Sharma & Gummagolmath, 2012). Sharma and Gummagolmath (2012) report a Cuddy–Della Valle instability index of 32.6% for all-India guar yield over 1970–71 to 2007–08, rising to 51.1% for Rajasthan alone. USDA Foreign Agricultural Service (2014) reports that the crop does not respond to fertilisation or irrigation. Recorded all-India yields range from 128 to 684 kg/ha from 1997–98 to 2024–25 (Directorate of Economics and Statistics, 2024). For comparison, EU rapeseed yield had a coefficient of variation of 4% over 2019–24, compared with 16% for guar seed (FAO, 2026; Directorate of Economics and Statistics, 2024).

Abidi et al. (2015) note that the primary reason for cultivating guar is its utilisation in the oil and gas industry for hydraulic fracturing, where it serves as a thickener in the fracturing fluid. This implies that guar meal is a by-product, not the primary reason for growing the ingredient.

5.2 Guar gum and guar meal

A guar seed consists of approximately one-third endosperm, used principally to make guar gum, and two-thirds germ and hull, used to make protein-rich guar meal (Abidi et al., 2015). This two-thirds fraction is corroborated by Sharma and Gummagolmath (2012), who report guar gum recovery at around 31% of processed guar seed, with churi (hull) and korma (germ), both sold as animal feed, accounting for 29% and 37%, respectively. The combined feed fraction of 66% agrees within one percentage point with the anatomical split. Their reported seed composition (seed coat 14-17%, endosperm 35-42%, germ 43-47%) is also consistent.

The description of guar carries one ambiguity worth noting. The guar protein reported by Aas et al. (2022) may correspond to korma alone (37% of seed) or to churi and korma together (66%); however, under mass allocation, the distinction does not affect the result. The allocated area is 1,578 km² in either case because the allocation fraction cancels against the raw-crop requirement.

The Norwegian feed study reports 84,677 tonnes of guar protein. Treating this as the guar-meal fraction, approximately 127,000 tonnes of whole guar seed would be required.

$84{,}677 \,/\, (\frac{2}{3}) \approx 127{,}000 \text{ t of guar seed}$

5.3 Mass allocation applied to guar

The formula for calculating land use for guar cultivation is as follows:

$[84{,}677 \,/\, (\frac{2}{3}) \,/\, \text{yield}] \times \frac{2}{3} = 84{,}677 \,/\, \text{yield}$

$84{,}677 \text{ t} \,/\, 0.537 \text{ t/ha} \approx 1{,}578 \text{ km}^2$

The gross field area producing both the required meal and the accompanying gum is approximately 2,370 km². Mass allocation assigns about 1,578 km² to the meal and about 789 km² to the gum, accounting for both by-products of the guar seed.

5.4 Economic allocation

Guar gum is the principal product and has a higher value than guar meal. Using economic allocation, guar meal would be assigned less than two-thirds of the field. A published assessment of Indian guar korma (Mérieux NutriSciences & Blonk, 2025) uses economic allocation between gum and meal; however, it does not provide sufficiently transparent, representative price inputs to reproduce a national allocation factor. Sharma and Gummagolmath (2012) note that around 80% of Indian guar gum output is exported and that gum prices are highly volatile, which helps explain why a stable economic factor is difficult to establish.

If this study used economic allocation rather than mass allocation, the results would be materially lower. Assuming economic allocation assigns guar meal roughly half of what mass allocation does, the guar component would fall to around 789 km², and the total to around 5,350 km², or about 3.6 m²·yr/kg. These values illustrate possible outcomes of economic allocation, rather than calculated results.

6. Results

Table 6.
Cropland by crop group, with share of total and land use per kilogram of salmon (live weight).

Crop group	Feed ingredients represented	Cropland	m²·yr/kg	Share
Guar	Guar protein/meal	1,578 km²	1.075	25.7%
Rapeseed	Rapeseed oil	1,339 km²	0.912	21.8%
Soybeans	Soy protein concentrate, soybean oil	1,300 km²	0.886	21.2%
Wheat	Wheat, wheat gluten	595 km²	0.405	9.7%
Minor oil crops	Linseed, camelina, coconut	368 km²	0.251	6.0%
Sunflower	Sunflower ingredient	341 km²	0.232	5.6%
Peas	Pea flour, pea protein	334 km²	0.228	5.4%
Faba beans	Faba beans	266 km²	0.181	4.3%
Maize	Corn gluten	18 km²	0.012	0.3%
Total		**6,139 km²**	**4.18**	

The most significant result is that guar, which represents only 4.3% of feed ingredients, accounts for 25.7% of land use. This is because Indian guar seed yields around 0.537 t/ha, compared with 3.1 for European rapeseed and 5.6 for European wheat. Guar accounts for such a significant share because it is a low-yield crop. Mass allocation then assigns guar meal two-thirds of the field, whereas economic allocation would assign less, and the total would fall to about 5,350 km². Additionally, Indian guar yields have ranged from 128 to 684 kg/ha across individual years; therefore, the choice of averaging window can shift the total by about 4.5%.

6.1 Result per kilogram

6,139 km²·yr / 1,467,655 t of salmon ≈ 4.18 m²·yr/kg, live weight

The time dimension matters. This measure shows the land occupied for one year. It does not mean that an area of this size is cleared each year. The result is expressed per kilogram of live salmon because Norwegian production statistics use live or round weight. It should not be compared directly with figures per kilogram of edible fillet. Only part of a fish becomes edible product; an edible-weight figure would be substantially higher. The production figure used here is the 1,467,655 t reported by Aas et al. (2022), the quantity of salmon produced against which feed was consumed. It is not identical to the harvest statistic: Fiskeridirektoratet records 1,377,185 t of salmon sold as slaughtered in 2020, and dividing the cropland total by that figure instead would give approximately 4.5 m²·yr/kg.

6.2 Sensitivity analysis

Table 7.
Effect of alternative method choices on the total.

Variant	Total (km²)	Per kg live (m²·yr)
Central: mass allocation, matched six-year yields	6,139	4.18
Guarseed yield from full 28-year series (0.457 t/ha)	6,415	4.37
Guarseed yield from last ten years (0.492 t/ha)	6,283	4.28
Guarseed excluding the provisional final year (0.505 t/ha)	6,241	4.25
Soy protein allocated economically	6,535	4.45
Soy protein gross / no allocation[1]	7,348	5.01
Undocumented 16% of rapeseed at Russia/Belarus yield	6,263	4.27
Soy and rapeseed variants together	6,659	4.54
Guar meal allocated economically	5,351	3.65

[1]The conversion of soybeans to soy protein concentrate is taken from Philis et al. (2018), who report that Norway's 2015 SPC import of 362,217 t derived from a resource base of 711,673 t of soybeans, a ratio of 0.509 kg SPC per kg soybean.

A plausible span across methodological choices is 3.6–5.0 m²·yr/kg of live weight, or 5,351–7,348 km². No method changes the results by more than 5%, except for the allocation method for guar and the economic/gross allocation methods for soy.

7. Comparison with published estimates

7.1 *Comparison with published estimates of salmon land use*

Two published studies estimate agricultural land use for farmed salmon. Gephart et al. (2021) report 2.88 m²·yr/kg live weight for global farmed salmon, with a 95% credible interval of 0.94–4.83. The scope of their study covers on-farm land and feed-associated land. Hognes et al. (2011) report 3.3 m²/kg edible for a 2010 Norwegian feed diet. Applying the ratio of 1.74 kg live weight per kg of edible fillet reported by Winther et al. (2009) gives 1.90 m²/kg live weight.

While these figures provide published context for the land use associated with farmed salmon, they are not directly comparable to each other or to this estimate. They differ in reference year, geography, system boundary, and whether they include on-farm land. They provide a range within which published estimates fall, not measurements of the same quantity. The definition of an edible fraction also differs between sources, which is part of why converting between live and edible weight is not straightforward. Gephart et al. (2021) define the edible portion as the muscle fraction, giving 58.5% of live weight for salmon, whereas Hognes et al. (2011) apply a fillet yield of 1.74 kg live weight per kilogram of edible product, or 57.5%. Both are defensible, but a figure converted using one definition cannot be compared directly with a figure converted using the other. This is a further reason the estimate in this study is expressed at live weight, where no conversion is required.

Differences in land use per kg of live weight between figures largely reflect feed composition. Norwegian salmon feed was roughly 40% marine feed in 2010, and 22.4% marine by 2020, with plant ingredients rising correspondingly from roughly 60% to 73.1% of ingredient mass (Aas et al., 2022). Hognes et al. (2011) model the 2010 diet, whereas Gephart et al. (2021) draw on largely farm-level data from 2008–2015 and have a median crop fraction of about 50%. Both describe a materially less plant-dependent diet than Norway's in 2020, resulting in lower land figures. This study's estimate still falls within the 95% credible interval reported by Gephart et al. (2021).

7.2 *Comparison with other animal products*

To interpret this study, it is necessary to compare land use with other farmed species. Gephart et al. (2021, Supplementary Table S11) report land use for every major farmed aquatic species on the same live-weight basis and using the same mass allocation method applied in this study. They found salmon and trout to be the least land-intensive of the fed species (below tilapia, catfish, carp, shrimp and milkfish). Hognes et al. (2011), using the same model and boundary that produced their 3.3 m² estimate above, compared Norwegian salmon with Swedish pig and chicken and concluded that salmon occupied the least agricultural land of the three.

The figure calculated in this study is therefore not evidence that salmon farming is unusually land-intensive. The quantity is smaller than that of most alternatives, but large enough in absolute terms to be worth accounting for. Appendix A sets out both comparisons in full, including terrestrial proteins reported on a different accounting basis.

8. Where the land is

91.7% of feed ingredients were imported in 2020 (Aas et al., 2022). The associated cropland is therefore predominantly outside Norway. Documented supply chains include soy from Brazil and other countries, guar from India, rapeseed from Europe, and cereals and pulses from several European countries (Aas et al., 2022; Lerøy Seafood Group, 2025). Exact origins vary by ingredient, company, and year, and 2020 rapeseed sourcing patterns have since shifted. Norway had about 8,100 km² of fully cultivated agricultural land in 2024, about 2.5% of the mainland area. This sits within a total agricultural area of roughly 9,840 km², or about 3% of Norway (Statistics Norway, 2024). If salmon feed were produced entirely in Norway, it would occupy around 62% of the country's total agricultural area; however, the feed originates from other countries worldwide, so the impact is spread across many disjointed areas.

9. Limitations

The following limitations apply to the figure reported here.

1. The result is conditional on mass allocation. This is not a claim that salmon farming alone causes every hectare to be cultivated, which is particularly important for co-products such as guar meal, processed soy, wheat gluten, and oilseed ingredients. Section 6.2 quantifies the alternative's effect.
2. Salmon is not shown to be land-intensive compared with other animal proteins, and this report does not claim it is. Gephart et al. (2021) found that, on a consistent live-weight basis, farmed salmon and trout are the least land-intensive fed aquaculture species, below tilapia, catfish, carp, shrimp, and milkfish.
3. Land is only part of the industry's footprint. This report does not account for the marine ingredients that make up 22.4% of feed (Aas et al., 2022), the sea-surface area occupied by farms, or land-based facilities. Hognes et al. (2011) reported approximately 115 m² of sea primary-production area per kilogram of salmon against 3.3 m² of agricultural land, so a land-only account is partial by construction.
4. Not all cropland is equivalent. One hectare in Brazil, India or northern Europe differs greatly in biodiversity, water use, soil conditions and carbon consequences. This study treats hectares as interchangeable, when in reality they are not.
5. The six-year guarseed window is short for a rainfed crop whose yield tracks the monsoon and has ranged from 128 to 684 kg/ha. It was chosen for consistency with the other crops; the full 28-year series raises the total by about 4.5%, which bounds the effect without removing the limitation.

6. The production figure comes from Aas et al. (2022), not a harvest statistic. Fiskeridirektoratet records 1,377,185 t of salmon sold as slaughtered in 2020, and dividing the cropland total by that figure would give approximately 4.5 m²·yr/kg; the two answer different questions.
7. Live weight is a conventional but not a neutral functional unit. It provides a method to multiply the figure by national production statistics to compare it with published estimates. However, a protein-normalised or nutrient-normalised unit would rank species differently, and this study does not provide one.

10. Conclusion

The crop ingredients used in Norwegian salmon feed in 2020 occupied about 6,100 km² of agricultural land for one year, or about 4.2 m²·yr per kilogram of salmon produced. The figure is reproducible from publicly available data: a national ingredient inventory (Aas et al., 2022), published crop yields (FAO, 2026; USDA FAS, 2014; Directorate of Economics and Statistics, 2024), and a single consistent allocation rule. It requires no assumed feed conversion ratio and no proprietary datasets.

Two features of the result are worth carrying forward. First, the land is almost entirely outside Norway. With 91.7% of feed ingredients imported (Aas et al., 2022), the Norwegian marine sector, regulated, taxed, and debated, depends on cropland in Brazil, India, and across the European Union. Second, the distribution of that land bears little relation to feed composition. Guar protein makes up 4.3% of ingredients by mass and 25.7% of the land, because it is a low-yielding crop grown principally for guar gum rather than for animal feed (Abidi et al., 2015; Sharma & Gummagolmath, 2012). The largest single land component in Norwegian salmon feed is a by-product of an industry unconnected to aquaculture.

The figure should not be read as a fixed property of salmon farming. Marine ingredients accounted for roughly 90% of Norwegian salmon feed in 1990 (Ytrestøyl et al., 2015) and 22.4% in 2020 (Aas et al., 2022). Salmon nonetheless remains among the least land-intensive fed animal proteins, below tilapia, catfish, carp, shrimp, milkfish, and chicken on a comparable basis (Gephart et al., 2021).

What this study offers, therefore, is not a verdict but a measurement, and one that the existing literature is not well positioned to provide. In a systematic review of 31 salmonid life cycle assessments, land use was among the intended impact categories but was not one of the four indicators with sufficient consistent reporting to be quantified; the authors attribute this to a widespread lack of detailed feed composition data and recommend that future assessments prioritise collecting it (Budhathoki et al., 2025). The land exists, it is substantial, and it is attributable. Whether it grows or shrinks depends on ongoing feed formulation decisions, and those decisions can only be evaluated if the quantity is counted.

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The work of Tom Pedersen, Senior Advisor to the County Governor in Vestland, Norway inspired this report's methodology.

Appendix

The figures in Table A1 are taken from Gephart et al. (2021) and are all calculated on the same live-weight-mass-allocated basis as this study. The figures in Table A2 for land use from other farmed animal species are not calculated on a live-weight basis; rather, they are calculated per kilogram of product, accounting for the entire supply chain, resulting in significantly higher land use.

Table A1.
Farmed aquatic species and chicken

Species	m²·yr/kg live weight
Milkfish	11.71
Shrimp	7.53
Misc. carps	6.18
Chicken *	5.81
Tilapia	5.71
Catfish	5.56
Silver/bighead carp	4.56
Norwegian Salmon (this study)	4.18
Salmon, global	2.88
Trout	2.29
Bivalves	0.00
Seaweeds	0.00

Source: Gephart et al., 2021, Supplementary Table S11; live weight, mass allocation

* *Chicken is derived from Table S7 (14,525 m²·yr per tonne edible) at the 40% poultry edible portion given in their supplementary section S4.7*

Table A2.
Land use of other animal products, per kg of product (Poore & Nemecek, 2018)

Product	Land use (m²/kg of product)
Lamb & mutton	369.8
Beef (beef herd)	326.2
Cheese	87.8
Beef (dairy herd)	43.2
Pig meat	17.4
Poultry meat	12.2
Farmed fish	8.4
Eggs	6.3

Source: Poore & Nemecek (2018), *Science* 360(6392), 987–992
Note: *These figures are per kilogram of product rather than live weight, cover the full supply chain rather than stopping at the farm gate, and include pasture as well as cropland. The beef and lamb figures in particular are dominated by grazing land. They are not directly comparable with the cropland figure calculated in this study.*

This appendix is not part of the estimate above and should not be quoted alongside it as an equivalent figure. The main sections are calculated from Norwegian national feed data. What follows applies that result to production elsewhere on an assumption that has not been verified.

The arithmetic. FAO (2022) reports global Atlantic salmon production in 2020 at 2.71 million tonnes, which is the same year as the Norwegian feed data.

Table A3.
Illustrative extrapolation to global Atlantic salmon production

Feed intensity applied	Implied global cropland
3.65 m²·yr/kg	9,892 km²
4.18 m²·yr/kg (central)	11,328 km²
4.54 m²·yr/kg	12,303 km²

Roughly 9,900–12,300 km²·yr, of which:

Region	Cropland	Basis
Norway	6,139 km²	Calculated from national feed data
Rest of World	5,189 km²	Assumed at Norwegian feed intensity
Total	11,328 km²	Mixed

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