



Community engagement in a livelihood restoration program: Linking geothermal land acquisition, empowerment, and livelihood sustainability

Dany Yuda Saputra¹, Herdis Herdiansyah^{1,*}, Indra Kertati²

¹ Department Environmental Science, Graduate-School of Sustainable Development, Universitas Indonesia, Central Jakarta, Special Capital Region of Jakarta 10430, Indonesia;

² Public Administration, Faculty of Social and Political Science, Universitas 17 Agustus 1945, Semarang, Central Java 50233, Indonesia.

*Correspondence: herdis@ui.ac.id

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ABSTRACT

Background: This study examines how a Livelihood Restoration Program embedded in a community engagement framework contributes to livelihood recovery among households affected by land acquisition for a geothermal power plant in a mountainous district of West Sumatra, where energy transition, climate vulnerability, and resource-dependent livelihoods intersect. Using the Sustainable Livelihoods Framework, the study explores changes in the livelihood assets and experiences of equity, empowerment, and engagement of citizens. **Methods:** A convergent mixed methods design was applied, combining a census survey of 52 project-affected households with in-depth interviews with 12 informants, including PAP beneficiaries and key stakeholders, followed by separate quantitative and qualitative analyses and integrated interpretation. **Findings:** Quantitative results showed a positive and statistically significant, but modest, effect of program participation on livelihood assets, explaining approximately 10% of the observed variation, while climate, price, and market vulnerabilities are reflected in the remainder. Qualitative data indicate that human, social, financial, physical, and natural capital improvements are strongly linked to recovery motivation, adaptive abilities, knowledge and skills, productive capital support, and sustained mentoring. **Conclusion:** The Livelihood Restoration Program acts as a catalyst for capacity building and asset strengthening, but its integration with more meaningful community engagement and cross-sectoral institutional reforms in geothermal and regional development policy is critical for durable livelihood resilience and social justice. **Novelty/Originality of this article:** This study contributes by integrating quantitative and qualitative evidence to explain how community engagement influences livelihood restoration and sustainable livelihood outcomes in geothermal development.

KEYWORDS: community engagement; geothermal energy; livelihood restoration program; social justice; sustainable livelihood framework.

1. Introduction

Globally, geothermal energy continues to expand as a strategic low-carbon energy source, contributing to efforts to limit global warming below 1.5–2°C due to its ability to provide stable baseload power with relatively low emissions (Ardelia, 2023; Pattinussa & Aaron, 2025; Resosudarmo et al., 2023; Pambudi, 2018). Figure 1 illustrates Indonesia's leading position in global geothermal production, highlighting world's largest geothermal

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potentials, estimated at 27–28 GW (around 40% of global resources) (Alhamid et al., 2016; Bina et al., 2018; Fan & Nam, 2018; Pambudi, 2018), with an installed capacity of approximately 2.71 GW by 2025, positioning the country as a global leader and supporting its long-term energy transition target of 22 GW by 2060 (IRENA, 2025; MEMR, 2025).. The government targets capacity expansion to 22 GW by 2060 as part of the energy transition roadmap toward net zero emissions (MEMR, 2025). Although geothermal energy provides significant environmental benefits, its large-scale development may also affect rural communities whose livelihoods depend on land and natural resources.

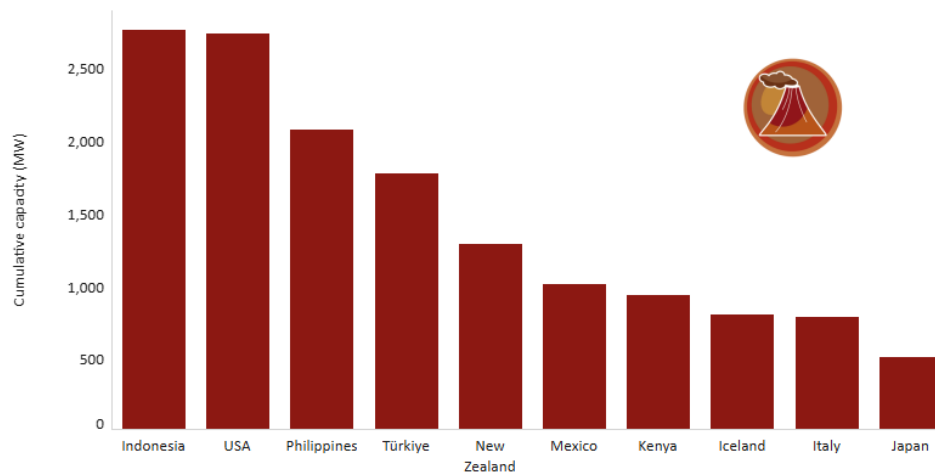


Fig. 1. Top 10 countries with the highest geothermal production (IRENA, 2025)

The expansion of geothermal power plants has significant social implications, especially in rural areas that rely heavily on land and natural resources as a basis for livelihood (Darma et al., 2020). Previous studies consistently report that land acquisition for large-scale energy projects can reduce access to productive resources, disrupt livelihoods, and increase socioeconomic vulnerability among affected households (Rukmana, 2024). Findings in various Asian and African countries show that power generation and dam projects drastically alter the local economy's structure, while cash-compensation-based mitigation alone is insufficient to restore the affected households' socio-economic conditions (Ali et al., 2022; Khanal et al., 2024; Xu et al., 2022). These challenges highlight the importance of community engagement in supporting sustainable livelihood recovery (CDC, 1997; Sutley & Lyles, 2021; Setiawan et al., 2023).

Community engagement includes two-way communication which differs from one-way socialization in that it places the community as a subject with capacities, local knowledge, and aspirations that must be accommodated (Ahmed, 2022; Bowen et al., 2010; Sutley & Lyles, 2021). Research on infrastructure and renewable energy projects shows that the quality of community engagement influences public trust, social acceptance of projects, and the success of local economic programs. Strong community engagement is associated with an increased sense of belonging and community-based innovation in managing environmental and social risks (Scholsberg & Coles, 2016; Scholz, 2020; Zaharuddin et al., 2025).

The Sustainable Livelihood Framework (SLF) is used to analyze Project Affected Persons' (PAPs) responses to large-scale projects by viewing livelihoods as the outcome of interactions among human, social, financial, physical, and natural capital within conditions of vulnerability, institutional structures, livelihood strategies, and outcomes (DFID, 2000; Serrat, 2017; World Bank, 2001, 2018). Compared with alternative approaches, SLF is more directly operationalizable for identifying which livelihood assets are most affected by land acquisition and for translating this diagnosis into concrete design, monitoring, and evaluation parameters for livelihood restoration programs in geothermal project-affected communities (Karki, 2021; IFC, 2023).

Various studies show that capital composition determines the capacity of affected communities to adapt to shocks from geothermal project development, where land acquisition erodes natural and physical capital foundations while diversified livelihood strategies integrating multiple capital types prove more resistant to the economic and ecological pressures introduced by large-scale energy infrastructure (Mahamoud Abdi et al., 2024; Kirarey and Sang, 2019; Kong'ani et al., 2021; Kurgat and Omwenga, 2016). Although post-project support that strengthens human and financial capital can partially restore adaptive capacity and improve household resilience, recovery remains constrained when access to markets and natural resources is structurally limited, across geothermal and other renewable energy sectors, the most durable outcomes against economic and ecological pressures emerge where community engagement is embedded throughout the project cycle and livelihood diversification spans multiple capital categories (Karki, 2021; Ma et al., 2024; Nweke-Eze, 2025; Schulz & Skinner, 2022; Setiawan et al., 2023; Sibarani & Somboonsuke, 2023; Singh et al., 2024; Xu et al., 2022; Yanto et al., 2025).

Within this framework, the Livelihood Restoration Program (LRP) is positioned as an operational instrument that connects sustainability principles with the practice of community engagement for project-affected persons who have lost land and income (Ali et al., 2022; CDC, 1997; Eizenberg & Jabareen, 2017; IFC, 2012; Li et al., 2018; Ma et al., 2024; Pinuji & de Vries, 2025; Sutley & Lyles, 2021; Xu et al., 2022). It does so through interventions such as training, provision of productive assets, capital support, technical assistance, and facilitation of access to markets and financial institutions (Ali et al., 2022; CDC, 1997; Eizenberg & Jabareen, 2017; IFC, 2012; Li et al., 2018; Ma et al., 2024; Pinuji & de Vries, 2025; Sutley & Lyles, 2021; Xu et al., 2022). Participatory LRP that incorporate local knowledge and long-term mentoring are generally more effective than short-term compensation programs (Hao et al., 2022; Moreno et al., 2017). These approaches strengthen livelihood assets while also improving trust, community ownership, and participation in decision-making (Schlosberg & Coles, 2016; Setiawan et al., 2023; Wolfe et al., 2020; Xu et al., 2022).

Indonesia provides an important context for this study because geothermal projects are commonly developed in agricultural regions where customary land tenure and local livelihood systems influence the implementation of livelihood restoration programs. (Darma et al., 2020; Fan & Nam, 2018). Land is a source of income and a support for social identity, kinship networks, and local knowledge (Rukmana, 2024). Thus, land loss and changes in access to resources trigger layered vulnerabilities, while early-stage weak community engagement often fosters long-term distrust and resistance (Sibarani & Somboonsuke, 2023; Zaharuddin et al., 2025).

This article draws on a case study in a mountainous district in Sumatra that hosts a large-scale geothermal power plant, where the acquisition of hundreds of hectares of land affects hundreds of families, including severely affected households and vulnerable groups (ADB, 2009; Limanté & Tereškinas, 2022). The Livelihood Restoration Program (LRP) in this context was implemented over three years from 2020 to 2023 to restore or improve the capacity, motivation, skills, and access to financial and field technical support of project-affected persons. This study addresses a gap in the literature on LRPs in Indonesian geothermal projects by examining how corporate involvement through LRP influences the capacity, motivation, skills, and livelihood assets of PAPs, identifying the dominant factors that shape program success through the lens of the Sustainable Livelihood Framework, and analyzing post-program contextual challenges to inform LRP designs that are more sensitive to community engagement and local livelihood dynamics.

2. Methods

The research was conducted in September–December 2025 located in 12 *lorongs* (sub-village), Pauh Duo Sub-district, South Solok Regency, West Sumatra, an agrarian area with geothermal potential and high dependence on plantation commodities such as rubber, oil palm, coffee, and tea (Natarajan et al., 2022; Yunisvita et al., 2025). South Solok was selected

because geothermal development has substantially affected land-based livelihoods, providing an appropriate setting to examine livelihood restoration and community engagement (Liu et al., 2024; World Bank, 2001, 2017; Natarajan et al., 2022; Yunisvita et al., 2025). *Nagari* (village) and *orong* (sub-village) are specific locations affected by land acquisition and are targeted by LRP, categorized as PAPs.

This study uses a convergent mixed-methods design in which quantitative and qualitative data are collected in parallel, analyzed separately, and integrated at the interpretation stage (Creswell & Plano Clark, 2018; Romero-Lankao et al., 2023). This approach was selected to capture changes in livelihood assets and internal factors such as motivation and skills, while also examining experiences, perceptions of justice, and community engagement dynamics in LRP and testing the consistency between statistical results and interview narratives, so that material conditions and social constructs like justice and empowerment can be mapped more comprehensively (Ab Samah et al., 2025; Batliwala, 2024; Hatzichristou et al., 2020; Liu et al., 2024; Natarajan et al., 2022; Romero-Lankao et al., 2023; Taylor, 2023; Uzorka et al., 2023). Quantitative and qualitative findings were integrated to provide a comprehensive understanding of livelihood restoration outcomes.

The study population included 202 affected households, of which 59 were validated as PAPs and considered as beneficiaries of the LRP Program (AMF, 2018). A total of 52 PAPs (88.1%) were successfully surveyed, while 7 (11.9%) could not be found because 4 had died and 3 had moved locations. The PAPs surveyed consisted of 67.3% men and 32.7% are women. Surveys are conducted once a month starting in September 2025 by census to minimize sampling bias by including all available program beneficiaries (Liu et al., 2024; Natarajan et al., 2022). Purposive sampling was used to conduct the qualitative component for 12 informants by the end of September 2025 considering variations in participation levels, types of livelihoods, and vulnerabilities. Key informants consisted of PAPs, government representatives, and project staff. Sample sizes were determined based on the principle of information sufficiency until thematic saturation is achieved (Braun & Clarke, 2021; Liu et al., 2024; Ab Samah et al., 2025).

Quantitative data were collected through structured household surveys compiled based on the SLF framework and international LRP practice guidelines, with participation intensity indicators such as activity type, frequency, and engagement duration (Natarajan et al., 2022; ADB, 2009). Motivation and attitudes toward the program are measured on a likert scale, including perception of benefits, trust in the organizers, and readiness to change livelihood strategies (World Bank, 2017; Romero-Lankao et al., 2023; Uzorka et al., 2023), while livelihood skills and assets are assessed through indicators of human, physical, financial, natural, and social assets, as well as perceptions of vulnerability to climate risks, price fluctuations, pest attacks, and market dynamics (Cai et al., 2021; Liu et al., 2024; Kuzior et al., 2022; Prasetyo & Kistanti, 2020; Ren et al., 2022; Yunisvita et al., 2025). The questionnaire was pilot-tested to evaluate clarity and internal consistency before formal data collection (Ab Samah et al., 2025; Liu et al., 2024). Qualitative data were obtained through semi-structured in-depth interviews conducted with 12 purposively selected informants, comprising 6 representatives of project-affected people, 3 local government officials, and 3 program managers. Each interview session lasted between 60 and 120 minutes. Prior to data collection, the Institutional Review Board (Approval No. KET-117/UN2.F13.D1.KE1/PPM.00/2024), and written informed consent was obtained from all participants. Thematic saturation was determined when no new codes or themes emerged from successive interviews, consistent with Braun and Clarke's (2006) saturation principle. The interviews explored key themes, including the engagement process, decision-making, perception of justice, empowerment, and implementation challenges. The entire procedure followed ethical principles, including informed consent and voluntary participation (Perrault & Keating, 2018; Uzorka et al., 2023; World Bank, 2017).

Surveyed data were analyzed using statistical software to generate descriptive statistics on participation intensity, livelihood assets, motivation, skills, and vulnerability perception (Liu et al., 2024; Romero-Lankao et al., 2023). The relationship between

engagement in LRP and asset indicators and internal factors was tested using Pearson correlation. Prior to regression analysis, assumptions of normality, linearity, homoscedasticity, and independence were assessed. Simple linear regression was used to assess the relative contribution of engagement to asset variation and vulnerability perception. Cronbach's alpha was used to assess the reliability of the instrument (Liu et al., 2024; Natarajan et al., 2022; Romero-Lankao et al., 2023; World Bank, 2021). Reflexive thematic analysis was used to analyze the qualitative data, including the familiarization stage, initial coding, theme development and review, theme name, and narrative writing (Braun & Clarke, 2021; Uzorka et al., 2023). The findings are integrated through joint displays that map key statistical results with a qualitative theme to identify convergence and explain the mechanisms behind quantitative relationships (Creswell & Plano Clark, 2018; Liu et al., 2024; Natarajan et al., 2022; Romero-Lankao et al., 2023).

3. Results and Discussion

3.1 Summary of the quantitative results

A total of 52 respondents were surveyed within 12 *jurongs* consist of 67.3% of men and 32.7% of women with a low education. The questionnaire demonstrated acceptable internal consistency, with a Cronbach's Alpha value of 0.701 (George & Mallery, 2003). The Pearson correlation test showed a significant positive relationship between PAP's participation in the LRP and livelihood assets, with a coefficient of approximately 0.325 and a one-way significance value of 0.009 in 52 respondents, indicating that the higher the participation, the higher the asset score, although the strength was only in the weak to moderate category. The regression model explained 10.6% of the variation in livelihood asset scores ($R^2 = 0.106$), indicating that LRP participation has a modest but meaningful influence on asset strengthening while the majority of variation is still shaped by other contextual factors.

The ANOVA confirmed that the regression model was statistically significant ($F = 5.919$, $p = 0.019$), indicating that LRP participation significantly predicted livelihood asset scores. The positive association between LRP participation and livelihood assets was statistically significant ($p < 0.05$). Overall, the regression model demonstrated that LRP participation significantly contributed to explaining variation in livelihood asset scores. The regression coefficient table results confirm the role of the LRP. The linear regression equation obtained is livelihood assets = $153,352 + 0.063 \times \text{LRP}$. Therefore, the formula for the resulting linear regression equation is:

$$Y = a + bX \quad (\text{Eq. 1})$$

The constant of 153.352 reflects the average of livelihood assets when the LRP score is zero, while the coefficient of 0.063 indicates that each increase of one unit of LRP score is related to an increase of 0.063 units of assets. This coefficient was significant ($t = 2.433$; $p = 0.019$) with a beta of 0.325, confirming that LRP was a positive predictor but of limited effect. The survey shows that PAPs face a variety of challenges that form a vulnerability context with the issue of unstable market prices (36.5%) and extreme climate (32.7%) as the main structural pressures that are beyond their control but greatly affect business income and sustainability. In addition, rising fertilizer prices and complex business treatments (7.7%) increase production costs and daily management burdens, while other factors such as pest attacks, limited capital and market access, low knowledge/skills, and physical burden (1.9–3.8%) still have the potential to weaken households' ability to respond to climate and market shocks despite being less dominant.

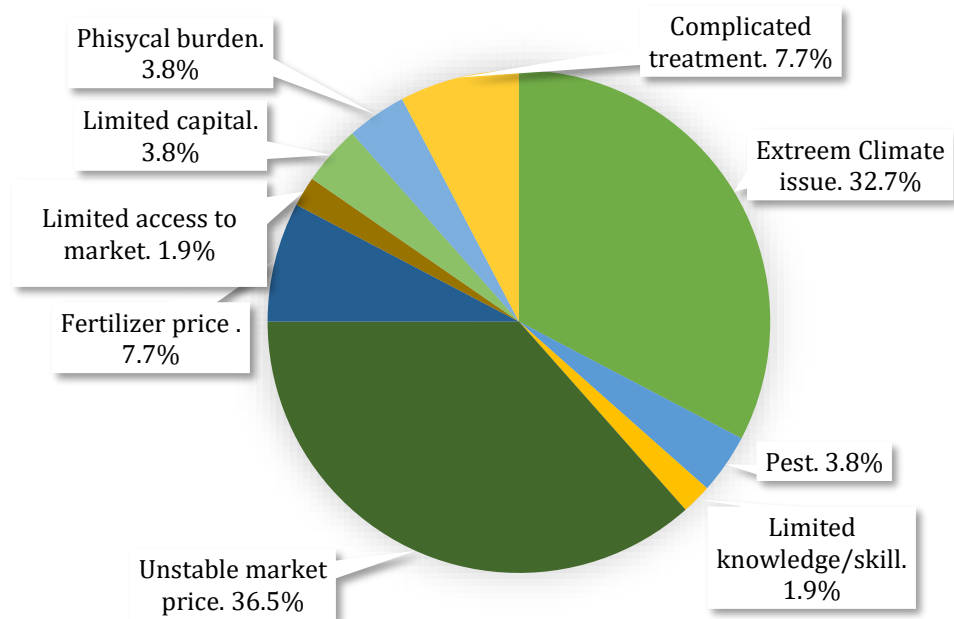


Fig. 2. Challenges faced by PAPs

Methodologically, the combination of correlation results, ANOVA, and regression coefficients showed that the regression model met the statistical feasibility criteria as an initial predictive model, since the significant correlation confirmed the existence of a linear relationship, the ANOVA test confirmed the model's meaningfulness, and the regression coefficient provided a quantitative estimate of the influence of the LRP on livelihood assets, although the small determination coefficient reminded that the program was not the only determining factor and generalizations must be careful. Empirically, the LRP functions as a trigger instrument for strengthening PAPs' livelihood assets, not the main determinant of welfare, by providing training, mentoring, and business support that citizens translate into skills improvement, better business management, and livelihood diversification, while the final outcome is highly dependent on households' ability to take advantage of opportunities, social networks, local market structures, and policy support, in line with findings in resettlement and livelihood support that show program interventions tend to be positive but not entirely decisive in the midst of complex economic-social structures (Ali et al., 2022; Karki, 2021; Ma et al., 2024; Singh et al., 2024; Setiawan et al., 2023; Xu et al., 2022). In this sense, the LRP operates as a meso-level catalyst that strengthens human, social, physical, and financial capitals but leaves welfare outcomes heavily mediated by pre-existing inequalities and broader market-policy dynamics. Therefore, livelihood restoration should be viewed as a component of a long-term territorial development strategy rather than a standalone compensatory mechanism attached to land acquisition (Ali et al., 2022; Ma et al., 2024; Setiawan et al., 2023; Singh et al., 2024; Xu et al., 2022).

Economically, LRP interventions contribute to strengthening financial and physical capital by improving business skills, access to capital, and cultivation or value-added practices (Ma et al., 2024; Sibarani & Somboonsuke, 2023). At the same time, evidence from China and other contexts shows that gains in these capitals translate unevenly into resilience and welfare because they are mediated by market access, spatial disadvantages, and the quality of public services within broader livelihood systems (Ma et al., 2024; Setiawan et al., 2023; Singh et al., 2024; Xu et al., 2022). Within the SLF, this implies that LRP can act as a lever to enhance core livelihood assets and their utilisation, but its longer-term effects on resilience and welfare depend on complementary improvements in markets, institutions, and policy processes so that capital strengthening is embedded in a more enabling and equitable economic environment (Karki, 2021).

Socially, the LRP strengthens social capital by promoting business groups, local institutions, and mentoring that link communities with companies and governments

(Setiawan et al., 2023; Fujikura et al., 2009). These patterns mirror evidence from hydropower, reservoir, and other displacement contexts, where institutional support and skills training reduce impoverishment risks when they translate into dense, supportive community networks and stronger social ties (Ali et al., 2022; Gong et al., 2021; Ma et al., 2024; Tan, 2020; Srinivasan & Nuthalapati, 2020; Xu et al., 2022). Overall, the social impact of LRP lies more in reinforcing solidarity, collective agency, and trust than in material assets alone, confirming that effective livelihood recovery must prioritise social institutions and relationships alongside income generation (Ma et al., 2024; Sibarani & Somboonsuke, 2023; Singh & Muhuri, 2026).

Ecologically, the LRP encourages commodity diversification and more sustainable cultivation practices, e.g., plant combinations and the use of local inputs such as compost (Ma et al., 2024; Sibarani & Somboonsuke, 2023). This pattern shows that the increase in Livelihood Assets does not only depend on land expansion or intensive exploitation, but also on strategies that emphasize resource efficiency and increased added value (Karki, 2021; Singh et al., 2024). This finding is consistent with LRPs in the energy sector and hydropower studies, where restoration schemes integrated with conservation agriculture and local resource management generate more positive socio-ecological outcomes than approaches focused solely on compensation or single-commodity promotion (Setiawan et al., 2023; Ma et al., 2024; Xu et al., 2022). Simultaneously, research on “double displacement” and environmental displacement highlights that resettlement and livelihood programs must anticipate environmental change and climate-related risks, so instruments like the LRP must be embedded in broader transitions that explicitly link economic recovery with ecological sustainability and climate-resilient resource governance (Miller et al., 2022; Lunstrum et al., 2016).

Overall, The findings demonstrate that comprehensive livelihood restoration programs combining material compensation, capacity building, institutional support, and medium-term assistance are more effective than compensation-based approaches that focus only on physical asset replacement (Ali et al., 2022; Fujikura et al., 2009; Ma et al., 2024; Setiawan et al., 2023). These results are consistent with previous studies reporting that integrated livelihood restoration programs generally achieve better long-term outcomes than one-time compensation schemes, and they show how selective engagement with human, social, financial, and physical capitals within the SLF contexts in shaping PAPs’ opportunities for sustainable livelihood improvement under ongoing climate, market, and governance pressures (Hay et al., 2019; Karki, 2021; Natarajan et al., 2022; Schulz & Skinner, 2022; Smyth et al., 2015; Singh et al., 2024; Xu et al., 2022).

The findings suggest that livelihood restoration should be supported by long-term institutional and policy measures to enhance household resilience beyond the implementation period of the LRP. In this study, the partial contribution of LRP participation to variation in livelihood assets indicates that livelihood recovery is a gradual, layered process that depends on sustained support across program design, project governance, benefit sharing, and protection from environmental impacts, so that households can move from basic asset recovery toward more adaptive and resilient livelihood strategies in practice (Ali et al., 2022; Fujikura et al., 2009; Ma et al., 2024; Setiawan et al., 2023; Singh & Muhuri, 2026; Tan, 2020; Gong et al., 2021; Srinivasan & Nuthalapati, 2020).

3.2 Summary of the qualitative results

Qualitative analysis from 12 informants (6 PAPs, 3 governments, and 3 LRP management and implementation division) interviewed with various stakeholders showed that the success of livelihood asset recovery through the program is inseparable from the close interaction between internal and external factors (Karki, 2021). The themes that emerged from the thematic analysis point to two prominent internal factors are the motivation to rise and the ability to adapt to changes in the structure of livelihood, while external factors include strengthening knowledge and skills, providing financial capital, and

sustainable assistance (Ma et al., 2024; Xu et al., 2022). All of these elements together form the configuration of strengthening human, social, financial, physical, and natural capital as described in the SLF framework (Karki, 2021). A summary of the analysis data related to the qualitatively dominant factors is presented in Table 1.

Table 1. Dominant factor of successful LRP

Dominant factor	Result Findings	Interpretation of the study findings
Strong motivation (internal)	Across several interviews conducted in 2025, the informant initially experienced collective fears regarding the future of livelihoods after the land acquisition plan, including fears of potential disasters, which triggered strong rejection of the project implementers (Compiled from Interview with Informant, 2025). It is stated by PAP 1, that <i>"We were scared at that time. What would become of us in the future? The land inherited from our family, passed down through generations, what little we had left, and now it was going to be taken away as well. What made us even more worried was that we feared it would end up like Lapindo, and what would happen to our village."</i> (PAP1, Interview, 2025). After socialization and compensation agreements, the compensation is reinvested in the form of the purchase of new land, houses, and the establishment of family- and group-based micro-enterprises. Women's groups formed joint business units, while some respondents initiated cooperatives and trading businesses that used compensation as the initial capital to rise.	Motivation is the main driver of the transformation from a crisis to a recovery phase. The psychological readiness to rise and the desire to improve welfare encourage compensation recipients to allocate resources to productive assets. Motivation has an individual and collective dimension, which is reflected in the emergence of social entrepreneurship initiatives and the willingness to build local economic institutions.
Adaptive capabilities (internal)	Across several interviews conducted in 2025, successful informants tended to quickly adapt to changes in economic and social conditions after land acquisition. The shift from traditional business patterns to agribusiness forms, the establishment of local economic institutions, and business diversification into the fields of trade, product processing, and services have all contributed to this adaptation. PAP 2 was shifting from being a farmer to a middleman using the skills obtained from LRP. <i>"From being a farmer, I adapted and became a middleman, thanks to the flexibility I gained from the LRP training."</i> (PAP2, Interview, 2025). Internal quantitative data from the program show that actors who make business strategy adjustments have a higher level of business sustainability. Conversely, the adaptation process occurs repeatedly, for example, from one type of business to another, in response to market demand dynamics.	Adaptability is understood as the capacity to modify livelihood strategies when the structure of opportunities and risks changes. Adaptation is not only a change in the type of business, but also the collective ability to build and manage new economic institutions. This factor shortens the post-project economic transition period and becomes a foundations of household and community livelihood resilience.
Knowledge and skill (external)	The program provides a series of technical and managerial training that can be directly applied in business practice across several interviews conducted in 2025. Training materials include more efficient agricultural and livestock cultivation, basic financial management, marketing, and institutional management. The	Knowledge and skills form the core of human capital strengthening within the framework of sustainable livelihoods. Relevant and applicable training allows

	training is tailored to local needs and updated regularly. The knowledge gained is then disseminated among group members and cooperatives. Respondents assessed that this knowledge strengthened confidence, professionalism in managing businesses, and ability to make economic decisions. As the PAP3 said that <i>"The cooperative management skills from the program were really valuable for us. We never had any formal education in cooperative management, and most of us only finished junior high school and never imagined we would ever be running an organization like a cooperative."</i> (PAP3, Interview, 2025)	participants to translate motivation and adaptation into more effective business strategies. The dissemination of knowledge through group and cooperative structures also increases collective capacity, so that the training benefits go beyond the individual level.
Supporting fund (external)	Based on interviews conducted with several informants in 2025, the program provides capital facilities in the form of grants, soft loans, and in-kind support for the purchase of business tools, stock goods, and other relevant means of production. Capital allocation is based on a business feasibility assessment and is supervised by accompanying elements and local officials. Respondents use capital to increase business scale, strengthen merchandise stocks, expand livestock activities, and add other productive assets. Capital serves as a bridge between one-time compensation and sustainable business development. PAP4 mention that she got <i>"The financial support, I received to purchase chicken chicks saved me when my sewing business went through a crisis."</i> (PAP4, Interview, 2025)	Financial capital acts as a lever that activates capacity that has been built through motivation, adaptation, and knowledge. The design of productive capital distribution accompanied by supervision reduces the risk of consumptive use. Nonetheless, the quality of management at the household and group levels, as well as by structural conditions such as market access and price stability, largely determine the success of capital use.
Ongoing assistance (external)	Based on an interview with a server in 2025, intensive mentoring is conducted from the initial stage of the program to the annual monitoring period. Mentoring activities include regular field visits, business and institutional management guidance, market access facilitation, and technical and administrative problem-solving in the field. Assistance is adjusted to the business cycle, for example, following the agricultural sector's planting calendar. There is also personal assistance for micro-business actors, including women, to overcome specific obstacles. Cross-agency coordination accelerates responses to the problems of participants. PAP2 mention that <i>"The facilitators taught us cooperative management in a regular and scheduled manner"</i> (PAP2, Interview, 2025).	Mentoring serves as a capacity-building and accountability mechanism that connects program design with implementation. With the sustainability of mentoring, participants gain consultation space, strategy correction, and wider network access. Context-sensitive assistance can reduce the risk of business failure and strengthen the legitimacy of the program in the eyes of the community.

Overall, the qualitative findings indicate that successful livelihood restoration resulted from the interaction between strong internal motivation and adaptive capacity, supported by continuous training, financial assistance, and institutional mentoring that helped participants reorganise their livelihoods after land acquisition (Ali et al., 2022; Ma et al., 2024; Setiawan et al., 2023; Xu et al., 2022). Together, these factors enabled affected households to move from initial uncertainty and resistance toward livelihood diversification through agribusiness development, new service and retail enterprises, and

strengthened cooperatives and business groups, in line with evidence that effective compensation must be embedded within broader packages of institutional support and community engagement in geothermal project contexts (Mahamoud Abdi et al., 2024; Nweke-Eze, 2025; Yanto et al., 2025; Singh & Muhuri, 2026).

On the external side, the program provides technical training on agriculture-livestock, business management, basic accounting, marketing, and institutional management that enriches human capital, is easy to apply, and disseminated through groups and cooperatives to strengthen collective capacity, consistent with the view that strengthening human capacity is the main pillar of sustainable livelihood programs (Karki, 2021). The provision of financial capital in the form of grants, soft loans, and in-kind support allows the translation of knowledge and motivation into productive businesses, with supervision to maintain appropriate of funds. These findings indicate that sustained external support is central to livelihood recovery, as capital is used to expand businesses, strengthen stocks, and develop livestock, thereby raising incomes and reducing short-term vulnerabilities (Ma et al., 2024; Xu et al., 2022). Continuous assistance through visits, technical guidance, institutional mentoring, and market facilitation helps communities connect project benefits to long-term livelihood goals, consistent with evidence on the importance of ongoing engagement and strong local organisations in geothermal and power projects (Ali et al., 2022; Setiawan et al., 2023; Nweke-Eze, 2025; Mahamoud Abdi et al., 2024; Yanto et al., 2025; Kurgat & Omwenga, 2016).

The empirical results show that the LRP does strengthen all five livelihood capitals, but its impact on household welfare does not operate in isolation and is always mediated by existing asset structures, market and institutional contexts, and household strategies (Karki, 2021; Ma et al., 2024; Tan, 2020; Gong et al., 2021; Kurgat & Omwenga, 2016; Singh & Muhuri, 2026; Nweke-Eze, 2025; Yanto et al., 2025; Srinivasan & Nuthalapati, 2020). In practical terms, this means that the LRP needs to be positioned as one component within a broader livelihood system, and program success depends on how well LRP interventions are synchronized with market policies, project governance, and long-term institutional support, so that asset strengthening can be translated into more equitable and sustainable welfare gains (Karki, 2021; Ma et al., 2024; Tan, 2020; Gong et al., 2021; Kurgat & Omwenga, 2016; Singh & Muhuri, 2026; Nweke-Eze, 2025; Yanto et al., 2025; Srinivasan & Nuthalapati, 2020).

Comparison with other studies helps clarify the position of this study's findings, but the main contribution lies in showing how an LRP in a geothermal context strengthens livelihood assets while remaining constrained by broader structural factors (Ma et al., 2024; Setiawan et al., 2023; Xu et al., 2022). The results indicate that integrating local knowledge and community initiatives with training, mentoring, and institutional support enhances human, social, financial, physical, and natural capital, yet increased assets do not automatically eliminate vulnerability when market access, governance quality, and agrarian policies are not addressed (Ma et al., 2024; Xu et al., 2022; Badhuri & Banerjee, 2025). This study therefore extends earlier work on large energy and dam projects by demonstrating, in a geothermal case, that LRP can move beyond physical compensation toward more holistic livelihood recovery, while still requiring long-term cross-sectoral coordination and policy commitment to overcome structural barriers beyond the program's direct control (Gong et al., 2021; Karki, 2021; Kurgat & Omwenga, 2016; Mahamoud Abdi et al., 2024; Nweke-Eze, 2025; Singh & Muhuri, 2026; Srinivasan & Nuthalapati, 2020; Vanclay, 2017; Yanto et al., 2025).

Taken together, the empirical results and comparative literature suggest that the LRP should be understood less as a technical add-on to land acquisition and more as a strategic lever within a broader transformation of local livelihood systems. By anchoring support in human, social, financial, physical, and natural capitals, the findings from this study show that livelihood recovery is more meaningful when households are enabled to reconfigure their asset portfolios and rebuild local institutions, rather than simply receiving compensation for what was lost (Gong et al., 2021; Ma et al., 2024; Tan, 2020). The evidence also indicates that, within the observed program, strengthened livelihood assets are most

effective when combined with sustained, participatory engagement with PAPs, allowing improvements in these capitals to translate into more durable wellbeing gains (Nweke-Eze, 2025; Setiawan et al., 2023; Singh & Muhuri, 2026; Vanclay, 2017).

3.3 Joint matrix

Integrating the quantitative and qualitative findings provides a more comprehensive understanding of how the LRP contributes to livelihood restoration. While the quantitative results demonstrate a significant positive association between LRP participation and livelihood assets, the qualitative findings explain the mechanisms through which this relationship is achieved, particularly through strengthening livelihood capitals and adaptive capacities. The integrated analysis demonstrates that quantitative relationships are supported by qualitative evidence, providing a clearer explanation of the mechanisms underlying livelihood recovery (Ma et al., 2024; Xu et al., 2022; Vanclay, 2017). Table 2 presents the joint display between the results of quantitative and qualitative analysis.

Table 2. Results of joint display

Quantitative Results	Meaning of the Quantitative Results	Qualitative Findings	Combined Interpretation	Program Implications
Linear analysis $Y=153,352+0,063X$ $r=0.325$ $F=5.919$ with a significance of 0.019.	The results of the analysis show that the LRP variables make a significant, although not dominant, positive contribution to the increase in livelihood assets, and the model used is statistically feasible.	Across interviews with several informants in 2025, the recovery of PAP livelihoods is supported by strong motivation to rise and the ability to adapt through changes and business diversification. Increased knowledge and skills, productive capital support, and ongoing mentoring strengthen their capacity to sustain and develop livelihoods.	Significant LRP participation was associated with stronger livelihood assets because continuous training, financial support, adaptive capacity, and sustained mentoring collectively strengthened multiple livelihood capital.	Future LRPs should combine long-term mentoring, institutional support, and market access to improve sustainable livelihood recovery.

The joint analysis indicates that improvements in livelihood assets were driven by the interaction between strengthened livelihood capitals and participants' adaptive capacities, explaining why the quantitative analysis identified a positive but moderate program effect. For example, business diversification, shifting economic roles, and the use of local networks have been used (Karki, 2021; Ma et al., 2024; Sibarani & Somboonsuke, 2023). This pattern is consistent with the literature that asserts that livelihood resilience is formed from the integration of internal capacity of PAPs and external support within the framework of sustainable livelihoods. Studies in the context of geothermal projects, hydropower, and agrifood show that a combination of assets, livelihood diversification strategies, and local institutional strength is more closely related to livelihood resilience than the direct impact of a single program (Bilali & Hauser, 2018; Setiawan et al., 2023; Singh et al., 2024; Zhang et al., 2024).

The implications for program design are that LRP should be reoriented from a narrow focus on asset recovery toward a core instrument for strengthening human, social, financial, physical, and natural capitals. Instead of treating compensation, initial training, and capital assistance as discrete project outputs, the evidence points to the need for long-term architectures of support that link livelihood restoration to evolving energy infrastructures,

local development pathways, and climate risks, so that PAPs can continuously adjust strategies as contexts change (Tan, 2020; Gong et al., 2021; Srinivasan & Nuthalapati, 2020). More specifically, the findings from this study, together with existing work on LRP and resettlement, point to three key recommendations. Livelihood restoration programs should integrate community engagement across the project cycle so that affected households participate meaningfully in planning, implementation, and monitoring (Nweke-Eze, 2025; Yanto et al., 2025). Program design also needs to align with corporate social responsibility and benefit-sharing commitments, with operators supporting livelihood recovery through capacity building, institutional mentoring, medium-term assistance, and co-produced socio-economic opportunities that strengthen and diversify livelihoods beyond one-off compensation (Mahamoud Abdi et al., 2024; Kurgat & Omwenga, 2016; Singh & Muhuri, 2026). The LRP should be positioned as one of the pillars in a broader policy package, which consistently links to the configuration of livelihood capital with institutional reforms, market support, and social protection at the macro level (Khanal et al., 2024; Ma et al., 2024).

4. Conclusions

Overall, the findings demonstrate that the LRP contributed to livelihood restoration, but its long-term effectiveness depends on continued community engagement and supportive institutional environments. The research limitations related to narrow variable coverage, potential memory bias, difficulty separating experiences during and after the program, and the absence of systematic measurement of meaningful participation and benefit distribution indicate important gaps that need to be addressed in future work. They point to the need for longitudinal mixed-methods studies that integrate indicators of community engagement, social justice, and long-term livelihood resilience to capture the dynamic effects of LRP and related policies on displaced households more fully over time. Thus, the main contribution of this research to the development of knowledge is the affirmation that the statistical significance of the livelihood restoration program does not automatically guarantee justice and sustainability without meaningful community engagement design and socio-environmental governance that is in favor of the affected residents, while the novelty of the research lies in the integration of quantitative analysis of livelihood assets, qualitative findings based on residents' experience, and theoretical reflection within the framework community involvement, social justice, and socio-environmental sustainability in the context of geothermal energy projects in Indonesia. Future research should develop multivariate models with additional variables, standardize measurement instruments aligned with SLF, and conduct comparative studies to test the generalizability of findings across project contexts.

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Author Contribution

Conceptualization, D.Y.S., and H.H.; Methodology, D.Y.S.; Formal analysis, D.Y.S. and I.K.; Investigation, D.Y.S.; Data curation, D.Y.S., and I.K.; Writing – original draft preparation, D.Y.S.; Writing – review and editing, H.H., and I.K.; Validation, H.H., and I.K.; Supervision,

H.H., and I.K.; Project administration, D.Y.S. All authors have read and approved the submitted version of the manuscript.

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Ethical Review Board Statement

The study was conducted in accordance with the Peraturan Rektor Universitas Indonesia Nomor 23 Tahun 2025 and approved by the Ethics Committee of School of Environmental Science (KET-117/UN2.F13.D1.KE1/PPM.00/2024).

Informed Consent Statement

Informed consent was obtained from all subjects involved in the study.

Data Availability Statement

The excel sheet of the data are available.

Conflicts of Interest

The authors declare no conflict of interest as the research was conducted with personal fund.

Declaration of Generative AI Use

During the preparation of this work, the authors used Gemini AI to assist in gaining a more complex understanding of the literature and help to structure and organize research results. After using this tool, the authors reviewed and edited the content as needed and took full responsibility for the content of the publication.

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Biographies of Authors

Dany Yuda Saputra, is a Senior Environmental and Social Consultant based in Indonesia. He is currently pursuing a Master of Science in Environmental Science at the School of Environmental Science, Universitas Indonesia, and previously completed a Bachelor's degree in Social Sciences (Criminology) at the University of Indonesia. His expertise includes social safeguards, environmental and social impact assessment, resettlement and livelihood restoration, and risk mitigation for infrastructure and renewable energy projects.

- Email: thesaputra2@gmail.com
- ORCID: N/A
- Web of Science ResearcherID: N/A
- Scopus Author ID: N/A
- Homepage: N/A

Herdis Herdiansyah, is a lecturer and researcher at the School of Environmental Science, Universitas Indonesia, and chairs its Social Environment/Community Engagement cluster. He holds advanced degrees in Environmental Science with earlier training in the humanities, and has been listed among the world's top 2% scientists in Stanford University's global ranking. His expertise covers environmental science, social environment, community empowerment, environmental economics, and academic writing, with extensive applied work on community engagement, participatory environmental governance, and sustainable development practice across diverse regions in Indonesia.

- Email: herdis@ui.ac.id
- ORCID: 0000-0002-9016-4062
- Web of Science ResearcherID: N/A
- Scopus Author ID: 57170905600
- Homepage: <https://scholar.ui.ac.id/en/persons/herdis-herdiansyah/>

Indra Kertati, is a public administration scholar based in Semarang, Indonesia, with long-standing academic and policy engagement at regional and national levels. She holds a doctoral degree (S3) in Public/State Administration and specializes in public administration, governance, gender, social policy, and poverty-related issues. Her work includes extensive publications on public service, bureaucratic reform, local development planning, gender and development, and women-headed households in Java and surrounding regions, often collaborating with local governments and research institutions.

- Email: indra-kertati@untagsmg.ac.id
- ORCID: 0000-0003-3223-9414
- Web of Science ResearcherID: N/A
- Scopus Author ID: 57226481270
- Homepage: <https://scholar.google.com/citations?user=KtpMHjAAAAAJ&hl=en>