LETTERS IN BIOMATHEMATICS
An International Journal

RESEARCH ARTICLE

OPEN ACCESS

Geographical Indication Governance for Agroindustrial Value Chain Upgrading through an Integrated AHP and ISM Analysis of Kintamani Arabica Coffee in Bali, Indonesia

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ABSTRACT

Legal protection of Kintamani Arabica coffee as a geographical indication (GI) does not automatically ensure competitiveness or farm-level value capture. This study integrated a historical Analytic Hierarchy Process (AHP) benchmark, Interpretive Structural Modeling (ISM), and MICMAC analysis to develop a proposed governance and value chain upgrading framework focused on Selulung Village, Bali, Indonesia. Between 2021 and 2022, Bangli Regency's Arabica cultivation area increased by 0.03%, while production and reported productivity declined by 9.78% and 12.65%, respectively. Hssistorical AHP weights prioritized private stakeholders and farmer groups (0.539), the Industry and Trade Service (0.244), the Plantation/Agriculture Service (0.123), and universities/research centers (0.094), with a reported consistency ratio of 0.044. Reconstruction of the documented structural self-interaction matrix produced a transitively closed reachability matrix comprising ten elements across six hierarchical levels and four operational tiers. Using mean driving and dependence powers of 6.0, MICMAC classified GI governance, government coordination, farmer organizations, traceability, and quality control as drivers. Monitoring and feedback, pricing and contracts, financing, diversification, and premium market positioning were dependent elements; no linkage or autonomous elements were identified. The proposed architecture combines forward product flows with bidirectional information exchange to connect institutional coordination, technical services, and market incentives. Its effects on quality, prices, income, and environmental performance require prospective field evaluation.

ARTICLE HISTORY
Received October 15, 2026
Accepted November 19, 2026

KEYWORDS
Analytic Hierarchy Process (ahp); Arabica Coffee; Circular Economy; Geographical Indication; Interpretive Structural Modeling (ism); Kintamani; Micmac Analysis; Traceability; Value Chain Upgrading.

1. Introduction

Origin-based specialty agricultural commodities derive their market differentiation and competitive advantage from the unique confluence of agroecological terroir, traditional cultivation practices, distinct sensory profiles, and institutional reputation. Kintamani Arabica coffee, cultivated on the volcanic highland slopes of Mount Batur in Bali, Indonesia, represents one of Southeast Asia's most celebrated origin-linked coffees. Recognized for its distinctive bright acidity, clean citrus and floral aroma, and medium body, the commodity achieved historic institutional recognition under Indonesian Geographical Indication (GI) Registration No. IG.00.2007.000001, making it the first registered agricultural GI in Indonesia (Directorate General of Intellectual Property, 2026; Mawardi, 2010). Through this legal certification, the name 'Kintamani' ceased to be merely an open geographic designation and was codified as a collective territorial intellectual property asset owned collectively by the producer community.

However, international experience across developing and emerging economies reveals that formal GI certification does not automatically guarantee sustained commercial competitiveness, equitable rent distribution, or farm-level value chain upgrading (Fasano & Pagliacci, 2026). The realization of economic value from GI status is conditioned on the presence of collective action, institutional cohesion, stringent quality assurance protocols, monitoring mechanisms, and coordinated supply chain linkages (Astaman et al., 2026). In fragmented smallholder landscapes, geographical indication systems frequently suffer from institutional inertia, where the initial momentum of obtaining a legal certificate is not succeeded by operational compliance enforcement, postharvest quality standardization, or transparent market linkages. In Kintamani, while the GI identity is recognized internationally, smallholder producers continue to face

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substantial vulnerabilities, including volatile cherry prices, uncoordinated marketing channels, opportunistic intermediate trading, and inadequate market feedback regarding cupping quality and export defect thresholds (Nuraisyah et al., 2025).

Regional production statistics provide context for agroindustrial upgrading. Bangli Regency's smallholder Arabica cultivated area changed from 5,921.18 ha in 2021 to 5,922.89 ha in 2022 (+0.03%), while production decreased from 2,172.48 to 1,959.91 tonnes (−9.78%) and reported productivity fell from 579.28 to 506.00 kg ha^{-1} $year^{-1}$ (−12.65%) (Bali Provincial Agriculture and Food Security Office, 2022a, 2022b). These indicators support attention to productivity, quality, and coordination alongside land management, but a two-year regional comparison does not establish the causes of decline or the effects of GI governance. Reported productivity is retained as a separate source indicator because its area denominator is not documented here and it does not equal production divided by total cultivated area.

Earlier empirical investigations into Kintamani coffee have explored individual facets of the sector, including industrial cluster development (Udayana, 2015), digital information-technology-based marketing channels (Udayana, 2017), supply chain structure and marketing mix optimization (Udayana & Wirajaya, 2021), the effectiveness of GAP implementation on specialty productivity (Suwedi et al., 2023), smallholder farmer group marketing strategies (Widari et al., 2023), agroindustrial development strategies in Ulian Village (Astini et al., 2024), and processing acceleration to empower local livelihoods (Suriati et al., 2025). While these studies establish an extensive empirical knowledge base, they collectively reveal a persistent conceptual and practical gap: upstream agronomy, postharvest biotechnology, institutional governance, traceability infrastructure, value addition, and commercial market access are consistently examined as isolated, compartmentalized interventions. In reality, value chain upgrading in a protected GI commodity requires an integrated, multi-stakeholder operational architecture wherein institutional priorities guide technical execution and market signals continuously inform production practices.

To resolve this fragmentation, an integrated multi-criteria decision-making and structural modeling approach is essential. The Analytic Hierarchy Process (AHP), pioneered by Saaty (1990), provides a rigorous mathematical framework for evaluating complex multi-actor decision environments and establishing normalized priority weights through pairwise comparisons. Concurrently, Interpretive Structural Modeling (ISM), developed by Warfield (1974) and refined by Sage (1977) and Attri et al. (2013), offers an established systems engineering methodology for mapping contextual causal relationships among heterogeneous system variables, transforming unstructured elements into a well-defined multi-level hierarchical digraph. Supplemented by MICMAC (Matrice d'Impacts Croisés Multiplication Appliquée à un Classement) analysis, ISM enables the classification of elements based on their driving power and dependence power (Sushil, 2012; Thakkar et al., 2007).

This study develops an integrated analytical and proposed operational framework for GI governance and agroindustrial value chain upgrading in Kintamani Arabica coffee, with Selulung Village as the focal setting. Its specific objectives are to:

1. Describe the documented Selulung context and regional Arabica production baseline;
2. Map cluster actors, forward product flows, and proposed return flows of quality and market information;
3. Formulate a qualitative SWOT strategic matrix synthesizing territorial strengths, systemic weaknesses, market opportunities, and environmental-market threats;
4. Integrate historical AHP actor priorities with a reproducible ISM analysis comprising SSIM conversion, reachability closure, level partitioning, and MICMAC classification; and
5. Synthesize an operational closed-loop agroindustrial model linking collective GI governance, digital lot traceability, selective processing, circular by-product valorization, and differentiated premium markets.

2. Materials and Methods

2.1 Study Area and Research Design

Selulung Village, Kintamani District, Bangli Regency, Bali Province, Indonesia, provides the focal setting for the proposed model. The village covers 5.91 km^2 and had 2,532 residents in 2024 (1,284 males and 1,248 females) across nine administrative hamlets (banjar dinas), according to BPS-Statistics of Bangli Regency (2025). These administrative data describe the setting; regional production statistics are analyzed at Bangli Regency level and should not be interpreted as village-specific measurements.

The study used a systems-based evidence synthesis combining secondary regional statistics, a historical AHP benchmark, documentary value chain analysis, qualitative SWOT synthesis, and ISM/MICMAC structural modeling. The resulting operational architecture is a proposal for implementation and evaluation. The documented analytical record does not document a new primary survey, a dated expert-elicitation protocol, or a field intervention evaluating the model.

2.2 Data Sources and Triangulation

The analysis drew on the following documentary and historical evidence streams. Source provenance is distinguished from independent verification, and the study does not assume that triangulation alone establishes validity:

1. **Official Macro-Statistics:** Regional land area, production volumes, and productivity trends were obtained from the official statistical repositories of the Bali Provincial Agriculture and Food Security Office (2022a, 2022b) and regional demographic registers from BPS-Statistics of Bangli Regency (2025).
2. **Regulatory and GI Policy Repositories:** Institutional mandates, collective specifications, and governance structures were extracted from the National Geographical Indication Book of Requirements for Kintamani Bali Arabica Coffee (Directorate General of Intellectual Property, 2026), Ministry of Law and Human Rights promotional directives (Directorate General of Intellectual Property, 2024), and Bangli Regent Regulation No. 13 of 2024 regarding the establishment and functional mandate of the Technical Implementation Unit (UPTD) Sentra IKM Kopi under the Bangli Regency Industry and Trade Office (Government of Bangli Regency, 2024).
3. **Empirical Literature and Technical Benchmarks:** Scientific data concerning Arabica cherry maturity chemistry, sensory volatile development, micro-climate vulnerabilities, postharvest processing, and cluster governance were retrieved from peer-reviewed studies (Ahmed et al., 2021; Filete et al., 2026; Mawardi, 2010; Osorio Pérez et al., 2023; Porter, 1998).
4. Historical Multi-Criteria Benchmark: Actor priority weights and accompanying consistency statistics were attributed in the available record to Udayana and Wirajaya (2021). They were retained as a historical benchmark. The original numerical pairwise comparison matrix was not included in the analytical record, so the eigenvector and maximum eigenvalue could not be independently reconstructed.
5. **Applied Technological Reports:** Downstream valorization initiatives, including organic antifungal coatings, cascara tea processing, and zero-waste coffee residue composting in Selulung, were compiled from research reports by the Directorate of Research and Community Service, Universitas Warmadewa (2025) and local export registries (Industry and Trade Office of Bangli Regency, n.d.).

2.3 Cluster and Value Chain Mapping

The structure of the Kintamani Arabica coffee agroindustrial system was mapped using industrial cluster theory (Porter, 1998) adapted to collective territorial geographical indications. Mapping captured both vertical physical flows (from agricultural input procurement, tree maintenance, selective harvesting, wet pulping, fermentation, washing, sun-drying, hulling, dry milling, grading, roasting, to domestic and export retailing) and horizontal institutional support flows (extension services, certification, credit, technological transfer, and market brokerage). Particular analytical scrutiny was directed toward identifying missing or distorted return flows—specifically cupping scorecards, green bean grading metrics, moisture content verifications, and price-premium signals from roasters back to smallholder producers.

2.4 Qualitative SWOT Synthesis

Internal organizational capabilities and external environmental factors were synthesized into a qualitative Strengths, Weaknesses, Opportunities, and Threats (SWOT) matrix, adopting the strategic management formulation framework of Rangkuti (2011). Internal factors evaluated included agroecological advantages, GI legal ownership, traditional Subak Abian social capital, processing infrastructure, quality consistency, and digital traceability capabilities. External factors evaluated included international specialty coffee market demand, third-wave coffee roaster expansion, public industrial development programs, volatile global C-market prices, climate change induced rainfall shifts, and pest-disease proliferation. Rather than relying on uncalibrated subjective scoring, the identified factors were synthesized into four strategic operational clusters: Strengths–Opportunities (SO), Weaknesses–Opportunities (WO), Strengths–Threats (ST), and Weaknesses–Threats (WT).

2.5 Analytic Hierarchy Process (AHP) Protocol

AHP provides a framework for comparing institutional actor priorities (Saaty, 1990). This study used the historical benchmark attributed to Udayana and Wirajaya (2021) for the following four actor groups; it did not conduct a new round of pairwise judgments:

- Actor 1 (A1): Direct Private Stakeholders (Subak Abian, smallholder farmer cooperatives, MPIG, private processors, exporters);
- Actor 2 (A2): Industry and Trade Service (Dinas Perindustrian dan Perdagangan / UPTD Sentra IKM Kopi);

• Actor 3 (A3): Plantation and Agriculture Service (Dinas Pertanian, Ketahanan Pangan dan Perikanan / BPP Extension Services);

• Actor 4 (A4): Higher Education and Research Institutions (Universities, research centers, accredited sensory testing laboratories).

For a positive reciprocal AHP judgment matrix $A = [a_{ij}]$, diagonal entries equal 1 and $a_{ji} = 1/a_{ij}$. Pairwise judgments are commonly elicited on Saaty's 1–9 scale. The following equations describe the benchmark method rather than a newly elicited matrix:

$A = [a_{ij}]$, $i, j = 1, \ldots, n$; $a_{ii} = 1$; $a_{ij} > 0$; $a_{ji} = 1/a_{ij}$.

The normalized priority vector w is the principal right eigenvector associated with the maximum eigenvalue λmax:

$Aw = \lambda_{max} w$; $\Sigma_i w_i = 1$.

The consistency index and consistency ratio are defined as:

$CI = (\lambda_{max} - n)/(n - 1)$.

$CR = CI/RI$.

For n = 4, RI = 0.90, and CR < 0.10 is conventionally treated as acceptable judgment consistency (Saaty, 1990). The reported λmax = 4.120 gives CI = 0.040 and CR = 0.044 after rounding. This arithmetic was checked, but the absence of the original pairwise matrix prevents independent confirmation of λmax or the reported priority vector. Acceptable CR is not proof of empirical validity or exact transitivity.

2.6 Interpretive Structural Modeling (ISM) and MICMAC Algorithm

Interpretive Structural Modeling (ISM) is an interactive structural modeling technique that transforms complex, poorly articulated mental models of systems into visually transparent, hierarchically partitioned structural directed graphs (Attri et al., 2013; Sushil, 2012; Warfield, 1974). To structure the institutional and operational upgrading of Kintamani Arabica coffee, ten strategic elements (E1 to E10) were established through stakeholder mapping and agroindustrial value chain diagnostics:

• E1: Geographical Indication (GI) and MPIG Governance Enforcement;
• E2: UPTD Sentra IKM and Multi-Agency Government Coordination;
• E3: Smallholder Farmer Organization and Subak Abian Strengthening;
• E4: Digital Lot-Based Farm Database and Value Chain Traceability;
• E5: Standard Operating Procedures (SOP), Quality Control (QC), Cupping Protocols, and Human Capital Capability;
• E6: Quality-Based Differential Pricing and Long-Term Buyer Contracts;
• E7: Value Chain Agricultural Financing and Working Capital Accessibility;
• E8: Value-Added Product Diversification and Circular By-Product Valorization;
• E9: GI Territorial Branding, Storytelling, and Premium Differentiated Markets;
• E10: Closed-Loop Monitoring, Evaluation, and Bidirectional Market Feedback.

The formal mathematical algorithm of ISM was executed through the following rigorous sequential stages:

Step 1: Structural Self-Interaction Matrix (SSIM) Construction

The contextual relation was defined as "Element E_i directly enables or facilitates element E_j." The SSIM in Table 7 was treated as the documented structural judgment set. The documented record does not specify expert numbers, selection, elicitation dates, individual judgments, or the consensus procedure; consequently, its links are interpreted as model assumptions pending documented stakeholder validation. The four operators were:

• V: $E_i \rightarrow E_j$, without a direct reverse link.
• A: $E_j \rightarrow E_i$, without a direct reverse link.
• X: $E_i \leftrightarrow E_j$.
• O: No direct link in either direction.

Step 2: Initial Reachability Matrix (IRM) Generation

The SSIM was converted to a 10 × 10 binary initial reachability matrix M using the following rules:

• V: $m_{ij} = 1$ and $m_{ji} = 0$.
• A: $m_{ij} = 0$ and $m_{ji} = 1$.
• X: $m_{ij} = 1$ and $m_{ji} = 1$.
• O: $m_{ij} = 0$ and $m_{ji} = 0$.

All diagonal entries were set to 1 to include self-reachability.

Step 3: Final Reachability Matrix (FRM) and Transitivity Verification

Transitive closure was computed by the Boolean Warshall update. A path $E_i \rightarrow E_k \rightarrow E_j$ establishes reachability from E_i to E_j; it does not, by itself, establish an empirically measured causal effect.

Initialize R = M. For k = 1, …, 10, update $r_{ij} \leftarrow r_{ij}$ OR (r_{ik} AND r_{kj}) for every i and j. The final matrix is M* = R.

An asterisk is used only when closure changes an initial 0 to 1. For the documented SSIM, no such changes were required: IRM = FRM. Driving and dependence powers were calculated from the resulting matrix:

• Driving power DP_i is the row sum, including self-reachability:

$DP_i = \Sigma_j m^*_{ij}$.

• Dependence power Dep_j is the column sum, including self-reachability:

$Dep_j = \Sigma_i m^*_{ij}$.

Step 4: Level Partitioning Iterations

Based on the Final Reachability Matrix, three sets were derived for each element E_i:

1. The **Reachability Set** R(E_i), consisting of element E_i itself and all other elements that it reaches:

$R(E_i) = \{E_j : m^*_{ij} = 1\}$.

2. The **Antecedent Set** A(E_i), consisting of element E_i itself and all other elements that reach it:

$A(E_i) = \{E_j : m^*_{ji} = 1\}$.

3. The intersection of the reachability and antecedent sets:

$I(E_i) = R(E_i) \cap A(E_i)$.

The fundamental condition for partitioning states that element E_i occupies the highest level (Level I, top of the structural hierarchy) if:

$R(E_i) = I(E_i)$.

Elements satisfying this condition were assigned to the current highest remaining level and removed. Reachability, antecedent, and intersection sets were then recalculated on the remaining submatrix. Six iterations produced Levels I–VI.

Step 5: MICMAC Analysis (Matrix of Cross-Impact Multiplications Applied to Classification)

Each element was plotted at (Dep_i, DP_i). The FRM contains 60 entries equal to 1, giving mean driving and dependence powers of 60/10 = 6.0. Values ≥ 6.0 were assigned to the high category and values < 6.0 to the low category. Thus, an element exactly on a dividing line belongs to the high category for that coordinate. This explicit convention determines the classification of E10, whose dependence equals 6.

• Quadrant I: Autonomous — DP < 6 and Dep < 6.

• Quadrant II: Dependent — DP < 6 and Dep ≥ 6.

• Quadrant III: Linkage — DP ≥ 6 and Dep ≥ 6.

• Quadrant IV: Drivers — DP ≥ 6 and Dep < 6.

2.7 Integration Architecture of AHP and ISM

AHP and ISM were integrated through role mapping rather than numerical multiplication. Historical AHP weights describe relative priorities among actor groups; ISM describes reachability among strategic elements. Actor groups were associated with relevant implementation roles, particularly E1–E3. AHP weights were not assigned independently to ISM elements, and MICMAC driving power was not inferred from AHP weights. The linkage is conceptual and operational rather than a jointly estimated quantitative model.

3. Results

3.1 Baseline and Production Performance Diagnostic

Table 1 combines the documented Selulung administrative setting with regional Arabica production indicators. The regional figures characterize Bangli Regency and do not constitute measurements of production or household income in Selulung.

Table 1. Smallholder Arabica coffee baseline and production performance in Bangli Regency and Selulung Village.

Indicator	Parameter Value	Empirical Reference	Analytical Interpretation for Agroindustrial Model
Selulung Village Total Area	5.91 km² (591.00 ha)	BPS Bangli (2025)	Village-scale cluster boundary for localized pilot implementation
Selulung Population (2024)	2,532 inhabitants (1,284 M / 1,248 F)	BPS Bangli (2025)	Local labor pool and human capital base for specialized processing
Local Administrative Units	9 Banjar Dinas	BPS Bangli (2025)	Field coordination units for farmer registration and traceability blocks
Bangli Arabica Area (2021)	5,921.18 ha	Bali Agric. Office (2022a)	Regional baseline of smallholder coffee production
Bangli Arabica Production (2021)	2,172.48 tonnes green bean	Bali Agric. Office (2022a)	Baseline annual regional commercial output
Bangli Arabica Area (2022)	5,922.89 ha	Bali Agric. Office (2022b)	Negligible land expansion (+1.71 ha or +0.03%)
Bangli Arabica Production (2022)	1,959.91 tonnes green bean	Bali Agric. Office (2022b)	Output decline of 212.57 tonnes (−9.78%) within one year.
Reported Regional Productivity	579.28 → 506.00 kg ha^{-1} $year^{-1}$	Bali Agric. Office (2022a, 2022b)	Reported decline of 73.28 kg ha^{-1} $year^{-1}$ (−12.65%); the productivity-area denominator requires source confirmation.

Cultivated area increased by 0.03%, while regional production declined by 9.78% and source-reported productivity declined by 12.65%. The productivity denominator requires confirmation from the original statistical metadata. These descriptive changes motivate consideration of farm rehabilitation, quality management, and institutional coordination, but do not isolate their causes or demonstrate the effectiveness of the proposed interventions.

3.2 Geographical Indication Standards and Lot-Based Traceability Architecture

Kintamani Arabica coffee is identified in the cited GI record under registration No. IG.00.2007.000001 (Directorate General of Intellectual Property, 2026). The proposed operational protocol emphasizes origin documentation, selective ripe-cherry harvesting, controlled processing, drying, and grading. Numerical processing targets in this manuscript are provisional operating specifications, not independently verified statements of binding GI requirements. They must be reconciled with the current official Book of Requirements before implementation. Alternative processing routes must also be checked for GI eligibility.

A proposed lot-based digital protocol links production and market records. A unique code, such as KNT-SLG-2026-B03-L012, would connect the seven data groups in Table 2. Implementation coverage, data accuracy, user accessibility, and the relationship between records and actual premiums remain to be evaluated.

Table 2. Proposed lot-based digital traceability data architecture for Kintamani Arabica coffee.

Data Group	Operational Fields	Verification Standard / Tool	Upgrading Function
1. Identity & Origin	Farmer Code, Subak Abian unit, Farm Block GPS, Tree Variety (Typica/Kartika/S-795), Altitude	Mobile GIS mapping & digital farm registry	Supports documented origin and detection of potential external blending; requires verification.
2. Harvest Data	Harvest date, gross cherry weight,	Digital optical sorting log &	Documents harvest selectivity and

	red-cherry maturity ratio (%), field-to-pulping time (<8 hrs)	scales	handling time for evaluation.
3. Processing Log	Processing route (washed, honey, or natural, subject to GI eligibility), pulper ID where applicable, fermentation conditions, and cleaning records	Route-specific station logs; calibrated sensors where available	Supports repeatable process control and investigation of quality defects.
4. Quality & Cupping	Moisture content (%), water activity (a_w), defect count (SCA Grade 1/2), cupping score (80–100), sensory notes	Calibrated moisture meter & Q-Grader cupping sheet	Documents measured quality and provides a basis for negotiated price differentiation.
5. Inventory & Lotting	Lot ID, net bag count, net weight (kg), grain-pro liner ID, warehouse temperature and relative humidity	Warehouse Management System (WMS) QR tag	Supports lot identity and storage monitoring; does not itself prevent moisture uptake.
6. Commercial Transaction	Off-taker/Buyer name, contract number, transaction date, negotiated base price, quality premium paid	Sales invoice, contract, and auditable payment records	Links physical delivery with transparent price realization for farmers
7. Closed-Loop Feedback	Roaster sensory evaluation, roast profile data, consumer feedback, defect claims, corrective actions	Cloud-based buyer feedback portal	Returns market intelligence to farmers to guide next season's cultivation/processing

3.3 Cluster Actor Mapping and Role Differentiation

Value chain upgrading requires multi-actor symbiosis rather than isolated individual efforts. Table 3 articulates the core functional roles and priority capacity-strengthening interventions across the nine primary cluster actors in Kintamani.

Table 3. ***Functional role differentiation and priority strengthening needs within the Kintamani coffee cluster.***

Cluster Actor	Institutional Mandate & Primary Function	Priority Capacity-Strengthening Need
Smallholder Farmers	On-farm husbandry, pruning, organic fertilizing, selective red-cherry picking, primary farm records	Training in GAP, organic pest control, farm rejuvenation, and digital farm logging
Subak Abian & Farmer Groups	Socio-cultural water and land coordination, collective cherry aggregation, communal labor organization	Formalizing internal control systems (ICS), standardizing harvest rules, collective price bargaining
Processing Units & Cooperatives	Controlled cherry pulping, fermentation, mechanical/sun-drying, hulling, sorting, and lot packing	Implementing GMP/SSOP standards, automated moisture monitoring, warehouse storage control
MPIG Kintamani Bali	Custodian of GI intellectual property, collective origin governance, GI logo licensing, code enforcement	Establishing independent field audit teams, strict GI label tracking, digital verification portal
UPTD Sentra IKM Kopi	Industrial service hub under Disperindag Bangli (Perbup No. 13/2024); shared processing machinery and lab	Expanding access to modern roasting/cupping facilities, SME incubation, packaging assistance
Agriculture & Extension Services	Agronomic guidance, disease mitigation, organic fertilizer subsidy allocation, seedling distribution	Aligning extension programs with measurable farm productivity targets and field soil diagnostics
Universities & Research Labs	Action research, biotechnology innovation, cupping calibration, circular economy design, impact evaluation	Joint technological development (e.g., antifungal coatings, zero-waste bio-fertilizer formulation)
Commercial	Product specification setting, off-take	Offering transparent quality-based forward

Buyers & Roasters	purchasing, specialty roasting, brand storytelling, domestic/export retailing	contracts; transmitting cupping scorecards back to groups
Financial & Tech Institutions	Pre-harvest working capital, low-interest microcredit (KUR), digital payment gateways, IoT traceability software	Designing harvest-cycle-compatible loan products; implementing accessible mobile inventory apps

3.4 Identification of Critical Bottleneck: Missing Closed-Loop Return Flow

The documentary value chain synthesis identifies limited return of quality and market information as a potential bottleneck. The cited export and local development accounts provide context, but do not quantify feedback coverage or information asymmetry among Selulung producers.

The proposed feedback mechanism would return moisture and defect assessments, cupping records, realized prices, and corrective actions to producer groups. This is intended to help producers relate farm and processing practices to buyer requirements. The prevalence of flat pricing, access to existing feedback, and the distribution of premiums require a primary baseline survey before effects can be evaluated.

3.5 Qualitative SWOT Strategic Synthesis

Table 4 presents the qualitative SWOT matrix synthesizing internal organizational capabilities against external macroeconomic and environmental forces (Rangkuti, 2011).

Table 4. Qualitative SWOT matrix for the Selulung–Kintamani Arabica coffee agroindustrial system.

Internal vs. External Factors	**Strengths (S)** **1. Official GI Registration No. IG.00.2007.000001 with strong domestic/global reputation.** **2. Unique volcanic highland agroecology (1,100–1,350 m asl, citrus-noted cup profile).** **3. Enduring socio-cultural institution of Subak Abian fostering collective solidarity.** **4. Operationalization of UPTD Sentra IKM Kopi Bangli as an industrial processing hub.** **5. Proven pilot innovations (antifungal coating, zero-waste processing, digital marketing).**	**Weaknesses (W)** **1. Absence of unified digital farmer-farm-lot database and systematic traceability.** **2. Wide farm-level variability in GAP compliance and cherry picking selectivity.** **3. Fragmented processing infrastructure and lack of localized certified cupping labs.** **4. Market dependence on unorganized collectors with flat volume-based spot pricing.** **5. Incomplete farm-gate production cost benchmarks and thin working capital reserves.**
Opportunities (O) 1. Booming global and domestic demand for single-origin specialty coffees. 2. Premium export markets (e.g., South Korea, Europe, Japan, North America). 3. Expansion of Bali horeca (hotel, restaurant, cafe) eco-tourism and coffee farm tours. 4. Government policy backing through UPTD Sentra IKM Kopi (Perbup No. 13/2024). 5. Circular economy valorization of coffee pulp/skin (cascara tea, bio-fertilizer).	SO Strategies (Growth & Differentiation) • Leverage GI legal identity and UPTD infrastructure to penetrate high-margin specialty export channels. • Expand agro-ecotourism and QR-code origin storytelling connecting tourists with Selulung coffee farms. • Scale zero-waste cascara tea and organic fertilizer production to generate secondary revenue streams.	WO Strategies (Infrastructure & Capability Upgrading) • Build a unified digital traceability system linking Subak Abian plots with UPTD processing logs. • Establish standardized QC and sensory cupping laboratories at UPTD to provide transparent grade certificates. • Formulate formal smallholder cooperatives to negotiate long-term quality-based forward off-take contracts.

Threats (T) 1. Global coffee price volatility and escalating fertilizer/logistics costs. 2. Climate change impacts (unpredictable rainfall patterns during cherry flowering and drying). 3. Aggressive market competition from other Indonesian GIs (Gayo, Toraja, Ijen). 4. Unauthorized trademark infringement and illicit blending of non-Kintamani beans. 5. Aging farmer demographic and youth outmigration to urban service sectors.	ST Strategies (Protection & Resilience Building) • Enforce strict legal protection and digital GI hologram tagging to prosecute illicit bean blending. • Promote agroforestry shade-tree management and soil conservation to mitigate climate variability. • Position Kintamani as an ultra-premium single-origin micro-lot brand to shield against C-market price swings.	WT Strategies (Vulnerability Mitigation & Reorganization) • Reorganize marketing channels away from informal middlemen toward direct cooperative-roaster trade. • Introduce season-compatible microcredit (KUR) to protect farmers from predatory pre-harvest loans. • Deploy modern mechanical drying technologies at UPTD to eliminate mold risks during unseasonal rains.

3.6 Historical AHP Actor Priorities and Consistency Arithmetic

Table 5 presents historical actor weights and reported consistency statistics attributed to Udayana and Wirajaya (2021). The weights sum to 1.000. The reported consistency arithmetic can be reproduced, but the original judgment matrix was not available for independent eigenanalysis.

Table 5. Historical AHP actor weights, proposed institutional roles, and reported consistency statistics.

Rank	Institutional Actor Group	Code	Priority Weight (w_i)	Proposed operational roles associated with historical actor groups
1	Direct Private Stakeholders	A1	0.539	Primary operational drivers: MPIG Kintamani Bali (GI custodian), Subak Abian, farmer cooperatives, private processing units, specialty roasters, and commercial exporters.
2	Industry and Trade Service	A2	0.244	Industrial hub and market facilitators: Bangli Regency Disperindag and UPTD Sentra IKM Kopi (providing shared machinery, processing standardization, SME incubation, and trade promotion).
3	Plantation & Agriculture Service	A3	0.123	Upstream technical authority: Bangli Regency Agriculture Office, Food Security Agency, and BPP field agricultural extension officers (providing GAP training, seedling distribution, pest control).
4	Universities & Research Centers	A4	0.094	Knowledge and innovation partners: Universitas Warmadewa, Universitas Udayana, and analytical laboratories (providing biotechnology, antifungal coatings, cupping validation, and policy monitoring).
Total			1.000	Reported λmax = 4.120; CI = 0.040; RI = 0.900; CR ≈ 0.044. Arithmetic checked; original judgment matrix unavailable.

Private stakeholders and the Industry and Trade Service account for 0.783, or 78.3%, of the normalized historical priority weights. This indicates their relative priority within that benchmark, not a measured share of institutional capability or MICMAC driving power. Using the reported λmax = 4.120 gives CI = 0.040 and CR ≈ 0.044, below 0.10. The provenance and continued relevance of the benchmark require confirmation against the original judgment records and current stakeholder priorities.

3.7 Mathematical Execution of Interpretive Structural Modeling (ISM)

Identification and Definition of Strategic Elements

Ten strategic elements were defined through the documentary cluster and value chain synthesis (Table 6).

Table 6. Strategic elements established for the Kintamani coffee agroindustrial system.

Element Code	Strategic Element Name	Operational Definition and Scope
E1	GI and MPIG Governance	Enforcement of collective GI Book of Requirements, GI brand protection, member certification, and internal audit.
E2	UPTD and Government Coordination	Multi-agency administrative integration (Disperindag, Agriculture Office, UPTD) providing shared machinery and services.
E3	Farmer Organization & Subak	Strengthening Subak Abian collective discipline, aggregation capacity, harvest scheduling, and internal control systems.
E4	Lot Traceability & Farm Database	Implementation of digital plot-level GPS mapping, farmer coding, harvest tagging, and end-to-end QR-code tracking.
E5	SOP, QC, Cupping & HR Capacity	Standardizing wet postharvest protocols (GMP/SSOP), mechanical moisture verification, Q-Grader cupping, and technical training.
E6	Quality Pricing & Buyer Contracts	Establishing transparent grading-based price scales, quality premiums, and multi-year direct-trade forward contracts.
E7	Value Chain Financing	Integrating harvest-cycle-compatible microfinance (KUR), working capital credit for cooperatives, and equipment financing.
E8	Diversification & Circular Economy	Commercialization of secondary products: cascara herbal tea, organic coffee-pulp compost, bio-briquettes, and honey coffee.
E9	GI Branding & Differentiated Markets	Strategic positioning of Kintamani single-origin specialty coffee in premium domestic horeca, direct-trade roasters, and export niches.
E10	Monitoring, Evaluation & Feedback	Establishing bidirectional reporting systems returning roaster cupping scorecards and market data to primary producers.

Structural Self-Interaction Matrix (SSIM)

The documented SSIM applies the relation "E_i directly enables or facilitates E_j" (Table 7). It was converted and checked as a structural judgment set. Because the elicitation record is incomplete, the matrix is presented transparently for replication and subsequent stakeholder review rather than described as independently validated expert consensus.

Table 7. Structural Self-Interaction Matrix (SSIM) for Kintamani Arabica coffee upgrading.

Elements	E10	E9	E8	E7	E6	E5	E4	E3	E2	E1
E1	V	V	V	V	V	V	V	X	X	—
E2	V	V	V	V	V	V	V	X	—	
E3	V	V	V	V	V	V	V	—		
E4	V	V	V	V	V	X	—			
E5	V	V	V	V	V	—				
E6	A	V	V	X	—					
E7	A	V	V	—						
E8	A	V	—							
E9	A	—								
E10	—									

Initial and Final Reachability Matrices with Transitivity Verification

Binary conversion of Table 7 produced an initial matrix that was already transitively closed. Boolean closure therefore added no links. Table 8 displays the identical initial and final matrices. E10 → E6, E7, E8, and E9 are direct relations specified by A entries in

the SSIM and are therefore reported without transitivity asterisks.

Table 8. Initial and final reachability matrix with verified driving and dependence powers.

Elements	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	DP	DP rank
E1	1	1	1	1	1	1	1	1	1	1	10	1
E2	1	1	1	1	1	1	1	1	1	1	10	1
E3	1	1	1	1	1	1	1	1	1	1	10	1
E4	0	0	0	1	1	1	1	1	1	1	7	2
E5	0	0	0	1	1	1	1	1	1	1	7	2
E6	0	0	0	0	0	1	1	1	1	0	4	4
E7	0	0	0	0	0	1	1	1	1	0	4	4
E8	0	0	0	0	0	0	0	1	1	0	2	5
E9	0	0	0	0	0	0	0	0	1	0	1	6
E10	0	0	0	0	0	1	1	1	1	1	5	3
Dep	3	3	3	5	5	8	8	9	10	6	Total = 60	
Dep rank	6	6	6	5	5	3	3	2	1	4		

Note: IRM = FRM; transitive closure introduced no additional entries. DP and Dep include self-reachability. Row and column totals both equal 60. Dense ranks are reported separately for DP and Dep and do not denote ISM levels.

Level Partitioning Iterations

Level partitioning on the remaining submatrix at each iteration produced six levels. Table 9 gives the assigned elements and their reachability, antecedent, and intersection sets at the iteration in which they were removed.

Table 9. Iterative level partitioning on the remaining reachability submatrix.

Iteration	Element	Reachability set R	Antecedent set A	Intersection R ∩ A	Level
1	E9	9	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	9	I
2	E8	8	1, 2, 3, 4, 5, 6, 7, 8, 10	8	II
3	E6	6, 7	1, 2, 3, 4, 5, 6, 7, 10	6, 7	III
3	E7	6, 7	1, 2, 3, 4, 5, 6, 7, 10	6, 7	III
4	E10	10	1, 2, 3, 4, 5, 10	10	IV
5	E4	4, 5	1, 2, 3, 4, 5	4, 5	V
5	E5	4, 5	1, 2, 3, 4, 5	4, 5	V
6	E1	1, 2, 3	1, 2, 3	1, 2, 3	VI
6	E2	1, 2, 3	1, 2, 3	1, 2, 3	VI
6	E3	1, 2, 3	1, 2, 3	1, 2, 3	VI

The six discrete mathematical levels are condensed into four overarching operational tiers to guide policy implementation:

- Tier IV: Root Institutional Drivers (Level VI) — E1 (GI/MPIG Governance), E2 (UPTD-Government Coordination), and E3 (Farmer Organization & Subak). These elements possess the maximum driving power (DP = 10) and lowest dependence (Dep = 3).
- Tier III: Technical and Informational Infrastructure (Levels V & IV) — E4 (Lot Traceability & Farm Database), E5 (SOP, QC, Cupping & HR Capacity), and E10 (Monitoring, Evaluation & Feedback).
- Tier II: Economic Operations and Value Realization (Levels III & II) — E6 (Quality Pricing & Buyer Contracts), E7 (Value Chain Financing), and E8 (Diversification & Circular Economy).
- Tier I: Strategic Outcome (Level I) — E9 (GI Branding and Differentiated Premium Markets), with DP = 1 and Dep = 10. All modeled elements reach E9, whereas E9 reaches only itself. This is a structural property of the specified model rather than a measured effect on brand value.

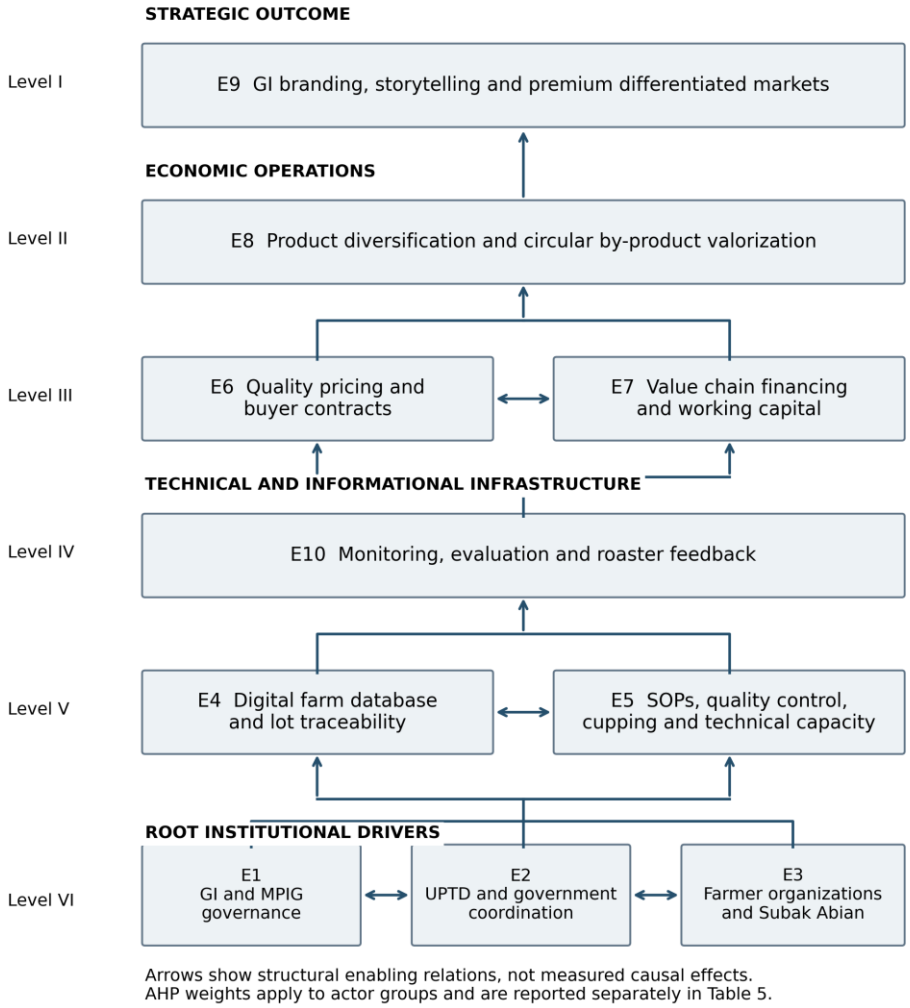

Figure 1. *ISM hierarchy with six levels and four operational tiers. Arrows indicate modeled enabling directions; reciprocal links identify mutually reachable elements. Historical AHP actor weights remain separate in Table 5.*

3.8 MICMAC Driving-Dependence Power Analysis

Figure 2 plots the actual coordinates from Table 8 using the specified mean boundaries (Dep = 6.0; DP = 6.0). The boundary convention assigns values equal to 6.0 to the high category. Table 8 and Figure 2 therefore classify E4 and E5 as drivers, and E10 as dependent.

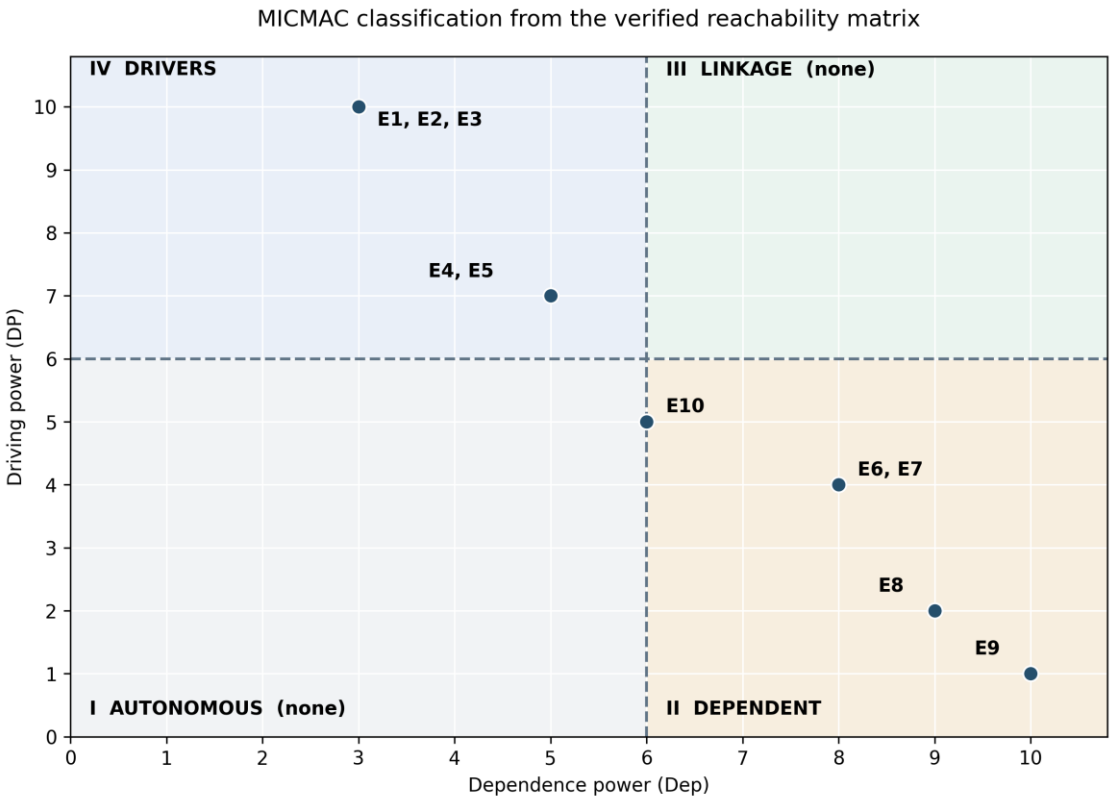

Figure 2. MICMAC analysis quadrant classification of the ten strategic elements.

The MICMAC analysis yields critical insights into the structural dynamics of the agroindustry:

1. Quadrant IV — Drivers: E1, E2, and E3 have DP = 10 and Dep = 3. E4 and E5 also belong to this quadrant, with DP = 7 and Dep = 5. The first group forms the root institutional level; the second forms the technical level above it. “Driver” is a MICMAC category and does not imply that every driver occupies the lowest ISM level.

2. Quadrant III — Linkage: No elements satisfy DP ≥ 6 and Dep ≥ 6. E4 and E5 meet the driver criteria, whereas E10 meets the dependent criteria under the stated mean-based classification.

3. Quadrant II — Dependent: E6 and E7 have (Dep, DP) = (8, 4), E8 has (9, 2), E9 has (10, 1), and E10 has (6, 5). E10 lies on the dependence boundary and is assigned to the high-dependence category. Its dependent classification is compatible with its position at ISM Level IV and in the technical and informational infrastructure tier.

4. Quadrant I — Autonomous: No elements have both DP < 6 and Dep < 6. Empty autonomous and linkage quadrants describe this particular matrix and threshold rule; they do not establish completeness, causal validity, or universal stability of the system.

3.9 The Integrated Selulung-Kintamani Agroindustrial Upgrading Model

The proposed Integrated Selulung–Kintamani Agroindustrial Model translates the analytical ordering into six forward product stages and four cross-cutting support systems. Bidirectional information exchange would return cupping scores, defects, and realized prices to producer groups. Figure 3 distinguishes these information flows from the forward physical product chain. The architecture has not yet been evaluated as an implemented intervention.

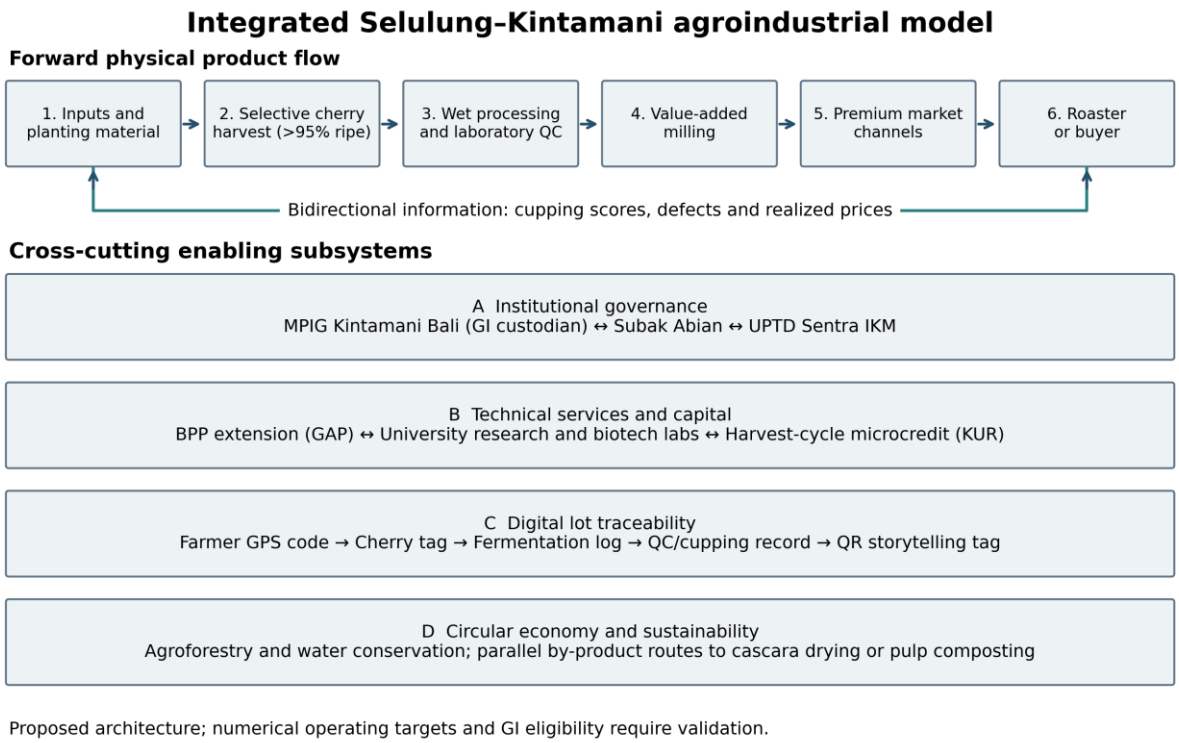

Figure 3. Conceptual operational architecture of the closed-loop Selulung–Kintamani Arabica Coffee Agroindustrial Model.

The operational execution of this architecture is partitioned across nine interconnected functional subsystems, detailed in Table 10.

Table 10. Proposed operational guidelines and provisional indicators for nine functional subsystems.

Operational Subsystem	Core Functional Mandate	Lead Implementing Actor(s)	Provisional KPI or operating target to validate
1. Seedling & Input Procurement	Supply of certified high-altitude Arabica varieties (S-795, Kartika), organic fertilizers, and shade-tree saplings.	Agriculture Office & Subak Abian	Record seedling provenance and plant health; agree a verified supply-coverage target.
2. Agroforestry & GAP Cultivation	Implementation of contour planting, terracing, shade regulation (legumes/oranges), and organic compost application.	Smallholder Farmers & Extension Service (BPP)	Provisional targets: ≥30% shade canopy and 25% yield improvement; validate agronomic suitability and baseline.
3. Selective Cherry Harvesting	Enforcing strict manual selective harvesting of fully ripe red cherries (>95% ripe; elimination of green/overripe fruit).	Subak Abian & Field Pickers	Cherry sorting log showing <5% green/defective cherries per batch
4. Standardized Wet Processing	Modern depulping, controlled fermentation (pH 4.5–5.0), clean washing, and parabolic drying to 11.5% moisture.	Village Processing Centers & UPTD Sentra IKM	Provisional moisture target: 11.0–12.0%; verify applicable GI/buyer limits and monitor mold indicators.
5. Value-Added Milling & Roasting	Hulling, gravity sorting, screen size calibration, defect elimination, specialty profile roasting, and nitrogen packaging.	UPTD Sentra IKM & Local Cooperatives	Provisional target: >85% output meeting agreed buyer grade; verify grading protocol and recovery basis.
6. Quality	Calibrated sensory cupping by	Accredited University Labs	Proposed reporting unit: one quality report

Certification & Cupping	certified Q-Graders, physical green bean grading, water activity testing, and lot certificates.	& MPIG Quality Panel	per 500-kg lot; adapt to actual lot size.
7. Digital Lot Traceability	Generating unique QR-codes connecting farm plot GPS, harvest date, process parameters, cupping notes, and producer photo.	Disperindag Bangli & Tech Providers	Proposed target: QR records for all exported lots; audit completeness, accuracy, and accessibility.
8. Closed-Loop Market Linkage	Direct-trade contracts with specialty roasters; transmission of cupping feedback; distribution of quality premiums to farmers.	Farmer Cooperatives & Specialty Roasters	Aspirational target: 20% premium over a defined comparable local farm-gate baseline; evaluate net returns and distribution.
9. Circular Bio-Valorization	Solar drying of fresh coffee skins for export cascara tea; microbial composting of mucilage and pulp into bio-fertilizer.	Women Farmer Groups (KWT) & Univ. Warmadewa	Measure by-product recovery, residual discharge, costs, and product sales; assess food/feed safety where applicable.

4. Discussion

4.1 Geographical Indication as an Agroindustrial Governance Asset

The framework treats GI protection as a collective governance arrangement whose economic benefits depend on implementation, quality assurance, and market relationships (Fasano & Pagliacci, 2026; Mawardi, 2010). The regional production decline does not establish that GI protection caused or failed to prevent that decline. Rather, the model identifies coordination and verification functions that can be examined in a prospective implementation study.

Within the proposed framework, MPIG and Subak Abian would coordinate compliance with the applicable GI Book of Requirements, maintain membership and origin records, and organize internal checks (Astaman et al., 2026; Mawardi, 2010). Current legal specifications and institutional mandates should be verified against the authoritative documents before adopting operating thresholds or assigning enforcement responsibilities.

4.2 Decoupling Agribusiness Competitiveness from Land Expansion

The 2021–2022 regional statistics show nearly unchanged cultivated area alongside lower production and reported productivity (Table 1). This pattern supports investigation of productivity and quality constraints, but does not establish that land expansion is ineffective or identify the sources of yield decline. The analysis also requires care because total cultivated area and the area used for reported productivity may differ.

Farm rehabilitation, shade management, soil management, selective harvesting, and processing control are candidate interventions for evaluation. The cited studies associate coffee quality with environmental conditions, maturity, and management (Ahmed et al., 2021; Filete et al., 2026; Osorio Pérez et al., 2023; Suwedi et al., 2023; Astini et al., 2024). The present study did not measure sugars, microbial activity, sensory changes, or premium responses, so specific biochemical mechanisms and economic effects remain hypotheses.

4.3 Methodological Synergy of Integrated AHP-ISM Analysis

The methodological contribution is a transparent connection between historical actor priorities and the structural ordering of proposed interventions. The framework complements earlier Kintamani cluster and marketing studies (Udayana, 2015; Udayana & Wirajaya, 2021; Widari et al., 2023), but does not demonstrate superior policy performance relative to alternative methods.

AHP supplies historical priorities for actor groups, while ISM organizes modeled enabling relationships (Thakkar et al., 2007). The two highest AHP weights sum to 0.783; this is a share of normalized priority, not institutional capability. Reconstructing the SSIM confirms six ISM levels and the root position of E1–E3. Without the original AHP judgment matrix and a documented SSIM elicitation protocol, computational consistency must be distinguished from independent empirical validation.

MICMAC assigns E1–E5 to Quadrant IV and E6–E10 to Quadrant II under the mean-based rule. E4 and E5 retain their technical role within ISM despite their driver classification, whereas E10 remains in that technical tier but is dependent in MICMAC. No linkage elements are identified. E9 is reached by every element and has DP = 1; this supports coordinating branding with upstream functions within the model, but does not prove that stand-alone promotion is ineffective or quantify any policy return.

4.4 Traceability Infrastructure and Closing the Feedback Loop

The value chain synthesis motivates a feedback mechanism linking producer practices, quality records, and buyer information. The prevalence of information asymmetry in Selulung was not measured through a documented primary sample. Baseline work should establish who currently receives quality assessments, how prices are determined, and how feedback is used (Nuraisyah et al., 2025).

The proposed protocol in Table 2 would link a lot identifier to farmer origin, harvest and processing records, quality assessments, and realized prices. A provisional 500-kg reporting unit is an implementation option, not an observed operating standard. Returning buyer assessments could support producer learning, but data accuracy, access, adoption, and effects on premiums and their distribution require pilot evaluation.

4.5 Institutional Symbiosis: MPIG, UPTD Sentra IKM, and Academia

The cited Bangli Regent Regulation No. 13 of 2024 is used in the supplied documentary account to locate UPTD Sentra IKM Kopi within the institutional architecture (Government of Bangli Regency, 2024). The proposed service roles below should be reconciled with the current regulation and an assessment of actual staffing, equipment, accreditation, and service capacity.

Within the proposed integrated architecture, an explicit division of institutional responsibilities is established:

1. **MPIG Kintamani Bali** functions as the legal guardian of the collective territorial brand, responsible for GI rule enforcement, internal compliance auditing, and certifying authentic product origin;

2. UPTD Sentra IKM Kopi is proposed as a shared processing and technical service hub. Equipment procurement, laboratory accreditation, service pricing, and access arrangements would require a documented capacity and feasibility assessment;

3. Subak Abian and Primary Cooperatives serve as the localized production and cherry aggregation base, enforcing communal harvesting rules and managing farmer member registries;

4. Universities and research centers would support process development, quality-method calibration, and evaluation. The local technological initiatives cited in the documentary record motivate these roles but do not establish that the integrated model has already been validated (Directorate of Research and Community Service, Universitas Warmadewa, 2025).

4.6 Circular Bio-Economy and Downstream Value Addition

Diversification and circular economy practices (E8, Tier II) are proposed options for by-product management and additional revenue. Their environmental and economic benefits depend on process inputs, yields, product quality, markets, and the baseline waste pathway; these outcomes were not quantified in the present structural analysis.

Cascara production and pulp composting are candidate valorization pathways motivated by the cited local accounts (Directorate of Research and Community Service, Universitas Warmadewa, 2025; Suriati et al., 2025). An export record alone does not establish buyer demand for zero-waste production or the commercial feasibility of these pathways. Food or feed applications require appropriate safety and regulatory assessment, while profitability, substitution effects, emissions, and household benefits require dedicated measurements.

5. Conclusions and Policy Recommendations

5.1 Conclusions

This study combined secondary regional evidence, historical AHP actor priorities, and a reproducible ISM/MICMAC analysis to propose a GI governance and value chain upgrading framework for Kintamani Arabica coffee. Bangli Regency's 2021–2022 statistics show a 0.03% increase in cultivated area alongside declines of 9.78% in production and 12.65% in reported productivity. These descriptive trends motivate investigation of farm and value chain constraints; they do not establish causal effects of governance or the proposed model.

The integrated analysis yields the following results and proposed implementation structure:

1. Historical AHP priorities were 0.539 for private stakeholders, 0.244 for the Industry and Trade Service, 0.123 for the Plantation/Agriculture Service, and 0.094 for universities/research centers. The reported CR = 0.044 is below 0.10, but independent eigenanalysis requires the original pairwise matrix.

2. The documented SSIM produced a transitively closed matrix without additional links. Level partitioning assigned E9 to Level I, E8 to Level II, E6–E7 to Level III, E10 to Level IV, E4–E5 to Level V, and E1–E3 to Level VI. The four operational tiers distinguish institutional drivers, technical and informational infrastructure, economic operations, and the strategic market outcome.

3. With mean boundaries at DP = 6 and Dep = 6, and equality assigned to the high category, MICMAC classified E1–E5 as

drivers and E6–E10 as dependent elements. Neither linkage nor autonomous elements were identified. These classifications describe structural reachability and must not be interpreted as measured causal effects or proof of policy effectiveness.

4. The proposed operational architecture combines forward product flows with bidirectional quality and market information exchange. Pilot implementation is required to determine whether the proposed coordination, traceability, processing, financing, and valorization arrangements improve quality, price realization, household income, or environmental performance.

5.2 Managerial and Policy Recommendations

The following recommendations are proposed for stakeholder consideration and pilot design; numerical operating targets require local agreement and validation:

• **For the Bangli Regency Government and Disperindag:** Accelerate the operational capacity of UPTD Sentra IKM Kopi (Perbup No. 13/2024) by equipping the center with accredited sensory cupping equipment, sample roasters, and grain testing laboratories. The UPTD should function as an open-access industrial service hub providing affordable processing services and digital QR-code lot tagging for smallholder cooperatives.

• **For MPIG Kintamani Bali:** Transition from a passive intellectual property administrative entity into an active territorial governance authority. Establish a trained internal audit team to conduct rigorous farm-level compliance inspections, enforce selective harvesting standards, monitor green bean moisture limits (11.0–12.0%), and license GI labels exclusively to verified, traceable lots.

• For Subak Abian and Farmer Cooperatives: Reinvigorate traditional collective norms to enforce selective red-cherry picking (>95% ripeness) among members. Establish communal collection centers equipped with digital scales and optical sorting logs, aggregating volume to negotiate direct-trade, quality-based forward contracts with specialty roasters while bypassing speculative middlemen.

• **For Commercial Buyers, Roasters, and Exporters:** Implement transparent, multi-tier pricing structures that pay measurable cash premiums for SCA Grade 1 specialty lots. Systematically share digital cupping scorecards and roast performance evaluations with producer groups to support continuous agroindustrial learning.

• **For Universities and Research Institutions:** Deepen action-research partnerships with UPTD and Selulung cooperatives, scaling up biotechnological applications such as organic antifungal green bean coatings, optimizing anaerobic wet fermentation protocols, and developing commercial packaging for circular cascara tea and organic bio-fertilizer.

5.3 Limitations and Directions for Future Research

The analysis is limited by its use of secondary regional data, a historical AHP benchmark without the original pairwise matrix, and an SSIM without a complete elicitation record. Reported productivity denominators and documentary legal/technical specifications require source-level confirmation. The operational targets in Table 10 are provisional and were not observed impacts. MICMAC results depend on the selected threshold and its equality convention; alternative thresholds should be examined in sensitivity analysis. Structural reachability and internal computational consistency do not establish causality, stakeholder consensus, or economic feasibility. Future work should document stakeholder recruitment and judgments, update AHP priorities, review SSIM links, and prospectively evaluate pilot lots against baseline quality, price, cost, income, and environmental indicators.

Acknowledgements

The authors express their profound gratitude to Universitas Warmadewa and Universitas Udayana for institutional, financial, and laboratory support. Sincere appreciation is extended to the Bangli Regency Government, the Industry and Trade Office (Disperindag), the Agriculture and Food Security Office, the management of UPTD Sentra IKM Kopi Bangli, the board of MPIG Kintamani Bali, the community leadership and Subak Abian members of Selulung Village, specialty coffee roasters, and all participating stakeholders who provided invaluable data, field access, and expert validation.

Author Contributions

• **I Gusti Bagus Udayana:** Conceptualization, methodology, formal AHP-ISM mathematical modeling, agroindustrial value chain framework development, investigation, project administration, supervision, and writing—original draft.

• **I Gusti Lanang Putu Tantra:** Economic and value chain analysis, business strategy evaluation, data validation, and writing—review and editing.

• **Made Sri Sumarniasih:** Agricultural and agroforestry systems analysis, field baseline validation, sustainability and circular bio-economy analysis, methodology, and writing—review and editing.

Data Availability Statement

Secondary statistical and documentary sources are cited in the reference list. The documented SSIM, identical initial/final reachability matrix, and corrected partition sets are reported in Tables 7–9, allowing reconstruction of the ISM results. The original AHP pairwise comparison matrix, complete SSIM elicitation records, and underlying primary field records are not included in the available analytical record; independent verification of those components requires access to the authors' source records.

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