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Cocoa Beyond Boundaries: Transforming Ivory Coast's Cocoa Sector Through By-Product Valorisation

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ABSTRACT

Ivory Coast supplies approximately 40% of global cocoa production, yet the majority of its 2.5 million smallholder farmers remain below the poverty line, earning less than $1.90 per day. This paradox persists because the sector relies overwhelmingly on raw bean exports, leaving the substantial economic value embedded in cocoa by-products—husks, pulp, and butter—largely unrealised. This study employed a mixed-methods approach combining primary survey data from 500 smallholder farmers across San Pedro, Soubré, and Issia with secondary data from ICCO reports, World Bank datasets, and Fair Trade International benchmarks. Economic modelling, life-cycle assessment (LCA) following ISO 14040 standards, cost-benefit analysis, GIS mapping of 120 cooperatives, and comparative policy analysis (Ivory Coast versus Ghana) were used to quantify economic, environmental, and social impacts. Results project that localised by-product processing could generate up to $172 million annually and create approximately 15,000 jobs, 40% benefiting women. Husk-derived biofuels yield 1.8 kg CO_2-eq/kg—a 47% reduction relative to diesel—and could electrify 30% of off-grid villages in Issia. The "Butter of Hope" women's cooperative demonstrated a 70% household income increase and a 14 percentage-point reduction in child labour. Increasing tax incentives from 10% to 20% is estimated to unlock $3.80 in export revenue per $1 invested. Findings demonstrate that cocoa by-product valorisation offers a replicable blueprint for transforming a commodity-trapped sector into a multi-sectoral development engine across the Global South. Policy reforms, gender-inclusive cooperative scaling, and investment in modular processing infrastructure are essential to realising this potential.

Keywords: cocoa by-products; circular economy; Ivory Coast; smallholder farmers; women's cooperatives

INTRODUCTION

Ivory Coast (Côte d'Ivoire) is the world's largest cocoa producer, accounting for approximately 40% of global supply and sustaining the livelihoods of an estimated 6 million people, including over 2.5 million smallholder farmers concentrated in the producing regions of San Pedro, Soubré, and Issia [1]. Despite this dominant market position, approximately 75% of these farmers live below the international poverty line of $1.90 per day, a paradox driven by price volatility, progressive deforestation (estimated at 15% forest loss since 2000), and severely underdeveloped processing infrastructure [2, 3]. As one farmer from Soubré observed: "We harvest gold but live in dust" (Koffi N'Guessan, survey response #247, 2024). This structural poverty persists not because of any scarcity of natural endowment, but because value capture along the cocoa supply chain remains concentrated in importing countries.

The economic inequity is compounded by the systematic neglect of cocoa by-products. The processing of Theobroma cacao generates substantial volumes of husks, pulp, and residual cocoa butter, each containing scientifically documented bioactive compounds—flavonoids, polyphenols, theobromine, organic acids, and fatty acids—that confer demonstrable nutritional, pharmaceutical, and industrial utility [4, 5]. Yet the majority of these materials are treated as waste, creating both an environmental burden and a foregone economic opportunity.

The seasonality of Ivory Coast's cocoa sector further compounds farmer vulnerability. Average household income stands at approximately $2,707 per year—well below the living income benchmark of $7,318—and only 7% of farmers currently achieve this benchmark [1, 2]. This study addresses three interlinked gaps: (1) no integrated analysis has assessed combined economic, environmental, and social returns of cocoa by-product valorisation within Ivory Coast's production context; (2) evidence-based models for women-inclusive cooperative scaling remain underdeveloped; and (3) comparative policy analysis between Ivory Coast and Ghana has not been systematically applied to derive actionable incentive structures for by-product processing.

This article makes the following original contributions: (a) the first integrated quantitative assessment of cocoa by-product valorisation potential in Ivory Coast; (b) life-cycle assessment data establishing the environmental case for husk-derived bioenergy; (c) evidence-based policy models derived from comparative Ivory Coast–Ghana analysis; and (d) a gender-inclusive cooperative scaling framework grounded in pilot data from the "Butter of Hope" cooperative in Issia.

METHODOLOGY

Research Design

This study adopted a mixed-methods research design integrating quantitative economic and environmental modelling with qualitative field data, enabling triangulation across three analytical dimensions: economic impact, environmental sustainability, and social equity [6]. The research was structured around four complementary strands.

Primary Data Collection

Structured surveys were administered to 500 smallholder farmers across San Pedro, Soubré, and Issia using stratified random sampling with strata defined by region, farm size, and cooperative membership [7, 8]. In-depth field interviews were conducted with representatives of 12 cooperatives—including the "Butter of Hope" women's cooperative in Issia—to evaluate gender-inclusive business models and identify institutional enablers and barriers to by-product valorisation.

Secondary Data and Case Study Analysis

Secondary data were drawn from ICCO commodity reports (2024), World Bank poverty and agricultural datasets (2020, 2024), Fair Trade International sustainability benchmarks (2023), and the Ivorian Ministry of Environment deforestation statistics (2024). International best practices were analysed through case studies of Ghana's Cocoa Board (Cocobod) subsidy and training programmes [9], Ecuador's cocoa pulp commercialisation sector, and Kenya's community-led asset-building cooperatives.

Economic and Environmental Modelling

Cost-benefit analysis was conducted for three priority by-product streams: husk-to-biofuel pellets, cocoa pulp processing, and cocoa butter refinement [10]. Life-cycle assessment (LCA) was conducted following ISO 14040:2006 and ISO 14044:2006 standards [11, 12], comparing greenhouse gas emissions from cocoa husk biofuel against the diesel baseline across the full production chain.

Spatial and Policy Analysis

GIS mapping identified locations of 120 cooperatives and optimised the placement of proposed modular processing infrastructure relative to raw material availability, transport corridors, and rural energy deficits [13]. Comparative policy analysis examined subsidy structures, tax incentive rates, and farmer training coverage between Ivory Coast and Ghana [14, 9].

Bioactive Compound Quantification

Polyphenol content in cocoa husks was quantified using Folin-Ciocalteu spectrophotometry, with flavonoid and procyanidin fractions characterised by high-performance liquid chromatography (HPLC) [5].

Cocoa butter fatty acid profiles were determined by gas chromatography-mass spectrometry (GC-MS) [15]. Pulp organic acid content was measured using titrimetric analysis.

RESULTS

Cocoa Husks: From Agricultural Waste to Multi-Sector Resource

Bioenergy applications.

LCA results confirm that husk-derived biofuel pellets generate 1.8 kg CO_2-eq per kilogram of energy equivalent—a 47% reduction relative to diesel (3.4 kg CO_2-eq/kg) [16, 17]. Modelling indicates that husk biofuel could supply approximately 20 MW per year, sufficient to electrify 30% of off-grid villages in the Issia sub-region. Husk pellet production is projected to generate $30 million per year across the three study regions (Table 1).

Polyphenol extraction and health applications.

Polyphenol-rich husk extracts have documented anti-inflammatory and antioxidant properties [5, 18]. A pilot intervention in San Pedro yielded a 20% reduction in clinic costs, equivalent to $500 per clinic per year. Husk polyphenol cooperatives in San Pedro are estimated to generate approximately $9 million per year (Table 1).

Soil restoration and agricultural productivity.

Composted cocoa husk applied to trial plots in Issia increased yields by 15–20% and reduced synthetic fertiliser expenditure by approximately $100 per hectare per year [19]. Deforestation rates in pilot circular-economy areas declined by 5% over the observation period.

Animal feed.

When subjected to detoxification processing, cocoa husks represent a viable and cost-competitive livestock feed supplement [20], estimated to generate approximately $5 million per year in the Issia region.

Cocoa Pulp: An Underexploited Commercial Opportunity

B1. Wine and juice production.

A pilot study in Soubré demonstrated a 25% increase in household income—equivalent to $50 per month—for 200 participating families [20]. The aggregate market potential is estimated at $20 million per year (Table 1).

B2. Pectin extraction and food preservation.

Application to jam and preserve production in Issia reduced post-harvest losses by 25%, saving approximately $2 million per year. Across the three regions, pectin applications are projected to generate $8 million per year (Table 1).

B3. Skincare and dermatological applications.

The organic acids present in cocoa pulp have documented efficacy in treating contact dermatitis from pesticide exposure [21]. Value-addition processing reduces BOD_5 from 28,000 mg/L to 4,200 mg/L—an 85% reduction—while generating $127 per hectare in additional revenue (Table 2).

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Cocoa Butter: Beyond the Chocolate Industry

C1. Pharmaceutical and cosmetic applications.

Cocoa butter's fatty acid profile (35% oleic, 34% stearic, 25% palmitic; melting point 34–38°C) renders it chemically ideal for topical pharmaceutical formulations and cosmetic emollients [22, 15]. Local production of ointments for eczema and skin conditions in Soubré is estimated to save $3 million per year in import substitution.

C2. Women's economic inclusion: The "Butter of Hope" cooperative.

The "Butter of Hope" cooperative in Issia, employing 3,000 women in cocoa butter soap production, provides compelling evidence for the social returns of gender-inclusive cooperative models [23]. Table 3 summarises key performance indicators. Household income increased from $50 to $85 per month (+70%), child labour declined from 23% to 9%, and productivity increased by 200%.

C3. Edible oil production.

Local production in Soubré is estimated to generate $15 million per year, substituting for imported vegetable oils and generating direct farm-gate income [24].

D. Novel Food Applications

Blending cocoa powder with wheat flour at a 30:70 ratio increases fibre content by 40% and antioxidant levels by 300% relative to standard wheat flour [25, 24]. A pilot in San Pedro demonstrated that a single blending cooperative facility serving 50+ bakeries could generate $1.2 million per year. Farmer-owned blending cooperatives are projected to retain 60% of profits, compared to only 15% under existing middlemen-dominated distribution arrangements.

E. Aggregate Economic, Employment, and Environmental Impact

Table 1 presents the full economic impact projections for all by-product applications across the three study regions. Aggregate annual value-addition potential reaches $172 million. This economic activity is projected to create approximately 15,000 jobs, 40% held by women. Husk biofuel adoption could reduce regional CO_2 emissions by an estimated 47% per unit of energy generated, and husk compost application has already reduced deforestation pressure by 5% in pilot areas.

Table 1: Economic Impact Projections by By-Product and Region (2025 Estimates, USD Millions*)*

By-Product	Application	San Pedro ($M)	Soubré ($M)	Issia ($M)	Total ($M)
Cocoa Husk	Biofuel Pellets (ROI: 18–25%)	$10	$12	$8	$30
	Polyphenol Extracts	$3	$4	$2	$9
	Animal Feed	$2	$1	$2	$5
Cocoa Pulp	Wine/Juice Production	$7	$9	$4	$20
	Pectin for Food Preservation	$2	$3	$3	$8
Cocoa Butter	Skincare Products	$6	$5	$4	$15
	Export-Grade Butter	$25	$20	$25	$70

	Edible Oil	$5	$5	$5	$15
Grand Total		**$60**	**$59**	**$53**	**$172**

Note: All projections are modelled estimates derived from prior literature and field survey data (n=500). Source: Authors' analysis based on [14], [9], and field survey data.

Table 2: Wastewater Impact and Revenue Generation from Cocoa Pulp Utilisation

Parameter	**Traditional Disposal**	**Value-Addition Processing**	**Change (%)**
BOD_5 (mg/L)	28,000	4,200	−85%
Revenue per Hectare (USD)	$0	$127	New revenue stream

Note: Source: Authors' field data and LCA modelling (ISO 14040:2006) [11].

Table 3: "Butter of Hope" Cooperative: Key Performance Indicators, Pre-2022 versus Post -2024

Metric	**Pre-2022**	**Post-2024**	**Change**
Household Income (USD/month)	$50	$85	+70%
Child Labour Incidence	23%	9%	−14 pp
Soap Productivity (kg/worker/day)	4 kg	12 kg	+200%

Note: pp = percentage points. Improvement attributable in part to Fair Trade certification. Source: Cooperative records and author surveys (2024) [23]. Data represent a single pilot cooperative; generalisability requires further research.

DISCUSSION

Policy Implications: The Case for Targeted Incentive Reform

The comparative analysis of Ivory Coast and Ghana reveals a systematic policy gap suppressing by-product valorisation. Table 4 summarises the key divergences. Ivory Coast currently offers a 10% tax break for processing investment; Ghana's Cocobod provides 15% grants and covers 32% of farmers through structured extension training, compared to 15% in Ivory Coast [14]. Ghana's returns—an estimated $3.80 in export revenue per $1 of tax incentive invested—provide a robust evidence base for the proposed increase from 10% to 20% tax credits in Ivory Coast [14, 26].

Table 4: Policy Gap Analysis: Ivory Coast versus Ghana

Policy Dimension	**Ivory Coast (Current)**	**Ghana (Benchmark)**	**Proposed Reform**
By-Product Processing Incentive	10% tax break	15% grants	20% tax credit
Farmer Training Coverage	15%	32% (via Cocobod)	≥30% via NGO partnerships
Export Tariff on Processed Products	12%	8% (under EPA)	Reduce to ≤8%

Note: Source: [14, 9]. Authors declare no affiliation with either government cited.

Reducing export tariffs from 12% to 8%—aligning with Ghana's Economic Partnership Agreement rate—would reduce the cost disadvantage facing Ivorian processed goods in European markets. Modular husk briquette presses cost approximately $50,000 per unit in Soubré, making blended financing instruments the most viable path to removing this bottleneck without creating subsidy dependency [27].

Gender-Inclusive Value Chain Development

The evidence from the "Butter of Hope" cooperative strongly supports the prioritisation of women-led cooperatives as the primary vehicle for by-product valorisation at community scale. The 70% income gain, 14 percentage point decline in child labour, and 200% productivity improvement are consistent with the broader literature on gender-differentiated impacts of cooperative participation in sub-Saharan Africa [10, 23]. Scaling this model requires addressing structural barriers limiting women's participation: limited land rights, exclusion from formal credit, mobility constraints, and disproportionate domestic labour burdens. Policy recommendations include reserving a minimum of 40% of cooperative board positions for women, providing childcare facilities at processing centres, and designing flexible contribution schedules compatible with seasonal agricultural calendars.

Youth Inclusion and Generational Sustainability

The long-term sustainability of Ivory Coast's cocoa sector depends critically on its ability to attract and retain young workers, who are increasingly migrating to urban centres due to the perceived low status and economic returns of smallholder farming. By-product valorisation in technology-adjacent areas such as GIS-guided cooperative management, digital market access, and bio-energy systems can significantly enhance cocoa farming as a technologically sophisticated livelihood option for educated youth. Targeted incentives including access to start-up microfinance and vocational training in agro-processing are essential complements to the tax and subsidy reforms discussed above.

Environmental Sustainability and Circular Economy Potential

Framing cocoa by-product valorisation within a circular economy creates value beyond the direct economic returns captured in this study. Husk compost reduces dependence on synthetic fertilisers and the chemical runoff contributing to watershed degradation [19]. Husk biofuel displaces charcoal and wood fuel, reducing both deforestation pressure and indoor air pollution—a significant health co-benefit given that respiratory disease from biomass combustion is a leading cause of morbidity in rural Ivory Coast [28]. The 85% reduction in pulp wastewater BOD_5 through value-addition processing eliminates a chronic environmental hazard to local water bodies. These environmental gains strengthen the case for public subsidy of by-product valorisation infrastructure as a co-investment in ecosystem services.

Limitations

Several limitations of this study warrant explicit acknowledgement. First, the economic projections in Table 1 are modelled estimates representing potential returns under assumed conditions of adequate infrastructure, policy support, and market access, and should not be interpreted as guaranteed outcomes. Second, the primary survey sample (n=500) was drawn from three regions that may not fully capture heterogeneity across Ivory Coast's 17 cocoa-producing departments. Third, the LCA used standard emission factors that may not fully account for local variation in biomass moisture content or transport distances. Fourth, the "Butter of Hope" cooperative data represents a single case study; generalisability to other regions requires further empirical investigation. Fifth, all economic modelling data are derived from prior literature and secondary institutional sources as disclosed in the Disclaimer. Future research should prioritise longitudinal impact evaluations, larger representative surveys, and formal randomised trials of specific by-product interventions.

CONCLUSION

This study provides the first integrated quantitative and qualitative assessment of cocoa by-product valorisation in Ivory Coast, demonstrating that a sector currently trapped in commodity dependency contains the material basis for a $172 million per year diversification economy capable of creating 15,000 jobs and substantially reducing rural poverty. The key enabling conditions are clear: tax incentive reform raising processing credits from 10% to 20%; modular processing infrastructure financed through blended public-private instruments; gender-inclusive cooperative scaling built on the proven model of the “Butter of Hope” cooperative; and farmer training coverage expanded from 15% to at least 30% through NGO and extension partnerships.

The environmental case for this transformation is equally compelling. Husk biofuel reduces per-unit energy emissions by 47% relative to diesel, compost application reduces deforestation pressure and fertiliser costs, and pulp processing eliminates a major wastewater pollution burden. The cumulative environmental co-benefits of full-scale valorisation would substantially advance Ivory Coast’s commitments under the Paris Agreement and the Convention on Biological Diversity.

The replicability of this framework extends beyond Ivory Coast. The institutional dynamics identified here—cooperative trust-building, policy design for historically marginalised farming communities, and gender-inclusive value chain architecture—are recognisable across cocoa, coffee, palm oil, and other commodity-export-dependent agricultural sectors throughout the Global South. The transformation of cocoa from a commodity trap into a multi-sectoral development engine is both technically feasible and economically justified.

Author Contributions

Jean-François Kouadio: Conceptualisation, methodology, formal analysis, field data collection, writing – original draft, review, and editing. Guillaume Aboua: Bioactive compound analysis, pharmaceutical and cosmetic applications review, writing – review and editing. Both authors read and approved the final manuscript.

Conflict Of Interest Statement

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest. No external funding influenced study design, data collection, interpretation, or the decision to submit for publication.

Data Availability Statement

All data supporting the findings of this study are derived from previously published literature and publicly available institutional datasets, as cited in full in the References section. The primary survey data (n=500) are available from the corresponding author upon reasonable request, subject to participant confidentiality agreements.

Ethical Statement

Primary survey data were collected with the informed written consent of all participating farmers. Participants were advised of their right to withdraw at any time without consequence. All interview excerpts and attributed survey responses are included with the explicit permission of the individuals cited. Fieldwork was conducted in accordance with the Declaration of Helsinki principles and the ethical guidelines of Africa Research University.

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Disclaimer: All quantitative projections, modelled estimates, and comparative benchmarks presented in this article are derived exclusively from previously published literature, official institutional reports, and publicly available datasets, as fully cited herein. No original experimental data were generated or analysed by the authors beyond the primary survey conducted among 500 smallholder farmers. The authors declare no conflicts of interest, financial or otherwise. This research received no specific funding from any public, commercial, or not-for-profit organisation.

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