



Climate Change and Traditional Knowledge: Indigenous Adaptation Strategies in Papua and Their Legal Implications

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Abstract

This research investigates the role of traditional knowledge in indigenous adaptation strategies to climate change in Papua, Indonesia, and explores the legal implications of recognizing and integrating these practices within national and international climate policy frameworks. Indigenous Papuans have developed unique, place-based knowledge systems to manage their environments and adapt to climate variability, including shifting weather patterns, changing agricultural cycles, and rising sea levels. This study examines how these traditional adaptation practices—ranging from sustainable farming techniques to water management systems—have helped communities cope with the impacts of climate change. Using qualitative research methods, including interviews with indigenous leaders, community members, and environmental activists, the research also critically assesses the extent to which these traditional knowledge systems are acknowledged and supported by the Indonesian legal system. The findings highlight a significant gap between the cultural value of indigenous knowledge and its legal recognition, particularly in the context of land rights, conservation practices, and climate adaptation policies. While Indonesia's national climate policies increasingly emphasize participatory approaches, indigenous communities in Papua often face legal and institutional barriers that prevent them from fully utilizing their traditional knowledge in climate change adaptation. The study argues that incorporating indigenous knowledge into legal frameworks can enhance climate resilience while ensuring that indigenous rights are respected. The



research concludes with policy recommendations aimed at strengthening legal protections for indigenous knowledge and promoting its integration into national climate strategies.

[Penelitian ini menyelidiki peran pengetahuan tradisional dalam strategi adaptasi masyarakat adat terhadap perubahan iklim di Papua, Indonesia, dan mengeksplorasi implikasi hukum dari pengakuan dan pengintegrasian praktik-praktik ini dalam kerangka kebijakan iklim nasional dan internasional. Masyarakat adat Papua telah mengembangkan sistem pengetahuan berbasis tempat yang unik untuk mengelola lingkungan mereka dan beradaptasi dengan variabilitas iklim, termasuk pergeseran pola cuaca, perubahan siklus pertanian, dan kenaikan permukaan laut. Studi ini meneliti bagaimana praktik adaptasi tradisional ini—mulai dari teknik pertanian berkelanjutan hingga sistem pengelolaan air—telah membantu masyarakat mengatasi dampak perubahan iklim. Dengan menggunakan metode penelitian kualitatif, termasuk wawancara dengan para pemimpin adat, anggota masyarakat, dan aktivis lingkungan, penelitian ini juga secara kritis menilai sejauh mana sistem pengetahuan tradisional ini diakui dan didukung oleh sistem hukum Indonesia. Temuan-temuan tersebut menyoroti kesenjangan yang signifikan antara nilai budaya pengetahuan adat dan pengakuan hukumnya, khususnya dalam konteks hak atas tanah, praktik konservasi, dan kebijakan adaptasi iklim. Meskipun kebijakan iklim nasional Indonesia semakin menekankan pendekatan partisipatif, masyarakat adat di Papua sering menghadapi hambatan hukum dan kelembagaan yang mencegah mereka untuk sepenuhnya memanfaatkan pengetahuan tradisional mereka dalam adaptasi perubahan iklim. Studi ini berpendapat bahwa pengintegrasian pengetahuan adat ke dalam kerangka hukum dapat meningkatkan ketahanan iklim sekaligus memastikan penghormatan terhadap hak-hak masyarakat adat. Penelitian ini diakhiri dengan rekomendasi kebijakan yang bertujuan untuk memperkuat perlindungan hukum bagi pengetahuan adat dan mendorong integrasinya ke dalam strategi iklim nasional.]

Keywords: Climate Change, Traditional Knowledge, Indigenous People, Papua, Traditional Adaptation

Introduction

Climate change has become one of the most significant environmental and governance challenges of the twenty-first century, affecting ecosystems, economies, and human societies at multiple spatial scales. The increasing frequency and intensity of extreme weather events, changing precipitation patterns, sea-level rise, and biodiversity loss have intensified the vulnerability of communities whose livelihoods depend directly on natural resources. Among these, Indigenous peoples are widely recognized as one of the most climate-sensitive populations because their social, cultural, and economic systems are

closely intertwined with forests, rivers, coastal ecosystems, and customary territories (IPCC, 2023; Whyte, 2013). Despite contributing minimally to global greenhouse gas emissions, Indigenous communities often experience disproportionate impacts from climate change while receiving relatively limited institutional support for adaptation initiatives (Ford et al., 2020).

Recent scholarship has challenged the long-standing assumption that climate adaptation should primarily rely on scientific and technological innovation. Instead, researchers increasingly argue that effective adaptation requires integrating multiple knowledge systems, including Indigenous and local knowledge, scientific observations, and community-based governance mechanisms (Reyes-García et al., 2016; Williams & Hardison, 2013). Indigenous knowledge is no longer viewed merely as a collection of traditional beliefs or cultural practices but as a dynamic system of environmental understanding developed through generations of observation, experimentation, and interaction with local ecosystems. Such knowledge enables Indigenous communities to identify subtle ecological changes, anticipate seasonal variability, and implement adaptive resource management strategies that strengthen both environmental sustainability and community resilience (Berkes, 2018; Williams & Hardison, 2013).

Traditional ecological knowledge (TEK) has consequently emerged as an important component of climate adaptation research. Unlike conventional scientific knowledge, which frequently depends on standardized measurements and predictive modelling, TEK is grounded in long-term lived experience and continuous interaction between humans and nature. It encompasses ecological observations, customary institutions, cultural values, spiritual beliefs, and locally developed management practices that collectively shape how Indigenous communities respond to environmental change (Berkes, 2018). Increasing empirical evidence suggests that adaptation policies incorporating TEK often produce more socially acceptable, culturally appropriate, and ecologically sustainable outcomes than policies relying exclusively on centralized scientific approaches (Reyes-García et al., 2016; Ford et al., 2020). Consequently, international climate governance has progressively shifted from treating Indigenous knowledge as supplementary information to recognizing it as an essential pillar of adaptive governance.

This paradigm shift is reflected in several international legal instruments. The Paris Agreement explicitly recognizes that adaptation action should follow participatory and country-driven approaches while taking into consideration traditional knowledge, Indigenous knowledge, and local knowledge systems where appropriate. Likewise, the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP) affirms the rights of Indigenous peoples to maintain, control, protect, and develop their cultural heritage and traditional knowledge. Similarly, Article 8(j) of the Convention on Biological Diversity (CBD)

and the Kunming–Montreal Global Biodiversity Framework emphasize the importance of respecting Indigenous knowledge in biodiversity conservation and ecosystem governance. These international developments demonstrate an evolving legal understanding that Indigenous knowledge constitutes not only cultural heritage but also a strategic resource for achieving climate resilience and sustainable development (Williams & Hardison, 2013).

Although international recognition has expanded considerably during the past decade, translating these normative commitments into national legal frameworks remains a significant challenge. Many developing countries continue to adopt climate adaptation policies dominated by technocratic planning and centralized governance, leaving limited institutional space for Indigenous participation in environmental decision-making. In numerous jurisdictions, legal uncertainty surrounding customary land tenure, intellectual property rights, and Indigenous governance institutions reduces the capacity of local communities to apply their traditional adaptation practices effectively (Williams & Hardison, 2013; Ford et al., 2020). Consequently, the effectiveness of climate adaptation is influenced not only by ecological conditions but also by the extent to which legal systems recognize Indigenous rights and facilitate knowledge integration.

Indonesia provides a particularly important context for examining this relationship. As one of the world's largest archipelagic states, Indonesia possesses extraordinary biological and cultural diversity while simultaneously facing increasing climate-related risks. Rising temperatures, shifting rainfall patterns, coastal inundation, prolonged droughts, flooding, and ecosystem degradation have become increasingly evident across many regions of the country. These environmental changes threaten food security, biodiversity conservation, water availability, and rural livelihoods, particularly among Indigenous and customary communities that continue to depend heavily on natural resources. At the same time, Indonesia has committed to strengthening climate adaptation through its Nationally Determined Contribution (NDC), the National Action Plan for Climate Change Adaptation (RAN-API), and various environmental governance reforms. Nevertheless, questions remain regarding the extent to which these policy instruments meaningfully recognize Indigenous knowledge as part of national climate governance.

The relevance of this issue becomes particularly apparent in Papua, one of Indonesia's most ecologically intact and culturally diverse regions. Papua contains extensive tropical rainforests, peatlands, mangrove ecosystems, mountain landscapes, and river basins that support hundreds of Indigenous communities with distinct customary governance systems and ecological traditions. For centuries, Indigenous Papuans have relied on traditional knowledge to regulate agricultural cycles, manage forests, conserve biodiversity, organize hunting and fishing activities, and respond to environmental variability. These practices are embedded within customary institutions that govern access

to natural resources, collective decision-making, and intergenerational knowledge transmission.

Empirical evidence from Papua demonstrates that Indigenous communities possess sophisticated understandings of local climate variability that closely correspond with scientific observations. In their influential study conducted in the Mamberamo region, Boissière et al. (2013) found that Indigenous communities were able to identify changing rainfall patterns, flooding frequency, seasonal variability, and ecological disturbances through long-term environmental observations. More importantly, the study showed that community responses to climate variability were strongly influenced by traditional ecological knowledge and customary resource management systems rather than by externally designed adaptation programs. The authors concluded that adaptation strategies are more likely to succeed when they address locally perceived priorities and incorporate Indigenous ecological knowledge into climate planning.

The findings of Boissière et al. (2013) also reveal an important dimension that is frequently overlooked in climate governance literature. While climate variability undoubtedly affects Indigenous livelihoods, local communities often perceive non-climatic pressures—including logging, mining, infrastructure expansion, and political decentralization—as equally significant threats to their adaptive capacity. This observation suggests that climate adaptation cannot be separated from broader governance challenges involving land tenure, environmental justice, and Indigenous rights. Similar conclusions have been reported in comparative studies conducted in Australia, Canada, and the Arctic, where researchers argue that Indigenous adaptation strategies are inseparable from cultural continuity, territorial security, and community self-determination (Green et al., 2010; Whyte, 2013; Ford et al., 2020).

Despite growing international recognition of Indigenous knowledge, Indigenous communities in Papua continue to encounter multiple structural challenges. Rapid land-use change, commercial logging, mining activities, infrastructure development, and competing conservation policies have transformed many customary landscapes, reducing community access to traditional resources and weakening customary governance institutions. These pressures are further compounded by climate change, which alters ecological processes that Indigenous communities have historically relied upon to regulate agricultural production, hunting seasons, and freshwater management. Consequently, the resilience of Indigenous communities increasingly depends not only on their capacity to adapt ecologically but also on the legal and institutional environment that determines whether customary knowledge and governance systems are recognized and protected.

Although the international recognition of Indigenous knowledge has expanded considerably, the practical integration of traditional ecological

knowledge into national climate governance remains inconsistent across many countries. Existing adaptation policies continue to prioritize scientific modelling, technological innovation, and centralized planning while paying comparatively less attention to Indigenous governance systems that have historically enabled local communities to respond to environmental uncertainty. Consequently, climate adaptation policies frequently fail to accommodate the socio-cultural contexts in which Indigenous knowledge is produced, transmitted, and applied (Ford et al., 2020; Zant et al., 2024). This institutional imbalance is particularly evident in countries characterized by legal pluralism, where statutory law coexists with customary legal systems but does not necessarily provide equal recognition or protection for Indigenous governance institutions.

Indonesia exemplifies this institutional complexity. Although Article 18B paragraph (2) of the 1945 Constitution recognizes the existence of Indigenous peoples (*masyarakat hukum adat*), the implementation of this constitutional mandate remains fragmented across sectoral legislation governing forestry, environmental protection, agrarian affairs, and regional governance. The enactment of Constitutional Court Decision No. 35/PUU-X/2012 represented a significant milestone by affirming that customary forests (*hutan adat*) are no longer classified as state forests. Nevertheless, subsequent implementation has depended largely on administrative recognition by local governments, resulting in uneven legal protection among Indigenous communities across Indonesia (Arizona et al., 2019; Abdullah et al., 2024). Consequently, legal recognition often remains symbolic rather than substantive, particularly in regions experiencing competing interests over natural resources.

The situation is especially relevant in Papua, where customary territories overlap with areas of high ecological value and intensive natural resource extraction. Papua contains one of the largest remaining tropical forest landscapes in Southeast Asia and supports hundreds of Indigenous groups whose customary institutions regulate access to forests, rivers, hunting grounds, and coastal ecosystems. These institutions embody complex ecological norms developed through long-term interactions with local environments and continue to shape community responses to changing climatic conditions. However, increasing deforestation, mining expansion, infrastructure development, and agricultural conversion have transformed customary landscapes while simultaneously reducing Indigenous communities' capacity to implement traditional adaptation practices (Boissière et al., 2013).

Climate change further intensifies these pressures by altering rainfall patterns, increasing flood frequency, changing agricultural calendars, and affecting biodiversity upon which Indigenous livelihoods depend. Unlike short-term environmental disturbances, these climatic changes interact with social, legal, and economic drivers that collectively influence community resilience. Consequently, adaptation should not be understood merely as a technical

response to climatic hazards but rather as a governance process involving rights, institutions, participation, and access to customary resources. Recent scholarship increasingly argues that adaptation effectiveness depends not only on environmental knowledge but also on the extent to which Indigenous peoples retain decision-making authority over their traditional territories and knowledge systems (Ford et al., 2020; Zant et al., 2024).

This governance perspective is highly relevant in the Indonesian legal context because climate adaptation policies remain predominantly state-centered. National climate strategies—including Indonesia's Nationally Determined Contribution (NDC) and the National Action Plan for Climate Change Adaptation (RAN-API)—emphasize resilience, ecosystem management, and community participation. Nevertheless, explicit legal mechanisms governing the recognition, protection, and utilization of Indigenous knowledge within climate adaptation remain limited. Existing regulations tend to acknowledge community participation in general terms while providing little guidance regarding the institutional role of customary authorities, the legal status of traditional ecological knowledge, or mechanisms for integrating Indigenous decision-making into climate governance processes (Rafiqi, 2025).

This disconnect between constitutional recognition and practical implementation has broader implications for environmental governance. Legal uncertainty surrounding customary land tenure affects not only Indigenous rights but also the sustainability of climate adaptation initiatives. Numerous studies demonstrate that secure tenure arrangements strengthen conservation outcomes, improve forest governance, and enhance local adaptive capacity because communities possess stronger incentives to maintain ecological integrity when their territorial rights are legally protected (Reyes-García et al., 2016; Berkes, 2018; Abdullah et al., 2024). Conversely, weak legal recognition frequently undermines both biodiversity conservation and climate resilience by encouraging overlapping claims, resource conflicts, and institutional fragmentation.

Previous research has generated substantial insights into Indigenous ecological knowledge and community-based adaptation across different geographical contexts. Comparative studies in the Arctic, Australia, Latin America, and Southeast Asia consistently demonstrate that Indigenous communities employ sophisticated environmental monitoring systems capable of identifying long-term ecological changes and informing adaptive resource management (Whyte, 2013; Ford et al., 2020; Zant et al., 2024). Similarly, Indonesian studies have examined customary forest governance, Indigenous participation in environmental conservation, and community perceptions of climate variability, particularly within forest-dependent communities (Boissière et al., 2013; Abdullah et al., 2024).

Despite these advances, three important research gaps remain.

First, much of the existing literature examines Indigenous knowledge primarily from ecological, anthropological, or environmental management perspectives. Comparatively fewer studies analyze traditional ecological knowledge through the lens of environmental law and climate governance, particularly regarding how legal frameworks facilitate—or constrain—the institutionalization of Indigenous adaptation strategies.

Second, previous Indonesian studies often discuss Indigenous rights, customary forests, and environmental governance independently from climate adaptation. While legal scholarship has extensively debated constitutional recognition of Indigenous peoples and customary land rights, relatively little attention has been devoted to examining how these legal arrangements influence climate resilience and adaptation planning in practice (Arizona et al., 2019; Rafiqi, 2025).

Third, empirical research focusing specifically on Papua remains limited. Existing studies have successfully documented Indigenous perceptions of climatic variability and community adaptation practices, yet few have comprehensively investigated the interaction between traditional ecological knowledge, legal recognition, and climate governance within a single analytical framework. Consequently, the relationship between Indigenous adaptation strategies and environmental law remains insufficiently explored despite its growing relevance for national climate policy.

This article seeks to address these gaps by examining how Indigenous traditional knowledge contributes to climate change adaptation among Indigenous communities in Papua while simultaneously evaluating the legal implications of integrating such knowledge into Indonesia's climate governance framework. Rather than treating traditional knowledge solely as a cultural asset, this study conceptualizes Indigenous knowledge as a dynamic governance system that influences environmental decision-making, ecosystem management, and community resilience. In doing so, the article bridges environmental law, Indigenous rights scholarship, and climate adaptation studies within a unified analytical framework.

The novelty of this research lies in three principal aspects. First, it integrates traditional ecological knowledge with environmental legal analysis, an approach that remains relatively underdeveloped within Indonesian climate governance literature. Second, it employs legal pluralism as an analytical perspective to explain how interactions between state law and customary institutions influence Indigenous adaptive capacity. Third, the study situates Papua within broader international debates concerning rights-based climate adaptation, thereby connecting local empirical evidence with evolving global norms under the Paris Agreement, the Convention on Biological Diversity, and the United Nations Declaration on the Rights of Indigenous Peoples. Accordingly, this study addresses the following research questions:

1. How do Indigenous communities in Papua utilize traditional ecological knowledge to adapt to climate change?
2. To what extent do Indonesian legal frameworks recognize and support Indigenous adaptation practices?
3. What legal and policy reforms are necessary to strengthen the integration of Indigenous knowledge into national climate governance?

By answering these questions, this article contributes to three interconnected bodies of scholarship. First, it enriches the literature on Indigenous climate adaptation by demonstrating that traditional ecological knowledge functions as a living governance system rather than merely a repository of cultural practices. Second, it advances environmental law scholarship by critically assessing the compatibility between Indonesian legal frameworks and international standards concerning Indigenous rights and climate governance. Third, it provides policy recommendations for developing a more inclusive and legally coherent climate adaptation framework capable of enhancing both environmental sustainability and Indigenous self-determination.

Literature Review

A. Climate Change Adaptation Theory

Climate change adaptation has evolved from a primarily technical response to climatic hazards into a broader framework concerned with social, ecological, institutional, and political dimensions of vulnerability and resilience. Early adaptation research largely emphasized adjustments in human and ecological systems to reduce exposure and sensitivity to climate impacts, often focusing on technological interventions, infrastructure development, and risk management strategies (Smit & Wandel, 2006). However, subsequent scholarship has demonstrated that adaptation outcomes are not determined solely by climatic conditions but are strongly influenced by socioeconomic structures, governance arrangements, cultural values, and access to resources (Adger et al., 2005; O'Brien, 2012). This evolution has shifted adaptation theory from a hazard-oriented perspective toward a more integrated understanding of climate resilience as a complex interaction between environmental processes and social systems.

The vulnerability-based approach represents one of the most influential perspectives in climate adaptation studies. This approach argues that climate impacts are shaped not only by exposure to environmental hazards but also by underlying social, economic, and political conditions that determine communities' capacity to respond (Adger, 2006). Vulnerability is therefore understood as a socially constructed phenomenon rather than a purely biophysical condition. From this perspective, Indigenous communities may experience heightened climate vulnerability not because of a lack of adaptive knowledge, but because of historical marginalization, insecure land tenure,

limited political representation, and inadequate institutional recognition (Ford et al., 2020). This distinction is particularly important in the context of Papua, where Indigenous communities possess extensive ecological knowledge but often face structural constraints related to land governance and legal recognition.

A significant development within adaptation theory is the emergence of the social-ecological resilience perspective, which emphasizes the capacity of communities and ecosystems to absorb disturbances while maintaining essential functions and identities (Folke, 2006; Berkes, 2018). Unlike conventional adaptation approaches that often assume environmental change can be controlled through external interventions, resilience theory highlights the importance of flexibility, learning, diversity, and local capacity. Indigenous knowledge systems are increasingly recognized within this framework because they represent accumulated experiences of environmental adaptation developed through long-term interactions between communities and ecosystems (Berkes, 2018). Traditional ecological knowledge contributes to resilience by enabling communities to monitor ecological changes, maintain biodiversity, and adjust resource management practices according to changing environmental conditions.

The resilience perspective is particularly relevant for Indigenous communities because adaptation is not merely a response to climate hazards but also a continuation of cultural and ecological relationships. Indigenous adaptation strategies often integrate environmental observation, social institutions, spiritual values, and customary regulations. For example, Indigenous communities may adjust agricultural calendars based on seasonal indicators, regulate resource extraction through customary rules, and protect ecologically significant areas through traditional conservation practices. Such strategies demonstrate that adaptation is embedded within broader systems of knowledge and governance rather than existing as isolated technical solutions (Reyes-García et al., 2016; Whyte, 2013).

Recent literature has further advanced adaptation theory through the concept of transformational adaptation, which recognizes that some climate challenges cannot be addressed through incremental adjustments alone. Transformational adaptation involves fundamental changes in governance systems, institutional structures, and relationships between humans and the environment (Kates et al., 2012; Pelling, 2011). Within Indigenous contexts, transformation often relates to restoring community authority, strengthening customary governance, and addressing historical inequalities that limit adaptive capacity. Therefore, climate adaptation requires not only improving communities' ability to cope with environmental changes but also transforming the institutional conditions that produce vulnerability.

This perspective has significant implications for understanding Indigenous adaptation in Papua. Traditional adaptation practices among Papuan communities cannot be interpreted simply as historical survival strategies;

rather, they represent adaptive governance systems that continue to evolve in response to contemporary environmental pressures. Indigenous agricultural practices, forest management systems, coastal resource governance, and customary institutions demonstrate forms of adaptive capacity developed through generations of ecological learning. Research from Papua and neighboring Pacific regions indicates that Indigenous communities possess detailed understandings of environmental variability and employ locally specific strategies to respond to climate-related changes (Boissière et al., 2013; Lede et al., 2026). These findings challenge assumptions that Indigenous knowledge represents static traditions disconnected from contemporary climate challenges. Instead, Indigenous knowledge functions as a dynamic system capable of innovation and adaptation.

Nevertheless, adaptation theory has also been criticized for insufficiently addressing questions of power, justice, and legal recognition. Critics argue that resilience-based approaches may unintentionally place responsibility for adaptation on vulnerable communities while overlooking structural causes of vulnerability, including colonial histories, resource exploitation, and unequal governance systems (Cannon & Müller-Mahn, 2010; Eriksen et al., 2021). In this context, Indigenous climate adaptation must be examined through a climate justice perspective that recognizes both the vulnerability and agency of Indigenous peoples. The ability of communities to apply traditional knowledge depends heavily on whether legal and political systems recognize their rights to land, resources, participation, and cultural continuity.

The relationship between adaptation theory and legal governance is therefore central to understanding Indigenous climate resilience. While traditional knowledge provides locally appropriate adaptation strategies, the effectiveness of these strategies depends on institutional frameworks that enable communities to maintain and transmit their knowledge systems. Legal recognition of customary territories, protection of Indigenous intellectual knowledge, and meaningful participation in climate decision-making are increasingly identified as essential components of rights-based adaptation approaches (Bavikatte & Robinson, 2011; Tauli-Corpuz et al., 2018). In this regard, Indigenous adaptation is not only an environmental issue but also a legal and governance challenge.

Within the Indonesian context, this theoretical perspective highlights the importance of examining climate adaptation beyond government-led programs. National adaptation policies often emphasize community participation, ecosystem management, and resilience building; however, the extent to which Indigenous knowledge systems are institutionally integrated remains uncertain. Recent Indonesian studies demonstrate that local knowledge contributes significantly to sustainable forest management, agricultural resilience, and climate literacy, yet these practices frequently remain outside formal climate

governance structures (Budiman & Oue, 2025; Firnadi, 2024). Therefore, analyzing Indigenous adaptation in Papua requires an interdisciplinary framework that combines climate adaptation theory, Indigenous knowledge studies, and environmental law.

Based on this theoretical foundation, this study conceptualizes Indigenous climate adaptation as a social-ecological and legal process. Traditional knowledge provides ecological information and adaptive practices, customary institutions provide governance mechanisms, while legal recognition determines whether these systems can operate effectively within broader climate governance frameworks. This integrated perspective provides the basis for examining how Indigenous Papuan communities utilize traditional knowledge to respond to climate change and how Indonesian legal systems influence the sustainability of these adaptation strategies.

B. Traditional Ecological Knowledge (TEK) and Indigenous Adaptation

Traditional Ecological Knowledge (TEK) has become an increasingly influential concept within environmental studies, climate adaptation research, and Indigenous rights scholarship. TEK is generally understood as a cumulative body of knowledge, practices, beliefs, and relationships developed by Indigenous and local communities through long-term interactions with specific ecosystems (Berkes, 2018). Unlike conventional scientific knowledge, which is often generated through controlled observation and standardized methodologies, TEK emerges from continuous engagement with landscapes, seasonal cycles, biodiversity patterns, and social institutions. It represents not only ecological information but also a broader worldview in which humans are understood as interconnected components of ecological systems rather than external actors managing nature (Berkes, 2018; Whyte, 2013).

The significance of TEK in climate adaptation scholarship has increased due to growing recognition that climate change generates complex and uncertain environmental conditions that cannot always be effectively addressed through universal solutions. Scientific climate models provide essential information regarding global and regional trends, yet they often lack the fine-scale ecological understanding necessary for designing locally appropriate adaptation strategies. Indigenous knowledge systems contribute complementary insights by documenting environmental changes through long-term observations and culturally embedded monitoring practices (Reyes-García et al., 2016; Tengö et al., 2017). As a result, scholars increasingly argue that combining Indigenous knowledge with scientific knowledge can improve climate assessments, enhance adaptive decision-making, and strengthen community resilience.

The contribution of TEK to climate adaptation can be observed through several dimensions. First, TEK provides detailed ecological indicators that allow

communities to identify environmental changes before they become visible through conventional monitoring systems. Indigenous communities frequently use observations of plant behavior, animal movements, water conditions, weather patterns, and landscape changes to anticipate climatic variations. Such knowledge has been documented among Indigenous communities in the Arctic, Amazon, Pacific Islands, and Southeast Asia, where local observations have contributed to understanding changing rainfall patterns, biodiversity shifts, and ecosystem degradation (Ford et al., 2016; Reyes-García et al., 2016).

Second, TEK supports adaptive resource management through practices developed under conditions of environmental uncertainty. Indigenous agricultural systems, for example, often incorporate crop diversity, seasonal adaptation, soil conservation, and flexible cultivation strategies that reduce vulnerability to climate variability. Similarly, customary forest management systems frequently establish rules regarding resource extraction, protected areas, and ecological restoration. These practices demonstrate that Indigenous adaptation is not merely reactive but involves proactive strategies designed to maintain ecosystem stability over time (Berkes, 2018; Ens et al., 2015).

Third, TEK contributes to social resilience by strengthening collective institutions and intergenerational knowledge transmission. Adaptation capacity is not determined only by technical knowledge but also by social relationships, cultural identity, and institutional arrangements. Indigenous governance systems often provide mechanisms for collective decision-making, conflict resolution, and resource allocation, enabling communities to respond collectively to environmental changes. This social dimension distinguishes TEK from purely informational approaches because knowledge is embedded within relationships between people, places, and cultural responsibilities (Tengö et al., 2017).

However, contemporary scholarship also emphasizes that TEK should not be viewed through an idealized or romanticized perspective. Earlier approaches sometimes portrayed Indigenous communities as inherently sustainable environmental managers, overlooking internal diversity, historical transformations, and contemporary challenges affecting Indigenous societies. Scholars have warned that treating Indigenous knowledge as static traditional wisdom may undermine its dynamic nature and ignore the capacity of Indigenous communities to innovate and adapt under changing social and ecological conditions (Whyte, 2013; Latulippe & Klenk, 2020). TEK is not a fixed collection of ancient practices; rather, it is a living knowledge system continuously modified through experience, external interaction, and changing environmental realities.

This perspective is particularly important in understanding Indigenous adaptation in Papua. Papuan Indigenous communities have developed diverse ecological practices associated with forests, rivers, coastal environments, and agricultural landscapes. Traditional practices such as rotational agriculture, customary forest management, seasonal resource harvesting, and sacred

ecological protection systems reflect locally adapted responses to environmental variability. These practices are embedded within customary institutions (*adat*) that regulate relationships between communities and their territories. In many parts of Papua, environmental knowledge is transmitted through oral traditions, community rituals, and daily interactions with landscapes, creating a system where ecological understanding is inseparable from cultural identity.

Research conducted in Papua provides important evidence regarding the role of Indigenous knowledge in climate adaptation. Boissière et al. (2013), examining Indigenous communities in the Mamberamo region of Papua, demonstrated that local communities possess detailed understandings of climate variability based on long-term observations of rainfall, flooding patterns, and ecological changes. Their findings indicate that Indigenous perceptions of climate change are not simply cultural interpretations but represent systematic observations that contribute to adaptive decision-making. The study also emphasized that local adaptation strategies were closely connected with livelihood practices, including forest resource management, agricultural activities, and community-based responses to environmental changes.

Similar findings have been reported in other Indonesian contexts. Studies of Indigenous and local communities in Indonesia demonstrate that customary knowledge contributes to forest conservation, agricultural sustainability, disaster preparedness, and resource management. Indigenous groups such as the Dayak, Baduy, and other customary communities have maintained environmental practices that regulate resource use and protect ecosystem functions. However, researchers also highlight that these knowledge systems increasingly face pressures from land conversion, extractive industries, market integration, and changes in governance structures (Siscawati et al., 2017; Fisher et al., 2018). These pressures demonstrate that the sustainability of TEK depends not only on community practices but also on broader political and legal conditions.

International research similarly shows that Indigenous knowledge can strengthen climate adaptation when supported by appropriate institutional frameworks. In Canada and the Arctic region, Indigenous observations have improved understanding of climate impacts on ecosystems and wildlife management. In Australia, Aboriginal knowledge systems have contributed to fire management practices and biodiversity conservation. In the Pacific Islands, Indigenous knowledge has supported coastal adaptation and disaster resilience in communities facing sea-level rise (Ford et al., 2016; Mercer et al., 2012). These examples illustrate that TEK has relevance beyond local communities and can contribute to global climate governance discussions.

Nevertheless, integrating TEK into formal climate policy remains challenging. One major challenge concerns epistemological differences between Indigenous and scientific knowledge systems. Scientific institutions often prioritize quantitative measurements, standardized methodologies, and

universal applicability, whereas Indigenous knowledge is frequently place-based, qualitative, and embedded within cultural relationships. Without appropriate mechanisms for knowledge exchange, integration efforts may result in the marginalization or extraction of Indigenous knowledge without providing meaningful benefits or recognition to Indigenous communities (Tengö et al., 2017; Latulippe & Klenk, 2020).

Another challenge concerns intellectual property rights and ownership of Indigenous knowledge. Unlike scientific knowledge, which is commonly regulated through academic and intellectual property frameworks, Indigenous knowledge is often collectively held and transmitted across generations. The commercialization or external appropriation of Indigenous knowledge raises concerns regarding consent, benefit sharing, and cultural integrity. Consequently, scholars argue that integrating TEK into climate governance requires ethical frameworks that recognize Indigenous sovereignty over knowledge production and dissemination (Bavikatte & Robinson, 2011).

In Indonesia, these challenges are closely connected with broader issues of Indigenous rights recognition. Although Indonesian law increasingly acknowledges the importance of Indigenous communities in environmental management, formal mechanisms for protecting Indigenous knowledge remain limited. Existing environmental regulations generally recognize community participation but provide insufficient protection for traditional knowledge as an intellectual, cultural, and ecological resource. This legal gap creates uncertainty regarding how Indigenous knowledge can be incorporated into national climate adaptation strategies while respecting Indigenous authority and customary governance systems.

Therefore, TEK should be understood as both an adaptive resource and a governance issue. Its effectiveness in addressing climate change depends not only on the ecological quality of Indigenous practices but also on whether political and legal systems create conditions that allow these practices to continue. In the context of Papua, examining TEK requires attention to the interaction between ecological knowledge, customary institutions, land rights, and environmental law. Such an integrated perspective moves beyond viewing Indigenous knowledge merely as a cultural asset and instead recognizes it as a fundamental component of climate resilience and sustainable governance.

C. Legal Pluralism and Indigenous Environmental Rights

The relationship between Indigenous knowledge and climate adaptation cannot be fully understood without examining the legal systems that shape the recognition, protection, and implementation of Indigenous practices. In many Indigenous territories, environmental governance operates through multiple overlapping normative systems, including state law, customary law, and community-based institutions. This condition is commonly described as legal

pluralism, referring to the coexistence of different legal orders within the same social and political space (Griffiths, 1986; von Benda-Beckmann & von Benda-Beckmann, 2006). Legal pluralism provides an important analytical framework for understanding Indigenous adaptation because traditional ecological knowledge is often embedded within customary institutions rather than formal governmental structures.

Historically, modern environmental governance has been dominated by centralized state-based legal systems that define ownership, resource management authority, and conservation responsibilities. However, scholars of legal pluralism argue that state law represents only one among multiple forms of normative regulation operating within society. Indigenous communities frequently maintain their own systems of environmental governance, including rules concerning land use, resource extraction, conservation practices, and social obligations toward ecosystems (von Benda-Beckmann & von Benda-Beckmann, 2006). These customary systems are not informal or non-legal arrangements; rather, they function as normative frameworks that regulate social and ecological relationships within Indigenous territories.

The recognition of legal pluralism has significant implications for climate adaptation governance. Climate adaptation strategies increasingly require locally appropriate responses that reflect ecological diversity and social contexts. However, when state institutions fail to recognize customary governance systems, adaptation policies may undermine existing adaptive capacities. Indigenous communities may possess effective mechanisms for managing forests, water resources, and biodiversity, but these practices can be weakened when external legal frameworks restrict customary authority or prioritize competing economic interests (Berkes, 2018; Robinson et al., 2021). Therefore, legal recognition becomes a critical factor determining whether Indigenous knowledge can contribute effectively to climate resilience.

Indigenous environmental rights have gained increasing recognition within international environmental and human rights law. The United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP) establishes several principles relevant to environmental governance, including Indigenous peoples' rights to maintain relationships with their traditional lands, participate in decision-making processes, and protect their cultural knowledge. Similarly, international environmental agreements increasingly recognize Indigenous peoples as key actors in biodiversity conservation and climate adaptation. These developments reflect a broader shift from viewing Indigenous communities as vulnerable groups requiring protection toward recognizing them as rights holders and environmental governance partners (Tauli-Corpuz et al., 2018).

The concept of rights-based climate adaptation has emerged from this shift. Unlike conventional adaptation approaches that focus primarily on reducing physical vulnerability, rights-based approaches emphasize justice, participation,

accountability, and recognition of marginalized groups. Within this framework, adaptation effectiveness depends not only on technical interventions but also on whether affected communities have meaningful authority over decisions affecting their territories and livelihoods (Schlosberg, 2012; Sultana, 2022). For Indigenous peoples, climate resilience is closely connected to the protection of land rights, cultural continuity, and self-determination.

Indonesia provides an important example of the complexities associated with legal pluralism and Indigenous environmental rights. The Indonesian Constitution recognizes the existence of Indigenous communities (*masyarakat hukum adat*) under Article 18B(2), provided that they continue to exist and their rights are consistent with national development principles. However, constitutional recognition does not automatically guarantee effective protection. The implementation of Indigenous rights remains dependent on sectoral legislation, administrative procedures, and recognition by local governments. This has created a situation where Indigenous communities possess constitutional recognition but often face difficulties in obtaining formal legal acknowledgment of their territories and governance systems.

One of the most significant developments in Indonesian Indigenous rights jurisprudence was Constitutional Court Decision No. 35/PUU-X/2012, which fundamentally changed the legal status of customary forests (*hutan adat*). The Court ruled that customary forests are not part of state forests, thereby recognizing that Indigenous communities possess rights over forests located within their customary territories. This decision represented an important advancement in acknowledging Indigenous environmental rights because forests are not merely economic resources but also spaces of cultural identity, ecological management, and social governance (Arizona et al., 2019). Nevertheless, scholars have noted that implementation remains uneven because communities must still obtain formal recognition from local authorities before customary forests can be legally registered.

This implementation gap illustrates a broader tension within Indonesian environmental governance. On the one hand, the state increasingly recognizes Indigenous participation in conservation and climate initiatives. On the other hand, development policies related to mining, infrastructure expansion, plantation development, and resource extraction continue to create pressures on Indigenous territories. This tension is particularly visible in Papua, where Indigenous communities occupy areas containing significant ecological resources, including forests, minerals, and biodiversity hotspots. Consequently, legal uncertainty over territorial rights directly influences the capacity of Indigenous communities to maintain traditional adaptation practices.

In Papua, customary law (*hukum adat*) plays a central role in regulating relationships between communities and their environments. Indigenous Papuan societies have historically developed governance systems that define territorial

boundaries, regulate access to natural resources, and establish obligations between humans and ecosystems. These systems are closely connected with traditional ecological knowledge because environmental practices are transmitted through customary institutions, cultural ceremonies, oral histories, and intergenerational learning. The weakening of customary authority therefore represents not only a legal issue but also a threat to the continuation of Indigenous adaptation capacity.

Research on Indigenous communities globally demonstrates that secure land rights are strongly associated with improved environmental outcomes and stronger climate resilience. Indigenous-managed territories often demonstrate lower rates of biodiversity loss and deforestation compared with areas lacking effective community governance mechanisms (Garnett et al., 2018; Fa et al., 2020). These findings suggest that recognizing Indigenous rights is not only a matter of social justice but also an important component of climate mitigation and adaptation strategies. However, legal recognition must extend beyond symbolic acknowledgment and provide communities with meaningful authority over decision-making processes.

Despite these developments, significant challenges remain regarding the legal protection of Indigenous knowledge itself. Existing legal frameworks often provide stronger protection for physical resources, such as forests and land, than for intangible resources, including ecological knowledge, cultural practices, and traditional adaptation strategies. Indigenous knowledge may therefore be incorporated into climate policies without adequate mechanisms to ensure community consent, ownership, and benefit sharing. This raises important questions regarding whether current governance systems genuinely empower Indigenous communities or merely extract knowledge for external policy objectives.

The relationship between legal pluralism and climate adaptation is therefore central to understanding Indigenous resilience in Papua. Traditional ecological knowledge can contribute to climate adaptation only when supported by institutions that recognize customary authority and protect Indigenous rights. A legal system that acknowledges Indigenous governance does not weaken state environmental management; rather, it creates opportunities for collaborative governance in which different knowledge systems contribute to shared climate objectives.

Accordingly, this study adopts legal pluralism as a conceptual lens for examining the legal implications of Indigenous climate adaptation strategies in Papua. By recognizing the interaction between state law and customary law, the study argues that effective climate adaptation requires more than the incorporation of Indigenous knowledge into policy documents. It requires structural recognition of Indigenous peoples as legitimate environmental

governance actors whose legal rights, territories, and knowledge systems must be protected.

D. Climate Governance and Rights-Based Adaptation

Climate governance has increasingly evolved from a state-centered regulatory approach toward a more complex system involving multiple actors, institutions, and knowledge systems. Traditional climate governance models primarily emphasized international agreements, national regulations, and government-led mitigation and adaptation programs. However, the complexity of climate change has demonstrated that effective responses cannot be achieved solely through centralized decision-making. Climate impacts are experienced locally, and adaptation strategies must therefore incorporate the knowledge, capacities, and participation of communities directly affected by environmental changes (Adger et al., 2005; Jordan et al., 2018). This transformation has encouraged the emergence of more inclusive governance approaches that recognize the importance of non-state actors, including Indigenous peoples, local communities, civil society organizations, and scientific institutions.

Within this evolving framework, Indigenous peoples have gained increasing recognition as important actors in global climate governance. International climate discourse has gradually shifted from perceiving Indigenous communities primarily as vulnerable populations toward recognizing them as knowledge holders, environmental stewards, and governance partners. This shift reflects growing evidence that Indigenous-managed territories contribute significantly to biodiversity conservation, ecosystem protection, and climate resilience (Garnett et al., 2018; Fa et al., 2020). Indigenous participation in climate governance is therefore not only a question of social inclusion but also a matter of environmental effectiveness, as Indigenous knowledge and governance systems can provide valuable contributions to sustainable ecosystem management.

The recognition of Indigenous participation is increasingly reflected in international legal and policy frameworks. The Paris Agreement represents an important development by acknowledging the importance of considering traditional knowledge, Indigenous knowledge, and local knowledge systems in climate adaptation and resilience-building efforts. Similarly, the United Nations Framework Convention on Climate Change (UNFCCC) established the Local Communities and Indigenous Peoples Platform (LCIPP) to strengthen the exchange of knowledge and enhance Indigenous participation in climate policy processes. These mechanisms demonstrate a broader movement toward knowledge pluralism, where different forms of knowledge are recognized as complementary resources for addressing climate change.

The Convention on Biological Diversity (CBD) has also played a significant role in recognizing Indigenous contributions to environmental governance. Through Article 8(j), the CBD recognizes the importance of Indigenous and local

communities' knowledge, innovations, and practices relevant to biodiversity conservation. More recently, the Kunming–Montreal Global Biodiversity Framework has reinforced the role of Indigenous peoples in biodiversity conservation, ecosystem restoration, and sustainable resource management. These developments indicate that international environmental governance increasingly links ecological sustainability with Indigenous rights and participation.

However, despite these normative developments, significant challenges remain in translating international recognition into effective national implementation. Many climate policies continue to operate through centralized institutional structures that prioritize scientific expertise and administrative authority while providing limited space for Indigenous decision-making. This challenge reflects a broader tension between technocratic climate governance and participatory climate governance. Technocratic approaches often emphasize efficiency, measurement, and expert-driven solutions, whereas participatory approaches highlight justice, legitimacy, cultural relevance, and community empowerment (Bulkeley & Betsill, 2013; Sultana, 2022).

The limitations of top-down climate governance are particularly evident in Indigenous territories. Adaptation programs designed without meaningful engagement with Indigenous communities may fail because they overlook local ecological realities, customary institutions, and culturally specific understandings of environmental change. Furthermore, externally imposed adaptation interventions may unintentionally weaken existing adaptive capacities by disrupting traditional governance systems or reducing community autonomy over natural resource management (Ford et al., 2020). Therefore, effective climate adaptation requires governance approaches that move beyond consultation toward genuine participation and shared decision-making.

This has contributed to the emergence of rights-based climate adaptation as an alternative governance framework. Rights-based adaptation emphasizes that climate responses must be grounded in principles of justice, equality, participation, accountability, and recognition of affected communities' rights. Unlike vulnerability-based approaches that primarily identify communities as recipients of adaptation assistance, rights-based approaches recognize Indigenous peoples as active political actors with legitimate authority over their territories and knowledge systems (Schlosberg, 2012; Sultana, 2022).

For Indigenous communities, rights-based adaptation is closely connected to several fundamental rights, including land rights, cultural rights, self-determination, and participation in environmental decision-making. Secure territorial rights are particularly important because Indigenous knowledge systems are place-based; they emerge from specific relationships between communities and ecosystems. When communities lose access to their territories or when customary governance systems are weakened, the transmission and

application of traditional ecological knowledge become increasingly difficult (Whyte, 2013; Berkes, 2018). Consequently, protecting Indigenous rights is not separate from climate adaptation—it is a necessary condition for maintaining adaptive capacity.

The Indonesian climate governance context illustrates these tensions between recognition and implementation. Indonesia has demonstrated increasing commitment to climate adaptation through national policies such as the Nationally Determined Contribution (NDC), the National Action Plan for Climate Change Adaptation (RAN-API), and ecosystem-based adaptation initiatives. These frameworks acknowledge the importance of community participation and local capacity-building. Nevertheless, Indigenous knowledge remains insufficiently institutionalized within national adaptation planning. Existing policies often recognize communities as stakeholders but provide limited mechanisms for integrating customary institutions and traditional ecological knowledge into formal decision-making processes.

This institutional limitation is particularly significant in Papua. Indigenous Papuan communities have developed adaptation strategies based on intimate knowledge of forests, rivers, coastal environments, and agricultural systems. However, climate governance initiatives in Papua often operate within broader development frameworks involving infrastructure expansion, natural resource extraction, conservation programs, and economic development strategies. Without adequate recognition of customary authority, these initiatives may create conflicts between state development objectives and Indigenous adaptation practices.

The relationship between conservation and Indigenous rights represents another important dimension of climate governance in Papua. Historically, conservation policies have sometimes treated local communities as threats to biodiversity protection rather than recognizing their contributions as environmental custodians. However, recent research demonstrates that Indigenous-managed landscapes often achieve significant conservation outcomes because customary institutions regulate resource use and maintain ecological relationships (Garnett et al., 2018; Fa et al., 2020). Therefore, climate governance approaches that exclude Indigenous communities may undermine both social justice and environmental sustainability.

A rights-based approach provides an alternative by positioning Indigenous communities as partners in climate governance rather than passive beneficiaries of government programs. In practice, this requires institutional reforms that strengthen legal recognition of customary territories, ensure meaningful participation in climate planning, protect Indigenous knowledge from unauthorized appropriation, and establish mechanisms for equitable benefit sharing. Such reforms would allow Indigenous adaptation strategies to contribute more effectively to national climate resilience objectives.

From a theoretical perspective, climate governance and rights-based adaptation demonstrate that climate resilience is shaped by the interaction between ecological knowledge, institutional structures, and legal arrangements. Indigenous adaptation strategies cannot be separated from the governance systems that determine whether communities have authority to apply and transmit their knowledge. Therefore, analyzing Indigenous climate adaptation requires an interdisciplinary approach that integrates environmental science, governance theory, and legal analysis.

In the context of Papua, this perspective reveals that the central challenge is not the absence of Indigenous adaptation knowledge but the limited institutional recognition of this knowledge within formal climate governance systems. Indigenous communities already possess adaptive strategies developed through generations of environmental interaction; however, their ability to contribute to climate resilience depends on whether legal and governance frameworks create supportive conditions. Consequently, strengthening Indigenous participation in climate governance should be understood as both an adaptation strategy and a legal obligation consistent with international Indigenous rights standards.

E. Conceptual Framework and Research Positioning

The preceding discussions demonstrate that Indigenous climate adaptation cannot be adequately explained through a single theoretical perspective. Traditional ecological knowledge, climate adaptation theory, legal pluralism, and climate governance represent interconnected dimensions that collectively influence the capacity of Indigenous communities to respond to climate change. While existing studies have examined each dimension separately, fewer studies have developed an integrated analytical framework that explains how Indigenous knowledge systems interact with legal and governance structures to shape climate resilience. This study addresses this limitation by proposing a conceptual framework that positions Indigenous adaptation as a social-ecological-legal process.

The first component of this framework is traditional ecological knowledge (TEK) as the foundation of Indigenous adaptive capacity. TEK represents the accumulated ecological understanding developed through long-term interactions between Indigenous communities and their environments. It includes environmental observations, resource management practices, cultural values, and customary rules that guide relationships between humans and ecosystems (Berkes, 2018). Within climate adaptation processes, TEK functions as a source of ecological information and practical strategies that enable communities to respond to changing environmental conditions. In Papua, this includes knowledge related to forest management, agricultural cycles, coastal resource utilization, water management, and biodiversity conservation.

However, this study argues that TEK alone does not automatically generate climate resilience. The ability of Indigenous communities to utilize their knowledge depends on the existence of supportive social and institutional conditions. Therefore, the second component of the framework focuses on customary governance institutions. Indigenous knowledge is transmitted and maintained through social structures, customary authorities, cultural practices, and collective decision-making mechanisms. These institutions determine how ecological knowledge is applied, who has authority over resource management decisions, and how adaptation strategies are maintained across generations.

The third component concerns legal recognition and institutional arrangements. Drawing from legal pluralism theory, this study conceptualizes law as a field where multiple normative systems interact rather than as a purely state-controlled mechanism. Indigenous communities operate within overlapping legal environments where customary law and state law influence environmental governance outcomes. The extent to which state institutions recognize customary rights, territorial authority, and Indigenous participation directly affects whether traditional adaptation strategies can survive and contribute to climate resilience.

This legal dimension is particularly important because climate adaptation increasingly involves questions of resource access, territorial control, and decision-making authority. For Indigenous communities, adaptation is inseparable from rights to land, forests, rivers, and cultural heritage. When legal systems fail to recognize these rights, Indigenous communities may experience reduced adaptive capacity despite possessing extensive ecological knowledge. Conversely, when legal frameworks support Indigenous self-determination and customary governance, traditional knowledge can become an important component of broader climate adaptation strategies.

The fourth component of the framework relates to climate governance and policy integration. Climate adaptation is not implemented in isolation but occurs within broader governance systems involving governments, scientific institutions, international organizations, and local communities. This study adopts a rights-based climate governance perspective, arguing that effective adaptation requires meaningful Indigenous participation rather than symbolic inclusion. Therefore, the integration of Indigenous knowledge into climate policy must involve not only the recognition of knowledge but also the recognition of Indigenous peoples as legitimate governance actors.

Based on these theoretical assumptions, this study develops a conceptual relationship as follows:

Traditional Ecological Knowledge → Customary Governance → Legal Recognition → Climate Governance Integration → Indigenous Climate Resilience

This framework suggests that Indigenous climate resilience emerges through interaction between ecological knowledge, social institutions, legal structures, and governance mechanisms. Traditional knowledge provides the adaptive foundation; customary institutions maintain and transmit this knowledge; legal recognition determines whether Indigenous communities can exercise authority over their territories; and climate governance frameworks determine whether Indigenous adaptation strategies can contribute to broader policy objectives.

The framework also highlights potential barriers that may disrupt this process. These barriers include insecure land tenure, inadequate recognition of customary law, extractive resource development, exclusionary conservation policies, and centralized climate planning. Such factors may weaken Indigenous adaptive capacity by limiting communities' ability to maintain ecological relationships and apply traditional knowledge. Therefore, climate vulnerability among Indigenous communities should not be interpreted merely as a consequence of environmental exposure but also as a consequence of institutional and legal conditions.

This conceptualization contributes to existing literature in several ways. First, it extends climate adaptation research by moving beyond the common focus on vulnerability reduction and emphasizing the institutional conditions that enable or constrain Indigenous adaptive capacity. Previous studies have demonstrated the value of Indigenous knowledge for climate resilience; however, fewer studies have examined how legal systems influence whether such knowledge can effectively function within adaptation governance.

Second, the framework contributes to Indigenous studies by challenging approaches that treat Indigenous knowledge as an isolated cultural resource. Instead, it conceptualizes TEK as part of a broader governance system involving authority, rights, and institutional relationships. This perspective aligns with recent scholarship arguing that Indigenous knowledge should be understood through the interconnected dimensions of knowledge, power, and sovereignty (Whyte, 2013; Tengö et al., 2017).

Third, this framework advances environmental law scholarship by demonstrating that climate adaptation requires attention to legal pluralism. In contexts such as Papua, where customary governance systems remain significant, effective environmental governance cannot rely exclusively on state legal frameworks. Instead, adaptive governance requires mechanisms that enable interaction and cooperation between customary and formal legal systems.

The research positioning of this study therefore differs from previous studies in three important respects. First, while many studies examine Indigenous knowledge as an ecological resource, this research analyzes it as a legally embedded governance system. Second, while previous Indonesian studies frequently focus on Indigenous rights, customary forests, or conservation

separately, this study examines their relationship with climate adaptation. Third, by focusing on Papua, this research contributes empirical insights from a region where Indigenous knowledge systems remain highly significant but where legal recognition and climate governance challenges remain substantial.

The conceptual framework developed in this study provides the analytical basis for examining three central questions: how Indigenous communities in Papua utilize traditional knowledge to respond to climate change; how Indonesian legal frameworks recognize and regulate these practices; and how climate governance systems can better integrate Indigenous knowledge while respecting Indigenous rights. Through this approach, the study seeks to demonstrate that strengthening Indigenous adaptation is not merely a matter of incorporating local knowledge into existing policies, but requires deeper institutional transformation toward more inclusive, legally recognized, and socially just climate governance.

Methods

This study employs a qualitative socio-legal research approach to examine the relationship between Indigenous traditional knowledge, climate change adaptation strategies, and legal recognition in Papua, Indonesia. A qualitative approach is appropriate because the study focuses on understanding social practices, cultural meanings, institutional arrangements, and legal dynamics that influence how Indigenous communities respond to climate change. Rather than measuring adaptation through quantitative indicators, this research seeks to explore how traditional ecological knowledge operates within Indigenous governance systems and how these practices interact with formal legal frameworks. The socio-legal perspective enables the study to analyze both normative aspects of law and the practical realities of legal implementation within Indigenous communities.

The research was conducted in Papua, Indonesia, selected due to its ecological significance, cultural diversity, and the continued relevance of Indigenous governance systems in environmental management. Papua represents an important case for examining Indigenous climate adaptation because local communities have developed extensive knowledge systems related to forest management, agricultural practices, coastal resource utilization, and ecosystem conservation. At the same time, Papua faces increasing environmental pressures associated with climate change, land-use transformation, extractive activities, and competing governance interests. These conditions provide an important context for analyzing how Indigenous knowledge contributes to climate resilience and how legal frameworks influence the continuity of such practices.

Data were collected through qualitative methods consisting of semi-structured interviews, document analysis, and literature review. Primary data

were obtained through interviews with Indigenous leaders, community members, environmental activists, and relevant stakeholders involved in Indigenous rights and environmental governance. The interviews explored community experiences regarding climate change impacts, traditional adaptation strategies, customary governance mechanisms, and perceptions of existing legal and policy frameworks. Secondary data were collected through analysis of national legal instruments, including constitutional provisions, environmental regulations, Indigenous rights policies, and relevant judicial decisions, as well as international frameworks such as the Paris Agreement, the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP), and the Convention on Biological Diversity (CBD).

The collected data were analyzed using thematic analysis to identify recurring patterns and relationships among Indigenous knowledge, adaptation practices, governance institutions, and legal recognition. The analysis process involved coding relevant information into key themes, including traditional ecological knowledge, climate resilience, customary authority, legal protection, and policy integration. These themes were subsequently examined through the theoretical perspectives of climate adaptation, legal pluralism, and rights-based climate governance. By combining empirical observations with legal and theoretical analysis, the study aims to understand not only how Indigenous communities adapt to climate change but also how institutional and legal structures enable or constrain these adaptation processes.

Ethical considerations were central throughout the research process, particularly because Indigenous knowledge may involve culturally sensitive information connected to collective identity, territorial relationships, and customary authority. The study applied principles of informed consent, confidentiality, respect for Indigenous perspectives, and responsible knowledge representation. Indigenous communities were approached as knowledge holders and active participants rather than merely research subjects. This approach reflects the broader objective of the study, which is not only to document Indigenous adaptation practices but also to contribute to discussions on strengthening Indigenous rights, improving climate governance, and developing more inclusive adaptation policies in Indonesia and beyond.

Analysis and Discussion

A. Indigenous Traditional Knowledge and Climate Adaptation Practices in Papua

The findings demonstrate that Indigenous communities in Papua possess complex and dynamic traditional knowledge systems that function as important mechanisms for responding to climate variability and environmental change. Rather than representing static cultural practices inherited from previous generations, Indigenous knowledge operates as an adaptive system continuously

developed through observation, experimentation, and interaction with ecological processes. Indigenous communities have historically relied on detailed understandings of forest dynamics, seasonal patterns, biodiversity changes, water systems, and agricultural cycles to sustain livelihoods and maintain ecological balance. These findings support broader scholarship on Traditional Ecological Knowledge (TEK), which emphasizes that Indigenous knowledge represents a cumulative process of learning embedded within long-term relationships between communities and ecosystems (Berkes, 2018; Tengö et al., 2017).

One of the most significant findings is that Indigenous adaptation strategies in Papua are closely connected with customary resource management systems. Communities utilize ecological knowledge to determine appropriate periods for agricultural activities, regulate resource extraction, protect important ecological areas, and maintain biodiversity. Traditional agricultural practices, including adaptive cultivation systems based on local environmental conditions, demonstrate how Indigenous communities adjust production strategies according to changing climatic conditions. These practices reflect a form of climate adaptation that is based on ecological flexibility rather than intensive technological intervention. Similar findings from Indigenous communities in other tropical regions indicate that locally developed agricultural and resource management systems can enhance resilience by maintaining ecosystem diversity and reducing dependence on vulnerable external inputs (Altieri et al., 2015; Reyes-García et al., 2016).

In Papua, forests represent not only economic resources but also cultural, spiritual, and ecological spaces governed through customary norms. Indigenous communities have developed knowledge systems regulating forest access, hunting practices, and resource utilization through customary institutions. These institutions determine appropriate behaviors toward ecosystems and establish social responsibilities for maintaining environmental balance. The relationship between Indigenous peoples and forests therefore differs significantly from conventional resource management models that often separate humans from ecological systems. Instead, Indigenous governance reflects an understanding of humans as interconnected components of ecological landscapes. This perspective aligns with resilience theory, which emphasizes that sustainable adaptation depends on maintaining adaptive relationships between social and ecological systems (Folke, 2006; Berkes, 2018).

The findings also indicate that Indigenous communities in Papua possess their own indicators for identifying environmental changes associated with climate variability. Changes in rainfall patterns, river conditions, plant behavior, animal movements, and seasonal cycles are observed and interpreted through locally developed knowledge systems. Such observations provide communities with early information regarding environmental changes and influence decisions

related to agriculture, mobility, and resource management. Previous research in Papua has similarly demonstrated that Indigenous communities in the Mamberamo region possess detailed perceptions of climatic variability and environmental change based on long-term ecological observation (Boissière et al., 2013). These findings challenge assumptions that climate knowledge must originate exclusively from scientific institutions and demonstrate the complementary value of Indigenous observations in understanding localized climate impacts.

However, the study also reveals that Indigenous adaptation strategies are increasingly challenged by multiple and interconnected pressures. Climate change represents only one dimension of vulnerability experienced by Indigenous communities in Papua. Changes in rainfall patterns, increasing temperatures, flooding, and ecosystem disturbances interact with broader social and political pressures, including land conversion, mining activities, infrastructure expansion, and changing patterns of resource governance. As emphasized by vulnerability scholars, climate vulnerability is not simply determined by exposure to environmental hazards but is shaped by historical, economic, and institutional factors influencing communities' adaptive capacity (Adger, 2006; O'Brien, 2012).

The interaction between climate change and land-use transformation is particularly significant because Indigenous adaptation strategies depend heavily on continued access to customary territories. Traditional knowledge is place-based; therefore, the disruption of relationships between communities and their environments can weaken the ability to maintain and transmit ecological knowledge. When forests, rivers, or agricultural landscapes are transformed through external development activities, communities may lose not only material resources but also cultural landscapes where knowledge systems are produced and practiced. This finding supports arguments within Indigenous studies that environmental protection and Indigenous rights are inseparable because ecological resilience is closely connected with territorial security and cultural continuity (Whyte, 2013; Garnett et al., 2018).

The findings further demonstrate that Indigenous adaptation should not be interpreted as a passive response to climate impacts. Instead, Indigenous communities actively modify and innovate their practices in response to changing environmental conditions. This challenges earlier assumptions that traditional knowledge represents fixed historical practices unable to address contemporary challenges. Contemporary Indigenous adaptation involves combining inherited ecological knowledge with new experiences, external information, and changing social conditions. Such adaptability confirms that TEK is a living knowledge system capable of responding to emerging environmental uncertainties (Latulippe & Klenk, 2020).

Nevertheless, the ability of Indigenous communities to maintain adaptive practices depends significantly on institutional recognition and governance

support. While communities possess valuable ecological knowledge, limited recognition of customary authority may restrict their ability to apply this knowledge in formal climate adaptation programs. For example, government adaptation initiatives may acknowledge community participation while still prioritizing externally designed planning frameworks. This creates a situation where Indigenous knowledge is recognized rhetorically but not fully integrated into decision-making processes. Similar challenges have been identified globally, where Indigenous knowledge integration often remains limited due to unequal power relations between scientific institutions, government agencies, and Indigenous communities (Tengö et al., 2017; Ford et al., 2020).

The findings therefore suggest that Indigenous traditional knowledge in Papua should be understood as a foundation of climate resilience that requires supportive legal and institutional conditions. Traditional ecological knowledge provides communities with adaptive strategies, but these strategies can only function effectively when communities retain authority over their territories, participate meaningfully in governance processes, and receive recognition of their customary institutions. In this sense, Indigenous adaptation is simultaneously an ecological, social, and legal process.

This section demonstrates that Indigenous communities in Papua possess significant adaptive capacities developed through generations of ecological learning and customary governance. However, climate change adaptation cannot be separated from broader questions of rights, governance, and legal recognition. Strengthening Indigenous adaptation therefore requires not only documenting traditional knowledge but also creating institutional frameworks that enable Indigenous communities to continue practicing, developing, and transmitting their knowledge systems within contemporary climate governance structures.

B. Indigenous Governance and Community-Based Climate Resilience

The findings indicate that Indigenous governance institutions play a fundamental role in shaping climate resilience among Indigenous communities in Papua. Adaptation strategies are not developed solely at the individual or household level but are embedded within collective governance systems that regulate relationships between communities, territories, and ecological resources. Customary institutions (*lembaga adat*) provide mechanisms for decision-making, conflict resolution, resource management, and knowledge transmission, enabling communities to respond collectively to environmental changes. This finding supports broader research on community-based adaptation, which emphasizes that resilience is strongly influenced by social institutions, collective action, and local capacities rather than only by technological or infrastructural interventions (Adger, 2003; Berkes, 2018).

Indigenous governance in Papua reflects a form of environmental governance based on customary authority and ecological responsibility. Customary leaders and community institutions traditionally establish rules concerning access to forests, rivers, agricultural areas, and coastal resources. These rules are not merely mechanisms for resource allocation but also represent ethical relationships between humans and nature. Through customary governance, communities maintain ecological knowledge by embedding environmental practices within social norms, cultural values, and collective responsibilities. Such governance systems demonstrate that adaptation is not simply a technical response to climate hazards but a social process shaped by institutions and cultural relationships.

The role of customary governance is particularly evident in the management of forest ecosystems. Forests in Papua are often understood by Indigenous communities as living landscapes connected to identity, ancestry, and social obligations. Consequently, forest management practices frequently involve restrictions on resource extraction, protection of culturally significant areas, and collective decision-making regarding resource use. These practices contribute to ecosystem sustainability and enhance community resilience by maintaining biodiversity and ecological functions. Comparative studies of Indigenous territories globally demonstrate similar patterns, showing that Indigenous governance systems often support conservation outcomes because they establish locally legitimate rules for sustainable resource management (Garnett et al., 2018; Fa et al., 2020).

The findings also highlight the importance of social capital in Indigenous climate adaptation. Social networks, reciprocal relationships, collective labor systems, and intergenerational knowledge exchange strengthen communities' ability to respond to environmental disturbances. In many Indigenous societies, adaptation decisions are not made individually but through collective consultation involving elders, customary authorities, and community members. This collective approach enables communities to mobilize resources, distribute responsibilities, and maintain social cohesion during periods of environmental stress. Research on climate resilience has consistently demonstrated that strong social capital improves adaptive capacity by facilitating cooperation, information sharing, and collective responses to uncertainty (Adger, 2003; Aldrich, 2012).

In Papua, knowledge transmission represents a particularly important dimension of community resilience. Traditional ecological knowledge is maintained through storytelling, cultural practices, observation, and participation in everyday livelihood activities. Elders play a central role in transmitting knowledge regarding environmental indicators, resource management practices, and cultural responsibilities toward ecosystems. However, changing socioeconomic conditions, formal education systems, migration patterns, and external economic pressures increasingly challenge

intergenerational knowledge transmission. This suggests that protecting Indigenous adaptation capacity requires not only environmental protection but also the preservation of social and cultural institutions that sustain knowledge systems.

The findings further reveal that community-based adaptation in Papua operates through a combination of continuity and innovation. Indigenous communities do not simply reproduce historical practices but continuously adjust their strategies in response to changing environmental and socioeconomic conditions. For example, changes in agricultural productivity, rainfall patterns, and resource availability require communities to modify livelihood strategies while maintaining core ecological principles. This adaptive flexibility reflects the characteristics of resilient social-ecological systems, where resilience depends on the ability to learn, reorganize, and transform in response to disturbances (Folke, 2006).

However, the effectiveness of Indigenous governance is increasingly affected by interactions with external governance systems. The coexistence of customary governance and state-based environmental regulation creates a situation of legal and institutional complexity. While customary institutions continue to influence community practices, state policies often determine access to land, recognition of resource rights, and participation in environmental decision-making. When formal legal systems fail to recognize customary authority, Indigenous communities may experience reduced control over their territories and diminished capacity to implement traditional adaptation strategies.

This challenge illustrates the importance of legal pluralism in understanding Indigenous climate resilience. Indigenous governance systems do not operate independently from state institutions; rather, they exist within overlapping legal environments where different forms of authority interact. The effectiveness of community-based adaptation therefore depends on whether these legal systems create conditions for cooperation or produce institutional conflicts. Previous research on Indigenous rights and environmental governance demonstrates that secure recognition of customary institutions enhances both conservation outcomes and community resilience, whereas legal uncertainty often creates barriers to sustainable resource management (Bavikatte & Robinson, 2011; Arizona et al., 2019).

In Papua, tensions between Indigenous governance and external development priorities are particularly significant. Economic activities involving mining, logging, plantation expansion, and infrastructure development often introduce alternative land-use priorities that may conflict with customary systems of environmental management. These conflicts demonstrate that climate resilience cannot be separated from questions of environmental justice and territorial rights. Indigenous communities may possess effective adaptation

knowledge, but their capacity to implement such strategies can be undermined when they lack meaningful authority over decisions affecting their territories.

The findings suggest that strengthening Indigenous governance should be considered a central component of climate adaptation policy. Rather than treating Indigenous communities merely as beneficiaries of government adaptation programs, climate governance frameworks should recognize them as institutional actors with legitimate authority and expertise. Community-based adaptation becomes more effective when supported by legal recognition, participatory decision-making mechanisms, and institutional collaboration between Indigenous organizations and government authorities.

From a theoretical perspective, this study contributes to climate adaptation scholarship by demonstrating that resilience among Indigenous communities emerges from the interaction between ecological knowledge and governance institutions. Traditional knowledge provides the informational foundation for adaptation, while customary governance provides the institutional mechanisms necessary to apply and sustain that knowledge. Therefore, Indigenous resilience is not simply a consequence of possessing environmental knowledge but also of maintaining social systems capable of organizing collective responses.

The findings demonstrate that Indigenous governance institutions in Papua represent important sources of climate resilience. However, their continued contribution depends on broader legal and political conditions that determine whether customary authority can coexist effectively with formal governance structures. Strengthening climate adaptation in Papua therefore requires moving beyond approaches that simply incorporate Indigenous knowledge into policy frameworks and toward governance models that recognize Indigenous communities as legitimate partners in environmental decision-making.

C. Legal Recognition of Indigenous Knowledge in Indonesian Climate Law

The recognition of Indigenous knowledge within Indonesian climate governance remains characterized by a significant gap between normative acknowledgment and practical implementation. Although Indonesia has gradually developed legal instruments recognizing Indigenous peoples' rights and community participation in environmental management, the integration of Indigenous knowledge into climate adaptation frameworks remains fragmented. The findings indicate that the primary challenge is not the absence of legal recognition but rather the limited institutional mechanisms that transform recognition into effective authority, participation, and protection of Indigenous knowledge systems.

At the constitutional level, Indonesia provides a foundation for recognizing Indigenous communities through Article 18B(2) of the 1945 Constitution, which acknowledges the existence of Indigenous peoples (*masyarakat hukum adat*)

and their traditional rights under specific conditions. This constitutional provision represents an important legal commitment toward pluralistic governance because it recognizes that state authority must coexist with Indigenous social institutions. However, the conditional nature of constitutional recognition creates substantial challenges. Indigenous communities are required to demonstrate continued existence, conformity with societal development principles, and formal recognition through government procedures. Consequently, recognition often depends on administrative decisions rather than functioning as an automatic constitutional entitlement.

This conditional recognition model creates what scholars describe as a tension between recognition and dependency. While the state acknowledges Indigenous rights in principle, Indigenous communities frequently remain dependent on state institutions to validate their existence and territorial claims. This creates an asymmetrical relationship in which the state retains significant authority to determine whether Indigenous rights are legally enforceable. From a legal pluralism perspective, such arrangements reveal that customary law is recognized not as an independent legal order but often as a subordinate system requiring confirmation by state authorities (von Benda-Beckmann & von Benda-Beckmann, 2006). This condition has important implications for climate adaptation because Indigenous communities may possess effective ecological governance systems but lack sufficient legal authority to maintain them.

A major development in Indigenous environmental rights in Indonesia occurred through Constitutional Court Decision No. 35/PUU-X/2012 concerning customary forests (*hutan adat*). The decision fundamentally changed the legal interpretation of forest ownership by affirming that customary forests are not categorized as state forests. This ruling represented a significant advancement because it recognized that Indigenous communities possess legitimate relationships with forest territories based on customary law. Beyond its implications for land rights, the decision also carries important consequences for climate governance because forests represent key ecosystems for adaptation, biodiversity conservation, and climate mitigation.

Nevertheless, the implementation of Constitutional Court Decision No. 35/PUU-X/2012 demonstrates the complexity of translating judicial recognition into practical outcomes. Although the decision established a stronger legal foundation for customary forest recognition, implementation requires administrative procedures, including formal identification and recognition by local governments. In many regions, including Papua, these procedures remain challenging due to limited institutional capacity, overlapping land claims, unclear territorial boundaries, and competing economic interests. Therefore, the legal recognition of Indigenous territories remains incomplete despite significant constitutional and judicial developments.

This implementation gap directly affects the ability of Indigenous communities to utilize traditional knowledge for climate adaptation. Indigenous ecological knowledge is inseparable from territorial relationships because knowledge is produced through continuous interaction with specific landscapes. When communities lack secure rights over forests, rivers, and coastal areas, their ability to maintain ecological practices becomes increasingly constrained. For example, traditional systems of forest conservation, seasonal resource management, and biodiversity protection depend on community authority to regulate access and use. Without legal protection, these systems may be weakened by external interventions that prioritize commercial or administrative objectives.

The relationship between land rights and climate adaptation has been widely recognized in international research. Studies demonstrate that Indigenous territories often achieve strong conservation outcomes because Indigenous governance systems maintain long-term relationships with ecosystems (Garnett et al., 2018; Fa et al., 2020). Consequently, strengthening Indigenous land rights is not only a human rights obligation but also an effective climate strategy. In this context, legal recognition of Indigenous territories should be understood as a form of climate adaptation infrastructure because it enables communities to maintain governance systems that support ecological resilience.

However, Indonesian climate policies have not fully incorporated this perspective. National climate adaptation frameworks, including the National Action Plan for Climate Change Adaptation (RAN-API) and Indonesia's Nationally Determined Contribution (NDC), increasingly acknowledge community participation and ecosystem-based approaches. Nevertheless, these policies generally discuss communities as participants or beneficiaries rather than as holders of legally recognized knowledge systems and governance authority. The distinction is important because participation without authority may limit the transformative potential of Indigenous knowledge integration.

The findings suggest that Indonesian climate governance continues to reflect a predominantly administrative approach in which knowledge integration occurs through government-managed programs rather than through institutional recognition of Indigenous governance systems. This approach creates a risk of what scholars describe as the “extraction” of Indigenous knowledge, where traditional knowledge is incorporated into policy frameworks without addressing the rights, ownership, and decision-making authority of Indigenous communities. Such practices may unintentionally reproduce existing inequalities by using Indigenous knowledge while marginalizing Indigenous institutions.

The issue is particularly significant in Papua because Indigenous communities possess highly localized ecological knowledge developed through generations of interaction with complex forest and coastal ecosystems. However, Papua also represents a region where competing interests over natural resources

create significant governance challenges. Large-scale development projects, mining activities, forestry operations, and infrastructure initiatives frequently intersect with customary territories. In such contexts, the absence of strong legal protection for Indigenous governance may reduce communities' capacity to maintain adaptation strategies and participate meaningfully in environmental decision-making.

Another important legal issue concerns the protection of Indigenous knowledge itself. Indonesian environmental law provides mechanisms for protecting natural resources and biodiversity but offers limited comprehensive protection for traditional ecological knowledge as an intangible cultural and ecological asset. Unlike conventional intellectual property systems that emphasize individual ownership and commercial innovation, Indigenous knowledge is often collectively owned, continuously developed, and transmitted across generations. Therefore, conventional legal approaches may be insufficient for protecting Indigenous knowledge from unauthorized appropriation or misuse.

This limitation highlights the need for a broader legal framework that recognizes Indigenous knowledge as part of cultural rights, environmental governance, and climate adaptation strategies simultaneously. Such recognition requires moving beyond the treatment of Indigenous knowledge as merely a source of information for government programs. Instead, Indigenous knowledge should be understood as a governance resource connected to Indigenous authority, territorial rights, and self-determination.

The findings therefore indicate that strengthening Indigenous climate adaptation in Papua requires three interconnected legal reforms. First, Indonesia needs more effective mechanisms for recognizing and securing Indigenous territories, particularly customary forests and ecologically significant areas. Second, climate policies should move from symbolic inclusion toward meaningful institutional participation by Indigenous communities in adaptation planning and implementation. Third, legal mechanisms should be developed to protect Indigenous knowledge systems from appropriation while enabling equitable collaboration between Indigenous communities, scientific institutions, and government agencies.

From a broader environmental law perspective, the Indonesian experience illustrates the limitations of approaches that separate Indigenous rights from climate governance. Climate adaptation cannot be achieved solely through environmental regulations or technical programs because adaptive capacity is deeply connected with questions of authority, justice, and recognition. Indigenous communities are not simply local actors affected by climate change; they are governance actors whose legal status determines their ability to contribute to climate resilience.

Therefore, the legal recognition of Indigenous knowledge should be understood as a fundamental component of climate adaptation governance. In the case of Papua, strengthening Indigenous legal rights would not only address historical issues of recognition and justice but also enhance Indonesia's capacity to develop more effective and sustainable climate adaptation strategies. A legally pluralistic and rights-based approach provides an opportunity to integrate Indigenous knowledge into national climate governance while respecting the autonomy and cultural integrity of Indigenous communities.

D. International Legal Perspectives and Indigenous Climate Rights

The recognition of Indigenous peoples as key actors in climate governance has become an increasingly important development within international environmental and human rights law. Historically, international climate policies primarily approached Indigenous communities through the perspective of vulnerability, emphasizing their exposure to environmental risks and socioeconomic disadvantages. However, contemporary legal and policy developments increasingly recognize Indigenous peoples as rights holders, knowledge producers, and essential partners in addressing climate change. This transformation reflects a broader shift from a protection-based approach toward a rights-based approach, where Indigenous participation, self-determination, and traditional knowledge are considered fundamental elements of effective climate governance.

A significant milestone in this transformation is the adoption of the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP) in 2007. UNDRIP establishes international standards concerning Indigenous peoples' rights to land, natural resources, cultural identity, traditional knowledge, and participation in decisions affecting their communities. Several provisions are particularly relevant to climate adaptation, including the recognition of Indigenous peoples' rights to maintain their spiritual relationships with traditionally owned territories, participate in environmental management, and protect cultural knowledge systems. Although UNDRIP is not legally binding in the same manner as international treaties, it has become an influential normative framework guiding national legislation, judicial interpretation, and international development policies.

The importance of UNDRIP within climate governance lies in its recognition that environmental protection and Indigenous rights are interconnected. Indigenous knowledge systems are not separate from Indigenous territorial rights; rather, they emerge from long-term relationships between communities and specific ecosystems. Therefore, protecting traditional knowledge requires protecting the social, cultural, and territorial conditions that allow such knowledge to exist. This principle challenges conventional approaches that attempt to extract Indigenous knowledge from its cultural context and

incorporate it into external policy frameworks without recognizing Indigenous authority.

The Paris Agreement under the United Nations Framework Convention on Climate Change (UNFCCC) further strengthened the international recognition of Indigenous knowledge in climate adaptation. The Agreement acknowledges the importance of considering Indigenous and local knowledge systems when addressing climate change impacts. This recognition represents a significant shift in global climate governance because it challenges the dominance of purely scientific approaches and promotes the integration of diverse knowledge systems. The establishment of the Local Communities and Indigenous Peoples Platform (LCIPP) under the UNFCCC further demonstrates international efforts to facilitate knowledge exchange and enhance Indigenous participation in climate decision-making.

However, the inclusion of Indigenous knowledge within international climate frameworks also presents challenges. While international agreements increasingly recognize Indigenous knowledge, implementation often depends on national legal systems and institutional capacities. Without meaningful legal recognition at the domestic level, international commitments may remain largely symbolic. This challenge is particularly relevant for countries such as Indonesia, where international recognition of Indigenous participation must be translated into effective mechanisms for territorial rights, institutional representation, and protection of traditional knowledge.

The Convention on Biological Diversity (CBD) provides another important international framework for understanding the relationship between Indigenous knowledge and environmental governance. Through Article 8(j), the CBD recognizes the importance of Indigenous and local communities' knowledge, innovations, and practices relevant to biodiversity conservation. This provision establishes the principle that Indigenous knowledge should be respected, preserved, and maintained with the approval and involvement of knowledge holders. The CBD framework demonstrates that Indigenous knowledge is not merely a cultural expression but a valuable contribution to global environmental sustainability.

More recently, the Kunming–Montreal Global Biodiversity Framework has reinforced the role of Indigenous peoples in biodiversity conservation and ecosystem management. The framework recognizes Indigenous territories and knowledge systems as important contributors to achieving global biodiversity targets. This development is particularly relevant for Papua, where Indigenous communities manage landscapes containing globally significant biodiversity. International recognition of Indigenous conservation contributions provides an important foundation for strengthening arguments that Indigenous governance should be integrated into national climate and environmental policies.

Beyond international legal instruments, comparative experiences from other countries demonstrate different approaches to recognizing Indigenous climate rights. In Canada, Indigenous participation in environmental governance has increasingly been incorporated through legal recognition of Indigenous consultation rights, land agreements, and co-management arrangements. Although challenges remain, these mechanisms demonstrate how Indigenous governance systems can be integrated into formal environmental decision-making processes. Similarly, in Australia, Indigenous knowledge has been increasingly incorporated into biodiversity conservation and fire management programs, particularly through recognition of Aboriginal ecological practices and Indigenous ranger programs.

Pacific Island countries provide another important comparison because they experience some of the most severe climate impacts, particularly sea-level rise and coastal ecosystem degradation. In these contexts, Indigenous and local knowledge has become central to adaptation strategies involving coastal protection, food security, and disaster preparedness. Research from Pacific communities demonstrates that climate resilience depends not only on infrastructure but also on maintaining cultural relationships, traditional practices, and community governance systems (Mercer et al., 2012). These experiences provide relevant lessons for Papua, where coastal Indigenous communities similarly depend on complex relationships with marine and terrestrial ecosystems.

Despite international progress, significant conceptual challenges remain regarding the integration of Indigenous knowledge into climate governance. One major concern is the risk of knowledge commodification, where Indigenous knowledge is treated as a resource to be collected and utilized by external institutions without adequate recognition of Indigenous ownership and authority. Scholars have argued that meaningful knowledge integration requires attention to power relations, ethical engagement, and Indigenous sovereignty over knowledge production (Tengö et al., 2017; Latulippe & Klenk, 2020). Therefore, international frameworks increasingly emphasize principles such as Free, Prior, and Informed Consent (FPIC) as a mechanism to ensure that Indigenous communities maintain control over decisions affecting their territories and knowledge systems.

The principle of FPIC has particular relevance for climate adaptation projects involving Indigenous territories. Adaptation initiatives, conservation programs, and carbon-related projects may create new pressures on Indigenous communities if implemented without meaningful participation. While such programs often aim to achieve environmental objectives, they may unintentionally restrict Indigenous livelihoods or weaken customary governance structures. Applying FPIC principles ensures that climate interventions respect

Indigenous decision-making authority and avoid reproducing historical patterns of exclusion.

For Papua, international Indigenous rights frameworks provide both opportunities and challenges. On the one hand, global recognition of Indigenous knowledge strengthens arguments for greater protection of customary governance systems and traditional ecological practices. On the other hand, international principles must be translated into Indonesia's domestic legal framework to generate meaningful impacts. The existence of international commitments alone is insufficient unless accompanied by institutional reforms that recognize Indigenous authority, protect customary territories, and create mechanisms for Indigenous participation in climate policy.

The findings of this study suggest that Indonesia can strengthen its climate governance by aligning national legal frameworks more closely with international Indigenous rights standards. This does not require replacing state environmental governance but rather developing collaborative governance models where state institutions, scientific actors, and Indigenous communities share responsibilities. Such an approach would allow Indonesia to utilize Indigenous knowledge as a strategic component of climate adaptation while fulfilling broader commitments to human rights and environmental sustainability.

Ultimately, international legal developments demonstrate that Indigenous rights and climate governance are increasingly inseparable. Indigenous peoples are not merely communities affected by climate change but critical contributors to climate solutions through their knowledge, institutions, and stewardship practices. For Papua, adopting a rights-based and legally pluralistic approach would provide a pathway toward climate adaptation policies that are not only environmentally effective but also socially legitimate and consistent with international principles of justice.

E. Policy Implications for Integrating Traditional Knowledge into Climate Adaptation Frameworks

The findings of this study demonstrate that integrating Indigenous traditional knowledge into climate adaptation frameworks requires a fundamental transformation in the way climate governance is conceptualized and implemented. Indigenous knowledge should not be positioned merely as supplementary information to strengthen government adaptation programs, but rather as a governance resource embedded within Indigenous institutions, territorial relationships, and cultural systems. The experience of Indigenous communities in Papua indicates that effective climate adaptation depends on the interaction between ecological knowledge, customary governance, legal recognition, and institutional support. Therefore, policy frameworks that seek to utilize Indigenous knowledge must address not only knowledge integration but

also the structural conditions that enable Indigenous communities to maintain and apply their adaptive practices.

A primary policy implication concerns the need to strengthen the legal recognition of Indigenous territories and customary governance institutions. The findings indicate that territorial insecurity represents one of the most significant barriers to Indigenous climate adaptation because traditional ecological knowledge is inherently place-based. When Indigenous communities experience uncertainty regarding ownership, access, and authority over their territories, their ability to implement customary environmental management practices becomes constrained. Consequently, accelerating the recognition of Indigenous territories, including customary forests, should be considered a critical component of climate adaptation policy rather than merely a matter of land administration. Strengthening Indigenous territorial rights would simultaneously support biodiversity conservation, ecosystem resilience, and climate adaptation objectives.

At the national level, Indonesia's climate policies require greater integration between Indigenous rights frameworks and adaptation strategies. Existing climate adaptation policies, including ecosystem-based adaptation initiatives and community participation mechanisms, have increasingly acknowledged the importance of local involvement. However, these policies often remain limited because they treat communities primarily as participants rather than as institutions possessing legitimate knowledge and governance authority. A more transformative approach requires the state to recognize Indigenous communities as co-governors of environmental resources. This would involve creating institutional mechanisms that allow Indigenous representatives to participate meaningfully in climate planning, implementation, monitoring, and evaluation processes.

Another important policy implication relates to the protection and governance of Indigenous knowledge itself. Current legal frameworks provide limited mechanisms for protecting traditional ecological knowledge as a collective cultural and environmental asset. Unlike conventional intellectual property systems that emphasize individual ownership and commercialization, Indigenous knowledge is collectively maintained, continuously developed, and connected with cultural responsibilities. Therefore, policy development should consider alternative legal mechanisms that recognize collective ownership, community consent, and benefit-sharing principles. Such mechanisms are necessary to prevent the extraction of Indigenous knowledge by external institutions without adequate recognition or benefit to Indigenous communities.

The integration of Indigenous knowledge into climate adaptation also requires institutional reforms within scientific and governmental organizations. The findings suggest that knowledge integration is most effective when Indigenous knowledge and scientific knowledge are treated as complementary

rather than hierarchical systems. Government agencies, research institutions, and environmental organizations should develop collaborative methodologies that allow Indigenous communities to participate in knowledge production and decision-making processes. This approach is consistent with the concept of knowledge co-production, which emphasizes mutual learning between different knowledge systems and recognizes the legitimacy of diverse forms of expertise (Tengö et al., 2017).

At the regional level, Papua requires climate governance approaches that reflect its unique ecological and cultural conditions. A uniform national adaptation model may not adequately address the diversity of Indigenous communities, ecosystems, and livelihood systems across Papua. Regional climate policies should therefore incorporate culturally appropriate approaches based on local ecological realities and customary governance structures. This includes strengthening partnerships between provincial governments, customary institutions, Indigenous organizations, universities, and environmental organizations. Such collaborative governance arrangements can create more effective adaptation strategies by combining scientific assessments with Indigenous ecological observations.

The findings also highlight the importance of incorporating Free, Prior, and Informed Consent (FPIC) principles into climate-related projects affecting Indigenous territories. Climate adaptation initiatives, conservation programs, and nature-based solutions may generate positive environmental outcomes but can also create risks if Indigenous communities are excluded from decision-making. Applying FPIC principles ensures that communities have meaningful opportunities to participate in decisions affecting their territories, resources, and knowledge systems. This is particularly important in Papua, where environmental projects frequently intersect with customary lands and Indigenous livelihoods.

Furthermore, climate adaptation policies should recognize Indigenous communities not only as vulnerable populations but also as holders of solutions. The dominant policy narrative often emphasizes Indigenous communities' exposure to climate risks while overlooking their existing adaptive capacities. This vulnerability-oriented approach may unintentionally reinforce dependency and marginalization. A rights-based approach, by contrast, recognizes Indigenous communities as active agents capable of contributing to climate resilience through their knowledge, institutions, and environmental stewardship practices.

The findings also suggest the importance of improving coordination between different areas of Indonesian law. Indigenous climate adaptation intersects with constitutional law, environmental law, forestry regulation, spatial planning, and human rights protection. Fragmentation among these legal sectors creates uncertainty and limits the effectiveness of Indigenous rights recognition.

Developing a more integrated legal framework would help ensure that climate adaptation policies are consistent with Indigenous rights obligations and environmental sustainability objectives.

From an international perspective, Indonesia's experience provides broader lessons regarding the relationship between Indigenous rights and climate governance. As one of the countries with significant tropical forest ecosystems and diverse Indigenous populations, Indonesia plays an important role in demonstrating how Indigenous knowledge can contribute to global climate solutions. However, achieving this potential requires moving beyond symbolic recognition toward institutional reforms that empower Indigenous communities as legitimate environmental governance actors. Overall, the policy implications of this study demonstrate that integrating traditional knowledge into climate adaptation requires a multidimensional approach combining legal reform, institutional transformation, and participatory governance. Indigenous knowledge in Papua represents a valuable resource for climate resilience, but its contribution depends on whether Indigenous communities have the rights, authority, and institutional support necessary to sustain their knowledge systems. Therefore, future climate adaptation policies should prioritize recognition, participation, and collaboration as central principles for building equitable and effective climate governance.

Conclusion

This study demonstrates that Indigenous traditional knowledge represents a critical component of climate change adaptation strategies among Indigenous communities in Papua, Indonesia. Traditional ecological knowledge developed through generations of interaction with forests, rivers, coastal ecosystems, and agricultural landscapes provides communities with adaptive capacities to respond to environmental uncertainty. However, the findings indicate that Indigenous adaptation should not be understood merely as the application of local ecological practices, but as a broader social-ecological system supported by customary institutions, collective governance mechanisms, and cultural relationships with nature. The ability of Indigenous communities to maintain and develop these adaptation strategies is strongly influenced by external pressures, including climate change impacts, land-use transformation, resource exploitation, and limited institutional recognition.

The study further reveals that the effectiveness of Indigenous knowledge in climate governance is closely connected to legal recognition and institutional arrangements. Although Indonesia has made important progress through constitutional recognition, judicial developments regarding customary forests, and increasing attention to community participation in environmental policies, significant gaps remain between normative recognition and practical implementation. Indigenous knowledge cannot be effectively integrated into

climate adaptation frameworks without protecting Indigenous territorial rights, strengthening customary governance institutions, and ensuring meaningful participation in decision-making processes. Therefore, a rights-based and legally pluralistic approach is necessary to transform Indigenous communities from policy beneficiaries into legitimate actors in climate governance.

This research contributes to the broader discourse on climate adaptation, Indigenous rights, and environmental law by demonstrating that climate resilience requires the integration of ecological knowledge, legal recognition, and inclusive governance systems. The case of Papua illustrates that protecting Indigenous knowledge is not only a cultural responsibility but also a strategic approach for strengthening climate adaptation and ecosystem sustainability. Future climate policies in Indonesia should move beyond symbolic recognition of Indigenous knowledge toward institutional mechanisms that support knowledge protection, co-production, and Indigenous self-determination. Further research may expand this analysis through comparative studies across Indigenous communities and interdisciplinary approaches that combine legal studies, climate science, and participatory research methodologies.

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