Profitability indicators should also capture cost structure, market resilience, and the ability to benefit from diversified value chains. Seaweed farming can become profitable when biomass sales are counted, but profitability is constrained by labor costs, annual biomass variation, immature supply chains, and limited access to space, so net profit margin, benefit-cost ratio, labor productivity, and market-channel diversity are all relevant metrics (Hasselström et al., 2020). Because continued growth depends on rising demand, output diversification, and in some settings compensation for environmental services, a complete indicator system should also include value-added product share, demand stability, and access to policy support or ecosystem-service payments.

4.3 Indicators for social benefits and industrial sustainability

Social-benefit indicators should measure how green *Porphyra* farming contributes to livelihoods, community resilience, and broader sustainable-development goals. Expert and policy-oriented assessments show that seaweed farming can support food security, decent work, economic growth, sustainable production, and multiple other SDGs, but these benefits depend on effective regulation and mitigation of negative trade-offs (Spillias et al., 2022). For this reason, social evaluation should include employment creation, household income support, participation of smallholders, contribution to local food systems, and alignment with public sustainability goals (Hossain et al., 2021).

Industrial sustainability indicators should then evaluate whether the *Porphyra* sector can remain competitive and adaptive over time. Long-term sustainability depends on improved and more consistent farm productivity, better product quality, technical support services, and diversification of value chains to reduce vulnerability to price fluctuations (Rimmer et al., 2021). Industry transformation also requires supportive governance, strategic planning, and robust value-chain coordination, so indicators such as technical extension coverage, innovation adoption, supply-chain maturity, marketing capacity, and policy support should be incorporated alongside ecological and economic measures (Yong et al., 2024).

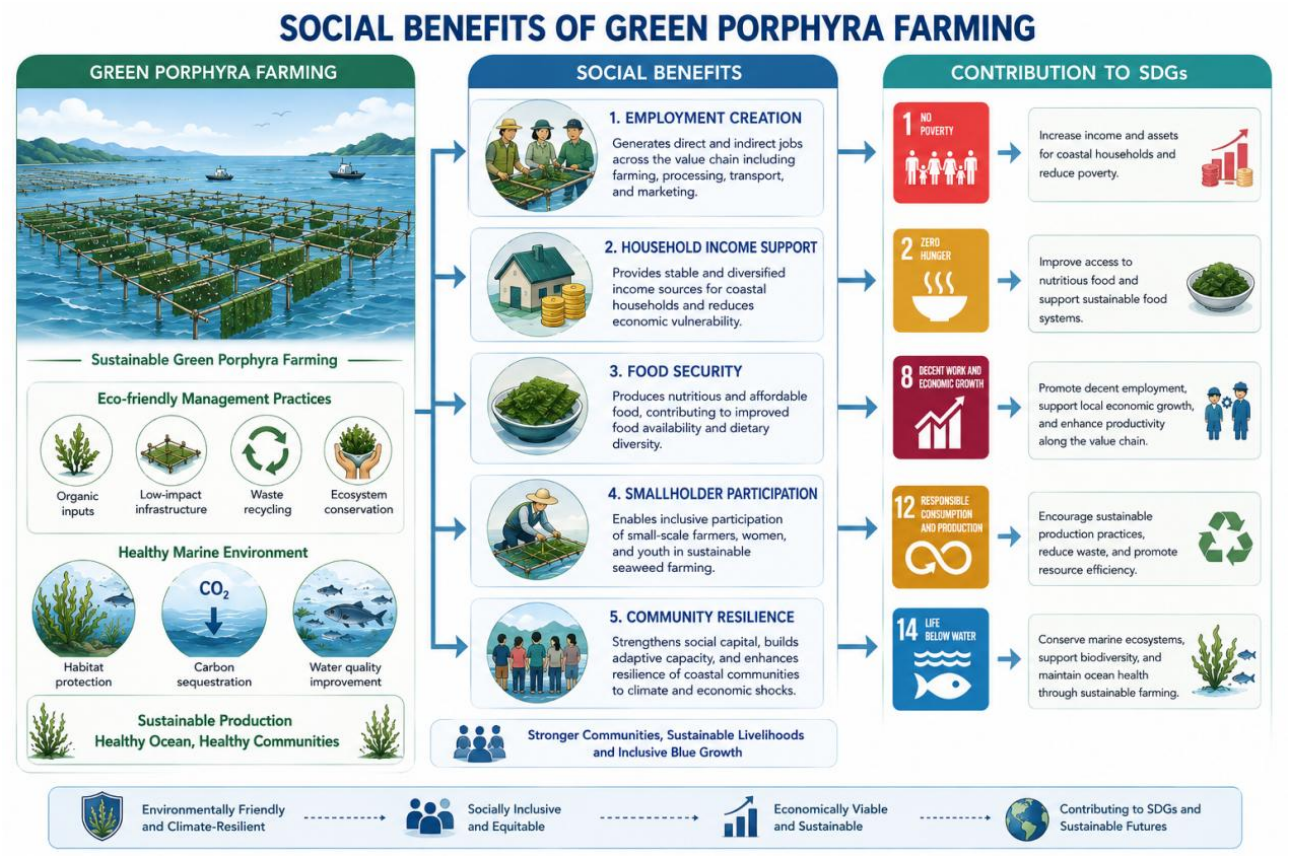

Figure 1 Conceptual pathways linking green *Porphyra* farming to social sustainability outcomes and sustainable development goals (SDGs)