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Community-Owned Circular Business Models for Livestock Waste: Participatory Value-Chain Design and Determinants of Adoption Readiness in Rural Indonesia

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ABSTRACT

Background: Livestock manure is simultaneously an environmental liability and a locally available nutrient resource, yet technical conversion into organic fertilizer does not automatically create a viable circular enterprise.

Aims: This study examined how participatory value-chain design and a community-owned business model can reduce operational uncertainty and strengthen household readiness to engage in livestock-waste valorization in Arjasa Village, East Java, Indonesia.

Methods: A Year-1 participatory mixed-methods case study combined a structured baseline survey of 60 livestock-keeping households, multi-actor discussions, process walkthroughs, value-chain mapping, and Business Model Canvas co-design. An exploratory logistic model assessed associations between adoption readiness and five designable mechanisms: access to an offtake memorandum of understanding, microfinance, perceived relative advantage, governance trust, and short training, with contextual controls.

Results: Forty-six percent of households met the operational definition of early adoption or firm participation commitment. Offtake access showed the largest association with readiness (OR = 3.40), followed by microfinance (OR = 2.60), perceived relative advantage (OR = 2.20 per 1 SD), governance trust (OR = 1.90 per 1 SD), and short training (OR = 1.80). The model showed useful exploratory discrimination (AUC = 0.81), while participatory mapping identified feedstock variability, inconsistent processing endpoints, weak quality records, and uncertain market absorption as the main value-chain frictions.

Conclusion: The findings support a risk-reduction architecture in which market assurance, light finance, credible governance, clear product value, and compact learning mechanisms are designed together rather than treated as separate interventions. Because the sample is small and cross-sectional, the regression estimates are interpreted as preliminary associations that require confirmation in subsequent implementation cycles.

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INTRODUCTION

Livestock manure sits at the center of a sustainability paradox: the same material that can pollute water, emit greenhouse gases, and create public-health burdens can also return nutrients and organic matter to agricultural soils. Recent circular-economy research therefore treats manure less as a disposal problem than as a potentially recoverable input for fertilizer, energy, and other bio-based products (Awasthi et al., 2022; Donner et al., 2021; Haque et al., 2023). System-level analyses further show that livestock can act as an important supplier of recyclable nutrients within agri-food systems, although circularity alone does not guarantee efficient use of those nutrients (Kleinpeter et al., 2023). Closed-loop farming models also indicate that manure recovery may generate economic value when resource flows, production decisions, and market channels are coordinated rather than managed separately (Jeng et al., 2024). This technical promise has encouraged many waste-valorization programs to focus on composting, digestion, fermentation, and processing equipment. Yet a recurring contradiction remains: technically feasible manure treatments can fail commercially when farmers, processors, and buyers do not share clear standards, incentives, or responsibilities. Circularity at village scale is therefore not simply a matter of converting waste into a product. It is an organizational problem in which material recovery must be matched by reliable coordination, value capture, and user confidence.

The difficulty is especially visible in smallholder settings, where livestock residues are generated in dispersed quantities and where operating margins leave little room for failed batches or unsold inventory. Evidence from livestock production shows that high operating costs, technical failures, and the neglect of end users can become stronger barriers to improved manure management than the availability of treatment technology itself (Tan et al., 2021). Farm scale and technology characteristics also shape the feasibility of manure-management options because land, labor, capital, and knowledge constraints are distributed unevenly across households (Pan et al., 2021). These constraints are amplified when upstream separation and storage are inconsistent, midstream quality endpoints are not recorded, and downstream buyers remain uncertain about dosage, product consistency, or supply continuity. Under such conditions, the value chain can lose value at several points even when the underlying resource has clear agronomic potential. The central challenge is consequently to stabilize not only the production process but also the institutional and market interfaces surrounding it. Circular business models are relevant because they connect resource recovery with value creation, delivery, and capture instead of treating environmental improvement as an isolated technical outcome (Cavicchi et al., 2022; Hina et al., 2022). A viable village enterprise therefore needs a design that reduces uncertainty across the entire chain, from residue collection to repeat purchase.

Arjasa Village in Jember Regency provides a useful setting for examining this problem because crop and livestock activities coexist with daily housing of animals and a locally accessible market for agricultural inputs. The Year-1 baseline documented a steady flow of manure, urine, and bedding, but it also showed heterogeneous handling practices, variable storage conditions, thin quality-control routines, and a strong dependence on local kiosks, farmer groups, and village institutions for market access. These characteristics create a realistic test of whether a circular enterprise can be built through organizational discipline rather than capital-intensive technology. The local institutional landscape is also important because a cooperative, farmer groups, and a village-owned enterprise can potentially coordinate aggregation, record keeping, working capital, and buyer relationships that individual households would struggle to manage alone. Research on inclusive agribusiness cautions, however, that integrating smallholders into commercial chains is not automatically equitable or durable unless coordination mechanisms reflect local capacities and power relations (Schoneveld, 2022). Similar work on contract farming shows that market linkage can reduce uncertainty and stimulate commercialization, but benefits depend on contract design, enforcement, and the distribution of risks between farmers and buyers (Arouna et al., 2021; Vicol et al., 2022). For Arjasa, the practical question is therefore not whether manure can be processed into liquid organic fertilizer and compost. The more consequential question is whether community institutions can organize the surrounding business system so that households perceive participation as credible, manageable, and worthwhile.

This question is urgent because adoption decisions in sustainable agriculture are shaped by more than expected profit. A global meta-analysis of diversified farming systems found that knowledge access, social networks, and farmer attitudes are among the most consistent adoption enablers, while the influence of financial and physical resources varies strongly across practices and locations (Sanchez Bogado et al., 2024). Studies of cooperative members similarly show that institutional participation can support fertilizer adoption by improving information, access, and coordination, although benefits are not uniform across households (Geffersa, 2024; Li et al., 2021). Trust is particularly important in collective schemes because participation depends on whether farmers regard rules, institutions, and other actors as legitimate and dependable (Sander et al., 2024). Perceived adoption risks also matter, as farmers may reject environmentally desirable practices when they expect additional cost, technical uncertainty, or market loss, while recent adoption research emphasizes perceived relative advantage and adaptive household decision-making as central to uptake (Rodriguez-Barillas et al., 2024; Williams et al., 2022). Recent behavioral research further suggests that perceived compatibility, economic motives, social norms, and information channels shape whether farmers intend to continue or initiate sustainable practices (Abe et al., 2025; Erekalo et al., 2025). These findings imply that a village circular enterprise must lower several forms of uncertainty simultaneously. Market assurance, affordable working capital, credible governance, visible product benefits, and short practical learning opportunities are therefore plausible design levers rather than peripheral program components.

Existing scholarship offers important pieces of this explanation but remains fragmented across research traditions. Manure-management studies have clarified technological options, environmental trade-offs, and farm-level adoption constraints, yet they often stop before specifying how a community enterprise should organize value capture and market relationships (Awasthi et al., 2022; Pan et al., 2021; Tan et al., 2021). Circular-business-model research has mapped drivers and barriers at the firm level and has emphasized the organizational capabilities required to translate circular principles into sustained business performance, while the Business Model Canvas and its sustainability extensions provide a structured language for value creation, delivery, and capture (Boldrini & Antheaume, 2021; Cavicchi et al., 2022; De Angelis, 2021; Hina et al., 2022; Pieroni et al., 2021; Santa-Maria et al., 2022). Work on agricultural waste recovery likewise stresses that stakeholder involvement, business models, and supply-chain design are indispensable for moving from technical recovery to economically viable circular agriculture (Haque et al., 2023). Participatory business-model research adds that co-design can reveal locally specific customer needs, governance expectations, and value propositions that would be missed by a purely technical approach (Mohammed et al., 2024). Meanwhile, adoption studies consistently demonstrate the roles of perceived benefit, trust, information, organizational membership, and market connections in farmers' decisions (Erekalo et al., 2025; Li et al., 2021; Rodriguez-Barillas et al., 2024; Sander et al., 2024). The dominant literature therefore explains either the technology, the business model, or the behavioral decision relatively well. What remains less developed is an empirical framework that connects all three within the same village-scale circular enterprise.

A second limitation concerns how these streams of research are operationalized in rural implementation studies. Business Model Canvas applications can become static descriptions when they are not anchored in observed value-chain bottlenecks, while adoption models can become detached from managerial decisions when predictors are not variables that local institutions can actually change. Conversely, participatory mapping can generate rich local knowledge without testing whether the proposed mechanisms are associated with household willingness to engage. Recent co-design research in circular bioeconomy contexts demonstrates the value of linking stakeholder participation with explicit business-model architecture, but evidence remains limited for manure-based enterprises led by village institutions (Mohammed et al., 2024). The gap is particularly important in settings where the same organization must simultaneously coordinate residue supply, basic processing discipline, quality assurance, packaging, working capital, and buyer relationships. No single intervention is likely to resolve these interacting frictions because market uncertainty can undermine production, financial constraints can delay participation, and weak governance can erode trust even when the product itself is technically acceptable. The critical research gap is therefore the absence of integrated, field-level evidence on whether participatory value-chain co-design can identify a coherent set of designable risk-reduction mechanisms and whether those mechanisms are associated with early adoption readiness. Addressing that gap requires a design that treats the value chain, the business model, and household decision-making as interconnected parts of the same circular system.

This study addresses that gap through a Year-1 participatory mixed-methods case study of livestock-waste valorization in Arjasa Village, East Java, Indonesia. It has three empirical objectives: to diagnose material, information, quality, and value-capture bottlenecks across the local livestock-waste chain; to co-design a community-owned Business Model Canvas that translates those bottlenecks into operational arrangements; and to examine the associations between five designable mechanisms and household adoption readiness. The five mechanisms are access to a simple offtake memorandum of understanding, access to light microfinance, perceived relative advantage, trust in cooperative or village-enterprise governance, and participation in short training. Theoretically, the study integrates circular-business-model thinking with adoption and institutional-risk perspectives by proposing a risk-reduction architecture in which market, liquidity, governance, information, and perceived-value uncertainties are addressed jointly. Methodologically, it combines participatory diagnosis with an exploratory household model so that qualitative design choices and quantitative patterns can be interpreted together. Practically, it provides a management-oriented blueprint for cooperatives and village enterprises that need to move from scattered waste-recovery activities toward repeatable routines and clearer market commitments. The study does not claim causal effects from the cross-sectional baseline; instead, it identifies preliminary associations and a co-designed intervention logic that can be tested longitudinally during subsequent implementation.

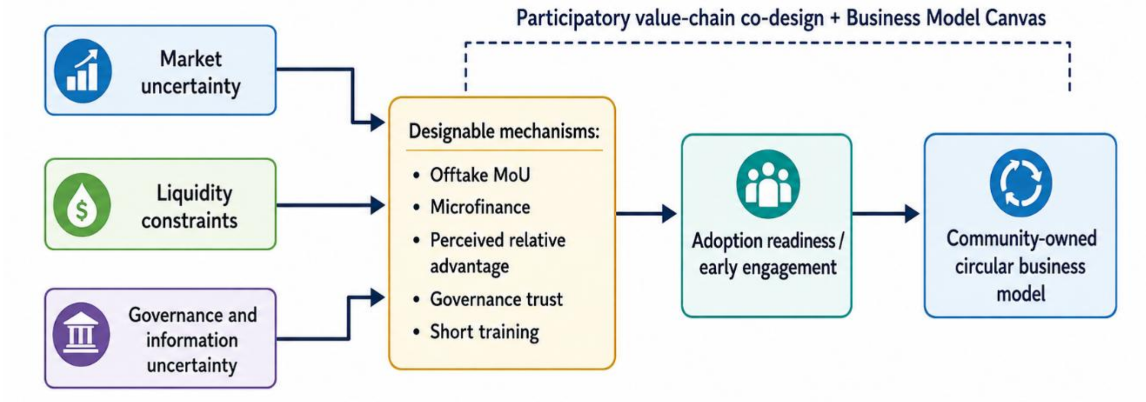

Figure 1. Conceptual framework: risk-reduction architecture for community-owned circular enterprise

Figure 1 links three recurrent uncertainties to five designable mechanisms and then to adoption readiness and the proposed community-owned business model. Participatory value-chain co-design and the Business Model Canvas organize these mechanisms; the arrows express the Year-1 intervention logic rather than causal effects established by the cross-sectional data.

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METHOD

2.1 Research Design

The study used a participatory mixed-methods case-study design that combined qualitative value-chain diagnosis with a quantitative household baseline and exploratory logistic regression. The design was selected because the Year-1 objective was not to test a mature intervention, but to identify bottlenecks, co-design workable institutional arrangements, and establish an empirical baseline for later implementation. Qualitative evidence was generated through multi-actor discussions and process walkthroughs, while quantitative evidence was generated through a structured survey of livestock-keeping households. The two evidence streams were integrated during value-chain mapping and Business Model Canvas development so that operational proposals were tied to observed constraints rather than imposed as a prescriptive template. The design followed a diagnosis-planning logic consistent with participatory research, with implementation and longer-term evaluation reserved for subsequent cycles. The quantitative model was therefore treated as exploratory and associational, not as a causal impact evaluation. Figure 2 summarizes the sequence from stakeholder mapping through integrated interpretation and Year-1 priority setting.

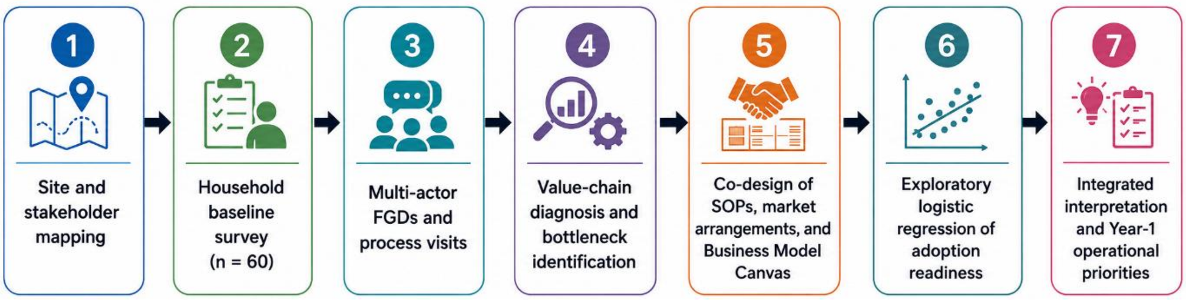

Figure 2. Year-1 participatory mixed-methods research workflow

Figure 2 summarizes the complete Year-1 sequence from stakeholder mapping and household baseline data to multi-actor diagnosis, co-design, exploratory modeling, and integrated priority setting. It clarifies that the logistic model complements, rather than replaces, the participatory evidence used to construct the business model.

2.2 Study Site and Period

The study was conducted in Arjasa Village, Jember Regency, East Java, Indonesia, during the 2025 Year-1 diagnostic and co-design cycle. Arjasa was selected because livestock and crop activities occur in close proximity, animals are commonly housed daily, and manure, urine, and bedding are generated with sufficient regularity to support local collection and processing. Site selection also considered the presence of farmer or livestock groups, a cooperative structure, a village-owned enterprise (BUMDesa), agricultural-input kiosks, and prospective local buyers that could participate in a community-owned business arrangement. These institutional actors were relevant because the proposed enterprise required coordination of collection, processing routines, quality records, packaging, working capital, and downstream market access. The study focused on liquid organic fertilizer and compost because both products could be produced with relatively simple operating procedures and low-cost quality checks under local conditions. The site was treated as an analytically informative rural case rather than as statistically representative of all Indonesian villages or emerging economies.

2.3 Population, Participant, and Sampling

The target population consisted of livestock-keeping households residing permanently in Arjasa and generating residues through daily animal management. The household sampling frame was constructed from a locally verified roster, and purposive stratified sampling was used to capture variation in herd scale and institutional involvement rather than to estimate village-wide prevalence. Eligible households owned or managed ruminants or poultry, generated residues regularly, were willing to complete the baseline survey and participate in follow-up activities, and could be contacted for verification; non-permanent residents and households declining informed consent were excluded. Sixty households were recruited, with recruitment monitored to avoid extreme underrepresentation of group or cooperative members and non-members. The primary unit of analysis was the livestock-keeping household, while additional qualitative informants included cooperative or farmer-group leaders, BUMDesa managers, agricultural-input kiosk operators, extension officers, and prospective local offtakers. Because only one household reported prior production of organic fertilizer, previous production experience was recorded descriptively rather than used as a sampling stratum. The sample size was considered adequate for a Year-1 exploratory baseline but limited for definitive multivariable inference, so regression estimates are interpreted cautiously and require re-estimation with a larger implementation sample.

2.4 Research Instruments and Operationalization

Four instruments were used: a structured household questionnaire, a multi-actor discussion guide, a process-walkthrough checklist, and a nine-block Business Model Canvas worksheet. The household questionnaire covered demographic and productive characteristics, residue handling, training exposure, access to small-scale finance, access to an offtake arrangement, distance to the nearest outlet, perceived relative advantage of the proposed local products, trust in cooperative or BUMDesa governance, and the outcome variable. Perceived relative advantage and governance trust were recorded as five-point rating indicators and standardized as z-scores for regression interpretation. The binary outcome was defined as adoption readiness, coded 1 when a respondent reported either early use or supply engagement in the current season or a firm stated commitment to participate in the planned local fertilizer arrangement, and 0 otherwise; this definition reflects Year-1 readiness rather than long-term technology adoption. The discussion guide mapped product flows, information and quality-standard flows, value-accrual points, responsibilities, market requirements, and perceived bottlenecks across upstream, midstream, and downstream nodes. The process checklist documented collection and storage practices, fermentation or composting routines, pH, temperature, moisture, filtration or sieving, packaging, batch records, delivery windows, and payment practices. The BMC worksheet captured key partners, key activities, value proposition, customer relationships, customer segments, key resources, channels, cost structure, and revenue streams, with each block linked back to evidence from the value-chain diagnosis.

2.5 Validity and Reliability

Instrument quality was addressed through a small field pilot, iterative wording refinement, enumerator training, and cross-checking of survey responses against process observations and stakeholder discussions. The pilot was used to assess clarity, local terminology, response burden, and the feasibility of recording operational variables before full data collection. Face and content validity were strengthened by comparing survey and discussion items with the study objectives and by reviewing their practical meaning with field actors involved in livestock management, extension, processing, and village enterprise operations. A data dictionary specified the operational definition, coding range, and unit of measure for each variable, which reduced ambiguity during data entry and cleaning. Daily completeness checks were conducted, and approximately 10% of entries were randomly validated by a field supervisor against source records or respondent confirmation. Because perceived relative advantage and governance trust were treated as single five-point indicators rather than multi-item psychometric scales, Cronbach's alpha was not applicable and no internal-consistency coefficient is claimed. This limitation is acknowledged explicitly, and future rounds should develop multi-item measures if the behavioral constructs are to be tested as latent variables.

2.6 Data Collection Procedure

Data collection proceeded in seven linked stages. First, the research team mapped livestock households, local institutions, processing locations, market outlets, and prospective buyers. Second, trained enumerators administered the structured baseline survey to the 60 selected households after informed consent was obtained and personal identifiers were separated from the analytical dataset. Third, multi-actor discussions were conducted to compare household practices with the expectations of cooperatives, BUMDesa management, kiosks, extension officers, and potential offtakers. Fourth, process walkthroughs documented residue collection, temporary storage, fermentation or composting, low-cost quality checks, packaging, logistics, and payment routines. Fifth, evidence from the survey, discussions, and walkthroughs was consolidated into a baseline value-chain map that distinguished material flow, information and quality flow, and value-capture points. Sixth, participants translated the diagnosed bottlenecks into co-designed operating arrangements, including compact SOPs, batch records, price tiers, deposit-return rules, short training, light microfinance, and simple offtake agreements, which were then organized in the Business Model Canvas. Seventh, qualitative and quantitative findings were integrated to prioritize Year-1 actions and define variables for subsequent monitoring. All household respondents and institutional informants participated voluntarily, informed consent was obtained, and personal identifiers were anonymized during data management.

2.7 Data Analysis

Qualitative data from discussions and process visits were analyzed using a structured framework matrix organized around upstream, midstream, downstream, governance, finance, quality, and market-access categories. Field notes were reduced into recurrent bottlenecks, proposed responses, areas of stakeholder agreement, and unresolved issues, and these themes were triangulated against survey distributions and direct process observations before being incorporated into the value-chain map and BMC. Quantitative analysis began with frequencies, percentages, means, and standard deviations for the 60-household baseline. Adoption readiness was then modeled with an exploratory binary logistic regression using robust standard errors, and results are reported as odds ratios, 95% confidence intervals, and p values, with alpha = .05 used as a descriptive significance threshold rather than proof of causality. The primary design variables were offtake access, microfinance access, standardized perceived relative advantage, standardized governance trust, and training participation; contextual controls were log herd size, livestock type, nonfarm income, and distance to the nearest outlet. Model performance was summarized using the area under the receiver-operating-characteristic curve, the Hosmer-Lemeshow calibration statistic, and the Brier score, while interpretation emphasized the direction and magnitude of associations because the small sample increases the risk of coefficient instability.

$$logit[P(Y_i = 1)] = \beta_0 + \beta_1 Offtake_i + \beta_2 Microfinance_i + \beta_3 RelAdv_i + \beta_4 Trust_i + \beta_5 Training_i + \beta_6 ln(Herd_i) + \beta_7 Cattle_i + \beta_8 Nonfarm_i + \beta_9 Distance_i$$

In the equation, Y represents adoption readiness; the first five predictors are the designable Year-1 mechanisms and the remaining variables are contextual controls. Perceived relative advantage and governance trust are standardized so their odds ratios represent a one-standard-deviation increase. The model is used for exploratory association and prioritization rather than causal attribution.

RESULTS AND DISCUSION

Results

3.1 Baseline Characteristics and Adoption Readiness

The baseline included 60 livestock-keeping households and showed a mixed level of operational readiness for a village-scale circular enterprise. Goats or sheep were the main livestock for 64% of respondents, while cattle accounted for 36%, and households kept an average of 3.4 animals. Daily stall-keeping was common at 82%, but only 58% separated solids, urine, and bedding and only 42% used temporary covered storage during rainfall. Exposure to enabling mechanisms was uneven, with 48% reporting short training, 40% having access to simple microfinance, and 38% having access to an offtake MoU. Mean governance trust was 3.7 on the five-point rating and mean perceived relative advantage was 3.6, indicating moderately favorable but not uniformly strong perceptions. Overall, 46% of households met the Year-1 operational definition of adoption readiness through early engagement or a firm commitment to participate.

Table 1. Baseline characteristics and residue-handling practices (n = 60)

Variable group	Indicator	Value
Demographics & assets	Main livestock: cattle (%)	36.0
	Main livestock: goats/sheep (%)	64.0
	Average number of animals per household (head)	3.4
Upstream practices	Daily stall-keeping (%)	82.0
	Separation of solids, urine, and bedding (%)	58.0
	Temporary covered storage during rains (%)	42.0
Program exposure	Attended a short training (%)	48.0
	Access to simple microfinance (%)	40.0
Perceptions & institutions	Governance trust (1-5, mean)	3.7
	Perceived relative advantage (1-5, mean)	3.6
Channels & markets	Nearest purchase point <= 2 km (%)	50.0
	Accessible offtake MoU (%)	38.0
Outcome	Adoption readiness: early engagement or firm commitment (%)	46.0

Table 1 shows that the main constraint was not the absence of livestock residues but the uneven discipline with which residues were separated, stored, and connected to market arrangements. The high share of daily stall-keeping implies a relatively dependable feedstock stream, yet the lower rates of separation and covered storage indicate substantial quality variability before materials reach the processing unit. Access to training, finance, and offtake arrangements was also below one half of the sample, leaving many households exposed to technical, liquidity, and market uncertainty at the same time. The perception scores suggest that households were not strongly resistant to the proposed enterprise, but neither trust nor perceived advantage had reached a level that could be treated as universal. The 46% readiness rate therefore represents a plausible early-engagement base rather than a mature adoption level. These baseline patterns justify a design that combines process standardization with market, finance, and governance mechanisms instead of focusing only on fertilizer production technology.

3.2 Baseline Value-Chain Diagnosis

The baseline value-chain diagnosis identified distinct bottlenecks across upstream, midstream, and downstream activities. Upstream supply was relatively continuous because animals were housed daily, but feedstock quality varied with inconsistent separation of manure, urine, bedding, and exposure to rainfall. Midstream processing existed in practical form, yet fermentation time, pH checks, turning frequency, curing, filtration, sieving, and batch documentation were not consistently defined across lots. Downstream market access depended on local agri-input kiosks, farmer-group outlets, the village store, and a small set of prospective anchor buyers, but product specifications and delivery commitments were still weak. The diagnosis also showed that processing units carried operational risk while a substantial share of value was expected to be captured closer to the retail point. These findings positioned quality discipline, transparent records, and buyer coordination as immediate design priorities before investment in more sophisticated technology.

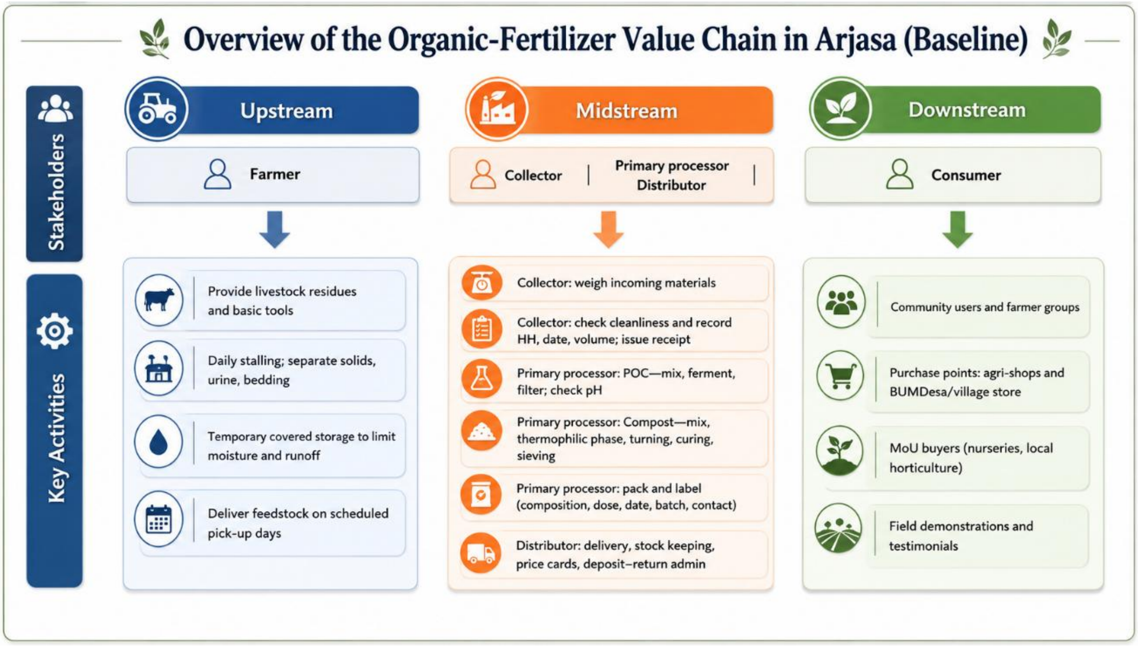

Figure 3. Current-state livestock-waste value chain in Arjasa at baseline

Figure 3 distinguishes the upstream, midstream, and downstream responsibilities observed or required at baseline. It shows that physical product movement must be accompanied by weighing, process control, labeling, pricing, dosage guidance, and feedback mechanisms. The map served as the diagnostic reference for separating current weaknesses from arrangements proposed during co-design, and it should not be read as evidence that every depicted practice had already been fully implemented.

Participatory Co-design and Business Model

The participatory co-design process translated the diagnosed bottlenecks into a more explicit management architecture for the Year-1 pilot. Stakeholders agreed on simple upstream sorting rules and covered storage, scheduled collection windows, compact processing SOPs, low-cost quality checks, and batch coding for both liquid and solid products. Downstream arrangements included practical package sizes, posted retail, wholesale, and member price tiers, field demonstrations, dosage information, and a deposit-return system for reusable jerrycans. Market uncertainty was addressed through simple offtake memoranda with one or two anchor buyers that could specify minimum volume, delivery windows, base prices, and complaint routines without creating a complex contract. The co-designed map also assigned performance indicators to adoption readiness, batch compliance, unit cost and margin, return rates, complaints, and outlet volumes. Together, these elements changed the intervention from a technology-centered waste-processing activity into a coordinated community-enterprise system with clearer roles and traceable operating routines.

Exploratory Model of Adoption Readiness

The exploratory logistic model identified five designable variables with positive associations with adoption readiness after inclusion of the contextual controls. Access to an offtake MoU had the largest estimated association, with an odds ratio of 3.40 and a 95% confidence interval of 1.40 to 8.35. Microfinance access was associated with 2.60 times higher odds of readiness, while a one-standard-deviation increase in perceived relative advantage was associated with an odds ratio of 2.20. Governance trust had an odds ratio of 1.90 per standard deviation, and participation in a short training had an odds ratio of 1.80. Herd size, livestock type, nonfarm income, and distance to the nearest outlet did not reach the .05 threshold in this small baseline model. Because the sample contains only 60 households and the outcome combines early engagement with firm commitment, these coefficients should be read as preliminary signals for program design rather than stable causal effects.

Table 2. Exploratory determinants of adoption readiness (n = 60)

Predictor	Odds Ratio	95% CI	p value	Sig.
Offtake MoU available (1 = yes)	3.40	1.40-8.35	0.007	Yes
Access to microfinance (1 = yes)	2.60	1.07-6.33	0.034	Yes
Perceived relative advantage (per 1 SD)	2.20	1.18-4.12	0.013	Yes
Governance trust (per 1 SD)	1.90	1.02-3.56	0.043	Yes
Attended a short training (1 = yes)	1.80	1.01-3.45	0.049	Yes
Herd size (log heads)	1.15	0.70-1.89	0.580	No
Livestock type: cattle (ref. goats/sheep)	1.21	0.54-2.71	0.640	No
Nonfarm income (1 = yes)	0.88	0.41-1.90	0.740	No
Distance to outlet (per km)	0.92	0.78-1.09	0.330	No

Model performance: AUC = 0.81 (95% CI 0.71-0.91); Hosmer-Lemeshow chi-square = 6.1, df = 8, p = .62; Brier score = 0.16.

Table 2 shows that the estimated confidence intervals for the five designable mechanisms are wider than would be expected in a large confirmatory study, which is consistent with the small Year-1 sample. Even so, the ordering of the odds ratios is operationally informative because it places market assurance and liquidity relief ahead of the softer behavioral mechanisms in estimated magnitude. The AUC of 0.81 indicates that the fitted model separated higher-readiness and lower-readiness households reasonably well within the observed sample. The Hosmer-Lemeshow statistic of 6.1 with p = .62 and the Brier score of 0.16 indicate acceptable in-sample calibration and probability accuracy for exploratory monitoring. These performance metrics do not remove the risk of overfitting or instability, and they should not be used to justify extrapolation beyond comparable Arjasa households. Their main value is to provide a transparent baseline against which a larger Year-2 model can be re-estimated and externally checked.

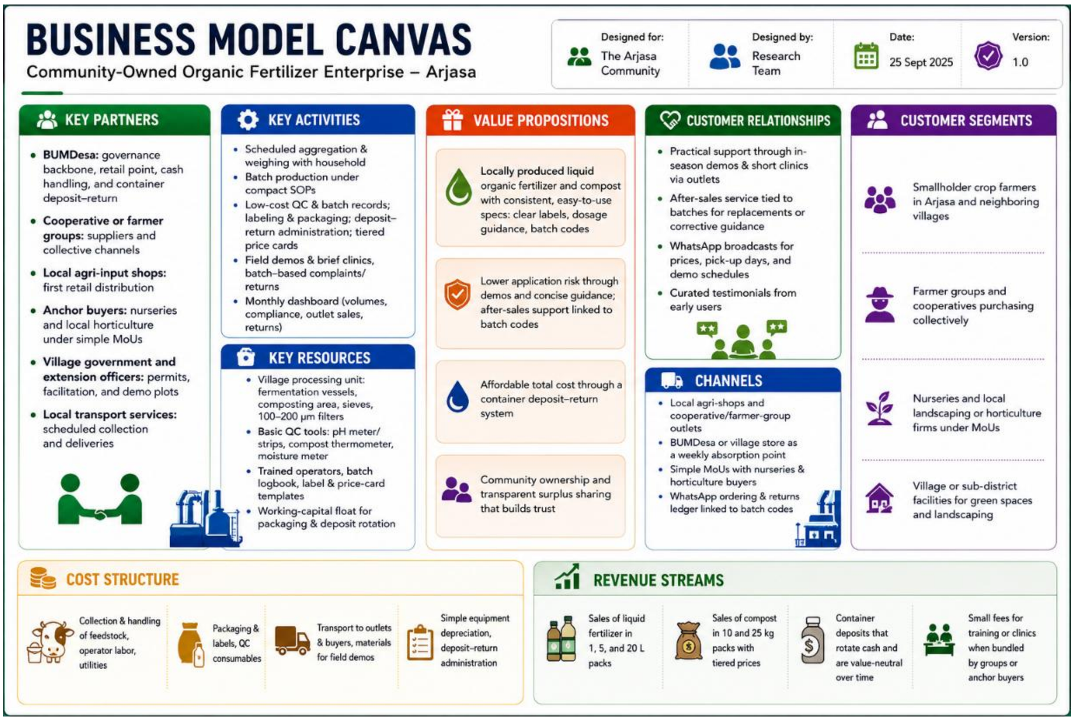

Figure 4. Business Model Canvas for the Arjasa organic-fertilizer community enterprise (Year 1)

Figure 4 consolidates the co-designed arrangements into a nine-block Business Model Canvas. It assigns village institutions, farmer organizations, retailers, anchor buyers, extension actors, and transport providers to clear roles in aggregation, processing, quality assurance, market coordination, and after-sales service. The value proposition combines locally produced organic fertilizer with traceable batches, clear dosage information, practical customer support, and transparent community governance. Costs and revenues remain provisional Year-1 assumptions that require validation through actual production and market trials.

Discussion

The first major finding is that the binding weaknesses in the Arjasa system were organizational and relational as much as technical. Residue availability was relatively stable, yet inconsistent separation, storage, process endpoints, quality records, and market commitments created breaks in the loop that a circular-economy label alone could not solve. This pattern supports the argument that circular agriculture requires coordinated resource flows and business arrangements rather than isolated recovery technologies (Haque et al., 2023; Kleinpeter et al., 2023). It also extends circular-business-model research by showing how value-chain diagnosis can give operational content to the Business Model Canvas at village scale, a concern often missed when canvases are treated as static presentation tools (Cavicchi et al., 2022; Hina et al., 2022). The co-designed combination of sorting rules, SOPs, batch records, price tiers, deposit-return, and buyer commitments is comparable to participatory bioeconomy work in which stakeholder co-creation makes value propositions more locally credible and socially embedded (Mohammed et al., 2024). The critical implication is that circularity in a resource-constrained community depends on closing coordination loops alongside material loops, because a fertilizer product that is technically recoverable but commercially unreliable does not constitute a functioning circular business model.

The strongest quantitative signal was the association between access to an offtake arrangement and adoption readiness, which suggests that market uncertainty is a central constraint in the early stage of the enterprise. A simple buyer commitment can change the decision environment by specifying expected volume, timing, base price, and minimum quality, thereby reducing the perceived risk that households or the processing unit will accumulate unsold output. This mechanism is consistent with field evidence showing that contract farming can support rural commercialization when market access and coordination failures are substantial (Arouna et al., 2021). It also fits research showing that the number of buyers and organizational membership can shape farmers' willingness to adopt risk-bearing sustainable practices (Rodriguez-Barillas et al., 2024). At the same time, contract-farming scholarship warns that agreements can reproduce power asymmetries or dissatisfaction when pricing, grading, payment, and enforcement are opaque (Schoneveld, 2022; Vicol et al., 2022). The Arjasa result should therefore not be interpreted as evidence that any contract is beneficial; rather, it supports a lightweight, transparent form of market assurance that is proportionate to local capacity and explicitly tied to quality and complaint rules. This modifies a purely technology-centered adoption explanation by positioning downstream market architecture as part of the adoption environment itself.

Access to light microfinance formed the second strongest association, highlighting the importance of modest liquidity constraints in decisions that do not require major capital investment. Households may accept the technical idea of manure valorization yet still delay participation when they must finance containers, packaging, transport, or other early-season inputs before sales occur. This finding complements evidence that cooperatives and value-chain finance can ease transaction and credit constraints that otherwise limit the uptake and intensity of agricultural inputs (Geffersa, 2024). It also helps explain why the financial mechanism in Arjasa was designed as a small rotating facility or advance rather than as long-term debt, since the relevant problem is working-capital timing rather than the acquisition of expensive machinery. The critical point is that finance operates here as a risk-buffering mechanism embedded in a commercial relationship, not as a standalone credit program. This interpretation is consistent with the broader inclusive-agribusiness literature, which emphasizes that financial services are most effective when coordinated with market access and organizational support rather than offered in isolation (Schoneveld, 2022). The practical contribution is therefore a value-chain financing logic in which repayment capacity is supported by predictable product movement and transparent records.

Perceived relative advantage was also positively associated with readiness, reinforcing the behavioral principle that farmers evaluate innovations through concrete expected benefits rather than through environmental narratives alone. In Arjasa, those benefits were translated into practical cues such as easier application, clearer dosage, fewer clogging problems, visible crop response, and locally accessible products. Recent adoption research similarly finds that attitudes, perceived compatibility, expected value, and information about benefits are central to farmers' intentions to initiate or continue sustainable practices (Abe et al., 2025; Erekalo et al., 2025). The global meta-analysis by Sanchez Bogado et al. (2024) further shows that farmer attitudes and access to knowledge can be more consistent adoption enablers than several forms of material capital. The Arjasa evidence adds a business-model dimension to this literature because perceived advantage is not treated only as a psychological property of the technology; it is deliberately shaped through product specification, packaging, labeling, demonstration, and after-sales support. An alternative explanation is that households already inclined to participate may rate the product more favorably, which is plausible in a cross-sectional design and prevents a causal interpretation. Even with that limitation, the finding indicates that value propositions must be made observable and operational if circular products are to compete with familiar inputs.

Governance trust and short training produced smaller but still meaningful positive associations, indicating that collective adoption depends on both institutional credibility and usable knowledge. Trust is particularly salient in a community-owned enterprise because households must believe that prices, deposits, batch records, complaint handling, and surplus sharing will be administered predictably by the cooperative or BUMDesa. This interpretation aligns with evidence that institutional and relational trust influences participation in collective environmental schemes and that cooperative structures can lower information and transaction barriers for farmers (Geffersa, 2024; Sander et al., 2024). The training result is also consistent with recent work showing that interpersonal information and practical knowledge channels can shape intentions to adopt composting and other sustainable land-management practices (Abe et al., 2025). Importantly, the Arjasa design does not treat training as a one-off awareness seminar; it ties short clinics to outlets, demonstrations, dosage guidance, and real purchasing or supply decisions. That integration may explain why training remains relevant even after perceived benefit and trust are considered, because it reduces task-specific uncertainty at the point of action. Conceptually, these findings extend adoption theory by showing that social learning and governance credibility can be designed as complementary components of a business operating system rather than as external extension activities.

Taken together, the findings position this study within a global literature that is moving from single-factor adoption explanations toward context-sensitive configurations of markets, institutions, perceptions, and capabilities. The contribution is not a claim that the five mechanisms independently cause adoption, but a proposition that they form a risk-reduction architecture whose components address different but interacting uncertainties. This configuration is consistent with research showing that sustainable-practice adoption varies across technologies and contexts and that bundled, locally tailored strategies are more plausible than universal incentives (Rodriguez-Barillas et al., 2024; Sanchez Bogado et al., 2024). It also advances circular-business-model work by linking stakeholder co-design directly to household readiness rather than evaluating the business model only at the firm or technology level (Hina et al., 2022; Mohammed et al., 2024). The boundary conditions are important: Arjasa benefits from functioning village institutions, nearby outlets, manageable transport distances, and a residue stream that can be aggregated, so the model should not be transferred mechanically to settings lacking those assets. Future testing should separate actual adoption from stated commitment, use larger and preferably longitudinal samples, validate multi-item measures of trust and perceived advantage, and track circularity indicators such as residue recovery, packaging returns, nutrient substitution, unit margins, and product quality. Within those limits, the study offers a conceptually integrated and operationally testable pathway for moving community livestock-waste initiatives from fragmented technical activities toward locally governed circular enterprises.

Implications

The findings have direct implications for village enterprises, cooperatives, extension services, and local policymakers developing small-scale circular agribusiness. Market assurance and working-capital timing deserve early priority because they showed the largest associations with household readiness, while quality assurance should remain simple but traceable through compact SOPs, batch codes, low-cost checks, posted prices, and a complaint log. Governance arrangements should make decision rights, deposit administration, price setting, and surplus distribution visible because community ownership alone does not guarantee trust. Extension is likely to be more useful when delivered as short, task-specific learning connected to outlet activity and real product decisions rather than as stand-alone classroom training. For policymakers, the transferable principle is to strengthen the coordination capacity of rural institutions instead of subsidizing processing equipment without parallel market and governance mechanisms. For researchers, the framework provides a set of mechanisms that can be followed longitudinally as readiness develops into actual adoption, repeat purchase, enterprise performance, and measurable circularity outcomes.

Limitations And Future Research

Several limitations qualify the interpretation of the findings. First, this is a single-village Year-1 case designed for participatory diagnosis and intervention planning rather than population-level inference, and the sample of 60 households is small relative to the number of variables in the exploratory logistic model. Second, the outcome combines early engagement with firm commitment because full market implementation had not yet matured, so it measures adoption readiness rather than sustained adoption behavior. Third, perceived relative advantage and governance trust were recorded as single rating indicators, which limits construct depth and precludes internal-consistency testing. Fourth, the cross-sectional baseline leaves open reverse association, while agronomic performance, environmental effects, actual value added, break-even volume, and long-term deposit-return behavior were not validated in Year 1. Future work should therefore use larger longitudinal samples, separate exposure from actual and sustained adoption, develop validated multi-item behavioral measures, and apply sensitivity analyses such as penalized logistic regression or bootstrap confidence intervals. It should also track unit costs, margins, residue recovery, nutrient return, packaging-return rates, product quality, and crop response across villages with different institutional and market conditions so that the transferability of the proposed model can be tested rather than assumed.

CONCLUSION

This study shows that transforming livestock waste into a community-owned circular enterprise is primarily a coordination challenge layered onto a technical resource-recovery opportunity. The Arjasa baseline identified a dependable residue stream but also exposed variability in upstream handling, inconsistent processing endpoints, weak traceability, and uncertain downstream absorption. Participatory co-design translated these weaknesses into an operating model built around scheduled collection, compact SOPs, low-cost quality control, batch records, transparent price tiers, deposit-return, short training, light finance, and simple offtake commitments. The Business Model Canvas then assigned partners, activities, resources, customer relationships, channels, costs, and revenues to these arrangements. The central contribution is therefore an integrated risk-reduction architecture that addresses market, liquidity, governance, information, and perceived-value uncertainties together rather than treating waste conversion as a stand-alone technology problem. This community-centered architecture places the cooperative and BUMDesa in coordinating roles that individual households would struggle to perform independently.

The exploratory household analysis supports this architecture while also defining its inferential limits. Offtake access showed the largest positive association with adoption readiness, followed by microfinance, perceived relative advantage, governance trust, and short training, whereas contextual controls were not statistically significant in the small baseline. The AUC, calibration statistic, and Brier score indicate useful in-sample performance for exploratory targeting and monitoring, but they do not establish causality or external validity. The next research cycle should implement the co-designed arrangements, distinguish actual adoption from stated commitment, enlarge the sample, and test whether the associations persist over time. Economic viability, product performance, circularity indicators, and governance outcomes should be monitored together so the business model can be revised using evidence. Subject to those tests, the study offers a realistic and transferable-in-principle pathway for rural institutions seeking to turn dispersed livestock residues into a repeatable, locally governed circular business system.

AUTHOR CONTRIBUTION STATEMENT

Dhanang Eka Putra: Conceptualization, methodology, research design, project administration, supervision, investigation, and writing of the original draft. Hariyono Rakhmad: Methodology, data curation, formal analysis, visualization, and review and editing of the manuscript. Huda Ahmad Hudori: Investigation, field data collection, stakeholder coordination, value-chain mapping, validation, and review and editing of the manuscript. Raden Roro Lia Chairina: Business model development, participatory analysis, interpretation of findings, validation, and review and editing of the manuscript. All authors contributed to the interpretation of the results, critically reviewed the manuscript, approved the final version for publication, and agreed to be accountable for the integrity and accuracy of the work.

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