Designing an Inclusive Sargassum-Aquafeed Value-Chain Training Programme: A Scalable Model for Coastal Resource Transformation and Women's Empowerment in Nigeria

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ABSTRACT

Coastal West Africa faces dual and interconnected crises: escalating sargassum blooms and aquaculture feed import dependency. Since 2011, massive sargassum influxes, part of the Great Atlantic Sargassum Belt have disrupted coastal ecosystems and communities across the region while Nigeria imports aquafeed ingredients. This paper presents a comprehensive framework for a five-year National Sargassum–Aquafeed Value-Chain Training Programme (NSAVTP) designed to address both challenges through circular economy principles. The NSAVTP proposes training 10,000 Nigerians across six curricula covering sargassum harvesting, processing, and aquafeed formulation, targeting 60% women and 70% youth participation. With a budget of USD 6.8 - USD 6.9 million, the programme aims to establish 1,000 certified micro-enterprises, reduce aquafeed imports by 30%, and process 50,000 tonnes of sargassum annually while generating $120–150 million in annual foreign exchange savings. Drawing on evidence from women-focused capacity-building in aquaculture value chains and successful training-of-trainers models, this article examines the theoretical foundations, implementation strategy, and anticipated socioeconomic and environmental impacts of this scalable model. The NSAVTP framework operationalizes Nigeria's blue economy agenda while advancing gender equality and climate adaptation in coastal communities.

Keywords: Aquaculture, Blue economy, Circular economy, Coastal livelihoods, Gender empowerment, Sargassum seaweed, Value chain.

INTRODUCTION

Nigeria has achieved remarkable fisheries and aquaculture expansion, with total fish production exceeding 1 million metric tonnes annually and aquaculture emerging as the fastest-growing subsector, positioning the country as sub-Saharan Africa's leading aquaculture producer (Saba et al., 2024; FAO, 2024). This growth masks a critical structural constraint: feed costs consume 60–70% of total production expenses, with heavy reliance on imported fishmeal and soybean meal (Adedeji & Okocha, 2011).

Concurrently, Nigeria's 853-kilometer coastline experiences unprecedented sargassum influxes. Since 2011, massive mats of pelagic Sargassum have formed the Great Atlantic Sargassum Belt (GASB), a transcontinental phenomenon stretching from West Africa to the Americas (Franks et al., 2016; Johnson et al., 2013; Fidai et al., 2024). These brown macroalgae accumulations create multifaceted coastal crises: ecological damage through oxygen depletion and smothering of seagrass beds (van Tussenbroek et al., 2017) and impediment of sea turtle nesting (Maurer et al., 2015); public health hazards through hydrogen sulfide and ammonia release during decomposition (Resiere et al., 2021; Resiere et al., 2023); economic disruption to fisheries and tourism; and damage to fishing equipment (Areola et al., 2024). In West Africa specifically, sargassum influxes have disrupted coastal livelihoods, hindered adaptation capacity, and created socioeconomic pressure on fishing-dependent communities (Atiglo et al., 2024; Areola et al., 2024).

Recent research demonstrates that macroalgae particularly brown seaweeds including Sargassum species can serve as viable aquafeed ingredients (Anetekhai, Nwatulegwu & Olateju, 2025). Macroalgae are rich in essential minerals, vitamins, fatty acids, and polysaccharides (MacArtain et al., 2007; Rajapakse & Kim, 2011), with documented growth-promoting and immune-enhancing properties in cultured fish (MacArtain et al., 2007; Rajapakse & Kim, 2011; Mouritsen, 2013). Studies have demonstrated that seaweed supplementation (3–10% dietary inclusion) enhances growth performance, antioxidant capacity, and stress response in species including Atlantic salmon and rainbow trout (Kamunde, Sappal, & Melegy, 2019). Sargassum specifically contains polyphenolic compounds with antioxidant effects and minerals (sodium, potassium, calcium, magnesium, iron, zinc, and manganese) suitable for aquafeed formulation (Anetekhai et al., 2025).

This convergence abundant biomass requiring management coupled with aquaculture sector facing feed constraints presents a transformative opportunity for developing regions like Nigeria where coastal communities face high unemployment, limited income-generating options, and environmental degradation simultaneously (Anetekhai et al., 2025; Saba et al., 2024).

Women constitute nearly half the global aquaculture workforce but face systemic barriers limiting their participation, income capture, and decision-making authority in fisheries and aquaculture value chains (FAO, 2021). In Nigeria specifically, while women participate extensively in post-harvest activities and marketing, they remain underrepresented in technical roles and farm management (Gbigbi, 2021). Targeted capacity-building addressing these barriers has demonstrated effectiveness: value chain training for women in sub-Saharan African small-scale fisheries raised household food security by 8–9 percentage points and dietary quality by 3 percentage points, with food security gains more than twice the magnitude of dietary quality improvements (Orkoh, & Hatab, 2026). Targeted capacity-building for women in aquaculture and fisheries value chains has demonstrated consistent positive impacts on household food security and dietary quality (Abu Hatab, 2025). Aquaculture interventions have been shown to produce modest positive effects on production value, income, and food consumption among participants in low- and middle-income countries, though evidence on nutrition and women's empowerment outcomes remains insufficient for firm conclusions (Gonzalez Parrao et al., 2021).

The training-of-trainers model wherein master trainers multiply programme impacts beyond direct beneficiaries has proven effective in diverse agricultural contexts, with evidence from farmer field schools demonstrating significant productivity and income gains (Davis et al., 2012), and represents a scalable pathway for institutionalising knowledge and practices in developing country contexts with limited extension capacity (Davis et al., 2020).

While individual components of value chain development technical training, women's empowerment, circular economy approaches have received research attention, the integration of these elements specifically addressing sargassum valorization and aquafeed sustainability in Nigerian context remains understudied. This paper contributes to the literature by: (1) examining a comprehensive, evidence-informed program design addressing the interconnected problems of coastal pollution, aquaculture feed insecurity, and youth/women unemployment; (2) positioning sargassum resource transformation within broader blue economy and circular economy frameworks; (3) analyzing implementation mechanisms for scalable capacity-building in developing country contexts; and (4) projecting measurable socioeconomic and environmental outcomes aligned with Nigeria's national development priorities and global Sustainable Development Goals.

Statement of the Problem

Nigeria has achieved remarkable aquaculture expansion, becoming sub-Saharan Africa's largest aquaculture producer with total fisheries output exceeding 1 million metric tonnes annually (Saba et al., 2024; FAO, 2024). However, this growth is constrained by unsustainable feed costs. Feed costs consume 60–70% of total aquaculture production expenses, directly undermining farm profitability and limiting farmer capacity to expand production (Adedeji & Okocha, 2011; WorldFish, 2024; Ogunji & Wuertz, 2023). Aquafeed ingredient imports constitute a persistent drain on Nigeria's foreign exchange reserves, with annual imports estimated at $400–500 million Ogunji & Wuertz, 2023).

This import dependency exposes Nigerian aquaculture operators to multiple vulnerabilities: currency exchange rate fluctuations, global commodity price volatility, international supply chain disruptions, and unfavourable trade terms. The result is a structural constraint limiting Nigeria's aquaculture competitiveness, farmer income, and the sector's contribution to national food security and economic development (Saba et al., 2024).

Since 2011, unprecedented influxes of pelagic Sargassum have formed the Great Atlantic Sargassum Belt (GASB), a transcontinental phenomenon extending from West Africa to the Americas. These brown macroalgae accumulations create acute environmental, public health, and economic damage. West Africa remains underrepresented in global sargassum research, with only 3.5% of global sargassum studies between 2010 and 2023 focusing on the region (Atiglo et al., 2024; Areola et al., 2024). Coastal communities face insufficient tools for early warning and management planning, leaving communities with inadequate adaptive strategies (Fidai et al., 2024; Areola et al., 2024); Nigeria's coastal communities face persistent high unemployment, particularly among youth (18–35 years) and women. Coastal livelihoods traditionally depend on fisheries and seasonal activities, providing limited income security and few opportunities for skill development or asset accumulation. Women, while participating extensively in post-harvest processing and marketing, concentrate in unpaid or low-paid activities and lack decision-making authority in household and community affairs (Adam & Njogu, 2023; FAO, 2021).

Rural-urban migration driven by limited economic opportunities strains urban labor markets while depleting coastal communities of youth productivity and social capital. The absence of structured income-generating activities, particularly those utilizing coastal resources and aligning with women's existing roles, perpetuates cycles of poverty and limits human capital development.

These three crises are not independent. Rather, they represent a failure to recognize and valorize underutilized coastal resources: Sargassum is simultaneously a waste problem and a potential input. The coastal biomass accumulating and degrading could instead be harvested, processed, and converted into aquafeed ingredients, simultaneously addressing coastal pollution while reducing import dependency. Coastal communities possess the geographic location, traditional knowledge, and labor force needed to address these crises. However, they lack structured training, market linkages, and enterprise support to transform resource access into livelihood opportunity.

Current policy approaches address these crises separately: environmental management programs focus on sargassum removal without valorization; agricultural policies target import substitution without leveraging local resources; and development programs emphasize generic skills training without connecting to specific value chains or environmental opportunities.

The Research Question

This integrated crisis context generates the central research question addressed by this paper: How can a comprehensive, evidence-informed capacity-building programme leverage sargassum valorization to simultaneously address aquaculture feed insecurity, coastal environmental degradation, and youth/women unemployment while operationalizing circular economy and blue economy principles in a developing country context?

This paper addresses a significant gap in the literature: while individual components (aquaculture feed alternatives, sargassum management, women's empowerment in value chains, circular economy approaches) have been studied, the systematic integration of these elements, specifically addressing sargassum valorization for aquafeed while advancing gender equality and youth employment in developing country context, remains understudied. By presenting a comprehensive programme design grounded in evidence from prior aquaculture interventions, circular economy frameworks, and gender-transformative development approaches, this paper contributes to development practice and policy by demonstrating how environmental challenges can become economic opportunities through integrated, inclusive, evidence-informed design.

The National Sargassum–Aquafeed Value-Chain Training Programme (NSAVTP) represents a systematic response to this question, grounded in evidence from aquaculture development, circular economy theory, and gender-transformative approaches.

Significance of Addressing these Integrated Problems

The magnitude of potential impact justifies urgent attention:

Food Security: Reducing aquafeed import costs would enable 30% expansion of domestic aquaculture capacity at current investment levels, improving fish availability for 50+ million Nigerians consuming insufficient animal protein.

Economic Impact: Foreign exchange savings of $120–150 million annually, combined with 25,000+ direct and indirect jobs, would meaningfully contribute to Nigeria's GDP growth and employment targets.

Environmental Management: Processing 50,000 tonnes of sargassum annually would reduce coastal pollution, restore ecosystem services (fisheries nursery function, tourism appeal), and support climate adaptation in vulnerable coastal communities.

Social Equity: Training 10,000 individuals (women,youth) with income-generating skills in a growing sector would directly address gender inequality and youth unemployment while building community resilience to climate and economic shocks.

Policy Innovation: Demonstrating an integrated approach to coastal resource management, circular economy operationalization, and inclusive development would provide a model applicable to other coastal nations facing similar sargassum challenges across Africa, the Caribbean, and Southeast Asia.

THEORETICAL FRAMEWORK AND CONCEPTUAL BASIS

Blue Economy and Circular Economy Principles

The blue economy concept emphasizes sustainable utilization of marine resources for economic growth, poverty reduction, and food security while preserving ecosystems (Pauli, 2010; African Development Bank, 2023). In Nigeria's context, the blue economy contributes 3–5% to national GDP and employs approximately 1.48 million individuals, with potential for substantial expansion through improved productivity and resource diversification (Saba et al., 2024).

The circular economy, defined as an economic system aimed at closing resource loops through waste reduction, resource efficiency, and regenerative design (Ghisellini et al., 2016), applies distinctly to marine biomass valorisation. Circular approaches in coastal contexts have been shown to reduce waste streams while generating local livelihood opportunities, though impacts vary considerably by intervention type and context (Ellen MacArthur Foundation, 2023; Stegmann, Londo, & Junginger, 2020). Applied to sargassum, the circular approach transforms what communities perceive as environmental "waste" into a resource input for aquafeed production, capturing economic value throughout the value chain while addressing coastal pollution (Anetekhai et al., 2025).

Value Chain Development and Market Systems Strengthening

Value chain frameworks emphasise the integration of producers with processors, traders, and end-users through coordinated technical, marketing, and organisational support (Ahmed & Lorica, 2002; Gonzalez Parrao et al., 2021). Effective value chain interventions in aquaculture address multiple points: production efficiency (input quality, technical practices), processing and product quality, market linkages, and enabling institutional environments. Evidence from Bangladesh indicates that value chain training combined with market linkage facilitation generates modest positive effects on farm productivity and household income (WorldFish, 2018;

Toufique & Belton, 2014), though impacts vary by intervention type, context, and the rigour of programme design (Gonzalez Parrao et al., 2021).

The NSAVTP operationalizes this framework by training participants across the complete sargassum-aquafeed value chain from harvesting to processing to feed formulation to enterprise management rather than addressing isolated technical components. This comprehensive approach addresses systemic constraints limiting commercialization and livelihood sustainability.

Gender-Responsive Capacity Development

Gender relations in aquaculture value chains reflect and reinforce broader societal patterns: unequal access to resources, limited decision-making authority, concentration in unpaid or low-paid activities, and time burdens from unpaid care work (Kruijssen et al., 2018; FAO, 2021). Gender-transformative approaches (GTAs) in agriculture and aquaculture address these structural dimensions through combined technical training, social norm engagement, and institutional strengthening (McDougall et al., 2021).

The NSAVTP incorporates gender-responsive design through: (1) deliberate women's participation targets (60%) reflecting their critical roles in fish processing and marketing; (2) flexible training schedules accommodating reproductive responsibilities; (3) support for women-led cooperatives and collective marketing; (4) content addressing gender norms and household decision-making; and (5) integration with women's savings groups where applicable. This multidimensional approach acknowledges that technical skills alone, without addressing social and institutional barriers, produce limited empowerment outcomes.

PROGRAMME DESIGN AND METHODOLOGY

Conceptualization and Curriculum Development

The NSAVTP emerged from participatory consultations with coastal communities, aquaculture operators, feed manufacturers, and government stakeholders conducted over 18 months (2023–2024). Curriculum development integrated international best practices from FAO training protocols, the Aquaculture for Income and Nutrition (AIN) project in Bangladesh (Keus et al., 2017), and regionally adapted models. Six modular curricula totaling 336 hours of instruction were designed to equip participants with competencies across the entire sargassum-aquafeed value chain:

Curriculum 1: Sargassum Collection and Handling (5 days, 40 hours) covers optimal harvesting locations, sustainable collection techniques respecting ecological considerations, safety protocols, quality assessment standards, post-harvest handling, and transportation logistics.

Curriculum 2: Sargassum Farming/Culture (10 days, 80 hours) addresses integrated multitrophic aquaculture (IMTA) principles wherein sargassum is cultivated alongside fed aquaculture species to capture excess nutrients, covering site selection, infrastructure, growth optimization, and harvest timing.

Curriculum 3: Processing and Pre-Milling (7 days, 56 hours) trains participants in washing, drying, preservation methods, grinding and milling equipment operation, quality control standardization, and storage protocols to ensure feed ingredient consistency.

Curriculum 4: Aquafeed Formulation and Pelletizing (10 days, 80 hours) covers fish nutritional requirements, feed formulation mathematics, pelletizing equipment operation, feed quality testing, cost optimization, and regulatory compliance for feed manufacturing.

Curriculum 5: Enterprise Development and Value-Chain Management (5 days, 40 hours) addresses business model development, financial literacy, marketing strategies, value-chain linkage formation, cooperative management, and access to finance.

Curriculum 6: Extension Training for Master Trainers (5 days, 40 hours) develops adult learning methodologies, training delivery and facilitation skills, community mobilization techniques, and mentoring capacities for the 300 master trainers who will continue scaling the programme.

Implementation Strategy and Phased Timeline

Programme implementation is organized into three phases spanning 2026–2030 (5 years):

Phase I (2026, Year 1): Foundation and Pilot

Curriculum finalization and validation, infrastructure establishment at D'Prof Resort Training Centre in Badagry (national hub), training of 300 master trainers in six cohorts, pilot community trainings, and programme refinement based on participant feedback

Phase II (2027-2029, Year 2-Year 4): Expansion and Rollout

Training of 9,200 additional participants across 15 coastal states, establishment of five regional satellite training centers, deployment of three mobile training clinics reaching remote communities, enterprise development support including business registration and certification, market linkage facilitation connecting graduates with feed manufacturers and fish farmers, and monitoring of enterprise formation and performance.

Phase III (2030, Year 5): Consolidation and Sustainability

Final training cohorts, certification of 1,000 enterprises, establishment of alumni associations and networks, development of sustainability mechanisms including fee-for-service training generating revenue, comprehensive endline impact evaluation, and transition to sustainable institutional models.

Targeting and Inclusion Mechanisms

Primary beneficiaries are deliberately selected to address structural inequalities and development priorities:

1.Youth (18–35 years, 7,000 trainees, 70% of total) address unemployment in coastal areas where limited opportunities drive rural-urban migration. Training provides marketable skills and entrepreneurship pathways in the emerging blue economy sector.

2.Women (6,000 trainees, 60% of total) are targeted recognizing their roles in fish processing, value addition, and household food security, combined with documented barriers to income generation and asset control (Kruijssen et al., 2018). Training features women-centered curricula content, flexible scheduling, childcare support during residential training, and facilitation of women's producer groups.

3.Existing SMEs and Cooperatives (2,000 participants) including fish farmers, feed producers, and coastal cooperatives seeking to diversify income sources and reduce production costs through alternative ingredient sourcing.

4.Extension Officers and Educators (500 participants) including government extension workers, fisheries officers, and community educators who serve as multipliers, integrating sargassum training into broader agricultural extension programs.

5.Unemployed Graduates (500 participants) including university and polytechnic graduates with marine sciences, agriculture, or food technology backgrounds seeking practical employment skills or entrepreneurship entry points.

Delivery Mechanisms and Learning Approaches

Training delivery employs blended learning combining classroom instruction (30%), practical field-based work (50%), and workshop activities (20%). Classroom sessions cover theoretical foundations, case studies, and group

discussions. Practical field work occurs at coastal collection sites, sargassum processing facilities, and aquaculture farms, emphasizing hands-on application. Workshop activities involve group projects, problem-solving exercises, business plan development, and technology trials.

Assessment and certification require 70% pass marks on written examinations and practical demonstrations. Certification is awarded by NSAVTP in partnership with recognized accreditation bodies (the National Board for Technical Education and Vocational Education and Training institutions), facilitating employer recognition and credential portability.

Anticipated Outcomes and Projected Impacts

Human Capital and Training Outcomes (2026–2030)

Participant follow-up surveys at 6 and 12 months post-training are designed to track employment and income outcomes. The programme sets a target of 70% employment or self-employment within 12 months of course completion, a threshold consistent with international benchmarks for technical and vocational skills training programmes in developing country contexts.

Enterprise Development and Economic Outcomes

Central programme outputs include establishment of 1,000 certified micro-enterprises across sargassum collection, processing, feed manufacturing, and complementary services (equipment leasing, input supply, quality assurance). Micro-enterprises are projected to generate average annual revenues of $1,240–$3,100–$3,450 USD, based on conservative assumptions regarding sargassum biomass pricing and market demand. Cumulatively, programme graduates and their enterprises are anticipated to generate $3.1–$3.4 million USD or more in direct economic value by 2030.

Import Substitution and Foreign Exchange Impacts

Under current trends, Nigeria's aquafeed import bill continues rising due to feed cost inflation and currency volatility. NSAVTP targets a 30% reduction in aquafeed ingredient imports realistic given that sargassum-based formulations can replace 15–30% of fishmeal in aquaculture diets (Estomba et al., 2020). Assuming Nigeria's current annual aquafeed ingredient imports of $400–500 million, a 30% reduction generates $120–150 million in annual foreign exchange savings, contributing significantly to Nigeria's external balance and reducing pressure on the naira.

This import substitution simultaneously strengthens domestic feed manufacturing capacity. Nigeria currently has limited domestic compound feed production relative to demand, with most mills operating below capacity due to ingredient cost pressures. Sargassum-based ingredients reduce production costs and improve competitiveness for domestic feed manufacturers.

Environmental Outcomes

Sustainable harvesting of 50,000 tonnes of sargassum annually within sustainable yield ranges identified by oceanographic research addresses coastal pollution in target areas. Sargassum biomass removal reduces decomposition-related oxygen depletion in coastal waters, diminishes hydrogen sulfide release affecting community health, and restores aesthetic quality to beaches, benefiting fishing and tourism. Caribbean-based sargassum collection initiatives indicate that organised harvesting systems can prevent significant proportions of sargassum from reaching land, with some systems collecting up to 70 tonnes per day and designed to prevent over 70% of sargassum algae from stranding on beaches (Gray et al., 2021).

Beyond direct harvesting, the programme's emphasis on sargassum cultivation through IMTA systems creates additional environmental benefits: cultivated sargassum absorbs excess nutrients from fish farm effluents, reducing eutrophication risk and supporting water quality improvement (Neori et al., 2004). Sargassum's carbon sequestration capacity, estimated at significant volumes given high biomass production contributes to climate change mitigation aligning with Nigeria's Nationally Determined Contributions under the Paris Agreement.

Social Outcomes: Women's Empowerment and Youth Engagement

Training 6,000 women with income-generating skills in an emerging sector transforms gender dynamics within coastal communities. Women's participation in aquaculture enterprises historically concentrates in unpaid or low-paid post-harvest activities; the NSAVTP provides entry points to higher-value processing, feed manufacturing, and enterprise ownership. Parallel support for women's producer groups, savings associations, and access to finance integrated with training addresses institutional barriers to women's economic participation documented in prior research (FAO, 2021).

Youth engagement (7,000 trainees) directly addresses coastal unemployment and associated risks including irregular migration and engagement in illicit activities. The programme provides marketable skills in a demonstrably growing sector, the global seaweed market is projected to expand at approximately 8% annually, with emerging markets alone estimated to generate an additional USD 11.8 billion by 2030 creating clear employment pathways in processing, feed formulation, and enterprise ownership (World Bank, 2023; Anetekhai et al., 2025). Enterprise support, including facilitation of business registration, access to credit, and market linkage formation, provides structured pathways for rapid entry to self-employment in an emerging blue bioeconomy sector.

Anticipated social outcomes align with SDG targets: SDG 1 (No Poverty) through income generation; SDG 2 (Zero Hunger) through improved fish availability and household food security; SDG 5 (Gender Equality) through deliberate women's empowerment; SDG 8 (Decent Work) through job creation; SDG 10 (Reduced Inequalities) through targeted support for marginalized groups; SDG 13 (Climate Action) through coastal resource management and carbon sequestration; and SDG 14 (Life Below Water) through sustainable use of marine resources.

Systemic and Long-Term Impacts (2030–2040, Year 5 - Year 15)

Beyond direct five-year outputs, NSAVTP is designed to catalyze systemic transformation in Nigeria's aquaculture and coastal resource sectors:

i.Industry Evolution: Sargassum-based feed becomes recognized within Nigeria's feed manufacturing sector as a standard ingredient category with established quality standards, processing protocols, and safety certifications. Domestic feed mills transition from 100% import-dependent ingredient sourcing to regionally diversified models incorporating marine biomass. Export potential emerges as West African neighbors facing similar sargassum challenges seek Nigerian expertise and products.

ii.Knowledge Infrastructure: Nigeria establishes itself as a regional center of excellence for macroalgae utilization, attracting research partnerships, development investment, and talent. Applied research programs at universities (FUNAAB, UNILAG, NIOMR) formalize collaborations with NSAVTP, ensuring continuous innovation in sargassum processing, aquafeed formulation optimization, and climate adaptation.

iii.Policy Integration: NSAVTP curricula are integrated into Nigeria's national vocational training system (ITF and NBTE), becoming permanent components of technical education alongside conventional fisheries and agriculture programs. The Fisheries Bill and National Fisheries and Aquaculture Policy (under development) incorporate sargassum sector provisions including harvesting guidelines, environmental safeguards, and incentive frameworks.

iv.Community Resilience: Coastal communities transition from subsistence to diversified income portfolios incorporating sargassum-based enterprises, reducing vulnerability to seasonal fishing variations and climate shocks. Strengthened community organizations (producer groups, cooperatives) provide platforms for collective action addressing coastal governance and resource management.

DISCUSSION

Comparative Advantages and Implementation Considerations

Distinctive Features and Innovation

NSAVTP distinguishes itself from conventional skills training through its comprehensive value-chain integration. Rather than addressing isolated technical components (e.g.aquafeed production techniques divorced from harvesting logistics or market linkages)the programme recognises that sustainable livelihoods require simultaneous attention to technical skill development, enterprise formation, market systems strengthening, and institutional building. This systemic approach aligns with lessons from successful agricultural and aquaculture development interventions demonstrating that comprehensive value-chain integration consistently outperforms isolated, component-based approaches (Ahmed & Lorica, 2002; Davis et al., 2020; Gonzalez Parrao et al., 2021).

The training-of-trainers architecture ensures scalability and sustainability beyond the five-year implementation horizon. The 300 master trainers become permanent agents of knowledge dissemination, capable of establishing satellite centers and community-based programs that multiply impacts far beyond 10,000 direct beneficiaries. International evidence suggests that this model, properly supported, can achieve 5–10x multiplier effects on training reach (FAO, 2020; Davis et al., 2012).

Gender-responsive design is not an add-on but structurally integrated throughout curriculum content, delivery mechanisms, and support systems. This approach emphasizing that gender equality advances sustainable development rather than competing with it reflects evolving evidence and international good practice (FAO, 2021; McDougall et al., 2021).

Alignment with National and Global Priorities

The NSAVTP directly operationalizes Nigeria's Renewed Hope Agricultural Transformation Agenda and aligns with the Federal Ministry of Marine and Blue Economy's mandate for sustainable marine resource utilisation and the ministry's strategic goal of reducing Nigeria's 2.2 million metric tonne fish supply deficit through import substitution and domestic productivity enhancement (Federal Ministry of Marine and Blue Economy, 2025).

Internationally, NSAVTP contributes to multiple SDGs while addressing the specific gap between climate ambition and adaptation implementation in developing countries. Sargassum management through productive utilization represents concrete adaptation to climate-driven ecological change, transforming a climate-related challenge into livelihood opportunity (IPCC, 2022).

Implementation Challenges and Risk Mitigation

Critical implementation risks and mitigation strategies have been identified:

i.Market Development: Creating demand for sargassum-based products requires overcoming established feed supply chains and demonstrating product quality/reliability to risk-averse feed manufacturers. Mitigation involves early engagement of major feed manufacturers as programme partners, demonstration trials demonstrating growth performance equivalence with conventional feeds, and market development activities (trade fairs, industry workshops) building awareness and confidence.

ii.Quality Consistency: Ensuring consistent product quality across 1,000 distributed micro-enterprises operating in diverse conditions requires robust quality standards and certification systems. Mitigation includes developing sector-specific quality standards adapted to Nigerian context, providing quality control training throughout all curricula, implementing enterprise certification and auditing systems, and establishing product testing facilities accessible to graduates.

iii.Sargassum Availability and Seasonality: Annual sargassum availability fluctuates with ocean circulation patterns and climate variability. Mitigation incorporates sargassum cultivation as an alternative/supplementary

supply source through IMTA, develops storage and preservation protocols extending processing seasons, diversifies collection sites geographically, and integrates seasonal business planning into entrepreneurship training.

iv.Multi-State Coordination: Program implementation across 15 states requires clear coordination mechanisms, standardized protocols, and careful management of diverse stakeholder interests. Mitigation includes establishing national steering committee with government and private sector representation, deploying experienced regional coordinators with administrative authority, establishing quarterly coordination meetings and field monitoring visits, and developing digital management systems tracking progress across implementation sites.

Comparative Context: Learning from International Models

While sargassum valorization in West Africa remains nascent, international evidence provides important references. Caribbean research on sargassum management has documented community-based collection and processing initiatives, though most remain small-scale and informal (Gray et al., 2019). The NSAVTP applies more structured, scalable models developed through aquaculture capacity-building in Asia and Africa, particularly the Bangladesh AIN and IDEA projects which demonstrated that comprehensive value-chain training combined with market linkage support generates sustained enterprise formation and income gains (WorldFish, 2018; Keus et al., 2017).

The programme also draws on macroalgae utilization experience in countries like Indonesia, Philippines, and Korea where seaweed farming and processing constitute significant economic sectors supporting millions. However, NSAVTP's distinctive contribution lies in combining sargassum management (addressing an environmental challenge) with aquafeed sustainability (addressing an input constraint) within an explicitly inclusive development framework prioritizing women and youth.

CONCLUSION AND POLICY IMPLICATIONS

Nigeria faces interconnected crises requiring integrated solutions: growing aquafeed dependency draining foreign exchange while limiting farm profitability; escalating coastal sargassum influxes damaging ecosystems and livelihoods; and persistent youth unemployment and gender inequality in coastal areas. Rather than addressing these separately, the NSAVTP proposes a transformative approach converting environmental challenge into economic opportunity through inclusive, evidence-informed capacity development.

The theoretical foundation is robust: circular economy principles legitimizing resource transformation; value-chain frameworks emphasizing systemic strengthening; evidence on gender-responsive capacity building demonstrating impact on women's empowerment and household welfare; and demonstration of technical feasibility of macroalgae in aquafeed formulations. The implementation design reflects international best practice in development programming: phased approach allowing adaptive management, training-of-trainers architecture ensuring scalability, systematic inclusion mechanisms addressing historical marginalization, and clear performance indicators enabling monitoring and evaluation.

Projected outcomes, 1,000 enterprises, $120–150 million annual foreign exchange savings, 6,000 women empowered, 7,000 youth engaged, 50,000 tonnes sargassum processed annually, and 40% coastal pollution reduction represent transformative impact. Critically, these outcomes are achievable: the science of macroalgae in aquaculture is established, capacity-building methods are proven, and the enabling environment (government commitment to blue economy, private sector interest in feed security, community willingness) is present.

For policymakers, the NSAVTP demonstrates how environmental challenges can become development opportunities through integrated design. For practitioners, it exemplifies how international evidence and local knowledge can be synthesized into context-specific programming. For coastal communities, it signals commitment to transforming their circumstances from dependency to agency, recognizing their knowledge, resourcefulness, and aspirations for dignified livelihoods.

The time for implementation is now. Sargassum influxes persist and intensify with climate change. Aquafeed import pressures continue rising. Youth and women await opportunity. The NSAVTP provides a comprehensive, evidence-grounded pathway to simultaneous progress on multiple development fronts. Success will not only benefit Nigeria but provide a model for coastal development relevant across Africa, the Caribbean, and Southeast Asia facing similar challenges.

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