CLIMATE SMART AGRIBUSINESS FINANCING (CSAF) FORESTRY AND WASTE MANAGEMENT

GLOBAL ISSUES & LOCAL PERSPECTIVES

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Preface

This book adopts an exegetical approach as well as a pedagogic model, making it attractive agriculture and environmental economics teachers, professional practitioners and scholars. It is eschews pedantry and lays bars the issues in such clarity that conduces to learning. The book elaborates on contemporaneous **Climate Smart Agribusiness Financing (CSAF) Forestry and Waste Management** issues of global significance and at the same time, is mindful of local or national perspectives making it appealing both to international and national interests. The book explores the ways in which **Climate Smart Agribusiness Financing (CSAF) Forestry and Waste Management** issues are and should be presented to increase the public's stock of knowledge, increase awareness about burning issues and empower the scholars and public to engage in the participatory dialogue **Climate Smart Agribusiness Financing (CSAF) Forestry and Waste Management** necessary in policy making process that will stimulate increase in food production and environmental sustainability. **Climate Smart Agribusiness Financing (CSAF) Forestry and Waste Management :** *Global Issues & Local Perspectives* is organized in two parts. Part One deals with The Concept of **Climate Smart Agribusiness Financing (CSAF)**, Part Two is concerned with The Concept of **Forestry and Waste Management**

Eteyen Nyong; August 2026

Chapter 12

Agro-Processing and Aquaculture Effluent Impacts on Fish Diversity and Water Quality in Southwest Nigerian River Systems: A Green Financing Perspective.

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1.0 Introduction

Water bodies across Southwest Nigeria bear visible and measurable evidence of sustained pollution pressure. Rivers that once ran clear enough to reveal sandy substrates now carry a grey-brown discoloration, which are attributed to high turbidity, organic loading, and dissolved oxygen (DO) depletion beyond the tolerance range of most commercially and ecologically important fish species. The Ona River at Ibadan, the Ogun River at Abeokuta, the Osun River at Osogbo, and numerous tributaries threading through Ondo and Ekiti states each exhibits this degraded water quality profile to varying degrees. The primary sources of contamination are well established: cassava processors, palm oil mills, abattoirs, brewery outflows, and a dense network of fish farms operating within or adjacent to these catchments, the majority of which discharge effluents with no pre-treatment (Awogbami *et al.*, 2023; Ojewole *et al.*, 2024).

The scale of contamination is substantial: Southwest Nigeria hosts some of the highest concentrations of agro-industrial activity on the continent. Cassava processing alone produces waste streams with biochemical oxygen demand (BOD) levels that exceeds 5,000 mg/L, against the 30 mg/L standard set by the NESREA (Oladapo *et al.*, 2023). Palm oil mill effluent (POME), is a dark, acidic, and nutrient-rich liquid, that is occasionally discharged into watercourses across Ondo and Ogun states, producing hypoxic conditions that eliminate sensitive fish species within days of a significant discharge event (Awogbami *et al.*, 2023). Aquaculture contributes a different but equally disruptive suite of stressors: uneaten feed particles, fish metabolites, and antibiotic residues that accumulate in receiving water bodies and modify the microbial and chemical environment in ways that disadvantage wild fish populations (Ojewole *et al.*, 2024).

The ecological consequences are quantifiable; fish assemblages in heavily polluted stretches of Southwest Nigerian rivers are now dominated by pollution-tolerant generalist species, while rheophilic and oxygen-sensitive taxa that historically characterised these systems, including representatives of the families Mormyridae, Schilbeidae, and the commercially important *Synodontis* species, have retreated or disappeared from affected zones (Arimoro *et al.*, 2024). Beyond the loss of species richness, the decline in functional diversity, the range of ecological roles performed by the fish community carries downstream consequences for nutrient cycling, trophic regulation, and the overall resilience of freshwater systems that support both subsistence livelihoods and food supply.

The financial dimension of this crisis is the point from which this chapter departs from most ecological literature on Nigerian water quality. Reversing the damage in these river systems demands capital: capital for wastewater treatment infrastructure, for cleaner production technology, and for monitoring systems capable of enforcing compliance rather than merely documenting violations. Nigeria's federal and state budgets have not reliably delivered this capital. The country's green bond framework, first activated at the sovereign level in 2017 and more recently expanded through sustainability-linked loans and blended-finance vehicles, offers a funding architecture that could plausibly be redirected toward freshwater remediation at scale (Obayagbona and Imade, 2024; Nkombo, 2024). Whether this redirection occurs depends on the political will to classify river ecosystem restoration as a green-eligible expenditure and to hold borrowers accountable to measurable ecological outcomes. This chapter makes the case that it should, and draws on the Southwest Nigerian evidence base to specify how such capital should be deployed.

2.0 The Agro-Processing Landscape in Southwest Nigeria

2.1 Dominant Industries and Their Geographic Distribution

Southwest Nigeria encompasses six states: Lagos, Ogun, Oyo, Osun, Ondo, and Ekiti. The region's agricultural economy is built on several commodities requiring industrial processing before they reach consumers, and it is at the processing stage that the most environmentally consequential waste is generated.

Cassava is the most extensively processed crop in the region. Nigeria produces approximately 60 million metric tonnes of cassava annually, with the Southwest accounting for a substantial share of both production and value-added processing (Oladapo *et al.*, 2023). Converting cassava roots into garri, fufu, and high-quality flour generates large volumes of steep water and pressing liquor containing cyanogenic compounds, high suspended solid concentrations, and organic matter capable of driving significant oxygen depletion in receiving water bodies (Nweke and Onuoha, 2024). Processing units range from household-scale wooden presses in rural communities to semi-mechanised operations serving urban markets. Across both scales, proximity to streams and rivers is deliberate because water is used at nearly every stage of processing, from soaking and fermentation through to washing (Izah *et al.*, 2023).

Palm oil processing is the second major source of agro-industrial effluent, particularly in Ondo, Ogun, and Imo states. POME is generated in large volumes during sterilisation, digestion, and clarification. For every tonne of crude palm oil produced, approximately 2.5 tonnes of POME are released, and in the small-scale mills that dominate Southwest Nigeria, this liquid is typically discharged directly into surface drainage rather than managed through purpose-built lagoons or treatment plants (Awogbami *et al.*, 2023). POME has a characteristically low pH of between 3.5 and 4.5, an extremely high BOD of 25,000 to 65,000 mg/L, and a deep brownish-red colour that suppresses aquatic photosynthesis in receiving waters.

Abattoir operations concentrated around urban centres, particularly the large Bodija market abattoir in Ibadan and slaughterhouses in Lagos and Abeokuta, contribute a third major waste stream. Effluent from these facilities contains blood, urine, fat residues, undigested feed, and pathogenic microorganisms. Studies conducted at the Oko-Oba River in Agege, Lagos, where an abattoir drains directly into the watercourse, documented BOD values of 5,009 mg/L along with elevated lead, chromium, and nickel concentrations (Agboola *et al.*, 2024). The combination of organic loading and heavy metal contamination creates a compound stress environment for aquatic biota that is qualitatively more damaging than single-source pollution.

Breweries, textile mills, and food processing factories along the Lagos-Ibadan corridor add to this cumulative burden. Their effluents tend to be more chemically diverse, often including synthetic dyes, surfactants, and heavy metals. The Ona River in Ibadan, which receives effluent from multiple industrial estates along its course, has recorded BOD and chemical oxygen demand (COD) values exceeding permissible limits across multiple monitoring campaigns from 2022 through 2024 (Mmonwuba *et al.*, 2023; Laniyan *et al.*, 2024).

2.2 The Regulatory Gap

Nigeria's regulatory framework for industrial effluent discharge exists in credible statutory form. NESREA's National Environmental (Surface and Groundwater Quality) Regulations, gazetted in 2011, set enforceable standards for BOD, COD, suspended solids, heavy metals, and other parameters. The problem lies in the gap between legislation and enforcement. Most small and medium-scale agro-processing operations do not hold environmental permits, rarely conduct self-monitoring, and have never received a compliance inspection (Ohwo and Ndakara, 2022). Where inspections do occur, financial penalties for non-compliance are low enough to be absorbed as a routine operating cost rather than functioning as a deterrent.

This enforcement weakness is not unique to Nigeria among sub-Saharan African economies, but its consequences in Southwest Nigeria are acute given the density of industrial activity relative to the flow volume of many local rivers. Several tributaries of the Ogun and Osun systems have essentially no dilution capacity during the dry season, meaning that pollutant loads entering between December and March remain chemically concentrated at ecologically damaging levels for extended periods (Adeogun *et al.*, 2024).

3.0 The Expanding Aquaculture Sector and Its Effluent Profile

3.1 Growth Trajectory and Southwest Nigeria's Share

Nigeria is the second-largest aquaculture producer in Africa, with total production reaching approximately 321,000 tonnes in 2022 and growing at an estimated 3% annually (Ogunji and Wuertz, 2023). African catfish (*Clarias gariepinus*) accounts for 54% of national aquaculture output, with Nile tilapia (*Oreochromis niloticus*) making up much of the remainder. Southwest Nigeria, with its relatively reliable water supply, proximity to urban feed markets, and strong consumer demand for fresh catfish, hosts a disproportionately large share of the country's registered fish farms. Ondo, Ogun, and Oyo states together account for a significant portion of domestic aquaculture, and the number of unregistered operations is estimated to be considerably higher (Ojewole *et al.*, 2024).

While this growth trajectory is broadly positive for food security, Nigeria imports an estimated 700,000 tonnes of fish annually to supplement domestic production, and aquaculture remains the most viable path to closing that gap (FAO, 2024). The environmental cost of unmanaged expansion falls directly on the river systems that many farming communities rely on for water abstraction and, in some cases, for wild fingerling collection.

3.2 Composition and Environmental Load of Aquaculture Effluent

Aquaculture wastewater derives from three principal sources: uneaten feed settling on pond floors or suspended in the water column, metabolic waste products of cultured fish such as ammonia, urea, and carbon dioxide, and residues of veterinary medicines, particularly antibiotics administered to counter bacterial infections under intensive stocking conditions (Ojewole *et al.*, 2024). The effluent composition varies substantially by culture system. Open earthen ponds, the dominant system in Southwest Nigeria, generate a diffuse but chronically elevated effluent load, while recirculating aquaculture systems (RAS), which are expensive and largely confined to commercial-scale operators, concentrate waste but allow for controlled pre-discharge treatment.

When earthen pond water is flushed or harvested, the effluent released into adjacent watercourses contains total suspended solids reaching 150 to 300 mg/L, ammonia nitrogen at concentrations toxic to sensitive wild fish species at levels above 0.5 mg/L, and phosphorus loads sufficient to trigger algal blooms in slow-moving or impounded reaches (Ojewole *et al.*, 2024). Ojewole *et al.* (2024), publishing in *Scientific African*, identified eutrophication, food poisoning through bioaccumulation, and antibiotic resistance gene proliferation as the three most ecologically consequential outcomes of unmanaged aquaculture wastewater discharge in Nigerian freshwater systems.

The antibiotic residue dimension warrants particular attention. Oxytetracycline, florfenicol, and sulfonamides are routinely used in Nigerian fish farms to control *Aeromonas hydrophila* and other bacterial pathogens. When these compounds enter river water, they exert selection pressure on microbial communities, accelerating the development and spread of antibiotic resistance genes (ARGs) detectable in river sediments downstream of farm discharge points. Evidence from comparable West African contexts shows that ARG proliferation alters microbial community structure in ways that reduce the natural self-purification capacity of rivers, producing a feedback loop in which pollution impairs the very mechanisms through which rivers recover from pollution (Zhou *et al.*, 2024).

3.3 Cumulative Loading in Shared Catchments

The most problematic situations arise in catchments where agro-processing operations and fish farms share the same watercourse. The Odo-Owa stream in Ogun State illustrates this precisely: organic effluent from a fish farm interacted with upstream processing waste to drive dissolved oxygen below 4 mg/L, the threshold below which *Chrysichthys nigrodigitatus* and *Labeo parvus* begin to experience acute physiological failure (Adeogun *et al.*, 2024). Synergistic effects from combined waste streams are harder to attribute and monitor than single-source impacts, which partly explains why they attract comparatively limited regulatory attention.

4.0 Water Quality Deterioration: Mechanisms and Measured Outcomes

4.1 Physicochemical Changes in Receiving Water Bodies

The physicochemical changes driven by agro-processing and aquaculture effluent in Southwest Nigerian rivers follow a predictable pattern, even if specific parameters and magnitudes vary by effluent type, season, and river morphology.

Dissolved oxygen (DO) is the most ecologically critical variable affected. Organic matter entering a river exerts a biological oxygen demand as microbial communities decompose it, consuming oxygen faster than surface reaeration can replenish it. Monitoring in the Ona River catchment between 2022 and 2024 documented DO values as low as 2.1 mg/L at stations immediately downstream of industrial discharge points, compared with 7.2 to 8.0 mg/L at upstream reference stations (Mmonwuba *et al.*, 2023; Laniyan *et al.*, 2024). At the Ogbuamuma River in Imo State, DO dropped to 4.3 mg/L while nitrate concentrations spiked between 21.6 and 40.2 mg/L at heavily impacted stations (Ogbuamuma *et al.*, 2024). Most stenothermal, oxygen-sensitive fish species require DO above 5 mg/L for normal aerobic function and cannot survive extended exposure below 4 mg/L.

BOD and COD values at discharge-affected stations in Southwest Nigerian rivers routinely exceed national permissible limits by margins that render the figures almost implausible. BOD levels of 200 to 800 mg/L are not uncommon in stretches of the Ogun River receiving POME during peak processing season (Awogbami *et al.*, 2023). COD values at the Ona River have been sufficient to classify it as heavily polluted under all major water quality index schemes (Mmonwuba *et al.*, 2023). Both parameters serve as proxies for the physiological stress imposed on aquatic biota.

Nitrogen and phosphorus loading from aquaculture and agro-processing drives eutrophication, the nutrient-driven proliferation of algae and cyanobacteria that depletes oxygen during nocturnal respiration and physically clogs fish gill structures. In Southwest Nigerian rivers, where water temperatures range from 26°C to 32°C year-round, algal growth kinetics following nutrient enrichment are considerably faster than in temperate systems, meaning eutrophication events can develop within days of a significant effluent discharge (Akinnawo, 2023). The nitrogen cycle in these warm, shallow systems also generates elevated ammonia concentrations from organic decomposition, with un-ionised ammonia (NH_3) being directly toxic to sensitive species at concentrations above 0.02 mg/L (Ojewole *et al.*, 2024).

pH shifts, driven by the acidity of POME and cassava pressing liquor, push river chemistry outside the tolerances of most freshwater fish, which function optimally between pH 6.5 and 8.5 and experience reproductive disruption, skeletal abnormalities, and immune suppression at values below 6.0 (Awogbami *et al.*, 2023). Heavy metal accumulation from abattoir and industrial effluents, including lead, cadmium, chromium, and nickel, constitutes a more insidious form of water quality degradation because these metals persist in sediments long after the source is removed, bioaccumulate in fish tissue through the food chain, and pose a direct public health risk to communities consuming locally caught fish (Agboola *et al.*, 2024).

4.2 Seasonal Dynamics

River pollution in Southwest Nigeria follows a pronounced seasonal pattern that affects both the severity of water quality degradation and its ecological consequences. During the dry season, running roughly from November to March, pollutant loads concentrate in reduced water volumes, driving parameter exceedances to their annual peaks. This coincides with the spawning period for many indigenous fish species, making them particularly vulnerable to chemical stressors at precisely the moment when reproductive success determines next-year population size.

During the wet season, from April to October, effluent concentrations are diluted but large pulse loads of non-point-source pollution are mobilised from agricultural runoff, carrying pesticides, fertiliser residues, and topsoil from cassava farmlands into rivers already burdened by point-source discharges. The net result is that no season offers clean water for aquatic biota in the most affected catchments; the stressors shift in character but not in ecological consequence (Awogbami *et al.*, 2023; Adeogun *et al.*, 2024).

5.0 Impacts on Freshwater Fish Diversity

5.1 Historical Context and Baseline Diversity

Southwest Nigerian rivers historically supported species-rich fish assemblages reflecting the region's position within the wider Niger Basin ichthyofaunal province and its distinctive semi-independent drainage systems flowing from the Yoruba uplands to the Bight of Benin. Surveys conducted before the major industrialisation of the Lagos-Ibadan corridor in the 1980s recorded over 200 freshwater fish species across the region's main river systems, including rheophilic species adapted to fast-flowing, well-oxygenated headwaters and highly specialised predators associated with structurally complex riverine habitats (Arimoro *et al.*, 2024).

This historical baseline is the appropriate reference point against which contemporary degradation should be measured. Without it, researchers and policymakers risk calibrating their expectations against an already-degraded condition, a phenomenon known in the fisheries literature as shifting baseline syndrome. The species that have disappeared from these rivers did not do so because they were ecologically marginal; they disappeared because the habitat conditions their survival required were removed.

5.2 Documented Changes in Species Composition and Abundance

Contemporary fish surveys in Southwest Nigerian rivers consistently document community simplification. Studies conducted in the Ogun and Osun systems between 2022 and 2024 found that stations downstream of major effluent discharge points were dominated by *Tilapia zillii*, *Clarias gariepinus*, *Hemichromis bimaculatus*, and *Parachanna obscura*, all generalist species capable of tolerating reduced oxygen, elevated turbidity, and acidic conditions. Species from the families Mormyridae, Alestidae, and Citharinidae, which require clean, well-oxygenated water and are sensitive to both chemical stressors and habitat modification, were absent or dramatically reduced at impacted stations (Arimoro *et al.*, 2024).

The Ona River study in Ibadan documented a specific pattern with bioindicator significance: the Ephemeroptera-Plecoptera-Trichoptera (EPT) assemblage, which serves as a standard bioindicator of water quality, was entirely absent at the most impacted stations, while pollution-tolerant Dipteran larvae dominated the benthic invertebrate community (Jonah *et al.*, 2020). Fish assemblage structure at comparable sites typically mirrors this bioindicator outcome: where EPT insects are absent, fish communities are structurally simplified and dominated by opportunistic generalists.

The loss of functional diversity is as ecologically significant as the loss of species richness. When predatory species that historically regulated invertebrate populations decline, prey populations can irrupt, reshaping community structure from the base of the food web upward. When filter-feeding fish decline, particulate organic matter accumulates more rapidly in the water column, accelerating eutrophication and further degrading conditions for sensitive taxa. These cascading effects mean that the ecological damage from agro-processing and aquaculture effluent extends well beyond directly affected fish species to restructure the trophic dynamics of impacted river reaches (Arimoro *et al.*, 2024).

5.3 Implications for Artisanal Fisheries and Food Security

The simplification of fish communities in Southwest Nigerian rivers translates directly into declining catch yields and reduced dietary quality for riparian communities, often among the poorest in the region, whose livelihoods depend on artisanal fishing. Evidence from comparable river systems across West Africa documents that a shift from diverse multi-species assemblages to communities dominated by two or three generalist species reduces both the nutritional diversity and the economic value of catches per unit effort, compounding the livelihood pressures already weighing on artisanal fishing households (Karani, 2024).

In the context of Southwest Nigeria, where protein deficits characterise the diets of a significant share of the population, the progressive loss of riverine fish drives communities either toward more expensive market fish, toward greater consumption of farmed catfish that may carry antibiotic residues, or toward reduced protein intake altogether. The health and economic costs of this trajectory are real but are rarely quantified in forms that are visible to financing institutions evaluating investments in water quality infrastructure.

6.0 Existing Governance and Management Frameworks

6.1 Regulatory Institutions and Their Limitations

Nigeria's environmental regulatory architecture involves multiple institutions at federal and state levels. At the federal level, NESREA is the primary enforcement body for environmental quality standards, operating under the National Environmental Standards and Regulations Enforcement Agency (Establishment) Act of 2007. State-level environmental protection agencies (SEPAs) hold concurrent jurisdiction over local point-source discharges, and their institutional capacity varies considerably across the six Southwest states.

In practice, jurisdictional overlap creates accountability gaps rather than complementary oversight. Agro-processing operations below certain employment and turnover thresholds fall outside NESREA's formal registration requirements, while SEPAs frequently lack the laboratory capacity, inspection vehicles, and qualified personnel to conduct meaningful compliance monitoring (Ohwo and Ndakara, 2022). The result is a regulatory system with adequate statutory authority but insufficient operational capacity to translate that authority into behaviour change at the mill or farm gate.

6.2 International Commitments and SDG Alignment

Nigeria's commitment to Sustainable Development Goal 6 (SDG 6) - clean water and sanitation provides the overarching framework within which river quality improvement should be situated. A 2025 review of Nigeria's SDG 6 performance documented persistent gaps in wastewater treatment coverage, particularly for industrial and agricultural effluent, with significant shortfalls against targets for the proportion of safely treated wastewater (Adewoye *et al.*, 2025). This framing is relevant for green finance because SDG alignment is among the criteria that multilateral development banks and green bond framework administrators use to assess the eligibility of proposed expenditures.

The Paris Agreement's adaptation provisions are also applicable. Southwest Nigeria's river systems deliver critical ecosystem services, including water supply, flood attenuation, and fishery provisioning, that climate change is projected to degrade through altered rainfall patterns and increased drought frequency. Investments that restore river ecosystem function simultaneously advance climate adaptation objectives, making them eligible for climate finance instruments that might not otherwise classify freshwater biodiversity as a core concern.

7.0 A Green Financing Perspective

7.1 The Concept and Architecture of Green Finance

Green finance refers to financial instruments and institutional arrangements designed to direct capital toward activities that produce measurable environmental benefits while meeting the risk-return criteria required by investors. The category encompasses a range of tools: green bonds, sustainability-linked loans, green loans, green equity, blended-finance structures that combine concessional public capital with commercial private investment, and payment-for-ecosystem-services arrangements that generate revenue streams from verified ecological improvement (ASM, 2024).

The defining logic of green finance instruments is accountability. Unlike conventional loans or grants, green bonds issued under frameworks conforming to the International Capital Market Association (ICMA) Green Bond Principles require issuers to ring-fence proceeds for verified green expenditures, report on the use of funds, and ideally report on measured environmental outcomes. Sustainability-linked loans (SLLs) tie the interest rate to the borrower's performance against pre-agreed environmental key performance indicators (KPIs), creating a financial incentive for meeting targets rather than simply spending money on designated activities (ASM, 2024).

7.2 Nigeria's Green Finance Trajectory

Nigeria entered the sovereign green bond market ahead of most African peers. Its first sovereign green bond, issued in December 2017 at N10.69 billion, was Africa's first climate-certified sovereign green bond, with proceeds directed toward solar energy and afforestation projects (Obayagbona and Imade, 2024). Subsequent issuances followed, and in 2025 the Federal Government issued a third sovereign green bond worth N50 billion targeting renewable energy, clean transportation, water management, and climate adaptation (Nkombo, 2024).

Nigeria also announced plans for a US$250 million international sovereign green bond in September 2024, with proceeds directed toward climate mitigation and adaptation projects (Obayagbona and Imade, 2024). At the subnational level, Lagos State has issued green bonds for urban infrastructure, and Gombe State announced plans for a N30 billion green bond targeting climate-smart agriculture (Nkombo, 2024). Despite this trajectory, Africa's share of the global green bond market remains below 1% of total global issuance, which exceeded US$2 trillion by 2022 (ADB, 2024). Freshwater ecosystem restoration, which requires sustained capital rather than single-project investments, has not yet been systematically incorporated into Nigeria's green finance agenda.

7.3 Applying Green Finance to River System Restoration

The application of green finance to agro-processing and aquaculture effluent management in Southwest Nigeria requires addressing the problem at two distinct scales: individual facility-level treatment investment and catchment-level ecosystem restoration.

At the facility level, the primary need is capital for effluent treatment infrastructure that small and medium-scale agro-processors cannot finance from operating cash flows. A cassava mill processing 20 tonnes of raw tubers daily requires a constructed wetland, biodigester, or equivalent biological treatment system that may cost N2 to N5 million to install, an amount representing months or years of net income for operators in the informal economy. Green loans channelled through commercial banks, with interest rate subsidies funded through concessional capital from multilateral development banks, could make this investment accessible at affordable repayment schedules (ASM, 2024; ECOWAS Bank for Investment and Development, 2026). Sustainability-linked loans tied to verified reductions in effluent BOD concentrations at facility discharge points would add the accountability dimension that distinguishes green finance from conventional subsidised lending.

For aquaculture operations, the priority investment is adoption of constructed wetlands and integrated aquaculture-agriculture systems that redirect nutrient-laden effluent toward crop production rather than discharging it into rivers. Phytoremediation using water hyacinth (*Eichhornia crassipes*) and other aquatic macrophytes has demonstrated cost-effective nutrient removal in Nigerian trials, and its capital requirements are modest enough for smallholder fish farmers to manage with limited loan capital (Ojewole *et al.*, 2024). Recirculating aquaculture systems represent a higher-capital investment requiring larger loan sizes but offer virtually zero effluent discharge and are likely the long-term direction for commercial-scale operations if environmental standards tighten.

At the catchment level, restoration of riparian buffers, re-establishment of wetland areas that historically intercepted agricultural runoff before it reached main channels, and targeted removal of accumulated sediments and legacy pollutants from impacted river beds produce diffuse, long-term benefits rather than easily monetisable returns. These are precisely the expenditures most difficult to finance through commercial instruments but most appropriate for sovereign green bond proceeds or climate adaptation grants channelled through multilateral climate funds, including the Green Climate Fund, which maintains an active country programme in Nigeria through the Federal Ministry of Finance (ADB, 2024).

7.4 Green Finance for Monitoring and Institutional Capacity

A significant part of the green finance challenge in Southwest Nigeria involves funding the monitoring and institutional systems without which any treatment investment produces unverifiable outcomes. Green bond and sustainability-linked loan frameworks require credible measurement, reporting, and verification (MRV) systems to demonstrate that proceeds have been spent as intended and that environmental outcomes have been achieved. Nigeria's existing water quality monitoring infrastructure, fragmented across federal and state agencies with inadequate equipment and limited laboratory capacity, cannot currently support the MRV requirements of serious international green finance issuances linked to freshwater ecosystem outcomes (Adewoye *et al.*, 2025).

Addressing this MRV deficit requires dedicated investment in institutional capacity, and blended-finance structures that combine grant capital, technical assistance, and private investment have a clear role in delivering it. Grant funding from development partners such as the United States Agency for International Development, the European Union's Global Gateway initiative, and the African Development Bank could finance the establishment of river basin monitoring networks with automatic sensing stations, laboratory capacity, and data management systems. Once this monitoring infrastructure exists, it creates the verified environmental baseline against which green bond-financed interventions can demonstrate improvement, which in turn unlocks the commercial investment needed to scale impact.

7.5 Policy Reforms That Green Finance Requires

Green finance alone cannot deliver river ecosystem restoration in Southwest Nigeria. Three foundational policy reforms are necessary.

First, formal classification of freshwater ecosystem restoration as a green-eligible expenditure category within Nigeria's National Green Bond Framework is needed. The current framework prioritises renewable energy, energy efficiency, and sustainable agriculture, but does not explicitly list river water quality improvement or aquatic biodiversity conservation as eligible project categories. Expanding the framework to include these would signal to issuers and investors that river restoration bonds are a legitimate instrument, and would allow existing participants to develop standardised project templates for facility-level effluent treatment financing (Obayagbona and Imade, 2024).

Second, strengthened NESREA enforcement capacity is essential. Green finance for treatment infrastructure produces environmental outcomes only if non-compliance with effluent standards carries a real cost. Operators who do not treat their effluent must not be able to undercut, on price, those who do. NESREA's enforcement budget, inspection frequency, and penalty schedules all require reform, and this reform could itself be partially financed through a green finance facility dedicated to regulatory capacity building.

Third, coordination between Nigeria's aquaculture regulatory framework and its environmental regulatory framework needs strengthening. Fish farm licences are currently issued by State Ministries of Agriculture without systematic environmental impact assessment or reference to NESREA effluent standards. Integrating environmental compliance into aquaculture licensing, with graduated standards tied to farm size, stocking density, and proximity to sensitive river reaches, would create the regulatory foundation that green-financed treatment investment requires.

8.0 Case for Integration: Ecological and Financial Returns

8.1 The Economic Case for Investing in River Health

The case for green finance in river ecosystem restoration in Southwest Nigeria is not purely ecological. There is a coherent economic argument built on avoided costs of water treatment at urban intakes, sustained yield from artisanal fisheries that healthy rivers support, reduced healthcare costs from waterborne disease in riverside communities, and the long-term productivity of irrigated agriculture drawing on rivers with acceptable chemical quality.

The Ogun-Osun River Basin Development Authority manages a network of dams and irrigation schemes across Southwest Nigeria that depend on adequate water quality in the Ogun River catchment. Deterioration of raw water quality at intake points requires increased chemical dosing and filter maintenance at treatment works, costs that fall on urban water consumers and state budgets. Quantifying these avoided-treatment costs provides one basis for the cost-benefit analysis that green bond issuers and impact investors require before committing capital. When these economic co-benefits are aggregated alongside the ecological and public health returns, the case for directing green finance toward Southwest Nigeria's river systems becomes considerably stronger than a purely environmental framing would suggest.8.2 Insights from Similar Situations

Morocco's sustainability-linked agricultural loans, tied to water use efficiency key performance indicators, offer a transferable model for incentivizing effluent management in Nigeria's agro-processing sector (ASM, 2024). In that programme, agribusiness firms received preferential lending rates contingent on demonstrated and measured reductions in water consumption and pollutant load, verified by independent auditors. The financial incentive was modest in absolute terms but, combined with market reputation effects, was sufficient to drive behaviour change among participating firms.

Kenya's experience with integrated catchment management in the Lake Victoria basin, where donor-financed wetland restoration substantially reduced nutrient loading from agricultural areas, demonstrates the ecological effectiveness of the basin-scale approach that Southwest Nigeria's interconnected river systems would require. The lesson from Kenya is that ecological success depends as much on community engagement and land use planning as on physical treatment infrastructure, and that community buy-in is itself an investment requiring dedicated funding and time to cultivate (Karani, 2024).

9.0 Conclusion

Southwest Nigerian rivers face sustained pressure from agro-processing and aquaculture effluents that drive water quality parameters well beyond the thresholds at which ecologically and economically important fish species can reproduce and survive. The mechanisms of damage are well documented: organic loading depletes dissolved oxygen, nutrient enrichment drives eutrophication, heavy metals bioaccumulate through food chains, and antibiotic residues compromise the microbial communities that underpin natural river self-purification. Ecological outcomes are recorded across multiple river systems: community simplification, disappearance of sensitive taxa, and declining artisanal catch yields that affect food security among some of the region's most economically marginalised communities.

The regulatory system that should prevent these outcomes has the correct statutory architecture but lacks the operational capacity and political commitment to enforce it. The budgetary resources to build that capacity and simultaneously finance the treatment infrastructure that compliance would demand have not flowed through conventional public spending channels. Green finance represents a structured alternative, and Nigeria's sovereign green bond programme, its growing sustainability-linked loan market, and its engagement with multilateral climate finance all provide the scaffolding on which a targeted strategy for river ecosystem restoration could be built.

What this requires in practice is specific: formal inclusion of freshwater restoration in Nigeria's Green Bond Framework eligibility criteria; green loan products through commercial banks for small and medium-scale agro-processors unable to self-finance treatment systems; integration of environmental compliance into aquaculture licensing; and grant-funded investment in the monitoring infrastructure that makes any of this verifiable and therefore credible to international investors. None of these steps is technically complicated. They require political commitment to treating river ecosystems as productive assets rather than convenient waste disposal channels, and they require financial institutions to recognise that in Southwest Nigeria, the cost of not investing in clean rivers is ultimately higher than the cost of doing so.

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