FOOD
FORWARD
NDCs

Implementing sustainable aquaculture management systems

Overview

The cultivation of aquatic food such as fish, shellfish and aquatic plants – also known as '**aquaculture**' – has developed rapidly in recent decades and become a major component of many economies across the world. Seafood production from **aquaculture recently surpassed that from wild fish catch**, now contributing to **more than half of aquatic food for human consumption**, with that share expected to increase to almost two-thirds by 2030. As both the global population and per capita seafood consumption rise, **aquaculture has become a critical component** in alleviating some pressure on wild fish catch and ensuring food security and livelihoods for communities worldwide.

However, intensive aquaculture's rapid growth has also had unintended negative environmental, social and economic consequences that require a shift to more sustainable aquaculture practices. **Major environmental problems** include pollution and biodiversity impacts on natural aquatic ecosystems, salinization of groundwater, use of large volumes of freshwater and transmission of diseases to wild fish population. Measures are needed to ensure that aquaculture is part of the overall transition to equitable, sustainable food systems – and not a hindrance to it.

Concrete measures to implement

- **Alternative feeding strategies** can improve the **Feed Conversion Ratio (FCR)** and replace unsustainable inputs (e.g., wild fishes) in aquaculture feed with:

    - Terrestrial plant-based protein: Supplement carnivorous fish diets with cereals and pulses and replace fish oil with microalgae and yeast products.
    - Waste from seafood processing plants (e.g., fish heads, innards, trimmings), and adding algae or ethanol yeast to boost the protein content of fish waste.
    - Locally available, inexpensive, and underutilized ingredients, such as fruit peels, grain bran, sustainably harvested/raised native insects, or food losses along the food supply chain.
    - Alternative protein sources such as insect meal and microbial-based proteins.
- Recirculating Aquaculture Systems (RAS) collect and remove waste products, uneaten feed and bacteria from the water where fish live. This technology is suitable for indoor and outdoor tank- or pond-based systems. RAS recycles and purifies water within aquaculture systems, thereby reducing the need for excessive water use (100 times less water per kilo of fish than traditional land-based systems) and limiting the negative impacts of aquaculture on surrounding ecosystems. In addition, RAS can help to continuously monitor water quality of aquaculture systems, which reduces disease risks and antibiotics needs.
- Aquaponics are systems that integrate aquaculture with hydroponics, creating a closed-loop system where fish waste provides nutrients for plant growth, and plants help filter and purify the water for fish. This method not only maximizes resource use but also promotes a synergistic relationship between fish farming and plant cultivation.
- Precision Aquaculture is the real-time monitoring and management of aquaculture operations, to optimize feeding regimes, monitor environmental conditions, and detect health issues promptly, leading to improved resource efficiency and reduced environmental impact.
- Integrated Multi-Trophic Aquaculture (IMTA) refers to more diverse and less costly approaches that involve farming of multiple species in the same aquatic space, creating a mutually beneficial relationship between them. For instance, fish farming can be combined with the cultivation of seaweed and filter-feeding organisms. This approach enhances nutrient recycling, reduces waste and promotes a more balanced ecosystem within aquaculture systems.

- **Moving offshore aquaculture from coastal areas further into the open ocean**. Open oceans have more pristine water and stronger, and steadier currents that continually flush the farms of fish waste and pests. This provides farmed fish with more stable salinity and temperature, making fish less vulnerable to disease and other environmental stressors. However, offshore aquaculture does not resolve many of the environmental concerns associated with conventional coastal systems and needs to be carefully assessed and implemented along with other sustainability measures.
- **Selective breeding and farming of genetically improved fish strains** contribute to the development of aquaculture species with desirable traits, such as faster growth rates, disease resistance and **improved Feed Conversion Ratio (FCR)**. These genetic improvements enhance the overall efficiency and sustainability of aquaculture operations. However, measures for selective breeding and farming of genetically improved fish strains **must be tied to a range of accompanying measures**, including risk and economic assessments and capacity-building for their specific management.

Enabling governance measures

- Distinguish between **extensive and intensive aquaculture** production systems. More intensive aquaculture systems have more adverse environmental impacts, while extensive pond farming can be done more sustainably and support food and nutritional security. The **agroecology principles** can be applied to increase the sustainable of aquaculture production.
- Strong national regulations for responsible aquaculture development building on **FAO's technical guidelines for aquaculture certification**.
- Improved promotion and enforcement of standards for biosecurity, environmental protection and zoning.
- Careful zoning and selection of sites for aquaculture.
- Sufficient funding for equity-sensitive national aquaculture research and development, including on fish breeding and strain improvement.
- Strengthen the enabling environment and investment in the development of sustainable fish feed and the feed production sector.
- Equitabily integrate small-scale aquaculture farmers in the informal work sector into the formal work sector. Integration can advantage small-scale

producers through gaining social security and greater access to finances for scaling up business.

- Improved fish health management, including continuous disease monitoring and surveillance within and across national borders, public-private vaccination programmes, breeding for disease resistance and strengthened biosecurity in hatcheries and breeding centers.
- Capacity development through professional training and extension services on sustainability for aquaculture producers/fish farmers.
- Investment in improved infrastructure for cold chains, to reduce spoilage, such as transportation and electricity (preferably powered by renewable energy).
- Ensure that data and monitoring systems are well functioning.
- Improve supply chain transparency and traceability.
- Develop mandatory eco-certifications and standards for aquaculture producers.
- Promote the consumption of low-trophic level organisms (i.e., herbivores like oysters and mussels) among consumers.

Tools and MRV systems to monitor progress

FAO is currently developing Guidelines for Sustainable Aquaculture.

Link: https://www.fao.org/in-action/gsa/es/

The certification programme Best Aquaculture Practices provides several guidance documents related to sustainable aquaculture.

Link: https://www.bapcertification.org/Home

Climate change mitigation benefits

Sustainable aquaculture practices mitigate climate change through:

- Enhanced sequestration of so-called blue carbon, i.e. carbon in coastal and marine ecosystems, if combined with other measures such as the restoration of seagrass.
- Reduced N_2O emissions from nutrient recycling.
- Sourcing feed from sustainably produced agricultural crops.
- Dietary shifts from terrestrial animal protein to aquatic food proteins through sustainable aquaculture and fisheries can lead to a significant reduction in GHG emissions for terrestrial food systems globally.
- Consumption of locally produced aquaculture products can reduce GHG emissions from imported aquatic foods with high GHG emissions and long transporation distances.

Other environmental benefits

Sustainable aquaculture helps reduce marine pollution and limits degradation of coastal habitats.

Adaptation benefits

- Sustainable aquaculture practices, such as the use of recirculating systems and integrated multitrophic approaches, can enhance the resilience of aquaculture systems to climate-related challenges, ensuring continuity in food production.

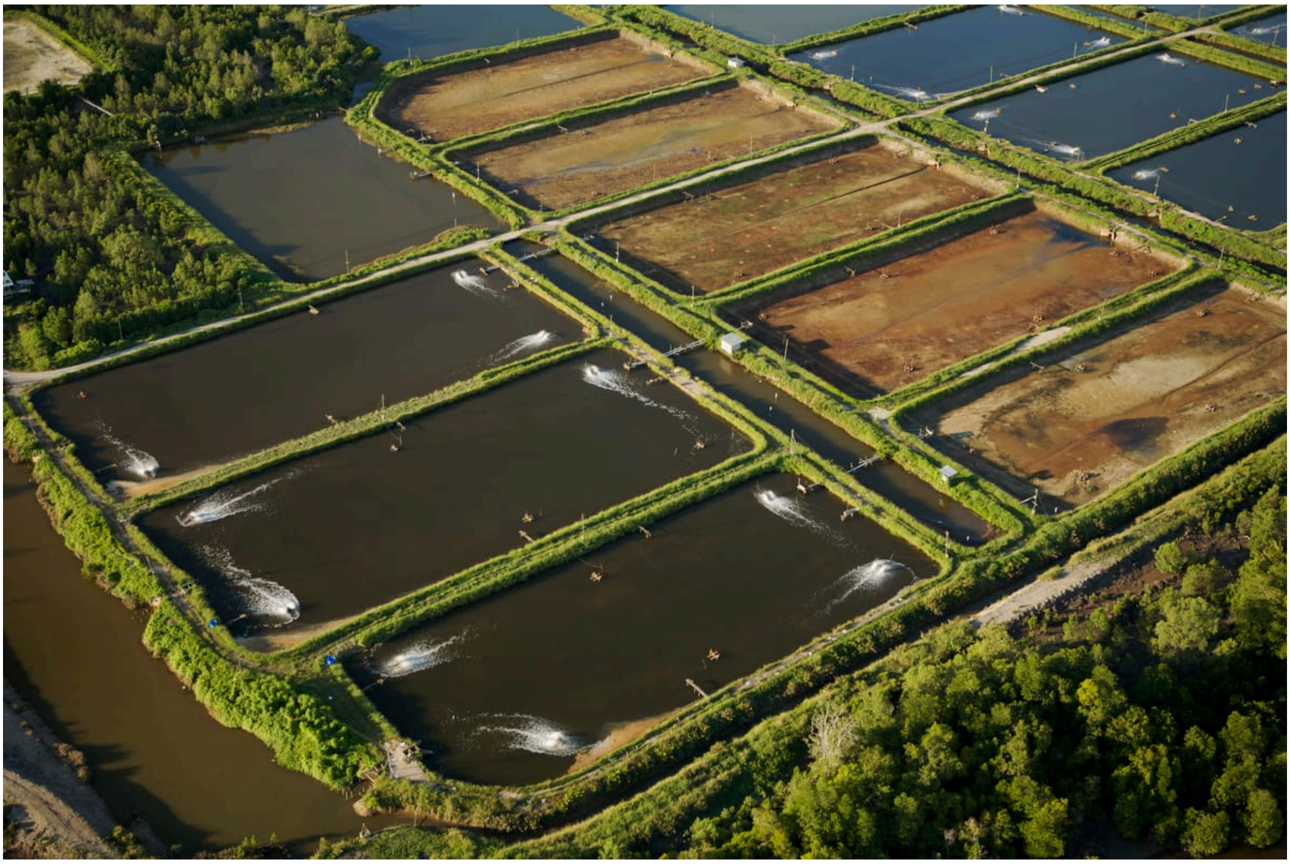
- Aquaculture can also reduce pressure on marine ecosystems from fishing and contribute to ecosystem conservation.

Other sustainable development benefits

- Improved **global food security**: Sustainable aquaculture is a resource-efficient way of producing nutritious and protein-rich food. If land-based aquaculture systems are deployed close to urban areas, these systems can improve urban food security and nutrition.
- **Conservation of aquatic and marine habitats and biodiversity**:
    - Adopting sustainable methods helps minimize the ecological footprint of aquaculture, ensuring that aquatic ecosystems remain healthy and resilient. This is crucial for the long-term health of marine and freshwater environments.
    - Sustainable aquaculture can help alleviate pressure on natural fisheries by providing an alternative and controlled source of seafood. This is essential for maintaining the health and biodiversity of oceans and inland water bodies.
    - Sustainable integrated aquaculture production methods can even help restore ecosystem function, e.g. by planting mangroves on pond dykes and enhancing ecosystem biodiversity.
- Enhanced **economic opportunities and livelihoods**: Aquaculture is a significant economic driver, especially in coastal and rural communities. Sustainable practices not only contribute to the economic well-being of those directly involved in aquaculture but also support related industries, such as processing, transportation and marketing.
- **Social equity and community well-being**: Sustainable aquaculture practices prioritize social considerations, including equitable distribution of benefits, fair and safe labour practices, and community engagement. By fostering social equity, responsible aquaculture contributes to the overall well-being of communities, creating a positive impact on both individuals and society.
- **Gender equity:** Since women play a significant role in aquaculture production globally, sustainable aquaculture has a high potential to

support women’s economic independence as small-scale actors.

- Sustainable consumption: Adopting sustainable aquaculture practices not only addresses consumer expectations – which are increasingly geared towards more sustainable options – but also opens market access opportunities through certifications and labels that signify responsible and eco-friendly production.



Main implementation challenges and potential negative externalities and trade-offs

- High startup costs: Implementing sustainable aquaculture practices often involves significant upfront investments in technologies such as RAS, precision equipment and sustainable feed formulations. This financial barrier may be challenging for small-scale farmers or operations with limited resources.
- Technical complexity: Some sustainable practices, such as precision aquaculture and advanced genetics for selective breeding, require specialized knowledge and technical expertise. Small-scale or traditional farmers may face challenges in adopting and adapting to these sophisticated technologies, limiting widespread implementation.

- Limited availability of alternative feeds: While there is a growing interest in replacing traditional fishmeal with alternative protein sources in aquaculture feeds, the widespread availability and cost-effectiveness of these alternatives remain challenging. Scaling up production of alternative feeds (such as insect meal or plant-based proteins) to meet the demands of the aquaculture industry may take time.
- Disease management: Intensive aquaculture practices, particularly in closed systems, can create conditions conducive to the spread of diseases. Disease outbreaks pose a significant risk to the sustainability of aquaculture operations, necessitating effective disease management strategies that balance environmental concerns with the need for disease control.
- Certification challenges: While certification schemes such as the Aquaculture Stewardship Council (ASC) and Best Aquaculture Practices (BAP) aim to promote sustainability, achieving and maintaining certification can be challenging and costly for some producers. Compliance with rigorous standards may require additional administrative efforts and dissuade some producers from participating. It can be especially difficult for small-scale aquaculture producers to fullfill requirements for certification, thus blocking access to markets in industrialized countries.
- Aquaponic systems can lack economic profitability and be less attractive to larger industrial operations; however, such systems can be suitable for small-scale farming operations with access to water testing technology and electricity.
- Overfishing:
    - To produce popular carnivorous fish such as salmon or sea bass, large quantities of smaller forage fish are caught and processed into fishmeal (i.e. ground fish) and fish oil. Some forage fish are being overfished in the process, which has implications for the entire food web.
    - Next to, and as a consequence of, the negative impacts on the food web, overfishing especially threatens the food and nutritional security of coastal communities that depend on fishery products.
- Fishing of small fish for aquaculture feed also aggravates food insecurity for the local communities where it occurs, as the caught fish are of food

quality and can provide important protein sources for local populations.

- Risks of marine aquaculture:

    - Escape of non-native species or genetically modified fish: competition for food and habitat between escaped farmed fish and native species. Potential negative impact on genetic diversity of local fish population if farmed fish escape and breed with wild species.
    - Contamination of aquatic environment from use of drugs (e.g. antibiotics, hormones, anesthetics, pigments or vitamins used to control health of farmed fish stock) and herbicides (used to control algae growth on net pens) produces negative impacts on local aquatic biodiversity and marine life.
    - Nutrient pollution of aquatic environment from fish sewage (e.g. fish waste or leftover feedstuff): This may lead to oxygen depletion in the water, which can stress or kill aquatic creatures. In addition, nutrients sink to the ocean floor where they can impact biodiversity.
    - Introduction of new diseases and parasites by fish stock: Fish crowded together in nets or pens are more susceptible to stress, which can foster disease and parasites that may then spread to wild species.

- Disadvantages of land-based aquaculture:

    - Energy intensity:

        - Certain sustainable practices, particularly those involving intensive recirculating systems, can be energy-intensive. The energy requirements for maintaining water quality and regulating environmental conditions may increase operational costs and contribute to the overall carbon footprint of aquaculture operations.
        - Production systems like RAS and aquaponics require steady access to electricity. In many rural communities, there is either nonexistent or sporadic access to electricty, treatening the production system and making it unfeasible.

    - Conversion, destruction, and depletion of terrestrial ecosystems:

        - South America experiences high rates of deforestation to make land suitable for production of soybeans that are used as fish feed. The shift to alternative, predominantly plant-based feeds may even increase environmental concerns related to land use change for feedstock production.
        - Worldwide, mangroves are replaced by facilities for shrimp farming in salty coastal waters.
    - **Land and water use conflicts**: Competition for land and water resources can arise, particularly in areas with high population density or where aquaculture competes with other land uses. Balancing the needs of aquaculture with other sectors, such as agriculture and conservation, can be complex and may lead to conflicts over resource allocation.

Measures to address challenges and negative externalities and trade-offs

- Many of the challenges mentioned above can be overcome by creating framework conditions that are favourable to sustainable aquaculture practices. This includes technical and financial support for small-scale producers, research and development related to stock health and alternative fish feedstuff, appropriate zoning, and selection of production sites or improved enforcement of relevant national legislation. See *Enabling governance measures*.
- Land-based closed aquaculture systems may avoid some of the negative effects of marine aquaculture, including minimized pollution of local environment from waste and nutrients, no fish escapes and limited spread of disease. However, they can consume large amounts of fresh water, competing with other uses and natural ecosystems.
- Sustainable aquaculture operations must increase efficiency (e.g. by lowering on-farm energy usage; shifting to low-emissions energy sources; using or reusing durable, low-emissions materials for farming infrastructure) and reduce nutrient inputs and wastes that lead to greenhouse gas emissions, while also working toward carbon neutrality using biofuels and clean energy sources to power on-farm operations.

Implementation costs

- Sustainable aquaculture practices often involve **significant upfront investment costs**. However, no estimates of the costs of implementing specific sustainable aquaculture practices are available.

Intervention in practice

- Since 2017 in Madagascar's highlands, a region with higher food and nutritional insecurity, the Federal Ministry for Economic Cooperation and Development (BMZ) through GIZ supports rice farmers to integrate fish farming into their operations. Rice-fish culture enables the direct addition of fish production into existing rice fields. Through trainings and practical examples, rice farmers learn how to identify suitable rice fields, optimally use the fields for rice-fish farming, and produce quality fingerlings. Fertilizer and pesticide application is prohibited, as fish eat snails and insects while fish waste provides nutrients. On average, rice-carp farmers in the program were able to harvest 50 kilogram of fish in addition to the rice crop, and rice production increased by 10-20 percent.
- In Eastern Canada, the company Cooke Aquaculture Inc. is implementing Integrated Multi-Trophic Aquaculture with support from the University of New Brunswick. The company farms species from different levels of the food web in an integrated manner. Blue mussels and kelp are raised downstream from salmon pens. The mussels feed on waste from the salmon while the kelp takes up inorganic nutrients. Sea urchins and sea cucumbers consume larger particles on the ocean floor. Salmon and mussels are sold as food while seaweeds are used in restaurants and cosmetics manufacturing.

References

1. Ahmed, N. et al. (May 2017). Can greening of aquaculture sequester blue carbon? *Ambio, 46*(4), 468-477. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5385666/
2. Cho, R. (2016, April 13). Making Fish Farming More Sustainable. https://news.climate.columbia.edu/2016/04/13/making-fish-farming-more-sustainable/

3. HLPE (2023). *Reducing inequalities for food security and nutrition*. Rome, CFS HLPE-FSN. Available from https://www.fao.org/cfs/cfs-hlpe/insights/news-insights/news-detail/reducing-inequalities-for-food-security-and-nutrition/en.
4. Jones, A. R. (February 2022). Climate-Friendly Seafood: The Potential for Emissions Reduction and Carbon Capture in Marine Aquaculture. *BioScience, 72*(2), 123-143. https://academic.oup.com/bioscience/article/72/2/123/6485038
5. Khan, R. (2023). Sustainable Aquaculture Practices for Food Security and Livelihoods. *International Journal of Agro Studies and Life Sciences, 2*(2), 7-13. https://edupublications.com/index.php/ijasls/article/view/57
6. Ragasa, C. et al. (February 2022). Sustainable aquaculture development in sub-Saharan Africa. *Nature Food, 3*, 92-94. https://doi.org/10.1038/s43016-022-00467-1

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