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Integrating *Kearifan Lokal* (Local Wisdom) with Climate Adaptation Strategies: A Participatory Action Research on Enhancing Community Resilience and Achieving SDG 13 in Indonesia's Coastal Communities

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A B S T R A C T

Coastal communities in Indonesia face existential threats from climate change. Conventional top-down adaptation strategies often fail due to a disconnect from local socio-ecological realities, overlooking a critical resource: traditional ecological knowledge, or *kearifan lokal*. This study investigates a knowledge co-production model that synergizes *kearifan lokal* with modern climate science to build community resilience. We employed a 24-month, mixed-methods Participatory Action Research (PAR) design in three highly exposed coastal villages in North Java, Indonesia. Ethical protocols, including Free, Prior, and Informed Consent (FPIC), were foundational. Qualitative data were gathered from in-depth interviews (n=30), focus groups (n=12), and ethnographic observation. Quantitative data came from a pre-test/post-test household survey (n=450) measuring a validated, multi-dimensional Community Resilience Index (CRI). Interventions were co-designed, blending traditional practices like the *pranata mangsa* (ethno-astronomical calendar) and the *wana tirta* (mangrove philosophy) with scientific recommendations. A linear mixed-effects model was used to analyze changes in CRI scores. The co-designed strategies led to a statistically significant increase in the mean CRI from a baseline of 2.8 (SD=0.65) to 4.2 (SD=0.48) post-intervention ($p<0.001$). Significant improvements were observed across all resilience dimensions, most notably in Economic Capital (+59.1%) and Adaptive Capacity & Governance (+51.7%). The revitalization of practices such as the restoration of 50 hectares of mangroves, guided by both *wana tirta* principles and scientific species selection, enhanced coastal protection and local livelihoods. In conclusion, the co-production of knowledge, facilitated through a PAR framework, is a potent mechanism for building effective, culturally embedded, and sustainable climate resilience. This model empowers communities as active agents in their adaptation journey and offers a scalable, evidence-based pathway for achieving SDG 13 in Indonesia and other climate-vulnerable nations.

1. Introduction

The Indonesian archipelago, with its vast coastline of over 99,000 kilometers and more than 17,000 islands, is situated at the epicenter of the global climate crisis. Its coastal zones, which host a majority of the nation's population and are hubs of immense economic activity, confront an escalating suite of climate-induced hazards, including sea-level rise, saltwater intrusion, coastal erosion, and an increased frequency of extreme weather events. Projections forewarn a dire future; by 2050, large swaths of major urban centers like Jakarta could be inundated, threatening to displace millions and trigger unprecedented economic disruption. These climate impacts are dangerously amplified by non-climatic stressors such as land subsidence, rapid and often unplanned urbanization, and the systemic degradation of natural coastal defenses like mangrove forests and coral reefs. In this context, strengthening the climate resilience of coastal communities is not merely an environmental objective but a fundamental developmental imperative for ensuring national stability and achieving sustainable progress.[1-3]

Historically, responses to these threats, both nationally and internationally, have been dominated by large-scale, capital-intensive, and top-down adaptation paradigms. These approaches, typically centered on engineering solutions like sea walls and dikes, are often designed with limited input from the communities they aim to protect. While well-intentioned, such externally driven strategies frequently suffer from a critical flaw: a profound disconnect from the local socio-cultural, economic, and ecological context. This can lead to maladaptation, where interventions inadvertently exacerbate vulnerability by creating unforeseen negative consequences, disrupting local livelihoods, or damaging ecosystems. Moreover, without genuine community buy-in, these projects often fall into disrepair, becoming unsustainable once external funding and technical oversight are withdrawn. This highlights a systemic gap in conventional adaptation planning: the persistent failure to recognize, respect, and integrate the sophisticated knowledge systems that are already embedded within communities.[4,5]

For millennia, indigenous and local communities across Indonesia have cultivated and transmitted a rich body of knowledge and practice to navigate and thrive within their dynamic environments. This knowledge, known in Indonesia as kearifan lokal (local wisdom), represents a holistic and deeply contextualized understanding of local ecosystems, weather phenomena, and principles of sustainable resource management. It is not a static relic of the past but a living, adaptive system of knowledge, continuously refined through observation, experience, and intergenerational transmission. This wisdom manifests in diverse forms, from ethno-astronomical calendars like the Javanese pranata mangsa, which guides maritime and agricultural activities based on nuanced ecological indicators, to community-enforced ethics for mangrove conservation and sustainable fishing techniques that ensure long-term ecosystem health.[6]

Despite its proven value, kearifan lokal is increasingly imperiled by the forces of rapid modernization, cultural homogenization, and the marginalization of local voices in environmental governance and policy-making. The global climate discourse, however, is beginning to recognize the critical need to bridge the divide between scientific and indigenous knowledge systems. This principle is enshrined within the Paris Agreement and underscored in reports by the Intergovernmental Panel on Climate Change (IPCC), which call for adaptation strategies that are inclusive and built upon the best available science and relevant local and indigenous knowledge. The process of knowledge co-production—the collaborative weaving together of these different ways of knowing—offers a pathway to develop adaptation strategies that are not only scientifically sound but also culturally resonant, locally legitimate, and economically sustainable. Crucially, this process empowers local communities, transforming them from passive recipients of aid into active agents and innovators in their own resilience-building journey, fostering a deep sense of ownership that is essential for long-term success.[7,8]

Although this recognition is growing, a significant gap persists in the empirical literature. There is a scarcity of research that moves beyond simply documenting traditional practices to systematically implementing and rigorously evaluating the processes and outcomes of integrating kearifan lokal with scientific adaptation planning, particularly within the acutely vulnerable coastal context of Indonesia.

Therefore, the aim of this study is to design, implement, and evaluate an integrated climate adaptation model that synergizes kearifan lokal with scientific knowledge through a process of knowledge co-production to enhance the resilience of coastal communities in Indonesia. The novelty of this research lies in its use of a Participatory Action Research (PAR) framework, which moves beyond extractive research methodologies to actively co-create, test, and refine tangible adaptation solutions with the communities themselves. By quantitatively assessing the impact of this integrated approach on a multi-dimensional Community Resilience Index (CRI) and linking these outcomes directly to the objectives of Sustainable Development Goal 13 (Climate Action), this study provides a scalable, evidence-based model for

2. Methods

Recognizing the ethical complexities of research involving indigenous knowledge, this study was grounded in a commitment to decolonial research principles. The research protocol was approved by Enigma Institutional Review Board, but we went further by engaging in a comprehensive community-level consent process. Free, Prior, and Informed Consent (FPIC) was secured through a series of public meetings in each village, where the research aims, methods, potential risks, and benefits were transparently discussed in the local language. A formal Memorandum of Understanding was co-developed and signed by village leaders and the research team.

To address knowledge governance, a community knowledge protocol was established, stipulating that all documented kearifan lokal remains the collective intellectual property of the communities. Data is stored in a community-managed archive, and any use of this data outside of this project requires explicit community permission. As institute-based researchers, we engaged in continuous reflexivity, acknowledging our position of relative power. We employed trained local facilitators, conducted all community engagements in Bahasa Indonesia or Javanese, and structured the research process to prioritize community voices and decision-making authority, positioning ourselves as facilitators rather than external experts.

This study employed a mixed-methods Participatory Action Research (PAR) design, an iterative and collaborative methodology aimed at producing practical knowledge to drive transformative social change. The research was conducted over a 24-month period (January 2023 – December 2024) in three coastal villages in the Pekalongan Regency, North Java, Indonesia. These villages—referred to as Village A, Village B, and Village C to protect anonymity—were purposefully selected based on several criteria: (1) High exposure to climate hazards: Documented history of recurrent tidal flooding (rob), significant coastal erosion, and high dependency on climate-sensitive livelihoods; (2) Presence of active kearifan lokal: Preliminary scoping confirmed the persistence of traditional ecological knowledge systems and robust social structures; (3) Community willingness to participate: Village leaders and community groups expressed strong interest and commitment to engaging in a long-term collaborative project. The purposive selection of these sites means that while the findings provide deep contextual insights, their generalizability to all coastal communities must be considered with caution. The region of North Java itself represents a critical "laboratory" for adaptation research due to its dense population and severe land subsidence, which compounds the effects of global sea-level rise.

The PAR process was structured around four iterative and overlapping phases: (1) Phase 1: Diagnosis and Collaborative Planning (Months 1-6). This phase focused on building trust and co-developing a shared understanding of local climate vulnerabilities. A core research team was formed, comprising university researchers, officials from the Regional Disaster Management Agency (BPBD), and 12 elected community representatives from each village.

To ensure diverse representation and mitigate elite capture, the election process was stratified to guarantee the inclusion of women, youth, elders, and members of different livelihood groups (fishers, farmers, traders). Activities included transect walks, participatory mapping of risks and resources, and workshops to develop historical timelines and seasonal calendars; (2) Phase 2: Co-design of Integrated Strategies (Months 7-12). This phase was dedicated to knowledge co-production. Data from Phase 1, including detailed documentation of kearifan lokal practices, were brought into dialogue with scientific climate projections and adaptation options. In a series of workshops, we explored potential conflicts and synergies between knowledge systems. Disagreements were resolved through a consensus-based deliberation process, prioritizing solutions that were perceived by the community as both effective and culturally appropriate. For instance, a debate between planting faster-growing but non-native mangrove species (scientific recommendation) and culturally significant but slower-growing native species (traditional preference) was resolved by piloting both in different zones and letting the community evaluate the results; (3) Phase 3: Implementation and Monitoring (Months 13-20). The co-designed strategies were implemented by the community, with the research team and local government providing technical and logistical support. A participatory monitoring and evaluation (PM&E) system was established, enabling community members to track key indicators (such as mangrove seedling survival, flood levels, and fish catch), thus fostering adaptive management; (4) Phase 4: Evaluation and Reflection (Months 21-24). The final phase evaluated the outcomes of the interventions and reflected on the PAR process. This involved the post-intervention data collection and community workshops to discuss successes, challenges, and pathways for sustaining the initiatives.

To quantitatively measure resilience, we developed a composite Community Resilience Index (CRI). The index was adapted from established theoretical frameworks, primarily the place-based model proposed by Cutter et al., which conceptualizes resilience across multiple interconnected dimensions. The development and validation process was multi-staged: (1) Framework Adaptation: Based on a review of literature and existing resilience indices, we identified five core dimensions relevant to the Indonesian coastal context: Social Capital, Economic Capital, Physical Infrastructure & Services, Adaptive Capacity & Governance, and Ecosystem Integrity; (2) Indicator Co-generation: A long list of potential indicators for each dimension was developed. Through participatory workshops, community members selected, refined, and added indicators that they deemed most relevant to their local experience of resilience, ensuring high content validity; (3) Pilot Testing: The resulting survey instrument, containing 15 indicators (Table 1), was pilot-tested with 30 households in a neighboring village to check for clarity, cultural appropriateness, and length. Feedback was used to finalize the questionnaire; (4) Reliability: Internal consistency of the final CRI scale was assessed using data from the baseline survey. The calculated Cronbach's alpha was 0.88, indicating high reliability.

The overall CRI for each household was calculated as the unweighted average of the scores across all 15 indicators. The use of an unweighted average was a deliberate choice made in consultation with the community research team to ensure the index was transparent, easily understandable, and straightforward to calculate at the local level. We acknowledge this simplification as a limitation and discuss its implications.

Table 1. Community Resilience Index (CRI)

Dimensions and Indicators

DIMENSION	INDICATORS
Social Capital	• Level of trust in neighbors and community leaders. • Participation rate in community groups/activities (*gotong royong*). • Strength of social support networks during floods.
Economic Capital	• Livelihood diversification (number of income sources). • Household savings and access to credit. • Access to markets for selling products.
Physical Infrastructure & Services	• Quality of housing and protective infrastructure, such as embankments. • Access to and effectiveness of early warning systems. • Access to clean water, sanitation, and health services.
Adaptive Capacity & Governance	• Access to climate information and knowledge. • Presence and functionality of local adaptation plans. • Community participation in village decision-making.
Ecosystem Integrity	• Perceived health and coverage of mangrove ecosystems. • Perceived coastal water quality and fish stocks. • Adoption of sustainable resource management practices.

A mixed-methods approach was used for data collection at baseline (Month 6) and post-intervention (Month 24). Semi-structured in-depth interviews (IDIs) were conducted with 30 key informants (elders, fishing group heads, women leaders, local officials) to explore perceptions of climate change and the role of kearifan lokal. Twelve focus group discussions (FGDs) were held with distinct community groups to gather collective perspectives. Continuous ethnographic observation was maintained throughout the project, with detailed field notes documenting community meetings and daily life. A structured household survey was administered to a randomly selected sample of 450 households (150 per village), representing approximately 30% of the total households. The same households were surveyed at both time points to allow for paired analysis.

Transcripts and field notes were analyzed using thematic analysis in NVivo 12. The analysis used a hybrid approach of deductive codes based on the CRI framework and inductive codes emerging from the data. To ensure credibility, findings were triangulated across different data sources (IDIs, FGDs, observation) and subjected to member checking, where preliminary interpretations were presented back to the community for feedback and validation. Quantitative data were analyzed using R (version 4.2.2). To account for the nested structure of the data (households within villages), a linear mixed-effects model (LMM) was used to assess the change in CRI scores from pre- to post-intervention. 'Time' (pre/post) was included as a fixed effect, with random intercepts for 'Household' and 'Village' to control for non-independence of observations. A second LMM was constructed to explore the predictors of resilience change. The post-intervention CRI score was used as the outcome variable, with the baseline CRI score as a covariate, along with key demographic variables (such as household head gender, education level, and livelihood diversification) as fixed effects. A p-value of < 0.05 was considered statistically significant for all analyses.

3. Results and discussion

The three study villages had a combined population of 5,230 individuals (1,510 households). The survey sample (n=450) was demographically representative. The average household size was 3.5 members, with 78% of households male-headed. The primary livelihood was fisheries (55%), followed by aquaculture (22%) and small-scale trade (13%). Educational attainment was modest; 45% of household heads had only completed primary school.

The baseline assessment revealed a state of high vulnerability. The mean CRI score for the combined communities was 2.8 (SD=0.65) on a 5-point scale. As shown in Figure 1, the lowest scores were in Economic Capital (Mean=2.2) and Physical Infrastructure (Mean=2.4), reflecting a heavy reliance on single, climate-sensitive income sources and inadequate protection against tidal flooding. The highest baseline score was in Social Capital (Mean=3.4), indicating strong pre-existing social networks that provided a crucial foundation for the PAR process.

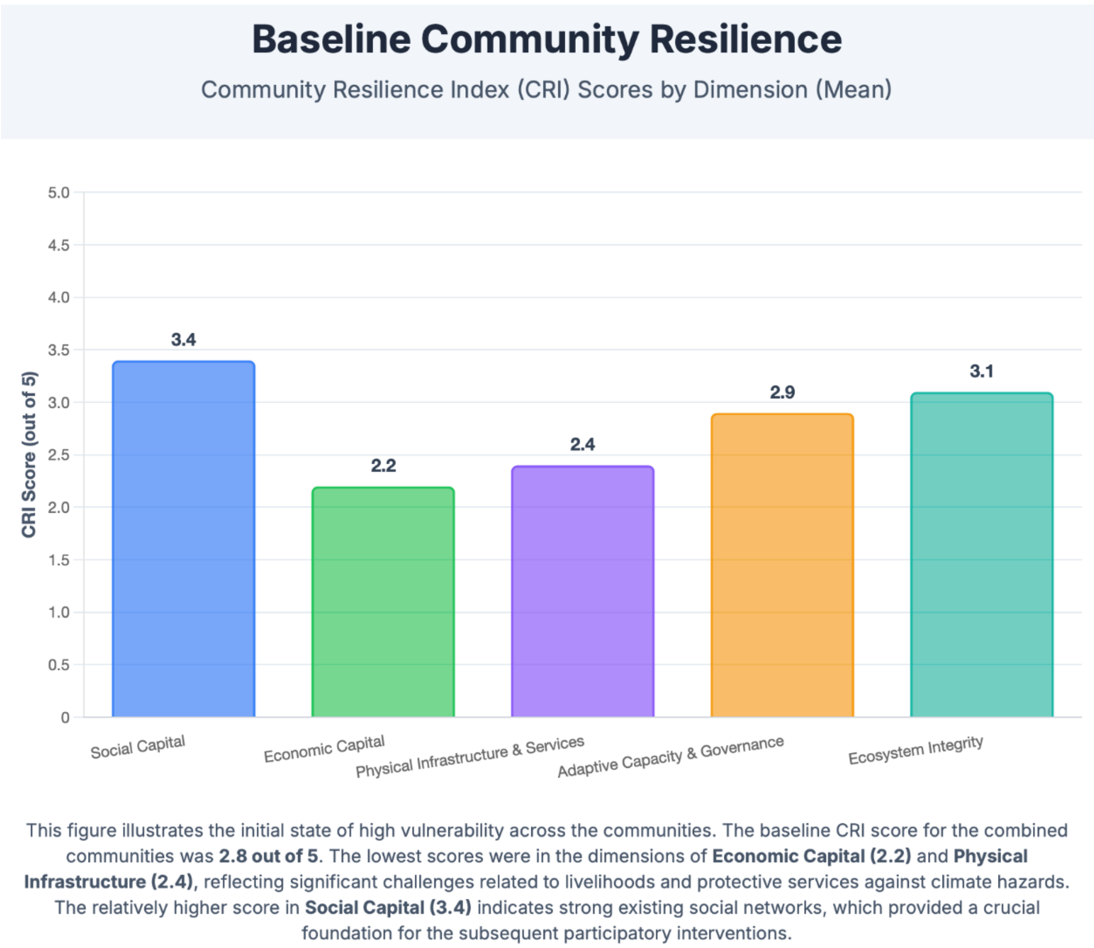

Figure 1. Baseline Community Resilience Index (CRI) Scores by Dimension (Mean ± 95% CI)

The qualitative analysis unearthed a rich repository of kearifan lokal relevant to climate adaptation. Three practices were prioritized by the community for revitalization and integration: (1) Pranata Mangsa (The Traditional Calendar): This was revealed to be more than a simple predictive calendar. It is a complex ethno-astronomical and ecological knowledge system that connects the position of star constellations (like

Pleiades), wind patterns, and the behavior of marine fauna to seasonal changes, tidal patterns, and storm risks. One elder explained, "The sea speaks, and the stars translate. When the Waluku (Orion's Belt) star is low in the west at dawn, the sea is calm, inviting us. But this is not just about fishing; it is about respecting the rhythm given to us by the ancestors." This knowledge, intrinsically linked to a worldview of cosmic balance, was being eroded among younger generations who relied more on smartphone weather apps; (2) Wana Tirta (Forest and Water Philosophy): This Javanese philosophy articulates the symbiotic, almost sacred, relationship between coastal mangrove forests (wana) and the ocean (tirta). It underpinned traditional zoning of coastal areas, with specific zones designated as sacred and off-limits to harvesting, which functioned as fish nurseries. Community members recalled ancestral rules against cutting Avicennia species, believed to be inhabited by protective spirits that safeguard the village from the sea's wrath. This philosophy frames mangroves not as a mere resource, but as a living entity integral to the community's spiritual and physical well-being; (3) Gotong Royong (Mutual Cooperation): This deep-seated cultural value of collective action and reciprocity was the engine of community life. It manifested in practices like the regular collective clearing of waterways to mitigate flooding and the communal repair of fishing boats and infrastructure after storms. It represents the social technology that enables community-based resource management and disaster response. The PAR process facilitated the blending of these traditional practices with scientific knowledge, resulting in a portfolio of four main interventions (summarized in figure 2).

Figure 2. Integrated climate adaptation strategies

The post-intervention assessment revealed a substantial and statistically significant improvement in overall community resilience. The LMM analysis showed that the mean CRI score increased by 1.4 points (95% CI: 1.25, 1.55) from a baseline of 2.8 to a post-intervention score of 4.2, an effect that was highly significant ($p<0.001$). Significant improvements were recorded across all five dimensions of resilience (Figure 3). The most dramatic gains were observed in Economic Capital (+59.1%) and Physical Infrastructure & Services (+58.3%), driven by the success of the livelihood diversification programs and the enhanced coastal protection afforded by the rehabilitated mangroves and the new EWS. The increase in Adaptive Capacity & Governance (+51.7%) reflects the success of the PAR process in strengthening local institutions and empowering the community in decision-making. While all villages showed significant improvement, inter-village analysis revealed slight variations, with Village C showing the largest gains in Ecosystem Integrity, likely due to its larger mangrove rehabilitation area (Table 2).

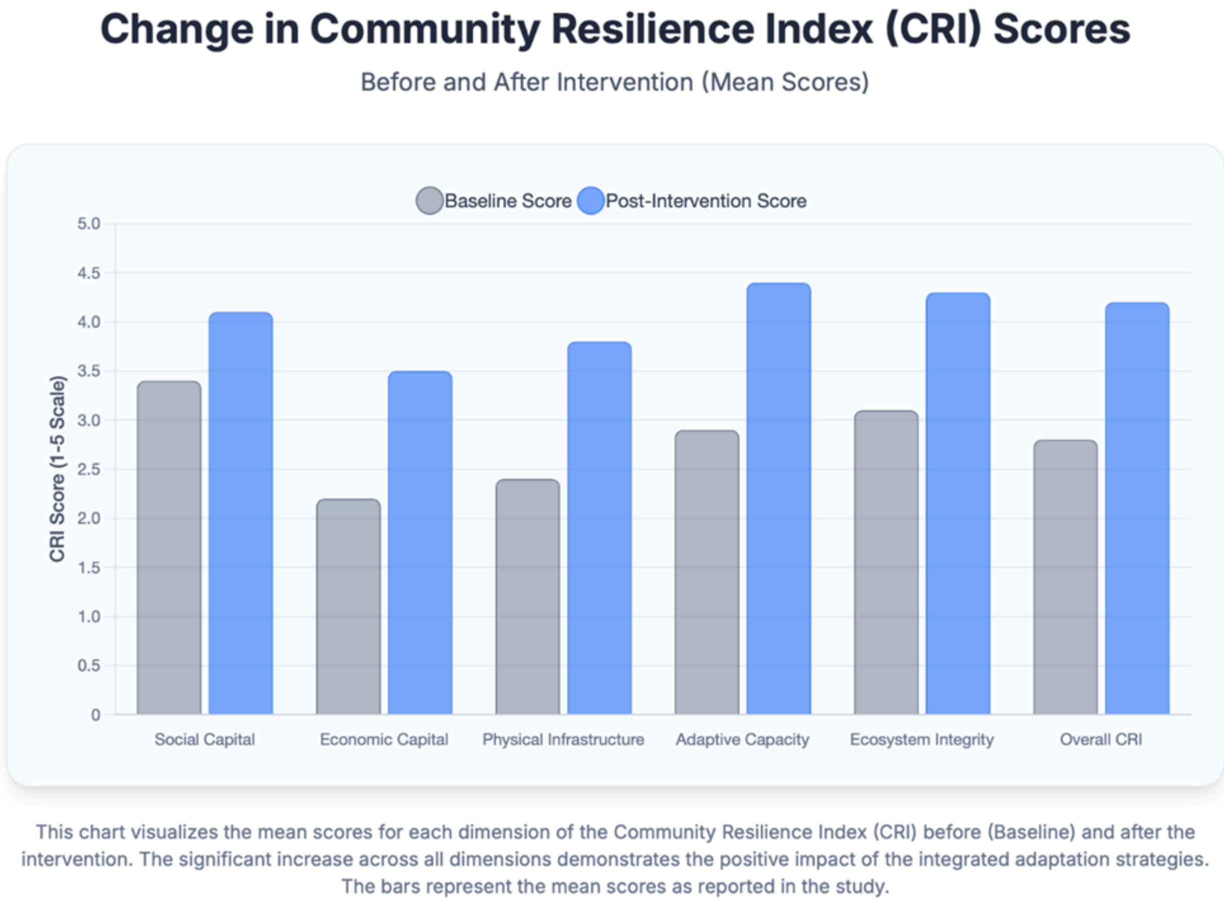

Figure 3. Change in Community Resilience Index (CRI) Scores Before and After Intervention (Mean ± 95% CI)

Table 2. Community Resilience Index (CRI) Scores by Village

Before and After Intervention

VILLAGE	BASELINE MEAN (SD)	POST-INTERVENTION MEAN (SD)	MEAN DIFFERENCE (95% CI)
Village A	2.9 (0.62)	4.1 (0.45)	+1.2 (1.01, 1.39)
Village B	2.7 (0.68)	4.2 (0.49)	+1.5 (1.30, 1.70)
Village C	2.8 (0.65)	4.3 (0.50)	+1.5 (1.32, 1.68)
Overall	**2.8 (0.65)**	**4.2 (0.48)**	**+1.4 (1.25, 1.55)**

This table presents a disaggregated view of the Community Resilience Index (CRI) scores for each participating village, comparing the baseline data with the post-intervention outcomes. The "Overall" row provides a summary of the aggregate impact across all three communities.

The secondary regression analysis identified several factors associated with greater improvements in CRI scores (figure 4). Livelihood diversification at baseline was the strongest significant predictor (β= 0.25, p<0.01), indicating that households with more income sources were better able to leverage the new opportunities created by the project. Furthermore, households that reported higher participation in community activities (gotong royong) at baseline also showed significantly greater increases in their CRI scores (β= 0.18, p<0.05), highlighting the importance of social capital as a foundation for adaptive capacity. No significant difference was found based on the gender of the household head.

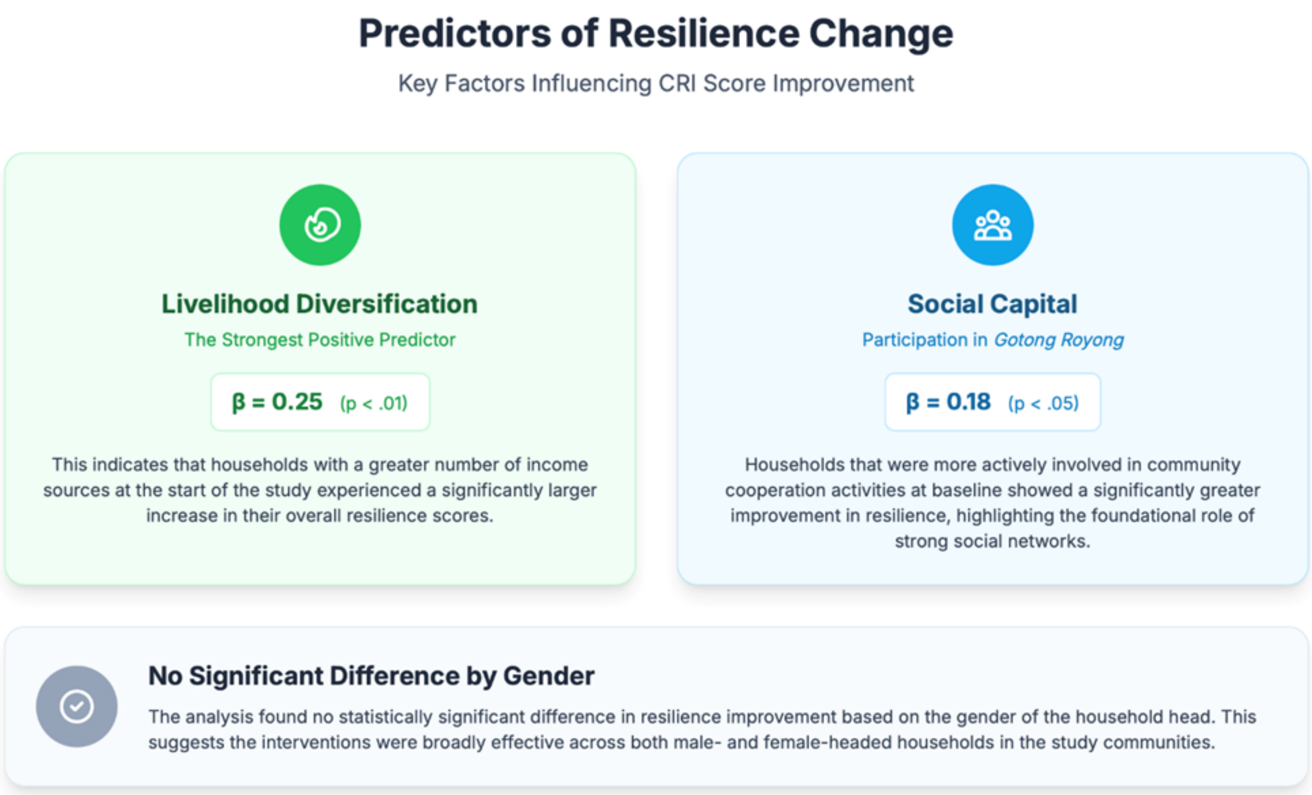

Figure 4. Predictors of resilience change

Qualitative findings corroborated the quantitative results and provided deeper insight into the community's experience. A fisher from Village C stated, "*The new mangrove forest is our green wall. The waves during the last storm were much calmer. And now, the crabs and shrimp are coming back, giving my wife extra income.*"

The process itself was seen as transformative. A youth leader involved in the EWS team remarked, "*Before, we saw the elders' stories about the stars as just stories. Now, we see it is science, just like the science from the government. When we combine them, the warning is stronger, and people listen.*"

The process was not without challenges. An initial unintended consequence of the micro-enterprise program was heightened competition between women's groups. However, this was resolved through a series of community-led mediations. As the head of a women's group in Village A noted, "*At first, we argued. But the process taught us to talk and plan together. Before, we were just waiting for help. Now, we are in control. We know our own strength.*"

The findings of this study provide compelling, multi-faceted evidence that the co-production of knowledge, synergizing *kearifan lokal* with modern climate science through a PAR framework, is a profoundly effective pathway for enhancing the resilience of vulnerable coastal communities. The 50% increase in the CRI represents not just a statistical improvement but tangible, lived enhancements in the social, economic, ecological, and governance fabric of these communities.

The core success of the intervention lies in its practical demonstration of how local and scientific knowledge systems can be synergistically woven together to create adaptation strategies that are more robust, legitimate, and effective than either system could produce in isolation. This study moves beyond simply documenting traditional knowledge to illuminating the mechanisms of its integration. For instance, the community EWS became effective precisely because it bridged epistemologies. The *pranata mangsa* provided hyper-local, nuanced indicators of impending weather that broad-scale meteorological models often miss. When combined with BMKG's forecasts, it created an EWS that was not only more accurate but, crucially, more trusted. Community members were more likely to act upon warnings that incorporated familiar, culturally-grounded indicators. This aligns with the "multiple evidence base" approach, which argues that integrating diverse knowledge systems enhances the salience and legitimacy of environmental action.[8-11]

Similarly, the hybrid mangrove rehabilitation strategy succeeded where many top-down reforestation projects fail. The scientific input on salt-tolerant species improved the biological resilience of the new ecosystem, while the community's wana tirta-guided knowledge of optimal planting locations ensured higher seedling survival rates. This co-production process avoids the pitfalls of ecologically inappropriate interventions and simultaneously revitalizes cultural practices, thereby strengthening the entire social-ecological system in a feedback loop of resilience.[12,13]

While the outcomes were positive, the process of knowledge co-production was not seamless. It required navigating complex "seams" between different worldviews, values, and power dynamics. The PAR framework provided a crucial space for this negotiation. As facilitators, our role was to ensure that the process did not instrumentalize kearifan lokal as a mere data input into a pre-determined scientific framework. This meant ceding a significant degree of control and being open to outcomes we did not anticipate. For example, during the planning for the EWS, our initial model prioritized the technical SMS system. However, the community insisted that the system's authority must reside with the "climate champions" who interpret both knowledge streams, with the SMS serving as a tool, not the primary source. This re-centering of local agency was critical for the system's legitimacy. By consciously navigating these power dynamics and prioritizing community decision-making, the process avoided becoming extractive and instead fostered genuine partnership.[14-17]

The PAR framework was not merely a research methodology; it was a resilience-building intervention in its own right. By positioning community members as co-researchers, the process fundamentally shifted power dynamics and cultivated a deep sense of local ownership. This is a stark contrast to conventional consultation, where community input is often solicited but does not influence final decisions. The iterative cycles of planning, acting, and reflecting enabled adaptive management and fostered collective social learning.[18,19] This empowerment is a core component of adaptive capacity. The 51.7% increase in the Adaptive Capacity & Governance dimension of the CRI is a quantitative testament to this process. The ultimate success was the formal adoption of the community-devised adaptation plans into village law and budgets. This marks a critical transition from a short-term, project-based intervention to a sustained, institutionalized process of adaptive governance, a key step towards long-term resilience that is not dependent on external aid.

Despite the robust findings, this study has several limitations. First, the findings are based on three villages in a specific regency, and the use of purposive sampling means that the results may not be generalizable to all coastal communities in Indonesia, which are highly diverse. Second, the PAR design is susceptible to potential biases; the Hawthorne effect (participants altering behavior because they are being observed) and social desirability bias in survey responses may have influenced the outcomes. We sought to mitigate this through long-term ethnographic engagement to build trust and normalize our presence. Third, the CRI, while validated for this context, has limitations. Its reliance on some self-reported indicators makes it subject to perceptual changes, and the unweighted calculation method simplifies the complex interactions between different resilience dimensions. Future research could explore participatory weighting techniques to develop a more nuanced index. Finally, while the study institutionalized the adaptation plans, the long-term sustainability of these initiatives in the face of political changes or new economic pressures remains a critical question that warrants longitudinal follow-up research.

4. Conclusion

Climate change poses an urgent and complex challenge to Indonesia's coastal communities, threatening their livelihoods, cultures, and existence. This study demonstrates that a powerful pathway to enhanced resilience lies within the communities themselves, embedded in their rich traditions of kearifan lokal. By employing a Participatory Action Research approach, we have shown that the co-production of local and scientific knowledge is a profoundly effective mechanism for building robust, multi-dimensional community resilience. The co-designed strategies led to a statistically significant 50% increase in the overall Community Resilience Index, with tangible gains across social, economic, infrastructural, governance, and ecological dimensions. The key to this success was a process that moved beyond mere integration to genuine knowledge co-production, which empowered local actors, navigated power dynamics, and ensured that adaptation strategies were ecologically sound, socially acceptable, and culturally embedded. This research provides a validated, scalable model for moving beyond top-down adaptation planning. It offers a clear directive for policymakers in Indonesia and other climate-vulnerable nations: to achieve SDG 13 and build a truly climate-resilient future, we must respect the knowledge of local communities and invest in the genuine partnerships that place them at the heart of the solution.

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