

Assessing Climate Village Program Sustainability Using Multidimensional Scaling

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Abstract

Climate change poses severe threats to rural socio ecological systems, necessitating decentralized, community based climate action. While Indonesia's Climate Village Program (ProKlim) serves as a primary local adaptation and mitigation policy, conventional evaluative methods rely heavily on descriptive scorecards, obscuring multidimensional dynamics and the systemic role of stakeholder partnerships. This study addresses these gaps by implementing an integrated evaluation framework that combines Sustainability Transition Theory, Collaborative Governance, and Multidimensional Scaling (MDS) via the modified Rapfish technique. We assessed 20 validated attributes across institutional, social, economic, and environmental dimensions using perceptual data from 30 systematically selected stakeholders involved in the Pentahelix partnership model in Wonocoyo Village, Trenggalek Regency. The multidimensional sustainability index scored 58.36 (moderately sustainable). At the dimensional level, institutional governance achieved the highest score (77.23, highly sustainable), followed by environmental quality (67.65) and social dynamics (52.14). Conversely, the economic dimension recorded a less sustainable score (36.42), reflecting systemic barriers in converting ecological actions into tangible financial welfare. Leverage analysis highlighted program monitoring and evaluation, community mutual cooperation (*gotong royong*), local economic benefits, and the continuity of environmental initiatives as critical anchor attributes. Goodness of fit metrics (Stress = 0.15 - 0.16; $R^2 = 0.90 - 0.93$) and Monte Carlo simulations confirmed model stability. These findings establish that high institutional capability alone cannot guarantee localized socio ecological transformations without explicit economic feedback loops, offering scalable governance insights for national decentralized climate targets.

Keywords

Climate Village Program (ProKlim), Sustainability, Pentahelix Collaboration, Multidimensional Scaling, Climate Change

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1. INTRODUCTION

Climate change has become one of the most pressing global challenges today, threatening socio-ecological systems through rising temperatures, extreme weather events, loss of biodiversity, and ecosystem degradation. According to the Intergovernmental Panel on Climate Change (IPCC), global temperatures have risen by approximately 1.1°C above pre-industrial levels, which intensifies climate-related risks and threatens food security, environmental sustainability, and human well-being (Calvin et al., 2023). Developing countries like Indonesia are highly vulnerable to these impacts due to limited adaptive capacity and high dependency of local communities on natural resources. As part of its commitment to the Paris Agreement, Indonesia has set an ambitious

target to reduce greenhouse gas (GHG) emissions by 31.89% through its own efforts and up to 43.20% with international support by 2030 (KLHK, 2022). Achieving this target requires not only national policy interventions but also the active participation of local governments, communities, and decentralized stakeholders in real climate mitigation and adaptation initiatives at the grassroots level.

The urgency of decentralized climate action is prominent in Trenggalek Regency, East Java, Indonesia. Although more than 50% of the regency's area is covered by forest land, the Regional Development Planning Agency (Bappeda) of Trenggalek reported an increasing trend in regional GHG emissions during the 2021–2045 period (Bappeda Trenggalek, 2025). This emission trend is closely associated with

intensive natural resource utilization activities, including timber harvesting, which significantly reduces carbon sequestration capacity in the region. This paradoxical condition presents a major challenge to the regency's strategic vision of achieving Net Zero Carbon by 2045. Therefore, effective climate governance mechanisms capable of fostering cross-sectoral stakeholder participation and mobilizing long-term collective action at the village level are urgently required.

Conceptually, managing such complex environmental challenges requires comprehensive climate governance that emphasizes the involvement of multiple actors operating across various levels. Effective climate governance demands collaborative arrangements between government, community, businesses, academia, and media, collectively known as the pentahelix model, to mobilize resources, integrate diverse knowledge systems, and build institutional capacity (Hölscher et al., 2019). Within this framework, collaborative governance provides a formal institutional platform for these stakeholders to structure and align their contributions, minimize program fragmentation, and enhance resource efficiency (Zhao et al., 2024). This multi-stakeholder synergy transforms environmental management from top-down mandates into community-based adaptation, empowering rural communities to independently identify climate risks and sustain daily adaptive responses. However, the effectiveness of these decentralized actions is often tested by institutional vulnerabilities and limited local capacities. Climate governance at the village level is highly susceptible to institutional fragmentation and frequently over-relies on specific leadership figures; therefore, communal social practices and local wisdom must be formally integrated into governance structures to prevent program stagnation when external support concludes (Patrianti et al., 2026; Surtiari et al., 2024).

As an integrated response to these challenges, the Government of Indonesia launched the Climate Village Program (Program Kampung Iklim or ProKlim) as a national movement for community-based adaptation and mitigation. ProKlim aims to strengthen local resilience while promoting sustainable GHG emission reductions at the village or neighborhood level by integrating actions such as water resource conservation, regreening, waste management, and local food security (Aulia, 2025; Riani et al., 2024). Theoretically, this transformation process can be explained through Sustainability Transition Theory. This theory outlines how socio-ecological systems evolve toward sustainable states through institutional change, social innovation, and collective behavioral transformation (Hölscher and Frantzeskaki, 2021). In this context, ProKlim serves as a localized sustainability transition initiative where the pentahelix network acts as the primary vehicle driving long-term socio-ecological restructuring. Despite these structural goals, the long-term success of such community-based climate initiatives is frequently hindered by economic constraints. Various grassroots environmental programs often face systemic challenges where ecological actions have not yet translated into tangible eco-

nomic incentives or provided sustainable livelihood benefits without adequate financial support mechanisms (Gatto and Sadik-Zada, 2024; Sunderlin et al., 2024).

Although the literature on ProKlim in Indonesia continues to expand, most previous studies have been heavily dominated by qualitative descriptive approaches. For instance, Riani et al. (2024) examined ProKlim implementation from the perspective of general stakeholder participation levels, while Fitriani et al. (2024) focused primarily on the physical involvement of communities in localized mitigation actions. While these qualitative studies provide valuable insights into early implementation processes, they lack the ability to provide a precise quantitative assessment of the program's comprehensive sustainability status. Consequently, the relative and simultaneous contributions of institutional, social, economic, and environmental dimensions, as well as the sensitive attributes determining long-term continuity, remain empirically unidentified. To address these limitations, the application of quantitative methods such as Multidimensional Scaling (MDS) via a modified Rapid Appraisal for Fisheries (Rapfish) approach becomes highly relevant, as it can generate a comprehensive sustainability index while identifying key leverage factors for strategic policy intervention (Ismail et al., 2025; Suprijanto et al., 2025).

This study contributes a new scientific perspective by implementing an integrated evaluation framework that combines Sustainability Transition Theory, Collaborative Governance, and MDS to assess the sustainability performance of ProKlim within a pentahelix governance context in Wonocoyo Village, Trenggalek Regency. The pentahelix framework serves as a conceptual lens for understanding stakeholder involvement, while the MDS analysis evaluates sustainability performance across institutional, social, economic, and environmental dimensions. Therefore, the study does not directly measure the effectiveness of pentahelix collaboration. It is important to note that this study does not formulate formal hypotheses aimed at testing causal relationships (such as SEM or regression methods); instead, the MDS-Rapfish analysis is utilized fundamentally as an exploratory and diagnostic tool designed to map multidimensional ordination positions and isolate sensitive leverage factors from actual field dynamics. Ultimately, this study aims to evaluate the multidimensional sustainability status of ProKlim in Wonocoyo Village and identify the critical anchor attributes required to offer scalable governance insights for national decentralized climate targets.

2. EXPERIMENTAL SECTION

2.1 Materials

Field data collection was carried out from April to May 2026 in Wonocoyo Village, located within the Panggul District of Trenggalek Regency, East Java Province, Indonesia. Geographically, Wonocoyo occupies a coastal valley landscape positioned between the astronomical coordinates of 7°21'–7°31' South Latitude and 110°10'–111°40' East Longitude.

The village is characterized by diverse socio-ecological systems, including mangrove networks, agricultural lowlands, and community forests, making it highly sensitive to maritime climate anomalies and land degradation. Structurally, the selection of this location was done purposively. Wonocoyo Village serves as an ideal proxy for rural tropical climate adaptation modeling due to its established track record as an award-winning community evaluated for its consistent, long-term implementation of ProKlim through integrated pentahelix collaboration networks at the local level.

2.2 Methods

To support the multidimensional sustainability assessment, research respondents were selected using a non-probability quota sampling technique. A total of 30 key stakeholders were involved in this study, distributed proportionally across four main hamlets that serve as the active implementation centers for ProKlim activities in Wonocoyo Village. The selection criteria were strictly based on the respondents' direct involvement, institutional capacity, and representation within the local pentahelix governance structure, which encompasses the village government, community leaders, farmer and environmental groups, local entrepreneurs, and climate-driving cadres. In the context of a modified Rapfish-based Multidimensional Scaling (MDS) analysis, a sample size of 30 respondents is deemed methodologically adequate and operationally robust. This approach prioritizes high-quality data derived from expert judgments and well-informed key stakeholders who possess deep contextual competence over large-scale, generalized sample sizes.

This study employed a quantitative research design utilizing Multidimensional Scaling (MDS) through a modified Rapid Appraisal for Fisheries (Rapfish) algorithm, specifically adapted to a community-based climate governance context. While alternative composite indices or multivariate methods such as Structural Equation Modeling (SEM) or Principal Component Analysis (PCA) require extensive sample sizes and strict multicollinearity checks, and Analytical Hierarchy Process (AHP) relies heavily on subjective pairwise constraints, MDS operates effectively on specialized, high-quality stakeholder perceptual datasets. The MDS algorithm maps proximity coordinates in a low-dimensional space to minimize structural stress and maximize goodness-of-fit metrics. To ensure analytical transparency, the 20 sustainability attributes evaluated in this study, encompassing institutional, social, economic, and environmental dimensions along with their respective operational indicators and exact multi-point ordinal scoring criteria, are comprehensively detailed in Table 1.

The selection and operationalization of the 20 sustainability attributes were conducted through a systematic literature review and stakeholder-based validation process. Initially, potential attributes were identified from previous studies on sustainability assessment, community-based environmental management, climate adaptation programs, and ProKlim

implementation (Brontowiyono et al., 2022; Fitriani et al., 2024; Riani et al., 2024; Wicaksono et al., 2023). The preliminary attribute list was subsequently reviewed through expert judgment involving academics in environmental management, local government officers responsible for ProKlim implementation, and community representatives actively engaged in climate-related activities. This consultation process was undertaken to ensure the relevance, contextual suitability, and practical applicability of the selected attributes within the socio-ecological conditions of Wonocoyo Village. Following the validation process, the attributes were grouped into four sustainability dimensions: institutional, social, economic, and environmental. Each attribute was then operationalized into measurable indicators and assessed using a four-point ordinal scale ranging from 0 (not implemented) to 3 (well implemented), enabling qualitative field conditions to be transformed into quantitative inputs suitable for Multidimensional Scaling (MDS) analysis.

To populate this matrix, data collection utilized a non-probability purposive quota sampling strategy to gather inputs from 30 key informants. These individuals were selected based on their active role within the local Pentahelix network, split proportionally across Government (Village Board and Panggul Extension Officers), Academia (researchers conducting climate pilots), Business (local corporate representatives providing CSR grants), Community (ProKlim working unit leaders and local Agents of Change), and Media (regional journalists handling public environmental reports). This specialized sample profile ensures that the scoring data represents deeply informed institutional memory, thereby mitigating standard respondent bias.

The statistical robustness of the resulting ordination space was verified via two rigorous goodness-of-fit indicators, namely Kruskal's Stress value and the squared correlation coefficient R^2 . Ordination spaces yield reliable system approximations when Stress values fall strictly under 0.25 and R^2 approaches unity (Iskandar et al., 2024). To eliminate computational bias stemming from respondent subjectivity or data anomalies, we conducted a Monte Carlo simulation with 100 iterations. Discrepancies between the original MDS index and the simulated index of less than 5% confirmed the structural stability of the model. Finally, the relative influence of individual attributes was mathematically mapped using Root Mean Square (RMS) leverage analyses, identifying the critical leverage attributes controlling the system's position.

Although Monte Carlo simulation confirmed the stability of the sustainability indices, several sources of uncertainty should be acknowledged. First, the sustainability assessment relied on perceptual scoring provided by key stakeholders, which may be influenced by individual experiences, institutional interests, and subjective interpretations of program performance. Second, the use of ordinal scoring scales may introduce measurement uncertainty because respondents may perceive scoring categories differently. Third, despite

Table 1. Operationalized Sustainability Attributes and Scoring Criteria for ProKlim Analysis

Dimension	Code	Attribute Description	Scoring Criteria (Ordinal Scale 0–3)
Institutional	I1	Active institution;	0: Not implemented / Non existent 1: Low implementation / Weak 2: Moderate implementation / Fair 3: Well implemented / Optimal
	I2	Organizational structure;	
	I3	Stakeholder coordination;	
	I4	Village government policy support;	
	I5	Program monitoring and evaluation.	
Social	S1	Community participation;	0: Not implemented / Non existent 1: Low implementation / Weak 2: Moderate implementation / Fair 3: Well implemented / Optimal
	S2	Community awareness and understanding;	
	S3	Environmentally responsible behavior;	
	S4	Community capacity;	
	S5	Community mutual cooperation.	
Economic	EC1	Program funding;	0: Not implemented / Non existent 1: Low implementation / Weak 2: Moderate implementation / Fair 3: Well implemented / Optimal
	EC2	Local economic support;	
	EC3	Environment-based economic activities;	
	EC4	Economic benefits;	
	EC5	Business self-reliance.	
Environmental	EN1	Environmental management;	0: Not implemented / Non existent 1: Low implementation / Weak 2: Moderate implementation / Fair 3: Well implemented / Optimal
	EN2	Waste management;	
	EN3	Reforestation and conservation activities;	
	EN4	Environmental quality improvement;	
	EN5	Sustainability of program activities.	

Source: Synthesized and modified from (Brontowiyono et al., 2022; Fitriani et al., 2024; Riani et al., 2024; Wicaksono et al., 2023).

the selection of knowledgeable stakeholders representing the Pentahelix actors, potential response bias cannot be completely eliminated. Therefore, the resulting sustainability indices should be interpreted as diagnostic representations of perceived sustainability conditions rather than absolute measurements. Future studies are encouraged to integrate objective environmental, social, and economic indicators to improve the robustness and precision of sustainability assessments.

3. RESULTS AND DISCUSSION

The Multidimensional Scaling (MDS) analysis revealed that the implementation of ProKlim in Wonocoyo Village, supported by pentahelix stakeholder involvement, achieved an overall multidimensional sustainability index of 58.36. The assessment focused on sustainability performance across institutional, social, economic, and environmental dimensions, rather than on the effectiveness of pentahelix collaboration itself. This indicates that while the integrated climate action network has established functional baseline mechanisms, significant systemic imbalances persist among individual governance and socio economic dimensions. The breakdown of individual sustainability scores, model errors, and validation metrics is systematically provided in Table 2.

The model validation metrics confirm high empirical reliability. Across all four tested dimensions, Kruskal's Stress values fell within a narrow range of 0.151 to 0.165, which is well below the strict 0.25 failure ceiling, signaling low ordination error. Simultaneously, the squared correlation coefficients (R^2) recorded high values between 0.90 and 0.93, indicating that the 20 chosen attributes explain a significant portion of the total variance within the system. Furthermore, the Monte Carlo simulation generated absolute index discrepancies of only 0.06% to 1.95%. Because these values remain well below the 5% threshold, the results establish that the sustainability scores are highly stable and resilient against potential scoring anomalies or minor respondent bias.

Although this study focuses on a single ProKlim location in Wonocoyo Village, several findings may have broader relevance for similar community-based climate adaptation initiatives in Indonesia. The relatively strong institutional performance observed in this study reflects the importance of local governance support, stakeholder coordination, and monitoring mechanisms, which are common requirements across ProKlim implementation areas. Likewise, the relatively weak economic dimension highlights a challenge frequently reported in community-based environmental pro-

Table 2. Sustainability Assessment Results Based on Multidimensional Scaling (MDS) Analysis

Dimension	MDS (%)	Category	Stress Value	Squared Correlation (RSQ)	Monte Carlo (%)	Difference (%)
Institutional	77.23	Highly Sustainable	0.15	0.93	75.54	1.69
Social	52.14	Moderately Sustainable	0.15	0.93	51.52	0.62
Economic	36.42	Less Sustainable	0.16	0.93	36.36	0.06
Environmental	67.65	Moderately Sustainable	0.15	0.90	65.70	1.95
Multidimensional	58.36	Moderately Sustainable	–	–	–	–

Source: Analysis Results, (2026).

grams, where environmental achievements are not always accompanied by sustainable economic benefits. Nevertheless, the specific sustainability scores reported in this study are strongly influenced by local contextual factors and should not be generalized directly to all ProKlim locations. Future comparative studies involving multiple villages and regions are recommended to evaluate the consistency of these sustainability patterns across different implementation contexts.

The overall sustainability index obtained in this study indicates a moderately sustainable status, suggesting that ProKlim implementation in Wonocoyo Village has established a relatively stable foundation for long-term sustainability while still requiring improvements across several dimensions. This finding is consistent with previous sustainability assessments in Indonesia, which reported that institutional and environmental dimensions often play a critical role in determining the long-term success of environmental management programs (Kahirun et al., 2025). Similarly, studies on community-based environmental management have emphasized the importance of community participation, stakeholder engagement, and collaborative governance as key factors supporting the sustainability of environmental initiatives (Fitriani et al., 2024).

The sustainability pattern observed in Wonocoyo Village further confirms that strong institutional support frequently emerges as the primary driver of sustainability, whereas the economic dimension remains the most challenging aspect to maintain. Although effective governance structures, stakeholder coordination, and community participation contribute significantly to program continuity, these factors alone may not be sufficient to ensure long-term sustainability. Sustainable outcomes require complementary economic incentives, livelihood diversification opportunities, and reliable financing mechanisms that can generate tangible benefits for local communities. This finding reinforces the argument that environmental governance increasingly depends on collaborative arrangements involving government institutions, local communities, businesses, academia, and other stakeholders to achieve climate-related objectives. In this regard, Putri et al. (2026) highlighted that stakeholder engagement and multi-actor partnerships serve as essential mechanisms for strengthening climate action, enhancing institutional capacity, and improving sustainability outcomes

in Indonesia.

Therefore, the findings of this study contribute to the growing body of evidence on community-based climate adaptation and environmental governance in Indonesia, emphasizing that long-term sustainability can only be achieved through a balanced integration of institutional, social, environmental, and economic dimensions. Strengthening governance structures should be accompanied by efforts to expand local economic opportunities, enhance community participation, and foster multi-stakeholder collaboration to support more resilient and sustainable climate action outcomes.

3.1 Deep Analytical Evaluation of the Four Dimensions

3.1.1 The Governance Foundations: Institutional Dimension

The institutional dimension emerged as the strongest sustainability pillar, reflecting the presence of supportive village policies, active stakeholder coordination, and a relatively well-established monitoring mechanism. This result validates the study’s underlying hypothesis, demonstrating that governance architectures act as the primary operational anchor for rural climate transition actions. This performance is directly attributed to the proactive formal policy support issued by the village board (Attribute I4), which institutionalized climate action into village budgets. This pattern validates the core tenets of Collaborative Governance, illustrating that multi-sector actors can execute unified public tasks when backed by legitimate local policy structures (Hölscher and Frantzeskaki, 2021). Synergy across the Pentahelix elements was highly visible, with local academic bodies providing technical advice and regional media reporting on initiatives to maximize visibility.

Leverage analysis Figure 1 identified Program monitoring and evaluation (I5) as the primary anchor attribute within this dimension, yielding the highest Root Mean Square (RMS) value of 8.80. This highlights that structural sustainability depends fundamentally on continuous, collaborative monitoring systems rather than static program launching. These findings are consistent with the argument advanced by Ramdani and Mustalahti (2023) that the effectiveness of community-based climate governance in Indonesia is critically contingent upon the quality of multi-stakeholder engagement, whereby weak coordination among

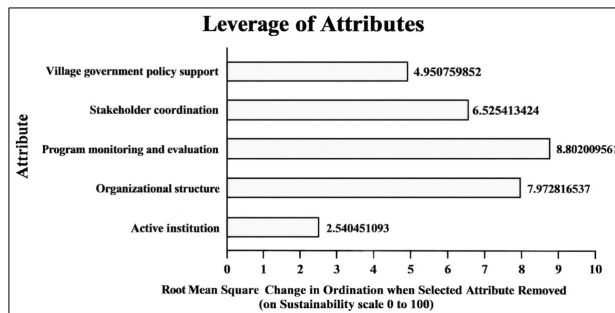


Figure 1. Leverage Analysis Results of the Institutional Dimension of ProKlim

local actors, government agencies, and non-governmental organizations tends to systematically undermine the long-term performance of adaptation programs such as ProKlim. This vulnerability is further compounded by the absence of adaptive verification mechanisms, as [Murun et al. \(2023\)](#) demonstrated that without systematized and sustainable reporting infrastructures, program achievements in developing country contexts remain highly susceptible to regression once external support is withdrawn. At the village level, these structural weaknesses are reinforced by the interplay of institutional fragmentation, financial precarity, and over-reliance on specific leadership figures, which collectively constrain communities' autonomous capacity to sustain program outcomes beyond initial implementation phases ([Patrianti et al., 2026](#)). Taken together, these dynamics suggest that the consolidation of ProKlim cannot be achieved through participatory expansion alone, but must be accompanied by the standardization of inter-actor communication protocols and the institutionalization of verification systems capable of persisting across cycles of local leadership transition.

3.1.2 Community Dynamics: Social and Environmental Dimensions

Both environmental and social dimensions were categorized as moderately sustainable, indicating that community based environmental actions and social participation mechanisms have been functioning relatively well but remain vulnerable to resource and institutional constraints. In the social sphere, leverage analysis (Figure 2) highlighted Environmentally responsible behavior (RMS = 10.14) and Community mutual cooperation (RMS = 2.30) as key sensitive attributes. This indicates that traditional social structures, such as the institutionalized *Gotong Royong* system, provide a ready made foundation for climate transition deployment.

Ecologically, these actions translate into notable landscape metrics, as indicated by the environmental index. Leverage calculations (Figure 3) marked the Sustainability of program activities (EN5, RMS = 18.38) and Environmental quality improvement (EN4, RMS = 12.56) as the sensitive nodes. This demonstrates that continuous eco system maintenance such as managing carbon dynamics via

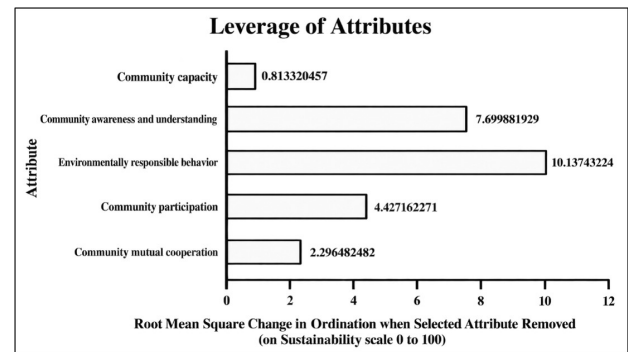


Figure 2. Rage Analysis Results of the Social Dimension of ProKlim

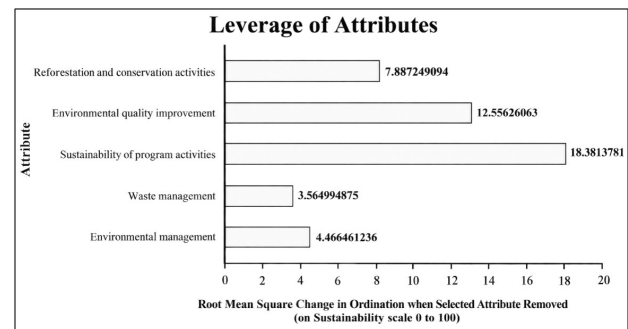


Figure 3. Leverage Analysis of Sustainability Attributes in the Environmental Dimension of ProKlim

community forestry and mangrove planting is critical for securing stable environmental outcomes.

The social dimension score recorded in this study, while reflecting functional community engagement, signals structural limitations that require deeper analysis. The institutionalized *gotong royong* system provides a culturally ready foundation for collective climate action; however, [Surtiari et al. \(2024\)](#) demonstrated that this form of informal communal mutual assistance can only substantially strengthen community adaptive capacity when formally recognized and embedded within governance structures. This institutional gap is further elaborated by [Aldyan et al. \(2024\)](#), who argued that integrating *kearifan lokal* into formal environmental policy is essential for sustainable resource management, and that legal recognition of indigenous knowledge simultaneously guarantees ecological sustainability and promotes social equity. Nevertheless, as [Firnadi \(2025\)](#) noted, formal climate policies in Indonesia frequently marginalize traditional knowledge due to epistemic biases, and integration through participatory governance models is therefore necessary to enhance both the cultural relevance and operational effectiveness of climate programs. These three dynamics the underutilization of informal social institutions, the absence of legal recognition for local knowledge, and the epistemic gap between formal policy and indigenous practice collec-

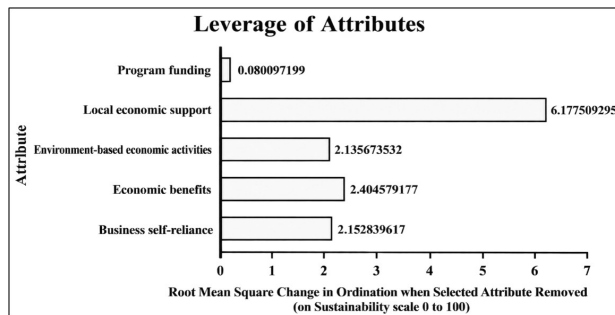


Figure 4. Leverage Analysis of Sustainability Attributes in the Economic Dimension of ProKlim

tively explain the moderate sustainability score observed in the social dimension of this study, and underscore why community-based climate programs such as ProKlim require not merely broader participation but deeper institutional anchoring of local wisdom within formal village regulatory and verification frameworks.

3.1.3 Systemic Failures: The Economic Dimension Bottleneck

The economic dimension represented the weakest component of sustainability, suggesting that environmental initiatives have not yet been translated into sufficiently strong economic incentives or livelihood benefits for local communities. This structural deficit represents the primary threat to the overall sustainability of ProKlim in Wonocoyo. Leverage calculations (Figure 4) revealed that Local economic support systems (EC2, RMS = 6.18) and Direct economic benefits (EC4, RMS = 2.40) are the most sensitive attributes. Currently, green micro enterprises, such as the local waste banking units and organic agricultural initiatives, operate at minimal profit margins or remain dependent on ad hoc village financial assistance, failing to generate widespread livelihood improvements for households.

The economic dimension recorded the lowest sustainability score (36.42), placing it in the less sustainable category and identifying it as the main challenge to the long-term sustainability of ProKlim in Wonocoyo Village. Leverage analysis revealed that local economic support systems (EC2) and direct economic benefits (EC4) were the most sensitive attributes, indicating that environment-based economic activities, including waste banking and organic agriculture, have not yet generated substantial financial returns for participating households.

This condition reflects broader structural, institutional, and socioeconomic constraints, such as limited market access, low-value-added opportunities, inadequate business development support, and weak financing mechanisms. Furthermore, Pentahelix collaboration has been more strongly oriented toward environmental conservation than economic empowerment. From a socioeconomic perspective, community members tend to prioritize short-term income-generating

activities when environmental initiatives provide limited economic benefits. These findings are consistent with Sustainability Transition Theory, which emphasizes that community-based environmental innovations require viable economic incentives to maintain long-term participation and institutional support (Hölscher and Frantzeskaki, 2021). Similar challenges have been reported in Indonesia, where community-based green enterprises often struggle to sustain operations due to weak financial incentives and limited integration into circular economy systems (Abdillah et al., 2024). Therefore, strengthening market access, green entrepreneurship, and sustainable financing through improved stakeholder coordination and support mechanisms may enhance the economic sustainability of ProKlim. In addition, emerging opportunities such as performance-based environmental financing and community-based carbon conservation initiatives may provide alternative funding mechanisms to support local livelihoods while contributing to broader climate mitigation and sustainable development goals (Gatto and Sadik-Zada, 2024; Sunderlin et al., 2024).

4. CONCLUSIONS

The pentahelix based Climate Village Program (ProKlim) in Wonocoyo Village, Trenggalek Regency, achieved a multidimensional sustainability index of 58.36, indicating a moderately sustainable status. Institutional governance showed the strongest performance (77.23), followed by environmental (67.65) and social (52.14) dimensions, while the economic dimension remained the main constraint (36.42). Leverage analysis identified monitoring and evaluation, *gotong royong* cooperation, economic benefits, and continuity of environmental activities as the most influential sustainability attributes. Strengthening green MSMEs, waste banks, and community based enterprises through collaboration among government, academia, and the private sector is essential to improve sustainability outcomes. This study assessed sustainability performance within the context of pentahelix-based ProKlim implementation but did not directly evaluate the effectiveness, interactions, or contributions of individual pentahelix actors. Therefore, pentahelix collaboration should be interpreted as the governance context of the assessment rather than evidence of collaboration effectiveness. Future studies should examine stakeholder interactions and collaborative governance dynamics using dedicated analytical approaches and broader comparative cases.

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