Circularity Opportunities in the Cashew Value Chain in Vietnam

A thesis presented in partial fulfilment of the requirements for the degree of

Master of Agribusiness

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA
UNIVERSITY OF NEW ZEALAND

School of Agriculture and Environment

Massey University

Manawatu Campus, New Zealand

Hoa Thi My Tran

2026

Abstract

The Vietnamese cashew industry, a global export leader, operates on a predominantly linear "take-make-dispose" model, leading to economic vulnerabilities and environmental degradation in part due to the systematic underutilization of by-products like cashew nut shells and apples. The application of Circular Economy principles may offer a promising pathway, however, achieving this potential necessitates a detailed analysis. First, it necessitates to understand the industry's structure, governance, and actor relationship through value chain analysis (VCA). Second, it requires to trace physical resource flows, quantify material inefficiencies, and pinpoint hotspots of material loss and underutilization through material flow analysis (MFA). Currently, a comprehensive, intergrated analysis connecting these three disciplines—value chain dynamics, material flows, and circularity potential—is lacking. This study fills that gap by conducting an integrated assessment of the cashew value chain in Binh Phuoc Province, Vietnam's primary cashew hub.

The research employed a qualitative approach. Primary data were collected in 2025 through 58 semi-structured interviews with key value chain actors (agricultural input suppliers, farmers, collectors, traders, processors and government officers) and direct measurements at farms and processing facilities. Participants were recruited using purposive and snowball sampling to capture diverse perspectives and multi-stage processes. For MFA, a sub-sample of 10 farms and 3 processing facilities was selected for on-site quantification of material conversions. Qualitative data were analyzed using Reflexive Thematic Analysis, while quantitative MFA data were used standard mass-balance procedures to map and quantify all material flows.

The findings reveal that the Vietnamese cashew sector is heavily reliant on raw nut imports (90%). The processed cashew nut value chain has a multi-layer structure and a variety of value chain players including agricultural input suppliers, smallholder farmers, traders, collectors, processors, and export brokers. It is dominated by processors who control information and limit smallholder upgrading. The material flow analysis uncovered a significant inefficiency: a mere 2% mass yield of kernel from the whole fruit harvested. This is associated with the systematic waste of the cashew apple (90% of the fruit) and only basic utilization of the cashew nutshell for cashew nutshell liquid (CNSL) extraction, which is then exported for advanced manufacturing. The research concludes that the sector exhibits uneven circularity−a form of partial adoption where byproduct valorization is incremental and economically opportunistic rather than planned. This highlights untapped potential for a more circular model that captures greater value domestically.

Consequently, transitioning to a more circular model is technically and economically viable but requires a systemic shift which encouraging greater collaboration between stakeholders. Recommendations include strengthening vertical and horizontal coordination to improve governance and equity, alongside government incentives to stimulate domestic investment in cashew apple valorization and advanced CNSL refining. This research contributes a novel, integrated framework for analyzing agri-food value chains and offers a practical roadmap for enhancing the sustainability and competitiveness of the Vietnamese cashew sector, underscoring that effective circularity necessitates integrated governance and supportive policies.

Key words: circular economy, value chain analysis, material flow analysis, by-product valorization, food loss and waste, cashew nut value chain, cashew Vietnam, agribusiness Vietnam, Binh Phuoc.

Acknowledgement

First and foremost, I extend my deepest gratitude to my supervisors, Assoc Prof Elena Garnevska and Professor Sarah McLaren. Thank you for your invaluable guidance, for pushing me with high expectations, and kind feedback. Your belief in my ability to reach the challenge and your words of encouragement meant the world to me and were a constant source of motivation.

My sincere thanks also go to the academic staffs, including Professor Nicola Shadbolt, Assoc Prof Thiagarajah Ramilan, Prof. Peter Tozer, Dr Shamim Shakur and Dr Yijing Wang for their insightful teachings. A special note of gratitude to my academic coaches, Vivien and Susanna. Thank you for standing by me during the toughest times, offering a safe space when I felt lost or overwhelmed.

I am eternally grateful to Education New Zealand and the Manaaki New Zealand Scholarships for making this life-changing journey possible. This scholarship has given me more than an education; it has allowed me to grow, to understand more about the world and others, and most importantly, about myself. My heartfelt thanks to my scholarship coordinator, Anna, for being so much more than your role required. You consistently ensured I felt seen, heard, and cared for, and for that, I am profoundly thankful.

This research would not have been possible without the generosity of the cashew value chain stakeholders in Binh Phuoc, Vietnam. I extend my warmest thanks to the local authorities, farmers, processors, and other stakeholders in the cashew value chain who shared their time, knowledge, and experiences with me.

To my beloved friends, classmates, flatmates, badminton partners, and the many kind souls that I've met along the way, you turned a foreign land into a home, thank you for making this journey unforgettable. I am deeply grateful for your presence and support.

Finally, to my family back home, your unwavering love and support across the distance have been my anchor. This journey was possible because I knew you were always with me.

Table of Contents

List of Figures

List of Tables

List of Abbreviations

BRC	British Retail Consortium
CE	Circular economy
CNS	Cashew nutshell
CNSL	Cashew nutshell liquid
CO2	Carbon Dioxide
EMF	Ellen MacArthur Foundation
ETIN	Ethical Trading Initiative Norway
EU	European Union
FAO	Food and Agriculture Organizations
FLW	Food loss and waste
FTA	Free trade area
GDP	Gross Domestic Product
GSO	General statistic office of Vietnam
HACCP	Hazard Analysis and Critical Control Points
INC	International Nuts and Dried Fruit Council
MARD	Minister of Agriculture and Rural Development
MFA	Material flow analysis
QDA	Quality Data Analysis
RCN	Raw cashew nut
SDG	Sustainable development goal
USA	United States of America
VCA	Value chain analysis
WTO	World Trade Organization

Chapter 1. Introduction

1.1. Background of research

Cashew nuts are a highly valued agricultural commodity in global markets, with demand having risen significantly recently; they rank as the third most consumed nut worldwide due to their nutritional benefits and growing use in plant-based and snack food industries (INC, 2023). Within this landscape, Vietnam has consistently been the world's largest exporter of cashew kernels for over a decade, accounting for 65% of global exports (INC, 2021, 2023). Recognized as an important industrial crop since 1989, the cashew industry is a critical pillar of Vietnam's agricultural economy. The total cultivation area spans approximately 304,000 hectares, yielding about 350,000 tons of dried raw cashew nuts and making Vietnam the world's third-largest producer (FAOSTAT, 2024; GSO, 2024). Cultivation is concentrated in the Southeast region, particularly in the provinces of Binh Phuoc, Dong Nai, Ba Ria Vung Tau, and Tay Ninh (GSO, 2024). Binh Phuoc alone, considered the country's cashew capital, accounts for 150,000 hectares and an output of 200,000 tons per year, representing nearly 50% of the national cultivation area and 57% of its output (GSO, 2024). In 2024, the sector achieved a record export volume of 725,300 tons of cashew kernels, generating USD 4.34 billion and solidifying cashew as Vietnam's third most valuable agricultural export and the 20th most valuable export product overall. As a result, this industry is a primary source of income for millions of households and a key driver of rural development.

The cashew value chain is traditionally structured into three main stages: (1) cultivation and raw nut collection by smallholder farmers, (2) processing (shelling, peeling, and grading) at processing facilities, (3) distribution and export (Agyemang et al., 2021). Despite its economic significance, the global cashew sector, particularly in Vietnam, predominantly operates on a traditional, linear "take-make-dispose" model. This linear model is fraught with systemic inefficiencies, including economic vulnerability, environmental degradation, and resource underutilization. According to ETIN (2018) and GSO (2024), the Vietnamese cashew sector faces price volatility and a dependency on imported raw nuts due to insufficient domestic supply, which squeezes profit margins, especially for smallholder farmers who hold the most vulnerable position in the chain.

A more pressing issue is the massive generation of biomass by-products, specifically the cashew apple and cashew nutshell (CNS), which, if not managed properly, cause significant environmental degradation. If left to rot on farms, the cashew apple creates foul odors, attracts insects, increases disease risks (Bhavana & Patil, 2021), and generates methane and CO_2 (Faye et al., 2024). The resulting leachate can lead to soil acidification and eutrophication, damaging local ecosystems (Sial et al., 2024). Concurrently, CNS is often disposed of in landfills or burned as fuel (Costa & Delgado, 2019; Omolola, 2024). Open burning of CNS, which is rich in anacardic acid, releases fine particles that pose respiratory and cardiovascular health risks (Cruz et al., 2024). This represents not only a severe environmental and health burden but is also an indicator of resource inefficiency, as significant inputs of labor, land, water, and nutrients are used to produce only a small edible portion.

Paradoxically, these by-products hold substantial untapped economic potential. The cashew apple is rich in nutrients and vitamins; its utilization could generate new jobs, improve food security, address micronutrient deficiencies, and contribute to achieving SDGs 1, 2, and 3 (alleviating poverty and hunger, and promoting good health) (World Bank, 2022; Nwosu et al., 2016). Furthermore, CNS is a source of Cashew Nutshell Liquid (CNSL), a versatile material that can replace fossil fuels in industrial products such as friction linings, paints, and resins (Bhaskaran, 2017; Darkunde et al., 2022). CNSL also shows promise for pharmaceutical and cosmetic applications, including anti-cancer treatments (Soares et al., 2022; Shilpa et al., 2015). Despite this potential, studies confirm that these by-products remain largely discarded or underutilized, representing a significant lost economic opportunity (Hidayati et al., 2021; Dimoso et al., 2024; Akyereko et al., 2023).

Agrifood systems are pivotal for global food security and livelihoods but are increasingly pressured by rising demand, resource inefficiency, and environmental degradation (Woodhill et al., 2022). A critical issue is food loss and waste (FLW), which accounts for nearly one-third of all food produced, contributing significantly to economic losses and greenhouse gas emissions (EMF, 2021). In this context, the Circular Economy (CE) model has emerged as a transformative paradigm. CE proposes a restorative and regenerative system designed to eliminate waste and keep materials in use indefinitely (EMF, 2013). Applied to agrifood systems, CE principles promote resource efficiency, by-product valorization, and closing material loops (Geissdoerfer et al., 2017). This model aligns with global Sustainable Development Goals (SDGs) and is enshrined in Vietnam's National Green Growth Strategy (2021-2030) in Decision 1658/QD-TTg dated October 1, 2021. The principles of CE are well-suited to agro-processing industries like cashew, which are characterized by high volumes of organic biomass. Instead of viewing by-products as waste, the CE framework sees them as potential resources with untapped economic value, creating opportunities for new revenue streams, reducing environmental impact, and enhanced resilience. Despite growing academic and policy interest in circular economy, empirical applications of CE principles within value chain analysis remain limited, particularly in agri-food systems and even more so in developing country contexts (Hofstetter et al., 2021, Kapoor et al., 2020; Miranda et al., 2021). Most CE research remains conceptual or focused on industrial manufacturing, with few studies examining how circular transitions actually unfold within the complex, fragmented, and perishable value chains. The Vietnamese cashew sector offers a critical and timely case to address this gap. As the world's leading kernel exporter, it is a mature, globally integrated industry; yet it remains locked in a linear model, generating massive biomass waste with untapped economic potential. This makes it an ideal empirical site to examine the opportunities for CE integration in a developing country agri-food system. However, a missing link in the Vietnamese cashew context is a quantitative account of its material metabolism – a presequisite for moving from qualitative advocacy to evidence-based system redesign. While existing studies have examined singular aspects, such as the value chain structure of the kernel itself (Hoang & Le, 2017; ETIN, 2018) or the technical potential of individual by-products (Hanh et al., 2024; Dao et al., 2022; Nguyen et al., 2022). A comprehensive analysis that integrates VCA, MFA, and circularity assessment within a single empirical study is lacking. Therefore, this study posits that a MFA is essential for designing impactful CE strategies. It addresses this gap by integrating MFA with VCA to first diagnose the system's physical and structural inefficiencies, thereby creating the evidence base needed to transition the Vietnamese cashew industry from its current linear model towards a more sustainable, resilient, and profitable circular model.

1.2. Research aim and objectives

The aim of this research is to conduct a in-depth assessment of the circularity potential of the Vietnamese cashew value chain. This will be achieved by integrating the analytical frameworks of value chain analysis (VCA), material flow analysis (MFA), and circular economy (CE) principles. This integrated approach is designed to provide a systemic understanding of the entire cashew value chain, moving beyond a narrow focus on the kernel to include the material flows and valorization potential of by-products. Consequently, this study will identify hidden inefficiencies, uncover new opportunities for value creation, and pinpoint the barriers and drivers for a transition towards a more circular model in the sector. This aim will be achieved by fulfilling four key objectives:

To map the cashew nut value chain in Binh Phuoc Province, Vietnam

To analyze the governance in cashew nut value chain in the region

To analyze the material flow in cashew sector

To analyze the circularity of cashew sector.

1.3. Thesis outline

This thesis is structured into seven chapters. Chapter 1 provides an introduction to the study, presenting the research background, problem statement, aims, and objectives, along with the overall thesis outline. Chapter 2 establishes the national and sectoral context, with an overview of Vietnam's agricultural economy, global cashew trade patterns, and the domestic cashew production and trade. Chapter 3 reviews the relevant theoretical and conceptual literature, focusing on the core frameworks of VCA, MFA, and the principles of the CE. Chapter 4 details the research methodology employed in the study. Chapter 5 presents the primary results and findings from the data analysis. Chapter 6 discusses these findings, interpreting their significance and relating them to the existing body of literature. Finally, Chapter 7 concludes the thesis by summarizing the key insights, offering practical recommendations, and proposing directions for future research.

Chapter 2. Study country background

2.1. An overview of Vietnam

Vietnam, officially known as the Socialist Republic of Vietnam, is a Southeast Asian nation with a total land area of 331,690 square kilometers (Vietnam Government Portal, 2025). It shares borders with China to the north, and Laos and Cambodia to the west. To the east and south, the country is bounded by the Eastern Sea (South China Sea) and the Pacific Ocean as shown in Figure 2.1. Vietnam possesses a long coastline of over 3,260 kilometers (excluding islands) and extends approximately 1,650 kilometers from its northernmost to southernmost points. The country's topography varies considerably, ranging from mountains and hills to fertile deltas. This strategic location, combined with a climate that spans tropical and temperate zones, has historically supported extensive agricultural production and sustained a large population, which was estimated at 101.8 million in 2025 (United Nations, 2025).

Figure 2.1. World map of Vietnam (Central Intelligence Agency, n.d.).

The most transformative period in modern Vietnam began with the launch of the Đổi Mới (Renovation) reforms in 1986, shifting from a closed, centrally planned economy to a dynamic, market-oriented system (Nguyen, 2022). The economic impact has been profound. Vietnam has maintained one of the highest GDP growth rates in Asia for decades, averaging 6-8% since the 1990s. This sustained expansion propelled the country from one of the world's poorest nations to lower-middle-income status in 2010 (Nguyen, 2022). By 2024, its GDP reached approximately USD 480 billion with a per capita income of USD 4,711, positioning it as the fourth-largest economy in Southeast Asia (GSO, 2025; World Bank, 2024). A key driver of this growth has been Vietnam's deep integration into the global economy. Since joining the World Trade Organization (WTO) in 2007, it has established diplomatic relations with 189 of 193 countries and has signed 185 bilateral and 77 multilateral agreements, including 15 FTAs covering 57 economies worldwide (Nguyen, 2022). This extensive network has been instrumental in attracting foreign direct investment (FDI) and integrating Vietnam into global value chains, fostering the development of high-value-added manufacturing and service sectors (Sahel & El Abbassi, 2025; Li et al., 2025). Consequently, the economic structure has shifted from a primarily agrarian base to one dominated by export-oriented manufacturing. Although agriculture's share of GDP has declined, it remains a vital sector, ensuring employment, rural stability, and serving as a major source of exports like rice, coffee, seafood, and cashew nut (Nguyen et al., 2025).

2.2. An overview of Vietnam agriculture

The agriculture sector is a cornerstone of Vietnam's economy and society, playing a vital role in the nation's development and the livelihoods of its people. This sector encompasses crop production, livestock, fisheries, and forestry, and is supported by Vietnam’s diverse landscapes−from the fertile deltas of the Mekong and Red Rivers to the central highlands−and a tropical climate that provides fertile soils, abundant water, and rich biodiversity (World Bank, 2016a). These conditions create an ideal environment for a wide variety of agricultural activities. The nation's varied agricultural ecology, which is categorized in Figure 2.2, allows different regions to specialize in distinct products.

Figure 2.2. Agricultural ecology in Viet Nam (Source: Ministry of Agriculture, Fisheries, Food Security and Nature Netherlands, 2022)

Since the Renovation reforms, Vietnam's agricultural sector has undergone a profound transformation. While its relative contribution to the economy has diminished, its absolute output and strategic importance have grown. As illustrated in Figure 2.3, agriculture's share of GDP plummeted from approximately 46% in the 1980s to around 12% by 2022, by which time its value had reached an estimated US$46 billion. This shift reflects the rapid growth of other sectors; in 2022, industry and services contributed 38.2% and 41.3% to GDP, respectively (GSO, 2023). Despite this relative decline, agriculture remains the nation's largest employer, engaging 13.9 million people, or about 40% of the total labor force (World Bank Data, 2024; Statista, 2024).

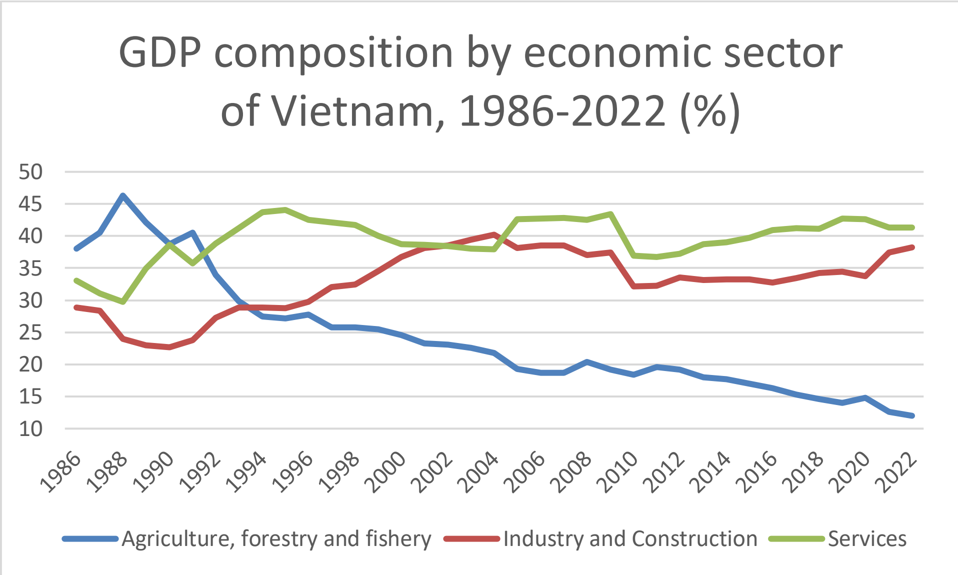

Figure 2.3. GDP composition by economic sector of Vietnam, 1986-2022 (%) (source: GSO 2023)

Beyond its economic contributions, agriculture is fundamental to Vietnam's food security, rural development, and social stability (Vietnam Sourcing Hub, 2023). The Renovation reforms were a pivotal turning point, transforming the country from a food-insecure nation into a major global agricultural exporter. Between 1986 and 2022, the sector's total output increased by approximately 230%, a testament to its enhanced productivity and commercialization (OECD, 2022). Today, Vietnam ranks among the world's leading producers and exporters of key commodities, including rice, coffee, pepper, and cashew nuts. This agricultural expansion has catalyzed the growth of upstream and downstream industries such as food processing, logistics, and agribusiness, thereby amplifying its overall impact on economic development.

In conclusion, although agriculture's share of GDP has declined in line with Vietnam's industrialization, its foundational role in the nation's social and economic fabric remains indispensable.

2.3. Vietnam's key agricultural products

Vietnam's agricultural sector is characterized by its diversity, including crop production, livestock, aquaculture, and forestry. This diversity underpins both domestic food security and the country's position as a major global exporter. The sector's output can be understood through its primary subsectors and the official commodities prioritized for strategic development.

The most crucial segment is cropping production, which is divided into annual and perennial crops. Annual crops are dominated by paddy rice, which constitutes over 90% of this category's production volume, underscoring its foundational role in the national diet and economy (GSO, 2023). Other significant annual crops include maize, sugarcane, and cassava. In contrast, the perennial crop sector includes fruit trees (e.g., mango, banana, longan) and high-value industrial crops. It is these industrial perennial crops−particularly coffee, rubber, cashew, and pepper−that are most critical for export, positioning Vietnam as a leading player in international agricultural markets.

Recognizing the strategic importance of these exports, the Ministry of Agriculture and Rural Development (MARD) has formally identified 11 key agro-commodities with high potential for trade integration and rural development by 2030 (Nguyen et al., 2017). This prioritized list includes rice, coffee, rubber, cassava, cashew, pepper, tea, oranges, pork, and shrimp. These commodities were selected based on rigorous criteria, including their economic value, productivity, and nutritional contribution. Their dominance is reflected in land allocation; collectively, rice, maize, coffee, rubber, cassava, and cashew as shown in Figure 2.4. Specifically, rice accounts for the vast majority (53%) of harvested land for these key products, cashew still commands a 2% share, highlighting its established role as a strategic crop.

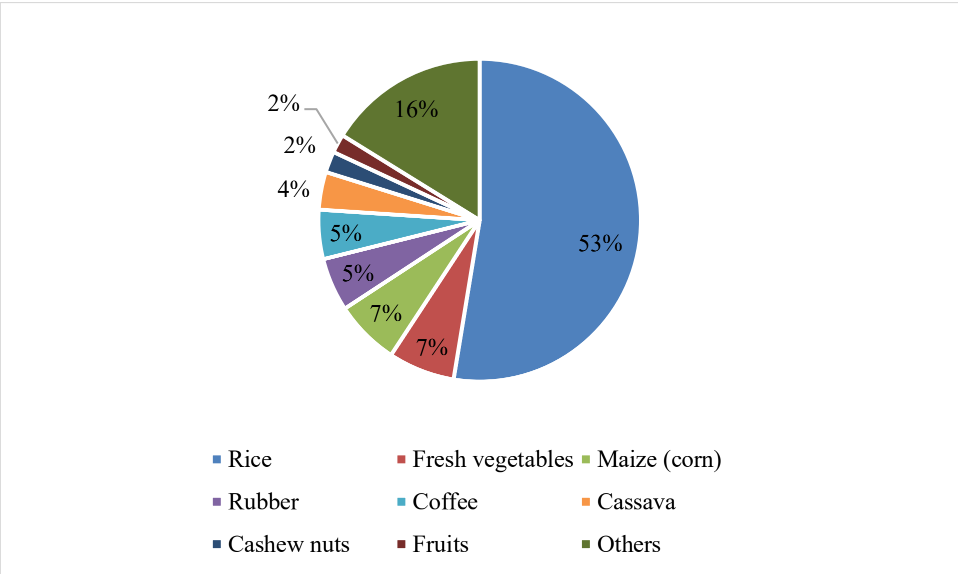

Figure 2.4. Agricultural products with land use allocation in 2023 (FAOSTAT, 2024)

2.4. Export trends of key agricultural sectors

Vietnam has solidified its role as a global agricultural exporter, with its international trade driven by key products such as rice, coffee, cashew nuts, pepper and fruits which demonstrates the sector's critical contribution to the national economy, as illustrated in Figure 2.5.

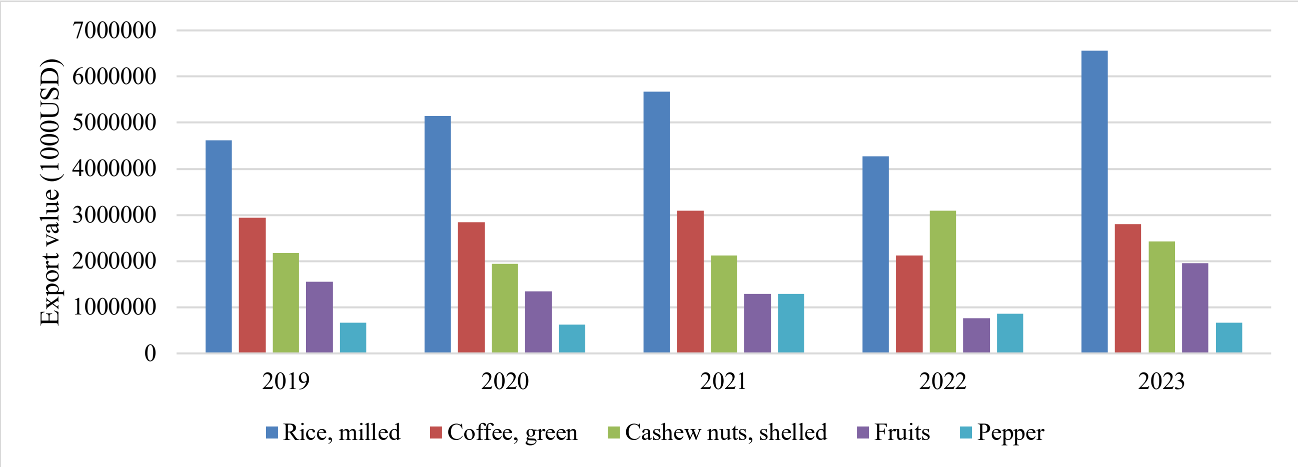

Figure 2.5. Top agricultural export products by value, 2018-2023 (1000 USD) (FAOSTAT, 2024)

Rice remains a cornerstone of Vietnam's agricultural exports, consistently ranking the country among the world's top three exporters. The value of these exports has shown a strong upward trend, culminating in record earnings of over $6.5 billion in 2023 (FAOSTAT, 2024).

Similarly, coffee is a major source of foreign exchange, with Vietnam maintaining its position as the world's second-largest exporter, primarily of robusta beans. The crop consistently generated approximately $3 billion annually from 2019 to 2023 (FAOSTAT, 2024).

Among these leading exports, cashew nuts have traditionally ranked second or third in value. Moreover, Vietnam is the undisputed global leader in the export of cashew kernels. From 2019 to 2023, the export value fluctuated, rising from $2.2 billion to a peak of $3.1 billion in 2022 before moderating to $2.4 billion in 2023 (FAOSTAT, 2024). The strategic importance of cashew is underscored by its efficiency; despite accounting for only about 2% of agricultural land allocation, it generates billions of dollars in annual export revenue, confirming its status as a high-value strategic crop.

2.5. Importance of cashew in agricultural sectors

The cashew nut industry is a cornerstone of Vietnam's agricultural sector, making significant contributions to both the national economy and rural socio-economic development. As the largest cashew kernel processor and exporter globally, Vietnam has transformed cashew production into a key part of its agricultural portfolio, shaping the country's position in the international agricultural trade.

Economically, cashew nuts consistently rank among Vietnam's most valuable agricultural exports. As of 2024, Vietnam exported approximately 725,300 tons of cashew nuts, generating $4.34 billion in revenue (GSO, 2024). This performance not only provides a critical source of foreign exchange but also solidifies cashew's position as a top-tier export commodity, typically ranking as the third largest agricultural product and within the top 20 of all export sectors nationally.

Beyond its export value, the cashew industry is a vital source of employment, providing livelihoods for over a million people, particularly in rural and economically disadvantaged regions. It is estimated that about 200,000 farming households are engaged in cultivation, with production concentrated in provinces such as Binh Phuoc, which accounts for 40% of the nation's cashew-growing area (ETIN, 2018; GSO, 2024). Furthermore, the cashew processing industry employs about one million workers across nearly 1,000 processing sites, ranging from large-scale enterprises to small household businesses. By generating widespread employment and stabilizing rural incomes, the cashew industry directly supports poverty reduction and aligns with the government's strategic goals for sustainable rural development.

2.6. Cashew world production trade pattern

2.6.1 Cashew nut production

Cashew nuts are cultivated commercially in approximately 34 countries across Africa, Asia, and Latin America (FAOSTAT, 2024). Over the past three decades, global production of raw cashew nuts (RCN) has experienced rapid growth. According to UNCTAD (2021) and FAOSTAT (2024), global RCN output more than doubled from 706,500 tons in 1990 to 1.53 million tons in 2000 and doubled again to 3.71 million tons by 2018. This upward trajectory has continued, with production peaking at 3.93 million tons in the 2023/24 season (FAOSTAT, 2024).

The global market is dominated by a few key producers, primarily Côte d'Ivoire, India, Vietnam, and Tanzania (Figure 2.6). In the 2019-2023 period, Côte d'Ivoire was a regional leader in West Africa, consistently leading global production, with its output surging from over 600,000 tons in 2019 to nearly 1.05 million tons in 2023. India maintained a stable production level of approximately 750,000 tons annually during the same period. Meanwhile, Vietnam's production showed more volatility, rising from 286,000 tons in 2019 to nearly 400,000 tons in 2021 before declining to 347,000 tons in 2023. In Eastern Africa, Tanzania was the regional leader, with production fluctuating around 200,000 tons each year.

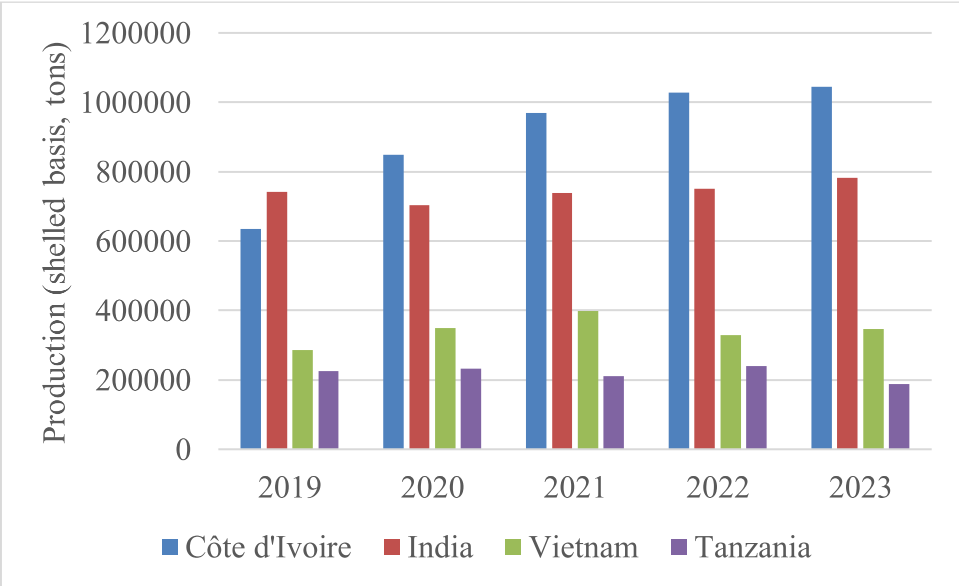

Figure 2.6. The largest cashew producers in the world, 2019 – 2023 (tons) (FAOSTAT, 2024)

2.6.2 Cashew nut importers

The global cashew trade is segmented into two primary flows: the import of raw materials for processing and the import of finished kernels for consumption.

On one hand, the market for raw cashew nuts (RCN) is dominated by two processing powerhouses. According to FAOSTAT (2024), Vietnam and India collectively accounted for over 98% of global RCN imports, which totaled nearly 3.2 million tons. Vietnam led as the largest importer (1.8 million tons, 55%), followed closely by India (1.4 million tons, 43%). Both nations primarily source raw cashews from Africa and Asia to supply their large-scale processing industries for re-export.

On the other hand, the import market for shelled cashew kernels is led by major consumer economies. Figure 2.7 illustrates the import volumes for the top destinations over the 2019-2023 period. The USA is the largest single destination, importing nearly 145,000 tons and representing 23% of global kernel imports in 2023. European nations are also key consumers, with Germany and the Netherlands each holding a 9% share (approximately 60,000 tons). Other significant importers include China, the UAE, and the UK (FAOSTAT, 2024), as illustrated in Figure 2.7.

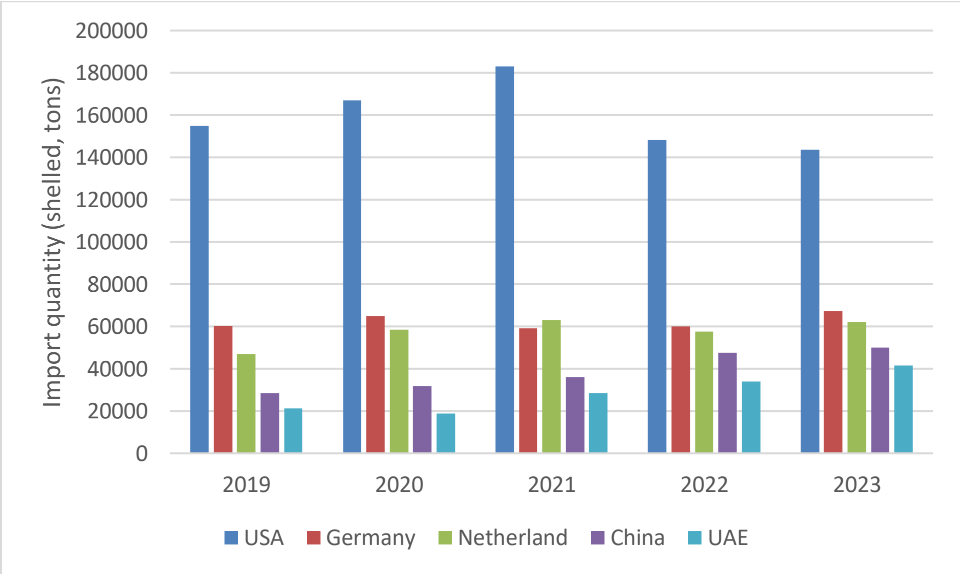

Figure 2.7. Largest cashew kernels importers, 2019 - 2023 (shelled, tons) (FAOSTAT, 2024)

2.6.3 Cashew kernel exporters

The global export market for shelled cashew kernels is dominated by Vietnam and India, though their market profiles and geographic focus differ significantly. According to INC statistics, Vietnam was the leading exporter of shelled cashew kernels in 2021, accounting for 65% of global exports. The main markets for Vietnam's exports were Western consumer markets, with the USA (36%), the European Union and the UK (30%). China is also a notable, though smaller, market for Vietnamese kernels (6%).

India was another major exporter; its market structure presents a contrast. Its primary markets were mainly Asia (59%), led by the UAE, Japan, and Saudi Arabia. The European Union and the UK represent its second-largest regional market, accounting for 34% of its export volume (INC, 2023).

2.6.4 World cashew nut consumption

According to the International Nuts and Dried Fruit Council (INC), in the 2022/23 crop year, almonds and walnuts ranked as the highest consumed nuts, accounting for 27% and 22% of global production, respectively. Cashews followed with 20%, while pistachios and hazelnuts accounted for 14% and 11%, respectively. Asia emerged as the leading region for nut consumption, representing 32% of the global total, followed closely by Europe at 31% and North America at 20%. The Middle East contributed around 12% of global consumption (INC, 2023).

Cashew nuts exhibited the second-highest annual growth rate among nuts, with a 7% increase over the last decade. According to INC statistics (2023), India, the USA, Germany, China, and the UK are the largest consumers of cashews in the world. In 2021, India consumed approximately 322 thousand tons of cashew kernels per year, followed by the USA with 182 thousand tons, and Germany with about 54 thousand tons. While India is both the largest producer and consumer of cashews, the other countries are primarily the largest importers and consumers.

2.7. Vietnamese cashew production and trade pattern

2.7.1 Cashew production in Vietnam

Cashew was first introduced to Vietnam in the 18th century and is valued for its resilience and economic potential (Binhphuoc.Gov, 2021). Cultivation subsequently spread across several regions, including the Southeast, Central Highlands, Central Coast, and the Mekong Delta (Figure 2.8). The sector was formally recognized as a key industrial crop by 1990, and by 1988, Vietnam had begun processing cashews for export, establishing its role as a major Asian producer.

The cultivation area has undergone significant changes, reflecting market dynamics. Starting from a base of 150,000 hectares in 1990, the area expanded rapidly to a peak of 440,000 hectares in 2007, driven by strong global demand (GSO, 2024; ETIN, 2018). However, a decline began in 2008, with the area falling to 321,100 hectares and further to approximately 304,400 hectares by 2023 (FAOSTAT, 2024). This contraction is largely attributed to falling cashew prices, reduced profitability, and increased competition from other high-value crops such as rubber, coffee, pepper, and fruit trees (BP GSO, 2024).

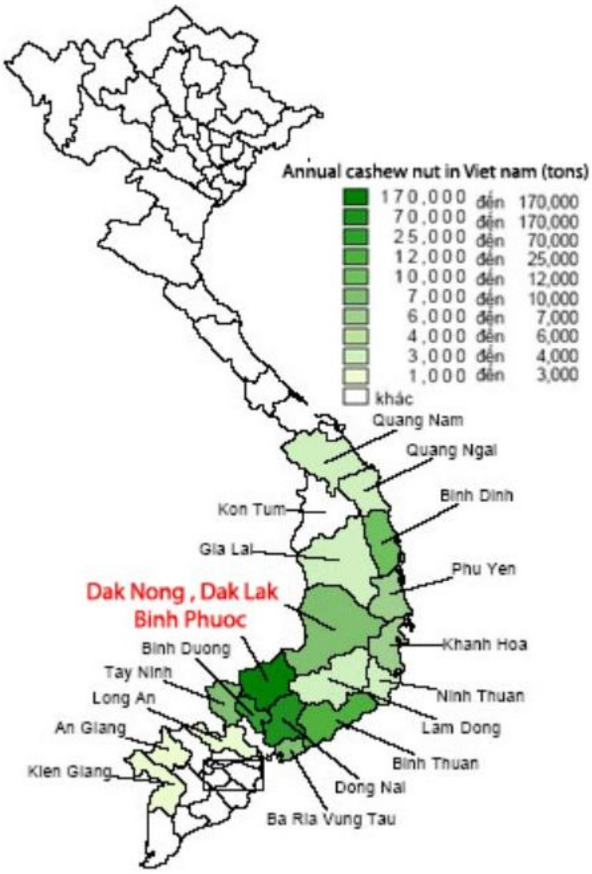

Figure 2.8. Cashew distribution and production map in Vietnam

Production volumes have shown considerable volatility, closely correlated with the changes in harvested area (Figure 2.9). After dropping from 275,439 tons in 2013 to around 216,000 tons in 2017, production surged to a peak of 400,000 tons in 2021 before moderating to about 350,000 tons in 2023 (FAO, 2024). This volatility stems from multiple challenges, including the reduction in farming area, fluctuating yields, and the aging of cashew orchards−approximately 30% of trees are over 20 years old and experiencing declining productivity (ETIN, 2018; MARD, 2024). Furthermore, climate change impacts and a lack of advanced farming techniques among growers have exacerbated yield instability, which fell to 800 kg/ha in 2013, recovered to 1.4 tons/ha by 2021, but declined again to 1.15 tons/ha in 2023 (GSO, 2024).

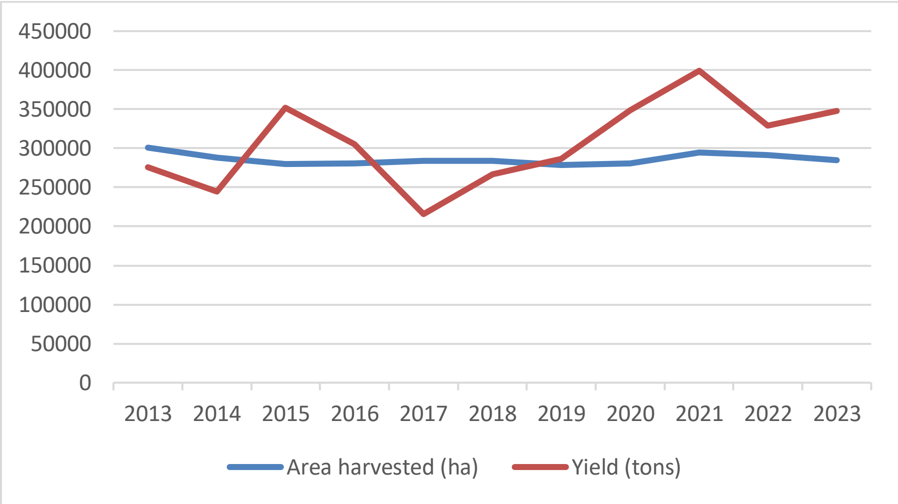

Figure 2.9. Vietnam cashew area harvested (ha) and yield (tons), 2013 – 2023 (FAOSTAT, 2024)

As of 2023, Vietnam's total cashew farming area was 304,400 hectares, with production heavily concentrated in the Southeastern region (GSO, 2024). Binh Phuoc Province is the undisputed national hub, accounting for 49% of the total area (approximately 150,000 hectares) and contributing nearly 57% of the country's total production (around 200,000 tons). Other significant provinces include Dong Nai (15% of the area) and Binh Thuan (6%), with smaller contributions from Binh Duong and Tay Ninh. This high concentration of cultivation and processing infrastructure solidifies Binh Phuoc's status as the heart of Vietnam's cashew industry.

2.7.2 Import of raw cashew nut in Vietnam

Vietnam as the global leader in cashew processing is underpinned by its massive import volume of raw cashew nuts (RCN). Driven by advanced processing capacity and competitive advantages, Vietnam sources RCN internationally for processing and re-export. According to FAOSTAT (2024), Vietnam's RCN imports surged from approximately 250,000 tons per year in 2012 to a peak of 2.5 million tons in 2021−representing a tenfold increase. In 2023, imports fell to 1.08 million tons, with a value of approximately USD 1.22 billion.

Vietnam's import sources have evolved, with a shift toward Southeast Asia. Africa, which produces over half of the world's RCN but processes only about 10% locally, has traditionally been a primary source, supplying roughly 50% of Vietnam's needs from countries like Côte d'Ivoire, Tanzania, Ghana, and Nigeria (OEC.WORLD, 2022; FAOSTAT, 2024; ETIN, 2018). However, Cambodia has emerged as a pivotal supplier. Following a 2017 agreement between the Vietnam Cashew Association and the Cambodian government, Vietnam committed to providing investment and technology to help Cambodia expand its cashew farming area to 500,000 hectares and production to one million tons by 2025 (ETIN, 2018). This strategic partnership, designed to secure a stable RCN supply for Vietnam. By 2022, Cambodia had become Vietnam's single largest source of RCN, supplying nearly 46% of total imports and surpassing all African nations (OEC.WORLD, 2022).

2.7.3 Export of shelled cashew kernels in Vietnam

Vietnam has consolidated its position as the world's leading exporter of shelled cashew kernels, a status supported by significant technological innovation and a dynamic processing sector. A key competitive advantage has been the domestic development of shelling and peeling machines, which are 40-50% cheaper than international alternatives, thereby reducing processing costs and enhancing global competitiveness (ETIN, 2018).

Driven by this technological edge, export volumes and values grew substantially over the past decade. From 2012 to 2021, exports surged from approximately 220,000 tons (USD 1.44 billion) to 506,000 tons (USD 3.89 billion) (FAOSTAT, 2024). Although 2023 saw a dip to 460,000 tons valued at USD 2.35 billion, the sector rebounded strongly. Preliminary data for 2024 indicates a record export volume of 725,300 tons, generating USD 4.34 billion and solidifying cashew as Vietnam's third most valuable agricultural export (General Department of Vietnam Customs, 2024). The United States remains the top destination (USD 759 million), followed by China (USD 302 million), the Netherlands (USD 267 million), and Germany (USD 175 million) (OEC.WORLD). Notably, markets in Germany, Iraq, and the UAE demonstrated the fastest growth between 2021 and 2022.

This export growth has been facilitated by a rapid expansion of the processing industry. According to ETIN (2018), the number of processing firms had nearly tripled from 160 in 2014 to 450 by 2017, with a total processing capacity of 1.4 million tons of raw cashew nuts per year. As a result, many small firms entered the market, either developing their own brands or producing value-added products such as roasted and coated cashews. However, most processors focus on producing cashew kernels. Established companies continued to expand, leading to increased competition within the industry, which in turn caused lower export prices (MIP, 2022). Furthermore, the high number of processors belies a concentration of export capability; VINACAS statistics indicate that only about 25% (256 companies) of processing firms are directly engaged in exporting, highlighting a significant gap between domestic processing capacity and international market access.

2.8. Key agricultural related policies.

In 2018, the Vietnamese government issued Decree No.109/2018/ND-CP and Decision No.885/QD-TTg, establishing a comprehensive plan for organic agriculture development from 2020 to 2030, aiming to align Vietnam's organic agriculture with global trends.

In 2022, the Decision No. 150/QD-TTg approved Vietnam's Sustainable Agriculture and Rural Development Strategy, aims to modernize the agricultural sector, improve rural livelihoods, and ensure environmental sustainability. The strategy focuses on industrial perennial crops, including cashew nuts, coffee, rubber, tea, and pepper, which are vital contributors to Vietnam's economy. The strategy aims to improve quality and sustainability by promoting organic and high-yield farming practices, enhancing processing capabilities, and expanding export markets. Vietnam also aims to increase competitiveness by improving processing technologies and supply chain efficiencies, develop value-added products, and foster public-private partnerships in the industry. By 2050, Vietnam aims to become a leading exporter of high-quality, climate-resilient agricultural products. The strategy also emphasizes the importance of sustainable farming practices to preserve soil health, reduce deforestation, and minimize water usage. It encourages the adoption of climate-smart agriculture and traceability and certification programs to ensure sustainable and ethical production. The strategy aims to ensure Vietnam remains a global leader in the commodity export while fostering environmental resilience and rural development.

Vietnam's National Agricultural Innovation Program (2017-2025) aims to enhance productivity and sustainability in agriculture by promoting innovation and technology through investments in R&D, developing resistant crop varieties, and supporting agribusinesses and startups to foster innovation in food production and processing (Gray & Jones, 2022).

Chapter 3. Literature review

This Literature Review establishes the theoretical foundation for the study, focusing on three core disciplines: VCA, MFA, CE. The chapter is structured into seven sections. It begins by defining the Value Chain (Section 3.1), then introduces the Agri-Food Value Chain (AFVC) —detailing its definition and analytical framework (Sections 3.2). Subsequently, it presents the theory of MFA (Section 3.3) and its specific application within agri-food systems (Section 3.4). The final sections explore the concept of the CE, moving from its general definition (Section 3.5) to its integration within value chains (Section 3.6) and, specifically, within the agri-food value chains (Section 3.7).

3.1. Value chain

The first and most foundational concept of value chain (VC) is introduced by M. Porter in his 1985 book, *Competitive Advantage: Creating and Sustaining Superior Performance.* Porter defines the value chain as a "*system of interdependent activities*" that a firm perform to "*design, produce, market, deliver and support its products or services*" to consumers. It includes primary activities such as inbound logistics, operations, outbound logistics, marketing and sales, and after-sales service, as well as support activities like product design, material procurement, human resources, technology development, and organizational infrastructure (Pande & Kumar Adil, 2019). This framework is to achieve competitive advantage by implementing distinctive and exclusive processes as shown in Figure 3.1. As a strategic management tool, the VC concept facilitates the analysis of business strategies and competitiveness in the context of globalization and international trade into specific activities thereby lowering cost and in a way that lead to differentiation (Porter, 1985).

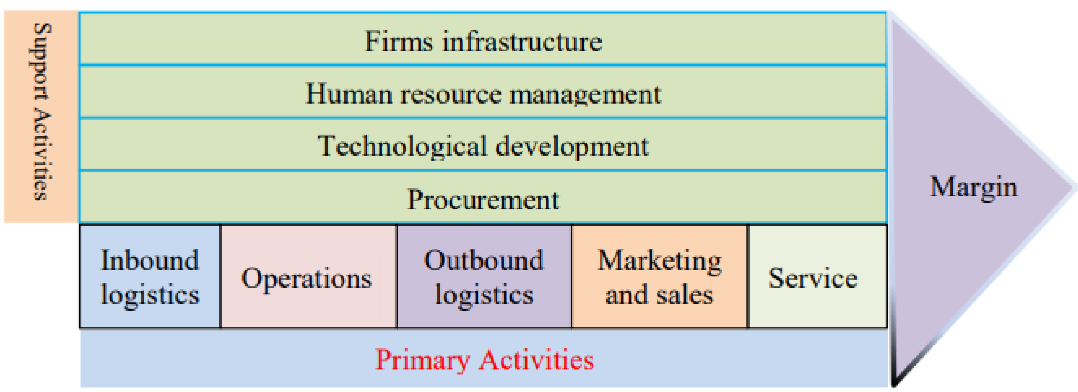

Figure 3.1. Porter value chain framework (Porter, 2001)

Building from Porter's work, Gereffi et al. (2001) has introduced the global value chain, especially when examining networks or chains rather than individual firms across multiple firms and countries. This perspective raises essential questions about governance, power dynamics, and chain operations. Donovan et al. (2015) expands on this by describing value chains as a collection of activities, actors, and strategic networks designed to meet consumer demands more effectively.

Webber and Labaste (2010) highlight the importance of linkages within value chains, including vertical connections that create consumer value and horizontal ties with other chains providing intermediate goods and services. Bellù (2013) further characterizes the value chain as "interconnected economic activities performed by vertically linked agents across various stages". Webber and Labaste (2010) and Bellù (2013) indicate that collaboration between various actors help perform tasks that enhance value of products or services. These studies suggest that value chains are not only about creating value but also about how this value is distributed among participants.

However, traditional VCs have become increasingly complex due to interconnections between actors across different countries. A VC can now be seen as "*a group of organizations exchanging materials, funds, and information while collaborating over the medium to long term*" (Monastyrnaya et al., 2017). It involves actors who perform activities, stakeholders influencing those activities, physical processes, business models, and the methods of designing, promoting, and offering products to consumers (UN, 2020).

Mac Clay & Feeney (2019, p33) identify some key elements that a generic value chain must include: "*inputs, outputs, and activities that drive transformation; agents involved in the activities with both vertical and horizontal connections; activities that add value and allocate it; the final products; end consumers; and shared challenges and opportunities among participants, power relations and governance structures*".

In this context, Esteban-Amaro et al. (2024) define the "*VC as comprising (i) a network of partners, (ii) flows of information, goods, and finances, and (iii) shared value*". They suggest the network partners include suppliers, customers, and users upstream and downstream, as well as an innovation network involving universities and knowledge institutions that develop new processes, technologies, products, and services. Jørgensen & Remmen (2018) add that regulatory networks engaging local, national, and international public authorities and civil society organizations also play a significant role in the value chain.

Building on these concepts and responding to the need for sustainability, D'heur (2015) defines a *sustainable value chain* as one that "*covers all stages of the lifecycle from idea/concept, raw material sourcing, production, and distribution, and end customers use to the point where the product goes back to a biological or technical cycle, thus closing the loop*." This definition reframes the value chain from a linear, economic structure to a circular, regenerative system, which serves as a key conceptual foundation for this study.

3.2. The Agri-Food Value Chain (AFVC)

3.2.1 Definition of AFVC

De Vries et al. (2022, p.176) define AFVCs as "*complex systems comprising a network of interdependent actors that cooperate to capture and create value by responding to consumer demand through a wide range of practices […] including production, harvesting, bulking, processing, trading, packaging, and retailing of food.*" Building on this foundations, Grohmann et al. (2023, p3) note that the AFVC has been conceptualized through several perspectives: (i) following Porter's (1985) value chain logic that includes various *activities* to produce, process, trade and consume an agricultural product, (ii) a set of *actors* connected through interactions, (iii) *networks* of actors. Hansen (2024) expands this view through the "farm-to-table" concept, which includes the supply of agricultural inputs and the entire value chain (feed, equipment, machinery, finance, R&D, and so on), agriculture (production), processing and modification, wholesale, retail and food service, and consumers. The author suggests the AFVC is a vertical axis that connects the input supply, production, processing, and sale of food products through both vertical integration and horizontal integration as depicted in Figure 3.2.

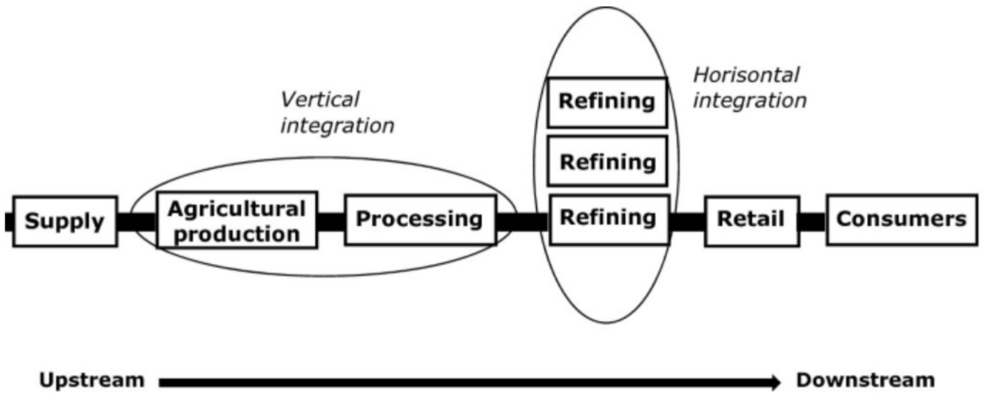

Figure 3.2. Vertical and horizontal integration in the agri-food value chain (Hansen, 2024)

Unlike other value chains, the AFVC is distinct due to its unique characteristic mainly dealing with living organisms and highly perishable products (Sporleder et al., 2011; Hansen, 2024). This perishability of agri-food products as well as the complex and dynamic of agricultural industries necessitates highly efficient and timely logistics system, highlighting the necessity of effective coordination between different actors in the value chain (Hansen, 2024, Schouten & Bitzer, 2015).

3.2.2 Agri-food value chain analysis (AFVCA)

According to Kaplinsky & Morris (2000), AFVCA is a strategic and analytical approach to understand how value is created, distributed and sustained across the entire food system from input, production, and processing to consumer consumption. According to Akyüz et al. (2023) and Salali et al. (2024) , agri-food value chain analysis is not a single tool but rather a suite of interconnected methods, includes analysis of: (i) institutional/ functional (mapping the actors, activities, and product flows in the value chain), (ii) economic/ financial structures (Value added analysis, cost – benefit analysis, price transmission analysis), (iii) social (labor conditions, gender roles, and community impact), and (iv) environmental (resource, emissions, biodiversity and sustainability assessments). As a result, a comprehensive AFVCA will usually start with mapping value chain, use value chain framework to understand interactions, relationships, power and governance between actors and finally layer on a social and environmental assessment to provide a better understanding of the value chain performance (Ingram et al., 2018). Hidayati et al. (2021) suggest that after mapping the value chain, value addition and governance are the two most important dimensions to understand key activities in an agri-food value chain.

3.2.2.1.Value chain mapping

Kaplinsky & Morris (2002) explained that value chain mapping identifies all activities necessary for a product or service, spanning the stages from conception to production and ultimately delivery to the final consumer. This involves profiling actors involved in production, distribution, marketing, and sales, while assessing their characteristics, cost and profit structures, employment impacts, and the flow of goods within domestic and foreign markets (Frederick, 2019). Such mapping provides a foundational understanding of how goods and services are created and delivered, offering insights into inefficiencies or opportunities for improvement.

Akyüz et al. (2023, p8) expand this concept by proposing a more comprehensive framework for value chain mapping through the integration of institutional or functional analysis. Their approach profiles the industry by describing, explaining, and measuring different aspects in physical terms. In this analysis, the industry is considered multiple perspectives from commodity production, processing, marketing, to final consumption. In detail, it examines: (a) technical processes required from production/producer to final consumption/consumer; (b) the inputs and intermediate goods at each stage of the value chain; (c) the interrelationships between the agents/actors involved at each stage; (d) the physical flows of goods between different agents/actors; and (e) problems in input supply, logistics, etc. This extended framework provides a more holistic understanding of the value chain, serving as a foundation for subsequent value addition and governance analysis (Hidayati et al., 2021; Akyüz et al., 2023).

3.2.2.2.Value addition

Value addition in the AFVC has evolved from basic post-harvest processing to a comprehensive strategy involving product differentiation, adoption of valued production methods (e.g., grass-fed beef ororganic certification), building strategic market linkages to ensure a greater share of the final price premium flows back to the producers and integrate sustainability considerations (USDA, 2008; Lu and Dudensing, 2015; Cucagna & Goldsmith, 2018; Clark et al., 2021; Akyüz et al. 2023).

Coltrain et al., (2000) define value addition as "*the process to economically add value to a product by changing its current place, time and form characteristics to characteristics more* *preferred in the marketplace."* Amanor-Boadu (2003) integrates activity with profitability, stating that value addition when a firm performs an activity traditionally done farther down the chain (e.g., a farmer milling grain) or if the firm is rewarded for performing an activity never before done in the chain.

Building on these foundations, Lu and Dudensing (2015, p4) connect value-addition agriculture to consumer preferences – their willingness to pay, and economic development strategies. The authors emphasize value addition as a portfolio of agricultural practices that enable farmers to align with consumer preferences for agricultural or food products with form, space, time, identity, and quality characteristics that are not present in conventionally produced raw agricultural commodities. It involves farmers changing their position on the value chain, creating closer or direct linkages with consumers, or changing production processes to alter or preserve certain intrinsic characteristics of their farm/ranch products.

Based on the USDA definition of VA, Clark et al., (2021, p191) outline value addition are commodities that meet at least one of five criteria: (i) has undergone a change in physical state (e.g., processing berries into jam, wheat into flour, or corn into ethanol); (ii) was produced in a manner that enhances its value (e.g., organic production); (iii) is physically segregated in a manner that enhances its value (e.g., an identity preservation system for a particular variety of grain or traceability of hormone-free livestock); (iv) is a source of farm- or ranch-based renewable energy (e.g., converting methane from animal waste to generate energy); or (v) is aggregated and marketed as a locally produced food product. These practices aim at expanding markets and increasing the producer's share of revenue (Rupasingha et al., 2018, p. 3).

At the analytical level, Cucagna and Goldsmith (2018) conceptualize value addition as the increase in economic value when raw agricultural materials are transformed into more desirable goods, measurable through marketing margins (the price spread between farm and retail value). Their work highlights that value creation is increasingly concentrated in downstream stages −processing and retail−where innovation, branding, and intangible assets driven by increased consumer demand for differentiated, high-quality, and convenient products. Akyüz et al. (2023) expand value addition through analytical lens by quantifying where and how value is created and distributed along the value chain to assess sustainability and profitability.

In developing country context, Hidayati et al. (2023) identify three orientations of value addition (quality, safety, and value orientation) in order to upgrade the value chain among smallholders including: (i) Commodity based orientation, which indicates smallholder's focus to produce and sell raw material products with minimal treatment;(ii) Processed based orientation indicates an expansion in value adding by smallholders via post-harvesting treatments; (iii) Branded/certified orientation, which indicates smallholders' orientation in optimizing value creation through branded and certified products. Cucagna & Goldsmith, (2018) add that producers (farmers) can capture a greater share of consumer value by engaging in value-adding activities and increasing engagement in higher levels of vertical coordination, such as contractual arrangements or vertical integration, to improve efficiency and competitiveness.

3.2.2.3.Governance

Governance in the AFVC refers to "*the multiple steering mechanisms that coordinate the activities among the various actors*" (Grohmann et al., 2023). According to the authors, these mechanisms operate primarily through formal and informal rules that codify expectations, rights, and obligations, thereby facilitating coordination and ensuring predictability within transactions. In simple with low-risk value chains, informal rules such as trust, reputation, or community norms are sufficient to guide activities. Nevertheless, in complex value chains, coordination become formalized through contract, certifications, and traceability systems that specify quality, safety, and sustainability requirements (Williamson, 1985; Havinga et al., 2015; Ingram et al., 2018; Grohmann et al., 2023).

According to Grohmann et al. (2023, p3) governance in AFVC must fulfill five essential coordination functions: rulemaking, adoption, implementation, monitoring, and enforcement. They explain:

(i) Rulemaking involves agenda setting, defining goals, negotiating and formulating concrete rules that may be revised as political, social, or economic conditions evolve.

(ii & iii) Adoption and implementation of the rules that translate these rules into practice by obligating participants to comply and ensuring that necessary measures are in place to achieve compliance.

(iv) Monitoring entails systematic inspections, audits, and documentation to verify adherence.

(v) Enforcement introduces sanctions are set of rules such as warnings and contractual penalties to the withdrawal of certification or legal action in order to assure behavioral compliance and legitimacy.

Governance is the central analysis in value chain research, as it reflects the degree of power, the coordination between actors and represents a form of non-market coordination of economic activity, where direct exchanges of information, standards, and resources occur among businesses (Gereffi & Kaplinsky, 2001; Humphrey & Memedovic, 2006). These authors indicate that the control exerted by lead actors (firms) over critical resources like market access, standards, and technological capabilities will shape production decisions, entry and exit dynamics, and the distribution of value along the chain (Gereffi & Kaplinsky, 2001).

Hidayati et al. (2021) further conceptualize governance in AFVCs as comprising three interrelated dimensions: vertical coordination, horizontal coordination, and information flow. Vertical coordination represents the hierarchical and relational linkages between actors at different stages of the chain that includes power relations, transaction terms, standard setting, and profit distribution (Trienekens et al., 2018; Collins, 2014; FAO, 2014). Strong vertical integration allows for closer control, efficient communication, and enhanced responsiveness among actors. According to Gereffi et al. (2005) and Guimarães et al. (2023), vertical governance can be classified into various structural forms, including market, modular, relational, captive, and hierarchical, based on transaction complexity, the codifiability of information, and suppliers' capabilities to meet buyer requirements.

In contrast, horizontal coordination refers to collaboration among actors operating at the same stage of the chain, such as farmer cooperatives, producer organizations (POs), or industry associations, which aims to improve bargaining power, share resources, achieve economies of scale, and enhance market access (FAO, 2014a; Thorpe, 2018). Evidence from Garnevska et al. (2011) demonstrates that well-functioning POs can significantly contribute to the economic and social well-being of their members and rural communities by fostering collective learning and local empowerment.

The third dimension, information flow, represents a vital governance mechanism that ensures transparency, traceability, and responsiveness across the chain. Bochtis et al., (2019) suggest efficient information sharing reduces information asymmetry, improves decision-making, and enhances overall value chain performance. Conversely, information asymmetry (e.g. when buyers possess more market knowledge than producers) can lead to market inefficiencies and power imbalances (Mishra & Dey, 2018; Reardon et al., 2009). Therefore, symetric and timely information exchange is critical for building trust and improving the resilience and inclusivity of agri-food value chains (Collins, 2014).

3.3. Material flow analysis

Baccini and Brunner (1991), in their book "*Metabolism of the Anthroposphere (1991)*, established the systematic framework for Material Flow Analysis (MFA). It provides the methodological basis for applying the law of conservation of mass to the human-dominated environment, which they termed the "*anthroposphere*" – defined as "*mankind's sphere of life, a complex technical system of energy, material, and information flows*". They advanced MFA from a general concept (like earlier studies on urban metabolism or chemical engineering mass balances) into a standardized tool for quantifying resource use, waste generation, and environmental emissions on a regional or city scale. This provided a crucial foundation for modern waste and resource management, as well as the transition to a CE (Brunner & Rechberger, 2004, Chen & Graedel, 2012).

Bringezu and Moriguchi (2002) extended MFA to encompass entire process chains−from extraction or harvest, chemical transformation, manufacturing, consumption, recycling, and disposal of materials – quantifying the inputs and outputs in physical unit (usually in tonnes). They differentiated between Material Flow Accounting (MFAc), which focuses on system-level input–output balances, Substance Flow Analysis (SFA) and MFA which extend this accounting toward dynamic modeling of material use within systems. While the principle is the same, MFA tracks bulk materials or goods (e.g., total biomass, steel), and SFA tracks specific elements or chemical compounds (e.g., phosphorus, cadmium).

Building on these foundations, Brunner and Rechberger (2017) redefined MFA as "*a systematic method for quantifying the flows and stocks of materials or substances within a specific system boundary in space and time*". It connects sources, pathways, and final sinks of materials, enabling a clear understanding of the entire lifecycle of materials under investigation. Similarly, Graedel (2019) characterized MFA as the central methodology of industrial ecology that "*quantifies the ways in which the materials that enable modern society are used, reused, and lost*". Graedel (2019) outlined its defining features: (i) system-level analysis rather than a singular material flow; (ii) a detailed description of each flow, whether physical or monetary; (iii) the quantification of significant material flows; and (iv) visualization through numerical and diagrammatic outputs.

More recently MFA has been used as a key tool in circular economy strategies and management of resource, waste, and the environment (Brunner & Rechberger, 2017; Graedel, 2019; European Commission, 2020; EMF, 2022; Ibáñez-Forés et al., 2023). MFA is employed to identify key material flows and stocks across different level (macro – meso – micro) – from national economic systems (Jacobi et al., 2018), industrial sectors (De Marco et al., 2009; Lombardi et al., 2021), to individual products or firms (Lagioia et al., 2012; Ravitz Wyngaard & Kissinger, 2019; Amicarelli et al., 2020).

Huang et al.(2012) further highlight M/SFA as a key tool for sustainable development assessment through four connection points: (i) create a systematic database to improve waste recycling efficiency and reduce resource extraction and emissions, (ii) identifying critical pathways for resource loss and inefficient use, (iii) establishing indicators to increase recycling levels and minimize waste volume, and promoting wiser resource use, (iv) optimizing material use and processing by applying modeling socioeconomic responses to different material or substance flows or a closed cycle industrial model.

By quantifying inflows, outflows, and losses, MFA helps detect critical material fluxes and environmental impacts, thereby supporting the modeling of socio-metabolic systems and the interactions between nature and society (Fischer-Kowalski & Rotmans, 2009; Haberl et al., 2011; Bogadottir, 2020). The approach provides reliable data for evaluating resource efficiency, circularity, and waste reduction initiatives (Allesch & Brunner, 2016; Wang et al., 2020; Khlifa et al., 2024). It informs decision-making by identifying inefficiencies and opportunities for product redesign, life extension, resource recovery, and closed-loop systems (Henri & Journeault, 2010; Blomsma et al., 2019; De Jesus et al., 2018, 2021).

3.4. Material Flow Analysis in agri-food system

In recent years, numerous studies have applied Material Flow Analysis (MFA) to examine resource consumption, energy consumption, and waste generation across different industries (Brunner & Rechberger, 2017; Amicarelli et al., 2021). Within the agri-food industry, MFA has proven to be a valuable tool for assessing the economic and environmental implications of production systems, supporting sustainable management practices and policy development

(Beretta et al., 2013; Amicarelli et al., 2020). These studies highlight that MFA enables a systematic understanding of food value chains and facilitates the identification of inefficiencies, waste hotspots, and opportunities for circularity.

In AFVC, MFA has been employed to measure and qualify FLW throughout the food supply chain−from agricultural production to processing, distribution, retail and final consumption (Beretta et al., 2013; Augustin et al., 2020). Studies demonstrate that its application extends across all stages of the agri-food system. For instance, at the agricultural stage, Tamura and Fujie (2014) analyzed the material cycle of agriculture in Japan, focusing on sugarcane, pasturage, and beef cattle. Their study highlighted the potential of MFA to enhance resource efficiency and employ industrial symbiosis to create environmental and economic benefit. Similarly, Ghani et al. (2017) applied MFA to farming and livestock systems, quantifying agricultural inputs and outputs and energy consumption, and identifying opportunities for recovery, reduce natural resource use and pollution to the environment.

At the industrial processing stage, Amicarelli et al. (2020) conducted MFA research on the Italian potato industry, combining top-down national statistics with bottom-up process data to measure food losses across production stages−from primary processing to chip and dried product manufacturing. Their findings revealed substantial wastage-related losses embedded in resources such as starch and energy, providing a quantitative basis for intervention and waste minimization to improve resource efficiency and circular production.

At the distribution and consumption stages, Leray et al. (2016) used MFA to evaluate food distribution, warehousing, and management practices, integrating both quantitative ("how much") and qualitative ("what" and "why") perspectives on food waste.

Further applications extend to the whole supply chain. Wyngaard and Kissinger (2019) applied MFA to desert food production system, examining resource use (water, land, energy and material) from cultivation to post harvest, shipping and waste disposal. Their study highlighted the biophysical strengths and constraints of different technologies and emphasized the need for stronger public policy investment to enhance food system sustainability. Similarly, Amicarelli et al. (2021) employed MFA in the entire Italian beef sector to evaluate natural resource use (water, energy, materials) and waste generation. Their study demonstrates that MFA enables a more comprehensive understanding of the metabolic processes within agri-food systems and provides accurate data for calculating environmental indicators such as carbon and water footprints and for conducting life cycle assessments. It also supports governments and businesses in evaluating resource use and waste management practices, as well as enhancing consumer awareness of sustainability and resilience in the agri-food sector.

Collectively, these studies confirm the utility of MFA as a critical tool for quantifying and managing flows within the agri-food system. It allows for the qualification and quantification of inputs (e.g., raw materials, water, energy) and outputs (e.g., food waste, emissions) along the entire food chain, while identifying critical loss points and resource inefficiencies (Amicarelli et al., 2020, 2021). Therefore, MFA supports the implementation of circular economy strategies by highlighting opportunities for reuse, recycling, and energy recovery from food waste, aligning with the Sustainable Development Goals (SDGs) and fostering industrial symbiosis initiatives (Amicarelli et al., 2021).

In the context of the Vietnamese cashew nut value chain, this study adopts a simplified MFA framework focused on mapping key material inputs (raw wet cashew nuts) to outputs (kernels, by-products) across major processing stages. This approach will provide an empirical foundation for understanding how material efficiency and circularity can be improved within the sector. By tracing physical flows and identifying points of material loss or underutilization, the analysis contributes to identifying opportunities for waste valorization and sustainable resource management in the cashew industry.

3.5. Circular economy

Circular economy concept

The academic definition of the circular economy (CE) has evolved over time, moving from a narrow focus on waste management to a broad, systemic approach and continues to draw attention from both researchers and practitioners (Kirchherr, 2021; Köhler et al., 2019; Vecchio et al., 2022). While there is no single, universally agreed-upon definition, key academic references show a clear progression.

The foundational ideas of CE emerged from various disciplines long before the term "circular economy" became mainstream. Economist Kenneth Boulding (1966) is often cited for his paper, "The Economics of the Coming Spaceship Earth." He contrasted the linear "*cowboy economy*", which assumes infinite resources, with a *"spaceman economy*", which operates within the finite limits of a closed system. His work provides foundation for comprehending the need for recycling and resource reuse – two fundamental principles of CE (Lewandowska et al., 2022; Viglioglia et al., 2021).

Walter Stahel (1982) proposed a "*closed-loop economy*", which focused on extending product lifespans through reuse, repair, or remanufacturing instead of disposal. Stahel (2010) later coined the term "*performance economy*", advocating for business models that sell a product's function rather than the product itself. This prolongs product lifecycles and reduces waste. His work has greatly influenced contemporary CE ideas that emphasise industrial resilience and sustainability.

Simultaneously, the field of industrial ecology emerged, viewing industrial systems as ecosystems where waste from one process becomes a resource for another, a concept referred to as "*industrial symbiosis*" (Graedel & Allenby, 1995).

Michael Braungart and William McDonough (2002) proposed the Cradle-to-Cradle (C2C) design philosophy, which is central to modern CE thinking. It re-conceptualized "*waste*" by distinguishing between biological nutrients (materials that can safely return to the biosphere) and technical nutrients (materials that can be infinitely cycled within industrial systems). This C2C approach emphasized resource recovery and waste minimization (Mang & Reed, 2017), moved the focus from mere recycling to intentional, regenerative design.

Expanding on CE concepts, Gunter Pauli (2010) in his book "*The Blue Economy*" promoted creative business strategies that produce no waste and coexist peacefully with natural systems. Pauli's strategy promotes the conversion of trash into useful resources, improving sustainability and environmental health (Hira et al., 2022).

While not a traditional academic institution, the Ellen MacArthur Foundation (EMF) has become arguably the most influential source for the contemporary definition of CE. Their widely cited definition describes CE as "*an industrial system that is restorative or regenerative by intention and design*" (EMF, 2015). They are credited with popularizing the three core principles: "(1) Design out waste and pollution; (2) Keep products and materials in use; (3) Regenerate natural systems." This framework shifted the focus from a narrow, end-of-life approach to a holistic, systemic one (Ghisellini, Cialani, & Ulgiati, 2016).

As the field matured, scholars began to analyze the various definitions to identify commonalities and gaps. Kirchherr et al. (2017) conducted a systematic review of 114 CE definitions from academic and professional sources. They found that while there was no single definition, most referenced the 3R principles (reduce, reuse, recycle). Their synthesis highlighted CE as "*an economic system that is based on business models which replace the 'end-of-life' concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes*."

In a more recent study, Kirchherr et al. (2023) analyzed 221 CE definitions from 2017-2023. They ultimately defined CE as "*The circular economy is a regenerative economic system which necessitates a paradigm shift to replace the 'end of life' concept with reducing, alternatively reusing, recycling, and recovering materials throughout the supply chain, with the aim to promote value maintenance and sustainable development, creating environmental quality, economic development, and social equity, to the benefit of current and future generations*.".

Strategies for CE implementation

The application of the Circular Economy represents a fundamental shift from the linear "take-make-dispose" model to one that is restorative and regenerative by design (EMF, 2015; Masi et al., 2017). This transition redefines how value is created, delivered, and captured across all stages of a product's lifecycle, emphasizing the prolonged circulation of products, components, and materials at their highest utility (Alhawari et al., 2021).

Common strategies in the CE literature to achieve circularity include "smarter product usage (refuse, rethink, reduce), extending product life (reuse, repair, maintain), and circulating materials at end-of-life (recycling, cascading)" (Brändström & Eriksson, 2022). Effective CE design principles involve "closing material loops (reusing materials), slowing them (extending product life), and narrowing them (increasing efficiency and reducing consumption)" (Esteban-Amaro et al., 2023).

Academic literature emphasizes that CE transition requires the integration of circular strategies across all stages, extending beyond traditional end-of-life management to encompass product design, business models, and multi-stakeholder collaboration (industry, consumers, policymakers, academia) (Kirchherr et al., 2023, Groenewald et al., 2024; Solomon et al., 2024). Esteban-Amaro et al. (2023) suggest that CE business models need a holistic approach that involves all stakeholders, rather than merely focusing on business profitability. According to Houssard et al. (2022), CE requires rethinking value creation across the VC, moving from individual gains to collective benefits, where cooperation and shared value creation enhance eco-efficiency and resilience across systems. Huybrechts et al. (2018) emphasize that successful CE adoption involves both bottom-up efforts from companies and top-down integration of CE principles in legislation and policy.

Kirchherr et al. (2021) indicate that the application of circular principles occurs at three levels: micro (individual products), meso (eco-industrial parks), and macro (city, nation, or global systems). At the micro level, which concerns individual firms and products, circularity is achieved through design innovation and alternative business models that extend product lifecycles such as designing for disassembly, modularity, and adopting service-based models−where consumers pay for access rather than ownership−allow materials and components to be reintegrated into production systems in both economically and environmentally viable ways (Bocken et al., 2016; Lüdeke-Freund et al., 2019). At the meso level, networks of firms and industrial actors collaborate to optimize material and energy flows. These collaborations often occur through eco-industrial parks, cross-sector partnerships, and circular marketplaces that facilitate resource sharing and knowledge exchange across value chains (Farooque et al., 2019; Genovese et al., 2017; Patala et al., 2022; Rajala et al., 2018). Within these arrangements, new intermediary roles−such as those managing the collection, transportation, and processing of secondary materials−emerge to enhance system-wide circularity (Tate et al., 2019). At the macro level, the broader institutional and policy environment shapes how effectively circular strategies can be adopted. National and regional governance systems, economic incentives, and regulatory frameworks can either foster or constrain CE implementation. For instance, certain policies may prioritize recycling initiatives while providing fewer incentives for practices aimed at reducing material use or redesigning products for longevity (Moreau et al., 2017; Ranta et al., 2018). Overall, this multi-level framework underscores that achieving a circular economy requires coordinated action among firms, industries, and policymakers, supported by enabling institutions and the emergence of new collaborative roles within the value chain.

3.6. Circular economy in the value chain

CE in the value chain refers to the idea of integrating CE principles into value chain operations to transform traditional linear processes into circular ones thereby promoting resource efficiency, waste minimization, and regenerative value creation (Pavel, 2018, Srividya et al., 2023).

Geissdoerfer et al. (2018, p. 713) conceptualize the circular value chain−within the broader circular supply chain−as an operational model that implements five strategies: closing, narrowing, slowing, intensifying, and dematerializing resource loops. This definition emphasizes the operational mechanisms that underpin circularity, focusing on the systemic redesign of material and information flows.

Pavel (2018) differentiates the circular value chain from Porter's (1985) traditional value chain, arguing that the latter reflects a linear economy which prioritizes organizational value creation through cost efficiency and competitive advantage, but ignores reverse logistics and generates social and environmental value. The circular model, by comparison, embeds sustainability principles across both primary and support activities, extending value creation beyond organizational boundaries to encompass broader societal and ecological outcomes (Pavel, 2018). Batista et al. (2018, p. 446) similarly highlight that circular value chains as "*the coordinated forward and reverse logistics via purposeful business ecosystem integration for value creation from products/ services, by-products and useful waste flows through prolonged life cycles that improve the economic, social and environmental sustainability of organizations*".

Kirchherr et al. (2017) proposed that a framework for implementing CE within value chains is the R hierarchy (Refuse, Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle, and Recover), often depicted as a ladder or funnel , where higher-level Rs represent the most significant environmental and economic benefits by keeping products and materials in circulation for as long as possible and at their highest utility as illustrated in the Figure 3.3. The framework operationalizes circularity through three principles: "*useful application of materials, extended lifespan of products & parts, and lastly smart products use & manufacturing*".

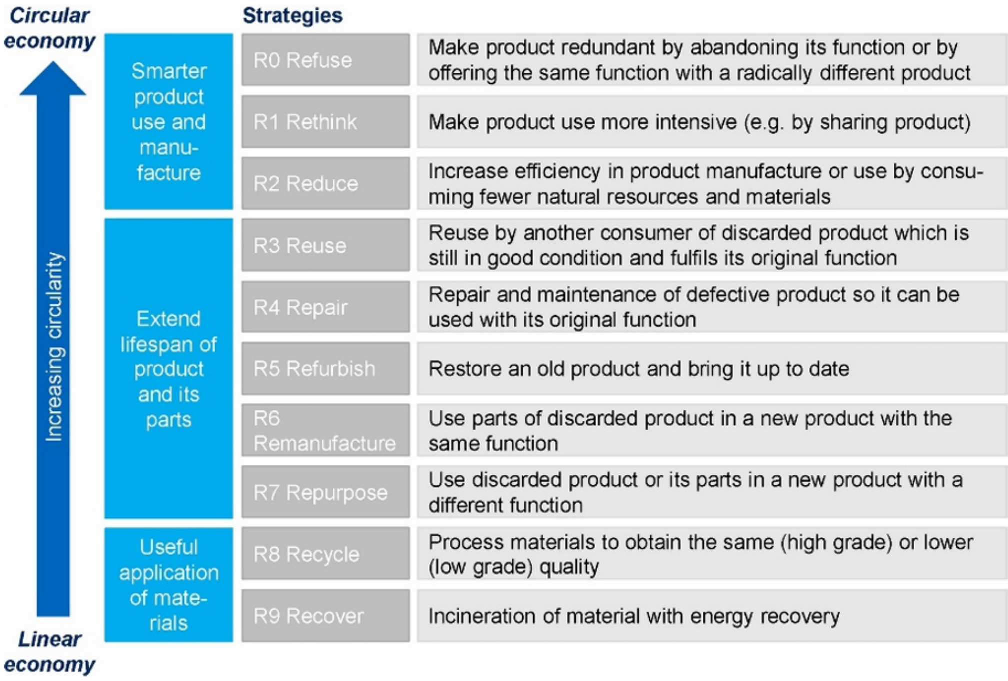

Figure 3.3. The 9R Framework (Kirchherr et al., 2017)

Building on this framework, Pavel (2018) proposed the definition of circular value chain as "*A process and activities by which organizations retain and regenerate values to an article from secondary raw materials through reverse logistics and propose regenerative value by practicing sustainability in supporting activities: human resources, procurement, technology, and firm infrastructure*" as presented below in Figure 3.4. This perspective aligns with the broader CE literature (Kalmykova et al., 2018; Batista et al., 2018, Vegter et al., 2020; Srividya et al., 2023, Solomon et al., 2024), which emphasizes a holistic transformation of value creation processes across all stages from material sourcing, design (for circularity/disassembly), manufacturing, distribution & sales, consumption & use, logistics, and recycling & recovery. These studies indicate that the circular value chains can be viewed as a holistic framework that not only closes material loops but also redefines the purpose of value creation, integrating economic competitiveness with environmental regeneration and social well-being.

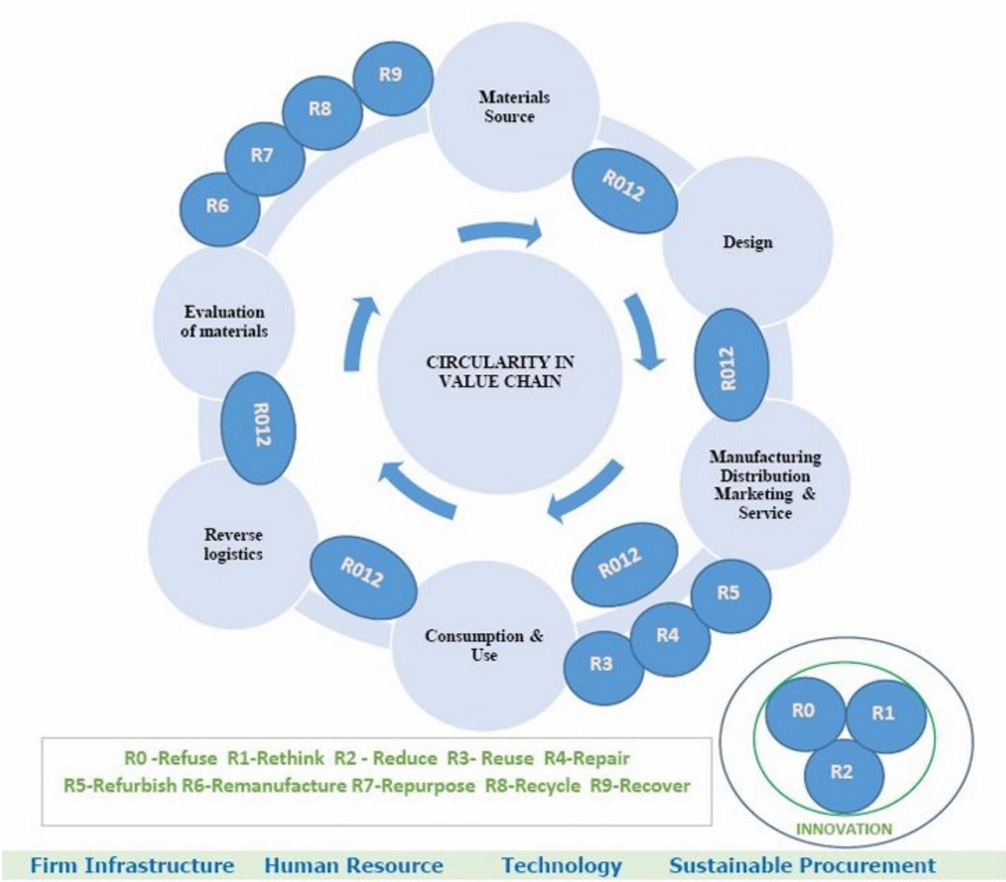

Figure 3.4. Framework for circular value chain (Pavel, 2018)

3.7. Circular economy in agrifood value chain

There is increasing interest in the concept of circular economy (CE) across sectors, including business, government, academia, and among consumers as a strategy to decouple economic growth from resource depletion. However, a well-established CE framework specifically tailored to the agri-food value chain is still developing. Stakeholders in the agri-food chain increasingly recognize businesses play a central role in operationalizing CE principles, adopting sustainable practices throughout production, manufacturing, and distribution systems (Russell et al., 2023; Sacco et al., 2021; Keyser & Mathijs, 2023).

Within the agri-food system, CE practices have been adopted to address the sector's complex environmental and socio-economic challenges including food security, resource scarcity, degradation of natural resources, and health hazards due to unsustainable practices (Nattassha et al., 2020, FAO, 2018). The agri-food chain is unique because its biological cycles generate significant organic waste and by-products, making CE principles such as reducing waste, reusing materials, and repurposing by-products particularly relevant (Klein & Tamasy, 2022). However, Kumar et al. (2021) argue that high levels of wastage and losses across food chain are major barriers to achieving circularity.

Food loss and waste (FLW) are central to CE discourse in agri-food systems. The concepts of "food loss" and "food waste" may or may not be recognized as distinct entities in the food supply chain (Kennard, 2019). FAO (2019) defines food loss as the quantity of food wasted during the post-harvest, production, and processing stages of the food supply chain. And food waste is defined by Edjabou et al. (2016) as the waste produced during food processing, post-harvest handling, storage, agriculture production, retail and wholesale distribution, domestic kitchens, and large-scale consumption. In practice, any food stuff that is discarded by a producer, processor, transporter, or consumer at any point in the food chain would be referred to as FLW.

Similarly, Jurgilevich et al., 2016 & Principato et al., 2019 highlight that FLW occurs throughout the value chain, and therefore represents substantial opportunities for CE interventions. Recent studies (Yontar, 2023; Jabbour et al., 2023; Abbate et al., 2023; Diéguez-Santana et al., 2022) suggest that integrating CE principles into food production and processing improves resource efficiency, minimizes waste, and promotes sustainability by fostering closed-loop systems. From environmental perspective, FLW represents not only discarded biomass but also wasted inputs such as fertilizer, water, energy, land and other inputs (Tanveer et al., 2021). They suggest that preventing and valorizing FLW contributes to conserving natural resources, reducing environmental burdens, supporting food security and fostering a societal well-being.

Common CE strategies in agri-food systems include waste valorization, energy and nutrient recovery, and the reuse of secondary materials without costly remanufacturing (Vlajic et al., 2018; Hogeboom et al., 2018; He et al., 2020). Many studies (e.g. Tanveer et al., 2021; Nattassha et al., 2020; Venkata et al., 2016) highlight that maximizing the value extraction from agri-food by-products and waste before final disposal. Converting these wastes into higher-value products like nutraceuticals, food ingredients, fertilizers, animal feed, biomaterial and bioenergy could create new business opportunities, strengthen local economies, enhance food security, and support intersectoral sustainability. For instance, wheat co-products are commonly repurposed for animal feed (Principato et al., 2020), byproducts like butter and pig blood can be valorized in other industries (Noya et al., 2017), waste streams (slaughterhouse waste, manure, post-consumer food scraps) are utilized for anaerobic digestion to produce biogas and digestate (Sharma et al., 2024).

Additionally, empirical evidence demonstrates the potential of circular economy practices in agricultural value chains. For example, in Vietnam's rice value chain, over 50 million tons of byproducts (straw and husks) are produced annually (UNDP, 2024). Traditionally, these residues are often burned, releasing large quantities of greenhouse gases. Recently, initiatives have turned these byproducts into valuable resources (UNDP, 2024). Rice straw is now being used as a substrate for mushroom cultivation, with the residue substrate composted into organic fertilizer. Rice husks are valorized as a clean energy source, burned in biomass boilers to generate electricity, while the resulting ash is used as an organic fertilizer. Straw and husks are also applied in biological bedding, construction materials, charcoal, handicrafts, and medicine. Similarly, Cherubin et al. (2021) in the study about Brazil's sugarcane sector, highlight a mature CE approach of integrating producing food (sugar) and bioenergy production (bioethanol and bioelectricity), the later represents a renewable energy alternative to fossil fuels with reduced impacts on biodiversity and food security (Cherubin et al., 2021). Sugarcane byproducts (straw, bagasse, molasses, filter cake, and vinasse) are systematically valorized. Bagasse and straw are used as fuels for cogeneration, producing steam and electricity for industrial needs (36.8 TWh) and national electricity demand (5.9% of Brazil's total production in 2019). The resulting ash, filter cake and vinasse are combined to produce a nutrient-rich biofertilizer returned to the fields and closed nutrient loops. Molasses is fermented to produce bioethanol. These rice and sugarcane value chain models exemplify how CE can simultaneously advance agricultural productivity, energy self-sufficiency, and environmental sustainability.

Despite these promising examples, CE adoption in agri-food systems faces challenges such as (1) high initial and transition costs, (2) operational knowledge and information gaps, (3) resistance to change, (4) technical knowledge and information needs, and (5) conflicting policies and institutional barriers, (6) insufficient coordination among actors (Keyser & Mathijs, 2023, Humberto et al., 2025). Overcoming these challenges requires a systemic approach involving alignment of regulatory frameworks, stakeholder collaboration, and reconfiguration of value creation processes to transition from linear models towards circular agri-food systems.

Chapter 4. Research method

The research methods used in this study will be presented in this chapter. This chapter includes the following sections: research approach, research methodology, the specific study area in Vietnam, sampling approach, data collection tools, data analysis techniques, and proposed steps for this research. Additionally, ethics considerations are emphasized as an important aspect of this study.

4.1. Research method

According to Creswell (2018), research methods and research design significantly depend on the research purpose, the researcher's expertise, and the target respondents. Research methods are commonly characterized into qualitative, quantitative, or mixed approaches. Qualitative approach is often used to develop theories, build a foundation of understanding for science and provide in-depth understanding of a phenomenon. Bhattacherjee (2012) supports the view that qualitative methods help identify multiple objectives and construct knowledge rather than merely exploring reality. On the other hand, quantitative research, which relies on numerical data and measurable variables, follows a deductive logic of theory testing. Martin and Bridgmon (2012) further argue that the use of large sample sizes in quantitative studies enhances objectivity compared to qualitative approaches. Martin and Bridgmon (2012) further argue that a quantitative approach, by surveying a large sample size, provides more objectivity than a qualitative approach. Because quantitative methods provide objectivity through numerical measurement, while qualitative methods offer depth, contextual understanding and flexibility. In this study, qualitative research design was used to gain in-depth knowledge of stakeholder perspectives, practices and governance structures. Within this qualitative framework, dedicated quantitative component is integrated for an MFA, because the MFA measures and quantifies the physical stocks and flows of materials within a system (Brunner & Rechberger, 2016).

This research objectives are to map the current cashew value chain in Binh Phuoc province, analyze the cashew nut value chain, analyze a material flow in the cashew sector, and analyze the circularity of the cashew sector in Binh Phuoc region. To achieve these objectives, this study uses semi-structured interviews as a primary tool for collecting rich, contextual data from stakeholders. Concurrently, the quantitative MFA is constructed using both physical measurements and quantitative information obtained from these interviews, secondary reports, and field observations. This approach ensures in-depth understanding, where the qualitative analysis explains how and why of the value chain, while the MFA quantifies the what and how much of its material metabolism in the cashew sector.

4.2. The specific study area in Vietnam

The study was conducted in Binh Phuoc province, recognized as the cashew capital of Vietnam. The province has a cashew cultivation area of 149,647 ha, accounting for over 52% of the country's total cashew-growing area of 285,200 ha (Binh Phuoc Statistical Yearbook, 2024; GSO, 2024). Additionally, Binh Phuoc's cashew production is significant, reaching 153.1 thousand tons compared to the national total of 347.6 thousand tons, representing more than 44% of the country's cashew output.

Binh Phuoc covers an area of 6,876.6 km² and had a population of 1,045,490 in 2023 (Binh Phuoc Statistical Yearbook, 2024). It is located in the Southeast region of Vietnam and borders several provinces, including Dak Nong, Binh Duong, Lam Dong, Dong Nai, and Tay Ninh. Additionally, it shares a border with Cambodia. Below is the administrative map of Binh Phuoc province (Figure 4.1). The province is divided into 11 district-level administrative units and 111 commune-level administrative units for governance. Depending on soil conditions and topography, Binh Phuoc exhibits diversity in both crop cultivation and livestock farming. Regarding cashew cultivation, the districts with the largest cultivation areas and highest yields include Bu Dang, with nearly 60 thousand ha of cashew plantations producing nearly 60 thousand tons per year, followed by Bu Gia Map and Phu Rieng, which have 31.38 thousand ha producing 40.79 thousand tons and 22.75 thousand ha yielding 30.70 thousand tons, respectively (Binh Phuoc Department of Agriculture and Rural Development, 2024). The distribution of cashew cultivation by district in Binh Phuoc province in 2022 is presented in Table 4.1 below.

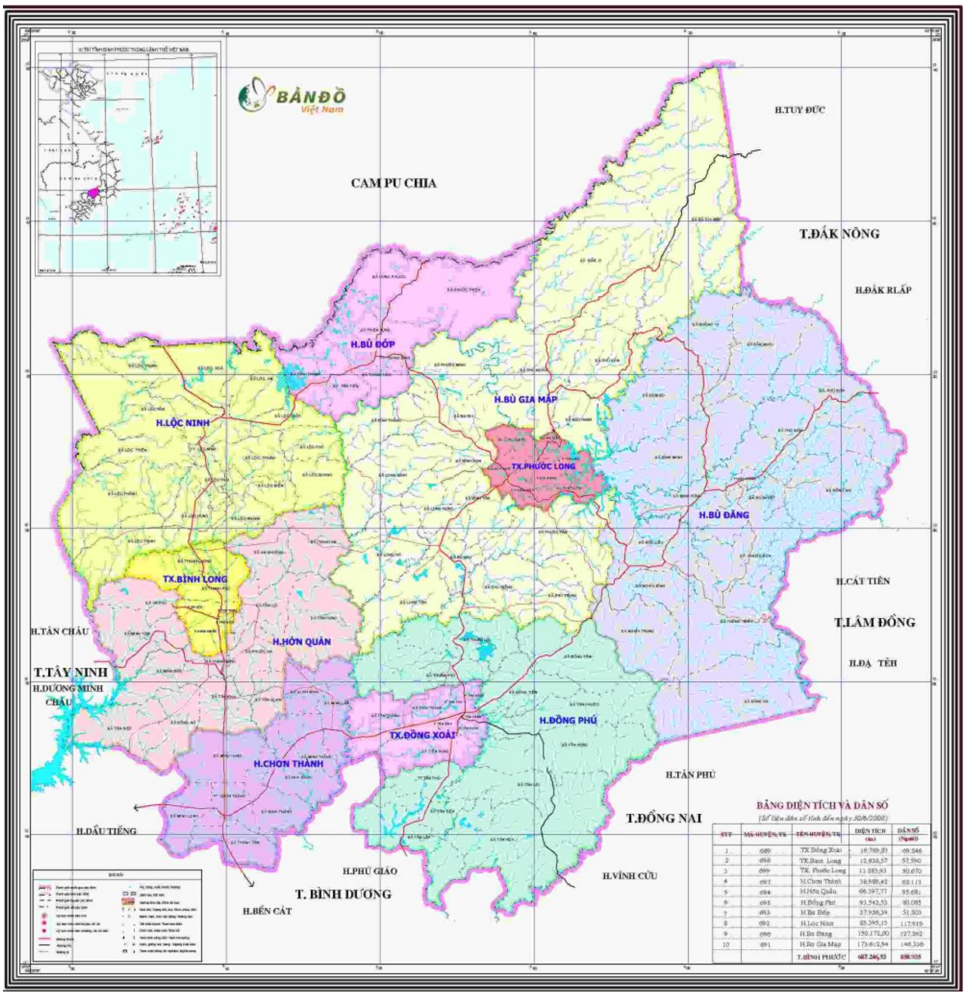

Figure 4.1. Administrative map of Binh Phuoc province (MARD BP)

Regarding the cashew processing, cashew manufacturers (also act as the importers and exporters) are primarily concentrated in Phuoc Long (with 262 companies) and Bu Dang (with 72 companies), along with approximately 1,000 small-scale processing household businesses scattered across Binh Phuoc province (Binh Phuoc Department of Agriculture and Rural Development, 2024).

Table 4.1. The distribution of cashew cultivation by district in Binh Phuoc in 2022

No.	District	Area (ha)	Productive Area (ha)	Yield (quintals/ha)	Production (tons)
	Total Province	**151,892**	**148,326**	**11.5**	**170,358**
1	Bu Dang	60,240	59,200	14.0	82,880
2	Phu Rieng	23,200	22,750	13.5	30,713
3	Bu Gia Map	32,150	31,380	13.0	40,794
4	Dong Phu	16,275	16,275	10.3	16,763
5	Phuoc Long	5,054	5,053	13.5	6,822
6	Loc Ninh	3,650	3,650	11.0	4,015
7	Hon Quan	3,850	3,685	10.3	3,796
8	Dong Xoai	1,500	1,410	10.0	1,410
9	Bu Dop	2,310	2,037	10.5	2,139
10	Binh Long	900	830	10.5	872
11	Chon Thanh	210	210	9.6	202

(Source: Department of Agriculture and Rural Development, 2024)

4.3. Data collection approaches

This study collected data from both primary and secondary sources. The primary data collection was designed to concurrently capture insights on value chain dynamics and some quantitative data required for MFA. Data collection was conducted from mid-December 2024 to the end of March 2025.

4.3.1 Secondary data collection

Secondary data was collected to contextualize the study and supplement the primary MFA data. Sources included:

- The Statistical Yearbooks of the General Statistics Office of Vietnam (GSO, 2023, 2024) and the Binh Phuoc Provincial Statistics Office (BP GSO, 2024).
- Publications and internal reports from the Department of Agriculture and Rural Development of Binh Phuoc Province and Binh Phuoc Cashew Association.

4.3.2 Primary data collection

Primary data was collected through two methods: semi-structured interviews and physical measurements.

4.3.2.1. Semi-structured interviews

Semi-structured interviews were conducted with key stakeholders across the cashew value chain, including agricultural suppliers, farmers, farmer groups, intermediaries (collectors/traders), processors, and relevant government agencies. This method was chosen as it allows participants to share in-depth insights based on their experiences, articulate their perspectives, and justify their statements (Adeoye-Olatunde & Olenik, 2021). Its flexibility also supports an iterative process, enabling the refinement of questions based on emerging findings from earlier interviews. The interview guide was designed to serve a dual purpose:

- Qualitative data: To explore themes of key stakeholders, material flows, governance structure, power relations, information flows, current practices, challenges, and circular economy practices.

- Some quantitative data for MFA: To solicit estimates of material flows. Respondents were asked to provide quantitative data in local or standard units (e.g., inputs per hectare, yield per hectare, quantity of raw nuts purchased per month, processing conversion rates, types and amounts of by-products and waste generated, prices of each inputs and outputs, conversion rate of CNS to CNSL).

4.3.2.2.Direct physical measurements for MFA

Direct physical measurement was considered the most accurate method for quantifying material flows (Amicarelli et al., 2020). In this research, on-site measurements were conducted at key material transfer points in the value chain to establish quantities and validate interview-based estimates. The measurement protocol and sites involved:

- *On-farm measurements*: conducted to determine initial mass of fresh cashew fruits, cashew apples and wet cashew nuts.

    - Site and sample selection: Measurements were taken from farms visited during the peak harvest season (February to March 2025). Different cashew varieties were identified through farm observations and farmer interviews.
    - Procedure: For each identified variety, whole fruits were collected, and a sample mass of approximately 2 kg was weighed using a 5kg-capacity digital scale. This sample size was chosen to be representative; as some individual cashew fruits can be large (e.g., ~100 g each), a 1 kg sample would contain too few fruits (~10) to reliably account for natural size variation within the variety. For each variety-specific sample, the following components were separately weighed and recorded: the whole fresh fruit, the separated cashew apple, the attached wet cashew nut.
    - Replication and standardization: The weighing procedure was performed in duplicate for each variety to ensure consistency. The recorded mass data for each component was standardized to a grams-per-fruit basis. Finally, the mean values (in g/fruit) for the whole fruit, apple, and nut were calculated by averaging the results across all sampled varieties. This produced the average conversion factors used for modeling material flows in the farm-stage MFA.

- *Processing facility measurements*: at selected processing facilities, measurements were conducted to capture mass flows, mass balance, nut counts and conversion rates for key processing stages. The protocol was as follows:

    - A 1 kg sample of raw cashew nuts was prepared for both wet (fresh) and sun-dried conditions. The total number of nuts in each 1 kg sample was counted. This nut count per kilogram was used to standardize all subsequent mass measurements to a consistent grams-per-nut basis, controlling for natural variation in nut size. The 1 kg sample was then tracked through two key processing stages:
        - Shelling stage: After mechanical shelling, the total mass of the resulting kernels and the separated hard shells were weighed. A 1 kg sub-sample of the unshelled kernels was taken, and the number of kernels was counted.

  - Peeling (Testa removal) stage: After the peeling process, the total mass of the final white kernels and the removed testa were weighed. Again, a 1 kg sub-sample of the peeled kernels was taken for a kernel count.

- This entire procedure−from the initial 1 kg raw nut sample through to the final peeled kernel count−was performed in duplicate within each facility to ensure reliability. Sample nuts were collected randomly from different locations within the facility's processing batch to ensure the sample was representative of the overall material stream.

4.4. Sampling methods

This study employed different sampling strategies for its qualitative and MFA data collection.

To identify and recruit interview participants across the cashew value chain, both purposive sampling and snowball sampling methods were used to collect data. Purposive sampling was applied initially to strategically select knowledgeable key informants who could provide a strong foundational understanding of the chain (Patton, 2015). Government agencies were first approached to provide background information and to introduce stakeholders within their local networks.

Snowball sampling was then applied to identify value chain players involve "multi-stage processes" in a social framework, which leverage the networks of their initial participants to access a wider, allow to reach populations that are difficult to identify or contact thereby providing a deeper exploration of the phenomenon, as the participants' unique accessibility, insights and perspectives (Naderifar et al., 2017). Thus, these approaches were used to gather information from various cashew actors along the value chain to ensure trust and quality data.

The dataset consisted of interviews with 58 different stakeholders across the cashew value chain in Binh Phuoc province. The sample included: farmers (30), cooperative (3), intermediaries (4), processors (21), and government officers (3) (farmers' associations representatives, Binh Phuoc MARD, and regional cashew association). Respondents were selected from districts with the highest levels of cashew cultivation and processing activity as discussed in Section 4.2. The distribution of interviews across these districts is detailed in Table 4.2 and illustrated in Figure 4.2.

Table 4.2. Data collection design for semi-structured interviews

		Farmers	Cooperatives	Intermediaries (traders/collectors)	Processors (Kernel + CNSL)	Government agencies
	Total	30	3	4	18+3	
Cashew cultivatation	Bu Dang	12	2	1	8+1	1
	Bu Gia Map	7	1	1		1
	Phu Rieng	6		1		
	Dong Phu	5		1	1	
Cashew processing	Phuoc Long				8+1	
Region's Administrative office	Dong Xoai				1+1	1

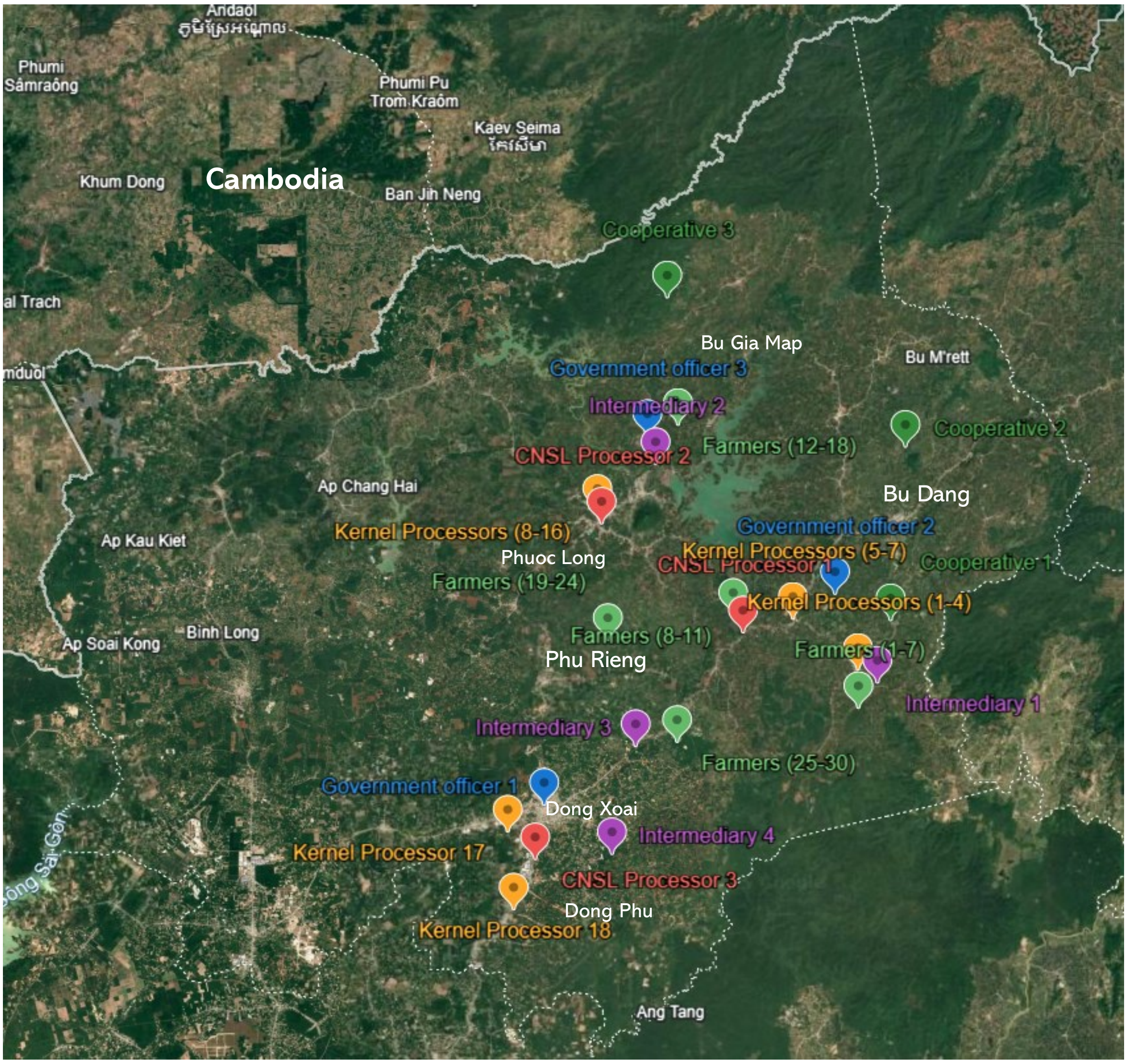

Figure 4.2. Geographic locations of data collection sites

The sampling strategy for direct physical measurements employed purposive sampling, with the objective of establishing accurate material conversion factors for the MFA rather than achieving statistical representativeness. The specific farms and processing facilities selected for direct measurement are detailed in Appendix 7.

On-farm measurements: From the larger pool of interviewed farmers, a purposive sub-sample of 10 farms was selected based on three criteria: 1) willingness to permit detailed on-site measurements, 2) cultivation of different cashew varieties, and 3) representation of different farm sizes and locations to capture variability.

Processing facility measurements: Similarly, a purposive sub-sample of 3 cashew kernel processing facilities was selected from among the interviewed processors. Selection criteria focused on both access and technological diversity: 1) agreement to provide access for in-process weighing and 2) variation in processing technology (e.g., manual vs. automatic mechanized).

4.5. Respondents' descriptive

General information about the interview respondents in the cashew nut value chain, such as gender distribution, labor age distribution, and educational background, year experience is presented in Table 4.3.

Table 4.3: Respondents' descriptive

Description	Attributes	Farmers	Intermediaries (Collectors & trader)	Processors (kernels + CNSL)	Government agencies
Number		30	4	21	3
Age	20 – 40 years	6	1	8	1
	40 – 55 years	9	3	9	2
	55 – 70 years	15		4	
Gender	Male	18	2	14	3
	Female	12	2	7	
Education	Primary	3			
	Secondary	9			
	Highschool	13	2	6	
	College & University	5	2	15	3
Year experience	5 – 10 years	2	1	3	
	10 – 15 years	5	3	10	1
	>15 years	23		8	2

4.6. Data analysis

In this study, the data analysis consisted of two processes: reflexive thematic analysis for qualitative interview data and MFA modeling for quantitative physical data.

4.6.1 Qualitative data analysis: Reflexive thematic analysis

Qualitative data from semi-structured interviews were analyzed using Reflexive Thematic Analysis (TA) as developed by Braun and Clarke (2006; 2019). TA is a flexible, iterative method for identifying, analyzing, and reporting patterns (themes) within textual data. Its adaptability allows it to be used within different research paradigms and supports a hybrid of deductive and inductive coding (Almed et al., 2025; Braun & Clarke, 2006), making it suitable for analyzing complex systems like agricultural value chains.

The analysis followed Braun and Clarke's six-phase framework, adapted for this study as outlined in Table 4.4. A key feature of this approach is its emphasis on reflexivity, requiring the researcher to continually reflect on their assumptions and theoretical positions throughout the analytic process (Braun & Clarke, 2019).

Table 4.4. Thematic analysis phases and practical applications

Thematic analysis phase	Practical application in this study
1. Familiarization with the data	Immersion in interview transcripts by repeated reading and note-taking, using reflective memos to capture early observations.
2. Generating initial codes	Manual coding of transcripts to identify significant features. A hybrid strategy was used: deductive codes derived from core concepts (based on predefined theoretical constructs such as VCA, MFA, CE principles) and inductive codes emerging from the data.
3. Searching for themes	Collating codes into broader patterns related to value chain dynamics, material management and circularity.
4. Reviewing themes	Checking themes for internal coherence and fit with the entire dataset; refining by splitting, combining, or discarding themes.
5. Defining and naming themes	Articulating the essence and scope of each theme; selecting illustrative data extracts.
6. Writing up	Findings were presented through an analytical narrative that linked the themes to literature and theoretical frameworks within the cashew value-chain context.

(adapted from Braun & Clarke, 2006; 2019)

4.6.2 Data analysis for MFA modelling

The quantitative data for the MFA was analyzed by establishing a mass balance of the cashew value chain. The analysis comprised three phases: data preparation, model construction, and economic valuation, followed the MFA protocol (Brunner & Rechberger, 2016).

Data preparation and standardization

All primary data ─ direct weight measurements and quantitative estimates from interviews as discussed in Section 4.3.1 ─ were compiled and organized in a Microsoft Excel spreadsheet. All mass units were standardized to grams, and monetary values were recorded in Vietnamese Đồng (VND). Key physical conversion factors were calculated from the direct measurements. For the farm stage, this included the average mass of whole fruit, cashew apple and wet nut, and the nut-to-apple ratio. For the processing stage, factors such as the average mass of wet and dried nuts, the kernel recovery rate (%), and the generation rates of shells and testa (kg per kg of input nuts) were established. Quantitative information collected during stakeholder interviews for the 2024-2025 reference period were calculated as averages or medians and, where feasible, cross-verified with data from industry associations to ensure robustness.

Model construction and calculation:

The MFA model was constructed with a system boundary defined as "from farm to processed kernel," encompassing all processes from harvesting to the production of shelled kernels. Using Excel, the quantified material flows were calculated by applying the measured conversion factors (e.g., g/nut, nut-to-apple ratio, kernel recovery rate) to activity data, such as total regional cultivation area and average farm yield obtained from interviews and secondary statistics. This scaling procedure quantified the annual material flows for the entire provincial cashew system, with detailed results discussed in Chapter 6, Section 6.2. A core methodological step involved standardizing all material flows relative to a functional unit of 1 kg of final shelled kernel. This was achieved by working backward from the final product using the established conversion factors to determine the associated quantities of raw nuts, cashew apples, whole fruit and biomass waste required. The resulting flows were visualized using Microsoft Visio to create process flow diagrams, clearly illustrating the movement and transformation of materials across the value chain stages.

Economic value flow integration

To complement the biophysical analysis and assess economic distribution, a value flow analysis was integrated. For each major material flow quantified in the MFA─including primary products (fresh fruit, wet/dried nuts, kernels) and by-products (cashew apple, shell, shell cake, CNSL)─an average market price per kilogram was established based on interview data. The quantified material flow for each product (in kg) was then multiplied by its corresponding average price (in VND/kg). This calculation generated the estimated economic value moving through each transformation stage of the value chain. The outcomes of this integrated material-economic analysis are presented in Chapter 5 (Tables 5.1, 5.2, and 5.3 and Figure 5.37), providing a comprehensive overview of the system's metabolism and its value creation potential.

4.7. Ethical considerations

Ethical considerations are fundamental to ensuring that research involving human participants (in this study including suppliers, farmers, traders, processors, government officers) was conducted responsibly and respectfully (Creswell, 2014). This study followed the ethical principles required by the Massey University Human Ethics Committee (MUHEC). Ethics application had been submited to obtain ethics approval (Appendix 8) before beginning of the data collection. Before conducting interviews, participants were provided with clear information about the research purpose, procedures, and their rights, including the right to withdraw at any time without consequence. Informed consent was obtained through either written or verbal agreement, in accordance with ethical research practices that emphasize respect for people and autonomy (Bell, Bryman, & Harley, 2015). Confidentiality and anonymity will be strictly maintained and used only for research purposes (Flick, 2013). Additionally, the research had avoided causing any harm or discomfort to participants and will respect local customs and cultural practices throughout the process (Morse, 2009). Eventually, primary data was securely stored and accessible only to the researcher, supervisors, while secondary data was used responsibly, with proper citation and acknowledgment of sources (Bazeley, 2013).

Chapter 5. Result of this study

This chapter discusses the transformation of cashew nut, cashew nut value chain mapping, material flow of cashew by-products, and comprehensive overview of the transformation of materials flow and economic value in cashew industry.

5.1. Material flow of cashew nut

This section discusses how the cashew nut transforms from cashew cultivation to finished products purchased by the consumers as illustrated in Figure 5.1. This section also explains the activities done by the value chain actors and how those activities change the products.

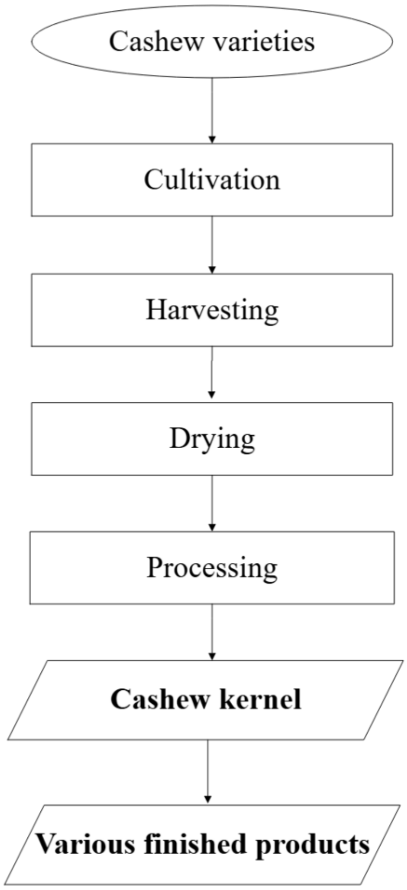

Figure 5.1. The transformation of cashew nuts from farm to finished products

5.1.1 Cashew varieties

Over the 35 years since cashew trees were first introduced in Binh Phuoc, various cashew varieties have been cultivated, propagated, or replanted. The result reveals that the age distribution of cashew trees is approximately 12.5% are under five years old, 25% are between 5–10 years, 15% are between 10–20 years, and around 47.5% are more than 20 years old.

Cashew varieties grown in Binh Phuoc fall into two main categories: traditional local varieties and high-yield improved varieties. Among the latter, PN1, AB29, and AB0508 are the most widely adopted. Local varieties and PN1, which have been cultivated in the region for decades, generally produce small to medium-sized nuts.

Farmers select seeds for seedlings based on long-term field observation. They often identify and select superior trees based on traits such as disease resistance, nut size, and long-term yield performance, either within their own gardens or neighboring farms. They then either propagate seeds from these trees or acquire seedlings from trusted nurseries. As one farmer explained: *"We observe our cashew trees all year round, selecting those that consistently produce healthy, large, and dense nuts. We also observe high-yield, pest-resistant trees in our neighbor's garden to purchase seeds."*

More recently, grafted cashew varieties like AB29 and AB0508, developed by the Cashew Research Institute, have gained popularity among farmers due to their superior traits. Successful field trials have prompted many to switch partially or entirely to grafted varieties, with an adoption rate of approximately 70%. A farmer highlighted their benefits, stating: *"Grafted varieties yield more, produce larger and more uniform nuts, and begin bearing fruit as early as 2 to 3 years after planting."*

However, not all farmers embrace grafted varieties. One farmer shared a contrasting view: "*We prefer propagating seeds from selected trees rather than adopting grafted varieties. While grafted trees offer larger nuts, they demand more inputs−such as fertilizers and pesticides−and have weaker trunks prone to breakage. From our experience, seed-grown trees are more robust, pest-resistant, and maintain high yields even after 20 years."*

5.1.2 Cultivation

Cashew cultivation encompasses various agronomic practices including tree planting, fertilization strategies, tree pruning, canopy management, orchard sanitation, weed control measures, pest management and prevention, as well as irrigation. Each of these aspects is discussed in detail below.

Tree Planting

Cashew cultivation in Binh Phuoc typically begins with either self-propagation, purchasing seedlings, or acquiring grafted varieties from certified nurseries or agricultural research centers. Due to the region's distinct wet and dry seasons, most farmers prefer planting during the rainy season (from June to November) to utilize the natural rainfall. However, in areas with access to water sources such as rivers, ponds, or lakes, planting can also occur during the dry season.

As one farmer explained: "*Our region has two distinct seasons: dry and rainy. The dry season is characterized by high temperatures and limited water, so we prefer to plant during the rainy season to take advantage of natural water for better growth*."

Another farmer added: *"Since my orchard is close to the river, I can plant new trees in any season. However, we still prioritize the rainy season to align with fertilization and care routines."*

One grower highlighted the practice of replanting: *"After the harvest, we cut the old, low-yielding trees and replace them with new ones. This timing coincides with the onset of the rainy season, making it ideal for replanting."*

Planting holes are typically 50 cm^2 and are treated with lime. Spacing varies based on soil type and farmer experience, ranging from 4x4 m to 6x6 m, with some even using 7x7 m. A common configuration is 5x5 m, allowing for approximately 400 trees per hectare. As the canopy expands, farmers thin the orchards, reducing density to about 100 trees/ha, using wider spacing such as 10x10 m or 12x12 m.

Fertilization

A variety of fertilizers are used in cashew orchards, including chemical fertilizers, animal manure (from chickens, cows, goats, and buffalo), organic compost (such as straw, fallen leaves, coffee husks, and rice husks), and microbial fertilizers. Some use only one type, while others combine multiple types based on experience, availability, affordability and familiarity to them. For example, one farmer makes use of local resources, ferments chicken and goat manure, coffee husks, and rice husks with microbial additives. Another creates compost from fallen cashew leaves, small branches, and weeds to enrich the soil. Meanwhile, some farmers, who do not raise livestock or have time for composting, prefer using ready-made fertilizers from agricultural suppliers.

The research indicates varying fertilizer practices among farmers. A small proportion use only organic fertilizers, about one-third combine organic and chemical fertilizers while roughly half rely solely on chemical fertilizers (nitrogen, phosphorus, and potassium).

Fertilizer application ranges from 1–3 times per year, depending on the orchard's condition and economic constraints. Most farmers apply fertilizer after harvest – when trees are weakest and again after leaf shedding and fruit setting, to support tree's growth and disease resistance.

Despite understanding the importance of fertilization, many farmers apply less than the recommended amounts, typically 2–7 kg per tree per year, due to economic challenges and unstable cashew prices. One farmer explained: *"Cashew is hardy and requires little care. In tough years, we didn't fertilize at all. Fortunately, our soil remains fertile enough to maintain yields."* Another shared: "*Though our fertilizer use is below recommended levels, we try to distribute it over multiple stages to support healthy growth for the trees."*

Pruning and Canopy Shaping

In the early stages of cultivation, farmers prune low-hanging branches near the ground. Later, as the tree matures, they trim branches strategically to shape the canopy into a layered structure, allowing the tree to receive adequate sunlight for better vegetative growth, increase shoot density, reduce pest infestations, and higher fruit yields.

One farmer shared: *"Pruning is typically done twice a year, alongside weeding and orchard maintenance. The best times for pruning are after harvest and before leaf shedding, when flower bud differentiation occurs."*

Orchard Sanitation and Weed Control

To keep the orchard clean, reduce competition for nutrients, and prevent fire hazards, weeds are typically cleared three times a year: twice during fertilization periods and once before harvest. Two main methods are used: manual cutting or herbicide spraying. According to the interviews, about 55% of farmers prefer cutting, while the remaining use herbicides.

A farmer explained: "*We usually cut weeds instead of spraying herbicides to save herbicides' costs. Additionally, herbicide spraying can lead to faster soil erosion."* Organic farmers also rely on manual cutting. However, another expressed contrasting view: "*Weeds grow too quickly, and using herbicides helps reduce the frequency of weed removal."*

After weed removal, dried plant material such as grasses, leaves, and branches is either collected with adding microbial additives to enhance soil organic matter or burned to maintain orchard cleanliness. During the third annual cleanup (pre-harvest), most farmers prefer burning. One farmer explained: *"During the third cleanup, we prefer to burn weeds, leaves, and branches instead of composting them. A clean orchard makes harvesting easier. Moreover, these residues have limited nutritional value, while the ash produced after burning helps fertilize the soil.*"

Plant health management and pest control

Cashew trees are vulnerable to various pests and diseases, including mosquito bugs, thrips, shoot borers, stem borers, branch borers, anthracnose, and leaf blight. Farmers frequently inspect their orchards to detect and manage pest and disease outbreaks promptly. One farmer explained: "*Through training sessions on cashew care and years of farming experience, we've learned how to identify early disease symptoms and apply appropriate preventive measures*."

Most farmers apply pesticides in moderate quantities, prioritizing tree health while minimizing resistance build-up. When encountering pest or disease problems, they commonly consult neighboring farmers or local agricultural supply centers. One farmer remarked *"We only use pesticides when specific trees are infected. Applying too much can stress the tree and increase resistance."*

The data indicated that a very small portion of farmers rely on biological pest control methods, while the majority use chemical solutions. One farmer shared: "*Biological treatments are either ineffective or take too long to work, and their costs are too high*." One farmer added "*We initially tried biological methods after attending training sessions, but they were slow and had low effectiveness. In the end, due to poor results and limited economic benefits, we stopped using them*."

Irrigation practices

Cashew trees are well-adapted to drought conditions and suit the two-season climate (rainy and dry) typical of the region. During the rainy season, trees are naturally irrigated by rainfall. However, in the dry season, water becomes scarce, and most cashew orchards do not receive supplemental irrigation. As one farmer explained: *"During years of severe drought, water sources are limited, and my cashew orchard almost completely fails."*

Another farmer noted: "*We don't irrigate the cashew trees directly, but they benefit from the water we provide to intercropped plants like coffee or fruit trees. That might be why our cashew yield wasn't affected by the drought last year."*

A third farmer added: *"We follow a garden–pond–livestock model. Even in last year's drought, we had some water stored in the pond, which helped us irrigate the cashew trees and maintain productivity."*

Based on interviews, more than one third of orchards receive some irrigation, primarily when intercropping with water-demanding species. The scarcity of nearby water sources and long distances from irrigation infrastructure explain why monoculture cashew cultivation remains dominant in Binh Phuoc province.

5.1.3 Harvesting

Cashew harvest is characterized by a single annual season in the local dry season. Generally, in Vietnam, the cashew season is from February to May. The nut, which is the true seed of the cashew fruit, initially appears green and gradually turns gray as it matures. Meanwhile, the cashew apple (pseudo fruit) develops after the nut appears, initially green and later turning yellow, red, or orange when ripe. Once the nut is fully mature and the kernel has reached its maximum development, at the same time, the cashew apple ripens, becomes soft and falls to the ground. Farmers will collect the nuts by detaching them from the cashew apples. The cashew apples are typically left in the orchard, where they decompose and return nutrients to the soil, supporting the growth of the trees. After separation, cashew nuts are either sold immediately as wet raw cashew nuts or sun-dried and sold later, depending on the farmer's strategy.

5.1.4 Drying

To preserve kernel quality, freshly harvested cashew nuts must be dried on the same day or following day. One trader explained: *"We purchase the nuts on the day of harvest and arrange for immediate drying because the juice from the cashew apple contains high levels of water and sugar, which can affect kernel quality. If left too long, the nuts develop a sour odor and begin to mold."*

Moreover, because cashew kernels have high fat content, prompt drying is essential to maintain their quality. Cashew nuts are usually sun-dried for 3 to 5 days. A farmer shared: *"After 3 to 5 sunny days of drying, we press a fingernail into the shell−if there's no visible mark, the nut is sufficiently dry. Proper drying allows us to store cashews for up to a year without compromising quality.*"

During the drying process, immature, shriveled, or poor-quality nuts are sorted out. This practice is common both at the farm level and at traders and processors. At the traders and processors, drying is also carried out under sunlight, using visual inspection similar to that of farmers. Additionally, to ensure quality, moisture content is measured by special equipment before storage (Figure 5.2). As one trader noted: *"After drying, we test the moisture content of the nuts. Once it drops below 10%, typically around 9%, the nuts are bagged and stored in warehouses."*

Figure 5.2. Cashew moisture meter

Processors also visually inspect the nuts during drying, removing defective ones. However, immediate processing is not recommended. A processor explained: *"Dried cashews are not processed right away. They are stored for about 10 to 14 days before processing, allowing the moisture within the nuts to redistribute evenly and stabilize the raw inputs for more consistent processing."*

Furthermore, to standardize and improve cashew quality for domestic and export markets, Vietnam introduced a national quality standard TCVN 12380:2018 in 2018, which is also followed by traders and processors. This regulation clearly defines quality criteria for raw cashew nuts, supporting food safety management and enhancing the commercial value of Vietnamese cashews in international markets.

Figure 5.3. a) The ripe cashew nut in tree b) Raw wet cashew after harvesting c) Raw dried cashew

5.1.5 Processing

Once raw cashew nuts have been dried and stored for several days, they undergo processing to produce various products. The two primary processed products are roasted cashew nuts, which are ready for consumption, and raw cashew kernels, which are primarily designated for export. However, in recent years, raw cashew kernels have increasingly been utilized as input materials in food and beverage manufacturing processes. The sequence of processing stages is illustrated in Figure 5.4, and the visual transformation of cashew nuts from raw dried cashew nut to final products is presented in Figure 5.5.

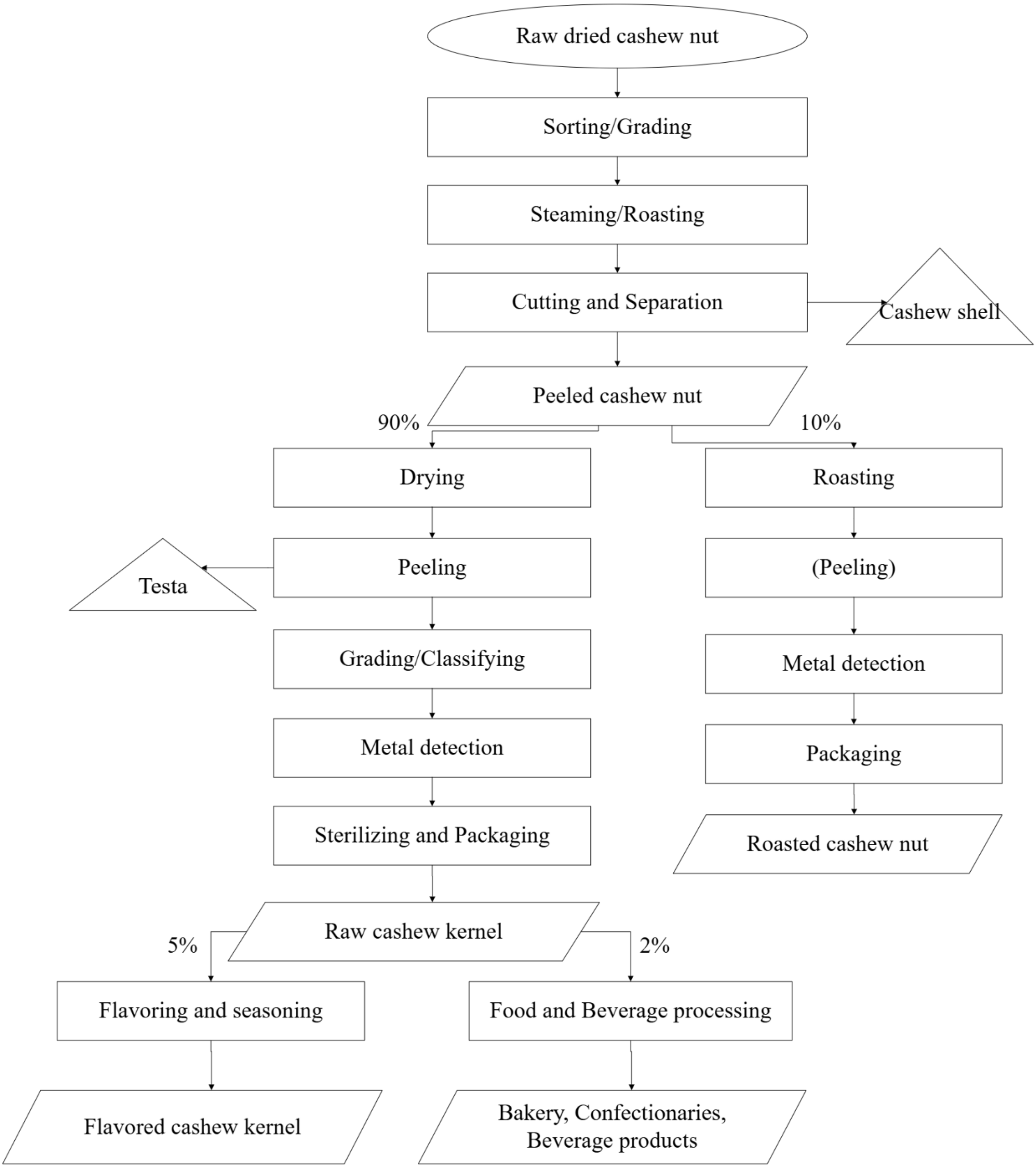

Figure 5.4. Cashew nut processing

Figure 5.5. a) raw dried cashew nuts b) peeled cashew nuts c) raw cashew kernels

Sorting/Grading

First, the dried raw cashew nuts are sieved to remove impurities such as soil, twigs, leaves and classified by size (as Figure 5.6). Due to the irregular shape of the cashew nut, this classification step is crucial to optimize subsequent processing such as steaming and cutting, as steaming parameters and cutting blade diameters are adjusted according to the nut size.

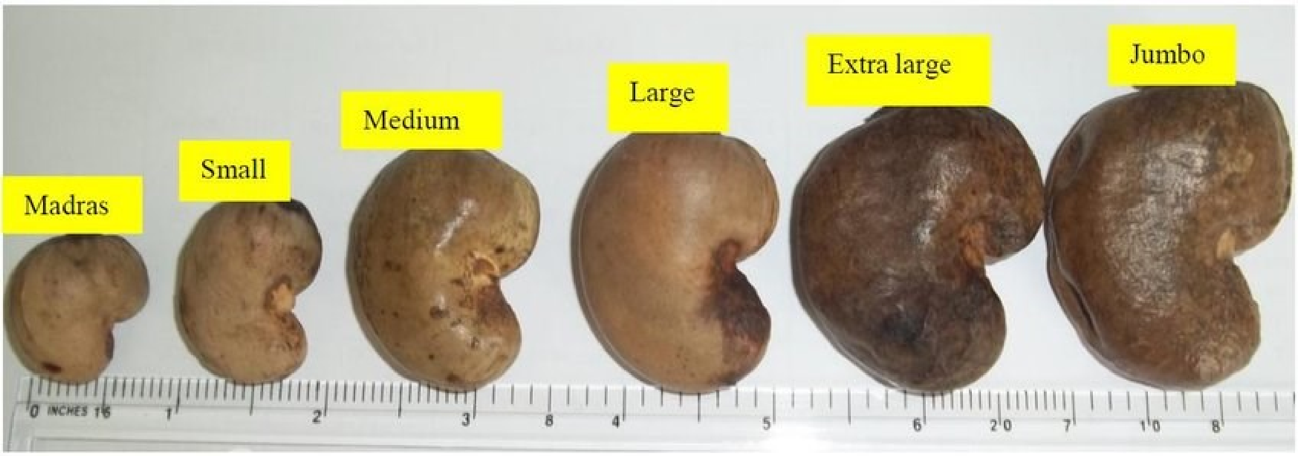

Figure 5.6. Cashew nuts are classified into different sizes (Source: The interviewed company)

Steaming/ Roasting

Next, the nuts are steamed or roasted to soften the hard outer shells, facilitating the shelling process. In recent years a steam-processing method utilizing saturated steam generated from boilers have become widely adopted compared to the roasted method because they ensure uniform heating, enhance efficiency, and minimize quality degradation. While industrial plants often employ specialized machinery to automate the process, the micro-scale businesses still rely on manual techniques by using traditional or household steaming devices to treat the nuts. Typically, raw cashew nuts are steamed for approximately 30 to 45 minutes in saturated steam. Following steaming, the nuts undergo a natural cooling process over the course of about 12 hours to ensure optimal moisture content distribution and reduce the structural damage before proceeding to the shelling phase.

Cutting and Separation

Following the steaming and cooling process, the cashew nuts are cut and separated to remove the hard shell. This step requires precision to ensure the integrity of the kernels. Depending on the equipment available and the scale of the processing facility, shelling can be performed either mechanically or manually. For industrial-scale processing plants, modern machinery is employed to automate the shelling process with the supporting of conveyors to ensure the nut uniformity, reduce labor intensity and enhance efficiency. These machines are designed to accommodate different nut sizes, with adjustable blades that precisely cut through the hard outer shell without damaging the kernel inside. In contrast, micro-scale processing units often rely on manual shelling techniques. Skilled workers use specialized hand tools to crack open the shells, carefully adjusting the blade to match the size of each nut thereby requiring significant expertise, as excessive force or improper handling can lead to kernel breakage, reducing the overall quality of the final product. During the shelling process, workers wear multiple layers of protective gloves to prevent direct contact with the CNSL, a naturally occurring acidic substance that can cause skin irritation or burns.

Figure 5.7. a) The cashew cutting and separation at micro-scale processing b) Cashew shell separation manually in small-scale processing c) Peeled cashew nuts after cutting and separating

Peeling

After the shelling process, peeled cashew nuts undergo two distinct production pathways to become raw cashew kernels or roasted cashew nuts (Figure 5.8). Of which, approximately 90% of the peeled cashew nuts proceed to the next stage, where their thin outer skin (testa/husk) is peeled to become the raw cashew kernels. These kernels are primarily designated for export while a small portion is served as a key ingredient in various food and beverage products such as confectionery products, baked goods, and beverages, cashew butter. The remaining 10% of the peeled cashews are roasted to create salt-roasted cashew nuts, a traditional specialty widely consumed in Vietnam as the rich flavor and crunchy texture.

Figure 5.8. The raw cashew kernels and roasted cashew nuts (ready to eat)

Grading/Classifying

In the production of raw cashew kernels, the peeled cashew nuts are dried about 24 hours by hot air to reduce moisture content until approximately 3–4% and facilitate the removal of the testa/husk (the thin brown skin covering the kernel). Next, the nuts are peeled by specialized equipment. During this process, various cashew products are produced, including 1) whole kernels remain intact; 2) split kernels are naturally break during processing; 3) pieces with different size and 4) by-products: the testa and in some cases encompasses the cashew germ and cashew powder.

Following peeling, the kernels are then graded based on several criteria, including size (typically measured in kernels per pound, such as W180, W240, W320, W450), color of the kernel (white, scorched or lightly blemished or scorched seconds or dessert), whole or broken status (e.g., whole kernels, splits, pieces) are illustrated in figure 5.9, 5.10 and 5.11 below.

Figure 5.9. Cashew classification by size

Figure 5.10. a) whole cashew, b) splits cashew c) cashew pieces

Then the defective kernels and low-quality kernels (speckle kernel, blemished kernels or partially peeled kernels – small fragment of testa later become the superficial damage kernel (scrapes)) are manually removed by trained workers to ensure high-quality standards (Figure). The final steps include metal detection, sterilization, fumigation, and packaging, ensuring compliance with food safety regulations.

Figure 5.11. a) defective kernels b) low quality kernels c) partially peeled kernels

At this stage, over 90% of raw cashew kernels are exported to international markets, while the remaining portion is retained for value-added processing. These products must adhere to Vietnamese Standard TCVN 4850:2010, which establishes quality and food safety criteria, serving as a legal framework for government inspection and export compliance. Additionally, to meet the stringent requirements of high-demand markets, medium to large-scale processing companies obtain internationally recognized certifications such as: ISO (International Organization for Standardization), HACCP (Hazard Analysis and Critical Control Points), HALAL (Certification for Muslim consumer markets), BRC (British Retail Consortium certification for food safety).

Further processing (Flavoring, seasoning, food and beverage processing)

Beyond raw kernel exports, some cashew kernels are further additional processed to create various ready-to-eat products, aiming to enhance product value and diversify the cashew-based product portfolio. These encompass 1) flavored cashew nuts (enhanced with seasonings such as honey, cheese, garlic, or chili), 2) bakery and confectionery products (used in cakes, cookies, and chocolate-based products), cashew-based beverages (cashew milk or other plant-based drinks). The product portfolio is illustrated in the figures 5.12 – 13 – 14 below, showcasing the transformation of cashew kernels into various consumer-ready goods.

Figure 5.12. Different flavored cashew nut products

Figure 5.13. Different cashew beverage products (cashew milk coffee, cashew milk, cashew tofu)

Figure 5.14. Different confectionary and bakery cashew-based products

Roasting to packaging

Regarding the roasted cashew nut processing, the peeled nuts are roasted mainly with cashew wood as the fuel source because of the ability to distribute heat more evenly, ensure roasted nut quality more consistently and enhance the nut's flavor profile. Just small portions of processors use gas as the fuel source. The roasting process occurs approximately 30 to 35 minutes depending on factors such as nut size, batch volume, and specific processing techniques employed by each facility. During this stage, shelled cashew kernels can be roasted with or without salt, depending on the desired final product. Once roasted, cashew nuts may be sold with the testa intact or removed, based on market preferences. Processors note that cashews retaining their testa tend to have a longer shelf life, lasting up to 12 months, whereas skinless cashews typically remain fresh for 6 to 9 months. The testa as a natural protective layer preserves the nut's texture and flavor over time. After roasting, the cashew nuts are cooled down until ambient temperature before packaging. The packaging process is tailored to customer specifications such as weight, and packaging types aligns with both consumer demands and the strategic positioning of the business (Figure 5.15 – 16 – 17).

Figure 5.15. Roasted cashew nut with testa with different packaging types

Figure 5.16. Roasted cashew nut without testa with different packaging types

Figure 5.17. Various cashew nut products are distributed in retail chains

Energy and resource consumption during processing

During cashew nut production, energy consumption is derived from multiple sources. Based on field observations and interview data, electricity is supplied from the national grid to power processing equipment and lighting systems while water is sourced from wells for cleaning and steaming operations. Additionally, heat generation to produce hot air for steaming, roasting or drying is generated by using wood-based mass, mainly the cashew wood. According to interviews with cashew processors, cashew wood and other types of low-cost wood are commonly used due to their affordability and availability. One processor explained: *"We mainly use cashew wood and other woods because it is the cheapest option. We don't use cashew shells because we can sell them at 4,000 VND per kilogram, while we can buy cashew wood for just 300 VND per kilogram."*

Figure 5.18. The heat generation uses cashew wood as the primary material

5.2. Cashew nut value chain mapping

The cashew nut value chain in Vietnam involves the participation of various stakeholders, as illustrated in Figure 5.19. Overall, the participants in the value chain include agricultural input suppliers, farmers, intermediary traders, collectors, cashew processors. Notably, many processors simultaneously play the roles of importers, processors, and exporters. The downstream segment of the chain includes export brokers, wholesalers and retailers or retail chains, all contribute to the function and value creation within the cashew sector.

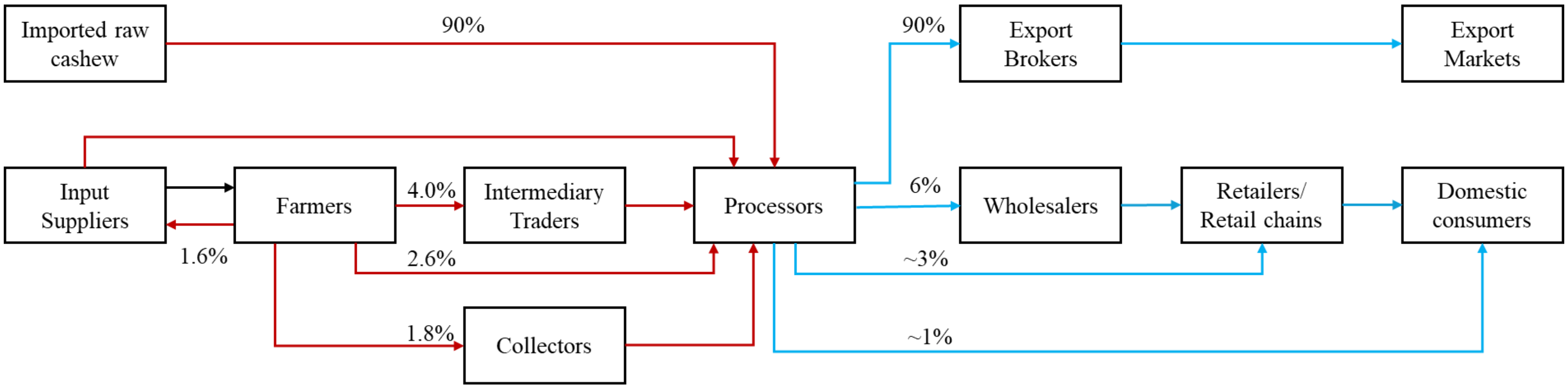

Figure 5.19. Cashew value chain in Vietnam (percentage shows the input and output flows as a proportion of material flows in the chain upstream (red lines) and downstream (blue lines) of the processor)

5.1.1 Agricultural input suppliers

The input suppliers are small-scale and serve as a crucial player in the cashew value chain. They not only provide agricultural inputs such as plant varieties, fertilizers, pesticides, and agricultural machinery but also offer technical advice on the use of agricultural inputs, cultivation techniques and nursing techniques.

One supplier shared: "*When farmers come to our shop to purchase agricultural materials, we guide them on variety selection, cultivation techniques, and effective nursing methods. Sometimes I even visit their farms to observe and offer advice tailored to their specific conditions. This helps build our reputation and ensures they continue coming back.*"

Furthermore, some suppliers allow farmers to purchase agricultural inputs on credit. For those experiencing financial difficulties, suppliers may also offer cash advances or credit arrangements. In return, the farmers agree either to repay the debt or to sell their harvested cashew nuts to the supplying party. As one supplier explained: *"These farmers are our loyal customers. They've been buying from us for years and have become trusted partners. So, I'm willing to provide them with cash in advance, and in return, when harvest season comes, they either repay the amount or sell their cashews to me."*

According to the interviews, approximately 16% of raw cashew nuts are sold to agricultural input suppliers.

5.2.2 Cashew Farmers

Cashew growers in Binh Phuoc are typically smallholder farmers engaged in extensive cultivation. Their farm size varies from 0.5 to 20 ha, with most farms ranging between 3 and 7 ha. The result of this study indicated that most of interviewed farmers own medium size farms (between 4 and 7 ha), only small number operated on very small (less than 1 hectare) or relatively large (10 to 20 ha). All interviewed farmers operated their own land.

Binh Phuoc has unique geographical location characterized by the tropical monsoon climate, combined with its topography and soil conditions, making it an ideal region for cultivating both annual and perennial industrial crops such as cashew, coffee, pepper, rubber, and fruit trees. Indeed, the findings indicate that more than half of the farmers cultivated cashew on nearly all of their farmland, while about one-third allocated most of their land to the crop. Only a few farmers maintained a more diversified land use, combining cashew with other crops.

Due to the cashew wide-spreading canopies, it is commonly planted far apart. In the region, most cashews are grown in monoculture systems, although a small proportion is intercropped with shade-tolerant species. According to the interviews, almost all cashews are cultivated as monoculture, with the remainder intercropped with coffee. Farmers shared: *"Back in the 1990s, when we first expanded our farmland and began cultivating cashew, before 2005, the newly planted trees had not yet produced income. So, we grew food crops like rice, corn, legumes, and pineapples, along with vegetables and herbs such as ginger and turmeric, to diversify our income sources. These intercropping practices continued until the cashew trees matured and provided a canopy cover, at which point we transitioned to intercropping with coffee−a high-value, shade-loving crop."*

Figure 5.20. Typical cashew farming in Vietnam

Despite being a resilient and low-maintenance crop, cashew trees still require timely and appropriate care to ensure optimal productivity and resilience to climatic stress. While a few farmers admitted minimal engagement, only returning to their farms during harvest time, the majority acknowledged that investing in orchard care helps cashew trees grow better and leads to higher productivity. Farmers explained that "*After the harvest season, usually around May to June, they begin pruning branches, fertilizing, cleaning the orchard, inspecting for pests and diseases, and applying preventative or curative treatments when needed*."

In addition, following leaf shedding, many farmers apply supplementary fertilizers and nutrients to stimulate new leaf growth, support flower and fruit development, and protect blossoms and developing nuts. For small-scale orchards (less than 3 ha), once their own farm tasks are completed, farmers often seek additional income by working as hired laborers for neighboring farms. One farmer shared: *"Because our orchard is small, after finishing all the necessary work on my farm, I often take on part-time jobs or help neighbors with their orchards to earn extra income."* In contrast, on larger farms, it is common practice to hire experienced neighboring farmers or external laborers to support orchard management. As one farmer explained: *"Managing our orchard is a year-round responsibility until the next harvest. At certain times, when my family and I cannot handle all the tasks ourselves, we must hire neighbors or outside workers to assist with the workload."*

Investment in pest control, fertilizers, and nutrients varies based on each farmer's perspective. Some believe that since cashew trees are well-adaptable, they do not require intensive care, especially given the low market price of cashew nuts, which discourages large investment. Others recognize the importance of proper care and nutrition for improving yields, yet economic constraints limit their ability to invest.

According to the findings of the study, on average, most farmers spend approximately 20–25 million VND (equivalent to USD 800–1000) per hectare annually on orchard care. Empirical data from farmer interviews and field observations underscore a clear correlation between investment in orchard care and productivity. As one farmer shared, *"Every year I spend around 22 million per hectare for fertilizers, pruning, and labor. Without that, the trees wouldn't give much fruit."* Farmers who do not invest in care tend to have low yields, averaging around 1 ton/ha. A farmer explained, *"I couldn't afford fertilizer this year, and my yield dropped to just over 900 kg per hectare."* In contrast, those who provide moderate care typically achieve 2 tons/ha, and well-managed orchards can reach 3 to 3.5 tons/ha. One experienced grower commented, *"With enough pruning, watering, and nutrients, I consistently get more than 3 tons per hectare."* Moreover, farms that receive proper care and fertilization tend to maintain higher yields even under adverse weather conditions and climate change. As one interviewee explained, *"The rain came late, but my trees still fruited well because I had taken care of the soil and used both chemical fertilizers and organic compost timely."* On the other hand, unmanaged orchards suffer significantly, with yields dropping to as low as 400–600 kg/ha. Another farmer noted, *"We just left the trees on their own last season, and when the drought hit, the fruits didn't form properly, so we only got half a ton."*

During the cashew harvest season, farmers collect fallen nuts from the ground mainly or pick them directly if needed. They shared that, "*During the early and late stages of the season, when yields and production are low, we manually pick or shake the branches to make the nuts fall. However, during peak harvest, the volume of natural fallen nuts is substantial.*"

The harvesting process differs depending on the size of the orchard and the availability of labor. In small-scale orchards, harvesting is typically carried out by family members. In contrast, larger farms often hire seasonal laborers from nearby communities or from other provinces in the southwest regions of Vietnam. During harvest, most farms focus on collecting the cashew nuts, while the cashew apples are usually left on the ground to decompose and return nutrients to the soil.

Figure 5.21. Cashew harvesting

After harvesting, cashew nuts are primarily sold fresh, while a smaller portion is sun-dried and stored for sale at higher market prices. The study data reveals that about two-third of farmers sell their entire wet cashew yield on the same day as harvest. Many farmers cite limited drying spaces and labor as key reasons for this immediate sale. For financially constrained households, selling wet cashew provides essential income to cover daily expenses and repay debts.

The rest of farmers adopt a mixed strategy, selling wet cashews at the early and late stages of the season, while retaining during peak season (when high volume, the nuts are denser and of higher quality) for drying for later market opportunities. Households with sufficient facilities such as drying yards and laborers, are more inclined to store cashews for later sales. However, they may still sell wet nuts if market conditions are favorable or if they lack the necessary resources. Consequently, the proportion of dried cashew stocks remains low. Through the interviews, the price of raw wet cashews in 2024 fluctuated from about 29,000 VND - 18,000 VND/kg (USD 1.1 – 0.7), the price gradually decreased from the beginning of the season to the end of the season, depending on the quality of the cashews and the region. Meanwhile, farmers who stocked dry raw cashews shared that the price of raw dry cashews last year increased significantly from 35,000 VND - 42,000 VND/kg (USD 1.3 – 1.6), especially in the last months of 2024.

Wet cashew nuts are typically sold at midday or in the afternoon, depending on the quantity harvested. A single sack of wet cashews weighs approximately 40 – 50 kg or up to 60 – 80 kg. Farmers who accumulate a significant quantity in the morning prefer to transport their produce immediately. A respondent noted, *"We sell our cashews after harvesting because transporting them on motorbikes is difficult if we wait until the afternoon when the load becomes too heavy. Moreover, during peak summer temperature of 38–42°C, prolonged exposure the cashews to sunlight might cause moisture loss, reduce in weight."*

The transportation and sales patterns of cashew nuts in Vietnam are shaped by farm size, market access, and logistical infrastructure. Farmers typically distribute their harvest through various channels including intermediary traders, collectors, cashew processing companies and the procurement teams of these companies, and agricultural input suppliers.

For small-scale farmers with limited cashew yields, self-transportation to nearby collection points within a radius of about 5 km is a common practice. More than one third of farmers' respondents sell exclusively to familiar buyers, such as agricultural input suppliers and collectors (usually groceries shops owners), which also serve as their creditors. These farmers prioritize long-term relationships over price competitiveness, as these buyers provide financial flexibility, including short-term loans or the ability to purchase goods on credit until the next harvest. One farmer explained, "*While grocery stores and agricultural suppliers may offer lower prices, we maintain these relationships because they provide financial support during* *difficult times.*" Conversely, another two third of farmers facing no debt constraints, on the other hand, have greater bargaining power and tend to select buyers (traders, processors,…) based on the highest offered price. A respondent stated, "*I compare offers from different buyers and sell to the highest bidder."*

Cooperatives/ Farmer' Groups

There are relatively few cooperatives and farmer groups operating in the region. Recently, as part of efforts to promote the collective economy, the Vietnamese government has encouraged the establishment of agricultural cooperatives to enhance farmers' competitiveness and market access. As a result, various cooperative models and informal farmer groups have been formed, primarily aiming to strengthen collective bargaining power: both in procuring agricultural inputs and selling outputs. These groups also facilitate knowledge sharing and resource pooling among members. As one farmer group member explained: *"We are individuals who share common values and mutual interests, so we formed a group to exchange farming techniques, jointly purchase inputs, share agricultural equipment, and coordinate better in price negotiations when selling our products."*

For farmer groups, an arrangement involves a representative with cashew processors to negotiate prices and determine the most favorable buyer. As one farmer shared: *"The deals are usually concluded via phone calls or text messages. At the end of each harvesting day, the fresh cashew nuts are collected at a designated orchard and picked up by processors. Selling in bulk with good quality directly to processors allows us to achieve a higher price (about 300–500 VND/kg more) and improve our profit margins."*

In the case of formal cooperatives, their operations tend to be more structured. A cooperative director stated: *"Before the harvest season, we make a preliminary forecast of the total output and then contact several buyers and processing companies to negotiate prices, terms, and requirements. For buyers with large volumes, we sign formal supply contracts. Depending on the client's demand, we supply either raw wet or dried cashew nuts according to their request. In the past, our cooperative operated a value chain to supply organic raw cashew, which commanded a higher of 1000 – 2000 VND/kg above market price. However, in recent years, due to intense market competition, the price has only been equal to or 200–500 VND/kg higher than the market rate."*

5.2.3 Intermediary traders

Intermediary traders operate with a more structured and business-oriented approach. Typically situated in or near major cashew-producing areas such as Bu Dang and Phuoc Long District, these traders are capable of purchasing large quantities of raw cashew nuts directly from farmers in both the local region and neighboring provinces. Many of them have familial roots in cashew farming or began as small collectors before expanding into more established trading operations. Over time, they have invested in essential infrastructure such as warehouses, drying yards, labor forces, and require substantial capital to operate at scale. One trade explained *"Initially, we only purchased cashews within our own area. After investing in infrastructure and expanding our business operations, we began sourcing from neighboring provinces to meet the growing demand for raw materials from processors."*

These intermediary traders are active throughout the year, purchasing wet raw cashews during the harvest season and dried cashews once the season ends. Prices are generally influenced by signals from the processing companies, particularly based on the raw kernel price. However, in today's increasingly competitive market landscape, with multiple buyers and sellers, these traders revealed that they sometimes offer higher of 500 to 1,000 VND per kilogram over competitors to maintain loyalty among their farmer suppliers. One trade explained "*With rising processing capacity within the province and growing raw material scarcity, we sometimes have to increase our purchase price to compete with other buyers and retain our farmer partners."*

During the cashew peak season, to collect the cashew nut, intermediary traders send trucks to large farms for direct collection. For smaller volumes, farmers usually deliver the raw cashews to the trader's facility. Upon receipt, wet cashew nuts undergo a preliminary quality assessment based on visual appearance, size, and nut count per kilogram. Given the high volume of raw cashew and the time-sensitive nature of post-harvest handling, these traders often hire seasonal laborers (either local workers or those from the Southwest region) to assist in drying and warehousing.

Figure 5.22. Farmers deliver the raw wet cashew to trader's facility

The nuts are sun-dried for three to five days. During the drying process, defective or low-quality nuts are removed. Once dried, the raw cashew nuts are subject to visual inspection and moisture testing using specialized equipment. The acceptable moisture level is below 10%, typically around 9%. The dried nuts are then packed into jute bags and stored in warehouses. As one trader explained: *"Even though we conduct a preliminary inspection when purchasing fresh cashews, we still carry out additional quality checks during and after drying to ensure consistent product standards. The nuts must be dried to a moisture content below 10%, in line with the national standard for raw cashew nuts (TCVN 12380:2018), as well as in accordance with contractual requirements from processors."*

Figure 5.23. Cashew drying and later stock in the warehouse

5.2.4 Collectors

Insights from the study indicate that approximately 42% of raw cashew nuts are sold to raw cashew collectors.

In key processing areas such as Phuoc Long and Bu Dang, cashew nuts are typically purchased directly by traders and processors. In contrast, in more remote communes or districts, raw wet cashews are often gathered by collectors. These collectors are usually small-scale actors, including local grocery stores, agricultural input suppliers, or informal buying groups. During peak harvest seasons, when supply volume surges, the collection network may operate in two tiers. First-tier collectors procure directly from farmers, while second-tier collectors, usually with more capital, aggregate cashews from the first-tier and supply them in bulk to processors.

These collectors do not conduct formal quality assessments but instead rely on their personal experience to evaluate nut quality. Once collected, the cashews are transported to processing facilities. According to interviewees: *"The purchasing price is initially determined by processing companies. We then adjust it based on estimated weight loss, nut quality, market price fluctuations, logistics costs, and our profit margin. However, the price cannot be set too low, or we risk losing our suppliers to competitors offering better rates."*

First-tier collectors typically travel to cashew farms with high yields to handle collection themselves. In cases of lower yields, farmers often transport their own products to designated buying points. Second-tier collectors may purchase a small volume directly from farmers, but the majority is sourced from the first-tier. After aggregation, raw cashews are transported often overnight to processors. These collectors perform rapid, experience-based assessments before contacting processors for price negotiations. One second-tier collector explained: *"We've been in this trade for over 20 years and have built strong networks on both the supply and demand sides. When selling, we prioritize either securing a higher price or dealing with buyers who are more flexible with quality standards."*

Figure 5.24. a) Collecting cashew nut at farm b) Collector’s designated buying point

5.2.5 Processors

Based on the processing capacity, cashew nut processors in Vietnam are typically categorized into four tiers based on their processing capacity: 1) large-scale processors handle approximately 100 − 500 tons of raw cashew per day; 2) medium-scale processors handle between 50−100 tons per day; 3) small-scale processors manage between 20−30 tons per day; and 4) micro-scale processors with an annual processing volume of approximately 10–40 tons. Many of these enterprises have evolved from traditional farming households or small-scale traders, gradually transforming into formally registered businesses.

To meet the stringent quality and food safety standards of importing countries, medium- and large-scale processing companies have obtained international certifications such as ISO, HACCP, BRC, and Halal. These certifications enable them to access and compete in highly demanding global markets. Currently, Vietnam exports raw cashew kernels to about 100 markets worldwide, including the United States, European Union, United Kingdom, China, the Middle East, Australia, and New Zealand.

Regarding sourcing activities, due to the industry's considerable scale and Vietnam's domestic supply of raw cashew nuts meets only about 10% of total processing demand. This significant supply gap forces processors to rely heavily on imports, particularly from other Asian countries (mainly Cambodia and Indonesia) and numerous African nations. Therefore, in addition to acting as processors, many companies also play the role of importers of raw materials and re-exporters of processed cashew kernels.

Processors procure cashew nuts both domestically and internationally. Large-scale companies often send procurement teams directly to exporting countries to purchase raw cashews. As one processor explained: *"Our production capacity can reach up to 100 tons per day, which requires a large volume of raw materials. To be more proactive in securing inputs, we maintain procurement teams responsible for sourcing cashews both within Vietnam and overseas, especially in Africa."*

Other companies rely on intermediary brokers. The quality of raw cashew nuts is usually assessed according to the Vietnamese National Standard (TCVN), along with additional criteria depending on each processor's requirements. If the cashews meet these standards, the pre-agreed purchase price applies. Otherwise, the price may be subject to renegotiation. One processor noted: *"We import dried raw cashew nuts through brokers based on predefined standards. Upon arrival, the quality is inspected jointly by three parties: the seller, the broker, and Vinacontrol (a third-party quality control agency). If the shipment fails to meet the agreed standards, we renegotiate the price."*

Beyond producing the key cashew kernel products, recently, some cashew processors have invested in machinery to produce value-added products themselves or outsource production through OEM contracts. One processor shared: *"Being born in a region rich in cashew resources, we want to generate more value from this product. That's why we've been researching and developing new offerings such as roasted flavored cashew nuts, cashew cakes, cashew candies, and cashew milk. These products are still relatively new in Vietnam, and we aim to create new consumer demands and capture new market segments. However, this requires considerable time for brand building and customer awareness."*

Approximately 90% of the raw cashew kernels and small portion of flavored and roasted cashew nut in Vietnam are exported. This is mainly due to limited understanding of international marketing, lack of insight into consumer preferences, and high export taxes on processed products. As one processor shared: *"We are just a small player, lacking the resources: whether human, technical, or financial, to develop high-value cashew products tailored for export markets."* A larger processor added: *"Demand for deeply processed cashew products is still very limited, so we mainly focus on raw kernel processing."* Another processor revealed*: "When exporting raw cashew kernels, Vietnamese sellers and importers are exempt from export/import taxes, so buyers are willing to pay a higher price for the raw product. In* *contrast, a tax is payable on processed products which means that importers try to reduce the price at which they purchase imported processed cashew kernels."*

Furthermore, government is incentivizing the creation of national geographical indicator for cashew nut products in this region under one commune one product (OCOP) scheme.

Micro-scale processors

Micro-scale processors are extremely small-scale cashew processors. They typically originate from small farming households, collectors, or local grocery shops. The only product they produce is *salt-roasted cashew nuts*, a local traditional snack. The entire processing operation is manual and conducted by family members using basic tools (Figure 5.25).

Figure 5.25. Cutting tool to remove the cashew hard shell

The raw cashew nuts used as input are usually sourced from their own farms or purchased from relatives and acquaintances. As one micro-scale processor explained: "*Because our entire process is manual and our production scale is very limited, we only select raw cashews from our own garden, or from relatives and close contacts."*

Once harvested or purchased, wet raw cashews are sun-dried and stored for processing throughout the year. Typically, production is concentrated during key festive seasons or based on specific customer orders. Their main customers are local residents, nearby grocery stores, and traditional markets. As noted by one micro-scale processor: *"Due to the high price of cashews and the fact that consumption mainly peaks during holidays such as Tet, we intensify our production during those periods. Outside of that, we only process upon receiving orders, mostly from people in the local community, small shops, or markets."*

5.2.6 Export Brokers

Export brokers refer to individuals or groups who operate outside the processing areas. However, most processors are reluctant to disclose detailed information about these brokers. As a result, the understanding of brokers' roles is based primarily on the accounts provided by processors.

Many cashew processing enterprises in Vietnam have grown from humble beginnings, founded by former farmers or local traders who gradually transitioned into formal businesses. While mastering the technical aspects of cashew processing is generally not a major challenge for these enterprises, navigating the complexities of international trade remains a significant challenge. As one processor explained: *"Exporting cashew kernels to diverse global markets requires in-depth knowledge of buyer preferences, quality standards, technical specifications, and regulatory requirements−areas where we often lack expertise."* This is where kernel brokers emerge as critical intermediaries within the value chain. These brokers may operate as independent individuals or formal brokerage firms and serve as facilitators between Vietnamese processors and international buyers. The processor further noted: *"Our products meet international quality standards such as ISO, HACCP, BRC, and Halal, as required by importers or brokers. We supply products according to their specifications."* Brokers typically offer a wide range of services, including identifying and connecting with potential markets, understanding customer requirements, advising on product quality and technical specifications, negotiating prices and contractual terms, and often assisting with logistics and export compliance.

Beyond their commercial functions, kernel brokers also play a risk-mitigation role in cross-border transactions. By ensuring that deals are carried out transparently and in accordance with agreed-upon terms, they help foster trust and long-term business relationships between Vietnamese processors and overseas buyers. As one processor emphasized: *"Cashew nuts are among the highest-value agricultural products we trade. Working with brokers who maintain close relationships with international buyers gives us greater confidence in securing timely and reliable payments."*

5.2.7 Distribution

Processed cashew nuts (ready to eat products) from processors are then distributed to end consumers through three main channels. With the exception of information shared directly by local retailers, most insights regarding wholesalers and retail chains were obtained from interviews with processors and field observations conducted at retail chain stores.

Traditional Channel (Processors – Wholesalers – Retailers – Consumers)

In the traditional retail channel, cashew products may be distributed either through wholesalers or directly to retailers, depending on geographic proximity. Within the same province or nearby provinces, products are typically distributed directly to retailers, including small local grocery stores, open-air markets, street vendors, and individual resellers. In addition to marketing strategies, processors often leverage personal relationships and local reputations to promote and sell their products. For more distant provinces, distribution is commonly facilitated through wholesalers who act as intermediaries between processors and retailers.

Modern Retail Channel (Processors – Retail chains – Consumers)

The modern retail channel encompasses supermarkets, convenience stores, and large retail chains such as Co.opmart, Vinmart, Lotte Mart, Bach Hoa Xanh, and Big C. Cashew products in these retail chain have greater product visibility, higher quality and packaging standards, and access to a wider customer base, especially in urban centers. Medium- and large-scale processors are the main suppliers for this channel, as they are able to meet stricter requirements regarding food safety certifications (e.g., HACCP, ISO, BRC), packaging design, and stable supply volume. Entry into this channel often requires formal contracts, product barcoding, and participation in promotional activities organized by retailers.

E-commerce Channel

E-commerce has become an increasingly important distribution channel for processed cashew nuts in Vietnam, particularly since the COVID-19 pandemic. Processors sell products through various online platforms such as Shopee, Lazada, Tiki, Sendo, Facebook Marketplace, and their own websites. This channel allows direct interaction with consumers, facilitating brand building. Processors often manage the e-commerce channel themselves or collaborate with digital marketing and fulfillment service providers.

5.3. Material flow of cashew by products

In parallel with the transformation of the cashew nut into kernels, in addition to the primary product: the raw cashew nut and cashew kernel, a wide range of by-products is also generated throughout the cashew cultivation and processing. Findings from this research reveal that by-products from cultivation include cashew leaves, branches, trunks, and apples, while those from processing consist of cashew testa (the thin brown skin) and cashew nutshell.

5.3.1 Cashew leaves and weed in the orchard

After the rainy season and fertilization, weeds tend to grow significantly and necessitate to be removed. The weeds along with cashew leaves are collected and burnt to clean the orchard, prevent pests and diseases, and reduce fire risk, especially during the dry season. Apart from this, cashew leaves are also gathered and placed under the tree trunks to conserve moisture, particularly in areas where water is scarce. Additionally, cashew leaves are mixed with microbiome additives to create compost, providing natural nutrients back to the soil.

Figure 5.26. The cashew leaves are collected to create compost and prevent water loss

5.3.2 Cashew branches, trunks

To ensure tree health, maintain productivity, and prevent disease, cashew trees are typically pruned on an annual basis. According to farmers, pruning enables cashew tree to receive adequate sunlight, support overall growth, and strengthen trees' structure, prevent pest infestations and diseases. The pruned stems and branches are collected and either left to decompose as organic mulch or burned for cooking fuel.

Figure 5.27. Cashew branches and cashew wood are collected to decompose naturally or further usage

Beyond routine pruning, cashew trees are also cut down annually for many reasons such as aging trees with declining yields, crop replacement or conversion, and damage from pests or disease. Once cut, the wood is sorted based on size and quality. Smaller branches and stems, especially those damaged by borers or trunk pests, are typically sold to cashew nut processors or CNSL processors at VND 200–300 per kilogram or per cubic meter. In contrast, larger, well-formed logs with minimal pest damage are valued for their dense grain and attractive color, making them suitable for furniture production. These higher-quality timber pieces are sold to furniture manufacturers or wood artisans at a premium rate VND 300–400 per kilogram or more, depending on the dimensions, uniformity, and finish potential of the wood.

5.3.3 Cashew apple

Cashew apple is one of the most underutilized, yet highly promising by-products generated during cashew harvesting, contributing significantly to the total biomass produced. According to data of this research, the production of 1 kg of dried cashew kernels requires approximately 45 kg of fresh cashew fruit, of which the cashew apple accounts for nearly 40 kg. The majority of cashew apples are discarded in the fields, despite their high nutritional value, rich in vitamin C, vitamin A, and B-complex vitamins, as well as essential minerals such as calcium, potassium, and magnesium, and natural sugars. These discarded apples naturally decompose into compost, enriching the soil and supporting the cashew trees' growth.

Cashew farmers consume only a small portion of the apples as fresh fruit or use them to make dishes or ferment them into cashew wine. In the last one to two years, however, there has been a modest increase in commercial utilization, with about 1% of cashew apples being sold in whole-fruit form, still attached to the nut. Nonetheless, several challenges hinder the broader commercialization of cashew apples. Due to their high moisture content and the firm attachment of the nut to the apple, detaching the two often causes the apple to leak juice and spoil rapidly. Furthermore, only cashew apples from grafted trees, which are shorter in height and produce larger, juicier, and sweeter fruit, are suitable for market sale. Traditional local varieties typically yield smaller, more astringent apples and are harder to harvest because the trees are tall, and the fruit is difficult to reach.

A farmer explained: *"Because cashew apples spoil very easily, they must be handled with great care, packaged like delicate fruits, wrapped individually, packed in foam boxes, kept refrigerated (cool preservation), and then transported to traditional markets in the southeastern and Mekong Delta provinces."*

Figure 5.28. Cashew apples are packed and marketed in the marketplaces

5.3.4 Cashew nutshell

During cashew nut processing, beyond the cashew testa, the cashew nutshell is notable not only for its volume but also for its high economic value through the extraction of cashew nutshell liquid (CNSL). This section will discuss the specific material flow and value chain of CNSL.

5.3.4.1.Material flow of cashew nutshell

The study revealed that despite variations in cashew sources among different countries (with 90% of cashew nuts processed in Vietnam being imported), cashew nutshells are generally 1 to 2 mm thick and account for around 65–72% of the total weight of the cashew nut. Previously, these shells were often discarded or sold at low prices as fuel for furnaces due to their high oil content. However, they are not suitable for use in heat and steam during kernel processing, as direct combustion produce black smoke and, without properly treatment could lead to environmental pollution. More recently, cashew nut shells have been utilized for extracting CNSL, a high-value product with widespread applications across various industries. The process of cashew nutshell oil extraction in Vietnam is illustrated in the Figure 5.29.

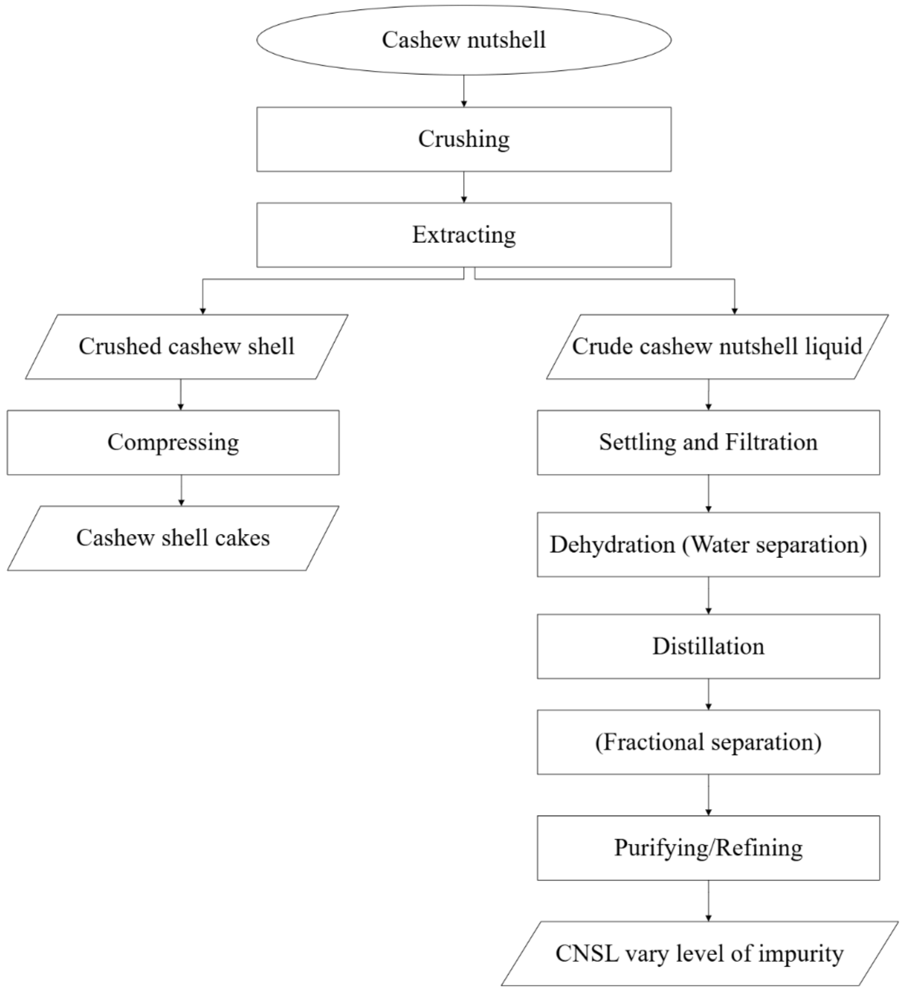

Figure 5.29. The cashew shell oil processing in Vietnam

First, cashew shells are collected from cashew processing facilities. Before being crushed, they are gathered and undergone preliminary quality inspection to check for moisture content and impurities. Crushing enhances oil extraction efficiency for later crude oil pressing.

The oil extraction process can be carried out using two main methods: thermal roasting at temperature of 180–200°C, or steam distillation, in which the shells are heated using steam to separate the oil. The latter method yields oil of higher quality but is typically implemented by large processors equipped with advanced technology. At this stage, two crude products are obtained: crushed cashew shell and crude cashew nutshell oil, which still contains significant impurities.

While the crushed cashew shell is either sold directly to domestic manufacturers or traders. Large processors compress the shell into cashew shell cakes to facilitate packaging and export logistics. One processor explained, *"The oil content in cashew shells can reach 28–30%,* *depending on the shell type. Through crushing and crude extraction, only about 18–25% of the shell oil is extracted; the remaining oil remains within the shells."*

Cashew residue contains a lot of natural fats and oils, is very flammable. This is usually mixed with other fuels such as wood chips, rice husks to maintain a stable combustion process and release a large amount of heat as well. This makes the use of cashew nutshell residue as fuel more convenient and easier, becoming a very efficient fuel source to provide energy for production activities. Therefore, it is often used to replace traditional fuels such as coal and firewood, helping users save costs and reduce pressure on natural resources. One disadvantage of using cashew residue is that the steam and boiler will be damaged faster because cashew resin is very toxic, over time it sticks to the furnace grate, furnace bars, and iron pipes, reducing the heat in the boiler. Therefore, people only use it sparingly for the purpose of mixing to increase heat quickly. Moreover, transporting cashew residue makes the vehicle dirty, and can pollute the environment.

Figure 5.30. a) cashew nut shell (left) b) crushed cashew nut shell (right)

Meanwhile, the crude CNSL undergoes further settling and filtration to remove residual shell debris. It is then dehydrated, fractionated based on chemical compounds such as anacardic acid, cardanol and cardol, and refined to produce various final products. In Vietnam, depending on each factory's capacity, scale, and technology, different products can be produced. The key products include cashew nutshell liquid (CNSL) with varying levels of purity, cardanol, and cashew shell extract oil (referring specifically to solvent-extracted CNSL, which retains more intact anacardic acid). These diverse finished products are primarily exported to South Korea, China, Japan, and the EU.

Figure 5.31. Cardanol (Light yellow to pale brown oil) and CNSL (Dark brown liquid)

Figure 5.32. A medium-scale CNSL processor in (Binh Phuoc), Vietnam

5.3.4.2.Mapping the value chain of cashew shell

Thanks to technological advancements in Vietnam, cashew shells, once considered waste in the cashew nut processing industry, have become a valuable raw material, forming a cashew shell value chain involving multiple stakeholders, as depicted in Figure 5.33. From cashew shells as the input material, two main products are derived: cashew nutshell liquid (CNSL) and cashew shell cake. Due to similarities in processing and involved participants, these two branches are integrated into a single value chain. Overall, the participants include cashew nut processors as input suppliers, shell collectors, processors, small-scale processors, and traders.

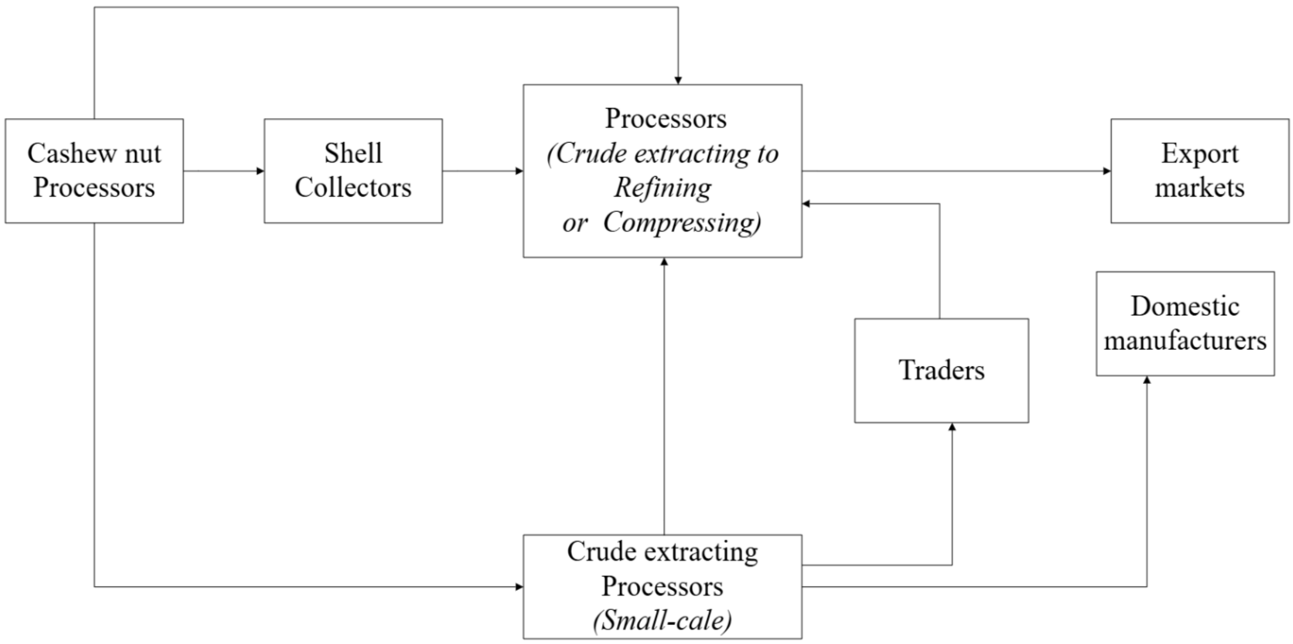

Figure 5.33. Cashew nutshell value chain in Vietnam

Cashew nut processors

Cashew nut processors act as buyers within the cashew nut value chain, yet simultaneously serve as suppliers of raw materials for the cashew nutshell liquid (CNSL) value chain. Although their primary focus is on kernel processing, with processing capacities ranging from 20 to 500 tons per day, cashew shells account for approximately 70% of the raw nut weight translating to 14 – 350 tons of shell waste daily. Previously, this massive quantity of shell was regarded as waste, which processors had to dispose of or sell cheaply to combustion kilns.

In recent years, however, technological advancements have transformed cashew shells into a valuable input for CNSL production. Nevertheless, cashew processors themselves do not engage in CNSL extraction, as their focus remains on producing high-quality white cashew kernels for export. As one processor explained: *"We have invested heavily in equipment and factory infrastructure for kernel processing. If we plan to expand further, we will continue improving the quality of our kernel products to ensure better export performance. Selling cashew shells now helps offset production costs, whereas before, we had to dispose of them.*

Moreover, CNSL production requires specific technical expertise, technology, and infrastructure".

Thus, technical barriers, technological requirements, and capital limitations constrain cashew processors from investing in CNSL processing.

Given the large volume of shells generated, they are typically collected and stored in dedicated warehouses during production. CNSL companies or cashew shell collectors then come to collect them. The frequency of collection either daily or every 2–3 days depends on the amount generated. Based on their production plans, cashew processors can estimate the amount of shell waste produced and proactively contact CNSL processors or shell collectors to negotiate prices. For smaller quantities, negotiations are usually conducted via phone calls or text messages, whereas for large volumes, formal contracts may be signed in advance.

Figure 5.34. A pile of cashew nutshell in a processor's warehouse

As explained by another cashew nut processor: *"During production, the shells are transported through suction pipes into the warehouse and then picked up on the same day. Collectors or CNSL companies transport the shells, and pricing is typically negotiated in advance or by phone based on our production batch schedule."*

Shell Collectors

Shell collectors are small-scale buyers of raw cashew shells. They are typically commodity traders who also supply fresh cashew nuts to cashew nut processors and trade other agricultural products within the local area. These collectors leverage their existing logistics systems, including trucks and transportation networks, to collect and deliver raw cashew shells to CNSL processors.

The purchase price of raw shells is usually determined based on the buying price offered by CNSL processors, transportation costs, and the collector's profit margin. Although the total volume of cashew shells traded is significant, the economic value per unit is relatively low, so most transactions are arranged informally via text messages or phone calls. After being purchased, the shells are transported directly to CNSL processing facilities.

As explained by one shell collector: *"We collect a large volume of shells, but we do not have storage facilities. In addition, cashew shells contain acidic substances that can stain warehouse floors black, so we typically deliver the shells to CNSL processors on the same day. The price is usually negotiated in advance through phone calls or text messages."*

Processors

CNSL processors in Vietnam vary in size, ranging from small-scale to medium and large enterprises. Their capacity depends on processing volume, but more importantly, on the level of technological investment in refining crude CNSL into higher-value purified derivatives.

Small-scale processors primarily engage in the crushing and extracting crude CNSL, which is then sold to medium and large - scale CNSL companies for further refinement or domestic manufacturers. In contrast, medium and large processors invest significantly in refining technologies and equipment, enabling them to produce higher-purity CNSL products that command better prices on both domestic and international markets.

These processors source raw cashew shells from cashew nut processing companies or independent collectors. CNSL companies often prioritize direct negotiations with major cashew nut processors to secure better prices and ensure a stable input supply, frequently formalized through contracts. However, due to lack sufficient logistical capacity to handle daily deliveries, CNSL processors also rely on shell collectors to fill the gap. One CNSL processor explained: *"To ensure continuous operation of our plant, we sign contracts with cashew nut processors in the region. At the same time, we still procure from collectors to supplement our supply."*

The purchase price of raw cashew shells is influenced by multiple factors, including the market price of raw cashew nut, raw cashew kernels, and the price of crude CNSL as determined by downstream refiners.

Once crude CNSL is extracted and partially filtered or settled, it is often sold to CNSL companies specializing in deep processing, traders or exported to international markets such as China and South Korea, where it undergoes further refinement. Meanwhile, medium and large processors are capable of producing a range of CNSL products with varying levels of purity and export these to Japan, South Korea, and European countries.

According to processors, Japanese manufacturers use high-purity CNSL-derived coatings for marine paints, which protect metal surfaces of ships from saltwater corrosion. In South Korea, CNSL is used as a raw material in generator components, while in Europe, it serves as a renewable source for biofuel and heating oil, contributing to sustainable energy solutions.

5.3.5 Cashew testa

During cashew nut processing, one of the notable by-products generated is the cashew nut testa. This is the thin, brown, papery skin that surrounds the kernel and accounts for approximately 6% of the kernel's total weight. While it remains intact in salted roasted cashew products where it acts as natural preservatives and helps extend product's shelf life, the testa is typically removed during the production of raw cashew kernels or peeled salted roasted cashews, becoming a by-product of the peeling process.

Despite high polyphenol content with antioxidant properties, cashew testa can cause a bitter taste therefore is often discarded during consumption. However, it has a certain nutritional value, including approximately 8% fat and 11% protein, and so has gained attention for potential use in animal feed formulations and in fertilizer production.

During the peeling stage of cashew kernel processing, several by-products are simultaneously detached and mixed with the cashew testa such as cashew nut germs (the sprout tips), broken kernel fragments, and cashew powder. As processors explain, when the testa is peeled off, it often comes away with small kernel pieces and powder adhering to it. These mixed materials are then separated, sorted, and classified based on the size of cashew kernel pieces, and then are sold at different prices. The kernel fragments are sold to confectionery and baking manufacturers. Testa mixed with more cashew powder is generally repurposed as a feed ingredient for livestock. Meanwhile, the cashew testa itself is used in organic fertilizer production or incorporated into animal feed formulations. Some processing companies compress the collected testa into cashew pellets, which are primarily exported to European markets as biomass fuel or fire-starting material.

Figure 5.35. a) Cashew husk with cashew nut pieces b) cashew husk and cashew nut powder

Figure 5.36. Cashew testa (cashew husk) and Cashew pellet

5.4. The transformation of material flows and economic value in the cashew industry

The material flow of cashew nuts and their associated by-products have been discussed in previous sections. This section provides a comprehensive analysis of how raw cashew fruits are transformed into finished products and by-products within the cashew processing industry in Binh Phuoc region. First, Table 5.1 outlines the physical conversion from raw cashew fruit biomass to obtain 1 kg of cashew kernels, highlighting the low yield ratio and the large volume of biomass involved. Next, Table 5.2 presents the economic value of both primary and secondary products, emphasizing the additional revenue that can be generated if by-products are utilized. Following this, Figure 5.37 offers a visual representation of the flow of products and by-products throughout the cashew industry. Finally, Table 5.3 summarizes the main output from each stage, their origin, primary uses or markets, and their estimated contribution to the overall economic value of the sector. Together, these components provide an integrated overview of material utilization and value creation in the Vietnamese cashew industry.

Firstly, Table 5.1 presents the standardized mass balance, showing the quantity of each component required to produce 1 kg of shelled cashew kernel. The results indicate that approximately 45 kilograms of fresh cashew fruits are required, resulting in an overall kernel yield of only 2.22% of the initial fresh fruit biomass. This extremely low extraction rate underscores the substantial amount of biomass (over 97%) that becomes by-products or residues throughout the production chain. These by-products include cashew apples, which constitute the bulk of the fruit mass and are often underutilized, as well as cashew shells generated during nut processing and testa removed during kernel peeling. Additional losses occur due to moisture evaporation, impurities, and processing inefficiencies. The findings reveal the profound structural inefficiency of kernel-centric cashew value chain, therefore, highlight the importance of improving by-product utilization strategies in the cashew value chain to enhance resource efficiency, reduce waste, and create additional revenue streams.

Table 5.1. Mass of different components in cashew value chain relative to 1kg cashew kernel, and yield relative to fresh cashew fruit (100%)

CASHEW MATERIAL FLOW	Quantity (g) per one average shelled cashew kernel	Standardize into 1000g shelled cashew kernel	Approximate Yield (%)
Fresh whole cashew (apple + nut)	74.700	45,135.95	100.00%
Cashew apple	65.900	39,818.73	88.22%
Wet raw cashew nut	8.800	5,317.22	11.78%
Dried raw cashew nut	5.882	3,554.29	7.87%
Water loss and impurities	2.918	1,762.93	3.91%
Cashew nutshell	4.118	2,488.22	5.51%
Cashew nutshell cake	3.212	1,940.79	4.30%
Crude cashew nutshell liquid (CNSL)	0.906	547.43	1.21%
Refined CNSL	0.688	415.71	0.92%
Loss and impurities	0.218	131.72	0.29%
Cashew Testa	0.109	65.86	0.15%
Shelled cashew kernel	1.655	1,000.00	2.22%

Meanwhile, Table 5.2 illustrates the economic valuation of main product and key byproducts, using the value of 1 kg of shelled cashew kernel as the baseline (100%). It presents both the current primary value chain pathway and potential alternative revenue streams from full biomass utilization. The table illustrates the progression of value addition from farm to processor:

- Current farmgate sales: Farmers currently sell wet cashew nuts, capturing approximately 73% of the final kernel value. If they dry the nuts, this increases to about 80%.
- Processor value addition: Processors then convert dried nuts into shelled kernels, realizing the full 100% baseline value. This stage involves significant investment in operation and infrastructure.

The analysis also highlights substantial untapped value:

- Unrealized farm-level revenue: The value for fresh whole cashew fruit (174%) represents the total potential revenue if 100% of the harvested biomass (apple + nut) were sold at farm-gate prices. This highlights a significant unrealized economic opportunity, as farmers currently sell only the nut portion, leaving the cashew apple largely uncommercialized. This value is not a direct market alternative to kernels but indicates the scale of value loss at the harvesting stage.
- Additional CNS valorization: The values for cashew shells represent additional revenue streams for processors either selling raw shells adds 5.5% or alternatively investing in further processing to produce shell cake (1.3%) and refined CNSL (35.6%). The latter offers substantially higher returns but requires capital investment. These are mutually exclusive alternatives to selling raw shells.

Table 5.2. Economic valuation and potential by-product revenue (per 1 kg of shelled cashew kernel)

Product	Stage of origin	Weight (kg)	Price (VND/kg)	Revenue (VND)	Economic contribution (%)	Note
A. Current primary value chain pathway						
Fresh whole cashew fruit (apple + nut)	Farm	45.14	7,000	315,952	173.6%	Represents the potential gross revenue if whole fruits were sold, highlighting the unrealized value of cashew apple.
Wet cashew nut (farmgate sale)	Farm	5.32	25,000	132,931	73.0%	Current main farmer income; first marketable product.
Dried cashew nut	Farm /Intermediaries	3.55	41,000	145,726	80.1%	Value-added step before processing.
Shelled cashew kernel (baseline)	Processing	1.00	182,000	182,000	**100.0%**	Final product; value includes processor's operational costs & margin.
B. Additive by-product revenue (Processor Options)						
Cashew nutshell (raw)	Processing	2.49	4,000	9,953	5.5%	Additive revenue for processors from selling raw shells without further processing investment
Alternative deep-processing pathway for shells:						
Cashew Nut Shell Cake	Further processing	1.94	1,200	2,329	1.3%	Mutually exclusive alternative to selling raw shells. Represents potential gross revenue from high-investment deep processing. Does not account for the additional operational, capital, and processing costs required to achieve this revenue.
Refined CNSL	Further processing	0.42	156,000	64,851	35.6%	

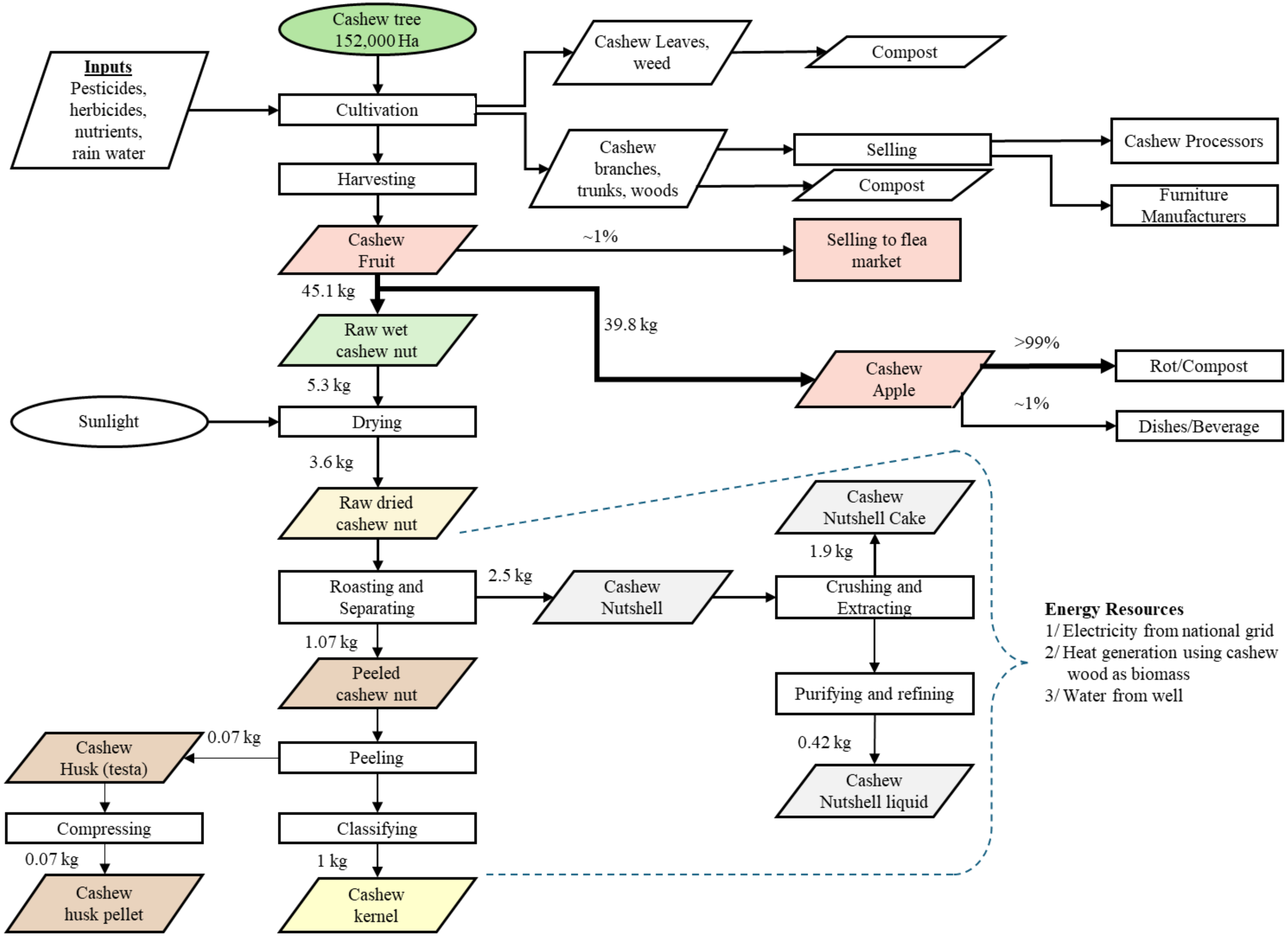

Figure 5.37. Material transformations along the Vietnamese cashew value chain

Following, Figure 5.37 synthesizes and provides the visualization of material transformations along the Vietnamese cashew value chain. It maps the transformation of fresh fruits into 1 kg of kernels, explicitly contrasting the narrow, high-value kernel pathway with the divergent fates of by-product streams. This shows the kernel-centric configuration of the chain despite the dominance of secondary material flows in terms of biomass volume.

In summary, Table 5.3 outlines the main outputs from each stage of the value chain. For each product and by-product, it details the stage of origin, primary use or market, and its estimated economic contribution under current and potential scenarios. This includes the potential value of by-products like testa, shell cake, and CNSL if further processing investments were made, contrasting with their current low-value or waste status.

Table 5.3. Cashew products and by-products: origin, use, and economic contribution

Product / By-product	Stage of Origin	Main Use / Market	Estimated Economic Contribution (%)
Cashew leaves	Cultivation	Compost/Orchard mulch	Negligible
Cashew trunks/branches (if harvested)	Cultivation (pruning & replacement)	Compost, heat generation, furniture (if high quality)	Negligible
Fresh cashew apple (if harvested)	Cultivation (harvest)	Mostly unutilized; potential for juice, alcohol, vinegar, dishes	Current: ~1%. Potential: Significant if markets develop.
Wet/Dried Cashew Nut	Farm/Intermediaries	Raw material for kernel processors	~73–80% (Farmgate value as % of final kernel price)
Cashew kernels	Processing (Finished product)	Food (domestic use or export (USA, EU...))	100% (Baseline)
Cashew Testa	Processing (After peeling and compressing)	Compost, animal feed, export to EU, India	Current: ~1%. Potential: Higher if extracted for tannins.
Cashew nutshell (Raw)	Processing	Low value bulk sale as raw material for CNSL processors	Current/Additive: ~5.5%
Cashew nutshell cake	Further processing	Domestic use and Export for heat generation (mainly EU)	Potential/Additive: ~1.3% (if shells processed)
Refined CNSL	Further processing	Export for further processing (EU, South Korea, China, Japan...)	Potential/Additive: ~35.6% (requires high investment)

Chapter 6. Discussion

This chapter is divided into three sections: the cashew nut value chain analysis (Section 6.1), material flow analysis (Section 6.2) and circularity analysis of the cashew sector in Binh Phuoc Province (Section 6.3).

6.1. Cashew nut value chain analysis in Binh Phuoc

This section discusses the structure of the value chain, the key players, how these players collaborate through horizontal and vertical coordination, and how information flows among the key players in Binh Phuoc Province, Vietnam.

The processed cashew value chain in Binh Phuoc

This study found that in Binh Phuoc Province, there is only one processed cashew value chain, with different processing levels resulting in two types of products: (1) white cashew kernels, commonly referred to as raw or peeled cashew kernels, and (2) high value-added processed products. This situation reflects a shift in the value chain's focus from producing basic raw materials to upgrading into higher-value products within the global cashew value chain. However, it is also noted that white kernels remain the main product, accounting for 90% of production, primarily for export to buyers in the US, EU, and China, who further process and label the products under their own brands in their respective countries. It is challenging for processors in Vietnam to shift from exporting raw kernels toward higher value-added products, such as roasted or flavored cashews, because they face stiff competition from international buyers, lack of capital and marketing capacity.

Regarding the cashew nut value chain, only three countries (India, Brazil, and Vietnam) are able to process all their own cashews and thus have a processed value chain (Costa & Delgado, 2019).

In contrast, two co-existing value chains, unprocessed and processed, are identified in other cashew-producing countries such as Tanzania (Krepl et al., 2016), Côte d'Ivoire (Costa & Delgado, 2019), Indonesia (Hidayati et al., 2021), Kenya (Omolola, 2024), and Gambia (Bojang & Emang, 2024). This is primarily because processing capacity in these countries remains underdeveloped. Many of these processors still rely on manual shelling methods, which are less efficient, labor-intensive and hazardous due to exposure to caustic CNSL.

Hence, a large proportion of raw cashew nuts is exported to Vietnam or India for conversion to processed cashew nuts.

The transformation of the cashew nut value chain into a processed cashew value chain in Vietnam has been driven by domestic machinery innovations since 2010, which have made machines more affordable and automated, improved processing yields, and reduced labor dependency, leading to an increased demand for raw materials. As a result, all domestically produced cashews are processed locally; however, this accounts for only about 10% of total processing capacity. The remaining 90% of raw cashews are imported from Africa and Asia to meet processing capacity and enable year-round operations. Pattanayak (2020) and Yomichan (2020) reported a similar situation in India, which faces insufficient raw cashew nut domestic production and is importing large volumes from West African countries to utilize processing capacity. They also highlighted that those cashew producing countries are restricting the export of raw material in favor of local processing. This is leading the two largest global cashew processing countries, Vietnam and India to have concerns about long-term supply security, and increasing vulnerability to price volatility, trade disruptions, and international competition.

Key players in the value chain

The cashew nut value chain in the region is characterized by a multi-layered structure with variety of VC players, including agricultural input suppliers, smallholder farmers, traders, collectors, processors, and export brokers. For the domestic market, distribution is channeled through three primary pathways: general trade (GT), modern trade (MT), e-commerce. This fragmented and multi-layered structure with various traders and collectors (intermediaries) is similar to many cashew nut and agricultural value chains in other developing countries, as outlined in research on India (Pattanayak, 2020), Tanzania (Krepl et al., 2016), Côte d'Ivoire (Costa & Delgado, 2019), Indonesia (Hidayati et al., 2021), Kenya (Omolola, 2024), and Gambia (Bojang & Emang, 2024). According to Trienekens (2009), such structures often face inherent challenges in coordination, information asymmetry, and quality control.

However, the Vietnamese value chain appears to be somehow different compared to those of many other developing countries. While similarly multi-layered, it is comparatively shorter and has undergone a significant upgrade in its domestic distribution, integrating modern retail and e-commerce channels−a contrast to the more traditional systems in countries like Tanzania

(Krepl et al., 2016), Côte d'Ivoire (Costa & Delgado, 2019), Indonesia (Hidayati et al., 2021), Kenya (Omolola, 2024), and Gambia (Bojang & Emang, 2024).

By contrast, agri-food chains in developed countries such as the US, UK, and Canada are more vertically integrated and consolidated (Sule et al., 2024). Sule et al. (2024) identified that these chains are mainly dominated by large agribusiness firms which exert strong influence over upstream suppliers by setting standards for traceability, food safety and ESG (environmental, social, governance) compliance. They suggest that developing countries can improve their agribusiness value chains through the adoption of sustainable practices, technological innovation, and policy support, thereby increasing productivity and efficiency, and market access.

Horizontal coordination

In terms of horizontal coordination, there is very weak coordination between players at the same level in the region. Regarding the producer groups, it is noted that there are only a few active cooperatives or farmer groups. A similar situation has been identified in many agricultural value chains in developing countries (de Janvry et al., 2019), the rice value chain specifically in Vietnam (Khong, 2022) and the cashew nut value chains in Indonesia (Hidayati, 2021), Gambia (Bojang & Emang, 2024), and Mozambique (Costa & Delgado, 2019). These studies highlight that, despite the existence of farmer organizations or cooperatives, their reach and capacity to enhance access to inputs, adoption of technology, or collective bargaining are restricted. Many smallholders still continue to operate independently, outside of these associations. This contributes to several challenges: reduced bargaining power with intermediaries and downstream actors, limited access to inputs and services, exclusion from value chain upgrading, increased transaction costs, poor quality control, and restricted access to branding and certifications. While the agri-food value chains in many developing countries have a lack of horizontal coordination, studies have shown that those of some developed countries are more collaborative, with cooperatives holding more than 50% market share. For instance, cooperatives account for 57% of the dairy sector and 42% of the fruit and vegetable sector in the EU, 75% of milk production in the US, and 94% of pig meat production in France, and 90% of dairy products in NZ (Candemir et al., 2021; Bijman et al., 2012; Wadsworth, 2019, Garnevska et al., 2017). These studies underscore that cooperatives facilitate collective bargaining power, access to shared processing facilities, marketing channels, quality control systems, and advanced inputs, thereby enabling farmers to capture more value and exert greater influence within the value chain.

Vertical coordination

In terms of vertical coordination, the findings of this research indicate that the region exhibits a buyer-driven chain with a dual governance structure: informal market-based governance in upstream segments and increasing modular or relational governance in the midstream and downstream segments. This coexistence of informal upstream and formal downstream governance modes is identified by Barrett et al., (2022) as a common pattern in middle-income or transitional agri-food economies, where modernization is partial and uneven. With regard to the buyer-driven chain, the processors act as the lead players, dictating prices which are calculated based on rates set by the international buyers where large retailers, branded manufacturers, or trading companies act as "lead firms" in the global cashew nut value chain. These buyer-driven chains are common in many commodity value chains due to their proximity to the consumer and evolution of modern retail systems (Gereffi et al., 1999, 2005; Reardon et al., 2009).

In the upstream segment, transactions between farmers with collectors, traders or processors are informal and based on trust with little to no formal contractual arrangement. This similar situation is usually identified in studies on agri-food value chains in developing countries (Barrett et al., 2022), low-income countries (Bernard & Giraud Héraud, 2024), the Vietnamese rice value chain (Khong, 2022) and cashew nut value chains in Indonesia (Hidayati et al., 2021), Mozambique (Ebong, 2019), Gambia (2022), Côte d'Ivoire (Tessmann, 2018). They suggest that these informal, ad hoc transactions will continue to dominate the farmer-trader interaction; farmers still remain as the price takers, unable to negotiate effectively or upgrade within the value chain.

In the midstream and downstream segments, transactions between traders with processors, processors with foreign importers, or processors with wholesalers/retailers are coordinated through formal contractual relationships. This structure is usually observed in agri-food value chains in developed countries, yet these are more integrated and highly coordinated than that of Vietnam (Deconinck, 2021; Bonanno & Çakır, 2022, Sule at el., 2024). According to Deconinck (2021), value chain concentration tends to be stronger in downstream segments than at the farm level, which leads to widespread concerns over the perceived weak position of farmers. This highlights the need to reduce intermediaries and promote greater vertical coordination across all chain segments to ensure competitiveness and inclusive upgrading.

Information flow

In terms of information flow, thanks to the adoption of mobile phones and internet access, information access has improved in the region. Price and quality requirements are communicated by processors who receive market cues from international buyers, and disseminate this information to intermediaries and farmers. Yet there are still asymmetries in information flow and decision-making power. While basic price awareness might increase, the quality, depth, and actionable nature of information remain limited for smallholders. They might know a price, but not why it is that price, how it relates to export markets, or how to improve their product in order to achieve a better price. As a result, they continue to be price takers. This situation is widely observed in agricultural value chains, not only in developing countries such as in South Africa (Hlatshwayo et al., 2021), the Gambia (Bojang & Emang, 2024), Mozambique (Costa & Delgado, 2019), and Ethiopia (Lee at al., 2021) but also in developed countries such as in the apple fruit value chain in Poland (Pietrzak et al., 2020). These studies suggest that mobile phone ownership and internet access are associated with higher agricultural prices; however, the impact of adoption of these technologies is not transformative enough to eliminate the power imbalance entirely. This is particularly the case in developing countries where intermediaries play a crucial role in connecting fragmented farmers but also exploit their position as information brokers. Detailed price and quality information are disseminated only in a filtered or manipulated form in order for the intermediaries to maintain their margins. According to Miller (2021), this information asymmetry, where lead players have greater capacity to obtain and control system-wide knowledge in order to maintain their market power, creates an unhealthy power dynamic within value chains. This undermines smallholders' ability to upgrade their position in the value chain, whether through process upgrades (better farming practices), product upgrades (higher quality varieties), or functional upgrades (taking on processing tasks).

6.2. Material flow in the cashew value chain

This section discusses the material flow within the cashew nut value chain, emphasizing the very low conversion rate of cashew fruit to cashew kernels as well as two major by-products generated during production and processing – cashew apple and cashew nutshell. It discusses how these by-products are managed and valorized.

6.2.1 Low conversion yield of cashew fruit to cashew kernel

The findings of this study indicate that to produce 1 kg of cashew kernels, approximately 45.1 kg of raw cashew fruit is required, resulting in a kernel yield of only about 2.2% by mass. The remaining biomass consists of about 88% pseudofruit (cashew apples), 5.5% shells, approximately 0.1% testa (brown skin) as processing residue, and about 5% water loss through evaporation. This 2% yield is not due to inefficiencies or food loss in post-harvest handling or processing (which are not taken into account in this study), but rather due to the inherent botanical structure of the cashew fruit which is characterized by the dominant cashew apple and the industry's historical focus solely on the kernel. This very low material conversion efficiency means that a significant amount of land, labor, water, and nutrients is used to produce a small quantity of edible kernel, while generating a large volume of other biomass. Studies on other tree nuts such as almonds, walnuts and pistachios have identified that these nuts also generate by-products such as hulls, shells, and skins during post-harvest handling and processing. However, the kernel-to-by-product ratio in these cases is much higher, at least 20%, compared to that of cashew. For instance, almonds have a kernel yield of 23%, with by-products including 70% husk and shell and 6% brown skin (Silva et al., 2025); the walnut' kernel ratio varies by variety but is generally around 40% of the whole fruit (Sharma & Sharma, 2001); pistachios have a kernel-to-nut ratio ranging from 47% to 57% (Tsanliti et al., 2010). Therefore, while by-product valorization efforts for other nuts always focus on shells, the biological structure of cashew presents a greater challenge, as it results in two major, distinct, and high-volume by-product streams (apple and shell), each requiring different valorization strategies. Research has asserted that tree nuts' by-products show significant potential for value-added applications in both food and non-food sectors, yet they remain heavily underutilized, particularly at the industrial level (Silva et al., 2025; Khir & Pan, 2019; Shakerardakani & Molaei, 2020). With the application of innovative techniques, these by-products could be transformed from their "current low-value status into high-revenue raw material streams" (Khir & Pan, 2019). However, many processors, especially in developing countries, struggle to efficiently utilize by-products generated during processing.

6.2.2 Cashew apple

Regarding the cashew apple, the findings of this research indicate that only a very small portion is consumed as fruit or used in vegetable dishes and beverages, while nearly 99% of cashew apples are left to rot on the farm. In Binh Phuoc, approximately 152,000 ha of cashew cultivation takes place with an average nut yield of 1,500 kg/ha, this translates to more than 2 million tons of cashew apples being wasted annually. This is largely attributed to their high perishability, seasonal availability, and astringent taste, combined with a lack of infrastructure, cold chains, and processing technologies. Yet, at the same time, they are rich in amino acids, vitamins, minerals, reducing sugars, and polyphenols.

According to van Walraven & Stark (2023), global cashew apple production is estimated at 36.9 million tons, yet only 1.3 million tons are utilized in industrial production. This underutilization is consistent across cashew-producing countries such as Mozambique (World Bank, 2022), Nigeria (Nwosu et al., 2016), Indonesia (Hidayati et al., 2021), Tanzania (Dimoso et al., 2024) and Ghana (Akyereko et al., 2023). These studies indicate that most cashew apples are left to rot on farms, with only small portions used as animal feed or consumed as snacks or juice during the harvest. India, the world's largest cashew nut producer, has made some efforts to commercialize cashew apple processing, most notably in the production of a special alcoholic beverage called feni, which received Geographical Indication status in 2009. Yet, a large portion of cashew apples in India still go to waste (Bhavana & Patil, 2021).

Recent studies have emphasized that this widespread wastage has significant economic and environmental implications, particularly as it takes place in developing countries. Economically, massive resources are used to cultivate the whole cashew fruit, yet only a small fraction (the nut) is monetized. If even part of the 99% of the apple currently wasted could be utilized, it could create an additional income stream for farmers and reduce their vulnerability to fluctuations in nut prices. Furthermore, cashew apple processing could generate new jobs and economic opportunities, improve food security and nutrition, address micronutrient deficiencies, and strengthen rural economies (Aluko et al., 2023, Dimoso et al., 2021; 2024). Several researchers suggest that greater utilization of cashew apples could contribute to achieving Sustainable Development Goals (SDGs) 1, 2, and 3 alleviating poverty and hunger, and support good health and well-being. According to Akanro et al. (2022) in their Benin study, valorizing cashew apples could create more income, reduce poverty by "6% for harvesters, 3.4% for juice traders, and 135.8% for processors" and also empower farmers by strengthening their position in the value chain. From an environmental perspective, multiple studies have identified that rotting cashew apples on farms can: (1) create foul odors and attract insects, rodents, and other pests, potentially increasing disease risks in farming communities (Bhavana & Patil, 2021); (2) decompose under anaerobic conditions, releasing approximately 64% methane and 33 % carbon dioxide (Faye et al., 2024); and (3) leach nutrients and organic acids into surrounding soil and water bodies, contributing to eutrophication and altering soil pH, which can damage local ecosystems (Sial et al., 2024).

Brazil has a more established tradition of processing and consuming the cashew apple, where it is not merely seen as a by-product but is recognized for its cultural and culinary value. In 2012, it was reported that around 12% of Brazil's cashew apple production was utilized (Paiva, 2012), with usage and industrial processing scale having increased that since. Cashew apples are consumed fresh and processed into a range of food and beverage products, while the resulting by-products (such as pomace or bagasse) are further valorized−; this is discussed in detail in Section 6.3. This illustrates that while many cashew-producing countries are still struggling with the primary challenge of valorizing the whole cashew apple, Brazil represents a more mature model, now exploring the valorization of secondary by-products.

6.2.3 Cashew nutshell (CNS)

The findings of this research reveal a positive trend in the industrial-scale valorization of cashew nut shells to produce cashew nut shell liquid (CNSL), a high-value product which would otherwise have environmental impacts if it was discarded due to its toxic components or burned without proper handling. Furthermore, the de-oiled shells (cashew shell cake) are then used as fuel after extracting the oil, and this represents a more advanced form of waste valorization that aligns with CE principles.

In the region, with nearly 700,000 tons of cashew kernels processed in 2023 (BP GSO, 2024), an estimated 1.743 million tons of cashew nutshells were generated. This could yield nearly 300,000 tons of CNSL, equating to around VND 46 billion (or about USD 1.8 million [1]) in economic value (based on the yield rates and indicative prices shown in Chapter 5, Table 2).

[1] US exchange rate: US 1 = VND 26,022 (02/06/2025)

This value represents about 50% of the value of kernels obtained from the same 700 thousand tons of raw cashew nuts, creating strong incentives for processors to invest in CNSL extraction. Compared to modern extraction methods like solvent extraction or cold pressing, which yield high-quality natural CNSL and preserve anacardic acid, the primary method used in the region is hot oil extraction. This method is simple, scalable, and industrially efficient, producing technical CNSL suitable for applications in surface coatings, paints, biofuels, varnishes, polymer production, ship paints, wood treatment, lacquer, lubricants, and friction materials. Yet, it reduces the availability of CNSL for specialized pharmaceutical and biomedical applications (Vichitra et al., 2025). Furthermore, the de-oiled shells (cashew shell cake) are then used as fuel after extracting the oil, this represents a more advanced form of waste valorization that align with circular economy principles. This study also found that raw CNSL at various levels of purification (including cardanol and cardol) is exported to countries like the US, EU, Japan, Korea Republic, India and China for further processing into high-value derivatives. This suggests a gap in local processing capabilities and highlights the opportunity to move up the value chain by developing domestic industries that convert CNSL into specialized chemicals and finished products. This will enhance local value addition andhas potential to create a new, integrated sub-value chain within the cashew industry.

In contrast, India has a long-established CNSL industry with more advanced extraction technologies and well-developed downstream sectors. In 2023, India processed approximately 2 million tons of raw cashew nuts (1.2 million tons imported and 0.8 million tons domestically produced) (FAOSTAT, 2025), generating an estimated 900 thousand tons of CNSL. According to APEDA India (2025), in the fiscal year 2023–2024, India exported 3,508.18 tons of CNSL (USD 1.93 million) and 9,714.12 tons of cardanol (USD 7.36 million), with designated export destinations including China, Vietnam, Mexico, South Korea, Japan, Europe, and the USA (APEDA, 2025; India Stats, 2023). This indicates that beyond exports, a significant quantity of CNSL is used domestically for producing industrial products, allowing India to capture more economic value. Various studies highlight the wide range of CNSL applications in India including foundry chemicals, paints, laminating resins, rubber compounding resins, cashew cements, polyurethane-based polymers, surfactants, epoxy resins, friction linings, and chemical intermediates (Bhaskaran, 2017; Darkunde et al., 2022; Singaravelu et al., 2019). This reflects India’s move beyond raw extraction to the establishment of a network of chemical and manufacturing industries that utilize CNSL as a base material for high-value products. While some raw or refined CNSL is exported, a large portion is retained for domestic industries to maximize internal economic, which is further discussed in Section 6.3.

Conversely, various studies have found that CNSL valorization in African cashew-producing countries such as Côte d'Ivoire (Costa & Delgado, 2019), Kenya (Omolola, 2024), Gambia (Bojang & Emang, 2024), Tanzania (Mang'ana et al., 2024), and Mozambique (World Bank, 2022) remains underdeveloped. In Tanzania, for instance, only 5% of raw cashew nuts are processed locally, with limited value addition, including CNSL extraction. As a result, a large proportion of cashew shells are either discarded or used as low-value fuel, contributing to disposal costs and environmental challenges. Cruz et al. (2024) highlight that the open burning of CNS rich in anacardic acid releases fine particles that, when breathed in, raise the risk of cardiovascular disease, bronchitis and asthma, and that discarded CNS contributes soil acidification and fire hazards. However, studies also point to a positive shift: many African countries are beginning to reduce their reliance on raw nut exports and are developing domestic processing industries, often with support from foreign investors (World Bank, 2025). They suggest that CNSL is a central focus of this transition, which is recognized not just as waste, but as a vital source of economic value, a foundation for new industries, and a critical component in building a more circular and environmentally sustainable agricultural sector. The ultimate goal is to "close the cashew loop," foster local processing, and generate green jobs.

6.3. Circularity the cashew sector in the region

Based on the MFA results, this section discusses the circularity of the cashew sector in Binh Phuoc Province and identifies opportunities to further develop the valorization of cashew apples and CNSL in Section 6.3.1 and Section 6.3.2. It then discusses the uneven levels of circularity between these two by-products and the barriers to transition towards a more circular model in Section 6.3.3.

6.3.1 Cashew apple

Cashew apples, rather than being treated as a "by-product," are considered "waste" in Binh Phuoc Province; there are no established processing, market, or innovation pathways in the upstream segment of the value chain. This reflects an open-loop system and a classic example of the linear "take–make–dispose" model, resulting in significant food loss and missed opportunities for valorization. In contrast, the circular economy (CE) concept emphasizes recapturing, reusing, and converting resources into valuable inputs, designing out pollution, and integrating by-products into the value chain.

By contrast, Brazil has developed successful valorization pathways for cashew apples, where they are not only processed into various food and beverage products at an industrial scale but also further valorized through the use of secondary by-products (cashew bagasse/pomace). This progress is partly due to the development of cashew varieties whose apples fall to the ground without being damaged, thereby extending the logistics window and processing time before spoilage (Filgueiras et al., 1997). Furthermore, the consumption of fresh cashew apples is supported by modern techniques like modified atmosphere packaging and storage at 5°C, which can extend shelf life up to 21 days (Paiva, 2012) or processed into a wide range of products, including Cajuína (a non-alcoholic clarified juice exported to the USA, Netherlands, Portugal, and Switzerland), fruit juice blends, candy, wine, jam, and animal feed. Recently, attention in Brazil has turned to the cashew apple pomace or bagasse, the secondary by-product from juice extraction as a resource for further valorization (Da Silva et al., 2023, Oliveira et al., 2020, 2022; Sucupira et al., 2020).

Beyond Brazil, a growing body of research highlights multiple pathways for cashew apple utilization. Studies have demonstrated the potential to transform this underutilized biomass into a diverse range of products including food and beverage products (juice, nectar, wine, vinegar, spirits, jam, jelly, marmalade), biorefinery and industrial applications (animal feed, biofuel, biogas, bioethanol), and medical uses (therapeutic agents, functional foods, nutraceuticals) (Aidoo et al., 2022; Dheeraj et al., 2023; Bhavana & Patil, 2021; Da Silva et al., 2023; Mtashobya et al., 2025). These provide a roadmap for Vietnam, demonstrating the potential to create new revenue streams in the upstream segment and foster a more diversified and resilient cashew industry. Importantly, it shows that the challenge does not lie in the inherent qualities of the fruit itself, but rather in the strategic priorities and institutional framework of the Vietnamese industry. This suggests that solutions require not only advanced technologies but also new mindsets and business models to capture value from all parts of the fruit.

6.3.2 Cashew nutshell liquid (CNSL)

In terms of CNSL, the MFA results of this study indicate that extracting cashew nut shells (CNS) into CNSL transforms a waste product into a tradable commodity, introduced a degree of circularity, and moving beyond the traditional low-value practice of burning CNS for fuel.

Yet, the domestic value chain functions as only a partial closed-loop system: CNSL is extracted using simple mechanical methods in most processing plants, after which the majority of crude CNSL is exported to other countries for advanced processing, as discussed in the MFA section. This confines the by-product to a low-profitability loop, suggesting that circularity is present only at the basic extraction stage, while higher-value derivatives remain underdeveloped locally. The residual shells left after oil extraction could also be repurposed, for example as a renewable fuel source, biomass briquettes, or raw material for activated carbon, thereby improving resource efficiency and moving the system closer to full circularity.

The MFA results indicate that Vietnam's and India's CNSL industries share a similar structural dependency, as both countries rely heavily on imported raw cashew nuts to utilize their full processing capacity, generating substantial biomass in the form of CNS, which can serve as the primary feedstock for CNSL extraction. Various studies have documented that India has invested in and established advanced distillation and refining technologies to produce high-purity derivatives such as cardanol, a key ingredient in high-value industrial products thereby stimulating the development of downstream industries as discussed in Section 6.2.3 (Bhaskaran, 2017; Darkunde et al., 2022; Singaravelu et al., 2019). More recently, India has shifted its focus beyond basic mechanical and thermal extraction methods toward advanced techniques such as solvent extraction (Static Solvent Extraction, Soxhlet Extraction, Ultrasonic Extraction, Supercritical CO_2 Extraction) and pyrolysis to not only improve yield and purity but also preserve valuable bioactive compounds, such as anacardic acid, which shows promise in industrial and pharmaceutical applications (Prakash, 2020; Darkunde et al., 2022). This technological progression demonstrates a more mature, circular value chain in India, where upstream biomass utilization is closely integrated with downstream industrial development. The incorporation of CNSL into diverse sectors reflects India's strategic upgrading of its cashew by-product economy.

Brazil, with its long-standing history of cashew cultivation, is also transitioning toward a more circular bioeconomy model. Although Brazil processes a smaller share of global cashew nuts, it has focused on niche, high-value applications of CNSL, particularly in the pharmaceutical and cosmetics industries. Several studies have examined the bioactive properties of CNSL's phenolic compounds (anacardic acid, cardanol, cardol), identifying their antioxidant, anti-inflammatory, antibacterial, cytotoxic, and antiparasitic activities and indicating the long-term value of CNSL may lie in its use as a source of active ingredients for medical and cosmetic products (Soares et al., 2022). For instance, research has documented the effects of anacardic acid, cardol, and cardanol on brain tumor cells (Shilpa et al., 2015), breast cancer cells and growth inhibition (Huang et al., 2014), and pancreatic cancer cells (Park et al., 2014). While these studies remain in early research stages, they illustrate a promising trajectory for CNSL from industrial chemicals to high-value pharmaceuticals.

The contrasting cases of India and Brazil highlight two distinct strategies: India leverages its large biomass base to support both industrial and emerging pharmaceutical applications, whereas Brazil, with a smaller raw material supply, focuses on niche, high-end markets such as anti-cancer treatments and bioactive cosmetics. In comparison, Vietnam remains positioned as a supplier of raw and crude materials, with limited downstream valorization. This underscores a strategic gap and an opportunity for Vietnam to upgrade its CNSL value chain by adopting advanced extraction technologies and exploring high-value applications in industrial and pharmaceutical domains.

6.3.3 Uneven circularity and the barriers in transition toward CE in the cashew sector

The above discussion indicates the cashew value chain in Binh Phuoc Province adopts a partly circular economy (CE) model, with no circularity in cashew apples and only partial circularity in cashew nut shells. This coexistence of two scenarios in CE implementation within the Vietnamese cashew value chain indicates the incremental nature of CE implementation, where multiple interpretations and practical approaches lead to opportunistic, step-by-step adoption in areas that make the most economic sense. The partial circularity of CNSL reflects the incremental adoption of simple, low-risk circular strategies due to resource constraints (human, capital, technology). Kirchherr et al. (2017, 2023) emphasize that CE should be comprehensively and systematically implemented at the macro (nation, region), meso (industrial parks), and micro (consumers, products, companies) levels to enable sustainable development, yet, in practice it is often implemented through incremental shifts within existing systems as shown in this study.

The findings of this study also indicate that the non-circularity of cashew apples is linked to their classification as food waste or low-value byproducts, along with their perishability, seasonal availability, dispersed production across farms, and lack of farmer, processor and consumer's awareness. By contrast, the partial circularity of CNSL emerges because cashew shells are produced in large volumes at centralized processing facilities in the region, and there is significant industrial capacity. The processing into CNSL is also supported by its high industrial value, long shelf life, and ease of storage and transport. The distinction between dispersed production waste and concentrated industrial waste is also evident in other agricultural value chains, even in developed countries such as those for wine, citrus, and apple juice. In these sectors, large-scale processing generates massive amounts of biomass waste that can be valorized through multiple pathways. For instance, in the wine value chains of France, Italy, and Portugal, grape marc is processed into polyphenols, dietary fiber, and antioxidants via chemical treatment; bioenergy and biochar via thermal treatment; and composts and biofuels via biological treatment (Agraso-Otero et al., 2025; Provenzano et al., 2024; Rivera et al., 2007; Demiral & Ayan, 2011; Corbin et al., 2015). Other vineyard residues, such as grape stalks and pruning, are often managed in a decentralized way by individual farmers. This highlights that when byproducts are generated at large, centralized processing plants, it is logistically easier to manage and valorize them into high-value products using mature and widely adopted technologies. By contrast, agricultural byproducts are usually generated at dispersed, small-scale farms, making collection costly and difficult, with limited available technology, capital and expertise, weak policy and institutional support. This hinders the utilization of byproducts and integration of these processing routes in the downstream domestic value chain – as can be seen in the case of cashew by-products in Vietnam.

Humberto et al. (2025) outline five main barriers to CE in agri-food value chains, all of which are evident in Vietnam's cashew sector: (1) high initial and transition costs limit small-scale farmers and processors from investing in modern technologies; (2) operational knowledge and information gap; (3) technical knowledge gaps, particularly in processing cashew apples and advancing CNSL derivatives; (4) resistance to change is reinforced by cultural and market perceptions of cashew apples as 'waste', (5) weak coordination and the absence of clear policies on by-product utilization reflect institutional barriers. Interpreted through a value chain lens, it is suggested that the barriers for the cashew industry in Vietnam are mainly rooted in a lack of coordination in both horizontal (among smallholder farmers and processors) and vertical (between farmers, processors and government agencies) directions in the value chain. These barriers have impeded the development of downstream uses for cashew by-products like apples and CNSL, limiting Vietnam's ability to move beyond raw material exports toward a more circular and value-added cashew economy.

Chapter 7. Conclusion

This chapter summarizes the key results of the studies (Section 7.1), recommendations for key cashew stakeholders (Section 7.2), implications of this study (Section 7.3), limitations of this study (Section 7.4), and provides suggestions for future research related to this topic (Section 7.5).

7.1. Summary of key results

The result of this study indicates there is only one processed cashew value chain with different levels of processing that produces two types of products: 90% white cashew kernels and 10% highly processed cashew such as roasted and flavored cashew (Section 6.1). Although all these cashew products are processed domestically, local production accounts for only 10%, while the remaining 90% of raw cashews are imported to fully utilize the processing capacity. The study also found that the cashew value chain in Binh Phuoc Province has a multi-layered structure with a variety of VC players including agricultural input suppliers, smallholder farmers, traders, collectors, processors, and export brokers. Domestic distribution occurs through three channels: general trade (GT), modern trade (MT), and e-commerce. The findings also suggest that there is very weak horizontal coordination between players in the region. With regard to vertical coordination, governance is characterized as informal market-based in the upstream segment, and more formal and contractual relationships in the midstream and downstream segments. The information flows among players are asymmetric with decision-making power concentrated in processors, limiting the smallholders' ability to upgrade their position within the value chain.

In terms of material flows, the cashew kernel is the main commercial product in the cashew value chain. The findings of this study suggest that there is very low conversion yield of cashew fruit to cashew kernel (2% by mass), and the main by-products are cashew apple and cashew nutshell. Cashew apple, which makes up nearly 90% of the fruit, is currently underutilized and usually left to rot on farms. Cashew nut shells, which represent around 5% of the whole fruit, are fully utilized for CNSL extraction, representing a small sub-value chain within the broader cashew sector.

These indicate a situation of partial circularity in the cashew industry. The cashew apple is not generally utilized, and cashew nutshell processing is limited to crude extraction with processing into higher value derivatives remaining underdeveloped locally whilst the CNSL is exported to other countries for advanced processing. This uneven circularity in the cashew sector illustrates the incremental and opportunistic nature of CE implementation with step-by-step adoption based on immediate economic returns.

7.2. Recommendations from the study

The findings of this study highlight the weak coordination between players, heavy reliance on imported raw materials, and limited or no value addition to cashew processing by-products. The recommendations based on this research are therefore strengthening value chain governance and coordination. The latter requires vertical coordination (improved linkages between farmers, processors, and exporters) and horizontal coordination (cooperation among farmers, cooperatives, and/or SME processors). Additionally, financial, regulatory, and institutional measures from government are needed to foster a more resilient, equitable and transition into close-loop circular cashew sector in Binh Phuoc.

Recommendations for government or policymakers

The findings of this study indicate the uneven circularity in the cashew sector is due to incremental development driven by immediate economic opportunities. To achieve a comprehensive systematic transformation towards a full circular model, governments should integrate cashew by-product valorization into regional Green Growth Strategies and Agricultural Restructuring Plans. This requires not only investing in in-depth and scalable research on cashew by-products and but also creating platforms that foster public–private partnerships, where researchers can present innovations and businesses can identify potential collaborators. Furthermore, the underutilization of cashew apples is closely linked to low public awareness of their nutritional value and economic potential. Governments can address this gap by promoting education and awareness at both local and national levels, helping to shift perceptions about cashew apples from waste to valuable co-products and thereby stimulating demand for both raw and processed forms, which in turn creates stronger incentives for valorization.

Since the raw cashews that are processed in the region are nearly 90% imported, increasing the proportion of domestic supply is crucial to reduce the vulnerability of the sector to international disruption. Government should foster domestic cultivation by funding research into high-yield, high-quality cashew varieties and offering subsidies or credit guarantees for replanting old, unproductive orchards.

The findings from this study indicate there is very weak horizontal and vertical coordination in the cashew sector. This means that smallholder cashew farmers and processors work independently and therefore have limited bargaining power (farmers with traders/processors, and processors with brokers and international buyers). Thus, government should introduce incentive structures and supportive frameworks to facilitate both horizontal and vertical coordination to improve market access, ensure fairer prices, and allow farmers and processors to pool resources for investment in advanced production and processing technologies. For example, financial incentives like tax breaks, grants, and low-interest loans should be offered in order to lower the financial risks and burdens for farmers adopting sustainable practices and processors investing in innovative technologies.

Recommendations for cashew nut processors

The findings of this study highlight that cashew nut processors are the chain captains but mainly focus on kernel extraction, overlooking strategic opportunities for increasing supply chain security and value creation through both highly processed cashew nut products and byproducts (cashew apples and cashew nutshell). To reduce import risks and ensure a stable supply of high-quality local raw cashew nuts, processors should adopt strategic sourcing and integration through contractual relationship with domestic farmer cooperatives, provide them technical support and premium prices to incentivize quality improvement. This approach will strengthen supply chain security and can provide a marketing advantage ("Made from Vietnamese cashews").

Instead of the current practice of exporting – nearly 90% of the white cashew kernels, processors should collaborate horizontally to invest in technology, R&D, and marketing to create added value products. The aim should be to shift from being bulk B2B suppliers to developing own-brand cashew nut for domestic consumption and niche export markets to capture greater market value.

Recommendations for cashew apple processors

The current underutilization of cashew apple underscores that cashew farmer cooperatives and cashew nut processors could potentially become processors of cashew apple by leveraging their position in the value chain. Farmer cooperatives, being the central point for collecting raw cashew nuts from cashew fruits, are in the best position to capture the value of cashew apples at the source. These cooperatives could partner with research institutions to train members on proper harvesting, post-harvest handling, food safety, and processing techniques. They could then establish small-scale processing units, and invest in simple, cost-effective processing equipment to develop a local brand for their cashew apple products or process stable intermediate products for sale to processors or other food companies. This approach would not only generate additional income for members but also position cooperatives as strategic partners for processors seeking traceable and sustainable sourcing practices.

Alternatively, cashew nut processors, as the primary buyers and processors of nuts, could further scale up by-product utilization and integrate it into their existing operations by leveraging existing infrastructure, labor, and energy sources, thereby reducing initial investment costs. To guarantee a consistent supply of cashew apples, they should work closely with farmer cooperatives, offer a fair price for the apples in addition to the nuts and provide logistical support for rapid collection and transport to processing facilities.

Recommendations for CNSL processors

Instead of simply extracting and exporting crude CNSL, processors should collaborate horizontally to pool resources to invest in advanced technologies for extraction, refining, and high-value derivatives' production as highlighted in the circularity discussion (Section 6.3). They should also partner with research institutions to develop new applications for CNSL, thereby enabling the sector to capture a larger share of the value from this versatile industrial material.

Recommendations for farmers

The findings of this study indicate that there are very few cooperatives or farmer producer organizations (FPOs) in the region, and smallholders contribute only 10% of the raw input supply for the region’s total processing. The smallholders therefore have weak bargaining power, and in addition are disadvantaged due to information asymmetry and limited resources (human, financial, and technological) to upgrade their cultivation techniques and to capture value from cashew apples. It is recommended to establish cooperatives or FPOs to enable farmers to access credit, facilitate bulk purchasing of agricultural inputs, and adopt modern farming practices to increase both yield and quality of raw cashew nuts. This will improve their competitiveness against imported cashews and enable them to negotiate better prices with processors.

Farmers should also change their mindset from viewing the cashew apple as waste to viewing it as a second harvest product. As a group, cooperatives could make the valorization of this by-product both viable and effective.

7.3. Implications of the study

The study highlights the importance of combining VCA, MFA and CE frameworks to understand value creation and resource efficiency in agri-food chains. By analyzing by-products alongside the main product, it reveals hidden inefficiencies and uneven circularity that would be missed in a kernel-only value chain study.

The findings highlight how weak governance and lack of coordination hinder upgrading opportunities, including improved resource valorization. This underscores the need for multi-stakeholder partnerships and technology investment in processing of added value products.

The study also emphasizes the need for policy frameworks that not only support kernel exports but also enable systematic valorization of cashew by-products, with the government playing a crucial role in scaling CE adoption.

7.4. Limitations of the study

The research was conducted in Binh Phuoc province, Vietnamese largest cashew-producing and processing region. Given the province's size (11 districts and 111 communes) and the constraints of the study's time and research capacity, interviews were concentrated in the top four districts with the highest cashew production and processing. Thus, the findings may not be generalizable to the entire province as experiences and challenges of farmers in the largest, most productive communes/districts may differ from those in smaller, less developed areas. Besides, cashew cultivation and processing practices vary across Vietnam, meaning that results from Binh Phuoc may not be representative of other regions. Furthermore, information and economic indicators in this study were collected based on interviewees' experiences and perspectives, which may introduce selection bias.

Cashew varieties in the region differ in their nut-to-fruit ratio. As the MFA data was collected on selected farms in Binh Phuoc Province, this may not capture the full diversity of varieties and cultivation patterns, which could affect the calculated ratio between cashew apples and nuts.

After the fieldwork was completed, an administrative change occurred in Binh Phuoc, resulting in a merger with Dong Nai province. The latter is known for its industrial clusters, and this merger may therefore change the structural dynamics of the cashew sector, affecting supply chains, market access, and regional competitiveness.

7.5. Future research recommendations

This study is among the first to apply an integrated framework combining VCA, MFA, and CE principles, providing a holistic understanding not only of the structure of the cashew nut value chain but also how materials flow from cultivation to processing to final products. As the research employed qualitative methods, there is a need for quantitative studies to complement the findings presented here. Future studies could apply life cycle assessment (LCA) to measure the environmental impacts of the cashew life cycle from cultivation through processing and to distribution, cost–benefit analysis to evaluate the economic viability of by-product valorization, and more detailed MFA to quantify the variability in flows associated with different production, processing, and distribution activities. Such approaches would provide more precise estimates of environmental, social, and economic benefits, thereby strengthening the evidence base for policy and investment decisions.

References

Abualtaher, M., & Bar, E. S. (2019). Review of applying material flow analysis-based studies for a sustainable Norwegian Salmon aquaculture industry. *Journal of Applied Aquaculture*, *32*(1), 1–15. https://doi.org/10.1080/10454438.2019.1670769

Agraso-Otero, A., Tehseen, A., Rebolledo-Leiva, R., & González-García, S. (2025). Turning wine waste into value: A techno-economic and environmental study of phenolics, syngas and biochar production. *Industrial Crops and Products*, *232*, 121290.

Agyemang, M., Jia, F., Faibil, D., & Lin, Z. (2021). Mapping the environmental aspect of kernel product system in complex supply chains of the West Africa cashew industry. *Environmental Science and Pollution Research*, *28*(18), 22536-22550.

Ahmed, S. K., Mohammed, R. A., Nashwan, A. J., Ibrahim, R. H., Abdalla, A. Q., Ameen, B. M. M., & Khdhir, R. M. (2025). Using thematic analysis in qualitative research. *Journal of Medicine, Surgery, and Public Health*, *6*, 100198.

Aidoo, R., Kwofie, E. M., & Ngadi, M. O. (2022). Circularity of cashew apples: examining the product-process pathways, techno-functional, nutritional/Phytomolecular qualities for food applications. *ACS Food Science & Technology*, *2*(7), 1051-1066.

Akyereko, Y. G., Yeboah, G. B., Wireko-Manu, F. D., Alemawor, F., Mills-Robertson, F. C., & Odoom, W. (2023). Nutritional value and health benefits of cashew apple. *JSFA reports*, *3*(3), 110-118.

Alhawari, O.; Awan, U.; Bhutta, M.K.S.; Ali Ülkü, M. Insights from circular economy literature: A review of extant definitions and unravelling paths to future research. *Sustainability* **2021**, *13*, 859.

Allesch, A., & Brunner, P. H. (2017). Material flow analysis as a tool to improve waste management systems: the case of Austria. *Environmental science & technology*, *51*(1), 540-551.

Aluko, A., Kassim, N., & Makule, E. (2023). Underutilized cashew apple fruit: its utility and development as a source of nutrients and value added products in Tanzania.

Amicarelli, V., Bux, C., & Lagioia, G. (2020). How to measure food loss and waste? A material flow analysis application. *British Food Journal*, *123*(1), 67-85.

Amicarelli, V., Fiore, M., & Bux, C. (2021). Hidden flows assessment in the agri-food sector: Evidence from the Italian beef system. *British Food Journal*, *123*(13), 384-403.

APEDA, 2025, (Agricultural and Processed Food Products Export Development Authority) https://apeda.gov.in/cashew (access 04/08/2025)

Baccini, P., & Brunner, P. H. (1991). *Metabolism of the Anthroposphere*. Springer-Verlag.

Barrett, C. B., Reardon, T., Swinnen, J., & Zilberman, D. (2022). Agri-food value chain revolutions in low-and middle-income countries. *Journal of Economic Literature*, *60*(4), 1316-1377.

Barrett, C., Reardon, T., Swinnen, J., & Zilberman, D. (2019). Structural transformation and economic development: insights from the agri-food value chain revolution. *Cornell University*, 1-56.

Bassett, T. J., Koné, M., & Pavlovic, N. R. (2018). Power Relations and Upgrading in the Cashew Value Chain of Côte d'Ivoire. *Development and Change, 49*(5), 1223-1247.

Batista, L., Bourlakis, M., Smart, P., & Maull, R. (2018). In search of a circular supply chain archetype–a content-analysis-based literature review. *Production Planning & Control*, *29*(6), 438-451.

Beretta, C., Stoessel, F., Baier, U., & Hellweg, S. (2013). Quantifying food losses and the potential for reduction in Switzerland. *Waste management*, *33*(3), 764-773.

Bernard, T. & Giraud Héraud, E. 2024. Agrifood value chains in low-income countries – Accounting for market structure to inform policies. FAO Agricultural Development Economics Working Paper 24-03. Rome, FAO. https://doi.org/10.4060/cd0903en

Bhaskaran, E. Study of CNSL Processing Plants Located in Cuddalore District of Tamil Nadu, India. *J. Inst. Eng. India Ser. A* **98**, 115–120 (2017). https://doi.org/10.1007/s40030-017-0191-5

Bhaskaran, E. Study of CNSL Processing Plants Located in Cuddalore District of Tamil Nadu, India. (2017). *J. Inst. Eng. India Ser. A* **98**, 115–120. https://doi.org/10.1007/s40030-017-0191-5

Bhavana, A., and A. R. Patil. (2021). "Cashew apple processing and value addition: A review." *The Pharma Innovation Journal* 10, no. 8: 181-183.

Bijman, J., Iliopoulos, C., Poppe, K.J., Gijselinckx, C., Hagedorn, K., Hanisch, M., Hendrikse, G.W.J., Kühl,R., Ollila, P., Pyykkönen, P. and van der Sangen, G. (2012) Support for farmers' cooperatives, Brussels,European Commission, final report, p. 127. https://ec.europa.eu/info/food-farming-fisheries/key-policies/common-agricultural-policy/cmef/farmers-and-farming/ep-pilot-project-support-farmers-cooperatives_en.

Bingham, A. J. (2023). From data management to actionable findings: A five-phase process of qualitative data analysis. *International journal of qualitative methods*, *22*, 16094069231183620.

Binh Phuoc DARD, 2021, https://binhphuoc.gov.vn/vi/news/hoat-dong-huyen-thi-xa-thanh-pho/nguon-goc-dien-tich-san-luong-va-nang-suat-dieu-binh-phuoc-24130.html

Bocken, N., Miller, K., & Evans, S. (2016). Assessing the environmental impact of new Circular business models. *Proceedings of the "New Business Models"—Exploring a changing view on organizing value creation, Toulouse, France*, *1*, 16-17.

Bojang, B., & Emang, D. (2024). Can Cashew Value Chain Industry Improve Food Security: An Empirical Study from The Gambia. *Sustainability*, *16*(15), 6607.

Bonanno, A., & Çakır, M. (2022). The supplier–retailer relationship in contemporary food markets. *A Modern Guide to Food Economics*, 23-46.

BP GSO, (2024). Binh Phuoc Statistical yearbook 2023, https://www.niengiamthongke.net/home/ngtk-2023/nien-giam-thong-ke-binh-phuoc-2023

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative research in psychology*, *3*(2), 77-101.

Braun, V., & Clarke, V. (2019). Reflecting on reflexive thematic analysis. *Qualitative research in sport, exercise and health*, *11*(4), 589-597.

Brunner, P.H., Rechberger, H., 2017. *Handbook of material flow analysis. In For Environmental, Resource and Waste Engineers*, 2nd ed. CRC Press, Taylor & Francis Group, LLC, Boca Raton, London, New York.

Candemir, A., Duvaleix, S., & Latruffe, L. (2021). Agricultural cooperatives and farm sustainability–A literature review. *Journal of Economic Surveys*, *35*(4), 1118-1144.

Chertow, M. R., & Lombardi, D. R. (2005). Quantifying economic and environmental benefits of co-located firms.

Cherubin, M. R., Carvalho, J. L. N., Cerri, C. E. P., Nogueira, L. A. H., Souza, G. M., & Cantarella, H. (2021). Land use and management effects on sustainable sugarcane-derived bioenergy. *Land*, *10*(1), 72.

Circular Economy. (2020). The circularity gap report 2020. *Amsterdam: Circle Economy*.

Clark, J. K., Jablonski, B. B., Inwood, S., Irish, A., & Freedgood, J. (2021). A contemporary concept of the value (s)-added food and agriculture sector and rural development. *Community Development*, *52*(2), 186-204.

Colombo, B., Boffelli, A., Gaiardelli, P., Kalchschmidt, M., Madonna, A., & Sangalli, T. (2022, September). A multiple case study on collaboration for a circular economy: a focus on the Italian textile supply chain. In *IFIP International Conference on Advances in Production Management Systems* (pp. 408-415). Cham: Springer Nature Switzerland.

Costa, C., & Delgado, C. (2019). The cashew value chain in Mozambique. https://documents1.worldbank.org/curated/en/397581559633461087/pdf/The-Cashew-Value-Chain-in-Mozambique.pdf

Cruz, T., Maranon, A., Hernandez, C., Alvarez, O., Ayala-García, C., & Porras, A. (2024). Exploring the potential of cashew nutshells: A critical review of alternative applications. *BioResources*, *19*(3), 6768.

Cucagna, M. E., & Goldsmith, P. D. (2018). Value adding in the agri-food value chain. *International food and agribusiness management review*, *21*(3), 293-316.

Da Silva, J., De Brito, E. S., & Ferreira, S. R. S. (2023). Biorefinery of cashew by-products: Recovery of value-added compounds. *Food and Bioprocess Technology*, *16*(5), 944-960.

Dao, T. P., Vu, D. N., Nguyen, D. V., Pham, V. T., & Tran, T. Y. N. (2022). Study of jelly drying cashew apples (Anacardium occidentale L.) processing. *Food Science & Nutrition*, *10*(2), 363-373.

Darkunde, A., Kolhe, S., Somvanshi, S., & Nibe, R. L. (2022). Applications and Extraction of Cashew Nut Shell Liquid from Cashew Nut Shell. *International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)*, *2*, 226-236.

de Janvry, A., Sadoulet, E., & Trachtman, C. (2019). Achieving coordination in agricultural value chains: The role of lead agents and multi-stakeholder platforms.

De Keyser, E., & Mathijs, E. (2023). A typology of sustainable circular business models with applications in the bioeconomy. *Frontiers in Sustainable Food Systems*, *6*, 1028877.

de Vries, J. R., Turner, J. A., Finlay-Smits, S., Ryan, A., and Klerkx, L. (2022). Trust in agri-food value chains: a systematic review. *Int. Food Agribusiness Manag. Rev. in press* 26, 175–197. doi: 10.22434/ifamr2022.0032

Deconinck, K. (2021-02-17), "Concentration and market power in the food chain", OECD Food, Agriculture and Fisheries Papers, No. 151, OECD Publishing, Paris. http://dx.doi.org/10.1787/3151e4ca-en

Dheeraj, Srivastava, A., & Mishra, A. (2023). Mitigation of cashew apple fruits astringency. *Environmental Sustainability*, *6*(3), 319-329.

Dimoso, N., Aluko, A., Makule, E., & Kassim, N. (2021). Challenges and opportunities toward sustainable consumption and value addition of cashew apples in Tanzania. *Outlook on Agriculture*, *50*(2), 169-177.

Dimoso, N., Kassim, N., & Makule, E. (2024). Cashew apple in Tanzania: status of utilization, challenges, and opportunities for sustainable development. *F1000Research*, *11*, 1354.

Dokter, G., Mallalieu, A., Hallstedt, S. I., & Isaksson, O. (2025). Collaboration towards the design of sustainable and circular value chains: Reviewing the state-of-the-art in literature and practice. *Proceedings of the 6th Product Lifetimes and the Environment Conference (PLATE2025)*, (6). https://doi.org/10.54337/plate2025-10294

EMF (2013). Ellen MacArthur Foundation. *Towards the circular economy: Economic and business rationale for an accelerated transition.* https://content.ellenmacarthurfoundation.org/m/27265af68f11ef30/original/Towards-the-circular-economy-Vol-1.pdf

EMF (2021). Ellen MacArthur Foundation, Universal Circular Economy Policy Goals (2021), https://content.ellenmacarthurfoundation.org/m/99036b9257aee53/original/Universal-circular-economy-policy-goals.pdf

Esteban-Amaro, R., Estelles-Miguel, S., Lengua, I., Yannou, B., & Bouillass, G. (2024). Assessing circularity and sustainability of a value chain: A systematic literature review. *Business Strategy and the Environment*.

ETIN (2018). Ethical Trading Initiative Norway. Strengthening practices in the Vietnamese cashew nuts business. https://www.sustainablenutinitiative.com/wp-content/uploads/2019/09/IEH_kartleggingsstudie_Vietnam_web.pdf

FAO, (2019), https://www.fao.org/interactive/state-of-food-agriculture/2019/en

FAOSTAT (2025). https://www.fao.org/faostat/en/#data/TCL (access 04/08/2025)

Faye, O. K., Himbane, P. B., Diedhiou, A., & Ndiaye, L. G. (2024). Characterization of the anaerobic digestion of cashew apple pulp from of the casamance. *African Journal of Environmental Science and Technology*, *18*(4), 92-100.

Fearne, A., Garcia Martinez, M., & Dent, B. (2012). Dimensions of sustainable value chains: implications for value chain analysis. *Supply Chain Management: An International Journal*, *17*(6), 575-581.

Fernando, S., Garnevska, E., Thiagarajah, R. and Shadbolt, N. (2025). Cooperatives' level of vertical integration and farm financial performance amongst smallholder farmer-members. *Annals of Public and Cooperative Economics*. 96(1). 149-170.

Filgueiras, H. A. C., Alves, R. E., Mosca, J. L., & Menezes, J. B. (1997, August). Cashew apple for fresh consumption: research on harvest and postharvest technology in Brazil. In *International Symposium Effect of Pre-& Postharvest factors in Fruit Storage 485* (pp. 155-160).

Frederick, S. (2019). Global value chain mapping. In *Handbook on global value chains* (pp. 29-53). Edward Elgar Publishing.

Garnevska E., Liu G. and Shadbolt N., 2011. Factors for successful development of farmer cooperatives in northwest China. *International Food and Agribusiness Management Review*. 14(4), 69-84.

Garnevska, E., Callagher, L., Apparao, MD., Shadbolt, N. and Siedlok, F. (2017) The New Zealand Co-operative Economy Massey University, Palmerston North, New Zealand NZ COOP, New Zealand- Key Figures National Report https://coops4dev.coop/sites/default/files/2021-01/New%20Zealand%20Key%20Figures%20National%20Report.pdf

Garnevska, E., Hidayati, D.R, and McLaren, S. (2026). Circularity in Agri-food Value Chains in Developing Countries: Case in Indonesia. *Sustainability.* 18(2), 708.

Geissdoerfer, M., Savaget, P., Bocken, N. M. P., & Hultink, E. J. (2017). The circular economy – A new sustainability paradigm? *Journal of Cleaner Production*, 143, 757–768.

Gereffi, G. J. Humphrey, R. Kaplinsky and T.J. Sturgeon. 2001. Value chains and development. IDS Bulletin 32: 3.

Gereffi, G., J. Humphrey and T. Sturgeon. 2005. The governance of global value chains. *Review of International Political Economy 12(1)*: 78-104.

Ghani, L. A., Mahmood, N. Z., & Ali, N. A. (2017, July). Coupling material flow analysis (MFA) and geographic information system (GIS) methodologies for screening flow and emission of biomass energy in the agricultural system. In *Proceedings of the International Conference on Imaging, Signal Processing and Communication* (pp. 180-185).

Graedel, T. E. (2019). Material flow analysis from origin to evolution. *Environmental science & technology*, *53*(21), 12188-12196.

Groenewald, E. S., Jaramillo, M., Garg, A., & Pipalia, K. (2024). Circular economy strategies in supply chain management: towards zero waste. *Power System Technology*, *48*(1), 464-480.

Grohmann, P., Dietze, V., Krämer, C., & Feindt, P. H. (2023). Governance and trust in sustainability-based agri-food value chains. A comparative analysis of five cases in Germany. *Frontiers in Sustainable Food Systems*, *7*, 1130895.

GSO, (2024). General Statistics Office of Viet Nam

Guimarães, A. F., Malanski, P. D., Schiavi, S. M. D. A., & Bouroullec, M. D. M. (2022). Governance in agrifood global value chain: the scientific field in the recent 15 years. *Revista de Economia e Sociologia Rural*, *61*, e260595.

Hansen, H. O. (2024). Megatrends in Agriculture, Food Industry and Food Markets: An Empirical and Holistic Approach.

Havinga, T., Casey, D., & van Waarden, F. (2015). Changing regulatory arrangements in food governance. In *The Changing Landscape of Food Governance* (pp. 3-18). Edward Elgar Publishing.

Hendrickson, M. K., James, H. S., & Heffernan, W. (2019). Vertical integration and concentration in US agriculture. In *Encyclopedia of food and agricultural ethics* (pp. 2435-2444). Springer, Dordrecht.

Hidayati, D. R., Garnevska, E., & Childerhouse, P. (2021). Agrifood value chain assessment in developing countries: a case of Indonesia's cashew sector. In *E3S Web of Conferences* (Vol. 306, p. 02045). EDP Sciences.

Hidayati, D. R., Garnevska, E., & Childerhouse, P. (2023). Enabling sustainable agrifood value chain transformation in developing countries. *Journal of Cleaner Production*, *395*, 136300.

Hintz, K. S., Mombo, F., Auch, E., Pretzsch, J., & Giessen, L. (2025). Combining established methods for value chain and power analyses: Towards a comprehensive next-generation understanding of value chain governance. *MethodsX*, 103637.

Hlatshwayo, S. I., Ngidi, M., Ojo, T., Modi, A. T., Mabhaudhi, T., & Slotow, R. (2021). A typology of the level of market participation among smallholder farmers in South Africa: Limpopo and Mpumalanga Provinces. *Sustainability*, *13*(14), 7699.

Hofstetter, J. S., De Marchi, V., Sarkis, J., Govindan, K., Klassen, R., Ometto, A. R., Spraul, K. S., Bocken, N., Ashton, W. S., Sharma, S., Jaeger-Erben, M., Jensen, C., Dewick, P., Schröder, P., Sinkovics, N., Ibrahim, S. E., Fiske, L., Goerzen, A., & Vazquez-Brust, D. (2021). From Sustainable Global Value Chains to Circular Economy—Different Silos, Different Perspectives, but Many Opportunities to Build Bridges. Circular Economy and Sustainability, 1(1), 21–47. https://doi.org/10.1007/s43615-021-00015-2

Hogeboom, R. J., Kamphuis, I., & Hoekstra, A. Y. (2018). Water sustainability of investors: Development and application of an assessment framework. *Journal of Cleaner Production*, *202*, 642-648.

Houssard, C., Revéret, J. P., Maxime, D., Pouliot, Y., & Margni, M. (2022). Measuring shared value creation with eco-efficiency: Development of a multidimensional value framework for the dairy industry. *Journal of Cleaner Production*, *374*, 133840.

Huang H, Hua X, Liu N, Li X, Liu S, Chen X, Zhao C, Lan X, Yang C, Dou QP, Liu J. (2014). Anacardic acid induces cell apoptosis associated with induction of ATF4-dependent endoplasmic reticulum stress. Toxicol Lett 228(3):170–178. https://doi.org/10.1016/j.toxlet.2014.05.012

Humberto, J. S., Briceño, C. E. B., Zanon, L. G., & Nagano, M. S. (2025). Exploring the Barriers to Circular Economy Implementation in Agricultural Sector: A Way Forward to Achieve Sustainable Development Goal 2 (Zero Hunger). *Circular Economy and Sustainability*, 1-39.

Humphrey, J. and O. Memedovic. 2006. Global value chains in the agrifood sector (working paper). Available at: http://tinyurl.com/y8qh4obd.

Huybrechts, D., Derden, A., Van den Abeele, L., Vander Aa, S., & Smets, T. (2018). Best available techniques and the value chain perspective. *Journal of Cleaner Production*, *174*, 847-856.

Ibáñez-Forés, V., Alejandrino, C., Bovea, M. D., & Mercante, I. (2023). Prioritising organisational circular economy strategies by applying the partial order set theory: Tool and case study. *Journal of Cleaner Production*, *406*, 136727.

INC, 2024; International Nuts and Dried Fruit Council; Statistical Yearbook 2022 – 2023

INDIA STAT, 2021, https://www.data.gov.in/resource/country-wise-export-cashew-nut-shell-liquid-cardanol-india-2017-18-2021-22

Ingram, V., van Den Berg, J., Van Oorschot, M., Arets, E., & Judge, L. (2018). Governance options to enhance ecosystem services in cocoa, soy, tropical timber and palm oil value chains. *Environmental management*, *62*(1), 128-142.

Jacobi, N., Haas, W., Wiedenhofer, D., Mayer, A. (2018). Providing an economy-wide monitoring framework for the circular economy in Austria: status quo and challenges. Resour. Conserv. Recycl. 137, 156e166.

Jurgilevich, A., Birge, T., Kentala-Lehtonen, J., Korhonen-Kurki, K., Pietikäinen, J., Saikku, L., & Schösler, H. (2016). Transition towards circular economy in the food system. *Sustainability*, 8(1), 69.

Kalmykova, Y.; Sadagopan, M.; Rosado, L. (2018). Circular economy—From review of theories and practices to development of implementation tools. *Resour. Conserv. Recycl. 135*, 190–201.

Kaplisky, R. and M. Morris. 2002. A handbook for value chain research. Institute of Development Studies, Brighton, UK.

Kapoor, R.; Ghosh, P.; Kumar, M.; Sengupta, S.; Gupta, A.; Kumar, S.S.; Vijay, V.; Kumar, V.; Kumar Vijay, V.; Pant, D. (2020). Valorization of Agricultural Waste for Biogas Based Circular Economy in India: A Research Outlook. Bioresour. Technol. 304, 123036. https://doi.org/10.1016/j.biortech.2020.123036.

Khir, R., & Pan, Z. (2019). Walnuts. Integrated processing technologies for food and agricultural by-products, 391-411.

Khlifa, R., Yiougo, S. A. L., & Journeault, M. (2024). Methodology for material flow analysis at the organizational scale. *Journal of Cleaner Production*, *473*, 143564.

Khong, T. D. (2022). Vertical and Horizontal Coordination in Developing Countries' Agriculture: Evidence from Vietnam and Implications. *Asian Journal of Agriculture and Rural Development*, *12*(1), 40-52.

Kirchherr, J., Reike, D., & Hekkert, M. (2017). Conceptualizing the circular economy: An analysis of 114 definitions. *Resources, Conservation and Recycling*, 127, 221–232.

Kirchherr, J., Yang, N. H. N., Schulze-Spüntrup, F., Heerink, M. J., & Hartley, K. (2023). Conceptualizing the circular economy (revisited): an analysis of 221 definitions. *Resources, conservation and recycling*, *194*, 107001.

Klein, O., Nier, S. & Tamásy, C. (2022). Circular agri-food economies: business models and practices in the potato industry. *Sustain Sci 17*, 2237–2252 https://doi.org/10.1007/s11625-022-01106-1

Lacivita V., Derossi A., Caporizzi R., Lamacchia C., Speranza B., Guerrieri A., Racioppo A., Corbo M.R., Sinigaglia M., Severini C. 2024; Discover hidden value of almond by-products: Nutritional, sensory, technological and microbiological aspects. *Future Foods*. 10:100398. doi: 10.1016/j.fufo.2024.100398.

Lee, G., Suzuki, A., & Kim, Y. R. (2021). The Role of Agricultural Market Information on Farmers' Agricultural Outcomes: Evidence from Smallholder Coffee Producers in Ethiopia (No. HIAS-E-110).

Leray, L., Sahakian, M., & Erkman, S. (2016). Understanding household food metabolism: Relating micro-level material flow analysis to consumption practices. *Journal of Cleaner Production*, *125*, 44-55.

Lombardi, M., Costantino, M., 2020. A social innovation model for reducing food waste: the case study of an Italian non-profit organization,. *Adm. Sci.* 10, 45.

Lombardi, M., Rana, R., Fellner, J., 2021. Material flow analysis and sustainability of the Italian plastic packaging management. *J. Clean. Prod*. 287, 125573.

Mac Clay, P., & Feeney, R. (2019). Analyzing agribusiness value chains: a literature review. *Journal of Agribusiness Studies*, 22(1), 31-46.

Mang'ana K, Ngaiza R and Paul M. Unlocking the potential of Tanzania's cashew processing industry: A comparative analysis with Côte d'Ivoire and Mozambique . *F1000Research* 2024, 13:108 (https://doi.org/10.12688/f1000research.143364.1)

Maryono, M., Killoes, A. M., Adhikari, R., & Aziz, A. A. (2024). Agriculture development through multi-stakeholder partnerships in developing countries: A systematic literature review. *Agricultural Systems*, *213*, 103792.

Mehmood, A.; Ahmed, S.; Viza, E.; Bogush, A. (2021). Drivers and Barriers towards Circular Economy in Agri-food Supply Chain A Review. Bus. Strategy Dev. 4, 465–481.

MIC (2024). Ministry of Information and Communications, retrived from https://www.vietnam.vn/en/nam-2023-xuat-khau-dieu-chinh-thuc-thu-ve-364-ty-usd/

Miller, M. (2021). Big data, information asymmetry, and food supply chain management for resilience. *Journal of Agriculture, Food Systems, and Community Development*, *11*(1), 171-182.

Miranda, B. V., Monteiro, G. F. A., & Rodrigues, V. P. (2021). Circular agri-food systems: A governance perspective for the analysis of sustainable agri-food value chains. Technological Forecasting and Social Change, 170, 120878. https://doi.org/10.1016/j.techfore.2021.120878

Mtashobya, L. A., Mgeni, S. T., & Emmanuel, J. K. (2025). Potential Contributions of Cashew Apple Juice to Nutrition, Medicine and Bioethanol Generation: An Outlook. *Natural Product Communications*, *20*(7), 1934578X251357414.

Nattassha, R., Handayati, Y., Simatupang, T. M., & Siallagan, M. (2020). Understanding circular economy implementation in the agri-food supply chain: the case of an Indonesian organic fertiliser producer. *Agriculture & Food Security*, *9*(1), 10.

Nguyen, C. H., Tran, T. T. V., Tran, D. H., Nguyen, T. K. P., Tran, T. T. N., & Bui, T. N. (2022). Renewable surfactants from cashew nut shell liquid: Synthesis, characterization and application. *Theoretical Foundations of Chemical Engineering*, *56*(6), 1075-1087.

Nwosu, C., Adejumo, O. A., & Udoha, W. N. (2016). Cashew apple utilization in Nigeria: Challenges and prospects. *Journal of Stored Products and Postharvest Research*, *7*(2), 29-31.

OECD, (2022), OECD FOOD, AGRICULTURE AND FISHERIES PAPER N°181, https://www.oecd-ilibrary.org/docserver/9cc1f47a-en.pdf?expires=1728448942&id=id&accname=guest&checksum=21880FC2FBB9238776C0317DE6B1BBAD

Oliveira, N. N., Mothé, C. G., & Mothé, M. G. (2022). Sustainable uses of cashew tree rejects: Cashew apple bagasse and cashew gum. *Biomass Conversion and Biorefinery*, *12*(7), 2623-2630.

Oliveira, N.N., Mothé, C.G., Mothé, M.G. (2020). Cashew nut and cashew apple: a scientific and technological monitoring worldwide review. *J Food Sci Technol* **57**, 12–21. https://doi.org/10.1007/s13197-019-04051-7

Omolola, G. J. (2024). *Determinants of performance of smallholder farmers in the cashew value chain: A case study of the Coastal region of Kenya*. Czech University of Life Sciences Prague. https://theses.cz/id/gl6s6v/45600284

Paiva, 2012, Conference: ACA -African Cashew Alliance At: Cotonou, Benin; https://www.africancashewalliance.com/sites/default/files/documents/Draft%20Apple%20processing%20study%20brazil.pdf

Park, M., Upton, D., Blackmon, M., Dixon, V., Craver, S., Neal, D., Perkins, D. (2018). Anacardic acid inhibits pancreatic cancer cell growth, and potentiates chemotherapeutic effect by Chmp1A - ATM - p53 signaling pathway. BMC Complement Altern Med 18(1):71. https://doi. org/10.1186/s12906-018-2139-3

Pattanayak, K. P. (2020). Cashew nut Supply Chain Challenges in India. *The Mattingley Publishing Co., Inc*, *83*, 245-252.

Pavel, S. (2018). Circular economy: The beauty of circularity in value chain. *Journal of Economics and Business DOI*, *10*.

Pietrzak, M., Chlebicka, A., Kraciński, P., & Malak-Rawlikowska, A. (2020). Information asymmetry as a barrier in upgrading the position of local producers in the global value chain−Evidence from the apple sector in Poland. *Sustainability*, *12*(19), 7857.

Prakash, 2020, https://venturecenter.co.in/socialinnovations/wp-content/uploads/2020/10/Presentation-Wadgaonkar.pdf

Schouten, G., & Bitzer, V. (2015). The emergence of Southern standards in agricultural value chains: A new trend in sustainability governance? Ecological Economics, 120, 175-184.

Shakerardakani A, Molaei M. Post-Harvest pistachio waste: Methods of its reduction and conversion. Pistachio and Health Journal. 2020; 3 (2): 40-51.

Sharma OC and Sharma SD, Genetic divergence in seedling trees of Persian walnut (Juglans regia L.) for various metric nut and kernel characters in Himachal Pradesh. Sci Hort 88:163–171 (2001).

Sharma, P., Bano, A., Singh, S. P., Varjani, S., & Tong, Y. W. (2024). Sustainable organic waste management and future directions for environmental protection and techno-economic perspectives. *Current Pollution Reports*, *10*(3), 459-477.

Shilpa, P., Kaveri, K., Salimath, BP. (2015) Anti-metastatic action of anacardic acid targets VEGF-induced signalling pathways in epithelial to mesenchymal transition. Drug Discov Ther 9(1):53–65. https://doi.org/10.5582/ ddt.2014.01042

Sial, T. A., Rajpar, I., Khan, M. N., Ali, A., Shan, M., Rajput, A. B., & Shah, P. A. N. (2024). Impact of fruit and vegetable wastes on the environment and possible management strategies. In *Planet earth: Scientific proposals to solve urgent issues* (pp. 307-330). Cham: Springer International Publishing.

Silva, V., Oliveira, I., Pereira, J. A., & Gonçalves, B. (2025). Almond By-Products: A Comprehensive Review of Composition, Bioactivities, and Influencing Factors. *Foods*, *14*(6), 1042.

Singaravelu, D. L., Vijay, R., & Filip, P. (2019). Influence of various cashew friction dusts on the fade and recovery characteristics of non-asbestos copper free brake friction composites. *Wear*, *426*, 1129-1141.

Soares, V. D. M., Barreto, R. S., de Jesus, V. D. S., Santos, M. X., Santos, N. O., Andrade, B. S., ... & Aguiar, R. M. (2022). Pharmacological Activities of the Phenolic Constituents from Anacardium occidentale L.(Anacardiaceae): A Systematic Review. *Revista Brasileira de Plantas Medicinais*, *24*(4), 134-144.

Solazzo, R., Petriccione, G., & Perito, M. A. (2020). The contractual relationships in the Italian durum wheat chain: empirical survey evidence. *New Medit: Mediterranean Journal of Economics, Agriculture and Environment= Revue Méditerranéenne d'Economie Agriculture et Environment*, *19*(2).

Solomon, N. O., Simpa, P., Adenekan, O. A., & Obasi, S. C. (2024). Circular economy principles and their integration into global supply chain strategies. *Finance & Accounting Research Journal*, *6*(5), 747-762.

Srividya H, Malini MV, Brindha N, Dr. Manisha Kumari, Sayantani Ghosh, Dr. M. Gurusamy (2024). The Circular Economy: Redefining Value Chains For Sustainability. *Library ProgressI nternational*, 43(2), 24868-24874, https://journals.sagepub.com/doi/10.1177/10860266241297340

Stahel, W. R. (2016). The circular economy. *Nature News*, 531(7595), 435–438.

Sucupira, N. R., de Sousa Sabino, L. B., Neto, L. G., Gouveia, S. T., de Figueiredo, R. W., Maia, G. A., & de Sousa, P. H. M. (2020). Evaluation of cooking methods on the bioactive compounds of cashew apple fibre and its application in plant-based foods. *Heliyon*, *6*(11).

Sule, R., Raimi, B.O., Raimi, L. (2024). Agribusiness Value Chain Model in Developed Countries. In: Raimi, L., Olatidoye, O.P., Said, T.F.H. (eds) Agripreneurship and the Dynamic Agribusiness Value Chain. Springer, Singapore. https://doi.org/10.1007/978-981-97-7429-6_13

Tamura, S., & Fujie, K. (2014). Material cycle of agriculture on Miyakojima island: material flow analysis for sugar cane, pasturage and beef cattle. *Sustainability*, *6*(2), 812-835.

Tanveer, U., Ishaq, S., Gough, A. (2021). Circular Economy in Agri-Food Sector: Food Waste Management Perspective. In: Mor, R.S., Panghal, A., Kumar, V. (eds) Challenges and Opportunities of Circular Economy in Agri-Food Sector. *Environmental Footprints and Eco-design of Products and Processes*. Springer, Singapore. https://doi.org/10.1007/978-981-16-3791-9_4

Tenny, S., Brannan, J. M., & Brannan, G. D. (2022). 'Qualitative'studies. *StatPearls [Internet], StatPearls Publishing, FL*, 93-187.

Tray B., Garnevska E. and Shadbolt N., 2021. Linking smallholder producers to high-value markets through producer cooperatives: A case study of vegetable producer cooperatives in Cambodia. *International Food and Agribusiness Management Review*. 24(6). 905-920.

Trienekens, J. H. (2011). Agricultural value chains in developing countries a framework for analysis. *International food and agribusiness management review*, *14*(2), 51-82.

UNDP (2024). Training Program on Circular Economy & rice straw innovations in the Rice Value Chain, https://www.undp.org/vietnam/press-releases/training-program-circular-economy-rice-straw-innovations-rice-value-chain

UNSDG, 2025 United Nations Sustainable Development Goals. online: https://www.un.org/sustainabledevelopment/sustainable-consumption-production/

van Walraven, N., & Stark, A. H. (2023). From food waste to functional component: Cashew apple pomace. *Critical Reviews in Food Science and Nutrition*, *64*(20), 7101–7117. https://doi.org/10.1080/10408398.2023.2180616

Vegter, D., van Hillegersberg, J., & Olthaar, M. (2020). Supply chains in circular business models: processes and performance objectives. *Resources, Conservation and Recycling*, *162*, 105046.

Vermeulen, W. J. V. (2006). The social dimension of industrial ecology: On the implications of the inherent nature of social phenomena. *Progress in Industrial Ecology*, 3, 574–598.https://doi.org/10.1504/PIE.2006.012754

Vichitra, M., Sunil Kumar, M., Beemkumar, N., Subbiah, G., & Kamakshi Priya, K. (2025). Advances in extraction and sustainable utilization of cashew nut shell liquid (CNSL) for industrial applications. *International Journal of Chemical Reactor Engineering*, (0).

Wadsworth, J.J. (2019) Marketing Operations of Dairy Cooperatives 2017 (p. 48). Washington, DC:USDA Rural Development. https://www.rd.usda.gov/files/publications/RR234MarketingOperationsofDairyCooperatives2017.pdf

Wang, D., He, J., & Tang, Y. T. (2020). Assessing the transition of municipal solid waste management using combined material flow analysis and life cycle assessment. In *Proceedings of the 2020 International Conference on Resource Sustainability: Sustainable Urbanisation in the BRI Era (icRS Urbanisation 2020)* (pp. 77-92). Springer Singapore.

Wang, S., & Gu, Z. (2022). Mapping the field of value chain: A biblio and visualization analysis. *Sustainability*, *14*(12), 7063.

Williamson, O. E. (2008). The economic institutions of capitalism. *The political economy reader: Markets as institutions*, *27*.

Woodhill, J., Kishore, A., Njuki, J., Jones, K., & Hasnain, S. (2022). Food systems and rural wellbeing: challenges and opportunities. *Food Security*, *14*(5), 1099-1121.

Worldbank, 2023, In a Nutshell: Agri-processing adds value in Cote d'Ivoire's cashew industry, https://documents1.worldbank.org/curated/en/099610504222514487/pdf/IDU-5ed0f54e-d30d-4c7c-a1b3-adc112790a9b.pdf

Worldbank, 2024, https://www.worldbank.org/en/country/vietnam/overview#1

Yomichan, S., "Case Study: Opportunities and Potential of Cashew Trade Between India and Guinea Bissau 2018". Acta Scientific Agriculture 4.3 (2020): 01-17.

Zamora, E. A. (2016). Value chain analysis: A brief review. *Asian Journal of Innovation and Policy*, *5*(2), 116-128.

Zink, T., & Geyer, R. (2017). Circular economy rebound. *Journal of industrial ecology*, *21*(3), 593-602.

Appendices

Appendix 1: Research questionnaire for farmers

Identity & Farm characteristics

Interviewee' identity: Could you please tell me about your personal details? (age, educational background, cashew farming experience, motivation on cashew farming)

Farm characteristics: Could you please tell me about your farm? (farmland size, year of operation, ownership status, agricultural crop, percentage cashew farm, cashew varieties and reason behind it, number of cashew tree or hectare, age of tree)

Cashew cultivation

Could you please tell me about your cashew cultivation' input (what-how-why types of input, source of input, price of input, how impact on cashew yield)

Could you please tell me about your cultivation practices? (what-how-why, methods and why, tools and labors, irrigation (what source, how, equipment, what energy), waste and by-products (what happen with those, how deal,why)

Could you tell me about tree rejuvenation: how often, what happens with the old?

Could you tell me about what you do and or other farmers do to improve/increase productivity? How? Why?

Harvesting

Harvest: what do you do after cultivation of cashew? (when harvest (seasonal or year round), methods, techniques, tools used, frequency of harvest, yield of cashew (wet/dry basis per tree/hectare/farm)

Post harvest activities:

Raw Cashew: what happens after harvesting? (sell wet/dry to whom, drying and storing for later processing (shelf-life), selling volume

Wastes/By products after harvesting: Could you tell me about the waste and by-products during cashew cultivation and production? (What – How much – How – What techniques, tools – When – Why – other farmers' practices?

Cashew storage: Could you tell me how do you store your cashew? (material of packaging, method, time, perishability?), Any loss during storage and how to deal with?

Cashew selling & transportation

Cashew selling: Could you tell me how you sell the cashew? (types (wet, dry, unshelled,…) How? For whom? How transport? To where? Why?

Cashew apple selling (if any) Could you tell me how do you deal with cashew apple? (when, types (wet, fermented,…), selling and marketing activities? For whome? How transport? To where? Why?

Marketing: Could you tell me how do you arrange to sell your products? What market and percentage? How do you determine the price and why? How much? How the buyers assess the cashew nut quality? What if you have several buyers? How do you arrange to sell for them?

Payment: How do you arrange payment with buyers? (method of payment, delay payment)

Farmer group or cooperatives

Are you a member of farmer group or cooperative? Why?

Future, Opportunities, Challenges

Do you have any challenges in cashew cultivation, production? What is it? Do you receive any support from the government, cooperatives, or associations? What kind of assistance would help improve your farming practices (e.g., financial, technical, training)?

Do you see what are the opportunities of cashew cultivation in the next few years? Why?

What are you doing to increase income from cashew farming? What are other farmers doing to increase income?

Appendix 2: Research questionnaire for intermediaries (traders, collectors)

Identity & processors' characteristics

Interviewee' identity: Could you tell me about your personal details? (Role/Position in business, experience in position or cashew business? Why this business/career?

Company background: Could you tell me about your business or company? (business size, years of operation, trading volume, processing capacity, company products, role in cashew value chain)

Cashew sourcing activities

Suppliers: How do you buy the cashew nut? From whom (farmers, collectors,…), contract with suppliers?

Cashew volume: What types of cashew nut you buy? (wet/dry) and How many in quantity per month/season/year? How arrange to source cashew? Standards for cashew (moisture, size,…) How storage cashew whole year round? What doing in off-cashew season?

Cashew price: How do you set the price? Average price? what impact on cashew price? Why? How do market prices or buyer requirements affect your purchasing decisions?

Appendix 3: Research questionnaire for processors

Identity & processors' characteristics

Interviewee' identity: Could you tell me about your personal details (Role in business, experience in position or cashew business? Why this business/career)

Company background: Could you tell me about your company/business (business size, years of operation, processing capacity, company products)

Cashew sourcing activities

Suppliers: How does the company buy the cashew? (who are your suppliers/ what types of cashew (wet, dry,...)/ standards for cashew (moisture, size,…)/ contract with suppliers?

Cashew volume: How many in quantity cashew buying per month/season/year? How arrange to source cashew? How to utilize processing capacity all year round? Challenges in securing consistent quality/quantity?

Cashew price: How do your company set the price? Average price of cashew? what impact on cashew price?

Cashew quality: How do your company assess the quality of cashew nuts? (certification needed and its impacts on input/output price). Is there any quality standard do you apply for the raw cashew nut for example: origin, moisture percentage, size?

Payment with suppliers: How do you arrange the transaction with farmers/suppliers? What is the method of payment? Is there any payment contract?

Cashew value adding activities

Processing steps: What is the final product you produce (e.g., shelled kernels, roasted cashews, coated cashews)?) What do you do to add value for cashew nut?

Technology and labour: What technologies or equipment do you use for each processing stage? Who are involving in each stage?

Packaging & storage: How do you package and store processed cashews?

Cashew kernel size & quality: How do you set your cashew quality? Which certificate or standard do you follow? (ISO, HACCP, BCR,..)

Waste & By-products: What kinds of waste, by-products, unqualified nuts during processing and what happens with them? Quantities each? What do you deal with them?

Marketing, Selling and Transportation

Buyers: How do you sell your products? For whom (Domestic or Foreign buyers)? Which market? Percentage each market? Why? How to reach buyers?

Cashew kernels' price: How determine the price? What is the average price? Is domestic and export price the same? Why?

Payment: How do you arrange the payment? what method of payment? Selling and payment contract? Negotiation term?

Transportation: How do your company deliver (transport) your products to buyers? Where are they? (maping cashew value chain)

Challenges and Future plan

Do you have any challenges in cashew production? What is it?

Do you foresee changes in the cashew industry that could impact how you operate? (challenges and opportunities)

Are there government policies or incentives that support your processing activities? What additional support (funding, training) would help improve your operations?

What are you planning to do in the future? What are other processors doing?

Appendix 4: Questionaire for cooperatives

Cooperatives are the combination of cultivation of cashew, collection of cashew nut and may process cashew. So, the questions are similar to farmers and middleman/collectors/processors

Identity: Could you tell me about your personal details (Position in organization, describe role)

Cooperative' characteristics: Could you tell me details about your cooperatives (when established, how experience in cashew activities (cultivation, collecting, processing), role in cashew activities/value chain, number of membership, size of cooperative (hectare, tree,…))

Cooperative model: Could you tell me about your cooperative model?

Challenges: what challenges in operate/support cashew activities

Opportunities: what opportunities in operate/support cashew activities

Are there government policies or incentives that support your processing activities? What additional support (funding, training) would help improve your operations?

Appendix 5: Questionaire for exporters

Large processors companies will act as the exporters as well. Hence, to those large companies using the similar questionnaire for processor.

Identity & processors' characteristics

Interviewee' identity: Could you tell me about your personal details (Role in business, experience in position or cashew business? Why this business/career)

Company background: Could you tell me about your business/company(business size, years of operation, processing capacity, export volume, company products, export market)

Cashew processing:

Certification and quality: What standard/certification of target exported countries? How arrange and ensure quality and standards?

Cashew exporting:

Buyers: where are exported countries? Why? How reach them? Main market (US, EU, Middle-east, Asian, Ocean,..) estimate what percentage of market?

Volume: How many tons? How often?

Negotiation & price: How determine the price? What impact the price? How negotiate price based on quantity, quality?

Payment: what payment methods? Contract?

Challenges and risks: challenges and risks in export (not receive payment, supply chain disruptions due to lack of input cashew,…)

Opportunities: opportunities in cashew industry? Plan for the future?

Appendix 6: Questionaire for Government officer, Cashew Association

Identity*:* Could you tell me about your personal details (Position in organization, describe role, experience in the position/cashew-related division)

Provincial context: Could you provide an overview of the cashew industry in this province (e.g., production volumes, key players)? How significant is the cashew sector to the province's economy and rural development?

Role of government: Could you tell me about the role of government in supporting and coordinating? Or what government are doing to support cashew industry? Programs, initiatives, policies, provincial policies in support of cashew nut VN? What kind of support does MARD/DARD/Government provide to farmers and processors (e.g., training, subsidies, technical assistance)? Policies/program in cashew sector that had been implemented and future program?

Value chain structure: Describe key stage and stakeholders of cashew nut value chain in VN

Material flow: what main materials (raw cashew, kernel nut) and waste/by-products flow? What happen with them? Why?

Challenges & opportunities: challenges and opportunities in the cashew sector development

Future: What are government' priorities for improving the cashew value chain in the next 5–10 years?

Data: Are there reports, data, or resources you could share to help map the value chain and analyze material flows? (production, productivity, yield, import and export data (cashew, cashew shell oil,…)

Contact information: Could you recommend any specific stakeholders (e.g., processors and its location, farmer cooperatives, farmers and farming location, exporters) for further interviews?

Appendix 7: Primary data collection design

1. Data collection plan on farms

Location	Farmer number	Quantitative information			Direct measurements scale		
		Inputs prices	Outputs prices	Yeild	Weight of cashew whole fruit	Weight of cashew apple	Weight of wet cashew nut
Bu Dang	1	x	x	x	x	x	x
Bu Dang	2	x	x	x	x	x	x
Bu Dang	3	x	x	x	x	x	x
Bu Dang	4	x	x	x	x	x	x
Bu Dang	5	x	x	x	x	x	x
Bu Dang	6	x	x	x			
Bu Dang	7	x	x	x			
Bu Dang	8	x	x	x			
Bu Dang	9	x	x	x			
Bu Dang	10	x	x	x			
Bu Dang	11	x	x	x			
Bu Dang	12	x	x	x			
Bu Gia Map	13	x	x	x			
Bu Gia Map	14	x	x	x			
Bu Gia Map	15	x	x	x			
Bu Gia Map	16	x	x	x			
Bu Gia Map	17	x	x	x			
Bu Gia Map	18	x	x	x			
Bu Gia Map	19	x	x	x			
Phu Rieng	20	x	x	x	x	x	x
Phu Rieng	21	x	x	x	x	x	x
Phu Rieng	22	x	x	x			
Phu Rieng	23	x	x	x			
Phu Rieng	24	x	x	x			
Phu Rieng	25	x	x	x			
Dong Phu	26	x	x	x	x	x	x
Dong Phu	27	x	x	x	x	x	x
Dong Phu	28	x	x	x	x	x	x
Dong Phu	29	x	x	x			
Dong Phu	30	x	x	x			

2. Data collection plan at kernel processing facilities

Location	Kernel Processor number	Quantitative information					Direct measurements scale			
		Wet nut prices	Dried nut price	Kernel price	CNS price	Testa Price	Weight of wet nut	Weight of dried nut	Weight of peeled kernel	Weight of white kernel
Bu Dang	1	x	x	x	x	x	x	x	x	x
Bu Dang	2	x	x	x	x	x				
Bu Dang	3	x	x	x	x	x				
Bu Dang	4	x	x	x	x	x				
Bu Dang	5	x	x	x	x	x				
Bu Dang	6	x	x	x	x	x				
Bu Dang	7	x	x	x	x	x				
Bu Dang	8	x	x	x	x	x				
Phuoc Long	9	x	x	x	x	x				
Phuoc Long	10	x	x	x	x	x	x	x	x	x
Phuoc Long	11	x	x	x	x	x				
Phuoc Long	12	x	x	x	x	x				
Phuoc Long	13	x	x	x	x	x				
Phuoc Long	14	x	x	x	x	x				
Phuoc Long	15	x	x	x	x	x				
Phuoc Long	16	x	x	x	x	x				
Dong Xoai	17	x	x	x	x	x				
Dong Phu	18	x	x	x	x	x	x	x	x	x

3. Data collection plan at CNSL processing facilities

Location	CNSL Processor number	Quantitative information				
		Price of CNS	Conversion rate CNS to CNSL	Price of CNS cake	Price of crude CNSL	Price of refined CNSL
Bu Dang	1	x	x	x	x	x
Phuoc Long	2	x	x	x	x	x
Dong Xoai	3	x	x	x	x	x

Appendix 8: Research ethics approval

TE KUNENGA KI PŪREHUROA | MASSEY UNIVERSITY
UNIVERSITY OF NEW ZEALAND

9/12/2024

Dear: Hoa Tran

Re: Low Risk Notification - 4000029988 - MAgribusiness - Circularity opportunity of cashew nut value chain in Vietnam

Thank you for submitting a low risk notification for your research/teaching/evaluation.

This email is to acknowledge receipt of the low risk notification and to inform you that the details of your project have been recorded in our database for inclusion in the annual reports to the Health Research Council Ethics Committee (HRCEC) and the Massey University Research Committee (URC).

You may proceed with your research, though it is advisable to provide a couple of weeks before commencing, as all low risk notifications are checked for completeness and clarity by a Research Ethics Advisor. You may be contacted if your application is incomplete and/or further clarification is required.

The low risk notification for this project is valid for a maximum of three years.

Please notify me if situations subsequently occur which cause you to reconsider your initial ethical analysis.

If a sponsoring organisation, funding authority (e.g., the Health Research Council) or a journal require evidence of ethical approval from a Human Ethics Committee (with an approval number), you need to complete a full Massey University Human Ethics application to be reviewed and approved by one of our Human Ethics Committees. Applications must be submitted and approved prior to the commencement of the research.

Please note that travel undertaken by students must be approved by the supervisor and the relevant Pro Vice-Chancellor and be in accordance with the Policy and Procedures for Course-Related Student Travel Overseas. In addition, the supervisor must advise the University's Insurance Officer.

If you have any concerns about the conduct of this research that you want to raise with someone other than the researcher(s), please contact the Research Ethics Office, email humanethics@massey.ac.nz. "

Please include the following statement on all public documents (e.g., information sheet, consent form) related to your project:

> ***This project has been evaluated by peer review and judged to be low risk. Consequently, it has not been reviewed by one of the University's Human Ethics Committees. The researcher(s) named above are responsible for the ethical conduct of this research.***
>
> ***If you have any concerns about the ethical conduct of this research that you want to raise with someone other than the researcher(s), please contact Massey University Human Ethics by email: humanethics@massey.ac.nz.***

I wish you all the best in your research, teaching or evaluation activities and appreciate your thoughtful consideration of ethics principles and practices.

Ngā mihi nui,

Professor Tracy Riley
Acting Chair, Research Ethics Chair's Committee

Research Ethics, Graduate Research School and Ethics
Massey University, Private Bag 11 222, Palmerston North, 4442, New Zealand
E humanethics@massey.ac.nz; animalethics@massey.ac.nz
www.massey.ac.nz/research/ethics

Appendix 9: Reference letter and translated reference letter

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA
UNIVERSITY OF NEW ZEALAND

COLLEGE OF SCIENCES
TE WĀHANGA PŪTAIAO

REFERENCE LETTER

To Whom It May Concern

Subject: Reference Letter for Research on the Cashew Value Chain in Vietnam

Dear Sir/Madam,

This letter serves as a formal introduction for:

Ms Tran Thi My Hoa ID No: [redacted] **Student ID:** [redacted]

Major: Master of Agribusiness at Massey University, New Zealand

Ms Hoa is conducting research on the cashew value chain in Vietnam. To successfully conduct this research, Hoa seeks to engage with a variety of stakeholders, including farmers, processors, government agencies, and industry organizations. We kindly request your support in facilitating her access to necessary data, interviews, and introduction to relevant stakeholders within the cashew value chain in Vietnam.

Hoa's project was evaluated as low risk for human participants. Massey University Ethics Notification Number: 4000029988. Please be assured that her research will follow strict ethical standards, including informed consent from participants and all data collected will be handled with strict confidentiality and used solely for research purposes.

Upon completion of her research, a report summarizing her findings and insights will be shared with your organization for reference.

Should you have any questions or require further information, please contact Dr Elena Garnevska (e.v.garnevska@massey.ac.nz), telephone +6469517794.

We greatly appreciate your cooperation and assistance in supporting this research.

Sincerely,

School of Agriculture and Environment
PN433
Massey University
Private Bag 11 222
Palmerston North
New Zealand

Assoc Professor Elena Garnevska - Main supervisor
School of Agriculture and Environment | Massey University | Private Bag 11222 | Palmerston North 4442 | New Zealand
E-mail: e.v.garnevska@massey.ac.nz| Phone: +64 6 951 7794

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA
UNIVERSITY OF NEW ZEALAND

COLLEGE OF SCIENCES
TE WĀHANGA PŪTAIAO

THƯ GIỚI THIỆU

Kính gửi: Sở Nông Nghiệp và Phát triển Nông thôn Tỉnh Bình Phước

V/v: Thư giới thiệu nghiên cứu về Chuỗi giá trị hạt điều tại Việt Nam

Trường Đại Học Massey, New Zealand xin trân trọng giới thiệu:

Sinh viên: Trần Thị Mỹ Hoa CCCD: [redacted] MSSV: [redacted]

Chuyên ngành: Thạc sĩ Kinh doanh nông nghiệp tại Đại học Massey

Hoa đang tiến hành nghiên cứu về ngành hạt điều tại Việt Nam. Để tiến hành thành công nghiên cứu này, Hoa tìm cách tiếp cận nhiều bên liên quan, bao gồm nông dân, nhà chế biến, cơ quan chính phủ và các tổ chức trong ngành. Chúng tôi rất mong nhận được sự hỗ trợ của Quý Sở trong việc tạo điều kiện cho Hoa tiếp cận dữ liệu, phỏng vấn và giới thiệu Hoa với các bên liên quan có liên quan trong chuỗi giá trị hạt điều tại Việt Nam.

Dự án của Hoa được đánh giá là có rủi ro thấp đối với người tham gia. Số thông báo về đạo đức tại Đại học Massey: 4000029988. Xin hãy yên tâm rằng nghiên cứu của cô ấy sẽ tuân theo các tiêu chuẩn đạo đức nghiêm ngặt, bao gồm cả sự đồng ý có hiểu biết từ những người tham gia và tất cả dữ liệu thu thập được sẽ được xử lý với tính bảo mật nghiêm ngặt và chỉ được sử dụng cho mục đích nghiên cứu.

Sau khi hoàn thành nghiên cứu, một báo cáo tóm tắt các phát hiện, kết quả nghiên cứu và các khuyến nghị sẽ được gửi đến Quý cơ quan để tham khảo.

Nếu bạn có bất kỳ câu hỏi nào hoặc yêu cầu thêm thông tin, vui lòng liên hệ với Tiến sĩ Elena Garnevska (e.v.garnevska@massey.ac.nz), điện thoại +6469517794.

Kính mong Quý đơn vị tạo điều kiện và giúp đỡ sinh viên Trường đạt kết quả tốt.

Thay mặt Nhà trường, tôi xin cám ơn sự hỗ trợ, đóng góp của Quý đơn vị vào sự nghiệp giáo dục và đào tạo của nhà trường.

Trân trọng cám ơn!

School of Agriculture and Environment
PN433
Massey University
Private Bag 11 222
Palmerston North
New Zealand

Phó Giáo sư Elena Garnevska - Giám sát viên chính

Khoa Nông nghiệp và Môi trường | Đại học Massey | Private Bag 11222 | Palmerston North 4442 | New Zealand

E-mail: e.v.garnevska@massey.ac.nz| Điện thoại: +64 6 951 7794

Te Kunenga ki Pūrehuroa | School of Agriculture and Environment
Private Bag 11222, Palmerston North 4442, New Zealand, T +64 6 356 9099, contact@massey.ac.nz | massey.ac.nz/ag

Appendix 10: Participant consent form

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA
UNIVERSITY OF NEW ZEALAND

CONSENT FORM

INTRODUCTION

Good day! We am conducting research to explore the circularity opportunities in the cashew nut value chain in Vietnam. The interview is aimed to understand current practices in cashew from farming to processing, map cashew nut value chain along with its stakeholders, how materials are used.

As a semi-structured interview, it will take an estimated 45 - 60 minutes. We would deeply appreciate your participation in this research and would like to seek your permission. Rest assured that the information you will provide will be treated with utmost care and confidentiality and no individual name or company name will reflect in report. If at any point you feel uncomfortable answering some questions, you are free to discontinue the interview. Thank you very much.

INFORMATION AND RECORD CONSENT

I voluntarily consent to participate in this study and agree to have the interview audio recorded. I authorize the use of any information I provide in this survey to be included in the research, writing, and publication of its findings.

Name and Signature

Appendix 11: Translated participant consent form

PHIẾU ĐỒNG Ý

GIỚI THIỆU

Chào bạn! Chúng tôi đang tiến hành nghiên cứu để khám phá các cơ hội tuần hoàn trong chuỗi giá trị hạt điều tại Việt Nam. Mục đích của cuộc phỏng vấn là tìm hiểu các hoạt động hiện tại trong lĩnh vực điều, từ khâu trồng trọt đến chế biến, lập bản đồ chuỗi giá trị hạt điều cùng với các bên liên quan, và cách thức sử dụng nguyên liệu.

Là một cuộc phỏng vấn bán cấu trúc, cuộc phỏng vấn sẽ mất khoảng 45 - 60 phút. Chúng tôi rất trân trọng sự tham gia của bạn vào nghiên cứu này và mong muốn nhận được sự cho phép của bạn. Xin hãy yên tâm rằng thông tin bạn cung cấp sẽ được xử lý hết sức cẩn thận và bảo mật, và không có tên cá nhân hoặc tên công ty nào được phản ánh trong báo cáo. Nếu bạn cảm thấy không thoải mái khi trả lời một số câu hỏi, bạn có thể dừng cuộc phỏng vấn. Xin chân thành cảm ơn.

THÔNG TIN VÀ ĐỒNG Ý GHI ÂM

Tôi tự nguyện đồng ý tham gia nghiên cứu này và đồng ý cho ghi âm cuộc phỏng vấn. Tôi đồng ý cho phép sử dụng bất kỳ thông tin nào tôi cung cấp trong khảo sát này để phục vụ cho việc nghiên cứu, viết và xuất bản các kết quả nghiên cứu.

Họ và tên và chữ ký