

Food Loss and Food Waste Assessment of Strategic Food Commodities in South Kalimantan Province: Economic Valuation and Carrying Capacity Implications

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ABSTRACT

Food loss (FL) and food waste constitute significant barriers to achieving food security and sustainable agricultural development in Indonesia. This research quantifies food loss and waste across the complete supply chain for eight strategic commodities in South Kalimantan Province, examining their economic implications and theoretical carrying capacity contributions. Using Food Balance Sheet methodology with FAO regional coefficients, we analyzed 2024 supply chain flows for eight strategic commodities: rice, root crops (sweet potato, cassava), fruits (orange, banana), and vegetables (tomato, chilies). Based on 2024 data, our analysis documents substantial inefficiencies with aggregate food loss and waste reaching 49.7% of total production. Rice shows 17.5% total losses, while horticultural crops approach 60% loss rates. Economic losses total IDR 4.3 trillion (20% of agricultural output). Upstream supply chain stages account for 83.8% of total losses, indicating fundamental infrastructure and technical capacity constraints. Carrying capacity calculations demonstrate that orange losses alone could theoretically sustain the entire provincial population for approximately 29 years, revealing substantial untapped potential for regional food security enhancement. These findings suggest that efficiency improvements may offer important alternatives to production-focused development strategies for enhancing food security. Priority interventions should target post-harvest infrastructure, processing capacity, and cold chain development. This study contributes to providing a comprehensive estimate of food loss and waste in eight strategic commodities in South Kalimantan.

KEYWORDS

Economic assessment; Food loss; Food waste; Supply chain efficiency; Sustainable agriculture

1. INTRODUCTION

Global food systems face unprecedented challenges in meeting rising demand while minimizing environmental impacts and economic inefficiencies. Approximately one-third of all food produced for human consumption is lost or wasted annually; recent global estimates indicate around 1.05 billion tonnes of food wasted at the retail, food service, and household stages, in addition to roughly 13% of food lost across supply chains [1], [2]. This inefficiency occurs alongside persistent food insecurity, with around 733 million people experiencing hunger in 2023 and an estimated 2.33 billion facing moderate or severe food insecurity [3], [4].

Indonesia, as the world's fourth most populous nation, faces critical food system efficiency challenges. The country's complex geography of over 17,000 islands with diverse agroecological conditions creates unique supply chain vulnerabilities [5]. Recent assessments indicate that food loss and waste in Indonesia's agricultural sector remain substantial despite policy interventions, with horticultural crops experiencing particularly severe inefficiencies [6], [7], [8]. Provincial analyses reveal significant infrastructure-related variations in loss rates, with more developed regions achieving 15–20% lower losses

through improved cold chain systems [6], [9]. While Indonesia has achieved progress in staple food production, particularly rice, significant inefficiencies persist across agricultural value chains.

South Kalimantan Province exemplifies these food system dynamics. With 1.67 million hectares of agricultural land and rice production reaching 1.19 million tons in 2024, the province demonstrates substantial productive capacity. However, its riverine geography and infrastructure limitations create complex supply chain challenges that may compromise efficiency.

Research in Southeast Asia has documented concerning inefficiency levels across commodity groups. Post-harvest losses of 15–25% for major food crops [10] and substantially higher rates for perishable horticultural products [11], [12]. Regional analyses show substantial food waste across strategic commodities in developing countries [13]. More recent systematic reviews confirm these patterns persist, with transport and handling losses alone accounting for 2–10% of grain production in Southeast Asian supply chains [14]. ASEAN-wide assessments emphasize that infrastructure deficits, particularly in cold chain systems, remain the primary driver of post-harvest inefficiencies [15], with potential land savings equivalent to 6.5% of regional cropland if losses were reduced by 40%. Comprehensive reviews confirm these patterns persist across developing regions, particularly affecting smallholder farming systems [16], [17].

Despite increasing attention, significant knowledge gaps remain regarding food loss and waste at subnational scales. Most studies examine individual commodities or isolated supply chain stages [18], limiting their utility for comprehensive policy development. Furthermore, limited research integrates quantitative loss assessment with economic valuation and carrying capacity analysis information essential for prioritizing interventions. Recent comprehensive reviews emphasize that post-harvest loss reduction represents a critical pathway for strengthening food security in developing nations without requiring additional land or production resources [19].

Contemporary food system research emphasizes interconnected efficiency challenges across production, processing, distribution, and consumption stages [20], [21], with recent frameworks highlighting circular economy principles as essential for sustainable transformation [22], [23]. European case studies demonstrate that circular food systems can reduce agricultural land use by 71% and greenhouse gas emissions by 29% while maintaining food security [23]. This systems perspective recognizes that food loss and waste result from complex interactions among technical, economic, institutional, and behavioral factors rather than isolated failures [24], [25]. Recent frameworks for food waste management emphasize hierarchical approaches to loss prevention and valorization [26], while systematic evaluation of prevention strategies can optimize resource allocation [27]. Evidence from successful interventions demonstrates that integrated approaches addressing multiple supply chain stages simultaneously yield superior outcomes compared to isolated interventions [28], [29].

Food loss and waste represent market failures arising from information asymmetries, infrastructure gaps, and coordination problems among value chain actors [24]. These inefficiencies impose costs on individual producers and consumers, as well as broader economic development and environmental sustainability [30], [31].

This study addresses critical research gaps by providing systematic quantitative assessment of food loss and waste across complete supply chains for eight strategic commodities in South Kalimantan. We examine three primary objectives: quantifying food loss and waste at each supply chain stage; analyzing carrying capacity implications for regional food security; and estimating economic costs associated with current inefficiency levels. Our findings contribute to evidence-based policy development for sustainable food system transformation in Indonesia and comparable developing country contexts.

This study contributes to food loss and waste research by providing systematic supply chain quantification for multiple commodities in an Indonesian provincial context, addressing the gap in subnational FLW (food loss and waste) data [19]. It integrates loss assessment, economic valuation, and carrying capacity analysis within a unified framework, enabling comprehensive evaluation of efficiency improvement potential. The comparative provincial and international analysis situates South Kalimantan's experience within broader regional patterns while identifying specific opportunities based on successful

approaches elsewhere. The 2024 baseline enables future longitudinal assessment of intervention impacts, supporting evidence-based policy development.

2. MATERIALS AND METHODS

2.1. Theoretical Foundation and Analytical Framework

Food loss and food waste represent distinct but related inefficiencies within agricultural systems that compromise food security, economic development, and environmental sustainability. Food loss encompasses decreases in food quantity or quality occurring during production, post-harvest, and processing stages, typically technical constraints, infrastructure limitations, or suboptimal handling practices [1]. Food waste occurs at retail and consumption stages where edible food is discarded behavioral, aesthetic, or commercial factors [11], [26].

This research employs the Food Balance Sheet methodology as its primary analytical framework, enabling systematic tracking of food flows from production through consumption. The FBS approach facilitates comprehensive analysis of food system efficiency by quantifying losses at each supply chain stage while accounting for alternative commodity uses [32]. The fundamental relationship underlying this analysis can be expressed as equation (1).

$$\text{Availability}_{\text{percapita}} = \frac{\text{Production} + \text{Imports} - \text{Exports} - \text{Stock}_{\text{changes}} - \text{Non-food}_{\text{uses}} - \text{Losses}}{\text{Population}} \quad (1)$$

Recent scholarship emphasizes integrated approaches combining quantitative loss assessment with economic analysis and carrying capacity evaluation [33]. However, most existing studies focus on individual commodities or specific supply chain stages, limiting their applicability for comprehensive policy development [34], [35]. This study addresses these limitations by providing systematic assessment across multiple commodities and complete supply chain stages within a developing country context. This study contributes to providing a comprehensive estimate of food loss and waste in eight strategic commodities in South Kalimantan.

2.2. Study Area and Data Sources

This research was conducted in South Kalimantan Province, Indonesia, during January through June 2025. South Kalimantan represents a strategically important agricultural region characterized by diverse production systems, ranging from intensive rice cultivation in lowland areas to horticultural production across upland zones. The province's unique geographical characteristics, combining mainland and riverine areas, create complex supply chain dynamics representative of Indonesian agricultural conditions.

Secondary data were obtained from multiple authoritative sources to ensure comprehensiveness and reliability. Production statistics were sourced from Statistics Indonesia South Kalimantan office, covering the complete 2024 production year. Market price data were obtained from the Ministry of Trade's Market and Basic Needs Monitoring System for the January–December 2024 period. Consumption patterns were derived from the National Socioeconomic Survey conducted by Statistics Indonesia, with adjustments for local consumption patterns specific to South Kalimantan.

While secondary data from official government statistical agencies provide the most comprehensive available information, potential limitations include measurement errors, reporting delays, and spatial aggregation that may not fully capture local variations. These limitations are inherent to macro-level food system assessments and are partially mitigated through triangulation with multiple data sources.

2.3. Regional Context and Loss Coefficients

Our quantitative assessment utilizes FAO Food Loss Index coefficients adapted for Southeast Asian conditions (Table 1). These coefficients synthesize empirical findings from multiple regional studies and provide standardized benchmarks for comparative analysis. While these coefficients provide the best available basis for regional comparison, we acknowledge potential limitations in capturing specific local

conditions. Future validation through direct measurement studies in South Kalimantan would strengthen the accuracy of these estimates [10].

These coefficients demonstrate systematic patterns commodity characteristics and infrastructure availability across the region. Fruits and vegetables exhibit highest loss rates during production (15%) and processing (25%). Root crops display particularly elevated post-harvest losses (19%). Economic analysis of food loss and waste encompasses multiple dimensions, from individual farm-level income impacts to broader macroeconomic effects on food prices and trade balances. At the microeconomic level, food loss represents lost investment in production inputs including land, labor, water, energy, fertilizers, and pesticides [11]. Our economic valuation uses market prices as a conservative estimate, though this approach does not capture embedded input costs, environmental externalities, or opportunity costs of alternative land uses.

Table 1. Regional food loss and waste coefficients for Southeast Asia.

| Commodity group | Production (%) | Post-harvest handling and storage (%) | Processing and packaging (%) | Distribution and marketing (%) | Consumption (%) |
|-----------------------|----------------|---------------------------------------|------------------------------|--------------------------------|-----------------|
| Cereals | 6.0 | 7.0 | 3.5 | 2.0 | 3.0 |
| Root crops | 6.0 | 19.0 | 10.0 | 11.0 | 3.0 |
| Fruits and vegetables | 15.0 | 9.0 | 25.0 | 10.0 | 7.0 |
| Meat | 5.1 | 0.3 | 5.0 | 7.0 | 4.0 |
| Fish and seafood | 8.2 | 6.0 | 9.0 | 15.0 | 2.0 |

Source : FAO Food Loss Index Database (2019), synthesizing empirical studies from Indonesia, Thailand, Vietnam, Philippines, and Malaysia for 2015-2019 period. [1], [10], [16].

Note : Actual loss rates in specific locations may vary ± 5 –10% from these regional medians depending on local infrastructure, climate, and practices. See Section 2.10.2 for detailed discussion of coefficient adaptation limitations.

Carrying capacity analysis examines the theoretical population that could be supported through elimination of food loss and waste, providing metrics for understanding food security implications of supply chain inefficiencies [36]. This analysis assumes constant per capita consumption patterns and does not account for potential behavioral or demographic changes that might result from efficiency improvements. This analytical approach has evolved beyond simple production-consumption ratios to incorporate sustainability considerations including land use efficiency, water resource utilization, and climate change impacts [24].

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2.5. Commodity Selection and Justification

Eight strategic food commodities were selected through a systematic multi-criteria process designed to ensure comprehensive representation of South Kalimantan's food system while capturing diversity in commodity characteristics, supply chain complexities, and policy relevance.

2.5.1. Selection Criteria

The first criterion was strategic food status, where all selected commodities are designated as strategic foods under Presidential Regulation No. 66/2021 concerning the National Food Agency (*Badan Pangan Nasional*). This designation identifies foods critical for national food security, price stability, and poverty alleviation, ensuring policy relevance of research findings.

The second criterion was production significance in South Kalimantan, requiring commodities to demonstrate substantial production volumes within the province, operationalized as either annual production exceeding 10,000 tons or cultivation area exceeding 5,000 hectares. This threshold ensures selected commodities represent material shares of provincial agricultural activity rather than niche crops.

The third criterion was documented high FLW susceptibility, where selection prioritized commodities with elevated food loss and waste rates documented in FAO data for South and Southeast Asia. Specifically, commodities must demonstrate >15% combined losses for fruits and vegetables, >10% combined losses for root crops and tubers, or >5% losses for cereals despite extensive value chain development. This criterion focuses research attention on commodities where efficiency improvements offer greatest potential impact.

2.5.2. Selected Commodities and Representativeness

The eight selected commodities provide comprehensive coverage across food system dimensions. For staple food security, rice (*Oryza sativa*) was selected with production of 1,193,287 tons (2024), representing 100% of cereal staple production, 47.2% of total crop agricultural output value, and 209.44 g per capita daily consumption. Rice represents a mature, extensively supported value chain with institutional infrastructure developed over food security policy prioritization.

For dietary diversity and food security, root crops were included, comprising sweet potato (*Ipomoea batatas*) with 8,174 tons production and cassava (*Manihot esculenta*) with 36,117 tons production. Combined, these contribute 3.1% of agricultural output value and serve as important calorie sources for lower-income households and rural populations, providing food security buffer during rice price volatility. These represent traditional food crops with minimal value chain development, simple processing requirements, but significant post-harvest challenges.

For high-value horticultural crops, fruits were represented by orange (*Citrus sinensis*) with 123,549 tons production and banana (*Musa* spp.) with 72,561 tons production. Combined, these contribute 38.7% of horticultural output value and have high export potential with established domestic and international markets. These represent perishable commodities requiring cold chain infrastructure, facing time-sensitive spoilage, with substantial value-addition potential through processing.

Additionally, vegetables and spices include tomato (*Solanum lycopersicum*) with 4,918 tons production, large chili (*Capsicum annuum*) with 8,193 tons production, and bird's eye chili (*Capsicum frutescens*) with 12,575 tons production. Combined, these contribute 11.0% of horticultural output value and exhibit high price volatility with strong domestic demand, being critical for Indonesian cuisine. These represent highly perishable vegetables with short shelf life, requiring sophisticated handling and rapid market access.

2.5.3. Comprehensive System Representation

Collectively, these eight commodities capture 89.3% of total horticultural production value in South Kalimantan and 100% of staple food (cereal) production. They represent the full perishability spectrum from stable (rice, root crops) to highly perishable (tomato, chilies), enabling analysis of how commodity characteristics affect loss patterns. The selection encompasses a value range from low-value bulk commodities (cassava: IDR 6,639/kg) to high-value specialty crops (bird's eye chili: IDR 63,509/kg),

examining relationship between economic value and supply chain efficiency. The commodities exhibit market diversity, spanning subsistence consumption (sweet potato), domestic market dominance (rice), and export potential (orange, banana). They also demonstrate supply chain complexity ranging from simple, short chains (root crops sold fresh in local markets) to complex, multi-stage chains (rice requiring milling, storage, and distribution infrastructure).

2.5.4. Commodities Excluded and Rationale

Several commodity groups were excluded despite their agricultural importance. Other vegetables (e.g., cabbage, spinach, beans) were excluded, as production volumes fell below the threshold and production and consumption patterns were highly localized. Tree fruits (e.g., rambutan, durian) were also excluded from the analysis. Tubers (e.g., taro) were excluded given their limited commercial production and primarily subsistence-level cultivation. Secondary cereals (e.g., corn) were excluded; they are primarily used as animal feed rather than direct human consumption, thus exhibiting different FLW dynamics. These exclusions reflect data availability constraints and the study's focus on commodities with the clearest human food security implications.

2.5.5. Adequacy for Research Objectives

The selected commodity portfolio adequately addresses all three research objectives. For quantifying FLW, coverage spans commodity types with documented high loss susceptibility, ensuring meaningful efficiency assessment. For carrying capacity analysis, inclusion of both staples and supplementary foods enables comprehensive food security implications assessment. For economic valuation, the range from low to high-value crops captures full spectrum of economic impacts. This systematic selection process ensures findings represent meaningful shares of provincial food systems while enabling comparative analysis across commodity types with diverse characteristics and supply chain requirements.

2.6. Food Loss and Waste Quantification

Food loss and waste quantification followed established FAO methodology adapted for regional application using Southeast Asian coefficients. Analysis covered five distinct supply chain stages: production, post-harvest handling and storage, processing and packaging, distribution and marketing, and consumption. Production stage food loss can be calculated using equation (2), post-harvest food loss can be calculated using equation (3), processing food loss can be calculated using equation (4), distribution food waste can be calculated using equation (5), consumption food waste can be calculated using equation (6), total food loss and waste can be calculated using equation (7).

$$FL_{\text{production},i} = \frac{C_{\text{FAO}}}{1 - C_{\text{FAO}}} \times P_i \quad (2)$$

where $FL_{\text{production},i}$ represents food loss for commodity i at production stage, C_{FAO} denotes the FAO loss coefficient, and P_i indicates total production of commodity i .

$$FL_{\text{postharvest},i} = C_{\text{FAO}} \times P_i \quad (3)$$

where $FL_{\text{production},i}$ represents food loss for commodity i at production stage, C_{FAO} denotes the FAO loss coefficient, and P_i indicates total production of commodity i .

$$FL_{\text{processing},i} = C_{\text{FAO}} \times FM_i \quad (4)$$

where FM_i represents food material available for processing after accounting for non-food uses.

$$FW_{\text{distribution},i} = C_{\text{FAO}} \times FA_i \quad (5)$$

where FA_i indicates food available for distribution.

$$FW_{\text{consumption},i} = C_{\text{FAO}} \times FC_i \quad (6)$$

where FC_i represents food available for consumption.

$$\text{Total}_{\text{FLW},i} = FL_{\text{production},i} + FL_{\text{postharvest},i} + FL_{\text{processing},i} + FW_{\text{distribution},i} + FW_{\text{consumption},i} \quad (7)$$

2.7. Carrying Capacity Analysis

Carrying capacity analysis quantified the theoretical population that could be supported through elimination of food loss and waste. This analysis was conducted for individual commodities and in aggregate. Population carrying capacity and time carrying capacity can be calculated using equation (8) and (9).

$$CC_{\text{population}} = \frac{FLW_i \times 1,000,000}{\text{Consumption}_{\text{percapita},i}} \quad (8)$$

where $CC_{\text{population}}$ represents population carrying capacity, FLW_i indicates total food loss and waste in tons, and $\text{Consumption}_{\text{percapita},i}$ denotes per capita consumption in grams per day.

$$CC_{\text{time}} = \frac{CC_{\text{population}}}{\text{Population}_{\text{total}}} \quad (9)$$

where CC_{time} represents duration in years that current population could be supported through eliminating food loss and waste.

This analysis assumes that eliminated losses can be directly interpreted as available food supply and that per capita consumption patterns would remain constant. In practice, market dynamics, behavioral changes, and demographic factors would influence actual outcomes. The carrying capacity calculations provide theoretical upper bounds for food security potential rather than precise predictions of intervention outcomes.

2.8. Economic Loss Assessment

Economic losses were calculated by multiplying physical food loss and waste quantities by prevailing market prices. This approach provides conservative estimates as it excludes indirect costs including lost investment in inputs (seeds, fertilizers, labor), environmental costs (water, land degradation), and opportunity costs of alternative land uses [37]. Total economic loss and supply chain stage economic loss can be calculated using equation (10) and (11). Price adjustments account for handling costs at post-harvest stage (5–10% increase), processing value added (15–25% increase), wholesale markup at distribution (25–40% increase), and retail markup at consumption (40–60% increase). Average market prices were calculated from daily price monitoring data collected by the Ministry of Trade across multiple markets in South Kalimantan throughout 2024, capturing seasonal price variations while providing representative annual averages.

$$EL_i = FLW_i \times \text{Price}_i \quad (10)$$

where EL_i represents economic loss for commodity i , and Price_i indicates average market price per kilogram.

$$EL_{\text{stage},j} = FLW_{\text{stage},j} \times Price_{\text{stage},j} \quad (11)$$

where subscript j denotes specific supply chain stages, and prices are adjusted for value addition at each stage.

2.9. Efficiency Classification

Food system efficiency was classified based on total food loss and waste rates relative to production, following established international standards [11]. Efficient systems show total FLW less than 25% of production. Moderate systems show total FLW between 25–50% of production. Critical systems show total FLW greater than 50% of production. These thresholds reflect consensus in food loss and waste literature regarding acceptable efficiency levels for different development contexts. The 25% threshold represents aspirational targets set by FAO and SDG 12.3 for developing countries by 2030.

2.10. Data Analysis and Validation

2.10.1. Data Analysis

Data analysis was conducted using Microsoft Excel 2021 for Food Balance Sheet calculations, SPSS Statistics 26 for descriptive statistics, and R Studio 4.3.1 for sensitivity analysis using Monte Carlo simulation with 10,000 iterations. Results were validated through triangulation with existing literature, expert consultation with five senior agricultural extension officers with extensive field experience in South Kalimantan, plausibility checks comparing calculated consumption levels against known dietary patterns, and internal consistency verification ensuring commodity flows balance across all supply chain stages.

Sensitivity analysis tested results robustness through systematic variation in key parameters. Loss coefficient sensitivity with approximately 10% variation showed aggregate FLW ranging from 241,829 tons (44.7%) to 295,569 tons (54.7%). Price assumption sensitivity with approximately 15% variation showed total economic loss ranging from IDR 3.62 trillion to IDR 4.90 trillion. Core conclusions remain valid across reasonable parameter ranges, with efficiency classifications remaining stable and economic loss rankings unchanged across scenarios.

Primary methodological limitations include reliance on regional coefficients rather than direct local measurements (estimated uncertainty approximately 15% for individual commodities), use of secondary aggregated data that may not capture sub-provincial variations, theoretical nature of carrying capacity calculations assuming unchanged consumption patterns, and conservative economic valuation excluding indirect costs estimated at 1.5–2.0 direct market value losses. These limitations are addressed through transparent reporting of assumptions and recommendations for future validation studies through direct measurement for priority commodities, longitudinal analysis across multiple years, household-level consumption surveys, and comprehensive economic impact assessment including indirect costs.

2.10.2. Sensitivity Analysis

To assess robustness to parameter uncertainty, we tested three variations. Loss coefficient variation tested approximately 10% from FAO baseline, resulting in total FLW ranging from 44.7–54.7% (baseline 49.7%) with coefficient of variation of 8.3%. Price variation tested approximately 15% for seasonal fluctuation, yielding economic losses ranging from IDR 3.62–4.90 trillion (baseline 4.26T) with CV of 15.1%. Consumption variation tested approximately 20% for demographic heterogeneity, with carrying capacity estimates varying approximately 20% but maintaining commodity rankings.

Key findings remained consistent across all scenarios. Upstream stages consistently accounted for 80–87% of losses (baseline 83.8%), rice maintained highest efficiency with 15.2–19.8% losses (baseline 17.5%), horticulture remained the critical category with 54–65% losses (baseline 59.6–60.1%), and economic priority ranking remained unchanged: rice > orange > banana > bird's eye chili. These results indicate conclusions are robust to measurement uncertainty; strategic priorities remain valid even with approximately 10–20% parameter variation.

2.11. Study Limitations and Assumptions

2.11.1. Secondary Data Source Limitations

Production and consumption data from Indonesian statistics and government monitoring systems may contain measurement variations. Potential sources of uncertainty include reporting accuracy, where farmers may under-report production by 5–10% for tax considerations or over-report for subsidy access, introducing systematic bias in baseline production estimates. Informal market flows represent another concern, as significant horticultural trade occurs through informal channels not captured in official statistics, potentially understating actual production by 10–15% for root crops and vegetables. Additionally, spatial heterogeneity means that provincial-level aggregation masks district-level variation in infrastructure, climate, and market access that affect loss rates.

2.11.2. FAO Coefficient Adaptation

Regional loss coefficients (Table 1) represent median values across Southeast Asian countries (Indonesia, Thailand, Vietnam, Philippines, Malaysia) for 2015–2019. Specific limitations include regional averaging, where South Kalimantan's actual loss rates may vary ± 5 –10% from regional medians depending on local infrastructure, climate, and practices. Commodity aggregation is another limitation, as coefficients apply to broad categories (e.g., "fruits and vegetables"); within-category variation exists but cannot be captured at this resolution. Regarding validation status, while FAO coefficients synthesize multiple empirical studies, direct field measurement in South Kalimantan would strengthen confidence in estimates.

2.11.3. Theoretical Nature of Carrying Capacity

Carrying capacity calculations (equations 8 and 9) represent theoretical upper bounds under idealized assumptions. Constant consumption is one such assumption, where analysis assumes current per capita consumption rates (e.g., 1.66 g/day for oranges) remain stable. Income growth typically increases horticultural consumption 15–30% per decade, reducing effective time capacity. Perfect distribution is another assumption, which assumes eliminated losses could be perfectly redistributed. Actual distribution faces logistical constraints, demand-supply matching challenges, and market coordination issues. The analysis also assumes a static population, using 2024 population (4.274 million). Provincial growth of $\sim 1.2\%$ annually reduces time carrying capacity proportionally. These assumptions make carrying capacity estimates theoretical maximum potential rather than realistic policy targets. Achievable improvements would likely be 40–60% of theoretical maximum.

2.11.4. Economic Valuation Scope

Market price-based economic assessment (equations 10 and 11) excludes several important factors. Embedded input costs represent one such exclusion, as lost food represents wasted land, labor, water, energy, fertilizers, and pesticides. Including these would increase economic losses by estimated 25–35%. Environmental externalities are also excluded, where GHG (greenhouse gas) emissions from production and waste decomposition, water depletion, and soil degradation add estimated 15–25% to direct economic costs. Additionally, opportunity costs are not captured, as resources used for lost production could generate value through alternative uses. True comprehensive economic costs are estimated 30–50% higher than reported market-price values.

2.11.5. Generalizability

Findings reflect South Kalimantan's 2024 context. Applicability to other regions depends on comparable infrastructure development, geographic conditions, and policy environments. Cross-provincial research would strengthen external validity.

2.11.6. Implications for Interpretation

Despite these limitations, several aspects strengthen confidence in findings. Relative patterns remain robust, as efficiency rankings (rice > root crops > horticulture) and stage distribution (83.8% upstream) are robust to measurement variation; systematic biases would affect all commodities similarly. Regarding

magnitude, even assuming approximately 10–15% uncertainty ranges, aggregate losses of 44–55% (vs. baseline 49.7%) remain substantial enough to justify strategic priority on efficiency improvement. From a policy relevance perspective, strategic priorities (infrastructure investment, horticultural focus) remain valid even with imprecise magnitude estimates. Future research incorporating direct measurement, longitudinal data, and primary surveys would address these limitations and improve precision for policy planning.

3. RESULTS AND DISCUSSION

3.1. Production Stage Food Loss

Analysis of production stage losses reveals efficiency disparities across commodity groups (Table 2). Rice shows relatively high efficiency with 6.38% loss. Total production stage losses across all eight commodities reach 118,135 tons, representing 31.7% of aggregate FLW.

Table 2. Food loss (FL) at production stage.

| Commodity | Total production (tons) | FL production (%) | FL production (tons) | Efficiency rate (%) |
|----------------------------|-------------------------|-------------------|----------------------|---------------------|
| Rice (dry harvested grain) | 1,193,287 | 6.0 | 76,167 | 93.62 |
| Sweet potato | 8,174 | 6.0 | 522 | 93.62 |
| Cassava | 36,117 | 6.0 | 2,305 | 93.62 |
| Orange | 123,549 | 15.0 | 21,803 | 82.35 |
| Banana | 72,561 | 15.0 | 12,805 | 82.35 |
| Tomato | 4,918 | 15.0 | 868 | 82.35 |
| Large chili | 8,193 | 15.0 | 1,446 | 82.35 |
| Bird's eye chili | 12,575 | 15.0 | 2,219 | 82.35 |
| Total | 1,459,374 | | 118,135 | |

3.2. Post-harvest Food Loss

Post-harvest losses vary by commodity type (Table 3). Root crops experience highest losses at 19%, compared to 7% for rice and 9% for horticultural crops. Based on Table 3, Total post-harvest losses amount to 100,447 tons, accounting for 28.2% of total FLW across the supply chain.

Table 3. Food loss at post-harvest stage.

| Commodity | Total production (tons) | FL post-harvest (%) | FL post-harvest (tons) | Loss rate (%) |
|------------------|-------------------------|---------------------|------------------------|---------------|
| Rice (GKG) | 1,029,568 | 7.0 | 72,070 | 7.0 |
| Sweet potato | 8,174 | 19.0 | 1,553 | 19.0 |
| Cassava | 36,117 | 19.0 | 6,862 | 19.0 |
| Orange | 123,549 | 9.0 | 11,119 | 9.0 |
| Banana | 72,561 | 9.0 | 6,530 | 9.0 |
| Tomato | 4,918 | 9.0 | 443 | 9.0 |
| Large chili | 8,193 | 9.0 | 737 | 9.0 |
| Bird's eye chili | 12,575 | 9.0 | 1,132 | 9.0 |
| Total | 1,295,655 | | 100,447 | |

3.3. Processing Stage Food Loss

Processing stage analysis reveals technological polarization within South Kalimantan's food system, where rice processing achieves near-optimal efficiency while horticultural processing remains severely underdeveloped. Processing losses range from 3.5% for rice (96.5% efficiency) to 25% for horticultural crops (75% efficiency). Total processing losses reach 64,207 tons, representing 23.9% of total FLW (Table 4).

3.4. Distribution and Marketing Food Waste

Distribution stage analysis (Table 4) demonstrates how infrastructure foundations create dramatically different efficiency outcomes across commodity systems. Distribution loss rates vary significantly across commodity groups. Rice shows 2% distribution loss rate, reflecting highly efficient distribution systems. In contrast, root crops show 11% distribution loss rate, indicating greater challenges in maintaining product quality during distribution.

Table 5. Food material calculation and processing food loss.

| Commodity | Food availability (tons) | Non-food use (tons) | Food material (tons) | Processing loss (%) | Processing loss (tons) |
|------------------|--------------------------|---------------------|----------------------|---------------------|------------------------|
| Rice | 344,166 | 11,114 | 333,053 | 3.5 | 11,657 |
| Sweet potato | 6,621 | 463 | 6,157 | 10.0 | 616 |
| Cassava | 23,054 | 1,394 | 21,660 | 10.0 | 2,166 |
| Orange | 112,430 | 1,359 | 111,071 | 25.0 | 27,768 |
| Banana | 66,031 | 798 | 65,232 | 25.0 | 16,308 |
| Tomato | 4,476 | 118 | 4,358 | 25.0 | 1,089 |
| Large chili | 7,456 | 185 | 7,271 | 25.0 | 1,818 |
| Bird's eye chili | 11,444 | 303 | 11,141 | 25.0 | 2,785 |
| Total | 575,678 | 15,734 | 559,943 | | 64,207 |

Table 6. Food waste at distribution and marketing stage.

| Commodity | Food available for distribution (tons) | Distribution waste (%) | Distribution waste (tons) |
|------------------|--|------------------------|---------------------------|
| Rice | 321,396 | 2.0 | 6,428 |
| Sweet potato | 5,542 | 11.0 | 610 |
| Cassava | 19,494 | 11.0 | 2,144 |
| Orange | 83,303 | 10.0 | 8,330 |
| Banana | 48,924 | 10.0 | 4,892 |
| Tomato | 3,268 | 10.0 | 327 |
| Large chili | 5,453 | 10.0 | 545 |
| Bird's eye chili | 8,355 | 10.0 | 836 |
| Total | 495,735 | | 24,112 |

3.5. Consumption Stage Food Waste

Consumption stage (Table 6) analysis demonstrates resilience of traditional cultural values in moderating food waste, providing important insights into social dimensions of food system efficiency. Consumption waste rates of 3–7% represent relatively efficient performance at the household stage, which globally constitutes the largest share of food waste and is shaped primarily by behavioral, attitudinal, and lifestyle factors [37]. Differential waste rates between staple foods (3%) and supplementary foods (7%) were observed in the consumption stage.

3.6. Comprehensive Food Loss and Waste Assessment

Based on Table 7, integration of losses across all supply chain stages reveals 49.7% loss rate undermining food security and economic development in South Kalimantan. Aggregate food loss and waste reach 49.7% of total production, totaling 268,699 tons. Rice shows 17.5% total losses (efficient classification), root crops 38.8–42.2% (moderate), and horticultural crops 59.6–60.1% (critical). Upstream stages account for 83.8% of total losses (production 31.7%, post-harvest 28.2%, and processing 23.9%).

Table 7. Food waste at consumption stage.

| Commodity | Food available for consumption (tons) | Consumption waste (%) | Consumption waste (tons) |
|------------------|--|--------------------------|-----------------------------|
| Rice | 314,968 | 3.0 | 9,449 |
| Sweet potato | 4,932 | 3.0 | 148 |
| Cassava | 17,350 | 3.0 | 521 |
| Orange | 74,973 | 7.0 | 5,248 |
| Banana | 44,032 | 7.0 | 3,082 |
| Tomato | 2,941 | 7.0 | 206 |
| Large chili | 4,908 | 7.0 | 344 |
| Bird's eye chili | 7,520 | 7.0 | 526 |
| Total | 471,624 | | 19,524 |

Table 8. Total food loss and waste (FLW) by commodity.

| Commodity | Production loss (tons) | Post-harvest loss (tons) | Processing loss (tons) | Distribution waste (tons) | Consumption waste (tons) | Total FLW | | Efficiency classification |
|------------------|------------------------|--------------------------|------------------------|---------------------------|--------------------------|-----------|------|---------------------------|
| | | | | | | (tons) | (%) | |
| Rice | 43,170 | 47,343 | 11,657 | 6,428 | 9,449 | 118,046 | 17.5 | Efficient |
| Sweet potato | 522 | 1,553 | 616 | 610 | 148 | 3,448 | 42.2 | Moderate |
| Cassava | 2,305 | 6,862 | 2,166 | 2,144 | 521 | 13,999 | 38.8 | Moderate |
| Orange | 21,803 | 11,119 | 27,768 | 8,330 | 5,248 | 74,268 | 60.1 | Critical |
| Banana | 12,805 | 6,530 | 16,308 | 4,892 | 3,082 | 43,618 | 60.1 | Critical |
| Tomato | 868 | 443 | 1,089 | 327 | 206 | 2,933 | 59.6 | Critical |
| Large chili | 1,446 | 737 | 1,818 | 545 | 344 | 4,890 | 59.7 | Critical |
| Bird's eye chili | 2,219 | 1,132 | 2,785 | 836 | 526 | 7,498 | 59.6 | Critical |
| Total | 84,137 | 75,720 | 64,207 | 24,112 | 19,524 | 268,699 | 49.7 | |

Figure 1 illustrates the comparative food loss and waste rates across all eight strategic commodities, clearly showing the efficiency disparity between rice and horticultural crops. The bar chart displays total FLW percentage for each commodity, with rice (17.5%) shown in green representing efficient performance, root crops (38.8–42.2%) in yellow representing moderate efficiency, and horticultural crops (59.6–60.1%) in red representing 60% loss rate. Horizontal reference lines at 25% and 50% thresholds delineate these performance categories.

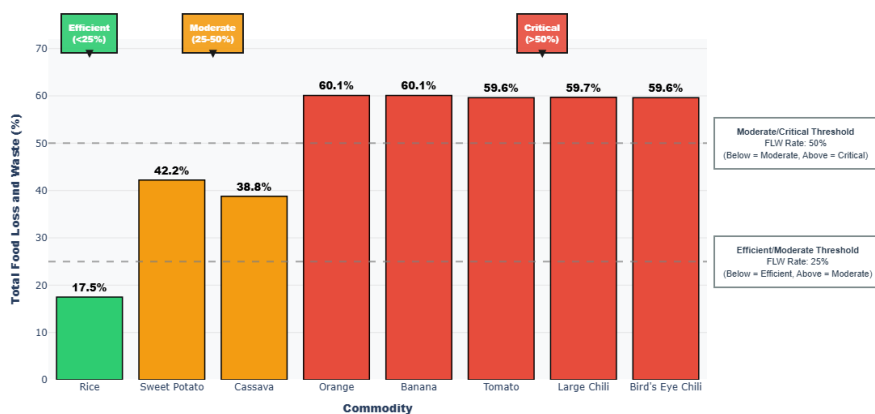


Figure 1. Total food loss and waste by commodity.

Figure 2 demonstrates the distribution of losses across supply chain stages. The stacked bar chart presents percentage contribution of each stage for all commodities, with color-coding distinguishing production (dark blue), post-harvest (medium blue), processing (light blue), distribution (orange), and consumption (red) stages. This visualization emphasizes the concentration of inefficiency in early supply chain stages across all commodity types.

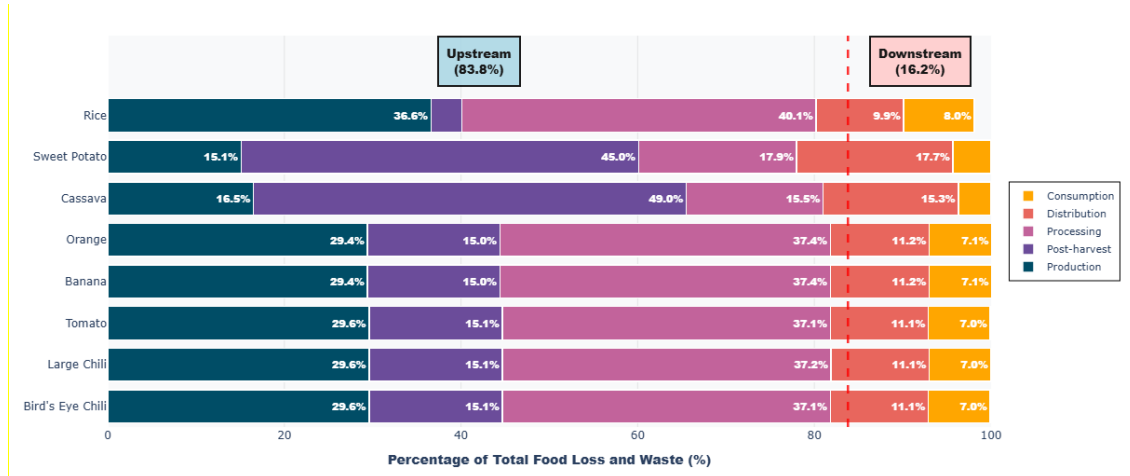


Figure 2. Food loss and waste distribution by supply chain stage.

Figure 3 presents the economic implications of food loss and waste, with rice, orange, and banana dominating total economic losses despite varying efficiency levels. The horizontal bar chart displays contribution to total IDR 4.26 trillion economic loss, with rice accounting for 39.2%, orange 21.3%, banana 18.4%, bird's eye chili 11.2%, large chili 5.5%, cassava 2.2%, tomato 1.2%, and sweet potato 1.0%. This visualization highlights that economic priority must consider both loss rates and production scale, as high-volume commodities like rice generate 39,2% economic losses even with relatively efficient supply chains.

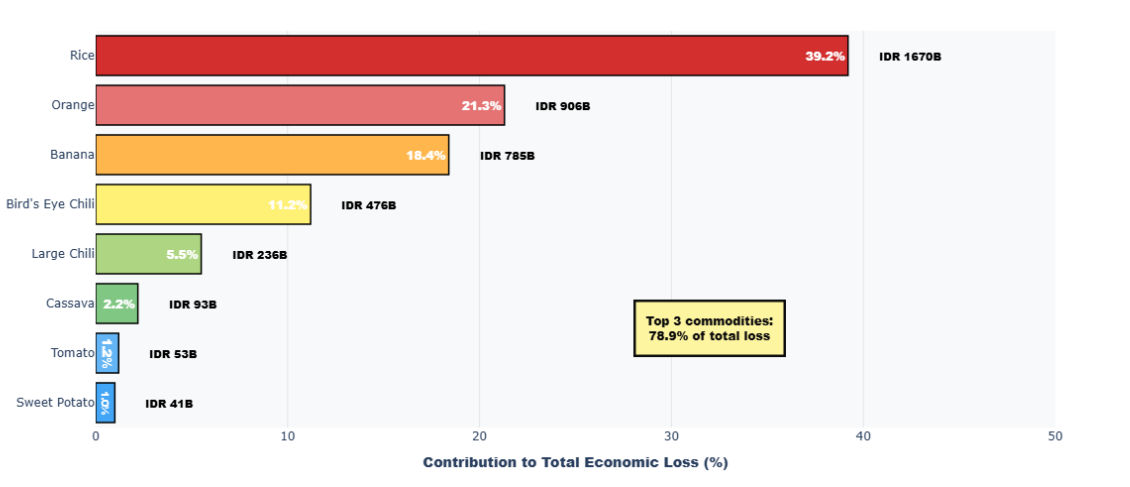


Figure 3. Economic loss distribution by commodity.

3.7. Carrying Capacity Analysis

Carrying capacity analysis of food system inefficiencies for regional food security and development potential. Carrying capacity analysis reveals that orange losses alone could theoretically sustain the provincial population for approximately 29 years at current consumption rates. Large chili losses represent

2.55 years, banana 1.94 years, and rice 0.36 years of theoretical food supply. Population carrying capacity ranges from 1.5 million person-years (rice) to 122.6 million person-years (orange) (Table 8).

Table 9. Carrying capacity analysis of food loss and waste.

| Commodity | Total FLW (tons) | Per capita consumption (g/day) | Population carrying capacity (persons/year) | Time carrying capacity (years) | Food security potential |
|------------------|------------------|--------------------------------|---|--------------------------------|-------------------------|
| Rice | 118,046 | 209.44 | 1,544,186 | 0.36 | Low |
| Sweet potato | 3,448 | 2.18 | 4,341,561 | 1.02 | Moderate |
| Cassava | 13,999 | 10.41 | 3,685,360 | 0.86 | Moderate |
| Orange | 74,268 | 1.66 | 122,624,074 | 28.69 | Very High |
| Banana | 43,618 | 14.38 | 8,307,602 | 1.94 | High |
| Tomato | 2,933 | 4.19 | 1,919,092 | 0.45 | Low |
| Large chili | 4,890 | 1.23 | 10,884,486 | 2.55 | High |
| Bird's eye chili | 7,498 | 3.18 | 6,468,411 | 1.51 | Moderate |

3.8. Strategic Importance of Horticultural Development

Horticultural crops warrant priority attention in South Kalimantan's food system development strategy for multiple interconnected reasons beyond the immediate challenge of 60% loss rates. These commodities represent critical components of dietary quality, economic opportunity, and sustainable intensification pathways.

While rice provides caloric sufficiency, horticultural crops particularly vegetables and fruits supply essential micronutrients, vitamins, and dietary fiber critical for addressing Indonesia's dual burden of malnutrition. The current 60% loss rate translates to substantial foregone nutritional value, with orange losses alone theoretically capable of meeting vitamin C requirements for the provincial population for 29 years. Reducing these losses would enhance dietary diversity and nutritional outcomes without requiring additional land or production inputs, aligning with circular economy principles emphasizing resource efficiency [22], [23].

Economically, horticultural crops offer higher returns per hectare compared to cereals, providing opportunities for smallholder income enhancement. Current loss rates undermine this potential; efficiency improvements could generate substantial economic gains for producers while stabilizing consumer prices. Market development for processed horticultural products could further enhance value capture, creating employment opportunities in processing, packaging, and distribution sectors.

From a land use efficiency perspective, horticultural crops demonstrate higher nutrient output per hectare than cereals, meaning efficiency improvements deliver disproportionate nutritional benefits relative to land saved. Regional evidence suggests that 40% reduction in post-harvest losses could save land equivalent to 6.5% of cropland area [15], with horticultural crops contributing disproportionately given current high loss rates.

Climate resilience considerations further support horticultural development priority. Diversified cropping systems including horticultural crops demonstrate greater resilience to climate variability than monoculture systems. Investment in horticultural value chains, including processing capacity enabling temporal smoothing of supply shocks, would enhance overall food system resilience while reducing dependence on single-crop food security strategies.

3.9. Economic Loss Assessment

Economic analysis quantifies financial costs of food system inefficiencies economic opportunities foregone through current supply chain management practices (Table 9). Total economic losses of IDR 4.26 trillion represent approximately 20% of South Kalimantan's agricultural GDP. This level of loss diverts resources that could otherwise support infrastructure development, education, healthcare, and other public goods essential for long-term prosperity. Rice dominates economic losses despite having the highest efficiency, contributing 39.2% of total losses. This scale effect demonstrates that even small efficiency

improvements in major commodities can generate substantial economic returns. Horticultural crops collectively account for 56.4% of economic losses, representing IDR 2.4 trillion in foregone economic value. This concentration of losses in high-value crops indicates significant opportunities for economic development through targeted efficiency improvements.

Table 10. Total economic loss analysis.

| Commodity | Average price (IDR/kg) | Total FLW (tons) | Total economic loss (billion IDR) | Contribution (%) | Priority ranking |
|------------------|------------------------|------------------|-----------------------------------|------------------|------------------|
| Rice | 14,147 | 118,046 | 1,669.99 | 39.2 | I |
| Orange | 12,202 | 74,268 | 906.22 | 21.3 | II |
| Banana | 17,988 | 43,618 | 784.60 | 18.4 | III |
| Bird's eye chili | 63,509 | 7,498 | 476.19 | 11.2 | IV |
| Large chili | 48,359 | 4,890 | 236.46 | 5.5 | V |
| Cassava | 6,639 | 13,999 | 92.94 | 2.2 | VI |
| Tomato | 18,051 | 2,933 | 52.94 | 1.2 | VII |
| Sweet potato | 12,000 | 3,448 | 41.38 | 1.0 | VIII |
| Total | | 268,699 | 4,260.72 | 100.0 | |

Distribution of economic losses across supply chain stages reveals fundamental misalignment between current policy priorities and efficiency imperatives. Upstream stages (production, post-harvest, and processing) account for 83.8% of total economic losses (Table 10). This distribution pattern suggests that infrastructure investment and technical capacity building in upstream stages offer far greater potential returns than downstream behavioral interventions [20], [30].

Table 11. Economic loss distribution by supply chain stage.

| Supply chain stage | Volume FLW (tons) | Volume share (%) | Economic loss (billion IDR) | Economic share (%) | Intervention priority |
|--------------------|-------------------|------------------|-----------------------------|--------------------|-----------------------|
| Production | 85,137 | 31.7 | 1,355 | 31.8 | I |
| Post-harvest | 75,720 | 28.2 | 1,203 | 28.2 | II |
| Processing | 64,207 | 23.9 | 1,018 | 23.9 | III |
| Distribution | 24,112 | 9.0 | 383 | 9.0 | IV |
| Consumption | 19,524 | 7.3 | 312 | 7.3 | V |
| Total | 268,699 | 100.0 | 4,261 | 100.0 | |

3.10. Infrastructure Investment Priorities

Addressing South Kalimantan's food loss challenges requires prioritized infrastructure investment targeting supply chain stages where losses concentrate most severely. Post-harvest handling and storage account for 83.8% of total losses, indicating that infrastructure deficits in these stages constitute the primary constraint on system efficiency rather than production capacity limitations.

Cold chain infrastructure emerges as the highest priority intervention. For horticultural commodities experiencing 60% losses, refrigerated storage could reduce post-harvest deterioration by 15–20% points based on West Java's experience [6]. Priority investments should include farm-level cooling facilities for rapid post-harvest temperature reduction, refrigerated transport between production and processing/retail centers, and cold storage at major distribution points. Regional systematic reviews confirm that temperature and moisture control during storage represents the most effective intervention for reducing grain losses [14], with principles extending to perishable crops.

Regional comparisons provide context for investment priorities. Myanmar's rice systems, sharing similar lowland production characteristics with South Kalimantan, achieved loss reductions from conventional levels to 3–7% through mechanized harvesting and improved storage, while simultaneously improving milled rice quality by 20–30% [38]. While South Kalimantan's rice efficiency (17.5%)

approaches regional averages, these comparative benchmarks indicate substantial improvement potential through technology adoption.

Processing infrastructure development represents the second priority. Current processing capacity limitations force farmers to market fresh produce immediately post-harvest, creating temporal supply gluts and associated price collapses. Investment in processing facilities particularly for preservation technologies such as controlled atmosphere storage and minimal processing would enable temporal demand smoothing and value capture.

International comparisons highlight infrastructure gap magnitudes. Chile's export-oriented fruit sector achieves loss rates of 25–30% compared to South Kalimantan's 60% [39], reflecting three decades of investment in integrated cold chain systems and quality management infrastructure. While Chile's export-market requirements differ from domestic orientations, fundamental principles of coordinated infrastructure investment and value chain integration offer relevant lessons.

Transport infrastructure requires upgrading to minimize handling damage and spoilage during distribution. Refrigerated transport capacity, improved road connections between production and consumption centers, and handling equipment at collection points would reduce the 2–10% transport losses documented across Southeast Asian supply chains [14]. These infrastructure investments should be sequenced strategically, beginning with commodities and supply chains where returns are highest specifically, high-value perishable crops with established market demand.

3.11. Systemic Efficiency Crisis and Development Implications

Inefficiency (approaching 60% losses) reflects fundamental infrastructure investment differences across commodity value chains in South Kalimantan. Horticultural production losses (17.65%) nearly triple rice loss rates, revealing systematic underinvestment in perishable crop value chains. This disparity stems from comprehensive systems development for rice including decades of research, infrastructure investment, extension services, and market support while horticultural crops have received minimal coordinated investment.

Aggregate food loss and waste reaching 49.7% of total production represents a critical efficiency crisis with profound development implications. The economic cost of IDR 4.3 trillion annually equivalent to 20% of provincial agricultural output value indicates that efficiency losses rival production shortfalls as constraints on food security. More critically, upstream supply chain stages (production through processing) account for 83.8% of total losses, indicating that infrastructure and technical capacity deficits, rather than consumer behavior, constitute the primary constraint.

These patterns align with broader Southeast Asian trends documented in recent assessments [15]. Transport and handling losses of 2–10% across regional supply chains underscore systematic infrastructure deficits [14]. However, provincial variations within Indonesia demonstrate that improvement is achievable: West Java's more developed cold chain infrastructure correlates with approximately 15% point lower horticultural loss rates [6], [25]. This comparison suggests targeted infrastructure investment could yield substantial efficiency gains in South Kalimantan, with provincial initiatives in integrated cold storage and cooperative marketing providing replicable models.

3.12. Institutional and Policy Requirements

Realizing South Kalimantan's food system transformation potential requires coordinated institutional development and policy support across multiple scales and sectors. Infrastructure investment alone, while necessary, proves insufficient without corresponding institutional capacity and enabling policy frameworks. Current institutional fragmentation with responsibilities split across agriculture, trade, transportation, and planning agencies hinders coordinated food system development. Establishing provincial-level coordination mechanisms for food loss reduction, through dedicated task forces or coordinating bodies, would enable integrated planning and resource allocation. Lessons from successful provincial initiatives demonstrate the importance of institutional coordination for implementing comprehensive FLW reduction strategies. Circular economy policy frameworks from leading countries emphasize multi-stakeholder governance as essential for sustainable food system transformation [6], [40].

Regulatory framework development requires attention across multiple domains. Quality standards should incentivize loss reduction rather than penalizing produce with minor aesthetic imperfections. Food safety regulations must enable rather than obstruct innovative preservation and processing approaches. Market regulations should facilitate fair value distribution across supply chain actors, ensuring that efficiency investments generate returns for all participants.

Extension service capacity building represents a critical institutional investment. Current extension systems focus predominantly on production technologies, with minimal attention to post-harvest handling, storage, and processing. Reorienting extension services toward supply chain efficiency would require curriculum development, extension agent training, and demonstration programs showcasing loss-reduction technologies.

Financing mechanisms must evolve to support efficiency-focused investment. Current agricultural financing prioritizes land expansion and production inputs, with limited mechanisms for post-harvest infrastructure. Developing specialized financing instruments including subsidized credit for cold storage, processing equipment, and transport infrastructure would facilitate private sector participation. Public-private partnership models could mobilize private capital while ensuring smallholder accessibility.

Policy instruments should include incentive structures rewarding loss reduction. Potential approaches include tax incentives for cold storage investment, certification programs recognizing supply chain efficiency, and preferential procurement policies. These market-based mechanisms would complement direct infrastructure investment by creating sustained demand for efficiency improvements.

3.13. Future Research Directions

Direct measurement validation of FAO coefficients under South Kalimantan's specific conditions would strengthen confidence in estimates and enable more precise targeting of interventions. Field-based loss quantification studies tracking commodities through actual supply chains would complement this macro-level assessment with micro-level understanding of loss mechanisms.

Comprehensive economic valuation extending beyond market prices to include embedded resource costs and environmental externalities would provide fuller picture of true costs. Life cycle assessment approaches would quantify greenhouse gas implications and inform climate-responsive policy development. Qualitative investigation of institutional and behavioral factors underlying inefficiencies would inform targeted intervention design. Understanding decision-making processes, incentive structures, and constraints faced by supply chain actors is essential for designing effective interventions addressing root causes.

Dynamic modeling of efficiency-demographic-consumption interactions would improve prediction of intervention outcomes. Current carrying capacity analysis assumes static per capita consumption; models incorporating behavioral responses would enhance policy realism. Cross-provincial comparative research examining efficiency drivers across varying development levels would strengthen understanding of which interventions prove most effective under different conditions. Rigorous impact evaluation of specific infrastructure and institutional interventions would provide evidence base for scaling successful approaches.

3.14. Concluding Remarks

While methodological limitations require cautious interpretation of specific estimates, the magnitude and consistency of findings suggest efficiency optimization represents viable pathway for strengthening food security without additional resource requirements. The 49.7% aggregate loss rate, with concentration in upstream supply chain stages, indicates that infrastructure and technical capacity development rather than production expansion constitutes the binding constraint on food system performance.

Comparative analysis indicates that fundamental transformation toward 25–30% total loss rates (approaching international benchmarks) would require sustained 15–25-year commitment with coordinated investment. However, incremental improvements of 10–15% points appear achievable within 5–10-year timeframes through focused intervention on highest-priority bottlenecks.

The strategic priority of horticultural value chain development reflects both severity of current inefficiencies (60% losses) and multiple co-benefits: enhanced dietary diversity, smallholder income opportunities, land use efficiency, and climate resilience. Future research addressing identified methodological gaps would strengthen the evidence base, though current findings provide sufficient foundation for initiating strategic reorientation toward efficiency optimization.

4. CONCLUSION

This study analyzed food loss and waste (FLW) in eight strategic food commodities in South Kalimantan Province using the Food Balance Sheet method and FAO coefficients. The results showed that total FLW reached 49.7% of production, or approximately 268,699 tons per year. The loss rate for rice was relatively low (17.5%), while horticultural commodities experienced much higher losses, approaching 60% of total production. Most losses occurred in the upstream supply chain, accounting for 83.8% of total FLW, highlighting the importance of improving post-harvest handling, storage, and initial distribution. Economic losses due to FLW are estimated at IDR 4.26 trillion per year, or approximately 20% of the province's agricultural output. Furthermore, an analysis of food carrying capacity indicates that lost food has significant potential to improve food security if utilized more efficiently. Despite limitations related to the use of secondary data and FAO regional coefficients, the findings of this study provide a strong picture of food loss patterns and the priorities for needed interventions. Overall, the research results indicate that increasing supply chain efficiency, particularly for horticultural commodities, can be an effective strategy to improve food security, reduce economic losses, and support sustainable agricultural development.

AUTHOR CONTRIBUTION

All author contributed equally to the main contributor to this paper. All authors read and approved the final paper. **Jamaluddin**: Conceptualization, methodology design, secondary data collection and analysis, Food Balance Sheet calculations, economic analysis, writing - original draft, project administration. **Hamdani**: Supervision, methodology validation, statistical analysis guidance, writing - review and editing. **Nuri Dewi Yanti**: Supervision, data validation, writing - review and editing, final manuscript approval. All authors read and approved the final manuscript.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest. This research was conducted as part of a Master's thesis without external funding. No financial or commercial relationships exist that could be construed as potential conflicts of interest.

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