

Participatory Rural Appraisal of Material Resources and Renewable Energy for Community-Based Local Food Security: Evidence from Cirinten Village, Indonesia

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Abstract

Community-based local food security depends on communities' capacity to mobilize natural resources, renewable energy, local knowledge, and collective action. This study aimed to assess material resources and renewable energy opportunities through participatory rural appraisal to support sustainable food-system development in Cirinten Village, Indonesia. Village sketch mapping, transect analysis, stakeholder mapping, and participatory interpretation were used to identify assets, relationships, environmental conditions, and development priorities. The assessment identified agricultural land, water, biological resources, livestock, fisheries, and biomass residues as key assets for productive activities. An integration model linking natural resources, renewable energy, value-added processing, community empowerment, and food security was developed. The model emphasizes capacity development, institutional strengthening, participatory governance, local knowledge, and partnerships as enabling factors for improving food availability, economic access, utilization, and long-term stability. Overall, participatory rural appraisal provides a context-specific framework for strengthening resilient village food systems, while proposed energy and processing options require further field validation.

Keywords: *Community-based local food security; Material resources; participatory rural appraisal; renewable energy; rural development.*

Introduction

Food security has evolved from a production-oriented concept into a multidimensional framework encompassing food availability, accessibility, utilization, stability, sustainability, and resilience. Increasing climate variability,

environmental degradation, and socioeconomic inequality have intensified the vulnerability of rural communities, particularly those relying on agriculture and natural resources. Consequently, strengthening community-based local food security requires integrated strategies that combine participatory governance, sustainable resource management, renewable energy utilization, and institutional collaboration rather than focusing solely on increasing agricultural production. Recent systematic reviews also emphasize that sustainable food systems should be assessed using holistic indicators that incorporate environmental, social, institutional, and economic dimensions (Manikas et al., 2023).

Indonesia possesses abundant agricultural land, tropical forests, freshwater ecosystems, and biomass resources that offer considerable opportunities to develop resilient local food systems. Indonesia has substantial agricultural, forest, freshwater, biological, and biomass resources that can support locally resilient food systems. However, the existence of resources does not automatically translate into food-system resilience. Post-harvest losses, limited processing capacity, weak market linkages, environmental pressures, and inadequate resource management practices can reduce the value generated by local assets. Community empowerment literature also shows that resource-based interventions become more sustainable when local actors participate in problem identification, solution design, and implementation. In the context of waste management, for example, community training and collaborative institutional arrangements have been used to transform environmental problems into opportunities for social and economic empowerment (Muyassarrah et al., 2022) (Kadir et al., 2024). Recent studies indicate that agroecological practices, renewable energy integration, and locally adapted innovations significantly enhance the resilience of smallholder farming systems while supporting environmental sustainability and food security. These findings demonstrate the importance of integrating natural resource management, renewable energy, and community participation into rural development strategies (Dagunga et al., 2023).

Cirinten Village, located in Cirinten District, Lebak Regency, Banten Province, Indonesia, represents a rural community with substantial ecological and socioeconomic potential. The village is characterized by agricultural land, plantations, forests, rivers, and settlements that provide diverse material resources supporting agriculture, agroforestry, fisheries, and rural livelihoods. The village sketch map developed through Participatory Rural Appraisal (PRA) illustrates the spatial distribution of these resources. In contrast, the village transect identifies agricultural commodities, water resources, environmental conditions, and development constraints. Despite this potential, field observations reveal challenges including limited infrastructure,

environmental degradation, inadequate waste management, and insufficient utilization of biomass and renewable energy resources, which collectively constrain sustainable local food security. These characteristics reflect the broader challenges experienced by many rural communities in achieving resilient food systems (Kapari et al., 2023).

The stakeholder relationships identified through the participatory Venn diagram demonstrate that community development in Cirinten Village depends on close interaction among the village government, farmer groups, women's organizations, youth organizations, educational institutions, health centers, religious institutions, and district authorities. These stakeholders collectively contribute to agricultural extension, environmental conservation, education, health services, and community welfare. Such institutional collaboration is an important form of social capital for implementing sustainable community empowerment programs, as successful rural development depends on collective decision-making and shared responsibility. Contemporary studies similarly conclude that participatory governance and collaborative food-system management improve institutional effectiveness, social inclusion, and community resilience (Egli et al., 2023).

Participatory Rural Appraisal is widely recognized as an effective community engagement approach because it actively involves local communities in identifying problems, mapping resources, establishing priorities, implementing actions, and evaluating development outcomes. In the present study, participation involved village officials, farmer groups, women, youth representatives, teachers, health workers, and community leaders through participatory mapping, transect walks, stakeholder analysis, focus group discussions, and field validation. This interaction facilitated the integration of scientific knowledge with local experience, ensuring that development recommendations reflected community priorities and ecological conditions. Recent research on participatory farming further demonstrates that collaborative research and co-production of knowledge improve innovation adoption, local ownership, and the long-term sustainability of rural development initiatives (Jackson-Smith & Veisi, 2023).

Recent advances in sustainable rural development also highlight the strategic role of renewable energy and locally available material resources in strengthening food systems. Agricultural residues, livestock manure, woody biomass, solar energy, and micro-hydropower can support irrigation, food processing, post-harvest preservation, and household energy while reducing dependence on fossil fuels. Likewise, agricultural by-products and locally available materials can be transformed into biochar, compost, and activated carbon, as well as into environmentally friendly technologies that enhance agricultural productivity and circular resource utilization. Integrating these opportunities within a participatory planning framework, therefore, offers a

promising pathway for improving food security, environmental sustainability, and rural economic resilience (Sadik et al., 2026).

Cirinten Village, located in Cirinten District, Lebak Regency, Banten Province, provides a relevant setting for examining these relationships. The village contains agricultural land, plantations, forest areas, rivers, settlements, and other natural assets that support farming and rural livelihoods. The statements about village conditions presented in this article are not intended as unsupported general claims; they are derived from the research team's field observations, participatory mapping, transect observations, stakeholder discussions, photographic documentation, and community validation conducted during the 2026 KUKERTA Nusantara field program.

PRA is appropriate for this setting because it enables community members to contribute local knowledge while jointly identifying resources, constraints, institutional relationships, and development options. Classic PRA scholarship emphasizes learning from local people through participatory visualization, field-based inquiry, and iterative reflection (Chambers, 1994). More recent participatory research also shows that community involvement can strengthen ownership, contextual relevance, and the adoption of locally appropriate innovations (Jackson-Smith & Veisi, 2023).

Previous studies have examined food security, participatory development, renewable energy, and natural-resource management from different perspectives. Nevertheless, fewer studies bring these elements together within a single village-level PRA framework that explicitly connects resource mapping, stakeholder relations, renewable energy opportunities, value-added processing, and community-based food security. This study addresses that gap by integrating three PRA instruments, among them the Village Sketch Map, Village Transect Analysis, and Participatory Venn Diagram, with field observation, focus-group discussion, and community validation. The study aims to identify the village's resource base and constraints, clarify the role of local institutions, and synthesize the findings into a context-specific framework to strengthen local food security. The framework is intended as a planning and empowerment tool; it is not presented as proof that all proposed technologies are technically or economically feasible for immediate deployment.

Methods

Research Design and Setting

This study used a qualitative Participatory Rural Appraisal (PRA) design to examine the relationships among material resources, renewable energy opportunities, institutional capacity, and local food security development in Cirinten Village, Cirinten District, Lebak Regency, Banten Province, Indonesia. PRA was selected because the research questions concern locally distributed resources, lived environmental conditions, institutional relationships, and community-defined development needs. These are domains in which community knowledge is essential for interpreting spatial and social conditions that cannot be adequately captured through secondary data alone (Pretty et al., 1995), (Chambers, 1994).

The field assessment was conducted as part of the 2026 KUKERTA Nusantara program from 17 to 30 July 2026. The participants were purposively selected from groups with direct knowledge of village resources and development conditions, including village government officials, farmer groups, women's organizations, youth representatives, community leaders, teachers, health workers, and residents. Conducted over two weeks (336 hours), the assessment employed participatory mapping, transect walks, stakeholder consultations, field observations, focus group discussions, and community-based validation to identify local resources, environmental conditions, institutional relationships, development constraints, and opportunities to strengthen community-based local food security.

This study employed a Participatory Rural Appraisal (PRA) approach to identify material resources, renewable energy potential, institutional relationships, and community needs for strengthening community-based local food security in Cirinten Village, Cirinten District, Lebak Regency, Banten Province, Indonesia. PRA was selected because it facilitates collaborative knowledge production by integrating scientific assessment with local knowledge and encourages active community participation throughout the planning process. The methodological framework combined participatory spatial mapping, field observation, stakeholder analysis, and community validation to generate evidence-based recommendations for sustainable rural development. This approach is widely recognized for improving community ownership, decision-making, and the effectiveness of rural development interventions (Smith & Diedrich, 2024).

The community engagement program involved the purposive participation of village government officials, farmer groups, women's organizations, youth organizations, community leaders, teachers, health workers, and local residents with knowledge of village resources and development issues. Participation was implemented through village meetings,

focus group discussions, participatory mapping sessions, transect walks, stakeholder consultations, and field validation. Community members actively identified village assets, environmental problems, institutional interactions, renewable energy opportunities, and local priorities, while the research team facilitated discussions, documented field observations, and synthesized collective findings. Such participatory interaction ensured that the assessment reflected local realities and strengthened community ownership of the proposed development strategies (Doustmohammadian et al., 2022).

Participation and data sources

The primary data consisted of participatory maps, transect observations, stakeholder diagrams, field notes, photographic documentation, focus-group discussions, stakeholder consultations, and the community validation record. Secondary literature was used to contextualize the field findings and to distinguish observed village conditions from technology or development options proposed based on prior research. Accordingly, statements about existing village assets and constraints are treated as field-derived findings. In contrast, statements about biogas, biochar, biomass briquettes, micro-hydropower, and solar photovoltaic systems are treated as potential options requiring further assessment.

Data were collected using three principal PRA tools. First, the Village Sketch Map was developed collaboratively to identify land use, settlements, agricultural areas, rivers, forests, public facilities, and potential material resources. Second, a Village Transect Analysis was conducted through systematic field walks with community representatives to document environmental characteristics, agricultural commodities, water resources, infrastructure, biomass availability, and renewable energy opportunities across different landscape zones. Third, a Participatory Venn Diagram was used to evaluate institutional relationships, stakeholder influence, collaboration intensity, and community access to public services. These tools were complemented by direct observation, field notes, photographic documentation, and focus group discussions to enhance data completeness and contextual understanding.

The collected information was analyzed using qualitative thematic analysis supported by participatory content validation. Field observations, discussion transcripts, and visual mapping outputs were coded into four analytical themes: (i) material resources, (ii) renewable energy potential, (iii) institutional capacity and stakeholder collaboration, and (iv) local food security opportunities. Triangulation was performed by comparing results obtained from participatory mapping, transect observations, stakeholder

discussions, and field verification to improve data credibility. The final findings were validated through a community consultation meeting in which participants reviewed, confirmed, and refined the interpretation before formulating recommendations for community empowerment and sustainable local food security. This iterative validation process is consistent with current recommendations for participatory community-based research that emphasize transparency, co-production of knowledge, and shared decision-making (Ongachi et al., 2026).

PRA instruments and procedures

The Village Sketch Map was prepared collaboratively with community representatives to locate settlements, agricultural land, plantations, forests, rivers, public facilities, transportation routes, environmental constraints, and potential resource areas. Participants first identified salient features on a shared village representation and then discussed the significance of each feature for livelihoods, food production, accessibility, and environmental management. The resulting map was checked against field observations.

The Village Transect Analysis was conducted through systematic field walks with community representatives across representative landscape zones. During the walks, the team documented agricultural commodities, water resources, settlement conditions, sanitation, infrastructure, environmental problems, biomass availability, and opportunities identified by participants. Observations were recorded in field notes and subsequently discussed with community members to reduce misinterpretation.

The Participatory Venn Diagram was used to examine institutional relationships. Participants identified organizations and institutions that interact with the village, discussed their perceived importance and accessibility, and represented relationships through relative position and size. The diagram was then discussed collectively to clarify the roles of the village government, religious institutions, farmer groups, youth organizations, schools, health facilities, universities, government agencies, and other actors.

The three instruments were complemented by focus-group discussions, direct observation, field notes, and community validation. The validation meeting allowed participants to review the interpreted findings, correct inaccuracies, and clarify priorities. This sequence mapping, field observation, stakeholder analysis, discussion, and validation was used to triangulate evidence and reduce dependence on any single data source.

Data analysis

The analysis combined deductive and inductive thematic analysis. Four analytical themes were defined from the study objectives and the information generated by the PRA tools: (1) material resources and productive assets; (2) renewable-energy opportunities; (3) institutional capacity and stakeholder collaboration; and (4) local food-security opportunities and constraints. Within these themes, recurring observations and participant statements were coded and compared across the sketch map, transect, Venn diagram, discussions, and field verification. Development priorities were treated as issues or opportunities repeatedly emphasized during participatory discussions and retained during community validation, rather than as statistically ranked priorities.

Triangulation was conducted by comparing evidence across the three PRA tools and supporting qualitative sources. The final interpretation was discussed with community participants before the development framework was formulated. The conceptual framework, therefore, represents a synthesis of field-derived findings and literature-informed development options. It should not be interpreted as an experimental assessment of technology performance.

Result

PRA findings: village resources, constraints, and institutional relationships

The PRA identified Cirinten Village as a resource-rich rural landscape with substantial natural capital but uneven technological and institutional capacity. The three complementary PRA instruments provided different but connected forms of evidence. The sketch map described the spatial distribution of natural and built resources; the transect analysis documented conditions and opportunities across landscape zones; and the Venn diagram clarified institutional relationships and perceived access to support.

The Participatory Rural Appraisal (PRA) identified Cirinten Village as a rural area possessing considerable natural resources, while simultaneously facing socio-economic and environmental constraints that influence community-based local food security. Three complementary participatory tools, namely the village sketch map (Figure 1), transect analysis (Figure 2), and stakeholder Venn diagram (Figure 3), enabled the community to identify

spatial characteristics, resource distribution, institutional relationships, and development priorities through collective discussions with village officials, farmer groups, women, youth organizations, religious leaders, and local residents. Such participatory assessment provides a holistic understanding of village systems and supports evidence-based planning for sustainable rural development. Similar participatory approaches have been widely recognized as effective for community empowerment and resilience planning (Smith & Diedrich, 2024).



Figure 1. Participatory sketch map illustrating the spatial distribution of natural resources, public facilities, transportation networks, environmental constraints, and development opportunities in Cirinten Village, Lebak Regency, Indonesia.

Village Transect Analysis of Cirinten Village, Cirinten District, Lebak Regency, Banten Province, Indonesia					
Coverage Area: Koncam Hamlet (Subdistrict Complex), Pasar Pasir Hamlet, and Kuping Hamlet					
No.	Component	 River	 Plantation / Garden	 Settlement	 Sanitation
					
1.	Community Resources	Various types of fish: catfish, nilem, wader, kepek, tawes, koi, gabus, and mas.	- Cash crop commodities: coffee, cloves, rubber. - Seasonal crops: rice, corn, peanuts, cassava, sweet potatoes. - Fruits: durian, rambutan, mangosteen, duku, banana, avocado.	- Foods: rice, cassava, sweet potato, vegetables, tofu, tempeh. - Beverages: coffee, milk. - Energy sources: LPG, electricity, firewood.	- Clean water sources: springs, wells, piped water. - Wastewater management: septic tanks. - bathing/washing in rivers or wells. - Waste management: burned, buried, or disposed in the river.
2.	Existing Problems	- Water pollution from household waste. - Decreased water quality and quantity. - Sedimentation.	- Land conversion. - Shift in land function. - Population growth. - Decline in crop productivity. - Unstable selling prices.	- Lack of clean water. - Inadequate healthcare services. - Limited public facilities and infrastructure.	- Low community awareness of environmental cleanliness. - Environmental pollution. - Inadequate waste management.
3.	Development Opportunities	- River-based tourism development. - Development of fish cultivation. - Improving water quality and availability.	- Sustainable agriculture development. - Improved crop quality and productivity. - Development of agro-industry.	- Economic improvement. - Enhanced public services. - Development of accessible infrastructure. - MSME development.	- Increased environmental awareness. - Improved waste management. - Enhanced environmental cleanliness.

Table 1. Village transect analysis summarizing natural resources, environmental issues, and development opportunities across the observed landscape units in Cirinten Village.

Figure 2. Village transect analysis summarizing community resources, environmental problems, agricultural conditions, sanitation, and sustainable development opportunities identified through participatory field observations.

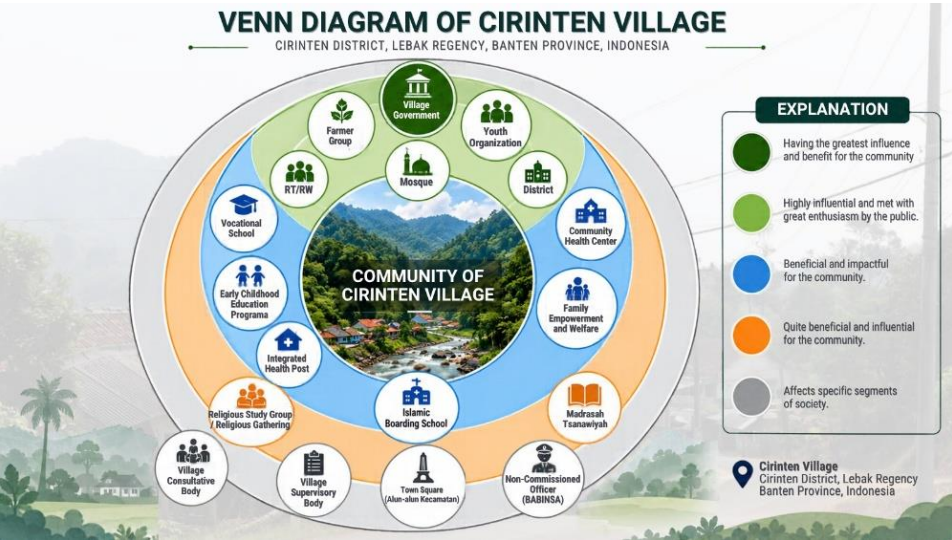


Figure 3. Stakeholder Venn diagram showing institutional relationships, influence levels, and community participation supporting rural development and local food security in Cirinten Village.

Village resource base and constraints

The sketch map and transect analysis identified rice fields, plantations, forests, rivers, a reservoir, household settlements, and other productive spaces as important elements of the village landscape. Agricultural commodities identified during the transect included rice, cassava, maize, peanuts, coffee, cloves, rubber, and seasonal fruits such as durian, mangosteen, rambutan, and avocado. These observations indicate a diversified resource base that can support food production and rural livelihoods.

The same field observations identified constraints that can reduce the benefits obtained from these assets. Participants and field observations pointed to limited accessibility, uneven infrastructure, environmental pollution, inadequate waste management, declining agricultural productivity, and dependence on conventional household fuels. These constraints are important because food-system resilience depends not only on the quantity of natural resources but also on the capacity to process, transport, conserve, and add value to them.

Stakeholder relationships and community participation

The Venn diagram showed that the village government, mosque and other religious institutions, farmer groups, youth organizations, neighborhood associations, schools, and health facilities occupy important positions in local development. Religious institutions were identified as important channels for community mobilization, while educational and health institutions contribute to capacity development and community services. At the same time, participants identified weaker linkages with universities, private-sector actors, and some external development agencies. This suggests that strengthening external partnerships is a potential pathway for technology transfer, training, market access, and continued community assistance.

Summary of PRA findings

Table 1. Summary of Participatory Rural Appraisal Findings in Cirinten Village

PRA Component	Main Findings	Challenges	Development Opportunities
Village Sketch Map	Mountainous landscape, river, rice fields, plantations, reservoir, forests	Limited accessibility, landslide susceptibility, and uneven infrastructure	Eco-tourism, agroforestry, and integrated watershed management

Village Transect	Diverse agricultural commodities, freshwater resources, and household settlements	Waste management, water pollution, and declining agricultural productivity	Sustainable agriculture, agro- processing, and renewable energy utilization
Stakeholder Venn Diagram	Strong participation of the village government, mosque, farmer groups, and neighborhood associations	Limited collaboration with external institutions	Multi- stakeholder partnerships, university collaboration, and technology transfer

The sketch map (Figure 1) illustrates that Cirinten Village is strategically located within an agricultural landscape characterized by extensive rice fields, plantations, forests, and river systems. These natural assets provide strong ecological support for food production while simultaneously creating opportunities for renewable energy utilization through biomass residues, micro-hydropower from river flows, and solar photovoltaic applications in agricultural activities. Nevertheless, limited road access, landslide susceptibility, and insufficient infrastructure remain significant barriers to market access and rural livelihoods. These findings correspond with previous studies emphasizing that geographical characteristics strongly determine rural resilience and sustainable food systems (Minas et al., 2024).

The transect analysis (Figure 2) further revealed that agricultural production remains dominated by rice, cassava, maize, peanuts, coffee, cloves, rubber, and seasonal fruits, including durian, mangosteen, rambutan, and avocado. Despite abundant natural resources, farmers experience unstable commodity prices, declining land productivity, inadequate waste management, and dependence on conventional household fuels. The community identified agricultural processing, environmentally friendly waste utilization, and renewable energy integration as priority interventions to increase product value and strengthen local food security. Recent studies indicate that integrating sustainable energy technologies into agricultural systems enhances productivity, reduces production costs, and improves rural livelihoods (Sadik et al., 2026).

The stakeholder mapping (Figure 3) demonstrates that the Village Government, mosque, farmer groups, youth organizations, neighborhood associations, schools, and health facilities constitute the principal institutions supporting community development. Religious institutions occupy a central

role in community mobilization, while educational institutions contribute to capacity building and environmental awareness. However, collaboration with universities, private industries, and governmental development agencies remains relatively limited. Strengthening institutional networks is therefore essential for accelerating innovation adoption, technology dissemination, and sustainable community empowerment. Similar institutional arrangements have been reported as critical success factors in participatory rural development programs (Smith & Diedrich, 2024).

Discussion

Community Participation during Participatory Rural Appraisal Activities

Community participation represented the central component of this empowerment program. Participatory activities involved village officials, farmer groups, women's organizations, youth organizations, religious leaders, local schools, and community members throughout the planning, field observation, problem identification, priority ranking, and validation stages. Rather than functioning as respondents, community members acted as co-researchers by identifying local resources, discussing village constraints, validating field findings, and proposing practical development solutions.

The participatory discussions generated consensus on several priority issues, including improving agricultural value addition, strengthening environmental sanitation, developing renewable energy utilization, enhancing clean water management, and expanding institutional collaboration. Local knowledge concerning agricultural practices, seasonal cropping patterns, watershed conservation, and community traditions substantially enriched the assessment process and increased the legitimacy of the proposed interventions. Community ownership of the planning process is widely recognized as an important determinant of sustainable empowerment outcomes (Smith & Diedrich, 2024).



Figure 4. Community participation during Participatory Rural Appraisal activities in Cirinten Village.

Integrated Analysis of Participatory Rural Appraisal Results

The three participatory tools collectively demonstrate that Cirinten Village possesses substantial natural capital but relatively limited technological and institutional capacities. Figure 4 conceptually summarizes the interaction among village resources, stakeholder participation, and sustainable development opportunities.

The sketch map identifies abundant agricultural land, forests, rivers, and reservoirs that provide the ecological foundation for food production. The transect analysis complements these findings by identifying operational constraints, including environmental pollution, inadequate waste management, declining productivity, and limited value-added processing. Meanwhile, the Venn diagram reveals that community institutions are relatively strong internally but require stronger external collaboration with universities, governmental agencies, and technology providers.

From a material-resources perspective, the PRA identified agricultural residues, including rice straw, cassava biomass, coffee husks, and livestock manure, as locally available biomass resources. Participants highlighted agricultural production, waste management, and resource utilization as important areas for further development. Building on these field findings and relevant literature, the authors identified several potential pathways for

resource recovery, including composting, biochar production, biogas generation, and biomass briquette production. These options are not reported as technologies selected or implemented by the community; rather, they represent literature-informed development opportunities derived from the resources identified during the PRA. Further technical, environmental, economic, and participatory assessment is therefore required to determine which options are appropriate for the local context. Similarly, the presence of river systems and solar resources suggests potential opportunities for micro-hydropower and solar photovoltaic applications, but these possibilities require site-specific technical and feasibility assessments before any implementation is considered. Likewise, river systems provide opportunities for micro-hydropower development, whereas solar photovoltaic systems can support irrigation pumping, agricultural processing, food drying, and community facilities. Integrating renewable energy with local agricultural resources, therefore, represents a practical strategy for strengthening community-based food security and sustainable rural livelihoods (Sadik et al., 2026).

Overall, the participatory assessment indicates that sustainable local food security in Cirinten Village depends not only on natural resource availability but also on strengthening human capacity, institutional collaboration, renewable energy adoption, and value-added processing of agricultural commodities. These findings reinforce recent international evidence showing that integrated community participation, sustainable energy access, and local resource management collectively improve rural resilience and long-term food system sustainability (Iannotti et al., 2024).

The conceptual integration model translates the findings of the PRA into a sequential pathway linking locally available resources with community-based food security. The first stage concerns the identification of natural and material resources, including agricultural land, water resources, biological resources, livestock, fisheries, and agricultural residues. These resources constitute the productive foundation of the village and provide inputs for agricultural and livelihood activities. The second stage connects this resource base with appropriate renewable-energy opportunities. Locally available biomass, solar radiation, and water flows may provide energy for productive activities such as irrigation, crop drying, food processing, and other post-harvest operations. The third stage focuses on value-added processing, through which agricultural commodities and their residues can be further utilized to improve product quality, reduce post-harvest losses, and create additional economic value. The fourth stage places community empowerment at the center of the process. Skills development, entrepreneurship, farmer and youth organizations, participatory governance, local knowledge, and collective action are required to enable the community to manage resources, adopt appropriate technologies, and develop value-added activities. The final stage

is improved local food security, reflected in greater food availability, better economic access, improved utilization, and enhanced stability. Thus, the model does not represent five independent components; rather, each stage provides an enabling condition for the subsequent stage, while community empowerment functions as a cross-cutting mechanism that connects resource management, energy use, processing, and food-system outcomes. Figure 5 presents a conceptual integration framework developed by the authors based on the PRA findings and relevant literature. The framework links the locally identified resource base with potential renewable-energy and value-added processing pathways. It should be interpreted as a planning and development framework rather than as evidence of technologies that have already been implemented or validated in Cirinten Village (García-López et al., 2024). Based on the PRA findings, the authors developed a conceptual integration model that explains how locally identified resources can be progressively connected to renewable-energy opportunities, value-added processing, and community empowerment to support local food security. The model is therefore presented as a development framework derived from the field assessment, rather than as evidence that all proposed technologies or processing activities have already been implemented in Cirinten Village.

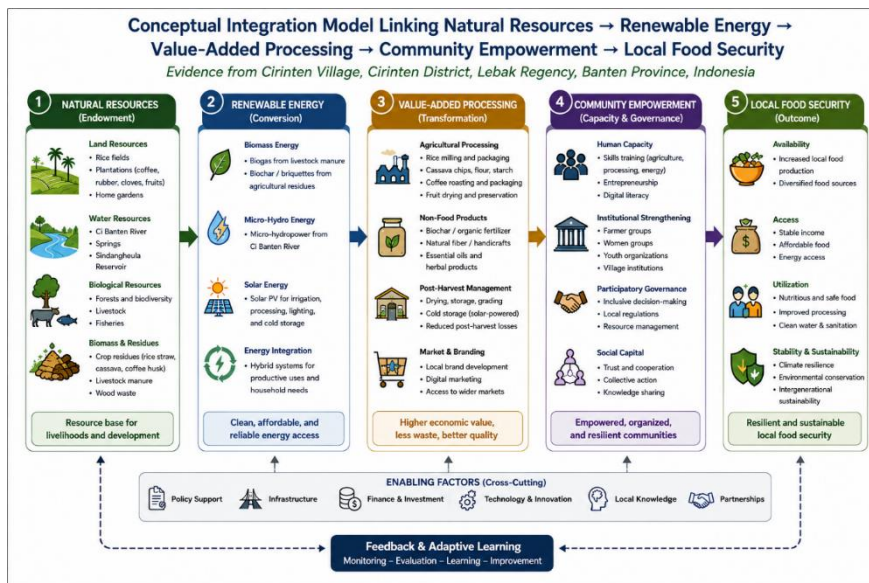


Figure 5. Conceptual integration model illustrating the pathway from PRA-identified natural and material resources through renewable-energy opportunities, value-added processing, and community empowerment toward improved local food security in Cirinten Village, Indonesia.

The subsequent stages in Figure 5 demonstrate how renewable energy can enable value-added processing and, ultimately, community-based food security. In the Cirinten context, locally available agricultural commodities such as rice, cassava, coffee, fruits, and other crops provide opportunities for milling, drying, packaging, preservation, and small-scale product diversification, while agricultural and livestock residues may serve as potential biomass resources. The model further places community empowerment at the center through skills development, entrepreneurship, farmer and youth organizations, participatory governance, local knowledge, and collective action. Importantly, these components represent development opportunities identified from the village assessment rather than technologies that have already been experimentally implemented. The expected outcome is a more resilient local food system characterized by improved food availability, access, utilization, and stability. Recent evidence supports this integrated interpretation: local food-system interventions are more effective when community participation and governance are incorporated, while systematic reviews indicate that locally oriented food-system approaches can contribute to food and nutrition security.

Conclusion and Suggestion

The study concludes that Cirinten Village has substantial potential to strengthen community-based local food security through the integrated management of natural resources, renewable-energy opportunities, value-added processing, and community empowerment. The PRA identified agricultural land, water resources, biological resources, livestock, fisheries, and biomass residues as important local assets, while also demonstrating the need for stronger human capacity, institutional collaboration, participatory governance, and partnerships. The resulting conceptual model provides a context-specific pathway for connecting these resources with potential energy and processing applications to support food availability, access, utilization, and stability. Nevertheless, the proposed technologies remain development opportunities and have not yet been technically or economically validated in the field.

Future development should prioritize technical, economic, and participatory feasibility assessments before any technology or integrated model is implemented. Technical assessment should evaluate resource availability, technology suitability, energy requirements, operational conditions, and environmental implications, while economic assessment

should consider investment costs, operating and maintenance requirements, potential economic returns, and market feasibility. Participatory validation should involve relevant community groups and local institutions to assess community priorities, affordability, usability, acceptance, and institutional readiness. The most feasible option can then be tested through a small-scale pilot and evaluated for its technical performance, economic viability, environmental effects, community acceptance, and contribution to local food security.

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