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What drives environmental impacts of fertilizers produced from fish wastes?

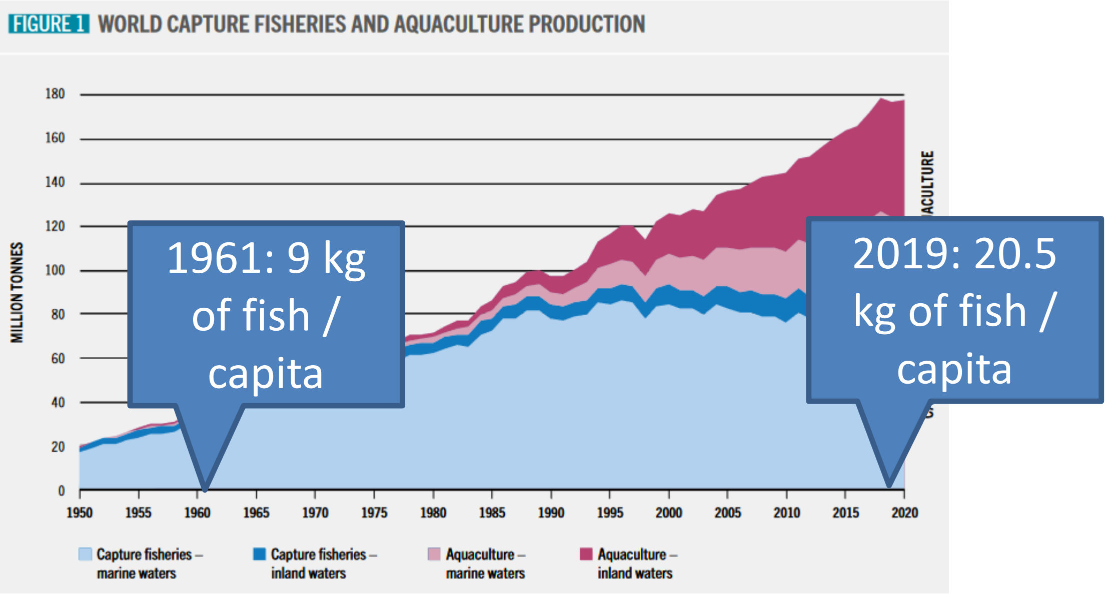
NERM 2024 – Nutrients in Europe Research Meeting, 16 – 17 April 2024, Brussels

Jan Landert, Laura de Baan, Jean-François Fabre, Claire Vialle, Caroline Sablayrolles, Diogo A. Teixeira, Helena I. Monteiro, Corinne Andreola, Marie Soone, Tommy C. Olsen, Laure Candy, Clement Chastrette, Christine Raynaud, Carlos Bald, Bruno Iñarra Chastagnol, Monica Gutierrez, Haizea Domínguez, Saioa Ramos, Joaquin Romero, and Iñaki Aramburu

The increase of waste from fish processing and aquaculture

- Increase in fish production and consumption.
- 5.7 million tonnes in the EU (European Commission, 2020)
- High amounts of waste (Villamil et al., 2017)
    - 50 – 70 % waste (viscera etc.)
    - 50% of waste directly discarded
- High nutrient content of waste (Zang et al., 2023)

- → High potential to be valorised to biobased fertilizers.



1961: 9 kg of fish / capita

2019: 20.5 kg of fish / capita

FAO (2022)

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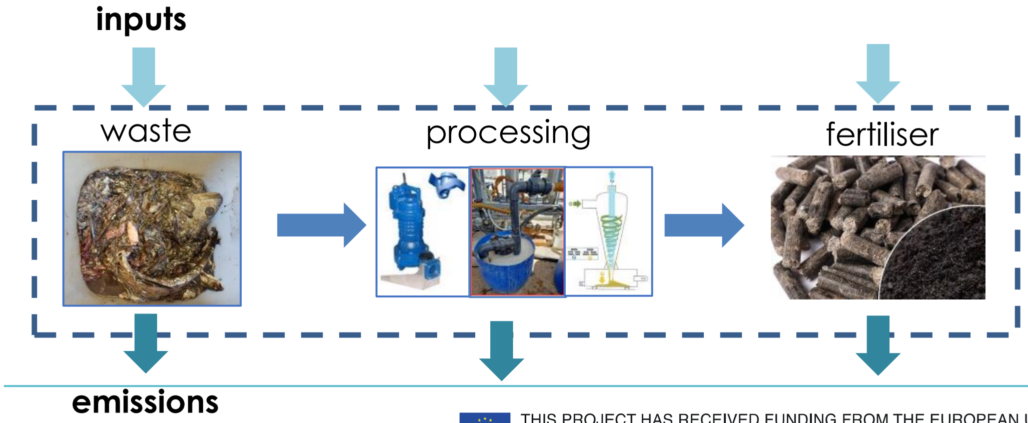
The project

Sea2Land

- Pilot production of biobased ferilisers (BBF) from fish waste.
  - 3 pilot studies on aquaculture waste
  - 3 pilot studies on processing waste of wild catch
- Aims:
  - Develop BBFs, determine agronomic & economic potential and **environmental impacts.**
- Here: Life cycle assessment of selected BBFs conducted



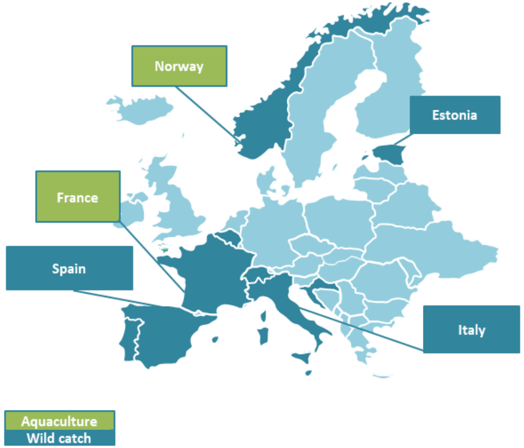
inputs

waste

processing

fertiliser

emissions



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LCA approach

- **Aims:** Identify hotspots in pilot BBF production to optimize environmental performance
- **Scope:** Cradle-to-factory gate with “burden-free” assumption for organic waste streams
- **Function unit:** Environmental impact of **1 kg fertilizer produced**
- **Allocation for co-products:** Economic allocation
- **Impact assessment:** Midpoint impacts from ImpactWorld+ (5 relevant indicators selected)
  - Climate change (short term, GWP 100)
  - Terrestrial Acidification
  - Marine Eutrophication (N)
  - Freshwater Eutrophication (P)
  - Mineral resource use

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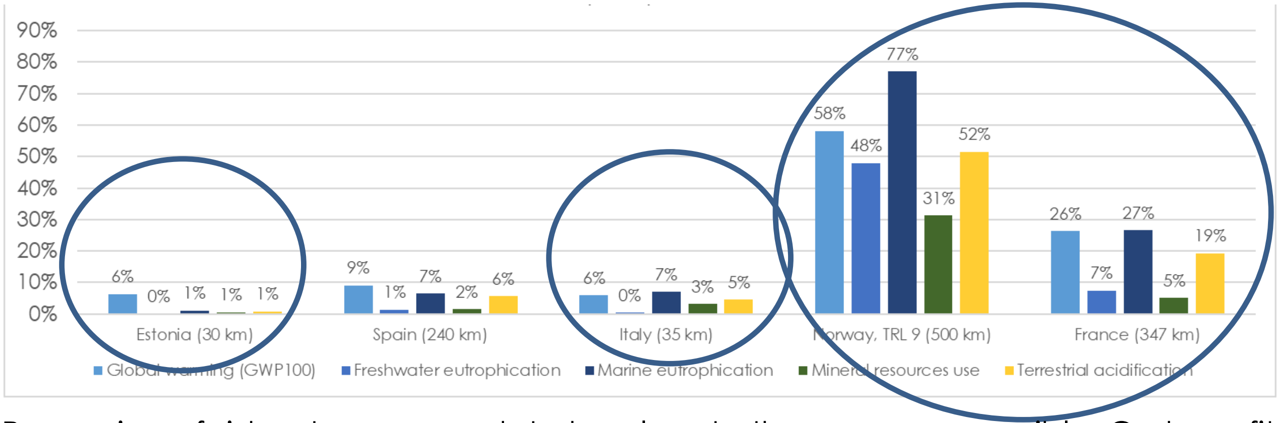
From fish waste to BBF: Processes of case studies

	Estonia	Spain	Italy	Norway	France
Input (waste)	Salmon scraps & food waste	Viscera (and tuna cooking brine)	Mollusk and fish waste	Fish sludge	Fish processing waste (heads, frames)
External processes	Transport to BBF factory	Transport to BBF factory	Transport to BBF factory	Mech. dewatering & drying; Transport	Transport to BBF factory
Mechanical treatment	Crushing	Grinding	Crushing / mincing	Mixing	Freezing & Grinding
Main treatment	**Bokashi fermentation**	**Acid autolysis**	**Enzymatic hydrolysis**	**-**	**Extrusion**
Liquid-solid separation	Gravitational	Gravitational, centrifugation, membrane filtration	Centrifugation	-	Centrifugation
Shaping	Granulation	-	-	Pelleting	-
Drying	Sun-powered drum drying	Vacuum concentration	Vacuum concentration (spray drying)		High temperature drying
BBF (packaged)	Granules	NPK solution	Hydrolysates	Pellets	Solid BBF

Transport (fish waste to BBF factory)

- Relative contribution of transport to environmental impacts



- → Processing of sides streams needs to be close to the source as possible. Co-benefits with odor emissions etc.

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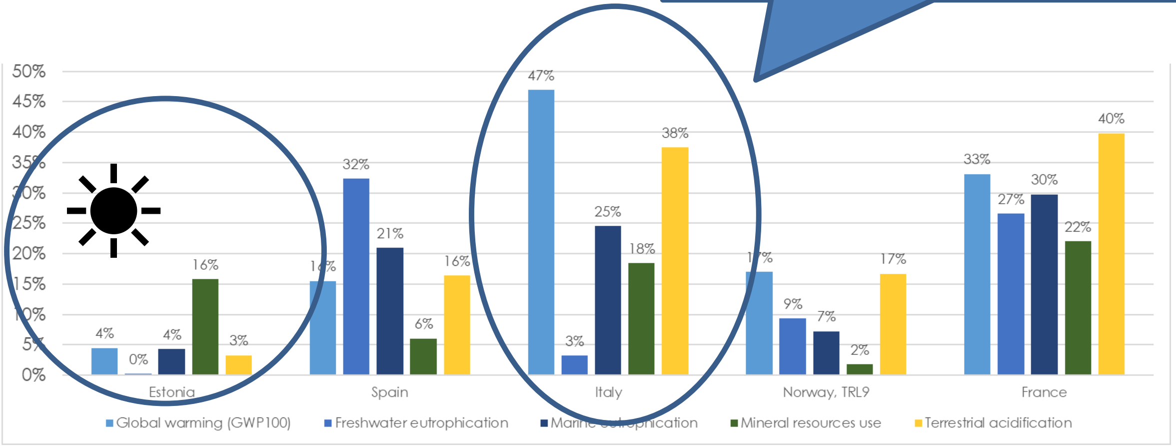
Common environmental hotspots

SEALAND

Drying

- Relative contribution of thermal drying to

Reduction with more efficient technology in industrial scenario (GWP100: -60%).



- High water content (Zang et al., 2023) → Water removal / nutrient concentration key.
- → Drying needs to be combined with energy efficient de-watering and needs to be based on heat recovery.
- → Other options: low temperature drying, biodrying (←→ GHG emissions, Guerra-Gorostegi et al., 2021).

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Other hotspots

- **Packaging**: Contribution to impacts ranges from 1% (France) to 25% (Estonia) for GWP100
  - → Packaging should be reduced, re-used and recycled as much as possible.

- **Capital goods: Buildings** have a high contribution to Mineral Resources Use (6% and 40%).
  - → Efficient use of buildings. Less important:
    - Materials for machinery (and mechanical treatment)

- **Enzymes (Italian pilot study):**
  - High impact due to enzyme substrate (maize, corn, wheat starch) on Freshwater Eutrophication.
  - Hydrolysis needed (biostimulant effect measurable in field trials)? Alternatives: Acid autolysis (Domínguez et al., 2024). Use of ultrasound (Qian et al., 2023).

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Discussion and conclusions

- **Environmental hotspots** for pilot production identified →Hotspots remained similar for assumed future industrial production.
- **Optimization:**
  - produce BBF close to fisheries
  - energy-efficient drying technology
  - reduce amount of packaging
  - test if optional high-impact processing steps (e.g. enzymatic hydrolysis) are agronomically justified
- **Burden-free assumption:**
  - Fisheries and aquaculture production excluded → if future demand increases, environmental impacts of potential system changes should be considered (e.g. Pradel et al., 2016)

Outlook

- Assess environmental impact of **BBF use** →including agronomic performance data (cradle-to-farm gate LCA of crop production with BBF).
- Comparison of crops fertilised with **BBF vs. mineral fertilisation**

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PARTNERS

- NEIKER – Member of Basque Research & Technology Alliance
- barna
- PIRINEA
- NUTRILCOOP
- AZTI – Member of Basque Research & Technology Alliance
- CATAR Agro Ressources
- Università Politecnica delle Marche
- AquaBioTech Group
- Universitat de Vic – Universitat Central de Catalunya
- Beta – Biodiversitat, Ecologia, Tecnologia Ambiental i Alimentària
- Fertinagro Biotech
- grønn gjødsel
- NIBIO – Norwegian Institute of Bioeconomy Research
- iSQ
- INP Toulouse
- Ghent University
- METK – Centre of Estonian Rural Research and Knowledge
- Università degli Studi di Milano
- Agricultures & Territoires – Chambre d'Agriculture Pyrénées-Atlantiques
- FiBL Switzerland
- Liège université Gembloux Agro-Bio Tech
- ULB – Université Libre de Bruxelles
- NLR
- iniciativas innovadoras
- Ministerio de Agricultura – Gobierno de Chile – INIA
- FiBL Europe
- IPS Konzalting
- CO·PE·MO – Cooperativa Pescatori Molluschicoltori

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Reduction in impacts due to assumed upscaled production

	Global warming (GWP100)	Terrestrial acidification	Marine eutrophication	Freshwater eutrophication	Mineral resources use	Average per case study
T3.1: Bokashi granules	-10%	-13%	-15%	-1%	-36%	-15%
T3.2: NPK solution with amino acids	-37%	-59%	-51%	-22%	-86%	-51%
T3.3: Hydrolysates	-38%	-37%	-31%	-5%	-53%	-33%
T4.1: Pelleted fish sludge	Not upscaled (already at industrial scale)					
T4.2: Solid BBF	-64%	-55%	-69%	-85%	-90%	-73%
Average per impact category	-37%	-41%	-42%	-28%	-66%	-

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LCA approach: More details (1)

- Basic assumptions: Burden free (use of ecoinvent cut-off, v.3)
- Upscaling of LCA:
  - Framework of van der Hulst et al., 2020:
    - **Process changes** (source of energy, source / ratio of sidestreams etc.)
    - **Size scaling** (larger machinery, buildings etc.) → efficiency gains?
    - **Minimizing waste / processing inputs:** Can inputs, waste-stream etc. be recycled? Synergies with other processes.
    - **External factors:** Change in future regulations or other (market) conditions?
    - **(Industrial learning:** process beyond TRL 9, difficult to quantify)
  - To reduce complexity: Only model expected changes in efficiency (different yield, processing time, inputs needed etc.).

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LCA approach: More details (2)

- Impact assessment method: Impact world+ (Bulle et al., 2019). Selected midpoint indicators:
  - Climate change, short term (GWP100)
  - Terrestrial and freshwater acidification (Roy et al. 2014, 2012)
  - Marine eutrophication (Roet et al. 2012)
  - Freshwater eutrophication (Melmes et al., 2012, Tirado-Seco, 2005)

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LCA upscaling assumptions Italian case study

- **Process changes:**
  - Change of drying process: Spray drying instead of vacuum evaporator (capacity, product quality) and gas as thermal energy source.
  - Different mix ratio of sidestreams (5:1 → 7:1 mollusc : fish waste*)* → more water needed to be heated removed again for concentrated hydrolysate production (Petrova et al., 2018)
- **Size scaling**
  - Larger machines → Less processing duration (machinery use) / kg of output (mechanical processes; biochemical processes have same length).
  - Increased machinery utilization (8 h / 365 days / year | 24 h / 365 days / year for drying equipment).
  - Average industrial building use (ecoinvent)
- **Minimizing waste / processing inputs:**
  - Re-use of unused syngas from pyrolysis for drying of solid fraction of hydrolysis (instead of lab oven; Andreola et al., 2023) incl. changed emissions to air.
- **External factors:**
  - Removal of odor emissions with biofilter (Neri et al., 2018) to obtain operation / construction permit.

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