

Integrated institutional model and API-based information system for seaweed agribusiness governance in South Sulawesi, Indonesia

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Abstract. Haruna B, Yunarti, Zam W. 2026. *Integrated institutional model and API-based information system for seaweed agribusiness governance in South Sulawesi, Indonesia.* *Asian J Agric* 10 (1): g100170. <https://doi.org/10.13057/asianjagric/g100170>. This study aimed to strengthen the governance of the seaweed agribusiness value chain in South Sulawesi, Indonesia, by developing an integrated institutional model and API-based information system. Preliminary analysis shows that the value chain is still characterized by information asymmetry, the dominance of intermediaries in market access, weak coordination between actors, and the lack of digital recording and consistent quality standards. This condition increases the cost of information, negotiation, and monitoring, and limits the bargaining position of farmers. The research uses a qualitative case study approach through in-depth interviews, FGD, document analysis, and expert validation. The data is thematically analyzed to map the actors, governance relationships, and main sources of transaction costs. The results of the analysis were used to design a new institutional model that strengthens the role of cooperatives and farmer groups as nodes for coordination, data consolidation, and collective negotiation, while improving working relationships with local governments, financial institutions, exporters, and universities. The model is operationalized through an API-based information system that supports data exchange, production recording, market demand, and documentation of transactions between actors. Validation is carried out through simulation-based functional testing of key operational scenarios, including production recording, market demand delivery, harvest ordering, and data synchronization between authorized users. The test results showed that the system was able to run key process flows consistently and provide a more transparent digital footprint for coordination needs. In agribusiness, this design has the potential to increase marketing certainty, assist production planning based on demand, accelerate coordination between sectors, and reduce farmers' reliance on informal information. Theoretically, these findings suggest that digitalization for smallholders will be more effective if it is accompanied by institutional restructuring, not just technology adoption. The developed system has achieved functional feasibility as the basis for pilot implementation and advanced field evaluation in South Sulawesi.

Keywords: API-driven platform, institutional model, seaweed agribusiness, transaction costs, value chain governance

Abbreviations: API: Application Programming Interface, FGD: Focus Group Discussion, NIE: New Institutional Economics, RBAC: Role-Based Access Control

INTRODUCTION

Indonesia is the world's largest producer of seaweed, contributing significantly to the coastal economy through job creation, household income, and the export of value-added products. However, this significant potential is limited by structural inefficiencies within the value chain. Rahmat et al. (2024) emphasized that institutional and coordination barriers, such as the dominance of intermediaries and inconsistent quality standards, remain primary constraints. In eastern coastal regions, including production centers in South Sulawesi such as Takalar, Bulukumba, Sinjai, Luwu, and Pangkep, farmers remain trapped in a dependency on collectors who control information. This weak position is worsened by local institutions that are unable to engage in collective bargaining or independently integrate market data (Kopp and Sexton 2020).

These inefficiencies are closely related to the high transaction costs caused by uncertain standards, fragmented information flows, and limited access to formal financing. Chatterjee (2023) explained that chronic reliance on

intermediaries leads to an unfair distribution of added value, where farmers receive only the lowest margins. Similar patterns are common in the agribusiness systems of developing countries, where collective institutions such as cooperatives often fail to reduce market risk (Muhonda et al. 2024). Consequently, technology adoption remains low, product standardization has stalled, and market improvement has become difficult (Utama et al. 2025).

The NIE perspective provides an analytical framework to understand inefficiencies that persist. NIE emphasizes that institutions determine incentive structures by regulating transaction costs, which include search, negotiation, and monitoring. According to Ghatak and Mookherjee (2025), information asymmetry and incomplete contracts impose high coordination costs on business actors, which, in turn, reduce incentives for productive investment. Although institutional innovation is considered capable of strengthening the position of smallholder farmers, implementation often fails due to a weak documentation system (Mardenli et al. 2024). This represents a gap in current literature as NIE principles are frequently discussed theoretically, while empirical studies

that operationalize these principles into concrete designs at the regional commodity level remain limited (Frolov 2021).

Conventional institutional strengthening alone, such as expanding cooperatives or formalizing farmer groups, is often insufficient in the seaweed agribusiness because the underlying problem is not only organizational weakness but also a failure of real-time coordination among actors involved in production, finance, logistics, quality control, and export transactions. Therefore, institutions require governance mechanisms that continuously update prices, record transactions, verify standards, and synchronize decisions among dispersed actors. Without these functions, cooperatives may reproduce existing inefficiencies rather than address them. For this reason, digital governance is institutionally necessary, not merely technically desirable.

From the perspective of NIE, digital systems function as a governance infrastructure that lowers search costs, strengthens contract enforcement, and enhances transparency in quality assurance. Digital platforms and technology-driven advisory services also support more accurate logistical coordination (Iliopoulos et al. 2025). In particular, the API architecture enables interoperability among farmers, cooperatives, collectors, financial institutions, exporters, researchers, and government agencies by enabling fragmented systems to exchange verified data in real-time (López-Morales et al. 2020). However, digitalization can also create new concentrations of power if data ownership, access rights, and governance rules are poorly designed (Reisman et al. 2024). In addition, low digital literacy and uneven internet access in coastal areas show that technology alone is not enough (Hackfort 2021). Therefore, effective transformation requires the integration of technical architecture with inclusive institutional rules and collective decision-making mechanisms (Cho and Murphy 2025; Ruder and Wittman 2025).

Existing studies on digital agribusiness governance have mostly focused on traceability systems, electronic marketplaces, mobile consulting tools, or technology adoption behaviors. While valuable, these approaches typically emphasize a single digital function, rather than redesigning coordination across the value chain. The study expands on previous work by integrating NIE-based governance restructuring with API-enabled multi-actor interoperability, so that digital systems are treated not only as an information tool, but also as an instrument for institutional coordination and transaction cost reduction. Therefore, this study examined the main seaweed-producing districts in South Sulawesi, Takalar, Bulukumba, Sinjai, Luwu, and Pangkep, with three objectives: (i) analyze the legacy institutional model that limit efficiency in the certain locations, (ii) design a new institutional model that aligns the roles of farmers, collectors, cooperatives, exporters, financial institutions, academics, and the government; and (iii) to operationalize this model through an API-based information system that integrates market access, financing services, price information, production inputs, and coordination data.

MATERIALS AND METHODS

Institutional analysis methodology

This study was conducted in five districts within South Sulawesi Province, Indonesia, namely Takalar, Bulukumba, Sinjai, Luwu, and Pangkep. These locations serve as primary production centers for *Kappaphycus alvarezii* and feature a comprehensive network of actors, including farmers, collectors, cooperatives, exporters, financial institutions, and government agencies. Each district was purposively selected for the significant contribution to production and distinct institutional characteristics. Takalar was selected as the largest production hub and a crucial economic pillar for coastal communities. Bulukumba offers environmental conditions highly conducive to *Eucheuma cottonii* cultivation. Sinjai is a major development area for *Gracilaria* sp., supported by strong local government commitment to enhancing production quality. Luwu was selected due to the active engagement of cooperatives in supporting smallholder business activities. Finally, Pangkep represents an archipelagic region with vast potential for seaweed cultivation and proactive government support through seedling distribution. Overall, site selection was based on (i) regional production output, (ii) the presence of key actors across the value chain, and (iii) reported coordination and integration challenges from previous studies.

The participants included seaweed farmers, collectors, cooperatives, export/processing firms, financial institutions, universities, and relevant government agencies. A purposive sampling method was used to identify key actors in each value chain segment. A snowball sample was taken based on the recommendations of initial informants to map the relevant institutional network. This approach was chosen because the transactional and coordination relationships in the seaweed value chain are network-based and not fully formally documented, so the identification of actors through probabilistic techniques is inadequate to capture the structure of actual institutional relationships. Minimum inclusion criteria were established to ensure data relevance, namely, farmers must have at least three years of experience and be active in commercial sales, and collectors had to routinely purchase from at least five farmers. Cooperatives must have provided services or engaged in transactions within the last two years. Exporters, financial institutions, and government agencies were selected for their direct involvement in the seaweed sector in the study areas.

In total, 34 key informants participated in in-depth interviews across the five districts. Furthermore, five Focus Group Discussions (FGDs) were conducted, one per district, with 10 representatives from each stakeholder group. To complement the qualitative data, semi-structured questionnaires were distributed to 102 respondents, primarily farmers and business owners, to obtain a quantitative overview of business and transaction patterns.

The semi-structured questionnaire was developed based on the design principles of survey instruments for social-applied research as recommended by Jiménez et al. (2024)

and structured into 28 questions posed in five main domains, including seaweed business characteristics, marketing and transaction patterns, access to financing, access to price and quality information, and institutional interactions between actors. Before being used in primary data collection, the instrument underwent an internal expert review by three researchers experienced in agribusiness and value chain governance, and was pilot tested with 10 respondents outside the primary sample to assess question clarity, local context relevance, and consistency of respondent interpretation. The pilot results were used to refine the wording of the questions and the interview sequence before full implementation. A summary of the instrument structure and variable domains is presented in Table 1.

Qualitative data were collected through face-to-face, in-depth interviews lasting 45-90 minutes. These interviews followed a semi-structured guide focusing on actor relationships, transaction mechanisms, price information sources, contract types, and coordination barriers. FGDs lasting 90-120 minutes were used to validate the value chain mapping, identify institutional constraints, and discuss proposed coordination mechanisms.

Qualitative data analysis is carried out in stages through thematic coding following the thematic analysis approach described by Campbell et al. (2021). Interview notes and FGD results were repeatedly read to identify information units related to transaction governance, vertical and horizontal coordination, information flow, and sources of transaction costs. The initial coding process produced analytical labels such as price information asymmetry, reliance on collectors, quality uncertainty, financing limitations, and weak institutional coordination. The labels were then grouped into broader categories, namely institutional governance, vertical coordination, horizontal coordination, information asymmetry, and contract mechanisms. This category was further synthesized into a main theme that describes the dominant institutional patterns in the seaweed value chain. To maintain analysis traceability, the field data excerpts were summarized into a coding matrix that connects the data source, analytical categories, and key themes.

To improve analytical accuracy, the results of coding and thematic interpretation were verified through peer debriefing and periodic discussions with two other members of the research team. This process includes cross-checking coding categories, review of interpretation consistency, and resolution of interpretation discrepancies until an analytical consensus is reached. The resulting institutional analysis is then used as a basis for designing an integrated institutional model and determining the needs of API-based information systems.

System design and development methodology

The methodology for designing and developing the integrated information system was derived directly from the institutional analysis and user needs identified in the previous stage. Rather than treating system development as a purely technical exercise, this study used an iterative research-and-design approach adapted from Agile (Scrum) principles, in which each development cycle served to test whether proposed digital functions could address observed coordination problems in the seaweed value chain. As illustrated in Figure 1, the workflow linked empirical institutional findings with repeated prototype refinement. In this study, Scrum was used mainly as a structured feedback mechanism to translate field evidence into practical system improvements rather than as a conventional software management model.

Table 1. Semi-structured questionnaire instrument structure

Domain	Number of items	Example of variables
Business characteristics	6	Farmland size, years of experience, production volume
Marketing and transactions	7	Type of buyer, frequency of transactions, payment mechanism
Access to financing	5	Sources of loans, financing barriers
Price and quality information	5	Source of price information, awareness of quality standards
Institutional interaction	5	Cooperative participation, access to counseling

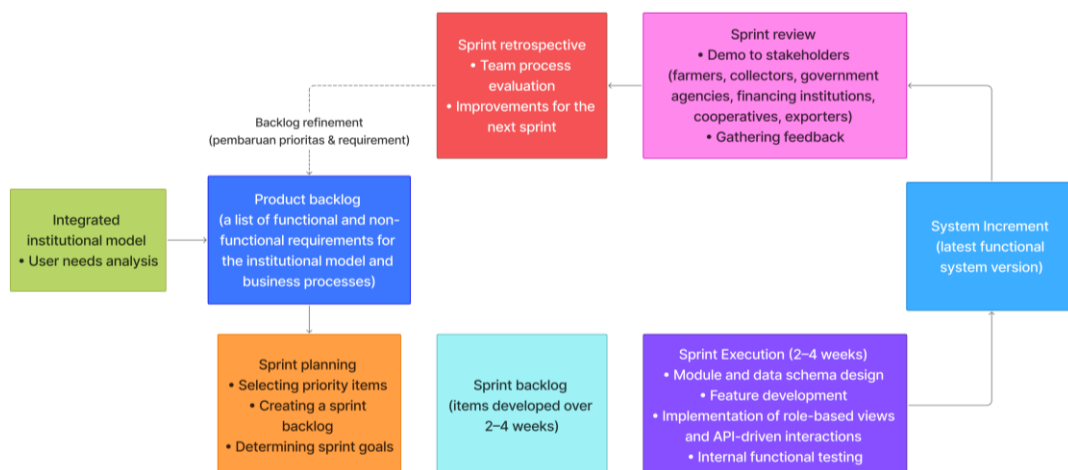


Figure 1. Agile scrum framework for seaweed information system

The process started with requirement identification through interviews and small-scale user workshops involving 20 key potential users. This group included five government representatives, three cooperative managers, six seaweed farmers, four traders/collectors, and two representatives from financial institutions. These participants were chosen because they represent actors directly involved in production, marketing, finance, regulation, and coordination. These participants were selected because they represented actors directly involved in production, marketing, finance, regulation, and coordination. In addition to mapping business processes, this stage documented existing digital practices such as spreadsheets, handwritten records, and fragmented administrative files in order to identify data integration gaps. Workshop findings were analyzed thematically to determine functional needs, coordination constraints, and governance requirements.

Based on the institutional findings, development priorities were organized around bottlenecks with the highest agribusiness value rather than around technical convenience. Three module groups were prioritized. First, data interoperability modules were developed because fragmented records among farmers, cooperatives, traders, and government agencies created delays, duplication, and weak planning capacity. These modules included API-based data exchange and shared data structures. Second, process automation modules were prioritized because manual procedures slowed transactions and increased administrative uncertainty. These modules included participant verification, subsidy or assistance approval flows, harvest stock recording, and order management. Third, governance and audit modules were prioritized because weak transparency and unclear authority were repeatedly identified as major institutional constraints. These modules included role-based access control, transaction audit trails, and institutional dashboards for monitoring aggregate activity.

Technical development was carried out in iterative cycles of two to four weeks using Laravel 9 to build the web platform, database structure, and RESTful API services. At the end of each cycle, functional prototypes were presented to stakeholder representatives to gather feedback on usability, business-process fit, and institutional relevance. Comments were recorded and analyzed qualitatively to identify required revisions, missing features, and changes in priority. Findings from each review cycle were then incorporated into the next development cycle.

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To improve research rigor and reproducibility, a feature was classified as functionally complete only when three criteria were met: (i) consistency with the intended business process, (ii) absence of critical operational errors, and (iii) ability to be independently used by the target actor group. In addition, institutional usability was evaluated using three criteria: (i) whether the feature improved transparency of information exchange, (ii) whether it clarified actor roles and access rights, and (iii) enabling transaction monitoring according to the proposed governance structure.

Through this iterative approach, the integrated institutional model served as the primary reference for each module design, while user feedback provided empirical validation of practical suitability. All workshop notes, prototype responses, and evaluation records were analyzed using descriptive thematic analysis to identify recurring user needs and assess alignment with institutional findings. The final result was a functional information system progressively refined to support coordination, accountability, and decision-making among actors in the South Sulawesi seaweed value chain.

RESULTS AND DISCUSSION

Value chain governance and transaction costs

Institutional analysis shows that the governance of seaweed agribusiness in South Sulawesi remains dominated by traditional buyer-driven value chain structures, in which collectors and exporters hold primary control over market access, price information, and quality determination. In this structure, farmers and farmer groups occupy the weakest bargaining position compared to downstream actors. The pattern of these relationships is illustrated in Figure 2, which shows two dominant forms of interaction the informal model based on patron-client relations and the formal model based on legality/contract. Although both patterns are found in the field, the mapping results show that the informal patron-client pattern is much more dominant in daily transaction practices and is the strongest institutional barrier to maintaining farmers' dependence on collectors. This dominance is especially evident in the centrality of collectors as the main link between farmers and downstream markets, as well as in their control over the flow of price information, quality standards, and purchasing decisions.

The results from interviews and FGDs indicate that most transactions between farmers and collectors occur through long-term patronage without written contracts. In practice, farmers bear the primary risks associated with price fluctuations and quality variations. Conversely, information regarding price and market demand flows asymmetrically through collectors and is rarely received by farmers in a transparent, real-time manner. This condition reinforces information asymmetry and farmers structural dependence on collectors as the primary market link. The results are consistent with Rahmat et al. (2024), who demonstrated that seaweed farmers rely on informal

networks and local traders for price information, generally built on trust and long-term community relationships.

The qualitative findings were strengthened by the results of a questionnaire of 102 respondents. A total of 71 respondents (69.6%) reported routinely selling harvests to a single permanent collector, reflecting the dominance of patronage-based relationships. In contrast, only 18 respondents (17.6%) had ever sold through cooperatives, and only 13 (12.8%) were engaged in formal contract schemes. Furthermore, 64 respondents (62.7%) had no direct knowledge of prices at the exporter or industrial level, obtaining information only during transactions with collectors. This pattern indicates that the value chain remains centralized around collectors, who are the primary controllers of information and market access.

This pattern is generally consistent across the five districts, although its intensity varies. Dependence on collectors remains highest in island and remote marketing areas, particularly Pangkep and parts of Luwu, where transportation constraints limit buyer competition. Transactions linked to cooperatives are relatively more common in Luwu and Sinjai, where local organizational support is stronger. Participation in formal contracts is highest in Takalar and Bulukumba, where large-scale production and easier market access increase engagement with processors and associated financing schemes. However, no district exhibits a fully competitive or fully transparent market structure, confirming that collector-centered governance remains the dominant regional pattern.

Transaction cost mapping derived from qualitative and semi-quantitative data identifies three primary components, (i) information costs, (ii) negotiation costs, and (iii) monitoring and enforcement costs. A systematic summary of these transaction costs is shown in Table 2. To strengthen the analytical interpretation, Table 2 presents

not only empirical indicators but also the relative severity, based on the prevalence of field findings, the proportion of respondents affected, and the magnitude of the procedural coordination obstacles identified.

The results in Table 2 indicate that information costs are the dominant barrier, as access to prices and market demand still relies on informal communication with collectors. This situation leads to sales decisions being made with limited information and to increased transactional uncertainty. This pattern aligns with studies in the agricultural sector of developing countries, which show that limited access to market information increases the transaction risks of smallholder farmers (Kubitza et al. 2025; Sharma and Sharma 2025).

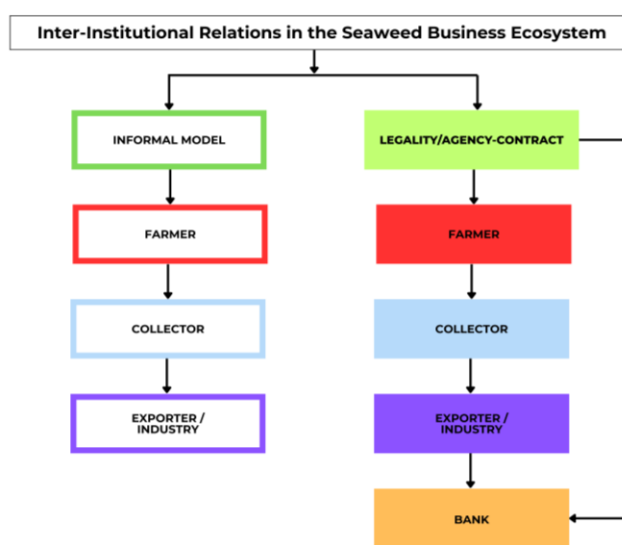


Figure 2. Inter-agency relations in the seaweed business

Table 2. Summary of transaction cost mapping in the seaweed value chain

Transaction cost component	Field findings	Empirical indicators	Relative severity	Impact on farmers
Information cost	Reliance on collectors for pricing information; no real-time price access; repetitive verbal communication	>60% of respondents do not know the price at the exporter level; price information is only obtained during transactions with collectors; access to market information is not available independently	High	Delays in sales decisions; price uncertainty; low bid position
Negotiation cost	There are no written quality standards, subjective quality assessments, or repetitive bargaining	±80% of respondents stated that prices are determined through direct negotiation based on subjective quality assessment by buyers	Medium-High	High price variation; inconsistent margins
Monitoring-enforcement cost	There is no written proof of transaction; manual or undocumented recording	±70% of farmers do not have formal transaction documentation; post-transaction quality/volume verification is difficult	Medium	Risk of disputes; poor contract certainty

Note: The relative severity was determined analytically based on the combination of the frequency of findings appearing in interviews/FGDs, the proportion of questionnaire respondents affected, and the procedural impact on transaction coordination. This category represents a structural comparative assessment and not a quantitative estimate of monetary costs

Negotiation costs primarily stem from the lack of quality standards and standardized assessment mechanisms. Negotiation costs are moderate to high due to the lack of written quality standards and uniform assessment mechanisms, making the bargaining process highly dependent on collectors' subjective judgments. Similar conditions are also found in the value chains of seaweed and other agricultural commodities (Seifert et al. 2020; Espinosa Diaz et al. 2023). Negotiation costs primarily stem from the lack of quality standards and standardized assessment mechanisms. Negotiation costs are moderate to high due to the lack of written quality standards and uniform assessment mechanisms, making the bargaining process highly dependent on collectors' subjective judgments. Similar conditions are also found in the value chains of seaweed and other agricultural commodities (Sharma and Sharma 2025).

Overall, these results suggest that improving the efficiency of the seaweed value chain requires institutional interventions that simultaneously improve the transparency of market information, quality standardization, and transaction documentation. Without integrated improvement across these three aspects, strengthening formal institutions may result only in changes to administrative organization, without substantively reducing barriers to market coordination.

An integrated institutional model for the governance of the seaweed business value chain

Based on the inefficiencies identified in traditional value chains, this study designs an integrated institutional model that reconstructs the roles and relationships among actors at the village, district, and provincial levels. This model, shown in Figure 3, positions the government not only as a passive regulator, but a dynamic mediator and facilitator linking financial institutions with the industrial sector. The main shift in this model is the strengthening of

cooperatives as the primary coordination node for consolidating production data, standardizing quality, and documenting transactions. The placement of cooperatives in a central position is based on field findings that cooperatives in the study area have performed initial coordinating functions, including limited collective marketing facilitation, input procurement, and financing administration assistance. However, they remain not digitally or institutionally integrated. Thus, the proposed model is a strengthening of existing institutional capacity, not the creation of a new organizational structure. This restructuring is a direct response to the high cost of information and the weak horizontal coordination of farmers. By integrating data through cooperatives as institutional gateways, information asymmetry previously concentrated on collectors can be structurally reduced, thereby increasing farmers' collective bargaining positions in downstream networks.

In this integrated model, each actor role is designed to close the transaction-cost gaps identified in the previous analysis phase. Exporters and industrial actors are required to provide demand information and delivery schedules through documented reporting mechanisms, which, in theory, lower negotiation costs by increasing contract certainty. Financial institutions use consolidated cooperative data to conduct more accurate and targeted creditworthiness assessments. Meanwhile, universities serve as knowledge partners providing technical support and data-driven policy evaluations. This model reflects a transition toward modernized, digitized cooperative practices, in which operational efficiency is achieved through integrated market functions and transparent data processing (Shi et al. 2022; Zheng et al. 2024). The synergy enables collective learning that strengthens the technical capacity of all members of the seaweed value chain governance (Ouerghemmi et al. 2024).

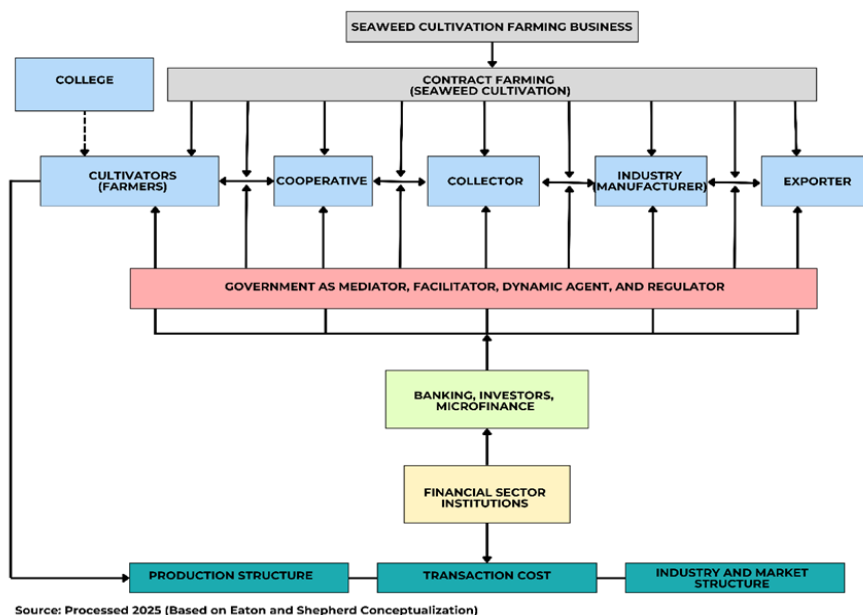


Figure 3. Results of the seaweed business institutional model

However, this model does not assume uniform institutional readiness of cooperatives. Variations in organizational capacity between regions indicate that full implementation still requires strengthening administrative capacity, data management, and operational readiness at the local level. Therefore, the model is positioned as a gradual governance framework whose implementation must be tailored to each region's institutional readiness.

The operational strength of this model was validated through expert judgment and a series of FGDs involving decision-making authorities from the five sample districts. The experts included the Heads of Fisheries Departments and the Heads of Aquaculture Divisions from Pangkep, Luwu, Bulukumba, Sinjai, and Takalar. These experts were selected based on the administrative authority in seaweed governance and the deep understanding of local institutional conflict dynamics. The initial model is presented to the validators for evaluation based on the feasibility of implementation, the clarity of the actors' roles, and its suitability for local governance practices. All inputs are documented and synthesized thematically based on the frequency of occurrence and the level of consensus among validators. This process resulted in three main themes, namely (i) realistic and adaptive model, which was deemed feasible because it does not eliminate existing actors such as collectors but rather restructures information flows, (ii) asymmetry reduction model which position cooperatives as data centers is a crucial step in breaking information dependency on intermediary price speculation; and (iii) governance interoperability, showing system that unites all business actors within a single coordination platform. The validators concluded that the model provides a clear framework for reducing transaction costs through integrated data transparency across all levels of government and business actors.

Information system architecture and operational examples

The integrated institutional model is operationalized through an API-based information system that is organized into three functional layers (i) data interoperability, (ii) process automation, and (iii) governance and auditing. Instead of simply being presented as a software architecture, each layer is designed to address previously identified transaction cost constraints in the seaweed value

chain, specifically information asymmetry, repetitive bargaining, and weak oversight.

The data interoperability layer standardizes records on farmers, land, production, transactions, pricing, cooperatives, support programs, and reports via shared databases and RESTful APIs. Its primary institutional function is to reduce the cost of information by replacing fragmented records and informal communications with common, accessible data sources for authorized actors. Shared access to production availability, price references, and transaction history also reduces uncertainty during negotiations between farmers, collectors, cooperatives, and exporters.

The process automation layer digitizes activities previously handled manually, including farmer and land registrations, production reporting, crop stock updates, order requests, and transaction confirmations. Its main contribution is to lower the cost of negotiation and coordination by reducing repetitive verbal confirmations, delays in record transfers, and inconsistent documentation. In practice, this layer enables a more timely match between market demand and available harvest supply.

The governance and audit layers introduce role-based access controls, approval workflows, and transaction logs. These functions are intended to reduce monitoring and enforcement costs by clarifying actors' responsibilities, recording consents, and creating traceable digital evidence of completed transactions. This is especially relevant in contexts where disputes over quantity, quality, payment timing, or delivery schedules have previously been handled informally.

The initial user interface used during the functional test is shown in Figure 4. The home page serves as a common entry point for farmers, cooperatives, collectors, and administrators. It displays a summary of market demand, production status, and institutional activity specific to each role. Usability feedback collected during the prototype session indicates that users value the ability to view pending demand and production information in a single location, rather than relying on repeated phone calls or messages. Farmers reported easier visibility of demand opportunities, while cooperative representatives noted faster coordination of crop planning and member verification.

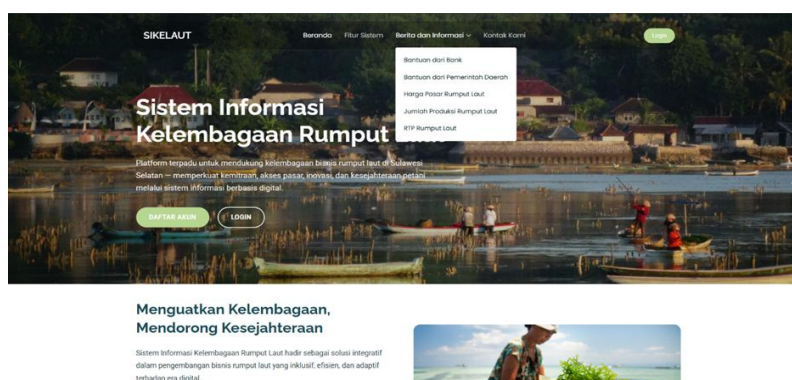


Figure 4. Landing page

Functional testing is carried out through scenario-based simulations that reflect common transactions. Six primary use-case scenarios were tested: farmer/land registration, production recording, market demand requests from exporters, harvest ordering by cooperatives, farmer availability confirmation, and transaction status synchronization. This test is designed to assess whether data can move consistently across actor roles and whether transaction steps can be documented end-to-end.

The simulation results demonstrate functional feasibility: all six scenarios operate without critical errors, authorized users can retrieve synchronized records, and transaction history is stored in a traceable format. System response times remain within the normal web-based operational range during testing. These findings show that architecture is technically capable of supporting transparent coordination processes. However, functional feasibility should not be interpreted as field effectiveness. The simulations were conducted under controlled conditions and did not involve full-scale commercial transactions, under real production constraints such as unstable connectivity, user input delays, opportunistic behavior, or seasonal supply shocks. Therefore, claims regarding increased revenues, changes in bargaining power, or long-term efficiency improvements require on-the-ground implementation and evaluation of future impacts.

Overall, the findings suggest that API-powered institutional systems can serve as coordination infrastructures, rather than just digital administrative tools. By integrating market demand, harvest availability, approvals, and transaction records into a single operational environment, the system demonstrates how digital governance can reduce transaction barriers in seaweed agribusiness. This interpretation is consistent with studies showing that API frameworks support flexible service integration and more efficient multi-stakeholder coordination in digital agribusiness systems (López-Morales et al. 2020; Abate et al. 2023).

Theoretical contributions through NIE lenses

Through the lens of NIE, the integrated institutional model and API-based information system in this study are constructed as structural instruments to mitigate three primary categories of transaction costs, namely measurement, bargaining, and enforcement. This approach demonstrates how digital interventions can transform asymmetric interaction procedures into standardized, symmetrical processes. The analysis results indicate that inefficiencies in traditional seaweed value chains are rooted in weak digital transaction documentation and fragmented price information, procedurally increasing uncertainty for smallholder farmers.

In this context, integrating cooperatives and farmer groups as a data consolidation node could structurally reduce measurement and bargaining costs by providing more comprehensive documentation of production, volume, and quality parameters. With structured production data available in the system, the negotiation process is no longer entirely dependent on verbal exchanges and subjective judgment, but is supported by more documented,

verifiable data references. Similarly, digital transaction documentation and audit trail features procedurally strengthen monitoring capacity and provide a better administrative basis for tracking and enforcing transaction agreements.

Unlike institutional studies that stop at organizational restructuring recommendations, this study shows that institutional innovation can be operationalized through integration with information system architectures that regulate access rights, documentation, and the coordination of data among actors. In this sense, the research contribution to the NIE literature lies in demonstrating how institutional design and digital infrastructure can be integrated as a transaction governance mechanism in the agribusiness value chain.

Nevertheless, it is important to emphasize that such contributions still lie in the level of design consistency and procedural validation, rather than on empirical proof of long-term economic impacts. Although stakeholders view digital record-keeping as a means to improve transparency and accountability, concerns regarding control over individual production data remain in the validation process. This shows that the risks of platformization and concentration of data control have not been fully addressed, but have only been mitigated through role-based governance design and auditing.

The theoretical contribution of this research is better understood as preliminary evidence that the proposed digital-institutional design is conceptually consistent with the NIE framework and provides a mechanism that, structurally, has the potential to lower transaction costs. This study does not claim to have empirically proven a transformation in bargaining or a redistribution of economic power, as such impacts can only be assessed through field implementation observations and longitudinal evaluations conducted after the system has been implemented in real operations.

Digital governance and platformization risks

From a digital governance perspective, the design of a system that integrates RBAC, audit trails, and institutional dashboards is an explicit effort to mitigate the risk of platformization. This risk is widely discussed in the digital agriculture literature because it can centralize data control on a single entity, leaving smallholders relying on closed platforms (Reisman et al. 2024; Sauvagerd et al. 2024). In the seaweed value chain, this condition can occur if access to price, market demand, and transaction data is controlled only by actors with greater digital capacity.

Field data in South Sulawesi shows that this issue is empirically relevant. Interviews and FGDs show that farmers support digital systems if they can open access to information about market prices and demand in a more transparent manner. However, they are also worried that large buyers are using individual production data to suppress prices or select certain suppliers. A farmer in Takalar said that the system would help if market prices could be seen together, but farmers would object if only buyers could see their harvest data. In Bulukumba, FGD participants emphasized the importance of cooperative

assistance to ensure that farmers understand digital information and are not overly dependent on other parties.

The level of digital literacy of farmers is also still diverse. Younger farmers are generally better equipped to use smartphones, while some senior farmers still rely on regular telephone communication, manual note-taking, or family assistance. In archipelagic areas such as Pangkep, limited internet networks are an additional obstacle. This shows that without assistance, digitalization risks widening the gap between farmers.

In response, the system places cooperatives and public institutions as managers of aggregate data, rather than as sole owners of individual data. User roles differentiate access rights to ensure sensitive data remains protected, while general information, such as reference prices and market demand, can be shared for coordination purposes. Thus, successful implementation depends not only on technology but also on user training, clear data access rules, and trust among stakeholders. The digitalization of the seaweed value chain needs to be carried out in stages to remain inclusive and transparent, and to empower farmers without creating new dependencies.

Practical feasibility and scalability

In the context of practical implementation, initial functional test results indicate a positive acceptance of core system features, particularly among cooperative managers and local government authorities in South Sulawesi. The stakeholders acknowledge the direct benefits of consolidating production and transaction data within a unified digital framework. However, this study explicitly identifies several structural barriers that could limit the system field effectiveness. These include limited digital literacy among smallholder farmers, disparities in connectivity infrastructure in coastal areas, the need for continuous technical training, and long-term system maintenance costs. Consequently, the claims regarding transaction cost reduction in this study are strictly limited to the procedural coordination barriers observed during functional simulations, rather than verified longitudinal macroeconomic impact estimations.

Based on observations from user workshops, prototype testing, and validation discussions, the categories of actors most ready for pilot implementation are active cooperatives, local government technical offices, and collector/aggregator business actors who already have basic administrative record-keeping practices and personnel accustomed to using simple digital devices. In contrast, individual smallholders, especially in areas with low connectivity and limited digital experience, are expected to require a phased implementation approach, mediated by cooperative institutions or field companions, before they can fully interact with the system. These findings suggest that the most realistic initial implementation strategy is an intermediary, institution-based, gradual approach, in which system adoption starts with more administratively and technically prepared institutional actors before being extended directly to the farmer level.

Regarding scalability, the API-based architecture, which modularly separates the data, process, and

governance layers, enables model replication in other coastal regions. This can be achieved by adapting institutional role configurations to suit local contexts. However, scalability is positioned as a technical-architectural projection rather than a universal empirical demonstration. Successful replication depends heavily on initial investments in local institutional mapping and the synchronization of region-specific business processes. Therefore, the model and system are more accurately viewed as an adaptable reference framework. Sustainability will be determined by strengthening human resource capacity and local policy commitments to bridge existing digital divides.

Study limitations

This study has several limitations. First, although institutional models and information systems are designed to reduce the costs of information, negotiation, and monitoring, the study has not quantitatively measured these cost reductions. Therefore, the efficiency findings at this stage are still procedural and functional. Second, the use of purposive and snowball sampling and the focus on five districts in South Sulawesi mean that the results of this study are not intended for statistical generalization to all seaweed sectors in Indonesia. However, these findings remain relevant as an in-depth case study for coastal areas with similar institutional characteristics. Third, the developed system has achieved functional readiness. Still, full-scale operational implementation and long-term impact evaluation have not yet been carried out, so its effectiveness in field practice still needs further study. Fourth, this study has not discussed in depth aspects of regulation and data governance, including the right of access to production data, approval mechanisms, and digital dispute resolution. Nonetheless, the integration between NIE-based institutional design and API-based system architecture provides an adequate conceptual and operational basis for subsequent policy development and testing.

In conclusion, this study shows that inefficiency in the seaweed value chain in South Sulawesi is primarily driven by information asymmetry, weak institutional coordination, and heavy reliance on intermediaries. Through NIE-based analysis, the study developed an integrated institutional model that places cooperatives and farmer groups as stronger coordination nodes in the flow of information and transactions. The model is then translated into an API-based information system designed to support data exchange, production recording, market demand tracking, and the documentation of transactions between actors. Functional testing shows that the system can execute key process flows, synchronize data among authorized users, and provide a more transparent digital footprint to support coordination needs. The main contribution of this research lies in the integration between institutional design and digital architecture as a practical approach to lowering transaction barriers at the procedural level. However, these results are still limited to functional feasibility and have not been evidence of long-term impacts on farmers' incomes, bargaining positions, or welfare. Therefore, further

research should focus on pilot implementation, quantitative impact measurement, and evaluation of adoption readiness across various coastal areas. With these steps, the proposed model can serve as a basis for developing more inclusive, efficient, and data-driven seaweed agribusiness governance.

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