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Community Based Industrial Symbiosis through Vermiculture: A Circular Resource Exchange Model for Post Disaster Recovery

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Abstract

Background: Natural disasters often have long-term impacts on agricultural land productivity and community livelihoods, particularly through soil degradation and disruptions to local economic activities.Objective: This study aimed to analyze how the Pesona Paya Nie Program established community-based industrial symbiosis through a vermiculture system as a circular resource exchange mechanism to support agricultural land rehabilitation and livelihood recovery in post-disaster settings. Method: This study employed a descriptive qualitative case study approach in Blang Mee Village, Bireuen Regency, Aceh, Indonesia. Data were obtained through a literature review and internal company documents, including program planning documents, value chain documentation, soil test results, and program implementation reports. Network mapping was used to identify nodes and resource flows within the exchange network, followed by thematic analysis. Findings and Implications: The findings showed that the program connected farmer groups, livestock groups, Tourism Awareness Groups (Pokdarwis), households, and vermiculture groups within an integrated resource exchange network. Organic waste was converted into vermicompost to improve soil organic carbon levels in post-disaster agricultural land while simultaneously strengthening knowledge exchange and stakeholder collaboration and generating environmental, social, and economic benefits. This study was limited to document-based qualitative analysis; therefore, future research should incorporate material flow analysis (MFA) or life cycle assessment (LCA) to quantitatively evaluate resource efficiency and environmental impacts. Conclusion: This study offers a community-based industrial symbiosis perspective, demonstrating that circular resource exchange principles can emerge within Corporate Social and Environmental Responsibility (Tanggung Jawab Sosial dan Lingkungan [TJSL]) programs to support environmental rehabilitation and post-disaster recovery

INTRODUCTION

Large-scale flood disasters can cause extensive infrastructure damage, substantial economic losses, and significant ecological impacts (Aitzhanova & Zhaparova, 2023; Lam et al., 2025; Lu et al., 2024; Yu et al., 2022). From an ecological perspective, Sun et al. (2022) reported that flooding can reduce vegetation productivity and slow ecosystem processes such as soil respiration and methane emissions, particularly under conditions of climate warming. In late 2025, a major flooding event affected several areas of Sumatra, including the provinces of Aceh, North Sumatra, and West Sumatra. The event was recorded as one of the disasters with the largest economic and ecological impacts in Indonesia over the past decade (BNPB, 2025). According to cumulative data from the National Disaster Management Agency (BNPB) as of December 19, 2025, the disaster resulted in 1,072 fatalities, 186 missing persons, and 7,000 injuries, while damaging 147,236 houses and 1,600 public facilities and affecting 52 regencies/cities (BNPB, 2025). Meanwhile, the Center of Economic and Law Studies (CELIOS) estimated that national economic losses resulting from the disaster could reach IDR 68.67 trillion, equivalent to a 0.29% decline in national GDP. Aceh Province alone was estimated to have suffered approximately IDR 2.2 trillion in losses, contributing to a 0.88% contraction in regional economic activity (Huda & Adhinegara, 2025). The agricultural sector was also severely affected. Data from the emergency response post indicated that, of the 89,582 hectares of rice fields affected by flooding in Aceh, approximately 27,065 hectares could no longer be cultivated because they were covered by 1–1.5 meters of sediment, with estimated losses in the rice sector exceeding IDR 1.164 trillion (Jayadi, 2025). Given that average rice productivity in Aceh is approximately 5.7 tons per hectare, the potential loss in rice production could reach hundreds of thousands of tons (Hasyim, 2026). These figures indicate a potential medium-term threat to food security and farmers' livelihoods.

One of the affected areas was Blang Mee Village in Bireuen Regency, Aceh Province. The flooding created two interrelated ecological problems. First, large quantities of organic waste accumulated, including rice straw from failed harvests, livestock manure that remained unmanaged because of emergency relocation, and extensive growth of water hyacinth (Eichhornia crassipes) following post-flood eutrophication in wetland ecosystems. This aquatic plant is characterized by rapid growth; however, the same characteristic can make E. crassipes a major environmental problem. One hectare of healthy water hyacinth can produce wet biomass of up to 415 tons (Pfingsten, I.A., 2017; Schardt, 1997), while its population can double within only two weeks (Penfound & Earle, 1948). The biomass production rate of E. crassipes has been reported to range from 60 to 100 tons per hectare per year, making it one of the aquatic weeds with the highest biomass productivity worldwide (Cui & Grace, 2008). Post-flood eutrophication, driven by nutrient inputs from agricultural and residential runoff, can accelerate the proliferation of E. crassipes. Experimental studies have shown that, under eutrophic water conditions, E. crassipes population density can increase more than sixfold, while individual biomass can reach 2.4 times that observed under low-nutrient conditions (Yu et al., 2019).

Second, the quality of agricultural soils deteriorated, as indicated by declining soil organic carbon (SOC) levels in rice fields and land managed by women farmer groups. Soil organic carbon is an important indicator of soil quality and agricultural sustainability. Its depletion is a major driver of soil degradation, contributing to reduced fertility and impaired ecosystem services (López i Losada et al., 2025). Flooding reduces oxygen availability in the soil and alters the activity and composition of soil microorganisms, particularly by favoring anaerobic microbial processes. These changes can negatively affect nutrient cycling and microbial diversity, thereby limiting the soil's capacity to retain and supply nutrients to plants (Unger et al., 2009).

Although these two problems are closely interconnected, their management has generally been undertaken through sector-specific interventions. Organic waste management is commonly positioned as a waste-reduction activity through composting or disposal (Azhar et al., 2024), whereas agricultural land rehabilitation is implemented separately through the application of organic or inorganic fertilizers. Such approaches leave the potential relationship between waste sources and land rehabilitation needs underutilized (Haque et al., 2023). Consequently, organic waste that could otherwise provide valuable resources continues to be perceived as an environmental burden, while soil rehabilitation depends on resources supplied from outside the local system. This condition highlights a gap in post-disaster resource management, namely the absence of an integrated mechanism capable of connecting waste sources with ecosystem recovery needs.

In recent years, the concept of the circular economy has emerged as a paradigm aimed at maintaining the value of resources for as long as possible through material reuse, waste reduction, and the development of closed-loop production systems (Korhonen et al., 2018). One operational application of this paradigm is industrial symbiosis, which involves the exchange of materials, energy, water, and knowledge among different actors, whereby the output of one process can be utilized as an input for another (Chertow, 2000). Through such mechanisms, waste is no longer viewed merely as a residual product but as a resource with economic and ecological value. Thus, industrial symbiosis is not solely oriented toward improving resource-use efficiency but can also generate environmental and social benefits through collaboration among actors.

Nevertheless, most research on industrial symbiosis has focused on formal industrial areas, eco-industrial parks, manufacturing clusters, or networks of companies with direct business relationships. The Kalundborg model in Denmark is one of the most widely cited examples in the literature, demonstrating the successful exchange of resources among industrial actors through mechanisms that developed incrementally over time (Fraccascia & Giannoccaro, 2020). In contrast, the application of industrial symbiosis principles in rural communities, particularly in post-disaster recovery contexts involving community groups, local organizations, and Corporate Social and Environmental Responsibility (Tanggung Jawab Sosial dan Lingkungan [TJSL]) initiatives, remains relatively underexplored. This gap suggests that the potential application of symbiotic principles beyond industrial areas has received limited attention, particularly in contexts where relationships among actors are shaped by social solidarity, shared recovery needs, and the utilization of locally available resources.

Previous studies on industrial symbiosis have predominantly examined resource exchange among industrial actors in formal industrial areas. Chertow (2000) developed a foundational taxonomy of industrial symbiosis and emphasized the roles of geographic proximity and interfirm collaboration. Boons et al. (2011) proposed a conceptual framework for understanding the dynamics of industrial symbiosis and highlighted the importance of social and institutional factors in network formation. Fraccascia and Giannoccaro (2020) reviewed indicators for measuring industrial symbiosis and noted that most empirical studies remain concentrated in developed countries and formal industrial settings. Schlüter et al. (2022) examined the role of industrial symbiosis facilitators in Nordic countries and found that facilitation mechanisms are critical to network development. Meanwhile, Haque et al. (2023) analyzed waste recovery in the agricultural sector and emphasized the relevance of circular economy principles for addressing agricultural challenges. From a circular economy perspective, Korhonen et al. (2018) provided a critical review of the concept and its limitations, while Serrat (2017) discussed knowledge-based solutions for sustainable development. However, studies specifically examining industrial symbiosis in post-disaster rural communities, particularly those facilitated through Corporate Social and Environmental Responsibility (Tanggung Jawab Sosial dan Lingkungan [TJSL]) programs, remain limited. This gap is significant because post-disaster contexts present distinctive conditions, including urgent recovery needs, disruptions to local economies, and the availability of underutilized biomass resources.

The Pesona Paya Nie Jaring Pengaman Pasca Bencana Program, initiated by PT Pupuk Iskandar Muda in Blang Mee Village, provides a relevant empirical context for addressing this gap. The program integrates various community groups, including farmer groups, livestock groups, Women Farmer Groups (Kelompok Wanita Tani [KWT]), Beujroh micro, small, and medium-sized enterprises (MSMEs), Tourism Awareness Groups (Kelompok Sadar Wisata [Pokdarwis]), and village residents, into a vermiculture-based circular value chain. Various types of organic waste that previously constituted environmental burdens are converted into vermicompost and other vermiculture products, which are subsequently reused to rehabilitate agricultural land, strengthen food security, and create new economic opportunities. This model is consistent with circular economy principles, which emphasize the recirculation of resources through closed-loop systems while simultaneously supporting sustainable livelihood development based on local assets (Korhonen et al., 2018; Serrat, 2017).

Unlike previous studies that have predominantly conceptualized industrial symbiosis as a resource exchange mechanism among industrial actors within formal industrial areas (Boons et al., 2011; Chertow, 2000), this study conceptualizes relationships among community actors as a form of symbiosis established through the exchange of materials, knowledge, and social resources in a post-disaster recovery context. Accordingly, this study does not focus on evaluating the success of the TJSL program itself but rather on mapping the structure of the exchange network formed through the vermiculture system, which functions as a central conversion hub within the circular value chain. This approach is expected to broaden understanding of the application of industrial symbiosis principles beyond industrial areas while contributing to the discourse on the integration of the circular economy, post-disaster recovery, and community empowerment (Boons et al., 2011; Schlüter et al., 2022).

Building on this research gap, this study seeks to contribute to the development of industrial symbiosis research by demonstrating how resource exchange principles can occur not only within formal industrial areas but also through community networks facilitated by TJSL programs in post-disaster recovery contexts. Using a network-mapping perspective, this study analyzes the structure of actors (nodes) and resource exchanges (flows) that constitute the circular value chain within the Pesona Paya Nie Program. It further examines how the vermiculture system functions as a conversion hub that simultaneously reduces organic waste accumulation and supports the rehabilitation of post-disaster agricultural land.

Accordingly, this study aims to analyze how the Pesona Paya Nie Program establishes community-based industrial symbiosis through a vermiculture system as a circular resource exchange mechanism to support agricultural land rehabilitation and livelihood recovery in post-disaster settings. Theoretically, this study is expected to enrich the literature on industrial symbiosis and the circular economy by extending the application of symbiotic principles to rural community contexts facilitated by TJSL programs. Practically, the findings are expected to provide input for companies in designing TJSL programs that generate sustainable resource exchange networks, for local governments in supporting post-disaster recovery efforts, for community groups in developing collaborative resource management practices, and for future researchers examining community-based industrial symbiosis in other contexts. The remainder of this article is organized as follows. The Methods section describes the research design and data sources. The Results and Discussion section presents findings on the circular value chain, node–flow mapping, classification of exchange types, soil test results, and identified relationships among actors and resource flows. The Conclusion section summarizes the key findings and their implications.

METHOD

This study employed a descriptive qualitative case study approach in Blang Mee Village, Kuta Blang District, Bireuen Regency, Aceh Province, Indonesia. The approach was used to develop an in-depth understanding of the relationships and social processes among actors involved in the Pesona Paya Nie Program rather than to test causal relationships (Neuman, 2014). The study relied entirely on secondary data obtained through a literature review and internal company documents. The literature review provided the conceptual basis for examining the Sustainable Livelihood Approach, industrial symbiosis, social capital, and social innovation (Neuman, 2014), while internal documents were used to reconstruct program implementation, relationships among actors, resource exchange processes, and program outcomes.

The unit of analysis was the resource exchange network established through the Pesona Paya Nie Program (Yin, 2017; Mills et al., 2012). The analysis focused on identifying actors as nodes and material exchanges, knowledge exchanges, and collaborative relationships as flows within the circular value chain. Data credibility was strengthened through source triangulation by comparing evidence across multiple documents. Theoretical triangulation was also conducted by interpreting the empirical findings through the Sustainable Livelihood Approach, industrial symbiosis, and post-disaster resilience literature to assess conceptual consistency and support the interpretation of the findings.

RESULTS AND DISCUSSION

The Value Chain System of the Pesona Paya Nie "Jaring Pengaman Pasca Bencana" Program

The Pesona Paya Nie Program establishes a value chain system that connects various community groups through the utilization of organic waste as a shared resource. In the network mapping, H1–H4 represent the groups supplying organic raw materials: H1, the Farmer Group (rice straw); H2, the Livestock Group (animal manure); H3, the Tourism Awareness Group (Pokdarwis) (water hyacinth); and H4, the community (household organic waste). Meanwhile, D1–D4 represent the beneficiary groups: D1, the Farmer Group (agriculture); D2, the Women Farmer Group (horticulture); D3, Beujroh MSMEs (home gardening); and D4, the community (food security). As shown in Figure 1, these groups are interconnected through the Vermiculture Group, which functions as the central hub within the system. Organic materials from various sources are subsequently converted into vermicompost as a value added product.

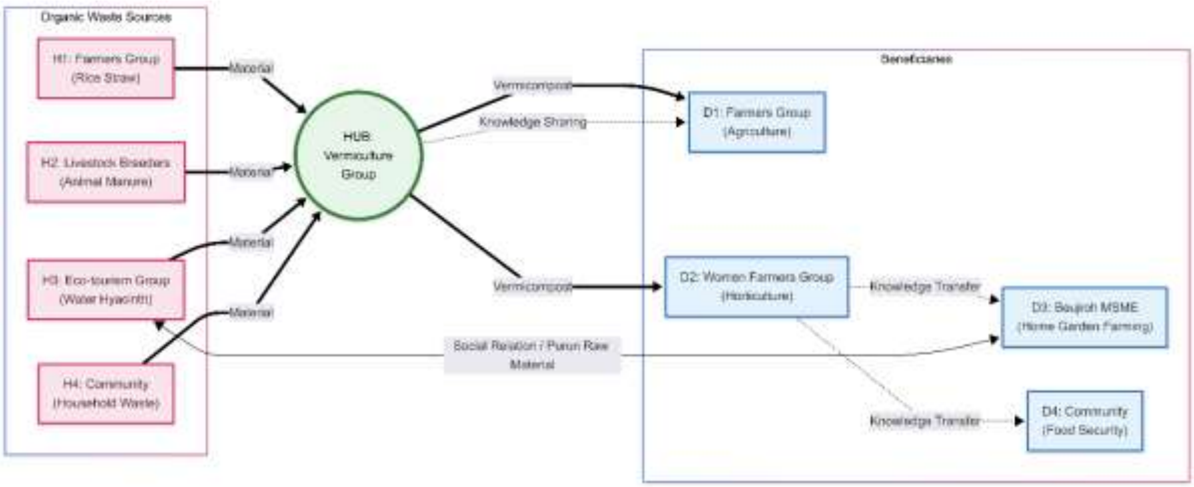

Figure 1. Mapping of the Node-Flow Network and Community Symbiosis Structure of the Pesona Paya Nie Program

Source: Internal company documents and network mapping analysis, 2026

H1-H4: Represent organic raw material provider groups

D1-D4: Represent beneficiary groups

Vermicompost is subsequently distributed to farmer groups and Women Farmer Groups (KWT) as an input to improve soil fertility and agricultural productivity. In addition to generating material flows, the system also facilitates knowledge exchange through mentoring on cultivation practices, vermiculture management, and sustainable agricultural practices across community groups. This knowledge transfer enables the adoption of the technology to extend beyond the initial beneficiary groups and reach other actors involved in the program. The resulting value chain therefore produces not only vermicompost as a tangible output but also fosters collaborative relationships among community groups. The KWT subsequently develops home based agricultural activities that support MSME operations, while the cultivation practices implemented contribute to strengthening community food security. Thus, the Pesona Paya Nie Program does not merely transform organic waste into economically valuable products but also establishes interconnections among actors that enable local resources to be continuously recirculated within an integrated and interconnected system.

Node–Flow Mapping of the Community Symbiosis Structure

The node–flow mapping demonstrates that the symbiotic structure within the Pesona Paya

Nie Program is established through systematic relationships among sources of organic waste, biological conversion processes, and the reuse of converted outputs to support agricultural land rehabilitation. As shown in Figure 2, failed harvest rice straw, animal manure, water hyacinth, and household kitchen waste, which previously constituted sources of environmental pollution, are positioned as biomass inputs within the vermiculture system. The transformation of waste from a residual material into a resource indicates a shift in material flows, which is a key characteristic of industrial symbiosis (Chertow, 2000).

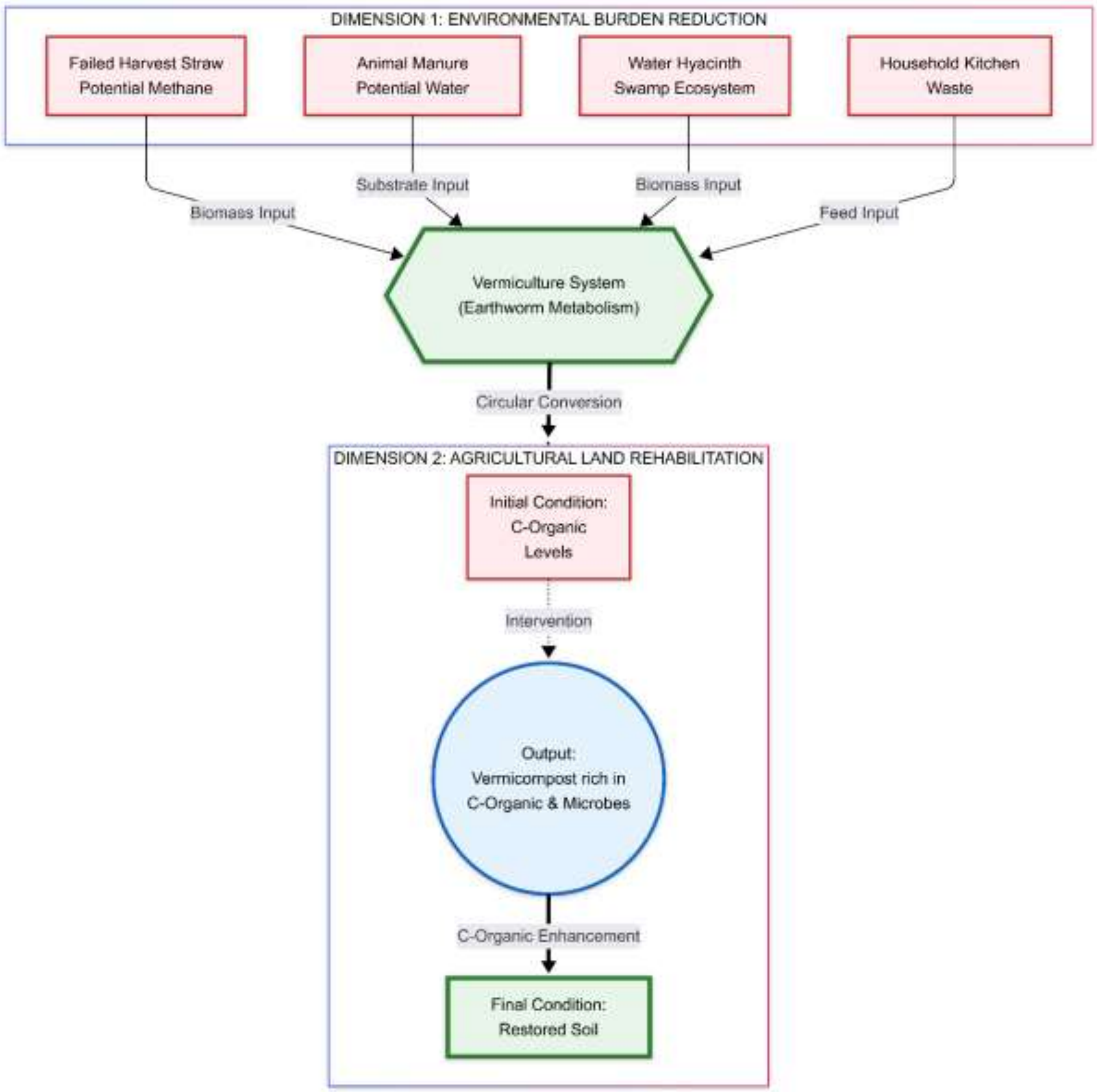

Figure 2. Vermiculture Convergence Mechanism
Source: Internal company documents and network mapping analysis, 2026

The Vermiculture Group functions as a hub connecting various biomass sources with the needs of agricultural land rehabilitation. Through the biological activity of earthworms, different types of organic waste are converted into vermicompost, which is subsequently applied to agricultural land. The vermicompost contains organic matter and microorganisms that contribute to increasing soil organic carbon (SOC) content, thereby supporting improvements in soil quality in areas that previously had very low SOC levels. Thus, the vermiculture system functions not only as a waste treatment technology but also as a resource exchange hub that connects various actors within a circular system. This position demonstrates that the value of a resource is not determined by its initial form as waste, but rather by its potential to be converted into products that generate ecological and social benefits.

The mapping results also reveal the interconnectedness of two key dimensions within the community symbiosis system. The first dimension focuses on reducing environmental burdens through the utilization of organic waste that could otherwise contribute to methane emissions, water pollution, wetland ecosystem invasion, and the accumulation of household waste. The second dimension demonstrates how vermicompost is utilized as an intervention to improve the quality of agricultural land characterized by low soil organic carbon content. Thus, material flows within the system do not end with waste management but continue into a land rehabilitation mechanism through increasing soil organic carbon content, thereby supporting the recovery of agricultural soil quality.

These findings indicate that the Pesona Paya Nie Program not only applies circular economy principles through the reuse of organic waste but also establishes a pattern of community based industrial symbiosis involving resource exchanges among actors at the community level. Unlike industrial symbiosis, which typically develops within industrial areas, the symbiosis established through the Pesona Paya Nie Program is built upon collaboration among community groups using locally available resources to generate simultaneous environmental, agricultural, and social benefits. Thus, the resulting node–flow structure demonstrates that relationships among actors not only improve resource use efficiency but also strengthen community adaptive capacity in supporting post disaster recovery.

Classification of Exchange Types within the Network

The network mapping indicates that resource exchange patterns within the Pesona Paya Nie Program exhibit characteristics that differ from conventional industrial symbiosis models, which generally develop within formal industrial areas. As shown in Figure 3, these differences are reflected not only in the types of actors involved but also in the motivations, contextual conditions, and governance mechanisms that shape the resource exchange network.

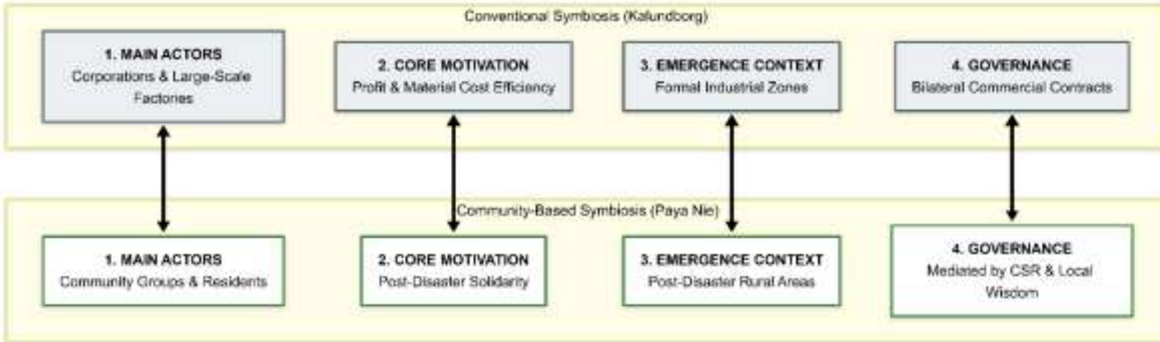

Figure 3. Comparison Matrix of Conventional Industrial Symbiosis vs. Community-Based Industrial Symbiosis

Source: Synthesized from Chertow (2000), Boons et al. (2011), Fraccascia & Giannoccaro (2020), and program document analysis, 2026

The primary actors in conventional models are generally companies or industrial areas that establish partnerships based on considerations of resource use efficiency and economic benefits (Chertow, 2000). In contrast, the Pesona Paya Nie Program demonstrates that the resource exchange network is established primarily by community groups, including farmer groups, livestock groups, Women Farmer Groups, Pokdarwis, and the Vermiculture Group. Relationships among actors develop through the utilization of locally available resources that were previously perceived as waste and are subsequently converted into resources that generate ecological, social, and economic benefits for the community. Differences are also evident in the motivations underlying the formation of the network. While conventional industrial symbiosis is generally oriented toward cost efficiency and material productivity, the network established through the Pesona Paya Nie Program emerged as a response to the needs of post disaster recovery. The management of rice straw, livestock manure, water hyacinth, and household organic waste is intended not only to reduce environmental burdens but also to accelerate agricultural land rehabilitation and strengthen community livelihood capacities. Thus, resource exchange is driven not solely by economic interests but also by the collective objective of strengthening community resilience.

Another characteristic distinguishing the two models is the context in which they emerge and the governance mechanisms underlying the networks. Conventional industrial symbiosis generally develops within industrial areas, where relationships among actors are established through commercial contracts. In contrast, the network within the Pesona Paya Nie Program developed in a post disaster rural setting with support from a Corporate Social and Environmental Responsibility (TJSL) program. Consequently, coordination is primarily facilitated through mentoring, trust, and collaboration among community groups. These findings demonstrate that the principles of industrial symbiosis can extend beyond formal industrial areas when mechanisms are available to connect local actors within an integrated resource exchange system. Based on these characteristics, this study conceptualizes the Pesona Paya Nie Program as a form of community based industrial symbiosis, namely a resource exchange system established by communities through cross group collaboration and the utilization of local resources to generate simultaneous environmental, social, and economic benefits. This finding extends the understanding of industrial symbiosis, which has predominantly been examined in industrial area contexts, by demonstrating that similar principles can also be applied within TJSL based community empowerment programs in post disaster rural areas.

Soil Test Data as an Indicator of the Target Output of Resource Conversion

The soil test results indicate that the agricultural land targeted by the Pesona Paya Nie Program continues to experience post disaster soil degradation. As shown in Table 1, soil organic carbon (SOC) content in the rice fields was classified as very low, while the land managed by the Women Farmer Group (KWT) was classified as low. These conditions indicate that the soil has lost part of its capacity to store organic matter, which plays an important role in maintaining soil structure, supporting microbial activity, and ensuring nutrient availability for plants. Meanwhile, nitrogen (N), phosphorus (P), and potassium (K) were generally within the moderate to high categories, indicating that the primary constraint was more closely associated with low soil organic matter content than with the availability of macronutrients.

Tabel 1. Soil Test Results

No	Parameter	Paddy Field	Women Farmers Group (KWT) Land	Interpretation
1.	pH	5	6	Soil conditions still require improvement to support optimal plant growth.
2.	Nitrogen (N)	Moderate	Moderate	Nitrogen availability is relatively sufficient, thus it is not a major limiting factor.
3.	Phosphorus (P)	High	High	Phosphorus content is classified as good and capable of supporting plant growth.
4.	Potassium (K)	Moderate	High	Potassium elements are available in sufficient quantities to support plant productivity.
5.	C-Organik	Very Low	Low	Indicates degradation of soil organic matter post-disaster, making it the primary target for vermicompost application.

Source: Internal company documents (soil test results of the Pesona Paya Nie Program), 2026

These findings provided the basis for designating vermicompost as the primary output of the vermiculture system developed through the Pesona Paya Nie Program. Unlike conventional compost, vermicompost is produced through the biological decomposition of organic materials by earthworms and is rich in organic carbon and beneficial microorganisms, while also having the potential to improve the physical, chemical, and biological properties of soil (Lim et al., 2015). Thus, the conversion of organic waste within the community based industrial symbiosis system is not intended solely to reduce waste accumulation but also to produce an output that corresponds to the rehabilitation needs of post disaster agricultural land. The soil test results demonstrate a clear linkage between inputs, the conversion process, and the intended utilization within the established symbiotic network. Organic waste originating from rice straw, livestock manure, water hyacinth, and household organic waste is converted into vermicompost and subsequently utilized to improve soil conditions characterized by organic carbon deficits. In other words, the resource exchange system established through the Pesona Paya Nie Program not only facilitates resource recovery but also creates a functional connection between waste management and the rehabilitation of agricultural ecosystems. These findings further demonstrate that material flows within the symbiotic network are structured around the compatibility between the characteristics of waste as a resource and the ecological needs of the recipient sites.

Identification of Relationships

The identification results indicate that relationships among actors in the Pesona Paya Nie Program are not linear but instead form an interdependent resource exchange network. Farmer groups, livestock groups, Pokdarwis, and households serve as biomass suppliers, providing rice straw, animal manure, water hyacinth, and household organic waste. These materials are subsequently converted through the vermiculture system into vermicompost, which is then reused by farmer groups and Women Farmer Groups to support agricultural land rehabilitation. These material flows are accompanied by knowledge transfer, technical assistance, and collaborative relationships that strengthen coordination among groups in maintaining the system over time.

Based on the network mapping, at least three types of relationships constitute the community symbiosis network. First, material relationships, involving the exchange of biomass and the reuse of vermicompost as a productive resource. Second, knowledge relationships, reflected in mentoring, training, and the dissemination of vermiculture management practices among beneficiary groups. Third, institutional relationships, referring to collaborative linkages between community groups and PT Pupuk Iskandar Muda as the program facilitator, enabling resource exchanges to take place in a coordinated manner. These three forms of relationships demonstrate that the system is not solely oriented toward waste utilization but also toward establishing a collaborative network that supports program sustainability.

Overall, the identification of relationships demonstrates that each actor performs a complementary function in establishing a community based industrial symbiosis system. The relationships formed extend beyond material exchanges to develop into a collaborative mechanism that integrates the objectives of reducing environmental burdens, rehabilitating agricultural land, and strengthening community capacity. These findings provide a basis for further discussion of how the characteristics of this network extend the application of the industrial symbiosis concept from industrial area contexts to TJSL based community empowerment.

The findings demonstrate that the Pesona Paya Nie “Jaring Pengaman Pasca Bencana” Program not only applies circular economy principles through the reuse of organic waste but also establishes a resource exchange structure that exhibits the characteristics of industrial symbiosis. Unlike industrial symbiosis practices that have predominantly been examined in formal industrial areas, the network established through the Pesona Paya Nie Program operates at the community level through collaboration among diverse community groups that exchange materials, knowledge, and institutional support. This finding demonstrates that the fundamental principle of industrial symbiosis proposed by Chertow (2000)—the utilization of the output of one process as an input for another—can also develop within community empowerment contexts when coordination mechanisms are available to connect diverse local actors. This study therefore extends the findings of Boons et al. (2011), which have primarily positioned symbiotic relationships within industrial and manufacturing networks.

The most fundamental difference between the findings of this study and classical industrial symbiosis models lies in the basis upon which the network is formed. In the Kalundborg model, relationships among actors developed in response to the need for greater efficiency in the use of energy, water, and materials, generating shared economic benefits (Fraccascia & Giannoccaro, 2020). In contrast, the network within the Pesona Paya Nie Program emerged as a response to post disaster recovery needs. Its primary motivations extend beyond resource efficiency to include ecological restoration, livelihood strengthening, and enhanced community resilience. Consequently, relationships among actors are developed primarily through social solidarity, trust, and mentoring facilitated by the TJSL program rather than through commercial contracts, as is commonly observed in industrial areas.

Another important finding is the role of the vermiculture system as a resource exchange hub within the symbiotic network. Biomass flows originating from rice straw, livestock manure, water hyacinth, and household organic waste are consolidated through a single biological conversion mechanism before being redistributed in the form of vermicompost to beneficiary groups. This position demonstrates that vermiculture functions not only as a waste treatment technology but also as a hub that connects multiple actors and integrates diverse resource flows into a single circular system. This characteristic reinforces the concept of a resource exchange network, which positions relationships among actors as a central element in the formation of industrial symbiosis. At the same time, the organic carbon and microorganism rich characteristics of vermicompost provide a scientific basis for demonstrating that the conversion process is directly relevant to the rehabilitation needs of post disaster agricultural land (Lim et al., 2015).

The soil test results further demonstrate that the resource exchange system within the Pesona Paya Nie Program is structured around the compatibility between the characteristics of waste as a resource and the ecological needs of the beneficiaries. The low soil organic carbon content of agricultural land provided the basis for selecting vermicompost as the primary output of the conversion system. This relationship demonstrates that resource recovery within the Pesona Paya Nie Program does not end with reducing the volume of waste but is directed toward restoring soil ecological functions through the addition of organic matter. This finding is consistent with the circular economy paradigm, which emphasizes the recirculation of resources to retain material value for as long as possible while generating environmental benefits (Korhonen et al., 2018). Thus, organic waste is no longer positioned merely as a residual material requiring disposal but as an asset capable of addressing the rehabilitation needs of agricultural ecosystems.

From a corporate social responsibility perspective, this study demonstrates that TJSL can function as an enabling mechanism for establishing a community based industrial symbiosis network. Unlike TJSL approaches that are often oriented toward the provision of assistance or infrastructure development, the Pesona Paya Nie Program illustrates how a company can facilitate relationships among community groups, thereby creating a resource exchange system capable of continuing beyond the direct intervention of the program. In this context, the company functions as a network orchestrator, bringing together local resources, knowledge, and community actors within a collaborative mechanism. This finding demonstrates that TJSL can generate not only direct social benefits but also strengthen community adaptive capacity through the development of collaborative resource governance.

Theoretically, this study contributes to the development of industrial symbiosis research by demonstrating that symbiotic principles are not limited to formal industrial areas but can also be applied in post disaster rural community contexts. In this case, Blang Mee Village, as an area supported by PT Pupuk Iskandar Muda, demonstrates that the presence of an industrial company can act as a catalyst for establishing resource exchange networks among local communities without requiring the formation of an industrial area as in conventional industrial symbiosis models. Through the Pesona Paya Nie TJSL Program, relationships among the company, community groups, and local resources have evolved into a collaborative mechanism that enables organic waste to be converted into productive resources for agricultural land rehabilitation.

These findings expand the scope of industrial symbiosis research from relationships among industrial actors to relationships among community groups mediated by TJSL programs. Accordingly, the concept of community based industrial symbiosis identified in this study offers an alternative perspective for explaining how the circular economy, environmental rehabilitation, and community empowerment can be integrated into a single mutually beneficial resource exchange system.

CONCLUSION

This study employed a descriptive qualitative case study approach in Blang Mee Village, Kuta Blang District, Bireuen Regency, Aceh Province, Indonesia. The approach was used to develop an in-depth understanding of the relationships and social processes among actors involved in the Pesona Paya Nie Program rather than to test causal relationships (Neuman, 2014). The study relied entirely on secondary data obtained through a literature review and internal company documents. The literature review provided the conceptual basis for examining the Sustainable Livelihood Approach, industrial symbiosis, social capital, and social innovation (Neuman, 2014), while internal documents were used to reconstruct program implementation, relationships among actors, resource exchange processes, and program outcomes.

The unit of analysis was the resource exchange network established through the Pesona Paya Nie Program (Yin, 2017; Mills et al., 2012). The analysis focused on identifying actors as nodes and material exchanges, knowledge exchanges, and collaborative relationships as flows within the circular value chain. Data credibility was strengthened through source triangulation by comparing evidence across multiple documents. Theoretical triangulation was also conducted by interpreting the empirical findings through the Sustainable Livelihood Approach, industrial symbiosis, and post-disaster resilience literature to assess conceptual consistency and support the interpretation of the findings.

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