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Disaster-Resilient Village Development: Implementing Landslide Detection Tools and a Solar Cell-Based Coffee Processing System

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ABSTRACT

This community service article talks about the results of the Kolaborasi Sosial Membangun Masyarakat (KOSABANGSA) program in Donorejo, Purworejo. The program combines landslide Early Warning System (EWS) technology with solar-powered coffee processing after harvest to help reduce disaster risk and boost the economy. The program's goal was to make communities more resilient to hydrometeorological hazards while also making local coffee more productive and easier to sell by sharing technology and building capacity through collaboration. The intervention was carried out using a participatory, descriptive, qualitative method. It included socialization, technical training, technology installation, focused mentoring, and long-term evaluation with the FPRB and Bangun Semi Farmers' Group. The results showed that participants made big strides in being ready for disasters, running their businesses, getting to alternative energy sources, and coming up with new products. The program comes to the conclusion that people should be involved in their communities and use the right technology.

ARTICLE INFORMATION

Keywords:
community empowerment; disaster risk reduction; early warning system; rural entrepreneurship; technology transfer

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INTRODUCTION

According to the 2023 Indonesian Disaster Risk Index (IRBI), Purworejo Regency in Central Java is one of the most disaster-prone areas in Indonesia. It is ranked fifth in Central Java and 190th nationwide, with about 90% of its 494 administrative units classified as disaster-prone (BNPB, 2021). Between 2020 and 2023, Kaligesing District saw 139 landslides. The most recent one happened in January 2025, when a landslide in Jogowono Hamlet, which is part of Donorejo Village, cut off road access, made it hard for people to get around, and led to an emergency response with the help of the local government (Badan Pusat Statistik Kabupaten Purworejo, 2021; BNPB, 2021; BPBD Purworejo, 2023). Heavy rain, tree cutting, and unsustainable land use are all factors that worsen these hazards. However, communities are still not ready for them, as shown in Figure 1 (Budiana et al., 2023).

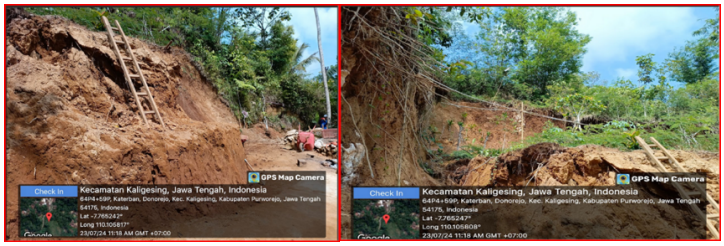

Figure 1. Disaster Area of Donofrio Village, Kaligesing District

The main issue this study looks at is clear and has three parts. First, Donorejo Village lacks a functioning, technology-based landslide early warning system that sends timely evacuation signals. Second, the Bangun Semi Coffee Farmers Group, which includes 16 farmers who grow robusta coffee on more than 21 hectares and produce about 20 tons of green beans each year, is limited by traditional post-harvest methods and unreliable energy sources. This stops the change to more valuable roasted coffee. Third, the village's Disaster Risk Reduction Forum (FPRB) lacks sufficient infrastructure, communication networks, and institutionalized capacity to reduce risks. These three deficits are structurally linked. Repeated disasters make farming less productive, and a weak economy makes it harder for the community to prepare for disasters (Rahayu et al., 2025; Saputro et al., 2024).

The Indonesian legal system provides a solid foundation for addressing these problems. Law No. 24 of 2007 on Disaster Management (Pemerintah Pusat Republik Indonesia, 2007) and BNPB Regulation No. 1 of 2012 on Disaster-Resilient Village development (Peraturan Kepala Badan Nasional Penanggulangan Bencana Nomor 1 Tahun 2012, 2014) (open institutional pathways for community-level adoption of Landslide Early Warning Systems (LEWS). At the same time, national renewable energy policies, such as feed-in tariff systems and solar home system programs, have helped farmers in rural areas adopt new technologies (Chalvatzis, 2011; Dellosa & Barocca, 2021; Karanjikar et al., 2024; Makinde & Obikoya, 2024).

The BNPB's Destana (Disaster-Resilient Village) framework describes a multi-stakeholder governance model that incorporates disaster risk reduction into village development (Rahayu et al., 2025; Wardana & Wicaksono, 2023). This framework is compelling in theory, but it needs to be looked at closely in practice. For example, local institutional bodies like the FPRB often act as administrative artifacts rather than active governance actors because they lack the power to enforce rules, the funds to sustain themselves, or the technical skills to implement risk-reduction mandates. The Destana model presupposes community cohesion and institutional preparedness that may be absent in agrarian villages characterized by fragmented social capital due to economic instability and seasonal migration. The coffee farmers' group is also a productive local institution, but because it is a loose cooperative rather than a formally registered business, it cannot access credit, technology extension services, or market links (Saputra, 2022). The cultural practice of communal labor (*gotong royong*), while esteemed in policy discourse as a resilience asset, necessitates critical evaluation: it is most effective when orchestrated by legitimate, technically proficient local institutions, and its absence as an organizing mechanism distinctly illustrates the institutional void this program aims to rectify (Wibawanti et al., 2023).

Modern LEWS architectures use LoRa-based IoT or Wireless Sensor Networks to connect tilt sensors, MEMS accelerometers, soil moisture sensors, and rain gauges. This enables real-time analytics in the cloud or at the edge (Gamperl & Singer, 2021). Data from Nepal and China show that robust sensor-based warning systems give people enough time to evacuate, significantly reducing deaths (Chen et al., 2023; Devkota et al., 2023). In Indonesia, community-managed LEWS deployment remains constrained by high costs, limited technical skills, and inconsistent funding. This is why open-source hardware, modular low-power design, and community-based maintenance models are so

important (Fathani et al., 2014). Solar-powered processing equipment has demonstrated the ability to increase coffee sorting and production throughput by up to 500% compared to manual methods. This lowers energy costs, improves product consistency, and gives women more opportunities to participate in the value chain (Chen et al., 2023; Semennikov et al., 2024; Yulistya et al., 2025). The use of solar cells in similar rural settings, such as agricultural machinery and transportation, demonstrates that photovoltaic systems can operate in areas with limited grid infrastructure (Siregar et al., 2021; Suyitno, 2023). Value chain integration is further enhanced by GMP and quality control training, digital marketing skills (Respatiningsih et al., 2022), and waste valorization, which turns coffee pulp into fermented animal feed. This supports a zero-waste production model that increases farmers' income (Wibawanti et al., 2023; Saputra, 2022).

The significant research gap is that there has been no empirical study in Indonesia that has examined the simultaneous integration of IoT-based landslide detection and decentralized solar coffee processing as a cohesive dual-pillar intervention in a multi-hazard rural setting, nor evaluated the impact of such integration on community preparedness, economic resilience, and local institutional capacity concurrently (Gamperl & Singer, 2021; Rahayu et al., 2025; Saputra, 2022). Current research examines disaster technology and agricultural energy adoption as distinct fields, neglecting the empirical exploration of their mutually reinforcing mechanisms and the governance conditions necessary for their self-sustainability. This study seeks to implement and assess an integrated model that merges sensor-based LEWS and solar-powered coffee processing in Donorejo Village, employing participatory action research, technical performance evaluation, and institutional capacity monitoring. The goal is to create a best-practice model that can be used again and again to turn disaster-prone farming villages into communities that can adapt, compete economically, and build strong institutions.

METHOD

This community service program employed a descriptive, qualitative methodology grounded in participatory principles, designed to ensure that the implementation process could be systematically documented, verified, and replicated in other villages with similar attributes. The participatory approach turned community members from passive recipients into active subjects. This made them feel they owned the intervention and ensured it would last (Chevalier & Buckles, 2019). The main goal of this methodological framework was to make it easier for the university team, village officials, the Disaster Risk Reduction Forum (FPRB), and the Bangun Semi Farmers' Group to work together to change people's behavior and share technology. The method aimed to produce thorough, accurate data on both the process and outcomes of community capacity building by integrating participatory action principles (Cornish et al., 2023).

There were four steps to the program: socialization, technical training, technology installation, and focused mentoring. After that, a long-term evaluation was conducted. The team held community meetings during the socialization phase to make sure everyone understood the program's goals and was on the same page. Both the Early Warning System management and the solar-powered coffee roasting operations had hands-on technical sessions during the training phase. Everyone in the community worked together to set up the technology and make sure everyone knew how to use and care for it. The last step was to keep seeking help and have regular evaluations to track progress and address new problems as they arose. This staged approach was meant to align with the main ideas of community-based development, in which outside support gradually gives way to local management (García, 2020; McMaster et al., 2024).

The main technological tools for this program were two main systems. The Landslide Early Warning System (LEWS), for example, used Long Range (LoRa) and Internet of Things (IoT) sensor

technology to detect ground movement and soil moisture levels indicative of slope instability. This made it possible to send out warnings about dangers right away. Second, the solar-powered coffee roasting machine was an energy-efficient way to process coffee after it was picked. This meant that it did not need as much energy from traditional sources, and the product was better (Majeed et al., 2022). The data collection employed three complementary methodologies: field observations to document implementation processes and community involvement, in-depth interviews with key informants, including village officials and farmer group members, and documentary analyses of program activities, training materials, and output records. This triangulation method ensured the completeness and accuracy of the qualitative data (Carter et al., 2014; Meja et al., 2025).

The Miles and Huberman interactive model was used to examine the data carefully. This model has three steps that occur simultaneously: concluding, verifying them, and presenting the data. Data reduction involved selecting, focusing on, simplifying, and transforming raw field notes and interview transcripts to identify key themes. Data display puts shorter information into charts, matrices, or narrative text to make it easier to understand and identify patterns. The last step was to draw conclusions and check them. This meant figuring out what the data meant and ensuring it was correct by comparing it with other data sources. The research team picked this analytical framework because it was both systematic and flexible. This made it easier for them to see how the program interventions affected the community's ability to respond to disasters and the long-term effectiveness of the practices they used.

RESULTS AND DISCUSSION

The Disaster Resilient Village Development Program in Donorejo Village was carried out through a series of coordinated actions that focused on two main partners: the Bangun Semi Coffee Farmer Group and the Disaster Risk Reduction Forum (FPRB). One of the most important new ideas was putting in a solar-powered coffee roasting machine to make post-harvest processing more efficient. Another was installing three units of the Landslide Early Warning System (EWS) technology at key vulnerable points to strengthen disaster mitigation. The program had a set order for its implementation. It started with socialization, then technical training, then installing the technology, then focused mentoring, and finally a long-term evaluation. All of this was done in collaboration with university teams, village officials, and community members.

In the first step, both partners used surveys, focus group discussions (FGDs), and field observations to identify their needs and the problems they faced. The mapping results showed that the Bangun Semi Farmers' Group only used traditional methods to process coffee. This led to inconsistent product quality and a lack of knowledge about how to use modern equipment. Only 30% of the 16 group members were able to turn coffee into value-added products, such as ground or roasted coffee. At the same time, the FPRB, which had 39 active members, had an early warning system in place but no longer working, and its members did not know how to respond to emergencies or prepare for disasters. During the socialization phase, all partner elements participated in interactive presentations and focus groups. All 15 active members of the farmer group (100%) participated in discussions about the program's goals, the benefits of solar-powered coffee roasting technology, and how to use coffee waste as animal feed. For the FPRB, 39 people, including community leaders, village officials, and volunteers, came to the socialization sessions. They showed strong initial commitment by completing needs questionnaires and actively participating in decisions about where to place equipment. After socialization, the program provided structured technical training tailored to each partner's needs. The Bangun Semi Farmers' Group learned to operate a solar-powered coffee roaster, package their products, keep basic business records, and make fermented animal feed from coffee waste. The training used hands-on methods to ensure participants learned useful skills. Pretest-

posttest evaluations showed that participants' financial literacy improved a lot, with average scores going up from 40 to 70, which is a 30-point gain. In the same way, all members who had never kept structured financial records before the training started began keeping digital or paper records.



Figure 2. Financial Statement Preparation Training

The FPRB's technical training focused on using and maintaining the Landslide Early Warning System (EWS), reading data, and responding in an emergency. Both classroom lessons and field simulations were included in the training. The pretest and posttest results showed that the average score increased from 55 to above 80 after training, indicating that students' technical knowledge and skills improved by 25 points. All 20 people who took the training finished it, and they all showed up. During the technology installation phase, everyone worked together to ensure community members knew how to use and care for the new technology. On December 7, 2025, one solar-powered coffee roasting machine was installed and began operating for the farmer group. The machine has a 3000-watt solar panel system, a spinning roasting drum, and very accurate time-and-temperature controls. Along with the solar-powered coffee processing equipment (pulper, dryer, grinder), they also got everything they needed to make, package, and keep track of their business.



Figure 3. Installation of Solar Cell Panels for Coffee Roasting Equipment



Figure 4. Solar Cell-Based Coffee Roasting Machine

The FPRB got three units of the Landslide Early Warning System (EWS). Through village risk mapping, strategic locations have been identified, including one unit in Jogowono Hamlet, two units in Katerban Hamlet, and one unit at the village hall. The EWS uses LoRa and IoT sensors to detect ground movement and soil moisture, which are indicators of an unstable slope. It enables the village office to send real-time hazard alerts via digital platforms and audible alarms. The system runs on 20W solar panels and has a battery backup, so it will keep working even when the power goes out. Table 1 presents the key quantitative indicators achieved during the implementation period for both partners.



Figure 5. Technology and Innovation of Solar Cell-Based Landslide Detection Device

Table 1. Summary of Key Program Outcomes

Indicator	Target	Achievement	Status
Farmer group members trained in roasting machine operation	15 members	16 members (100%)	Exceeded
FPRB members trained in EWS operation and maintenance	20 members	20 members (100%)	Achieved
Increase in pretest-posttest scores (farmers' financial literacy)	≥25 points	30 points	Exceeded
Increase in pretest-posttest scores (EWS technical skills)	≥20 points	25 points	Exceeded
Farmer group members actively using digital marketing	≥80%	87% (13 of 15 members)	Achieved
New distribution networks established	≥2	2 (Gapura UMKM Cooperative, local distributor)	Achieved
Increase in monthly group turnover	≥10%	10–15%	Achieved
EWS units installed and operational	3 units	3 units (100%)	Achieved
Village tool management team established	1 team	1 team (6 members)	Achieved
New volunteers recruited for FPRB	≥5	10 volunteers	Exceeded

After the technology was set up, the program offered focused mentoring and regular evaluations to monitor progress and address any new problems that arose. For the farmer group, mentoring meant getting help with the solar-powered roasting machine, keeping track of their finances, and learning about digital marketing. The group's partnership with the Gapura UMKM Marketing Cooperative gave them access to additional markets, enabling them to sell roasted coffee products to businesses in the Purworejo Regency government network. For the FPRB, mentoring involved regular supervisory visits to monitor EWS functionality, coordinate emergency response drills, and strengthen institutional coordination with village authorities and BPBD. A team of six people was put in charge of managing the village's tools, and ten new volunteers were brought on to

help with future disaster response and equipment maintenance tasks. During the implementation period, four monitoring and evaluation reports were prepared. These reports were used to make program changes and plan for its long-term success. The Bangun Semi Farmers' Group has experienced higher productivity and lower turnover, indicating that the program has had an economic impact. Before the intervention, the group made coffee using traditional manual methods that could only handle 0.5 kg at a time, took 150 minutes to complete, and used firewood as fuel. After the solar-powered roasting machine was installed, production capacity increased to 1.5 kg per batch, and processing time decreased to just 30 minutes. This was a threefold increase in capacity and an 80% decrease in processing time. The machine runs on solar power, so it does not need firewood. This cuts energy costs from about Rp12,500 per kilogram to Rp1,500 per kilogram. Table 2 shows how the Bangun Semi Farmers' Group's monthly turnover changed before and after the intervention. This is based on financial records kept after the bookkeeping training that was part of the program.

Table 2. Monthly Turnover of Bangun Semi Farmers' Group

Month	Period	Turnover (IDR)	Key Activities
August 2025	Pre-intervention	8,500,000	Conventional processing; limited marketing
September 2025	Pre-intervention	8,200,000	Conventional processing; limited marketing
October 2025	Post-intervention (early)	9,100,000	Socialization; initial digital marketing training
November 2025	Post-intervention (mid)	9,800,000	Digital marketing intensification; product rebranding; packaging improvement

Source: Financial report of the Bangun Semi Farmers Group, December 2025

Table 2 shows that the group's average monthly turnover increased from about IDR 8.3 million before the intervention to IDR 9.1 million in October, a 10% increase. The upward trend continued in November, reaching IDR 9.8 million as digital marketing efforts strengthened and product packaging improved. In December, the increase was larger, to IDR 10.5 million. This was after the solar-powered coffee roasting machine started working on December 7, 2025. This was a 28% increase from the baseline before the intervention. The social effects were just as important. All 16 members of the farmer group now consistently make monthly financial statements using either digital or paper-based bookkeeping systems. In digital marketing, 13 out of 15 active members (87%) use platforms such as WhatsApp Business, Instagram, and local marketplaces to promote their products and communicate with customers. Two new distribution networks were set up outside the village, helping the market reach beyond its borders. The program helped the FPRB build stronger institutions and get better prepared for disasters. The newly installed EWS can send out real-time early warnings to three at-risk areas. Alarms and digital notifications make it easy for the community to respond quickly. The creation of a dedicated village tool management team and the hiring of 10 new volunteers will make sure that equipment maintenance and disaster response activities can continue after the program ends.

The results of this program align with earlier studies that emphasize the need to combine disaster mitigation technology with efforts to strengthen local economies to build resilient communities. Fathani et al. (2014) and Rahayu et al. (2025) illustrated the efficacy of community-based Early Warning Systems in enhancing disaster preparedness in at-risk villages, while promoting community autonomy through involvement in equipment maintenance and system operation. The current program corroborates these findings, as the FPRB demonstrates enhanced capabilities in both technical operations and institutional coordination following the installation of solar-powered EWS. The economic results of this program are also in line with Yulistya et al. (2025) and Dellosa & Barocca

(2021), who stated that solar-powered coffee processing technologies improve efficiency, reduce production costs, and accelerate the adoption of new ideas in the rural MSME sector. The 80% reduction in processing time, 88% reduction in energy costs, and 28% increase in turnover after the intervention confirm these earlier results.

Moreover, enhancing business governance through financial record-keeping and digital marketing training aligns with Saputra (2022), who indicated that SME network collaboration and advancements in digital management substantially improve the competitiveness of small business collectives. The Bangun Semi Farmers' Group's successful collaboration with the Gapura UMKM Marketing Cooperative and their increased market access illustrate these advantages. The program's combination of disaster mitigation technology with renewable energy-based economic empowerment fills a hole that has been found in the literature, where many similar programs have not been able to last because disaster mitigation systems and community economic development have not been able to work together (Rahayu et al., 2025; Saputro et al., 2024). The Donorejo program demonstrates a model for holistic rural development in disaster-prone areas by simultaneously improving safety infrastructure and productive capacity. Several things make the program more likely to last. The farmer group will remain productive and have access to markets if they establish a local cadre trained in machine operation and maintenance, create Standard Operating Procedures (SOPs) for coffee processing, and formally partner with the Gapura UMKM Marketing Cooperative. For the FPRB, institutional continuity comes from establishing a village tool management team, recruiting new volunteers, and adding EWS functionality to village disaster response plans.

CONCLUSION

This study concludes that the integrated development of Donorejo Village, realized through the implementation of a landslide early warning system and a solar-powered post-harvest coffee processing technology, has significantly improved both community disaster resilience and local economic capacity. The results show that active community participation, technology transfer tailored to the situation, and long-term mentoring from multiple stakeholders are the most important factors for accelerating the transformation of farmer groups and disaster risk reduction forums into an independent, adaptable, and resilient village model. Combining sensor-based early detection tools with new ideas for renewable energy not only makes villages better prepared for hydrometeorological hazards but also improves product quality, gives coffee farmers more access to markets, strengthens local institutional networks, and creates a cross-sectoral, easily replicable collaborative ecosystem. The main contribution of this research is to provide empirical evidence that a collaborative, technology-based intervention strategy in disaster-prone rural areas can generate sustainable socioeconomic resilience, while offering a practical and conceptual reference for the development of similar resilient village models across Indonesia and in other regions facing comparable environmental and economic challenges.

DECLARATION OF GENERATIVE AI

The authors declare that no generative AI or AI-assisted technologies were used in the writing process of this manuscript.

CONFLICTING INTEREST STATEMENT

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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