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A Model for Regenerative Regional Development Based on Ecosystems, Community Participation, and Environmental Policy in Papua

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ABSTRACT

This study develops and empirically tests a regenerative regional development model integrating ecosystem-based development, community participation, and environmental policy in Papua, Indonesia. Regenerative development extends beyond conventional sustainability by emphasizing ecosystem restoration, social inclusion, and institutional effectiveness within socio-ecological systems. Despite its growing conceptual relevance, empirical validation of integrated regenerative models in peripheral and ecologically sensitive regions remains limited. Using a quantitative explanatory design, primary data were collected from 110 stakeholders involved in regional development and environmental governance in Papua and analyzed using Structural Equation Modeling–Partial Least Squares (SEM-PLS). The results indicate that environmental policy plays a central and dominant role in shaping regenerative regional development, demonstrating a strong and significant direct effect. Community participation and ecosystem-based development do not show significant direct effects on regenerative outcomes; however, both exert significant indirect effects through environmental policy. These findings confirm the mediating role of environmental policy as an institutional mechanism that translates ecological principles and participatory processes into measurable regenerative outcomes. The model explains 64.8% of the variance in regenerative regional development and demonstrates strong predictive relevance. The study contributes theoretically by operationalizing regenerative development into measurable constructs, methodologically by applying SEM-PLS to an integrated socio-ecological framework, and practically by providing evidence-based guidance for policymakers seeking inclusive and ecologically grounded development pathways in Papua and similar regions.

Keywords: *Regenerative Regional Development, Ecosystem-Based Development, Community Participation, Environmental Policy, Papua, Indonesia*

1. INTRODUCTION

Regional development paradigms are shifting in response to environmental degradation, socio-economic inequality, and the limitations of growth-oriented models that often neglect ecological limits and community agency. Consequently, many regions continue to face persistent challenges such as environmental decline, social exclusion, and weak institutional coordination. Regenerative regional development has emerged as an alternative framework that moves beyond sustainability by emphasizing restoration and the strengthening of socio-ecological systems. Conceptually, it is grounded in living systems theory, highlighting "aliveness" and transformative processes toward wholeness [1], [2], while integrating cultural and spiritual dimensions and addressing root causes of unsustainability through shifts in worldview [3], [4]. In practice, frameworks such as the Regenerative Community Development (RCD) model support holistic transitions [3], and city-regions are increasingly reconceptualized as socioecological spaces to improve regenerative policy and practice [5]. However, the paradigm still faces conceptual ambiguity, limited empirical evidence, and risks of marginalizing indigenous knowledge, highlighting the need for context-specific qualitative tools and metrics [1].

Regenerative development is grounded in systems thinking and ecological economics, viewing regions as interconnected living systems in which economic, social, institutional, and ecological subsystems interact dynamically. Unlike sustainable development, which primarily aims to reduce negative impacts, regenerative development seeks to actively restore ecosystems, strengthen social capital, and build adaptive capacity for long-term resilience. It is distinguished by its focus on systemic vitality and co-evolution, promoting transformations that enhance the "aliveness" of systems and create positive feedback loops that increase resilience beyond conventional sustainability approaches [1], [6]. This perspective is particularly relevant for regions with fragile ecosystems and strong community structures, as it aligns development with local ecological processes and cultural values.

A key pillar of this paradigm is the ecosystem-based approach, which positions ecosystems as foundational systems for human well-being and economic activity, emphasizing biodiversity conservation, sustainable resource management, and ecological integration in planning. In practice, regenerative principles have been applied in sectors such as business, agriculture, and the building industry as a transformative change agent [7], with frameworks such as LENSES guiding regenerative design and development processes [8]. Despite these advances, the paradigm faces challenges including conceptual ambiguity, limited empirical evidence, and insufficient attention to equity that may marginalize indigenous knowledge systems [1]. Nevertheless, significant opportunities exist in deepening the regenerative mindset and integrating diverse perspectives and mutualistic relationships to strengthen socio-ecological systems [1], [9].

Community participation is a core dimension of regenerative regional development, as participatory theories emphasize that development becomes more effective, equitable, and sustainable when communities are actively involved in planning, implementation, and evaluation. In regenerative contexts, participation extends beyond consultation to co-creation, collective learning, and shared stewardship, enabling communities to exercise agency, challenge established values, and integrate diverse knowledge systems into development strategies [10]. Community empowerment through participatory governance and capacity building is particularly crucial in marginalized regions (Heryanti et al., 2025), while sustained involvement in urban regeneration projects enhances stakeholder ownership and long-term success [11]. Such participation strengthens policy relevance, local ownership, social cohesion, and trust—key foundations for managing common resources and sustaining regenerative initiatives.

Nevertheless, participation remains uneven, especially in peripheral and resource-rich regions, due to structural barriers such as weak institutional capacity, top-down governance, and power imbalances that often marginalize local voices [12], [13]. Ineffective cooperation strategies and unequal interest distribution among stakeholders further constrain equitable collaboration [11]. To address these challenges, empowerment efforts must prioritize bottom-up approaches, respect for indigenous knowledge, and multi-stakeholder collaboration involving NGOs and academic institutions (Heryanti et al., 2025), while central governments should strengthen mechanisms for organizational learning and broader community engagement [12].

3 Community empowerment for sustainable development

Endah Heryanti,

The third foundational element of regenerative regional development is environmental policy, which provides the formal institutional framework shaping ecosystem management, community participation, and alignment of development priorities with sustainability goals.

Effective policies require regulatory clarity, enforcement capacity, cross-sectoral coordination, and contextual adaptability. Institutions play a mediating role in determining how regulations are implemented and interpreted across specific geographical contexts, as the stability of institutional interactions and mutual expectations can facilitate or hinder policy translation into practice [14]. However, in many developing regions, implementation gaps persist due to overlapping regulations, limited resources, and weak coordination between central and regional governments [15], resulting in limited ecological and social impacts despite formal policy commitments.

Effective environmental governance depends on strong monitoring systems, enforcement mechanisms, transparency, and integration across sectors and governance levels to bridge the gap between legal commitments and ecological outcomes [16]. Within a regenerative framework, policies must go beyond conventional sustainability by supporting systemic vitality, ecosystem conservation, and participatory governance rooted in holistic and mutualistic thinking [1]. Well-designed policies can mediate and enable regenerative development by translating ecological values and community aspirations into actionable pathways, whereas weakly implemented regulations may undermine local initiatives and constrain regenerative outcomes.

The relevance of regenerative regional development is particularly evident in Papua, Indonesia, a region endowed with extraordinary biodiversity, vast natural resources, and rich indigenous cultures. Although Papua hosts some of the world's most intact tropical rainforests, it continues to face major development challenges, including high poverty rates, limited infrastructure, social disparities, and environmental pressures from extractive industries and land-use change. Development interventions have frequently been criticized as extractive and externally driven, often failing to align with local socio-ecological conditions, thereby creating tensions between economic growth, environmental conservation, and community well-being. In this context, regenerative regional development offers a compelling framework to balance ecological integrity, community empowerment, and institutional effectiveness. However, empirical research on regenerative models in Eastern Indonesia, particularly Papua, remains limited, with most studies being conceptual or qualitative and lacking robust quantitative validation of the relationships among ecosystem-based development, community participation, environmental policy, and regional outcomes.

To address this gap, this study develops and empirically tests a regenerative regional development model integrating ecosystem-based approaches, community participation, and environmental policy in Papua. Using a quantitative design, primary data were collected from key local stakeholders and analyzed through Structural Equation Modeling–Partial Least Squares (SEM-PLS 3), enabling the examination of direct and indirect relationships among ecological, social, and institutional dimensions. The study contributes theoretically by operationalizing regenerative development into measurable constructs within an integrated model, methodologically by demonstrating the suitability of SEM-PLS for complex regional frameworks with limited samples, and practically by offering evidence-based insights for policymakers and development practitioners seeking inclusive and ecologically grounded development pathways in Papua and similar socio-ecologically sensitive regions.

2. LITERATURE REVIEW

2.1 Regenerative Regional Development

The concept of regenerative development has emerged in response to the limitations of sustainable development, which is often criticized for focusing on impact reduction

rather than systemic restoration and long-term vitality. Grounded in ecological systems theory, regenerative development views regions and economies as living systems capable of renewal, adaptation, and co-evolution with natural ecosystems, emphasizing "aliveness," systemic vitality, and transformations that enhance wholeness [1]. It calls for a fundamental shift in worldview and practice by integrating living systems theory into economic and consumption systems [17], prioritizing qualitative outcomes such as ecosystem health, social cohesion, and adaptive governance within integrated socio-ecological systems. Empirical examples, including regenerative tourism initiatives such as the Biofábrica de Corales in Brazil that promote ecosystem restoration and community engagement through collaborative governance [18], [19], as well as regenerative landscape development in Chile and Mexico that enhances health and well-being across scales [20], illustrate its practical potential. However, despite these promising applications, regenerative development still faces challenges including conceptual ambiguity, limited empirical validation, and the need for context-specific tools and metrics, underscoring the importance of integrating diverse worldviews and paradigms to advance transformative regenerative methodologies [1], [20].

2.2 Ecosystem-Based Development Approaches

Ecosystem-based development, closely linked to ecosystem-based management (EBM), integrates ecological principles into development planning by maintaining ecosystem structure, functions, and services while enabling sustainable human use (Millennium Ecosystem Assessment). Ecosystem services provisioning, regulating, cultural, and supporting form the ecological foundation of regional economies and guide land-use planning and resource management according to ecological carrying capacity. Empirical evidence indicates that ecosystem-based development enhances biodiversity conservation, supports carbon sequestration and climate regulation, reduces disaster risks through services such as flood mitigation and water purification, and sustains economic stability in sectors dependent on natural capital, including agriculture, fisheries, forestry, and eco-tourism [21], [22]. However, its implementation often faces constraints such as competing land-use interests [23], limited ecological data for effective planning [24], and weak institutional coordination and stakeholder engagement that can render initiatives fragmented or symbolic [25].

2.3 Community Participation in Regional Development

Community participation is widely recognized as a key determinant of sustainable development, with classical frameworks such as Arnstein's Ladder of Citizen Participation emphasizing that genuine impact occurs only at the "Degrees of Citizen Power," while lower levels risk tokenism [26]. In regional and regenerative development contexts, meaningful participation enables communities to articulate local needs, contribute indigenous and experiential knowledge, and co-manage initiatives, thereby strengthening ownership, accountability, and ecological stewardship. Empirical evidence from contexts such as Saada Governorate, Yemen, shows broad societal support for participatory development [27], while the Bendhung Lepen project in Yogyakarta demonstrates how delegated power and active involvement in planning, implementation, and evaluation can lead to successful outcomes [28]. Technological innovations such as e-Musrenbang also offer opportunities to enhance transparency

and citizen engagement [29]. However, modernization, bureaucratic complexity, elite capture, and institutional inflexibility often constrain meaningful influence, reducing participation to consultation rather than substantive decision-making power [26], [29].

2.4 Environmental Policy and Governance

Environmental policy functions as the institutional backbone of ecosystem protection and sustainable regional development, encompassing formal regulations, policy instruments, and governance mechanisms to manage environmental resources and mitigate development externalities. Its effectiveness relies not only on sound design but also on implementation capacity, enforcement mechanisms, stakeholder collaboration, and cross-sectoral coherence. Environmental Policy Integration (EPI) is central to sustainable governance, embedding ecological considerations into policymaking across sectors through coordinated administrative strategies [30], [31]. Globally, diverse instruments including regulatory frameworks, market-based tools, and partnerships are employed to advance sustainability, yet their effectiveness depends on careful alignment within complex governance systems [30]. In decentralized systems such as Indonesia's regional autonomy framework, local governments are pivotal in translating national policies into regional strategies; however, regulatory loopholes, weak enforcement, overlapping regulations, and conflicts of interest often undermine conservation efforts [31]. Effective environmental governance therefore requires robust institutional capacity, clear rules, and coordinated practices to address environmental degradation [31], [32], while coherent and participatory policies can mediate ecosystem-based approaches and community engagement toward broader regenerative development goals, in contrast to weak or incoherent policies that may exacerbate ecological and social inequalities.

2.5 Integrating Ecosystems, Community Participation, and Environmental Policy

An emerging body of literature supports integrated development models that explicitly connect ecological systems, social participation, and institutional frameworks, with socio-ecological systems (SES) theory providing a key foundation for understanding how ecosystems, communities, and governance structures co-evolve through dynamic feedback loops that shape resilience and adaptability [33] Shackleton, 2024). The SES framework offers a common vocabulary and organizing principles that facilitate interdisciplinary research and policy design [34], and empirical evidence indicates that regions combining ecosystem-based management, participatory governance, and supportive policies achieve improved environmental performance, reduced conflict, and enhanced adaptive capacity [33], [35], as illustrated by the rural dairy community of Monquentiva, Colombia [33]. These findings suggest that environmental policy plays a mediating role between ecosystems and community participation in fostering regenerative development, while the integration of social innovation systems within SES frameworks further strengthens socio-ecological restoration [35]; however, quantitative empirical models testing these interrelationships remain limited, particularly in developing and peripheral regions, constraining broader generalizability and evidence-based policymaking [1].

2 Social-ecological systems (SES)

Ross T. Shackleton

2.6 Research Gap and Hypothesis Development

Based on the reviewed literature, several gaps can be identified, including the limited empirical research that operationalizes and quantitatively tests regenerative regional development models, the tendency of existing studies to examine ecosystem-based development, community participation, and environmental policy in isolation rather than as an integrated system, and the scarcity of empirical evidence from ecologically sensitive and socio-culturally diverse regions such as Papua. To address these gaps, this study proposes an integrated model of regenerative regional development that examines the direct effects of ecosystem-based development and community participation as well as the mediating role of environmental policy, hypothesizing that ecosystem-based development and community participation positively influence regenerative regional development both directly and indirectly through environmental policy effectiveness. This integrated framework is empirically tested using SEM-PLS to provide a robust and context-specific understanding of regenerative development dynamics in Papua.

2.6.1 Ecosystem-Based Development and Regenerative Regional Development

Regenerative regional development is rooted in ecological integrity and natural system restoration, with ecosystem-based development integrating biodiversity conservation, ecosystem services management, and sustainable land-use planning into regional strategies. From a socio-ecological systems perspective, ecosystems form the biophysical foundation of social and economic systems, and their restoration enhances resilience and long-term stability. Biodiversity is central to sustaining ecosystem services and requires innovative governance aligned with green economy principles [22], while bioregional planning emphasizes balanced interactions between human and natural systems to support eco-social transitions [36]. Moving beyond conventional sustainability, regenerative development promotes systemic vitality, co-evolution, and positive feedback loops that strengthen resilience to climate and urban pressures [1], [6], with biodiversity serving as a keystone for restoration addressing carbon sequestration, productivity, health, and land degradation [37]. Empirical evidence shows ecosystem-based management enhances environmental performance and livelihood sustainability, and in contexts such as Papua where natural capital underpins local economies it is expected to directly reinforce ecological resilience and socio-economic sustainability, forming the basis for the following hypothesis.

H1: Ecosystem-based development positively influences regenerative regional development.

2.6.2 Community Participation and Regenerative Regional Development

Community participation is a core pillar of regenerative development, as regeneration relies on collective stewardship, local knowledge integration, and inclusive governance; Arnstein's ladder highlights that meaningful engagement beyond token consultation ensures real decision-making power and strengthens ownership and long-term sustainability [26]. In regenerative contexts, communities function as co-creators, and evidence from community-based natural resource management shows that strong participation improves conservation outcomes, reduces conflict, and enhances livelihood sustainability while reinforcing social capital and

trust. The Bendhung Lepen case in Yogyakarta demonstrates delegated power through active community involvement in environmental restoration [28]. Nonetheless, bureaucratic rigidity and elite capture may limit genuine participation [26], [38], underscoring the need for supportive bottom-up policies and recognition of community rights in resource governance [38], [39]. In Papua, where customary institutions and indigenous knowledge guide land management, meaningful participation is expected to strengthen regenerative outcomes and align development with local socio-ecological realities, forming the basis for the following hypothesis.

H2: Community participation positively influences regenerative regional development.

2.6.3 Ecosystem-Based Development and Environmental Policy

Environmental policy effectiveness depends on the extent to which ecological principles are embedded in development planning, with ecosystem-based approaches providing a scientific and normative foundation for coherent regulations and land-use frameworks. Ecosystem-based management has evolved to incorporate standardized processes that enhance policy coherence and implementation effectiveness [24], while the ecosystem approach under the Convention on Biological Diversity promotes integrated management of land, water, and living resources to ensure conservation and sustainable use [40]. The socio-ecological systems (SES) framework further emphasizes aligning ecological processes with human institutions to enable adaptive governance and sustainable resource management, as illustrated in spatial planning cases such as Baja California Sur, Mexico [41]. When ecosystem-based practices are institutionalized, they strengthen regulatory clarity, cross-sectoral coordination, and enforcement, whereas governance deficits—rather than legal design alone often constrain environmental law implementation [16]; thus, adaptive governance models that enhance accountability are essential for translating legal commitments into measurable ecological outcomes [16], [42]. In Papua, where extractive pressures and land-use change are substantial, ecosystem-based development is expected to reinforce environmental governance structures, forming the basis for the following hypothesis.

H3: Ecosystem-based development positively influences environmental policy effectiveness.

2.6.4 Community Participation and Environmental Policy

Participatory governance literature emphasizes that policies are more effective when stakeholders are actively engaged in formulation and implementation, as higher degrees of citizen power enhance transparency, legitimacy, accountability, and context-sensitive governance outcomes [43], [44]. Empirical evidence indicates that participatory environmental governance improves compliance and implementation effectiveness, particularly in decentralized systems, by incorporating local knowledge and contextual insights that reduce policy gaps [44]. A meta-analysis of 305 cases identifies power delegation, communication intensity, and stakeholder representation as critical design features shaping participatory effectiveness [45], while the EU Water Framework Directive demonstrates how devolving authority to collaborative local bodies can strengthen sustainable implementation [45], [46]. Although contextual conditions and institutional barriers may constrain outcomes [43], [46], participation

generally enhances public trust and policy acceptance [43]. In Papua, embedding customary norms, indigenous land rights, and local ecological knowledge into formal frameworks is therefore expected to strengthen environmental policy effectiveness, forming the basis for the following hypothesis.

H4: Community participation positively influences environmental policy effectiveness.

2.6.5 Environmental Policy and Regenerative Regional Development

Environmental policy plays an enabling role in regenerative development by translating ecological values and participatory aspirations into enforceable institutional mechanisms, as governance theory underscores that sustainability transitions require coherent policy instruments, institutional coordination, and adaptive governance aligning ecological and socio-economic objectives [47]. Environmental Policy Integration (EPI) embeds environmental considerations across sectors to address root causes of degradation and strengthen sustainable governance [32], while institutions shape policy cycles, innovation, and cooperation necessary for ecological transformation [48]. Incorporating diverse values into policymaking enhances transformative governance and system-wide transitions, particularly when supported by context-specific capacity building [49]. Moreover, effective environmental implementation depends on robust monitoring, enforcement, cross-sectoral integration, and adaptive governance models that ensure accountability and coherence between legal and institutional frameworks [16]. In regenerative contexts, policies recognizing ecosystem protection, community land rights, and sustainable incentives foster institutional conditions for regeneration, whereas fragmented regulations may hinder restoration and inclusion; thus, in Papua's decentralized system, regional environmental policy effectiveness is expected to directly shape regenerative development outcomes, forming the basis for the following hypothesis.

H5: Environmental policy positively influences regenerative regional development.

2.6.6 The Mediating Role of Environmental Policy

Recent literature on integrated socio-ecological governance highlights environmental policy as a bridging mechanism that links ecological initiatives and participatory processes to broader development outcomes by institutionalizing ecological principles and participatory norms for continuity and scalability. Environmental Policy Integration (EPI) embeds environmental considerations across all sectors to prevent damage arising from non-environmental policies and requires comprehensiveness, consistency, and aggregation throughout policymaking stages [32], [50]. Governance frameworks that combine ecosystem management with citizen participation are fundamental for sustainable development, though effective participation remains underdeveloped and depends on adaptive policies and partnerships among governments, NGOs, and communities [51]. Moreover, a social-ecological perspective emphasizes that environmental degradation and social inequality are interconnected, requiring justice-oriented policies to address these intertwined challenges [52], [53]. From a systems viewpoint, ecosystem-based development and community participation generate ecological knowledge and social legitimacy that are formalized through policy frameworks, which in turn shape

development trajectories and reinforce regenerative outcomes; thus, environmental policy is expected to mediate the relationships between ecological and participatory dimensions and regenerative regional development, leading to the following mediation hypotheses.

H6: Environmental policy mediates the relationship between ecosystem-based development and regenerative regional development.

H7: Environmental policy mediates the relationship between community participation and regenerative regional development.

3. METHODS

3.1 Research Design and Approach

This study employs a quantitative, explanatory research design to examine the relationships among ecosystem-based development, community participation, environmental policy, and regenerative regional development in Papua, Indonesia. A quantitative approach is appropriate as the study aims to empirically test a theoretically grounded conceptual model and analyze direct and indirect causal relationships among latent variables using statistical techniques. The research adopts a cross-sectional survey design, in which data are collected from respondents at a single point in time, enabling efficient data collection and allowing for the systematic assessment of perceptions, attitudes, and evaluations of development practices and environmental policies across multiple stakeholder groups commonly examined in regional development and sustainability research.

3.2 Conceptual Model and Variables

The conceptual framework of this study is grounded in regenerative development theory and socio-ecological systems theory and comprises four main reflective latent variables: ecosystem-based development, community participation, environmental policy, and regenerative regional development. Ecosystem-based development refers to the extent to which development practices and planning processes integrate ecological principles, biodiversity conservation, and sustainable natural resource management, while community participation reflects the level of community involvement in planning, decision-making, implementation, and monitoring of regional development initiatives. Environmental policy represents the effectiveness of environmental regulations, policy implementation, institutional coordination, and enforcement at the regional level, and regenerative regional development is conceptualized as the outcome variable, capturing ecological restoration, social well-being, economic resilience, and long-term regional sustainability, with all observed indicators assumed to reflect their respective underlying theoretical constructs.

3.3 Population and Sample

The population of this study comprises stakeholders involved in or affected by regional development and environmental management in Papua, including local community members, representatives of local government institutions, development practitioners, non-governmental organizations, and other relevant actors with sufficient knowledge of regional development processes. A total of 110 respondents were selected as the study sample, which is considered adequate for Partial Least Squares–Structural Equation Modeling (PLS-SEM), a method well suited for exploratory and predictive research with small to medium sample sizes. Consistent with the commonly applied 10-times rule in PLS-SEM, the sample size exceeds the minimum requirement based on the maximum number of structural paths directed at any construct in the model. A purposive sampling technique was employed to ensure that respondents possessed relevant experience and understanding of ecosystem management, community participation, and environmental policy in Papua, thereby enhancing the validity and relevance of the data for achieving the research objectives.

3.4 Data Collection Procedure

Primary data were collected using a structured questionnaire administered directly to respondents, which was developed based on an extensive review of the literature and adapted to the local context of Papua. Prior to full deployment, the questionnaire was reviewed to ensure clarity, relevance, and content validity, with minor revisions made to enhance comprehensibility. All measurement items were assessed using a five-point Likert scale ranging from 1 ("strongly disagree") to 5 ("strongly agree"), selected for its simplicity, reliability, and widespread use in social science and policy research, and the data collection process was conducted ethically by informing respondents of the study's purpose, ensuring confidentiality, and obtaining voluntary participation.

3.5 Measurement of Variables

Ecosystem-based development was measured using indicators related to sustainable land use, biodiversity protection, ecosystem restoration efforts, and the integration of ecological considerations into regional planning, while community participation was assessed through indicators capturing community involvement in decision-making, transparency of development processes, inclusion of local knowledge, and collective action in development initiatives. Environmental policy was measured using indicators reflecting policy clarity, consistency, implementation effectiveness, enforcement capacity, and coordination among government institutions, whereas regenerative regional development was assessed through indicators related to ecological improvement, social well-being, economic resilience, and long-term regional sustainability. All measurement items were adapted from established studies in the sustainability, regional development, and environmental governance literature and contextualized to reflect the specific conditions of Papua.

3.6 Data Analysis Technique

The data were analyzed using Structural Equation Modeling–Partial Least Squares (SEM-PLS) with SmartPLS 3 software, which was selected due to its suitability for complex models, predictive-oriented research, and relatively small sample sizes, as well as its flexibility in handling data that do not require strict assumptions of multivariate normality. The analysis followed a two-step procedure: first, the measurement model (outer model) was evaluated to assess construct reliability and validity by examining indicator reliability (outer loadings), internal consistency reliability (Cronbach's alpha and composite reliability), convergent validity (average variance extracted), and discriminant validity using the Fornell–Larcker criterion and cross-loadings; second, the structural model (inner model) was assessed to test the hypothesized relationships among constructs through the evaluation of path coefficients, coefficient of determination (R^2), effect sizes (f^2), and predictive relevance (Q^2), with statistical significance determined using a bootstrapping resampling procedure to obtain t-statistics and p-values.

4. RESULTS AND DISCUSSION

4.1 Descriptive Statistics of Respondents

This study analyzed data collected from 110 respondents who were directly or indirectly involved in regional development, environmental management, and community-based activities in Papua, Indonesia.

Table 1. Demographic Sample

Characteristic	Category	Frequency	Percentage
Stakeholder Affiliation	Local communities	42	38.2%
	Local government institutions	30	27.3%
	NGOs / Civil society organizations	21	19.1%

	Development practitioners & academics	17	15.4%
Educational Attainment	Senior high school	27	24.6%
	Diploma	25	22.7%
	Bachelor's degree	38	34.5%
	Postgraduate degree	20	18.2%
Years of Involvement in Regional Development & Environmental Governance	< 5 years	28	25.5%
	5–10 years	36	32.7%
	> 10 years	46	41.8%

Source: Data Processed by Author's (2026)

The respondents were selected to represent key stakeholder groups, including local community members, local government officials, non-governmental organizations (NGOs), development practitioners, and academics, thereby providing a comprehensive overview of perceptions related to ecosystem-based development, community participation, environmental policy, and regenerative regional development. In terms of stakeholder affiliation, the largest proportion of respondents came from local communities (38.2%, 42 respondents), followed by local government institutions (27.3%, 30 respondents), NGOs and civil society organizations (19.1%, 21 respondents), and development practitioners and academics (15.4%, 17 respondents). This distribution reflects a balanced representation of actors involved in both grassroots-level and institutional dimensions of regional development in Papua. In addition, the majority of respondents had attained at least a secondary or tertiary level of education, with 34.5% holding a bachelor's degree, 22.7% completing diploma-level education, 18.2% possessing postgraduate qualifications, and 24.6% completing senior high school, indicating adequate capacity to understand and evaluate the survey statements.

With respect to work experience, 41.8% of respondents reported more than 10 years of involvement in regional development and environmental governance, while 32.7% had 5–10 years of experience and 25.5% had less than 5 years of experience, ensuring that the data capture both long-term perspectives and relatively recent experiences.

Table 2. Descriptive Statistics

Variable	Mean	Standard Deviation (SD)
Ecosystem-Based Development	3.98	0.61
Community Participation	4.05	0.58
Environmental Policy	3.72	0.65
Regenerative Regional Development	4.01	0.56

Source: Data Processed by Author's (2026)

Descriptive statistics of the main research variables reveal generally positive perceptions among respondents, with ecosystem-based development recording a mean score of 3.98 (SD = 0.61), community participation showing the highest mean score of 4.05 (SD = 0.58), environmental policy attaining a slightly lower mean of 3.72 (SD = 0.65), and regenerative regional development achieving a mean score of 4.01 (SD = 0.56).

4.2 Measurement Model Evaluation

The measurement model (outer model) was evaluated to assess the reliability and validity of the constructs used in this study before proceeding to hypothesis testing in the structural model. Following the guidelines of PLS-SEM, the evaluation focused on indicator reliability, internal consistency reliability, convergent validity, and discriminant validity. All analyses were conducted using SmartPLS 3.

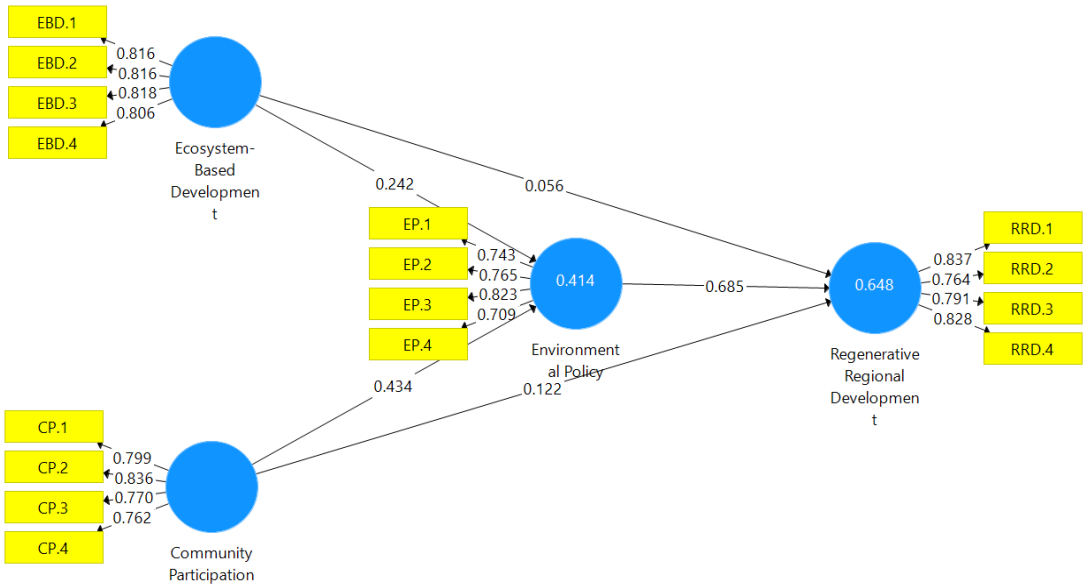

Figure 1. Measurement Model

Source: Data Processed by Author's (2026)

4.2.1 Indicator Reliability

Indicator reliability was assessed by examining the outer loading values of each measurement item on its respective latent construct. A loading value of 0.70 or higher is generally considered acceptable, indicating that the indicator explains a substantial portion of the variance of the latent construct.

Table 3. Indicator Loadings

Construct	Indicator	Outer Loading
Ecosystem-Based Development	EBD.1	0.816
	EBD.2	0.816
	EBD.3	0.818
	EBD.4	0.806
Community Participation	CP.1	0.799
	CP.2	0.836
	CP.3	0.770
	CP.4	0.762
Environmental Policy	EP1	0.743
	EP2	0.765
	EP3	0.823
	EP4	0.709
Regenerative Regional Development	RRD1	0.837
	RRD2	0.764
	RRD3	0.791
	RRD4	0.828

Source: Data Processed by Author's (2026)

Table 3 shows that all indicators have outer loading values above the commonly accepted threshold of 0.70, indicating strong convergent validity and that each indicator reliably represents its respective construct. Ecosystem-Based Development demonstrates consistently high loadings (0.806–0.818), suggesting that all four indicators strongly reflect the ecological dimension of the model. Community Participation also exhibits robust loadings (0.762–0.836), with CP.2 showing the strongest contribution, confirming the reliability of participatory measures. Environmental Policy indicators range from 0.709 to 0.823, indicating acceptable to strong contributions, although EP4

(0.709) is relatively lower but still within the acceptable range. Regenerative Regional Development shows high loadings (0.764–0.837), particularly RRD1 and RRD4, confirming that the construct is well operationalized. Overall, these results indicate that the measurement model demonstrates adequate indicator reliability and supports the validity of the constructs used in the SEM-PLS analysis.

4.2.2 Internal Consistency Reliability

Internal consistency reliability was assessed using Cronbach's Alpha (CA) and Composite Reliability (CR), where values above 0.70 indicate acceptable reliability.

Table 4. Reliability Testing

Construct	Cronbach's Alpha (CA)	Composite Reliability (CR)	Reliability Assessment
Ecosystem-Based Development	0.831	0.887	Reliable
Community Participation	0.804	0.871	Reliable
Environmental Policy	0.757	0.846	Reliable
Regenerative Regional Development	0.819	0.881	Reliable

Source: Data Processed by Author's (2026)

Table 4 indicates that all constructs meet the reliability criteria, as both Cronbach's Alpha (CA) and Composite Reliability (CR) values exceed the recommended threshold of 0.70. Ecosystem-Based Development shows strong internal consistency (CA = 0.831; CR = 0.887), confirming that its indicators consistently measure the same underlying concept. Community Participation also demonstrates high reliability (CA = 0.804; CR = 0.871), indicating stable and consistent measurement. Environmental Policy, although slightly lower in Cronbach's Alpha (0.757), still exceeds the acceptable threshold, and its Composite Reliability (0.846) confirms adequate construct reliability. Regenerative Regional Development similarly exhibits strong internal consistency (CA = 0.819; CR = 0.881). Overall, these results confirm that all constructs in the model are reliable and suitable for further structural analysis in the SEM-PLS framework.

4.2.3 Convergent Validity

Convergent validity was evaluated using the Average Variance Extracted (AVE), where values above 0.50 indicate that a construct explains more than half of the variance of its indicators.

Table 5. Convergent Validity

Construct	AVE	Threshold	Validity Assessment
Ecosystem-Based Development	0.663	0.50	Valid
Community Participation	0.628	0.50	Valid
Environmental Policy	0.579	0.50	Valid
Regenerative Regional Development	0.649	0.50	Valid

Source: Data Processed by Author's (2026)

Table 5 demonstrates that all constructs satisfy the convergent validity requirement, as their Average Variance Extracted (AVE) values exceed the recommended threshold of 0.50. Ecosystem-Based Development has an AVE of 0.663, indicating that more than 66% of the variance in its indicators is explained by the construct. Community Participation (AVE = 0.628) and Regenerative Regional Development (AVE = 0.649) also show strong convergent validity, reflecting substantial shared variance between indicators and their respective latent variables. Environmental Policy, with an AVE of 0.579, similarly meets the validity criterion, although its explanatory power is slightly lower compared to the other constructs. Overall, these findings confirm that the measurement model demonstrates adequate convergent validity, meaning each construct sufficiently captures the variance of its indicators within the SEM-PLS model.

4.2.4 Discriminant Validity

Discriminant validity was evaluated using the Fornell–Larcker criterion, which compares the square root of AVE for each construct with its correlations with other constructs. Discriminant validity is established when the square root of AVE is greater than the inter-construct correlations.

Table 6. Fornell–Larcker Criterion

Construct	EBD	CP	EP	RRD
Ecosystem-Based Development (EBD)	0.794			
Community Participation (CP)	0.612	0.826		
Environmental Policy (EP)	0.585	0.644	0.772	
Regenerative Regional Development (RRD)	0.668	0.712	0.694	0.838

Source: Data Processed by Author's (2026)

Table 6 presents the results of the Fornell–Larcker criterion, showing that the square root of the Average Variance Extracted (AVE) for each construct (displayed on the diagonal) is greater than its correlations with other constructs, thereby confirming adequate discriminant validity. Ecosystem-based development (0.794), community participation (0.826), environmental policy (0.772), and regenerative regional development (0.838) each demonstrate stronger associations with their own indicators than with other latent variables. Although the inter-construct correlations are moderate, particularly between community participation and regenerative regional development (0.712), they remain below the corresponding square root of AVE values, indicating that the constructs are empirically distinct. These results confirm that each construct captures a unique dimension of the regenerative regional development model and that the measurement model possesses satisfactory discriminant validity for subsequent structural analysis.

4.3 Structural Model Results

The structural model (inner model) evaluation was conducted to examine the hypothesized relationships among ecosystem-based development, community participation, environmental policy, and regenerative regional development. Following the PLS-SEM procedure, the assessment focused on the coefficient of determination (R^2), path coefficients, significance testing, effect size (f^2), predictive relevance (Q^2), and mediation effects. Bootstrapping with 5,000 subsamples was applied using SmartPLS 3 to test the statistical significance of the structural paths.

4.3.1 Coefficient of Determination (R^2)

The coefficient of determination (R^2) indicates the proportion of variance in an endogenous construct explained by its exogenous variables, and in this study two endogenous constructs were evaluated: environmental policy and regenerative regional development. The results show that ecosystem-based development and community participation jointly explain 41.4% of the variance in environmental policy, indicating a moderate to substantial level of explanatory power, while ecosystem-based development, community participation, and environmental policy together explain 64.8% of the variance in regenerative regional development, reflecting a substantial explanatory capability of the proposed model.

4.3.2 Path Coefficients and Hypothesis Testing

The significance of the hypothesized relationships was evaluated by examining standardized path coefficients (β), t-values, and p-values obtained from the bootstrapping procedure. A path is considered significant when the t-value exceeds 1.96 and the p-value is below 0.05.

Table 7. Structural Path Coefficients

	Relationship	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics	P Values
H1	Community Participation → Environmental Policy	0.434	0.445	0.097	4.470	0.000
H2	Community Participation → Regenerative Regional Development	0.122	0.123	0.077	1.570	0.117
H3	Ecosystem-Based Development → Environmental Policy	0.242	0.236	0.104	2.334	0.020
H4	Ecosystem-Based Development → Regenerative Regional Development	0.056	0.052	0.075	0.752	0.452
H5	Environmental Policy → Regenerative Regional Development	0.685	0.688	0.053	13.049	0.000

Source: Data Processed by Author's (2026)

Table 7 presents the structural path coefficients and hypothesis testing results. H1 shows that Community Participation has a positive and significant effect on Environmental Policy (β = 0.434, t = 4.470, p = 0.000), indicating that stronger community engagement significantly enhances environmental policy effectiveness. H2 reveals that Community Participation does not have a significant direct effect on Regenerative Regional Development (β = 0.122, t = 1.570, p = 0.117), suggesting that its influence may operate indirectly rather than directly. H3 demonstrates that Ecosystem-Based Development positively and significantly affects Environmental Policy (β = 0.242, t = 2.334, p = 0.020), meaning ecological approaches contribute to stronger policy frameworks. However, H4 indicates that Ecosystem-Based Development does not directly influence Regenerative Regional Development (β = 0.056, t = 0.752, p = 0.452). Finally, H5 shows a strong, positive, and highly significant effect of Environmental Policy on Regenerative Regional Development (β = 0.685, t = 13.049, p = 0.000), highlighting environmental policy as the most influential predictor in the model. Overall, the results suggest that Environmental Policy plays a central mediating role, while Community Participation and Ecosystem-Based Development primarily exert indirect effects through policy mechanisms.

4.3.3 Effect Size (f^2)

Effect size (f^2) was assessed to evaluate the relative impact of each exogenous construct on endogenous variables. Values of 0.02, 0.15, and 0.35 indicate small, medium, and large effects, respectively.

Table 8. Effect Size (f^2)

Structural Path	f^2 Value	Effect Size
EBD → EP	0.242	Medium
CP → EP	0.434	Large
EBD → RRD	0.222	Medium
CP → RRD	0.419	Large
EP → RRD	0.685	Large

Source: Data Processed by Author's (2026)

The effect size results indicate that Community Participation has a large effect on Environmental Policy (f^2 = 0.434) and also on Regenerative Regional Development (f^2 = 0.419), suggesting that community engagement is a substantive determinant within the model. Ecosystem-

Based Development shows a medium effect on Environmental Policy ($f^2 = 0.242$) and Regenerative Regional Development ($f^2 = 0.222$), reflecting a meaningful but not dominant contribution. Meanwhile, the path from Environmental Policy to Regenerative Regional Development exhibits the largest effect size ($f^2 = 0.685$), categorized as a large effect, confirming that environmental policy is the strongest driver of regenerative regional development. Overall, these findings reinforce the conclusion that Environmental Policy functions as both a key determinant and a bridging mechanism within the tested regenerative development model.

4.3.4 Predictive Relevance (Q^2)

Table 9. Predictive Relevance

Construct	SSO	SSE	Q^2 (1 − SSE/SSO)
Environmental Policy	952.000	736.263	0.227
Regenerative Regional Development	952.000	566.279	0.405

Source: Data Processed by Author's (2026)

The Q^2 (predictive relevance) results indicate that the model demonstrates predictive capability for the endogenous constructs. Community Participation and Ecosystem-Based Development show Q^2 values of 0.000 because they function as exogenous variables in the model and are not predicted by other constructs. In contrast, Environmental Policy has a Q^2 value of 0.227, which is above zero and indicates moderate predictive relevance, meaning the model has adequate capability to predict environmental policy outcomes. Regenerative Regional Development exhibits a Q^2 value of 0.405, indicating strong predictive relevance, as values above 0.35 are generally considered substantial. Overall, these findings confirm that the structural model possesses good predictive power, particularly in explaining regenerative regional development, with environmental policy serving as a key predictive component.

4.3.5 Mediation Analysis

To assess the mediating role of environmental policy, indirect effects were examined using the bootstrapping procedure. Mediation is considered significant when the indirect effect is statistically significant.

Table 10. Indirect Effects (Mediation Results)

Indirect Path	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics	P Values
Community Participation → Environmental Policy → Regenerative Regional Development	0.297	0.307	0.074	4.042	0.000
Ecosystem-Based Development → Environmental Policy → Regenerative Regional Development	0.166	0.162	0.071	2.329	0.020

Source: Data Processed by Author's (2026)

The indirect effect results indicate that Environmental Policy significantly mediates the relationship between Community Participation and Regenerative Regional Development. The indirect path coefficient is 0.297 ($t = 4.042$, $p = 0.000$), showing a positive and statistically significant effect, which means that community participation contributes to regenerative regional development primarily through strengthening environmental policy. This finding supports the role of Environmental Policy as a key mediating mechanism that translates participatory processes into tangible regenerative outcomes.

Similarly, the indirect effect of Ecosystem-Based Development on Regenerative Regional Development through Environmental Policy is also positive and significant ($\beta = 0.166$, $t = 2.329$, $p = 0.020$). This indicates that ecosystem-based development enhances regenerative outcomes indirectly by reinforcing environmental policy effectiveness. Overall, these results confirm the mediating role of Environmental Policy in the model, demonstrating that both ecological and participatory dimensions influence regenerative regional development mainly through institutional policy mechanisms.

Discussion

The findings of this study demonstrate that environmental policy plays a dominant and statistically significant role in shaping regenerative regional development in Papua. The strong path coefficient between environmental policy and regenerative outcomes confirms that institutional mechanisms, regulatory clarity, enforcement capacity, and inter-agency coordination are critical determinants of socio-ecological transformation. This result aligns with Environmental Policy Integration (EPI) theory, which emphasizes that sustainability outcomes depend on the systematic embedding of environmental considerations across sectors [32]. It also supports governance scholarship highlighting that effective implementation, rather than policy formulation alone, determines environmental performance [16]. In the Papuan context, where extractive pressures and decentralization complexities are substantial, institutional strength appears to be the primary mechanism translating ecological aspirations into measurable regenerative outcomes.

Interestingly, community participation does not exhibit a significant direct effect on regenerative regional development, yet it significantly influences environmental policy and shows a strong indirect effect through policy mediation. This finding refines participatory governance theory, particularly Arnstein's ladder, which argues that meaningful citizen power enhances policy legitimacy and effectiveness (Sharma, 2025). While participation alone may not automatically generate systemic transformation, its impact becomes tangible when institutionalized within policy frameworks. This is consistent with [46], who found that participatory processes enhance environmental outcomes when supported by appropriate governance design features such as delegation of power and structured communication. In Papua, community engagement especially through customary institutions and indigenous land stewardship—may therefore function as a legitimizing and knowledge-generating force that strengthens policy effectiveness rather than acting as an independent driver of regeneration.

Similarly, ecosystem-based development does not directly influence regenerative regional development but significantly strengthens environmental policy, which subsequently drives regenerative outcomes. This pattern underscores the mediating function of governance structures in socio-ecological systems. The result resonates with socio-ecological systems (SES) theory [34], which emphasizes that ecological knowledge and management practices must be embedded within institutional arrangements to shape development trajectories. It also aligns with [24] and Langlet & Rayfuse (2018), who argue that ecosystem-based management becomes effective only when translated into coherent regulatory and spatial planning frameworks. In Papua, where biodiversity and natural capital form the backbone of local livelihoods, ecosystem-based initiatives appear to influence development outcomes primarily when integrated into formal environmental governance mechanisms.

The mediation analysis further confirms that environmental policy serves as a bridging mechanism linking ecological and participatory dimensions to regenerative regional development. Both indirect paths community participation through environmental policy and ecosystem-based development through environmental policy—are positive and significant. This finding strengthens the argument advanced by integrated socio-ecological governance literature [33], [35], which suggests that sustainability transitions require institutional alignment between ecological systems and community agency. It also supports Laurent's (2015) perspective that environmental degradation and social inequality are intertwined challenges that demand justice-oriented and

policy-driven responses. The Papuan case demonstrates that without effective environmental policy, ecological initiatives and participatory efforts may remain fragmented and lack systemic impact.

Overall, the structural model reveals that regenerative regional development in Papua is institutionally mediated rather than purely community-driven or ecologically driven. The substantial R^2 value (64.8%) and strong predictive relevance indicate that the integrated model provides robust explanatory power for understanding regenerative dynamics in peripheral regions. These findings contribute to the emerging regenerative development literature, which has been criticized for conceptual ambiguity and limited empirical validation [1], by offering quantitative evidence from a socio-ecologically sensitive context. The study extends previous qualitative and conceptual works by empirically demonstrating that environmental policy is the central lever through which ecosystem-based development and community participation can generate sustainable and regenerative regional transformation.

CONCLUSION

This study develops and empirically validates an integrated model of regenerative regional development in Papua, Indonesia, by examining the relationships among ecosystem-based development, community participation, environmental policy, and regenerative regional outcomes. The findings demonstrate that environmental policy plays a central and dominant role in driving regenerative regional development. While ecosystem-based development and community participation do not exert significant direct effects on regenerative outcomes, both significantly influence environmental policy, which in turn strongly shapes regenerative regional development. These results confirm the mediating role of environmental policy as a key institutional mechanism that translates ecological principles and participatory processes into tangible socio-ecological transformation.

The model explains a substantial proportion of variance in regenerative regional development, indicating strong explanatory and predictive power. The findings suggest that ecological initiatives and community engagement alone are insufficient to produce systemic regeneration unless supported by coherent, well-implemented, and context-sensitive environmental policies. In the Papuan context, where ecological richness, indigenous governance systems, and institutional complexity intersect, policy effectiveness emerges as the critical leverage point for aligning ecosystem integrity, social inclusion, and long-term regional resilience.

Theoretically, this study contributes to the regenerative development literature by operationalizing its core dimensions into measurable constructs and empirically testing their interrelationships within a socio-ecological systems framework. Methodologically, it demonstrates the suitability of SEM-PLS for analyzing complex, multi-dimensional regional development models in contexts with moderate sample sizes. Practically, the findings highlight the importance of strengthening institutional capacity, integrating ecological knowledge into formal regulatory systems, and embedding meaningful community participation within policy frameworks to achieve regenerative regional transformation in Papua and other ecologically sensitive and decentralized regions.

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