Benchmarking of an Ivorian cashew processor with the dashboard of sustainability indicators for the cashew value chain

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Abstract

This study presents a comprehensive sustainability benchmarking of an Ivorian cashew processor (Cashew Coast), using a dashboard of sustainability indicators for the cashew value chain. Based on data collected in 2022-2023 and 2024 from the supply chain consisting of 9 423 organic cashew plantations and two processing facilities, the assessment examines Cashew Coast's performance relative to national (Côte d'Ivoire), regional (West Africa), and international (Vietnam) value chains. Economic indicators reveal Cashew Coast's strong performance in productivity and value creation, supported by good agricultural practices and expanding local processing capacity, despite ongoing sector-wide challenges in agricultural yields and achieving living income for producers. Social and governance performance slightly exceeds national and regional benchmarks, particularly in employment and gender equity, but lags in food security and land tenure. Environmentally, Cashew Coast achieved a negative carbon footprint during production (–1166 kg CO_2eq/t RCN) and significantly reduced processing emissions by over 60% between 2022 and 2024. With only 2% of plantations established following deforestation, the company leads regionally in environmental sustainability. Cashew Coast's operations were associated with a sustainability score of 0.59, exceeding the average scores observed for Côte d'Ivoire (0.47), West Africa (0.489), and Vietnam (0.505). Despite notable progress, further improvements are needed in processing efficiency and socio-environmental resilience, which are now targeted by a new sustainable strategic plan initiated in early 2025.

1 Introduction

In a context where expectations towards businesses and the agri-food industry are rapidly evolving, evaluating performance solely through financial metrics is no longer sufficient. It has become essential to integrate environmental, social, and economic dimensions into overall performance assessments. In response to this growing demand, sustainability dashboards are emerging as vital tools, capable of transforming large volumes of complex data into clear and actionable insights that support strategic decision-making (Matchaya et al. 2023). These dynamic tools are increasingly used to monitor progress towards global objectives such as the Sustainable Development Goals (SDGs), particularly in key areas like food security, climate adaptation, and food systems.

The cashew sector, which plays a critical role in the economies of several producing countries, is central to these concerns. Côte d'Ivoire, the world's leading exporter of raw cashew nuts, sees local processing not only as a way to add value but also as a sustainability challenge (Lebailly et al. 2023). In this context, Cashew Coast actively sought to have a Life Cycle Assessment (LCA) conducted, convinced that a comprehensive sustainability benchmark would be key to improving its operations. Fully committing to the sustainability journey required an independent assessment — and that's where CIRAD, an internationally recognised research organisation, came in. For CIRAD's team, the collaboration offered a chance to apply and refine its research methodologies in a real-world industrial context, producing data and insights that advance both science and practice in sustainable agriculture and food systems.

This article presents an in-depth analysis of this initiative, drawing on the sustainability dashboard developed through this partnership. The objective is twofold: first, to assess the environmental, social, and economic performance of an Ivorian cashew processor; second, to identify improvement levers and opportunities to strengthen sustainability within the value chain. This case study illustrates both the challenges and the potential benefits of a structured, data-driven approach to supporting the sustainable transition of the cashew sector in Côte d'Ivoire.

2 Material and methods

2.1 Cashew Coast: raw cashew nut sourcing and processing strategies

Cashew Coast is a business group composed of three entities (Cajooma, Ivoirienne de la Noix de Cajou (INC) and Cashew Food's) that operates in the sector of local sourcing and processing of raw cashew nuts (RCN) from Côte d'Ivoire, connecting farmers to consumers in a sustainable chain. Cajooma organises, trains and accompanies producers in sustainable agricultural practices to source organic RCNs from them to supply Cashew Food and INC's two processing plants, based at Bouaké and Azaguié respectively. As of 2024, Cajooma had relationships with 7 137 smallholders who own a total of 9 423 cashew farms (with a total area of 16 917 ha), covering 115 villages located mainly around Bouaké in the central regions of Côte d'Ivoire. Information about producers and the general characteristics of their cashew farms (geographical coordinates, area, cultivation system, etc.) are recorded in the System Analysis Programs (SAP, operated by field agents) to manage raw cashew nuts (RCN) traceability.

Cashew Coast is committed to working directly with farmers to create a positive impact on both producing communities and the environment, ensuring sustainable and ethical farming practices.

2.2 Data collection and processing

The dashboard of sustainability indicators for the cashew value chain introduced in (Avadí et al. 2025) was used, by feeding in Cashew Coast's operational data for the period 2022-2024. The data were collected using a stratified simple random sampling approach, combined with mixed methods including surveys, focus groups, field observations, direct measurements, in situ sampling, laboratory analyses, and the use of geo-referenced farm maps. Simple random samples of farms were taken from the different strata or types of cashew plantations previously identified using the FAO's two-stage stratification approach (FAO 2021).

All indicators were computed and a benchmarking exercise (against the national and regional scores, as well as the Vietnamese value chain) conducted. Discussions focus on the indicators that can be directly affected by companies' decisions, as certain indicators reflect country-wide or sector-wide policies and are not directly influenced by specific companies.

2.3 Computation of economic indicators

Economic indicators include the economic efficiency of different actors in the cashew value chain, such as Productivity and Value Added (VA), as well as Living Income indicators in the Company.

2.3.1 Productivity and Value-Added calculation

Productivity and VA were calculated for the farms and for Cashew Coast (Eq. 1-Eq. 5).

For the cashew farms, the estimation of productivity and VA was based on measurements of RCN yields and various agricultural products per hectare and other economic data provided by farmers for the 2024, 2023 and 2022 seasons, and collected during surveys. The computation of productivity is based on that of SDG indicator 2.4.1, and in particular sub-indicator 1 (Farm output value per ha), with an addition of farm output value per person working on holding (FAO 2019). Cashew farmers' total income and gross value added were calculated according to the model proposed by Levard et al. (2019). According to this model, net VA (per ha) is obtained by subtracting direct production costs (the cost of inputs, taxes, hired labor, land rental, depreciation of materials and equipment, and other production-related expenses) from total income (the total value of sales of agricultural products).

$$Value\ Added\ =\ Total\ income\ -\ Production\ costs \quad \textbf{Eq. 1}$$

For Cashew Coast, data of all transactions and economic flows related to the different chain phases such as RCN production (sourcing), Transport farm – plant, Processing, and Export/Transport plant - port), as well as the total farmers number and plantations area supplying it with RCN, and the total number of workers were extracted from its in-house ERP. Thus, the Enterprise's economic indicators such as Productivity and VA were computed. For each chain phase, productivity values expressed in USD/ha·year and USD/person·year were calculated by dividing the economic flows relating to the chain phase by the total RCN sourcing plantations area (ha) and the total number of people working on the chain phase respectively. VA values expressed in USD/ha·year and USD/person·year for each chain phase were obtained by subtracting the total intermediate consumptions costs (TIC_Coasts: raw materials, production costs, operating expenses, financial expenses and taxes) from the economic flows relating to the chain phase, and dividing by the total RCN sourcing plantations area (ha) and the total number of people working on the chain phase respectively.

$$Productivity\ (USD/ha\_year) = \frac{Economic\ flows\ (USD)}{Total\ RCN\ sourcing\ plantations\ area\ (ha)} \quad \textbf{Eq. 2}$$

$$Productivity\ (USD/pers\_year) = \frac{Economic\ flows\ (USD)}{Total\ number\ of\ people\ workers} \quad \textbf{Eq. 3}$$

$$VA\ (USD/ha\_year) = \frac{Economic\ flows\ (USD) - TIC_{Coasts}\ (USD)}{Total\ RCN\ sourcing\ plantations\ area\ (ha)} \quad \textbf{Eq. 4}$$

$$VA\ (USD/pers\_year) = \frac{Economic\ flows\ (USD) - TIC_{Coasts}(USD)}{Total\ number\ of\ people\ workers} \quad \textbf{Eq. 5}$$

2.3.2 Living Income Indicators calculation

The following Living Income Indicators were computed:

- Living Income Reference Price (LIRP) for cashew (Fairtrade International, 2019), expressed in USD/t.
- LIRP for cashew gap, expressed in % (Eq. 6).
- Living Wage/Living Income (LW/LI), expressed in USD/employee·month
- LW/LI gap, expressed in % (Eq. 7).

The Company producer prices (CPP, expressed in USD/t) and wages paid (USD/employee.month) were calculated and compared to the reference national LIRP and LW/LI references.

$$LIRP\ for\ cashew\ gap\ (\%) = \frac{LIRP - CPP}{LIRP} \quad \textbf{Eq. 6}$$

$$LW\ gap\ (\%) = \frac{LW - Company\ Wage}{LW \cancel{LI}} \qquad \textbf{Eq. 7}$$

2.4 Computation of social and governance indicators

For the computation of social and governance indicators, some corresponding to national references were extracted from global data sets. These include indicators such as:

- Minimum Dietary Diversity for Women (MDD-W) and Dietary Diversity Score (DDS) (https://www.dietquality.org/indicators/dietary-diversity-score-dds/map)
- Type of land tenure (expressed as perception of tenure security) (https://landportal.org/book/indicator/prindex-prindex2018ots)
- Women's Empowerment in Agriculture Index (WEAI and its variations A-WEAI (https://livestockdata.org/resources/womens-empowerment-agriculture-index-weai-scores-country)
- Proportion of youth not in education, employment or training (https://ilostat.ilo.org/data/)
- Daily wage for non-family labour (https://align-tool.com/)
  Labour Rights Index (LRI: Access to Decent Work), extracted from the Dashboard of WageIndicator 2024 (https://labourrightsindex.org/heatmap-2022).

To calculate Gender Inequality Index (GII), gender disparities are measured by four key sub-indices:

- salary (Ratio of Average Weighted Salary (Women)/Average Weighted Salary (men): SR_Index),
- empowerment (the representation rate of women in leadership positions and decision-making roles: Emp_Index),
- reproductive health (RH_Index), and
- work participation (the participation rate of women and men in different job levels: WPR_Index).

The Reproductive Health Index is assessed using a combination of quantitative and qualitative indicators. Key metrics include the percentage of women taking maternity leave, the quality of health benefits provided by the company, and a scoring system based on responses to a set of standardized questions. Each question is answered with a binary score (Yes: 1 / No: 0), reflecting the company’s policies and practices regarding reproductive rights and gender equality in the workplace. The assessed dimensions include whether the company prohibits inquiries about pregnancy during recruitment; mandates paid maternity leave of at least 14 weeks; ensures cash maternity benefits equivalent to at least 67% of prior wages; and provides these benefits through contributory social insurance or universal systems. Additionally, the index evaluates whether the company protects against dismissal due to pregnancy, supports flexible work arrangements for workers with family responsibilities, and restricts harmful work for pregnant women or nursing mothers. Other criteria include policies that ensure equal pay for work of equal value, prohibit sexual harassment, prohibit discrimination in employment, and allow women to perform the same jobs as men. Together, these components provide a comprehensive view of the company’s commitment to reproductive health and gender-inclusive employment practices.

The data for each sub-index is then normalized on a scale from 0 to 1 (0 representing perfect inequality and 1 representing perfect equality), then each sub-index value is transformed so that 0 indicates low inequality, and a value close to 1 indicates high inequality by using the formula: 1-X (where X represent the normalized sub-index value). Finally, the four sub-indices are aggregated by calculating their average to obtain the GII value using Eq. 8.

$$GII_{Company} = \frac{SR_{Index} + Emp_{\ Index} + RH_{Index} + WPR_{Index}}{4} \qquad \textbf{Eq. 8}$$

A low GII value indicates low inequality between women and men, and vice-versa (0: full equality, 1: full inequality).

2.5 Computation of environmental indicators

The environmental indicators include elements of environmental impacts associated with activities in the cashew sector, such as aspects of deforestation, damage to biodiversity, soil health, water stress and environmental externalities (through both biophysical and economic indicators). The following environmental indicators have been calculated to assess the company's environmental impacts compared with those of the cashew value chain in Côte d'Ivoire, West Africa and Vietnam, as shown in the dashboard (Avadí et al. 2025).

2.5.1 Agrobiodiversity index

The agricultural biodiversity indicator proposed here follows the approach of sub-indicators 8.1, 8.6 and 8.7 of indicator 2.4.1 of the SDGs (FAO 2019). During field surveys, from transects or plots, data were obtained by counting the species and varieties of crops and trees grown in cashew agroecosystems. The coverage or area occupied by each crop is also collected during the survey. The Gini-Simpson diversity index (GSDI) is then calculated for the crops inventoried using Eq. 9.

$$GSDI = 1 - \sum Pi^2 \qquad \textbf{Eq. 9}$$

Where: pi is the relative abundance of cultivated plant species i.

The agrobiodiversity index also includes another sub-index called “Natural vegetation, trees and pollinators index” (NVTPI) was calculated as the average of the following 3 sub-indicators and their associated scores (**Erreur ! Source du renvoi introuvable.**).

Table 1. Indicator assessing natural vegetation and the presence of pollinators in the cashew agroecosystem

Indicator	Answer	Score
Beekeeping	No	0
	Yes, wild	0.50
	Yes, raised	1
Productive area covered by natural or diverse vegetation	Absent	0
	Small	0.25
	Medium	0.5
	Significant	0.75
	Abundant	1
Presence of pollinators and beneficial animals	Absent	0
	Little	0.33
	Significant	0.66
	Abundant	1

The averages of these two previously calculated indices (GSDI and NVTPI) were used to assess the agrobiodiversity index according to TAPE FAO.

2.5.2 Biodiversity: Mean Species abundance Average

The analysis of the state of biodiversity in the cashew plantations supplying the company was carried out using the GLOBIO3 model, developed to assess the impact of anthropogenic and environmental pressures on biodiversity in the past, present and future, based on pressure-impact relationships and spatialized on a global scale at a resolution of 50 km x 50 km. It uses the mean abundance of original species, compared with their abundance in disturbed ecosystems, as an indicator of biodiversity (MSA: mean species abundance) (Alkemade et al. 2009; Schipper et al. 2020). To assess the average MSA index of the company's cashew sourcing areas, the geographical coordinates of all its cashew plantations were projected into the GLOBIO web explorer (https://www.globio.info/globioweb), in order to determine the average MSA of each RCN supply area, and then of all cashew sourcing areas by GIS analysis.

2.5.3 Global pesticide risk score: Exposure to pesticides

The global pesticide risk score of near cashew plantations exposure was extracted from a dataset (https://figshare.com/articles/dataset/Global_pesticide_pollution_risk_data_sets/10302218) (Tang et al. 2021). The average risk score of the company's cashew sourcing areas was carried out from the geolocalised Global pesticide risk score dataset, after projecting the geographical coordinates of all its cashew plantations by GIS analysis.

2.5.4 Proportion of degraded land: Soil health

The proportion of degraded land of the company's cashew sourcing areas is assessed by means of farm surveys focused on the four threats that combine the most common and easy to assess characteristics through farm surveys in its cashew producing areas (soil erosion, reduction in soil fertility, salinization of irrigated land, waterlogging). The farm survey captures farmer's knowledge about the situation of the agricultural holding in terms of soil degradation. The Methodological Note of SDG Indicator 2.4.1 highlights that the farm soil is degraded (unsustainable) if the combined area affected by any of these four selected threats to soil health is above 50% of the total agriculture area of the farm (FAO 2023). To assess soil degradation through the reduction in soil fertility, some observations can be *made in situ* on cashew plantations, followed by soils sampling for their organic carbon content analysis in the laboratory. In degraded soils, organic carbon contents in topsoil (0-30 cm) are often below 1% and, in some cases, even fall below 0.5%. These values indicate a significant degradation in soil health, which can lead to loss of fertility, increased erosion and reduced water storage capacity (FAO 2015).

2.5.5 Encroachment in protected areas

The encroachment is computed by GIS analysis, by projecting the geographical coordinates of cashew plantations extracted from SAP on the map of protected areas (UNEP-WCMC 2019).

2.5.6 Commodity deforestation

The commodity deforestation represents the proportion of recent (i.e. over the last 20 years) deforestation that can be attributed to the cashew plantations supplying the company. The deforestation associated with the expansion of cashew plantations supplying the company was computed using GIS analysis, by superimposing the geographical coordinates of these plantations onto the Masolele deforestation map for West Africa (Masolele et al. 2024).

2.5.7 LCA: Environmental impacts

The environmental impacts were computed with ReCiPe 2016 (midpoint and endpoint, hierarchical) as available in the CIRAD LCA platform (Biard et al. 2011) and an adapted carbon balance framework.

Results are presented per value chain including:

- Global Warming (kg CO2 eq/t RCN and kg CO2 eq/t kernel)
- Other impact categories per t RCN
- Single score (Pt/t RCN and Pt/t kernel).

2.5.8 Environmental externalities

The environmental externalities of the cashew plantations supplying the company were assessed through the following indicators:

- Assessing global climate regulation: Carbon storage in living biomass (t C/ha), Litter and dead wood carbon stock (t C/ha), Soil organic carbon stock (t C/ha)
- Assessing harvested wild goods: Net economic value of harvested wild goods (USD/ha)
- Assessing cultivated goods: Net economic value of cultivated goods (USD/ha)
- Assessing pollination services: Value of pollination services within the site boundaries (USD/ha)

The ecosystem services valuation of cashew plantations was assessed by means of surveys of farmers and *in situ* measurements and observations in the plantations. Carbon storage in cashew plantations is determined by estimating the above-ground biomass (AGB: woody biomass of trees/shrubs and herbaceous biomass), the below-ground biomass (BGB: roots and rootlets), the dead biomass (litter and dead wood), and soil organic matter contained in the superficial layer (30 cm). AGB and BGB are estimated using the pantropical allometric equations developed by Chave et al. (2014). The carbon stock in AGB and BGB is calculated by converting the total biomass estimated from the various allometric equations and multiplying it by the carbon fractionation rate of 0.5 suggested in the UNFCCC (2006) guideline. The estimation of organic carbon stock in herbaceous biomass and litter is performed after harvesting the entire herbaceous biomass and litter in 1 m² plots, to determine the dry matter after oven drying at 60°C and the organic carbon analysis in the laboratory.

Soil organic C content is determined by laboratory analysis. Soil organic carbon stock in the superficial layer is calculated by **Erreur ! Source du renvoi introuvable.**.

$$\text{Soil organic carbon (t C } ha^{-1}) = \text{C content (\%)} \times \text{Bulk density (t m}^{-3}) \times \text{Depth (m)} \qquad \textbf{Eq. 10}$$

2.6 Data normalization and scoring

The computed data for the various indicators were normalized and scored according to the guidelines outlined in the Cashew Value Chain Dashboard User Guide (Avadí et al. 2025). This step is essential to enable consistent comparison of performance across the company, and the full value chains in Côte d'Ivoire, West Africa, and Vietnam. The normalization of indicators was carried out on a 0 to 1 scale, using several strategies depending on the nature of each indicator:

- If the original indicator is expressed on a 0-1 scale, no normalization is needed.
- If the original indicator is expressed on a 0-100 scale, values are divided by 100.
- If the original indicator is expressed on a 0-1 scale where the smallest value represents the best results, the scale is normalized to 0-1 and the complements of the results are taken (0-1 inverted).
- If the original indicator (x) is expressed on a variable scale, the scale is normalized to 0-1 by means of a modified min-max normalization (0-1 relative): x/max(x), which is equivalent to (x-min(x))/(max(x)-min(x)).
- Indicators expressed as classes: specific normalization was applied on a class-by-class basis, scaled from 0 to 1.

Graphical representations of the normalized indicator scores were used to compare the performance of the company with the full value chains in Côte d'Ivoire, West Africa, and Vietnam.

3 Results and discussion

3.1 Economic indicators

Fig. 1 shows the economic indicators scores of Cashew Coast (a local cashew processor of Ivorian RCN, shipped to EU) for the years 2022-2023 and 2024 compared with those of Côte d'Ivoire, West Africa, and Vietnam-whole-VC.

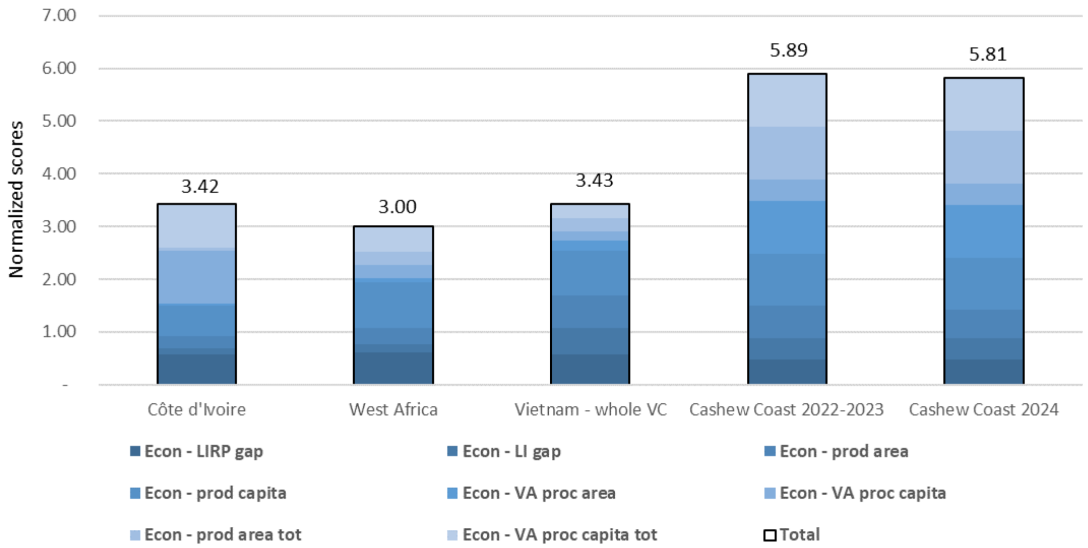

Fig. 1. Economic indicators

The economic indicators of Cashew Coast, a local cashew processor in Côte d'Ivoire, show a globally positive performance, though not without structural limitations. On a total score of 8 for the eight economic indicators assessed, the company recorded overall scores of 5.89 (2022–2023) and 5.81 (2024), outperforming Côte d'Ivoire (3.42), West Africa (3.00), and Vietnam (3.43), indicating its solid performance across key economic dimensions.

Cashew Coast achieves a Living Income gap score of 0.42, which is significantly higher than the averages for Côte d'Ivoire (0.12) and West Africa (0.15), and approaches the score reported for Vietnam (0.5). This strong performance can be attributed to the adoption of good agricultural practices promoted by Cashew Coast, enabling farmers to obtain organic certifications and access higher-value premium markets. Moreover, the implementation of these good production practices has been shown to positively impact both yield and income (Silué et al. 2025). This improvement suggests reduced poverty vulnerability among producers, likely due to stronger value chain integration and growing local processing capacity that creates jobs (World Bank 2025).

In terms of agricultural productivity, Cashew Coast scores 0.53 in 2024 (down from 0.6 in 2022–2023) for productivity per unit area, well above Côte d'Ivoire (0.23) and West Africa (0.3), though still below Vietnam (0.63) These results underline the need for investment in agronomic practices, improved inputs, and widespread innovation dissemination.

For productivity per person, Cashew Coast maintains a score of 1 across both periods, outperforming Côte d'Ivoire (0.57), West Africa (0.87), and Vietnam (0.84), pointing to strong labour efficiency and effective organizational management.

The company also achieves perfect scores (1) for both total productivity per area and value added per productive area, positioning it far ahead of Côte d'Ivoire (0.05 and 0.04, respectively), West Africa (0.26 and 0.08), and Vietnam (0.27 and 0.21).

In terms of value added per person, Cashew Coast scores 0.4, surpassing West Africa (0.24) and Vietnam (0.16) but falling behind Côte d'Ivoire (1), suggesting untapped potential in optimizing returns per worker, particularly through product upgrading or better distribution of value across the workforce.

Finally, with a score of 1 for total value added per capita, Cashew Coast demonstrates a robust business model that exceeds the average scores of Côte d'Ivoire (0.83), West Africa (0.48), and Vietnam (0.27).

Cashew Coast's economic performance reflects the positive outcomes of Côte d'Ivoire's industrial transformation policy. The company shows strong competitiveness in processing, labour productivity, and value creation. However, structural constraints, such as low agricultural yields and the difficulty of ensuring a living income for producers, underline the need for continued investment across the cashew value chain. While the concept of living income is new to cashew, lessons from cocoa and coffee show it's a long-term effort. Cashew Coast recognizes the importance of this issue and the need for deeper study and engagement. Strengthening the integration of cashew producers, improving agronomic practices, and supporting product diversification will be key to closing the gap with global leaders such as Vietnam.

3.2 Social and governance indicators

Fig. 2 shows Cashew Coast's social indicators scores for the years 2022-2023 and 2024 compared with those of Côte d'Ivoire, West Africa, and Vietnam - whole VC.

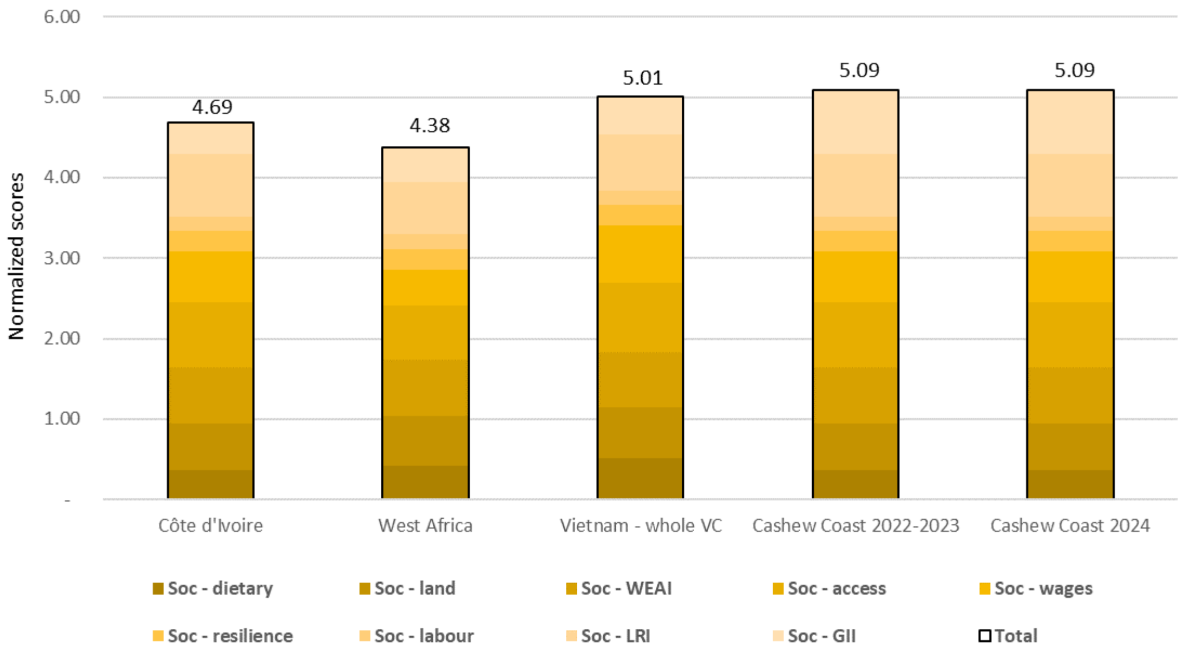

Fig. 2. Social indicators

Cashew Coast's social and governance performance remained globally stable between 2022–2023 and 2024, with scores generally aligned with those of Côte d'Ivoire. However, when benchmarked against West Africa and Vietnam, some critical gaps emerge, particularly regarding food security and land tenure.

The dietary indicator scores for Cashew Coast (0.36) remained stable and aligned with that of Côte d'Ivoire but was lower than the scores observed in West Africa (0.42) and Vietnam (0.52). This suggests limitations in food quality or accessibility.

Similarly, the land tenure security score (0.59) is slightly below West Africa (0.62) and Vietnam (0.63), indicating a persistent perception of insecurity, despite the existence of formal rights. According to Dinh et al. (2023), market incentives and subsidies may have a stronger influence on farmers' investment decisions than tenure security alone, suggesting that policies should combine land tenure improvements with economic support measures.

In contrast, Cashew Coast demonstrates strong social inclusion performance. Its score for access to decent work (0.79) is among the highest across regions, surpassing West Africa (0.64) and Vietnam (0.69). This reflects the positive impact of Côte d'Ivoire's local processing policies, which have created over 18,000 jobs by 2024, 66% of them held by women (World Bank 2025). The company's score for youth integration and access to education (0.81) is also high on par with Côte d'Ivoire and close to Vietnam (0.86), highlighting national efforts to connect young people to employment in agro-industrial sectors.

Cashew Coast offers relatively competitive wages (0.63), above the West African average (0.44) but below Vietnam (0.72), indicating a relatively competitive remuneration level within the local context.

Cashew Coast's Gender Inequality Index score of 0.79 is significantly higher than those of Côte d'Ivoire (0.39), West Africa (0.44), and Vietnam (0.48), reflecting the company's strong and active commitment to promoting gender equality.

Concerning labour risks and social resilience to climate risk, the scores remain low and identical across all regions (0.18 and 0.25 respectively). Although the social environment appears relatively stable, there is a growing need to improve adaptive capacities to address increasing climate risks (Thomas et al. 2019).

In summary, while Cashew Coast performs well in terms of decent work, youth integration, gender inclusion, and wages, it still faces challenges in food and land security — two essential pillars of sustainable social development. Addressing these weaknesses through targeted strategies could help consolidate the company's social resilience and long-term sustainability.

3.3 Environmental indicators

3.3.1 Climate Change Performance Across the Value Chain

Fig. 3 shows Cashew Coast's environmental indicators scores for the years 2022-2023 and 2024 compared with those of Côte d'Ivoire, West Africa, and Vietnam - whole VC.

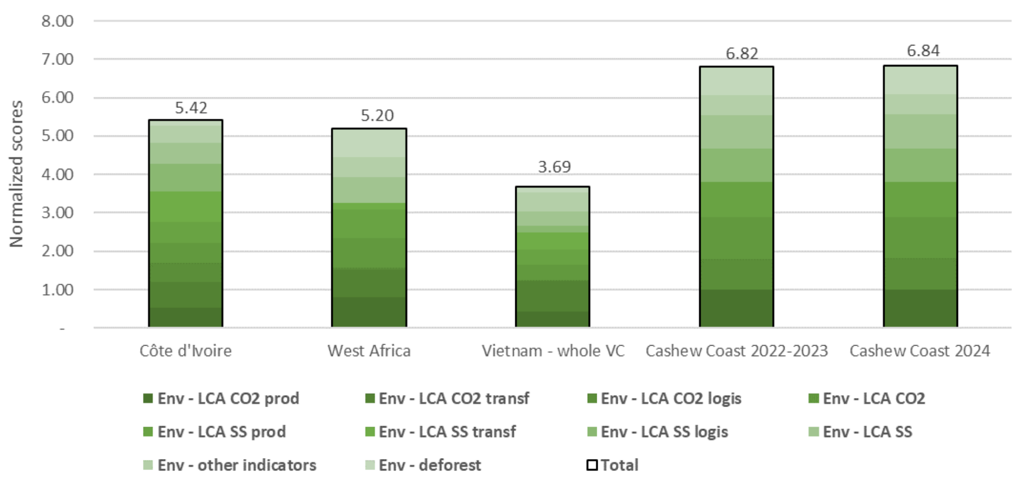

Fig. 3. Environmental indicators

Cashew Coast records strong environmental performance, with total scores of 6.82 (2022–2023) and 6.84 (2024), outperforming Côte d'Ivoire (5.42), West Africa (5.20), and Vietnam (3.69). However, Cashew Coast's environmental performance presents a dual dynamic: remarkable achievements in carbon mitigation at the production and logistics levels, contrasted with persistent weaknesses in processing.

In the production phase managed by its partner farmers, the company consistently achieves a top climate change score of 1 across both 2022–2023 and 2024, significantly outperforming Côte d'Ivoire (0.53), West Africa (0.80), and Vietnam (0.43). This performance is underpinned by a negative carbon footprint of –1166 kg CO_2eq/t, reflecting net carbon sequestration — a unique result among all benchmarked regions (Table 2). This outcome is attributable to regenerative agricultural practices (supported by organic certifications), which are increasingly recognized for their carbon storage in cashew farms, and climate benefits in African contexts (Victor et al. 2021; Agboka et al. 2025).

Processing remains the company's main environmental bottleneck, with a persistently high climate impact despite a slight reduction in emissions from 481.8 to 470 kg CO_2eq/t between 2022 and 2024. The climate change score remains at 0, significantly lower than those of Côte d'Ivoire, West Africa, and Vietnam. LCA results confirm this weakness, showing a score of 0 for processing, compared to 0.93 for production and 0.86 for logistics. This weak performance is mainly due to the low electricity grid intensity in the Azaguié area, where one of Cashew Coast's processing units is located; this forces the facility to rely heavily on fuel-powered generators, thereby significantly increasing its carbon footprint. These findings underscore the urgent need for investments in cleaner technologies, energy diversification, and process optimization—levers commonly cited in the agri-processing literature (Yakovleva et al. 2012; Lebailly et al. 2023). Notably, as a direct outcome of the LCA, operations in Azaguié were suspended and recentred in Bouaké, where grid conditions are more favorable. This strategic shift illustrates how sustainability assessments can inform and support concrete business decisions, reinforcing the practical value of such benchmarking efforts.

Regarding logistics (including transport from farm to plant, export from plant to port in Abidjan, and overseas shipping from Abidjan to Europe), Cashew Coast displays robust performance with a GHG score of 0.81 and a carbon footprint of just 16 kg CO_2eq/t, outperforming Côte d'Ivoire (42.4 kg CO_2eq/t), West Africa (79.4 kg CO_2eq/t), and Vietnam (80.6 kg CO_2eq/t). These results suggest a well-integrated local supply chain, which likely benefiting from short distances between production and processing.

Globally, the company's total climate change score remains stable (1.0 in 2022–2023, and 2024), although its net carbon footprint remained clearly negative, at –705.6 kg CO_2eq/t in 2022–2023 and –680 kg CO_2eq/t in 2024. This rare achievement highlights the effectiveness of Cashew Coast's environmental integration strategy and its potential role as a benchmark in the sector.

Table 2. Comparative analysis of key environmental indicators — including carbon emissions across the production, processing, and logistics phases, as well as deforestation rates

Environmental indicators	Unit	Côte d'Ivoire	West Africa	Vietnam - whole VC	Cashew Coast 2022-2023	Cashew Coast 2024
carbon footprint – production	kg CO2eq/t RCN	4 271.75	1840.91	5 260.29	-1203.3	-1166
carbon footprint –processing	kg CO2eq/t RCN	157.93	129.79	98.93	481.8	470
carbon footprint – logistics	kg CO2eq/t RCN	42.40	79.42	80.64	15.9	16
Total carbon footprint	kg CO2eq/t RCN	4 472.08	2 050.11	5 439.86	-705.6	-680
Deforestation	%	7%	2%	7%	2%	2%

3.3.2 Land Use and Deforestation

Beyond carbon metrics, Cashew Coast demonstrates commendable land management practices. The company maintains a low deforestation rate of 2%, compared to 7% in Côte d'Ivoire and Vietnam. This performance aligns with regional sustainability goals and supports forest-compatible value chains, in line with recent calls from CIFOR-ICRAF (Center for International Forestry Research and World Agroforestry) and other sustainability initiatives that benefit rural livelihoods while minimizing environmental impacts (Capistrano et al. 2023).

3.3.3 Synthesis and strategic implications

Overall, Cashew Coast exemplifies the benefits of an integrated, climate-smart value chain model. The combination of carbon-negative agriculture, low-emission logistics, and minimal deforestation positions the company as a leader in environmental sustainability within the cashew sector. However, the processing stage remains a critical vulnerability. Despite notable progress, environmental impact remains substantially higher than global averages, underscoring the need for targeted technological and energy transitions.

Achieving full alignment with international climate targets and Sustainable Development Goals (SDGs) will depend on the company's ability to decarbonize its processing operations. Addressing this challenge is essential not only to close the current performance gap but also to consolidate Cashew Coast's emerging status as a reference model for sustainable agri-business in Africa.

3.4 Benchmarking based on consolidated indicators for full value chain

The benchmarking of Cashew Coast across the full value chain highlights a well-balanced and robust sustainability profile, confirming its leading position relative to national, regional, and global comparators. The company achieves the highest consolidated score (0.594), significantly outperforming Côte d'Ivoire (0.470), West Africa (0.485), and Vietnam (0.505) (**Erreur ! Source du renvoi introuvable.**). This integrated performance is anchored in three main dimensions of sustainability (economic, environmental, and social) each contributing to its overall competitiveness.

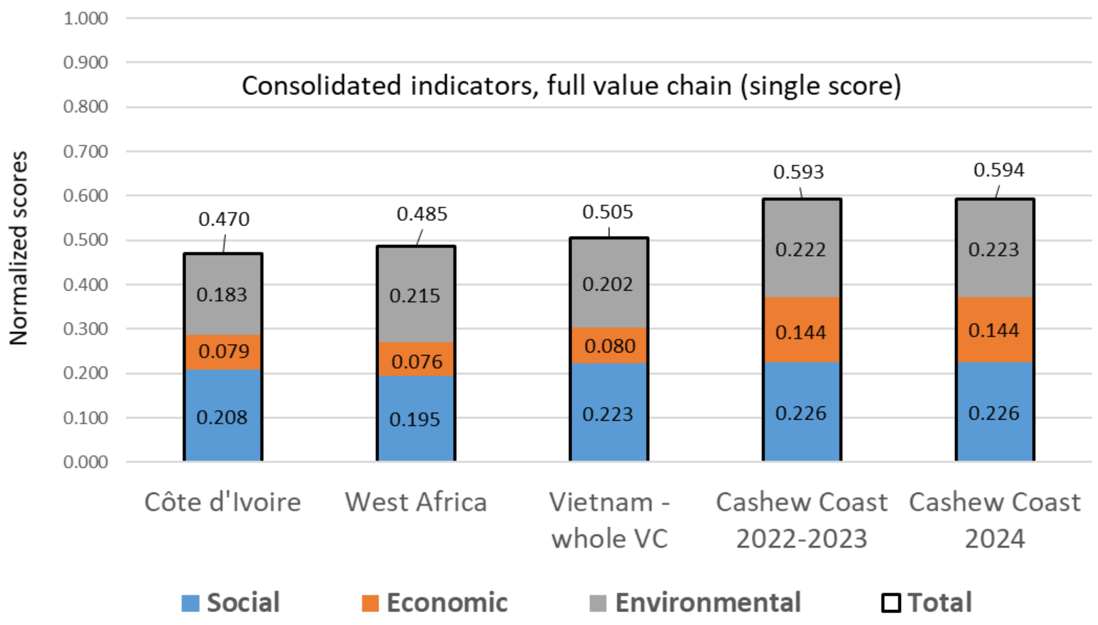

Fig. 4. Single scores of consolidated indicators by dimension for full value chain

From an economic perspective, Cashew Coast demonstrates clear leadership (0.144), suggesting superior value chain efficiency, stronger value addition, and better market integration. This aligns with recent findings emphasizing the importance of local processing, traceability, and market differentiation in driving economic sustainability in tropical commodity chains (FAO 2022; UNCTAD 2023).

On the environmental front, the company's score (0.223) confirms steady progress, underpinned by climate-smart practices in production and logistics. While the margin over West Africa (0.215) is moderate, it reflects a commitment to continuous improvement. This supports the argument that low-emission agricultural value chains are increasingly feasible through targeted investments and ecosystem-based approaches (Bernard and Giraud Héraud 2024).

In terms of the social dimension, Cashew Coast (0.226) performs above regional averages, although the margin with Vietnam (0.223) remains narrow. This indicates solid achievements in areas such as employment quality, gender inclusion, and producer relations, but also points to the need for deeper social innovation, particularly in labour conditions and smallholder engagement, consistent with calls for more inclusive agri-food systems (HLPE 2021; Aku et al. 2023).

In sum, Cashew Coast presents a coherent and high-performing sustainability model, with strong economic foundations, meaningful environmental progress, and competitive social performance. The company's positioning reflects not only its internal strategies but also the growing relevance of integrated sustainability frameworks in guiding agri-business development in the Global South.

4 Limitations

Despite the robustness of the findings, this study has several methodological limitations that should be acknowledged. First, the current set of indicators does not account for the positive socio-economic impact of indirect payments made to farmers through Cashew Coast's community investments (e.g., school loans, wells, local infrastructure), which contribute significantly to livelihoods but are not reflected in direct income metrics.

Second, data quality remains a constraint, particularly concerning the valuation of ecosystem services, the calculation of the Living Income, and associated reference prices. These limitations affect the reliability of some sustainability indicators.

Finally, the performance metrics presented rely primarily on average values and do not include measures of uncertainty or variability, such as error bars or confidence intervals. This is largely due to the use of pre-aggregated composite indicators, which provide useful cross-cutting insights but tend to obscure the diversity of situations within the value chain.

5 Conclusions

The analysis of Cashew Coast's performance across economic, social, and environmental dimensions reveals a well-balanced and robust sustainability profile. Economically, the company significantly outperforms regional and international benchmarks, particularly through high productivity and value addition. Socially, while it maintains a competitive position—especially in terms of gender equality, youth employment, and access to decent work—improvements are still needed in food security and land tenure. Environmentally, Cashew Coast demonstrates pioneering achievements, notably with a negative carbon footprint in the production phase and low deforestation rates, making it a reference for climate-smart agriculture in the cashew value chain.

Looking ahead, strengthening sustainability in processing and advancing social outcomes remain key priorities. Continued efforts to reduce transformation-related emissions and enhance social resilience, particularly in nutrition and land security, will be essential for consolidating Cashew Coast's leadership. Furthermore, its model of local value creation and environmental performance positions the company as a potential blueprint for sustainable cashew processing in West Africa and beyond. Future research and policy engagement could explore pathways to replicate and scale this model across the region, fostering inclusive and climate-resilient agricultural value chains.

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