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Shaping the Future of Aquaculture in Kuwait: Expansion, Diversification, and Sustainability

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ABSTRACT

Aquaculture accounts for around 50% of global seafood production, with its contribution expected to expand significantly in the coming decade. While countries in the Arabian Gulf region are leveraging aquaculture to meet rising seafood demand and enhance food security, Kuwait's sector remains largely underdeveloped. In this paper, challenges and opportunities for aquaculture intensification in Kuwait are identified, emphasizing the need for the development and intensification of farmed species and the adoption of sustainable farming systems. By examining case studies, existing aquaculture endeavors, and current regulatory frameworks, a roadmap is proposed for the sustainable expansion of Kuwait's aquaculture industry, which underscores the biological, economic, and regulatory dimensions. Recommendations include suitable species and systems for farming; considerations for local supply chain production; and ramping up aquaculture production while diversifying farmed species and farming systems will be critical in the future of Kuwait's seafood security.

1 | Introduction

Aquaculture has emerged as a cornerstone of global food production for human consumption, accounting for nearly half of the world's seafood supply [1]. Its contribution is projected to expand further over the next decade, particularly in regions with growing populations and increasing seafood consumption. In the Arabian Gulf, aquaculture holds immense potential to address rising demand, improve nutrition, and bolster national food security. Aquaculture production in the Arabian Gulf region has experienced accelerated growth: from the years 2000 to 2018, it went from roughly 49,000 tons to 541,000 tons [2, 3]—these regional trends are illustrated in Figure 1. While Iran is leading aquaculture production in the region, accounting for more than two-thirds of the total production, countries like Saudi Arabia have made concerted efforts to expand their production capacity. In contrast, Kuwait's aquaculture sector seems to be one of the least developed in the region, even though the country's 2035 vision highlights the need to “increase local productivity and development of nonoil economic sectors”, in addition to

a sustainable living environment [4]. There are several obstacles hampering the development of Kuwait's aquaculture sector in terms of scaling up production and diversifying both farmed species and farming systems. Currently, it is perceived that the role that the aquaculture sector plays in supporting Kuwait's food security is negligible.

Kuwait faces a complex set of challenges when it comes to aquaculture cultivation and scaling up production. The most evident would be the harsh environmental conditions: high water temperature, which can be stressful for marine species, affecting growth rates, and increasing susceptibility to disease outbreaks. The high salinity limits species that can be farmed in open systems without significant need for adaptation. There is a limited availability of land and water resources, with limited arable land and coastal areas that can be allocated for aquaculture development.

With a reliance on imports, especially in the case of the importation of fish feed, production costs are relatively high. Costs

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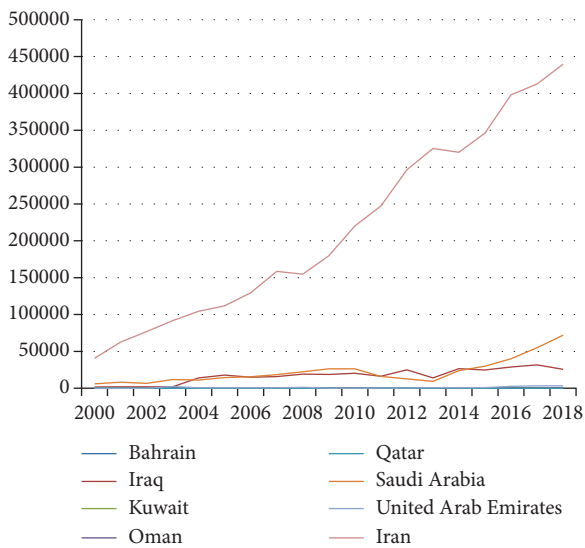


FIGURE 1 | Country-specific aquaculture production trends. Data source: [3], compiled from the food and agriculture organization of the United Nations through the World Bank.

associated with the logistics, as well as the relatively high cost of the feed itself, add to the production cost. There are no local production facilities for feed in Kuwait. Recirculating systems, process automation, and related sustainable technologies require a high initial investment, which can deter farmers from pursuing these technologies.

There is a lack of infrastructure and support—limited hatchery activity, insufficient processing facilities, and poor cold chain logistics. Better infrastructure is required, as continuous production requires a constant supply of larvae.

Limited research on native species and a reliance on imported fry restrict production options. Current production is largely reliant on species such as seabream (*Sparus aurata*), seabass (*Dicentrarchus labrax*), and Tilapia sp., with limited activity in farming native, heat-tolerant species. Information on disease management in aquaculture settings is not readily available, and lack of investment in R&D for disease prevention, diagnostics, and treatments hinders scaling up of production. Furthermore, lengthy and unclear licensing procedures discourage private investment. Ambiguous bureaucratic hurdles make progress difficult (E.A. [5]). When considering the environmental pressures, overfishing and habitat degradation have depleted wild stocks, while poorly regulated aquaculture activity risks exacerbating ecosystem degradation.

In terms of market challenges, consumers generally prefer wild-caught fish and its associated “freshness” and are resistant to consuming farmed seafood [6, 7]. Traditionally, cultural perceptions in Kuwait support a reliance on wild fisheries. Imported seafood may also present a lower and more competitive price point. A lack of public awareness, as well as investor awareness about food security and sustainability concerns facing the nation, present an additional challenge [8]. The presences of bacteria such as *Streptococcus agalactiae* [9], exacerbated by high temperatures and salinity, are associated with substantial fish kills [10], and with a warming climate can only be expected to worsen over time. Recently recorded summer surface temperature in

Kuwait Bay reached 37.6°C [10]. In the summer of 2001, a fish kill event claimed over 2500 tons of Klunzinger’s mullet, attributed to unusually high temperature encouraging the growth of *S. agalactiae* and harmful dinoflagellates [11]. The presence of *S. agalactiae*, combined with high temperatures and salinity, poses a risk to fish health and food security [12]. Expanding the range of farmed species and adopting advanced farming techniques are essential for achieving a sustainable aquaculture sector. Local species, such as orange-spotted grouper (*Epinephelus coioides*) and Sobaity Seabream (*Sparidentex hasta*), as well as nonlocal species like Pacific Whiteleg Shrimp (*Litopenaeus vannamei*), offer promising opportunities for diversification.

Developing an aquaculture sector that significantly but sustainably contributes to seafood security in Kuwait is a necessity. Kuwait’s wild capture fisheries are under significant pressure, with many commercial fish stocks experiencing sharp declines in catch trends, possibly due to overfishing or habitat degradation [13–15]. For example, the silver pomfret (*Pampus argenteus*) and Hilsa Shad (*Tenualosa ilisha*) stocks, which used to be major contributors to wild capture fisheries, have declined by around 85%–90% since the mid-1990s [13, 14]. Such catch declines, combined with the high demand for seafood, have made local seafood less accessible and affordable [16]. As a result, Kuwait increasingly relies on imports, exposing the nation to price volatility and supply chain disruptions. Over 80% of the seafood consumed in Kuwait is imported, and over 90% of all food consumed is imported [17]. While the nation is not considered food insecure, possible supply chain disruptions due to regional geopolitical tensions or similar circumstances that disrupt supply chains pose serious risks in the future. In this paper, we emphasize a sustainable expansion and diversification of the aquaculture sector to address Kuwait’s fragile seafood security. Specifically, we outline the feasibility of farming both local and nonlocal species using innovative systems while addressing the biological, economic, and regulatory aspects. Importantly, our approach aims to: (i) address key challenges currently facing the aquaculture sector and (ii) balance the sector’s growth with environmental sustainability, which is consistent with Kuwait’s broader food security goals and Vision 2035 requirements (MOFA).

2 | Methods

2.1 | Data Sources and Analysis

FAO reports and academic literature on aquaculture development in Kuwait and comparable regions were reviewed [15, 18]. Local aquaculture production data categorized by farmed species, species performance metrics [17–20], and existing regulatory frameworks (E.A. [5]) were analyzed to identify barriers and opportunities through information publicly available in local reports and publications. We obtained the local aquaculture production data from the official annual fisheries bulletin published between 2001 and 2019—we did not find aquaculture-related data prior to 2001 [16]. We also assessed Kuwait’s aquaculture licensing procedures, environmental impact assessment guidelines, and biosecurity measures. Visits were conducted at Sharq Fish Market as well as local supermarkets to obtain data on pricing. Field assessments

were conducted at two operational aquaculture farms in Kuwait. This study integrates data from national statistical bulletins with targeted field assessments to provide an accurate representation of aquaculture activity and development potential.

International aquaculture standards, such as those of the FAO and Aquaculture Stewardship Council, were used as benchmarks (shown in Table 1) to identify gaps and propose improvements [21, 22].

2.2 | Economic and Biological Feasibility Analysis

To evaluate species suitability for aquaculture, species with a successful record of cultivation were selected. The approximate cost of production was compared to the average selling price of the wild-caught landings of those species.

These species had established growth rates, resilience to containment conditions for aquaculture, and lifecycle requirements previously researched and outlined.

Profitability was assessed by calculating the difference between the average market price per kilogram of each species and the estimated production cost per kilogram under three aquaculture systems: recirculating aquaculture systems (RAS), cage farming, and pond farming. Market prices were derived from national fish landing data [23], while production costs were based on industry-standard estimates [24–26]: KD 7.50/kg for RAS, KD 5.00/kg for cage systems, and KD 4.00/kg for pond systems. The core equation applied was:

$$\text{Profit Margin (KD/kg)} = \text{Average Market Price (KD/kg)} - \text{Production Cost (KD/kg)} \quad (1)$$

To enable international comparison, all values were later converted to USD using the exchange rate of 1 KD = 3.26 USD. This approach allowed for a direct comparison of economic viability across species and production methods, highlighting which species are most suited for intensification under different farming systems.

In terms of production potential, an Ordinary Least Squares (OLS) linear regression model was used for 2001–2019. Forecasts for 2020–2035 were generated using the regression equation:

$$\text{Production}_t = \beta_0 + \beta_1 \times \text{Year}_t + \varepsilon_t. \quad (2)$$

Aquaculture production data was obtained from the Kuwait Fisheries Bulletin. There is an error in 2017 reporting, where an extra zero was added to the final amount. This error was corrected by dividing by 10. This study integrates primary data published by the national fisheries statistical bulletins with targeted field assessments to validate the description of existing aquaculture systems and production trends in Kuwait.

3 | Results and Discussion

3.1 | Current State of Kuwait’s Aquaculture Sector

Primary observations from local fish markets demonstrate a strong consumer preference for wild-caught fish, limited branding of farmed fish, dominance of imports, and inconsistent traceability of seafood products. These factors help explain the limited market penetration of farmed products. The 2020–2035 forecasts is based on business-as-usual conditions with limited growth—indicative of the unlikely expansion of Kuwait’s aquaculture sector without substantial investment, hatchery development, and policy reforms. Regression analysis revealed no statistically significant long-term trend in aquaculture production ($\beta_1 = -4.17$ tons/year, $p = 0.50$; $R^2 = 0.03$). Annual production fluctuated between 200 and 300 tons for most of the 20 year period, with occasional spikes due to isolated events and reporting errors rather than structural growth.

Over the past two decades, Kuwait’s aquaculture sector has stagnated in three major ways (Figure 2). First, in terms of production, the amount of harvested farmed species remained at around 300 tons between 2001 and 2019 (Figure 2). Second, most of this production lacks diversity in farmed species, with the dominant produced species being tilapia (Figure 3(a)). Indeed, the production of tilapia in Kuwait dwarfs that of other commercially important species, like seabreams and groupers. The low production of commercially important species is unlikely attributed to the lack of understanding of their biological aspects because the aquaculture-based research on local species, like the orange-spotted grouper (*Epinephelus coioides*), Sobaity Seabream (*Sparidentex hasta*), and Yellowfin Seabream (*Acanthopagrus latus*), has been thoroughly recognized by the Kuwait Institute

TABLE 1 | Aquaculture standards outlined by the FAO and the aquaculture stewardship council.

Focus area	FAO guidelines	ASC standards
Environmental Impact	Promotes minimal ecological impact and biodiversity conservation	Strict limits on water pollution and habitat protection
Social Responsibility	Supports equitable livelihoods and community well-being	Requires fair labor, stakeholder consultation, and community rights
Animal Welfare	Encourages health management and humane practices	Mandates health management and species-specific welfare conditions
Economic Viability	Emphasizes economically sustainable operations	Not a primary focus but supports economic viability through certification
Governance and Policy	Promotes effective policy frameworks and governance	Requires compliance with national regulations
Traceability	Encourages recordkeeping and product integrity	Demands full transparency and chain-of-custody documentation

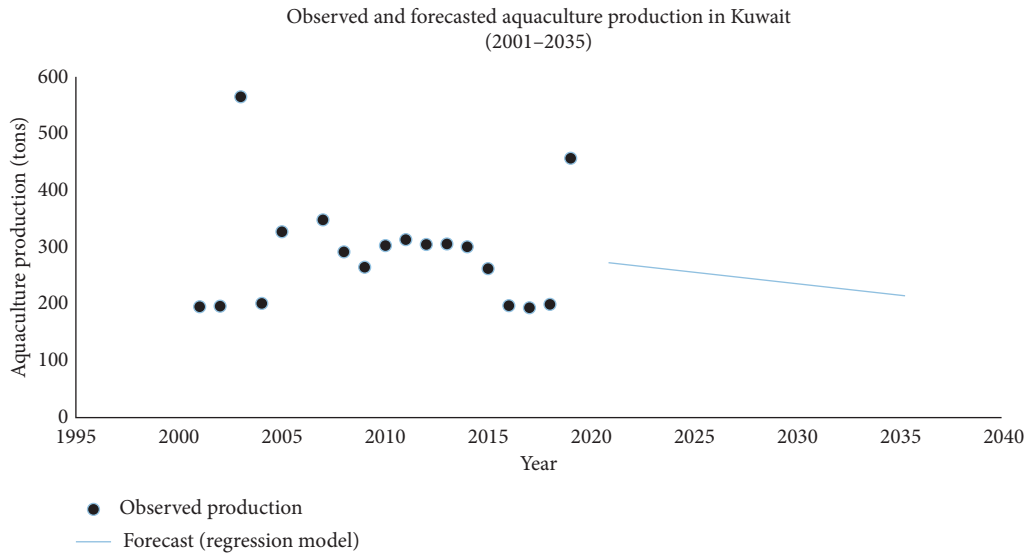


FIGURE 2 | Observed and forecasted aquaculture production in Kuwait. The forecast predicts continued stagnation with production ranging between 200 and 270 tons.

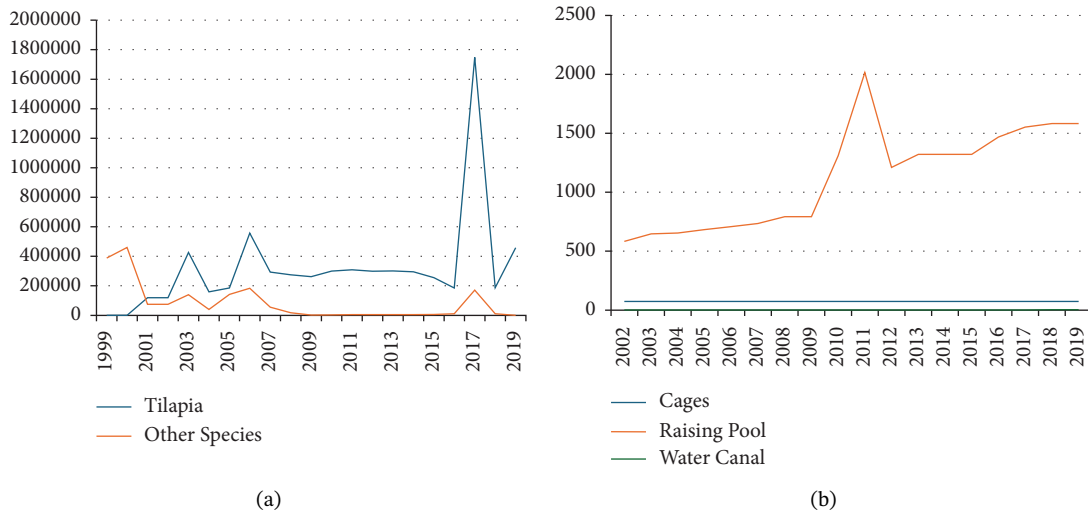


FIGURE 3 | (a) Kuwait’s total aquaculture production species, with blue line is tilapia production while the gray line is other fish species. (b) The types of farming systems as reported by the annual fisheries bulletin, with the dark blue line is “rising pools”, light blue line is “cages” and gray line is “water canal”.

for Scientific Research [15, 19, 20]. While there are plans to increase production by introducing more species, such as salmon, it remains at the research level [27].

Finally, Kuwait’s aquaculture sector is characterized by limited types of farming systems (Figure 3(b)). Most fish farming activities utilize traditional farming systems such as ponds and flow through systems in concrete tanks (also described as “rising pools”). These farms are generally limited in growth and are often in the developmental or pilot stages. Scaling up production is challenging when bottlenecks—like the lack of regional hatchery development—disrupt steady progress. Sustained high-volume production remains unattainable due to the prohibitive costs and logistical complexities involved in importing broodstock and larvae. Advanced technologies like RAS remain underutilized, and investment in research and development is

minimal. Farming in sea cages has been practiced previously but ended in 2001 due to concerns regarding disease outbreaks affecting the local ecosystem [11]. There are ambiguous plans to bring back sea cage farming, with plans announced in 2020 to develop the aquaculture sector further, welcoming bids on offshore sites on the southern coast [28].

When examining the regulatory frameworks pertinent to establishing an aquaculture venture, the Public Authority for Agriculture Affairs and Fish Resources (P.A.F.F.R)—one of the main governing bodies of fish wealth—does not have clear guidelines for the sustainable development and expansion of aquaculture operations. For example, Article No. 293, described in Kuwait’s FAO aquaculture sector overview, states that land-based aquaculture activity cannot occupy more than 10% of agricultural land, which sets a discouraging precedent for the

intensification of farming activity [18]. Land is already quite scarce in Kuwait, and policies such as Article No. 293 should not limit the means of production in this manner. Production is also limited by the lack of infrastructure and support provided to local farmers (E.A. [5]). Generally, most production in Kuwait is limited to *Tilapia sp.*, but there is potential for growth through the development of production techniques for local species.

3.2 | Feasibility of Diversified Farmed Species and Farming Systems

As Kuwait continues to develop its aquaculture sector, strategic choices must be made in terms of species and system selection. Native species such as the orange-spotted grouper (*Epinephelus coioides*) are well-adapted to local conditions, while nonnative species like *vannamei* and tiger shrimp offer proven commercial viability. Bivalves and algae present valuable opportunities not only for food and feed production but also for ecosystem services such as water purification and nutrient recycling.

While native species like orange-spotted groupers are well-suited to Kuwait’s environmental conditions, they require further research into breeding and disease management. They are being successfully cultivated in the UAE and Saudi Arabia [29]. Yellowfin seabream (*Acanthopagrus latus*) is another promising option that thrives in local conditions, and while there is yet to be documented cultivation in the GCC, a close relative of this species is being cultivated in India [30]. Sobaity Seabream (*Sparidentex hasta*) has been quite promising, with successful production in the region, most notably in Saudi Arabia [31]. While there are some successes in regional production of local species, there are still some limitations due to insufficient broodstock and supply of larvae, which are roadblocks to intensification of production [26, 29].

Nonlocal species such as Pacific Whiteleg shrimp (*Litopenaeus vannamei*) and tiger shrimp (*Penaeus monodon*) are highly resilient and economically viable, making them ideal candidates for expansion as they are well-established and commonly cultivated species. Looking at popular fish species consumed in Kuwait (Figure 4), we calculated profit margins by taking the average market price for each species [2] and subtracting the estimated production cost per kilo, depending on the farming method—RAS, cage, or pond. This gave us a clear picture of

which species are most profitable under different systems. While pond culture has significantly higher returns, the climate does not allow for sustainable large-scale pond cultivation, while a lack of suitable locations off the coast limits opportunities for sea cage farming. Silver pomfret had the most notable margins out of the selected species; however, production of this species is still in the early stages of research.

Given Kuwait’s hot climate and abundant sunlight, commercial algae production presents a lucrative and sustainable opportunity, particularly for aquaculture feed, biofuels, and wastewater management. High-protein microalgae like *Spirulina* and *Nanochloropsis* can serve as a sustainable alternative to fishmeal, reducing reliance on imported feeds for shrimp and fish farming. Additionally, oil-rich algae species offer potential for biofuel production, while their ability to absorb excess nutrients from aquaculture wastewater improves water quality in RAS systems. Integrating algae cultivation into local farming operations could enhance sustainability, lower costs, and create a circular economy, leveraging Kuwait’s natural climate advantages. Bivalves provide a similar ecosystem service, with the potential to bioremediate wastewater or be cultivated alongside other species in an Integrated Multitrophic Aquaculture (IMTA) or polyculture system. These are valuable high-protein ingredients that can be consumed or have other applications such as animal feed or pharmaceutical products.

Commonly used farming systems for cultivation include pond cultivation, cages, flow-through systems, and RAS). Table 2 outlines a comparison of various systems and their positive aspects, as well as potential drawbacks.

3.3 | Opportunities for Aquaculture Expansion

Integrating RAS and IMTA systems can optimize resource use and minimize environmental impact/overcome environmental challenges [32]. Investment in hatcheries and local feed production would create the opportunity for intensification of production through a steady supply of local products that would drive production costs down, in addition to focusing on heat- and high-salinity-tolerant species, such as our native wild fish species. High-value species with export potential can enhance Kuwait’s competitiveness in regional seafood markets, for example, species that provide lucrative biomedical or

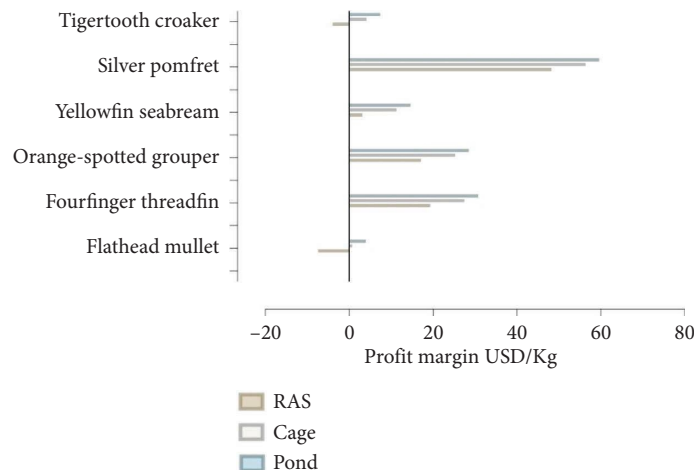


FIGURE 4 | Comparison of profit margins of selected farming systems and species.

TABLE 2 | Comparison of different farming systems.

System	Financial considerations	Environmental constraints	Resource requirements
Pond	Lowest cost option, suitable for small-scale operations	Effluent and sediment buildup, susceptible to climate events	Large land area, reliable water supply
Cage	Moderate cost, requires access to coastal/marine areas	Can impact wild ecosystems, sensitive to weather and pollution	Marine/coastal water access, anchorage, licensing
Flow-through	Moderate to high OPEX due to water pumping/treatment	Can cause downstream pollution, requires clean water source	High freshwater availability, water treatment infrastructure
Recirculating (RAS)	High CAPEX and OPEX, but high productivity and year-round production possible	Minimized environmental footprint but energy-intensive	Electricity, technical staff, continuous monitoring systems

pharmaceutical end products. In Saudi Arabia, for example, sea cucumbers are being cultivated, not for their local appeal or consumption but for export to Asian markets [33].

Policy Reform: Streamlining regulations and incentivizing sustainable practices can attract investment and accelerate industry growth. Government incentives and streamlined regulations, along with research and development partnerships with regional and international aquaculture research organizations, can promote the development of this sector.

Intensifying aquaculture production must be balanced with environmental stewardship. The systems that are chosen should be accommodating of the harsh climate and limited resources of the landscape. Because Kuwait is a desert and temperatures reach over 50 degrees Celsius in the summer, it would not be beneficial for typical outdoor grow-out systems to be used. Water should be conserved (and ideally, reused) due to scarcity. Monitoring frameworks and impact assessments are essential to mitigate risks such as water pollution, habitat loss, and disease outbreaks.

Policy reforms that could promote and improve sustainable aquaculture development should involve the following:

Other important aspects to consider in aquaculture expansion include simplification and standardization of licensing procedures, implementation of biosecurity measures, technological innovation, and economic incentives. For example, simplifying aquaculture licensing can reduce administrative burdens and encourage investment. The European Commission’s strategic guidelines advocate for transparent and efficient licensing to promote sustainable aquaculture growth and could provide the basis for a framework moving forward [34].

The implementation of strict biosecurity protocols is essential to prevent disease outbreaks that can devastate aquaculture and wild fish populations. The FAO emphasizes that effective governance and biosecurity measures are critical for sustainable aquaculture development [21]. Conducting thorough environmental assessments helps in understanding and mitigating the ecological impacts of aquaculture operations. Aligning national policies with international standards, such as those from the FAO and the Global Sustainable Aquaculture Roadmap, ensures environmental responsibility and competitiveness in the global market [35]. Developing traceability mechanisms ensures that

aquaculture products meet safety and quality standards, facilitating access to international markets. The European Commission highlights the importance of traceability in its aquaculture policy framework, as does the Global Seafood Alliance [34]. By integrating these policy reforms, supported by research and international guidelines on best practice, the aquaculture industry in Kuwait can advance towards sustainability, economic viability, and environmental stewardship. Investment in research and development for the breeding of native aquaculture species and the development of disease-resistant stock is essential for building a sustainable, local aquaculture sector. Such efforts reduce dependence on imported seed, lower mortality rates, and promote the use of species already adapted to local environmental conditions. This not only supports national food security and biodiversity conservation but also contributes to the long-term sustainability and competitiveness of the aquaculture industry in Kuwait. In terms of financial support, subsidies could be provided for sustainable farming technologies and alternative feed sources. A 50% feed subsidy is already provided by the Kuwaiti government. This brings down the cost of production considerably, as feed is approximately 50% of the cost of production [24]. The promotion of public-private partnerships would also promote the growth of the sector, with the collective cooperation bringing rapid development to the sector through synergistic alliances [36, 37].

4 | Conclusion

Kuwait’s aquaculture sector holds immense potential to contribute to food security, reduce reliance on imports, and support sustainable economic growth. By diversifying farmed species, adopting advanced technologies, such as RAS, and reforming regulatory frameworks, Kuwait can unlock this potential while safeguarding its marine and scarce freshwater ecosystems. This roadmap provides actionable steps to transform aquaculture into a cornerstone of Kuwait’s food production system, addressing issues like food security and fishery exploitation into a more sustainable future for all stakeholders.

We conclude with a few limitations in our study that might motivate future research. First, our estimate of production cost is based on industry averages. Additional studies that focus on determining the cost of farming other species using different farming systems may help provide a more general estimate of the

cost of production. Second, there is limited information available on regional production, which can be attributed to either a lack of production activity or limited information made available to the public.

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Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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