Adaptive pentahelix collaborative governance for forest and land fire mitigation: Advancing SDGs 13 (climate action) and SDGs 15 (life on land) in East Kotawaringin, Indonesia

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Abstract. This study examines the integration of the Pentahelix model within a collaborative governance framework for sustainable forest and land fire mitigation in Kotawaringin Timur, Central Kalimantan, Indonesia. Using a qualitative approach supported by actor-network analysis, the research identifies interactions among five key actors, such as government, academia, business, community, and media, in forming an adaptive governance system. Results indicate that collaborative effectiveness depends on institutional trust, cross-sector coordination, and the continuity of participatory mechanisms. While government–community relations remain dominant, academic and private sector engagement strengthens innovation and data-driven prevention. Combining Pentahelix and collaborative governance creates a flexible, SDG-focused model that helps communities become more resilient to climate change and restore ecosystems. Empirically, this model contributes to the achievement of SDG 13 (Climate Action) by improving adaptive capacity and SDG 15 (Life on Land) through community-based ecosystem management. This study concludes that sustainable fire mitigation requires institutionalized multi-actor collaboration combining policy coherence, local wisdom, and knowledge-based innovation to achieve long-term environmental governance.

1 Introduction

Forest and land fires (karhutla) are one of the biggest ecological disasters faced by Indonesia in the last two decades, especially in Kalimantan and Sumatra. East Kotawaringin Regency in Central Kalimantan Province is one of the areas with a high intensity of forest and land fires every year, which have a broad impact on public health, local economic stability, and the degradation of terrestrial ecosystems. The factors causing forest and land fires stem not only from biophysical and climatic conditions but also from weak environmental governance and cross-institutional coordination in their management. In a global context, forest and land

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fire mitigation has direct relevance to the achievement of the Sustainable Development Goals (SDGs), particularly Goal 13 (Addressing Climate Change) and Goal 15 (Maintaining Terrestrial Ecosystems), which emphasize the importance of strengthening institutional capacity and community participation in maintaining environmental sustainability.

The collaborative governance approach has become an important paradigm in addressing the complexities of managing ecological disasters such as forest and land fires. Collaborative governance is a collective decision-making process between public and non-public actors based on the principles of mutual trust, face-to-face dialogue, and a shared commitment to achieving public goals [1]. This approach is effective in addressing cross-sectoral issues, such as forest fires, because it creates adaptive and inclusive coordination mechanisms. A recent study in the International Journal of Disaster Risk Reduction confirms that multi-actor collaboration strengthens the adaptive capacity of local governments in reducing disaster risk through role allocation, information transparency, and cross-agency coordination [2].

In the context of strengthening collaboration, the Pentahelix model offers an extension of the triple helix and quadruple helix concepts by adding the role of society and media as key components in public governance innovation. This model brings together five important groups: the government, schools, businesses, communities, and the media [3]. Another study explain that the Pentahelix serves as an integrative framework for building sustainable disaster resilience, as it encourages synergy between academic innovation, business resources, government policy support, community participation, and media dissemination [4]. In the context of forest and land fire mitigation in Central Kalimantan, the integration of this model is crucial for strengthening coordination mechanisms and public engagement at the local level.

Various previous studies have highlighted the importance of collaboration in forest and land fire mitigation, but most remain sectoral and administrative in nature. Some studies emphasizes the importance of local wisdom in collaborative governance [5], while others points to weak institutional coordination and limited human resources in implementing disaster mitigation at the regional level [6]. However, research systematically integrating the Pentahelix model into a collaborative governance framework for forest and land fire mitigation at the local level remains very limited. Nevertheless, cross-national studies demonstrate that collaborative governance based on multi-actor networks can strengthen the effectiveness of environmental policies. For example, research published in Ecology and Society state that effective forest fire management requires an integrated institutional system, social innovation, and local community capacity [7]. This research represents a significant advancement in the field, as it develops a collaborative framework that empirically integrates collaborative governance theory and the Pentahelix model for regional forest and land fire mitigation.

This research is novel in three main aspects. First, conceptually, it integrates two major approaches, collaborative governance and the pentahelix model, into a single adaptive framework for sustainable forest and land fire mitigation. Second, methodologically, it offers an actor-network analysis-based approach to assess the dynamics of interactions between actors in forest and land fire mitigation. Third, it empirically situates the local context of East Kotawaringin Regency as a social laboratory for the development of collaborative models that facilitate the attainment of SDGs 13 and 15. Therefore, the results of this study are expected to make a tangible contribution to strengthening environmental governance in Indonesia, while enriching the international literature on the integration of multi-actor governance in ecological disaster management.

2 Methods

2.1 Research approach and design

This research employed a qualitative approach with a Comparative Qualitative Analysis (QCA) design. This qualitative approach was chosen because it allows for in-depth exploration of complex social and institutional phenomena within the context of collaborative governance for forest and land fire mitigation in East Kotawaringin Regency, Central Kalimantan. The QCA design was used to understand the configurative causal relationships between actors in the Pentahelix model—including government, academia, business, communities, and the media—as elements forming sustainable collaboration.

QCA is a method that bridges qualitative and quantitative approaches through set-theoretic analysis to identify the combination of conditions that produce an outcome [8]. This approach is relevant for examining collaborative governance, which is multi-actor and context-dependent [9]. Furthermore, the qualitative design employed adheres to the principles of naturalistic inquiry, where social reality is understood contextually and interpretively through the perspectives of the actors involved in the ecological disaster mitigation process [10].

Thus, this research not only attempts to describe the phenomenon but also explores the causal patterns between social and institutional variables that shape the effectiveness of collaborative governance at the local level (governance effectiveness).

2.2 Data analysis techniques

Data were analyzed using a Qualitative Comparative Analysis (QCA) approach, which allows researchers to identify combinations of factors that contribute to the effectiveness of collaborative governance. The analysis was conducted in three main stages: (1) Data condensation and coding which includes interview transcripts, observations, and documents were coded based on themes of collaboration, actor roles, institutional barriers, and policy innovations. (2) Condition calibration where each case (actor or institution) was classified on a membership score between 0 and 1 to determine the extent to which certain conditions were present in the context under study [8]. (3) Configurative analysis which was conducted to identify causal recipes or combinations of factors that explain the success and failure of collaboration (governance outcomes).

This approach results a non-linear but systemic understanding of the dynamics of forest and land fire mitigation, in qualitative Comparative analysis: an introduction to Research Design and Application, which emphasizes the importance of social configurations in the study of public policy and disaster management [11].

2.3 Validity and reliability

To ensure the validity and reliability of the research, four trustworthiness criteria were applied, namely [10] : (1) Credibility, conducted through member checking, triangulation of sources and methods, and cross-informant comparisons. (2) Transferability, presented a detailed, contextual description so that the findings can be applied to areas with similar characteristics. (3) Dependability, detailed recording of the entire research process is conducted in an audit trail to ensure methodological consistency. (4) Confirmability, verification of results are conducted through peer debriefing and comparison with empirical data to avoid subjective researcher error.

These validation principles refer to qualitative research best practices widely applied in reputable journals such as Qualitative Research, Public Administration Review, and the International Journal of Disaster Risk Reduction.

3 Results and Discussion

3.1 The dynamics of multi-actor collaboration in Forest and Land fire mitigation

Research results show that forest and land fire mitigation (karhutla) in East Kotawaringin Regency is carried out through a collaborative governance system involving five main elements in the Pentahelix model: government, academia, the business sector, communities, and the media. These five actors form a dynamic and adaptive network to address the recurring fire cycle each year.

The local government, through the Regional Disaster Management Agency (BPBD), the Forestry Service, and Manggala Agni, acts as the primary coordinator and policy driver. Local communities—particularly the Fire Awareness Community (MPA)—are key actors at the grassroots level, conducting patrols, outreach, and hotspot early detection. Academic institutions such as Palangka Raya University and CIMTROP provide support through spatial research, peat monitoring technology, and science-based mitigation training. Meanwhile, the business sector contributes through CSR programs, the provision of fire extinguishers, and logistical support. The media plays a strategic role as an agent of transparency and dissemination of public knowledge regarding forest and land fire policies and early warnings.

Actor-network analysis shows that government-community relationships have the highest level of interaction and the strongest mutual trust, followed by partnerships between government and academia. However, relations between the business world and the media remain sporadic. This pattern confirms that trust-building and cross-sector communication are the main foundations for forming effective collaborations, in accordance with the theory of Collaborative Governance [1]. In the context of the SDGs, this configuration directly strengthens SDG target 13.1, namely increasing adaptive capacity to climate change risks at the local level.

3.2 Effectiveness of collaborative governance and pentahelix performance

The effectiveness of collaboration in forest and land fire mitigation shows moderate results. Based on indicators of trust, shared motivation, and joint action, local governments have succeeded in creating a cross-agency coordination system, although it remains predominantly top-down. Cross-agency coordination forums operate intensively only during the emergency response period, but have not been permanently institutionalized. Consistent with this, that adaptive governance in regions often develops situationally and crisis-driven, rather than systemically [2].

In the pre-disaster phase, synergy between academia and the business sector demonstrated significant contributions through the development of satellite imagery-based fire risk maps, geospatial information systems, and community training. This collaboration helped strengthen early warning systems, a key indicator of SDG 13.3, related to increasing awareness and capacity for climate change mitigation. However, during the emergency response and rehabilitation phases, the intensity of collaboration decreased due to limited human resources, overlapping authorities, and the absence of a sustainable collaborative forum.

Substantively, the Pentahelix model has driven increased effectiveness in forest and land fire mitigation through cross-sector synergy, although the degree of integration is not yet optimal. This indicates that collaboration in East Kotawaringin has evolved toward an adaptive collaborative governance model, where relationships between actors are no longer linear but mutually reinforcing in the context of dynamic climate change. This finding demonstrates direct achievements towards SDG 13 (Climate Action), as collaborative governance has been shown to strengthen community-based resilience mechanisms and knowledge co-production.

3.3 Social power, local innovation, and adaptive learning

The social dimension is a crucial element in the effectiveness of collaboration. Local wisdom of the Dayak community—such as the customary prohibition against indiscriminate burning and the tradition of mutual cooperation in land preservation—strengthens the social legitimacy of mitigation programs. These values serve as social capital that increases trust between actors and supports the sustainability of collaboration [12, 13].

Social innovation also emerges in the form of the hotspot-free village incentive, a reward mechanism for villages that successfully reduce the number of fires each year. This program not only raises community ecological awareness but also strengthens the community-based monitoring system. This scheme establishes a social learning mechanism, where communities learn from successful practices across regions and implement strategies adaptive to local conditions.

This adaptive learning process creates a positive feedback loop between communities and the government, thus building a more resilient mitigation system. From a global perspective, such mechanisms reflect the concrete implementation of SDGs 13.1.3 and 15.1, namely strengthening the role of communities in the sustainable management of terrestrial ecosystems. Thus, the novelty of this research lies not only in its collaborative structure but also in the social transformations that emerge from multi-actor interactions.

3.4 Implementation challenges and institutional limitations

Although cross-sector collaboration has been ongoing, this study identified several structural and institutional barriers. First, overlapping authority between agencies such as the Regional Disaster Management Agency (BPBD), the Forestry Service, and the National Agency for Strategic and Strategic Planning (BRG) leads to inefficiencies in mitigation implementation. Second, mitigation budget allocations are still short-term and dependent on annual priorities. Third, human resource capacity at the village level is uneven, particularly in the use of fire monitoring technology.

From a social perspective, community participation still tends to be reactive, especially when disasters occur [14]. Sustainable participatory mechanisms have not yet been fully institutionalized. These challenges highlight the need for institutional redesign to ensure a more systemic implementation of the Pentahelix-based collaboration system. Institutional strengthening is crucial not only to improve coordination efficiency but also to ensure the sustainability of cross-sector collaboration that contributes to SDG 15 (Life on Land), particularly target 15.2 on sustainable forest management.

3.5 Integration of the pentahelix collaborative governance model as an sdgs-oriented adaptive model

The integration of the Pentahelix model with Collaborative Governance theory produces a new form of governance called the Adaptive Pentahelix Collaborative Governance Model. This model positions the interaction of the five helices as an interdependent adaptive system, where academic knowledge, public policy, business innovation, community participation, and media communication combine to form a governance ecosystem that is resilient to ecological disasters.

This model empirically demonstrates that: (1) Successful forest and land fire mitigation depends on the strength of social networks and trust between actors; (2) Inter-helix synergy accelerates the achievement of the SDGs by increasing adaptive capacity and ecosystem conservation; and (3) Data-driven collaboration and social innovation create sustainable and replicable governance at the local level.

Thus, this research provides a conceptual contribution in expanding Collaborative Governance theory toward an SDG-driven governance model [15]. This novelty confirms that effective collaborative governance is not merely an administrative instrument, but rather an adaptive strategy for achieving environmental sustainability in accordance with the global mandate of SDGs 13 and 15.

This research presents three main novelties. First, conceptually, this model integrates Collaborative Governance [1] with the Pentahelix Innovation Ecosystem [3] into an adaptive, SDG-oriented framework. Second, methodologically, the actor-network analysis approach is able to map empirical interactions between actors and comprehensively explain collaborative power structures. Third, empirically, this study confirms that community-based collaboration in East Kotawaringin serves as a social laboratory for sustainable collaborative governance models in Indonesia.

From a policy perspective, this study recommends the establishment of a Regional Pentahelix Forest and Land Fire Governance Forum as a permanent institutional platform to strengthen coordination, share real-time data, and oversee a mitigation agenda aligned with the SDGs. Integration of cross-sectoral fire information systems and environmental performance-based incentives can improve policy efficiency while strengthening local climate resilience.

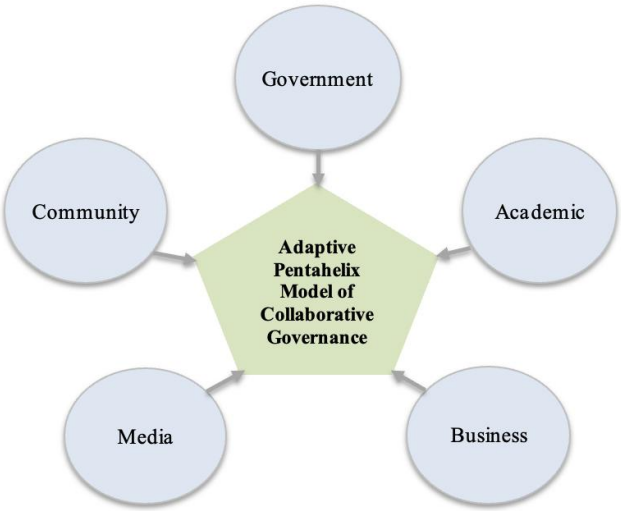

Fig. 1. Adaptive Pentahelix Collaborative Governance for Suistainable Fire Mitigation

4 Conclusion

The integration of the Pentahelix model into collaborative governance in East Kotawaringin Regency proves that cross-actor collaboration can be an effective mechanism in sustainable forest and land fire mitigation. This model not only strengthens institutional coordination and adaptive capacity, but also creates a direct impact on the achievement of SDG 13 (Climate Action) and SDG 15 (Life on Land). Through adaptive interactions between actors, based on trust, innovation, and local values, this study confirms that Pentahelix-based collaborative governance is a real form of SDG-oriented environmental governance — where policy, technology, and society combine to maintain ecosystem sustainability and climate resilience at the local and global levels.

Acknowledgment

The author gratefully acknowledges the support of the Regional Government of Kotawaringin Timur, the Provincial Environmental and Forestry Office of Central Kalimantan, and BPBD for facilitating field research. Sincere appreciation is extended to Manggala Agni, Masyarakat Peduli Api (MPA), and CIMTROP Universitas Palangka Raya for their collaboration and technical input. The author also thanks the participating community members, media, and private sector partners whose insights strengthened this study. This research was guided by the UNDP and UN SDG frameworks, aligning its outcomes with *SDG 13 (Climate Action)* and *SDG 15 (Life on Land).* And also, the author thank to LPDP EQUITY for supporting this publication. This publication is funded by the Indonesian Endowment Fund for Education (LPDP) on behalf of the Indonesian Ministry of Higher Education, Science and Technology, and managed under the EQUITY Program (Contract No. 4312/B3/DT.03.08/2025).

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