



Systemic Attributes of Climate Finance: Assessing Distributional and Functional Efficiency in Vulnerable Colombian Regions



Atributos sistémicos de la financiación climática: evaluación de la eficiencia distributiva y funcional en regiones vulnerables de Colombia

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Abstract

This study develops an integrated typology and a territorial assessment of the efficacy of climate change adaptation finance mechanisms in Colombia. Employing a multi-method approach, integrating qualitative coding, matrix categorization, geospatial mapping, and data visualization—finance mechanisms were classified into public, private, and market-based instruments. The findings reveal significant territorial disparities regarding financial accessibility and institutional coordination. Results demonstrate that the National Adaptation Fund (*Fondo Nacional de Adaptación*) and Payments for Environmental Services (PES) yield the highest adaptive impact. Conversely, private and hybrid mechanisms exhibit marginal utilization in high-vulnerability zones. The primary contribution of this research is the proposal of a structural analytical framework based on six systemic attributes: flexibility, territoriality, multi-level governance, risk management, institutional articulation, and absorptive capacity. This framework facilitates a rigorous evaluation of climate finance effectiveness and provides a strategic baseline for resource prioritization in vulnerable territories, serving as a robust decision-making tool for public policy and territorial planning.

Keywords: Adaptation; Financing; Climate change; Vulnerability; Mechanisms; Financial instruments.

Resumen

El presente estudio desarrolla una tipología integrada y una evaluación territorial de la eficacia de los mecanismos de financiamiento para la adaptación al cambio climático en Colombia. Mediante la implementación de un enfoque metodológico mixto que integra codificación cualitativa, categorización matricial, mapeo geoespacial y visualización de datos los mecanismos de financiación fueron clasificados en instrumentos públicos, privados y de mercado. Los hallazgos revelan disparidades territoriales significativas en términos de accesibilidad financiera y coordinación institucional. Los resultados demuestran que el Fondo Nacional de Adaptación y los Pagos por Servicios Ambientales (PSA) generan el mayor impacto adaptativo. Por el contrario, los mecanismos privados e híbridos exhiben una utilización marginal en zonas de alta vulnerabilidad. La contribución fundamental de esta investigación es

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la propuesta de un marco analítico estructural basado en seis atributos sistémicos: flexibilidad, territorialidad, gobernanza multinivel, gestión del riesgo, articulación institucional y capacidad de absorción. Dicho marco facilita una evaluación rigurosa de la efectividad del financiamiento climático y establece una línea base estratégica para la priorización de recursos en territorios vulnerables, constituyéndose como una herramienta robusta para la toma de decisiones en política pública y planificación territorial.

Palabras clave: Adaptación; Financiamiento; Cambio climático; Vulnerabilidad; Mecanismos; Instrumentos financieros.

Introduction

Climate finance has attained strategic prominence within the global agenda, driven not only by the escalating frequency of extreme weather events but also by the formidable challenges developing nations face in mobilizing resources aligned with their specific territorial requirements. Recent reports indicate that while the international climate finance architecture has matured, persistent inefficiencies remain regarding accessibility and alignment with local realities in vulnerable regions (Organización para la Cooperación y el Desarrollo Económicos [OECD], 2023). Within this context, Colombia emerges as one of the most susceptible nations to climate change impacts, a consequence of its high ecological diversity, socio-environmental fragility, and pervasive structural inequality.

Specialized international literature has demonstrated that the efficacy of climate finance is contingent upon factors such as multi-level governance, institutional capacity, administrative flexibility, and the degree of territorialization of financial instruments (Intergovernmental Panel on Climate Change [IPCC], 2022; UNEP, 2023). Nevertheless, studies focused on Latin America highlight significant systemic gaps between the supply of financing and local implementation capacities, particularly in jurisdictions characterized by weak institutional presence and high vulnerability (World Bank Group, 2023). This evidence suggests that quantifying available resources is insufficient; it is imperative to analyze the operational dynamics of these mechanisms within specific territorial contexts. In Colombia, while there is an increasing number of financing mechanisms

Theoretical framework

The paradigm of climate finance has evolved from a primary focus on resource mobilization toward an analytical emphasis on its tangible territorial efficacy. In this context, efficacy is defined as the extent to which financial flows yield verifiable outcomes in adaptation, vulnerability reduction, and resilience enhancement. Emerging literature suggests that performance is determined not merely by capital volume but by allocative efficiency, accessibility, and alignment with localized

priorities (Buchner et al., 2019; Weikmans & Roberts, 2017). Unlike mitigation mechanisms, where outcomes are quantifiable through emission reductions, adaptation interventions present significant methodological complexities due to the localized nature of their benefits; this has necessitated the adoption of multi-methodological approaches and contextualized evaluations (Watkiss & Hunt, 2013). The persistent financing gap for adaptation in developing nations underscores that fund availability does not guarantee equitable delivery to the most vulnerable jurisdictions, reinforcing the imperative to scrutinize spatial distribution patterns alongside nominal amounts (UNEP, 2023; Roberts et al., 2021).

Climate finance operates within intricate governance systems characterized by multi-scalar decision-making and heterogeneous actors. From the perspective of multi-level governance theory, the success of climate policy hinges on vertical coordination between national, regional, and local tiers, as well as horizontal interaction across public, private, and community sectors (Bulkeley, 2013). This is complemented by polycentric governance theory, which posits that decentralized decision centers can foster more effective responses when characterized by flexibility, cooperation, and institutional learning (Ostrom, 2010). Consequently, absorptive capacity—the ability of institutions and communities to access, manage, and execute resources—emerges as a critical determinant of financial efficacy (Cui & Huang, 2018). Research in developing contexts identifies institutional constraints, such as cumbersome administrative procedures, technical deficits, and accountability gaps, as systemic barriers that impede financial accessibility (Scobie, 2018; Khan et al., 2020).

Climate vulnerability is conceptualized as the intersection of exposure, sensitivity, and adaptive capacity, implying that impacts are disproportionately distributed based on the socio-economic, environmental, and political attributes of a given territory (Adger, 2006; Smit & Wandel, 2006). Within the framework of socio-ecological resilience, adaptation seeks not only to mitigate impacts but to augment the system's capacity for reorganization following disturbances (Folke, 2006). This perspective champions territorialized adaptation, which prioritizes local knowledge, participatory governance, and contextual suitability (Cutter et al., 2008). Recent evidence confirms that the integration of adequate financing, strengthened local governance, and territorial insights produces superior outcomes in climate resilience and adaptive equity (IPCC, 2022).

Drawing upon these conceptual foundations, this study integrates several theoretical traditions to provide a comprehensive understanding of climate finance mechanisms. Territorial coverage is grounded in vulnerability and adaptation theories emphasizing spatial equity in resource distribution. Institutional coordination is informed by multi-level and polycentric governance, addressing the need for actor articulation in fragmented contexts. Absorptive capacity is linked to the literature on institutional capabilities and development finance, highlighting the role of operational arrangements in resource execution. Finally, flexibility and institutional learning are situated within adaptive governance, while territoriality aligns with

socio-ecological and localized adaptation paradigms. This theoretical synthesis places the analysis within contemporary debates on financial effectiveness, territorial governance, and resilience, providing a robust framework for interpreting results and facilitating cross-regional comparisons.

Methodology

The research employed a multimethod approach designed to analyze both the regulatory framework and the operational and territorial behavior of climate finance mechanisms in Colombia. To ensure rigor and replicability, the mechanisms included in the analysis were selected based on explicit criteria: they had to be formally recognized instruments within the national regulatory framework on climate finance; contain verifiable technical information issued by governmental, multilateral, or financial institutions; demonstrate applicability or implementation potential in vulnerable territories; present an explicit climate objective related to adaptation or mitigation; and be representative of the national financial ecosystem through a balanced inclusion of public, private, mixed, and market-based mechanisms. Likewise, the selection of secondary sources was guided by criteria of relevance, technical rigor, and triangulation potential, incorporating only documents published after the Paris Agreement, reports produced by specialized organizations, and scientific literature capable of validating the regulatory and financial evidence.

The systematic document review enabled the identification of existing mechanisms, their legal foundations, and their operational characteristics. Subsequently, qualitative coding was conducted using NVivo software, selected because it supports pattern identification, attribute linkage, and information systematization without compromising analytical traceability, while reducing interpretive bias inherent in exclusively manual assessments. A categorization matrix complemented this process by establishing standardized criteria to compare heterogeneous mechanisms in terms of functioning, benefits, limitations, coverage, and types of financed projects. This tool was justified because it facilitates the integration of qualitative and semi-quantitative analyses, enabling the construction of a robust comparative typology.

In parallel, geospatial mapping allowed the correlation of the territorial distribution of mechanisms with the Climate Vulnerability Index, identifying areas of under-coverage and relevant spatial patterns. This tool was incorporated because it reveals territorial inequalities that cannot be observed solely through regulatory sources. Finally, the visualizations developed in Power BI were justified because they enable cross-analysis of coverage, attributes, and operational scales, clarifying hierarchies, gaps, and relationships among mechanisms more effectively than isolated textual descriptions. All components were integrated through analytical triangulation that combined regulatory evidence, qualitative coding, territorial analysis, and visual data to strengthen the consistency and robustness of the findings.

The study acknowledges several methodological limitations that should be considered when interpreting results and replicating the analysis. The reliance on secondary sources implies that the quality and depth of the study are conditioned by the availability, frequency, and completeness of information provided by institutions

Results and discusión

Classification of financial mechanisms

Public order mechanisms

Based on the origin of each of the mechanisms available for climate change adaptation, a structured classification is made that takes into account territoriality variables, as well as the relevance in areas of high vulnerability. Each mechanism describes its operation, benefits, key aspects for its implementation, strengths, and opportunities. This makes it possible to understand the diversity of existing instruments and to evaluate the effectiveness of these mechanisms with respect to the needs of the most vulnerable territories. The comparison between mechanisms where patterns of access, levels of institutional integration, and prioritized sectors are identified allows for a comprehensive understanding of the behavior of these instruments. Therefore, this classification becomes a tool of analysis of great magnitude that impacts decisions that include public policy, as well as territorial planning. For example, the National General Budget (NGB) is allocated directly by the government, but its risk is associated with political changes. The General Royalties System (GRS) provides direct financing, but it depends on the volatility of resources. Competitive funds encourage innovation and local participation, but can be delayed. Public loans mobilize large resources. The National Adaptation Fund (NAF) has high operational flexibility and involves complex administrative processes. The National Climate Change Adaptation Plan (NCCAP) maintains a multisectoral approach, but has institutional dependencies. The Green Climate Fund (GCF) has high financial capacity and innovation, while the UN Adaptation Fund is results-oriented and focused on community capacity building.

Strategic integration of financial mechanisms through public funds for climate change adaptation in vulnerable areas of Colombia

The integration of financial mechanisms for climate change adaptation in vulnerable areas in Colombia is an essential component in addressing extreme weather events and protecting citizens and their environment who are most at risk. For example, the NCCAP focuses its adaptation actions across the entire territory, which facilitates the identification of the most vulnerable sectors. The NAF is responsible for financing projects that are in line with the priorities defined above, while the NGB channels resources to different levels of government, enabling the implementation of these actions on both a local and national scale. Interinstitutional coordination

is another key factor for success in this integration. For example, the creation of specialized groups and the consolidation of IT platforms that enable the coordination and adoption of tracking and monitoring tools have a fundamental impact on making management more effective. This ensures that these spaces strengthen their environmental, financial, and territorial relationships so that these resources are used appropriately and promptly.

The design of integrated projects is also important for combining various sources of funding and thus maximizing their impact in the territories. One of the guiding principles of this integration is institutionality, which is essential because it ensures both administrative and technical quality in the implementation of climate action projects, integrating adequate resource management, accountability, transparency of information, improved environmental governance, and effective implementation. The benefits of integration are sustainable over time. Combining different sources of financing reduces dependence on a single fund, diversifies financial risk, increases geographical coverage, and attracts capital that complements public investment. The robustness of the financial structure contributes significantly to the country's social and ecological resilience, which promotes best practices as a transformative axis for an effective response to the impacts of climate change.

Private order mechanisms

Private mechanisms currently face a major challenge, which is how to carve out a space within the system that allows them to establish themselves as a real option for accessing financing by the most vulnerable communities. However, private financing for climate change is not straightforward: Governments must help create the right conditions for the private sector to contribute to the fight against climate change (Foro Económico Mundial, 2025). In private funds, the integration of strategies with environmental, social and governance (ESG) criteria, impact measurement, corporate governance provisions, and risk management are highly relevant variables for the application of these mechanisms. Elements such as alliances with government entities, diversification of initiatives, and the existence of financial products are key aspects for funds to be appropriate for the planned strategies. Among these, sustainable investment funds, public-private partnerships for adaptation, the business sector, green loans and credits, and social responsibility programs stand out.

Strategic integration of financial mechanisms by private funds for climate change adaptation in vulnerable areas of Colombia

One of the advantages of integrating mechanisms composed of private funds is the strengthening of a financial ecosystem that can positively impact investment in climate adaptation projects by promoting different sustainable practices in the national economy. Proof of this is that spending on climate change by the private sector has increased in recent years. For example, between 2011 and 2019, the private sector

invested more than 2.2 trillion Colombian pesos (Departamento Nacional de Planeación y Fundación para la Educación Superior y el Desarrollo Fedesarrollo, 2022). Of this amount, 34% has been allocated to adaptation actions and 58% to mitigation, while 8.4% implements comprehensive actions, i.e., mitigation and adaptation (Departamento Nacional de Planeación y Fundación para la Educación Superior y el Desarrollo Fedesarrollo, 2022).

When designing integrated projects, combining various financial instruments can have positive impacts. For example, an ecological restoration project may have green loans, corporate social responsibility strategies, and carbon credits. The integration of financing mechanisms for climate change adaptation includes scenarios of international cooperation where global and local policies are integrated through intergovernmental organizations. Social enterprises, as well as contributions from academia and research, promote the channeling of resources to the most vulnerable territories, where civil society and non-governmental organizations contribute significantly.

Collaborative platforms and knowledge centers contribute to improving the technical capabilities of the different actors involved in these mechanisms. One point of great importance to consider is training in risk management, financial components, and monitoring, which are fundamental to the consolidation of institutional actions. The interrelationship between each of the financial mechanisms contributes to risk reduction, improved resource management, and strengthened environmental governance. It is also a means of facilitating adaptation to climate change, thereby benefiting the communities most exposed to these risks.

Market mechanisms

The importance of diversifying financial instruments and making them more accessible makes market mechanisms an option that combines accessibility, flexibility, and diversification. These investments drive activities that are crucial for the decarbonization of the planet, from agriculture and bioenergy to low-carbon buildings and transportation (Climate Bonds Initiative, 2025).

Strategic integration of private financial mechanisms for climate change adaptation in vulnerable areas

In Colombia, climate change in high-risk areas requires the implementation of market mechanisms that channel investments toward recent and effective solutions. Green bonds, climate insurance, payment for environmental services, carbon credits, mandatory environmental compensation, and green credits are representative examples of high-impact tools that contribute to minimizing climate effects and addressing associated risks through approaches based on economic incentives. Green bonds mobilize capital toward projects with beneficial environmental impacts, such as ecological restoration, sustainable transportation, and energy efficiency. Climate

insurance has been an emerging tool that helps protect vulnerable communities from extreme weather events involving droughts, flooding, and crop damage, promoting risk protection and minimizing the effects that could occur in the event of a loss index.

Payment for environmental services (PESs) are financial incentives in cash or kind that recognize actions and practices associated with ecosystem preservation and restoration (Ministerio de Ambiente y Desarrollo Sostenible, 2025). Meanwhile, carbon credits, which are a system that offers economic incentives for companies and governments to seek to improve the quality of the environment (Ámbito jurídico, 2025), can finance mitigation and adaptation projects that can generate tradable credits in regulated or voluntary markets. This strengthens communities' access to equitable financing for the purpose of developing projects ranging from restoration to sustainable agriculture and wetland recovery.

On the other hand, mandatory environmental compensation, which aims to compensate or generate resources and surpluses for communities committed to the environmental sustainability of their forests and climate change (Corporación Aldea Global, 2025), as well as green credits, have been consolidating themselves as mechanisms that complement and incentivize companies' environmental responsibility efforts by promoting projects that have positive effects on the environment, the preservation of ecosystem services, and increased climate resilience. This ensures that the negative impacts of large economic projects are minimized and can be mitigated through investments in environmental measures. This allows these market mechanisms not only to mobilize resources toward adaptability but also to promote innovation, research, financial efficiency, and social balance. Its implementation must be accompanied by a solid regulatory framework, reliable transparency and accountability standards, strengthening of technical capacity at the institutional level, and community participation from the local to the regional level.

General analysis of financial mechanisms for climate change adaptation in vulnerable areas of Colombia

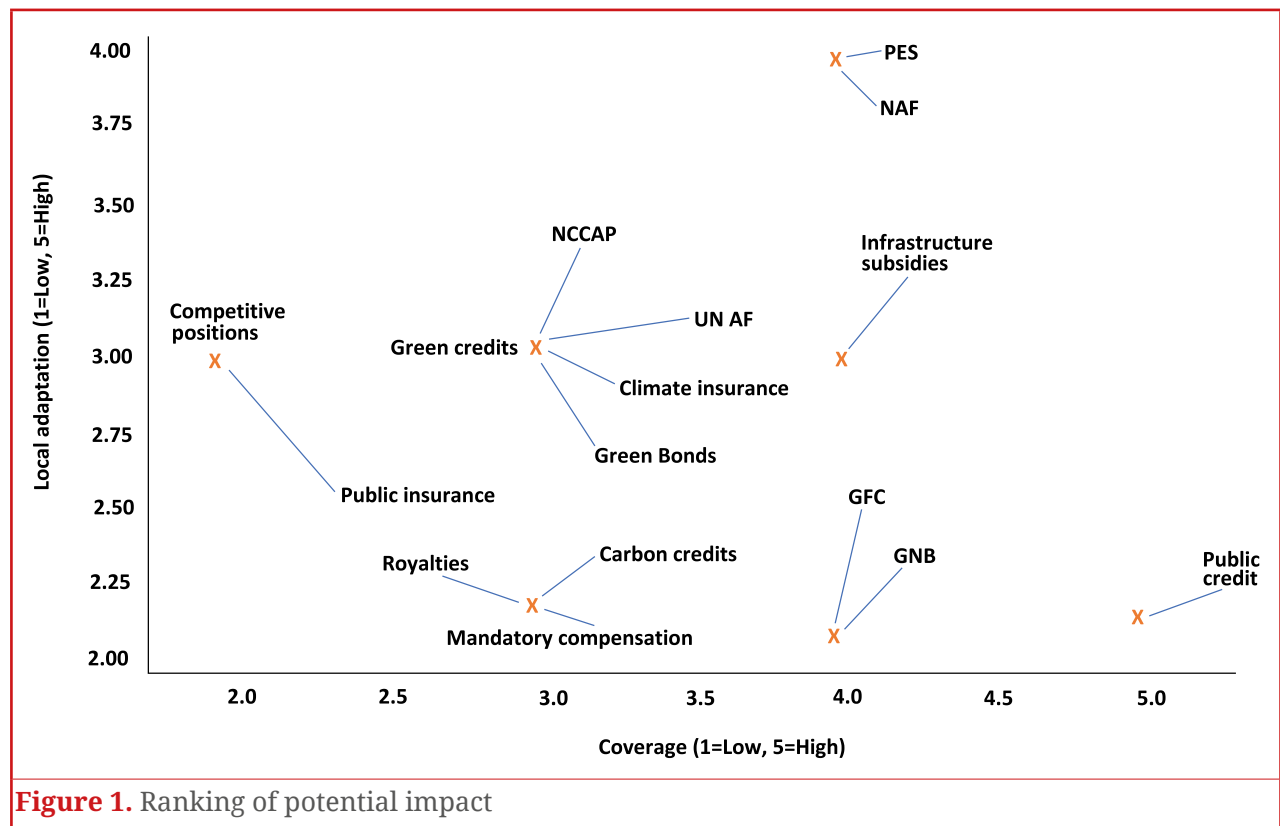
To determine, in general terms, which financial mechanisms for climate change adaptation are the most robust, a scatter diagram is drawn up showing the different mechanisms according to two criteria: the first is territorial coverage, measured on the horizontal axis and ranging from 1 (low) to 5 (high); and the second corresponds to the degree of contribution to local adaptation on the vertical axis, which also ranges from 1 (low) to 5 (high). Each orange X corresponds to an instrument, and many of them are positioned simultaneously, reflecting how much this mechanism is used and how effective it is in benefiting the most vulnerable communities. Figure 1 illustrates the hierarchy of financial mechanisms.

It can be noted that PSEs and NEF are at the top of the graph, standing out for their high adaptability and coverage, which makes them strong candidates for implemen-

tation. When combined, they could provide greater access to resources. Meanwhile, public credit and the NGB, although showing high coverage, are not strong in terms of community contribution or local adaptation. In the central area of the diagram, alternatives such as climate insurance, subsidies for resilient infrastructure, and the UN Adaptation Fund are mechanisms that reasonably balance both the degree of coverage and local adaptation. In the left quadrant of the same figure, there are lower levels of use and lower impact, which include competitive funds, royalties, and green bonds.

This shows that each region of Colombia has challenges and opportunities for implementing these types of mechanisms, which have cross-cutting elements that can enhance the implementation of an adaptation strategy. Climate justice arises from the understanding that global warming goes beyond an ecological crisis; it is also a human crisis, in which factors such as power, access to resources, and justice must be considered (Rodas Lopera, 2022).

Community participation, robust local governance, and access to sustainable financing are recurring and indispensable measures. An example of this is in the Pacific region, where one of the key factors for success is involving communities alongside institutions; in the Andean region, it is regulatory consolidation and watershed management; and in the Amazon, it is the empowerment of indigenous



peoples and a commitment to providing nature-based solutions. Meanwhile, some territories require particular emphasis: in the Caribbean region, resilient infrastructure and mangrove conservation are important aspects to consider in the ecological regulation of these areas. In the Orinoquía region, promoting silvopastoral practices and implementing climate insurance are of great importance. In the Amazon, environmental monitoring is key to preventing problems such as deforestation. All of the above require intensive work on national policies that combine mechanisms and include actions that mobilize social, environmental, and cultural aspects.

Regional analysis of financial mechanisms for climate change adaptation in Colombia

The financial robustness of public, private, and market mechanisms demonstrates their performance and applicability, which vary significantly depending on the territories where climatic heterogeneity and inequality in institutional structure have a significant impact on the efficiency of each of the mechanisms, which in turn are measured by factors related to local governance, access to technical and operational information, and the structure among different community actors. Therefore, effective adaptation depends not only on access to financing but also on the integration of these instruments in different regions of the country. Therefore, efforts to adapt to climate change are related to risk assessments in different geographical areas and for different sectors and activities (Gómez-Lee, 2021). The criteria accompanying refer to the significance of each of these elements in the relationship between the different factors that enhance the implementation of financial mechanisms in different regions of the country. This facilitates the development of resilient projects (Departamento Nacional de Planeación, 2025). These criteria are:

- Climate adaptation zones: Communities, research centers, and local initiatives that actively address climate change implement resilient structures, environmental education, and climate monitoring.
- Eco-rural areas: Rural regions with unique climates, local knowledge, and strong cultural identity. They promote ancestral practices, agroecology, and nature-based solutions.
- International funds: Sources of financing (Green Climate Fund, international cooperation, etc.) that support mitigation and adaptation initiatives. They channel resources to vulnerable areas.
- Funded projects: Active initiatives that implement climate solutions with external or government financial support. Represents the territorial implementation of climate plans.
- Strategic ecosystem areas: Key areas for biodiversity, water conservation, and climate balance. Priority areas for environmental protection and restoration actions.

- Climate-focused regions: Territories that integrate environmental policies, sustainable development, and adaptation into their territorial planning.
- Climate finance: Strategic allocation of economic resources to strengthen local climate response capacities.

Cross-cutting themes of climate adaptation

- Transfer of adaptive technologies: Introduction and dissemination of technical solutions for adaptation (water collection systems, biofilters, clean energy, among others).
- Community participation and local knowledge: Recognition and integration of ancestral knowledge and traditional practices as a fundamental part of the solution.
- Research and knowledge: scientific and community-based production for evidence-based policy design.

Comparative analysis of financial mechanisms based on the qualitative coding matrix

This type of analysis under the qualitative coding matrix allows for the comparison of various financial mechanisms that have been classified into key attributes such as functioning, benefits, scope, and territorial relevance. According to this analysis, national public funds such as the NGB and Corporate social responsibility have high coverage but low territorial specificity. On the other hand, international mechanisms such as the GCF and the NAF have greater levels of impact and results, but maintain barriers to access due to their rather demanding technical requirements. The most relevant attributes in the coding matrix are:

- Functioning: Describes how the financial mechanism operates
- Benefits: Illustrates the advantages offered by the mechanism
- Key aspects: These are the relevant characteristics or considerations in the mechanism.
- Areas of focus: These are the priority sectors or issues addressed by the mechanism.
- Typical projects: Examples of projects financed by the mechanism.
- Scope: geographical or institutional location where the mechanism operates.

A comma is encoded to determine how often each attribute influences each mechanism. In this case, a qualitative scale is used to represent the emphasis of each tribute in the description for each mechanism. This qualitative coding scale is:

- High prominence: the attribute is described in detail and is relevant to the mechanism.

- Medium prominence: the attribute is mentioned, and its description includes certain details.
- Low prominence: the attribute is mentioned briefly or superficially.
- Not mentioned: the attribute is not mentioned in the mechanism.

Table 1 describes the different types of mechanisms and codes them according to the rating variables described above.

Table 1. Encoding matrix.

Financial Mechanism	Operation	Benefits	Key Points	Areas of Focus	Typical Projects	Scope
Public Funds						
National General Budget (NGB)	3	2	2	0	0	2
General Royalties System	3	2	2	0	0	2
Competitive Funds	3	2	2	0	1	2
Public Credit	3	2	2	0	1	2
Public Assurance	3	2	2	0	1	2
National Adaptation Fund (NAF)	3	3	3	3	3	3
National Climate Change Adaptation Program (NCCAP)	3	3	3	3	3	3
Green Climate Fund (GCF)	3	3	3	3	3	3
United Nations Adaptation Fund (NAF)	3	3	3	3	3	3
Grants for Investment in Resilient Infrastructure	3	2	2	3	3	3
Private Funds						
Sustainable Investment Funds	3	3	3	3	0	2
Corporate Social Responsibility (CSR)	3	3	3	0	0	2
Corporate Funds	3	2	2	0	0	2
Public-Private Partnerships	3	3	3	0	1	2
Green Loans and Credits from Financial Institutions	3	2	2	0	0	2
Incentives and Corporate Social Responsibility (CSR) programs	3	3	2	0	0	2
Public-private partnerships for adaptation	3	3	3	0	1	2
Market Mechanisms						
Green Bonds	3	3	3	0	0	2
Climate Insurance	3	3	3	0	0	2
Payment for Environmental Services (PES) System	3	2	2	0	0	2
Carbon Credits	3	2	2	0	0	2
Mandatory Environmental Compensation	3	2	2	0	0	2
Green Credits	3	3	3	0	0	2

The above analysis provides a quantitative overview of the strongest mechanisms in the public, private, and market spheres, intending to identify those that are adaptable to each type of mechanism. It also provides a more accurate assessment of which ones are the most powerful and which ones have the least impact, as well as which ones are the most accessible and offer the best benefits.

Analysis of the relationship between financing mechanisms for climate adaptation

The relationship diagram shows the different interactions between the financing mechanisms for climate change adaptation in Colombia. Its purpose is to facilitate understanding of the financial ecosystem, which links public and private sources, as well as market instruments, to identify their connections and complementarity. The three categories are:

- **Public funds:** These consist of financial resources from the state. These funds are intended to finance resilient infrastructure, public policies, and strategic adaptation projects implemented by local governments or government entities.
- **Private funds:** These consist of resources from businesses or investors seeking to obtain economic benefits without disconnecting from environmental or social impact. This category includes corporate or business social responsibility programs, sustainable investment funds, green loans, and public-private partnerships.
- **Market mechanisms:** These are financial instruments managed by private, public, or mixed entities. This mechanism includes green bonds, such as climate insurance and carbon bonds. They focus on channeling resources to mitigation and adaptation initiatives using financing structures whose results, risk, and profitability are suitable for implementing the mechanism.

One of the key factors of the visualization diagram is that it can show the cross-relationships between each other, reflecting a strong interdependence:

- **Public funds - Private funds:** Their relationship is established through co-financing schemes, tax incentives, and public-private partnerships, which mobilize private sector resources for projects of public interest.
- **Private funds - Market mechanisms:** Their coordination through a scenario of investment in safer green bonds and green loans has a high impact. Private investors can finance sustainable projects in search of a financial return.
- **Public funds - Market mechanisms:** Their connection is regulation, state incentives, and participation in international mechanisms such as the GCF and the NEF.

Quantitative analysis of financing mechanisms for climate change adaptation

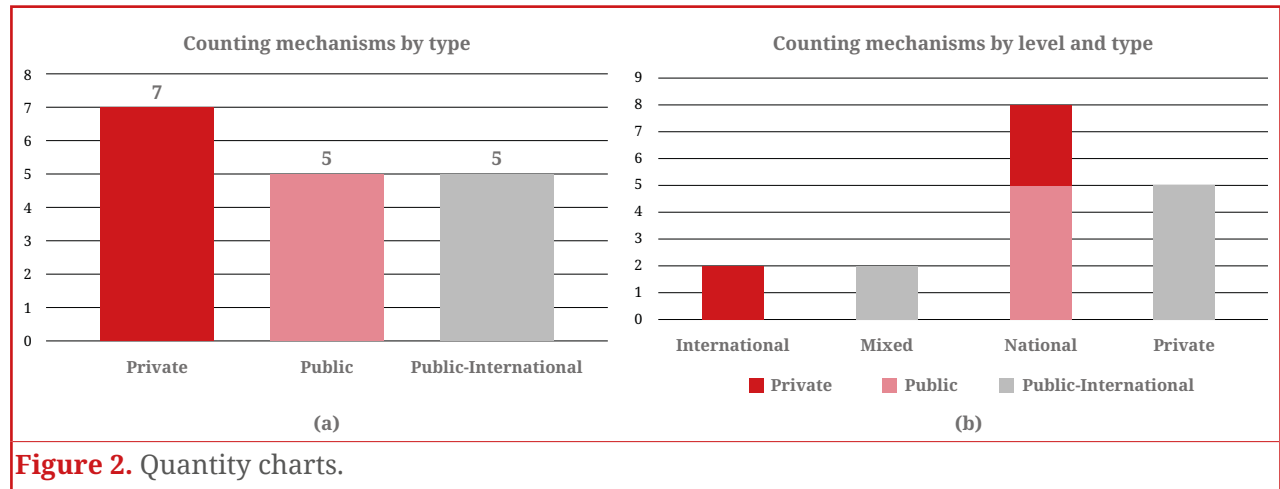
Complementing the qualitative analysis comprehensively, this quantitative analysis took into account financing mechanisms classified according to their source: public, private, or mixed. In addition to this, this classification also takes into account the level of operation, whether national, international, or private. Given the classification of mechanisms according to their type and level, it is possible to emphasize the orientation of each one. In light of the above, the characteristics of each type of mechanism are highlighted in accordance with the following description:

- **Public mechanisms:** These operate at the national level and are managed by the Colombian state apparatus. They include instruments such as the NGB, the CSR, competitive funds, and public credit. They also contain instruments with international reach, such as the NAF and the NCCAP, which channel resources to projects at the national level.
- **Private mechanisms:** These include sustainable investment funds, CSR and RSE programs, and green loans. Its management is based on the management carried out by companies as the main investors, as well as financial institutions that mobilize capital with a social and environmental focus.
- **Blended mechanisms:** Integrate the resources and capacity of both the public and private sectors. An example of this is public-private partnerships. These instruments enable the implementation of projects aimed at climate resilience.

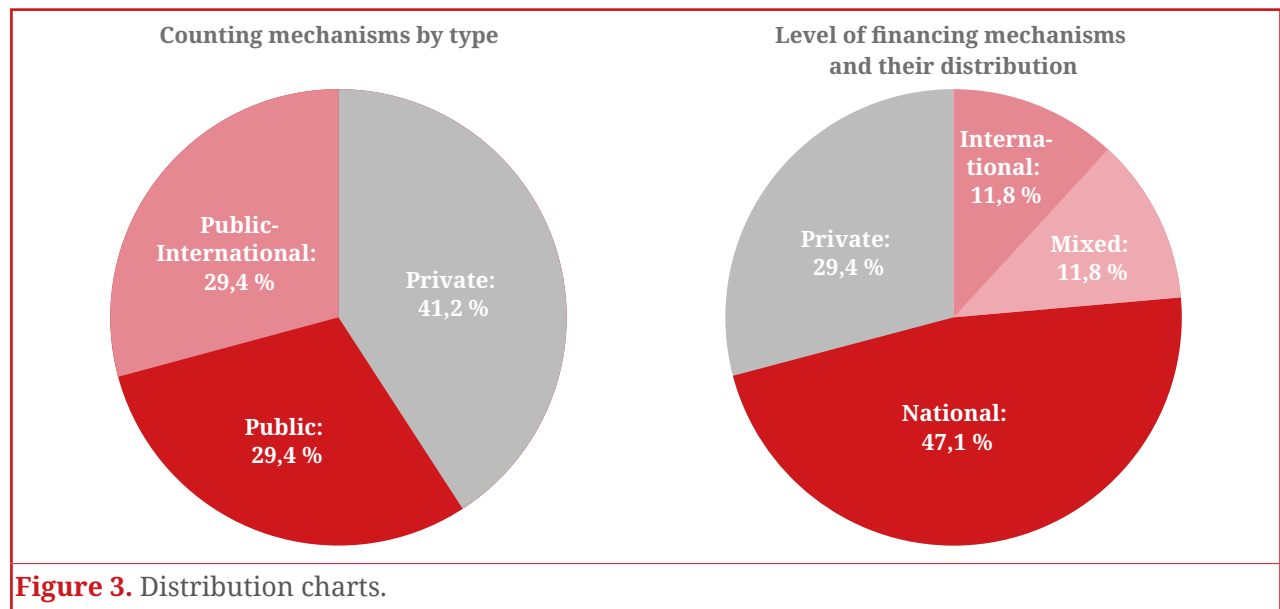
Although there is a concentration of instruments at the national level, their internationalization and the participation of the private sector are on the rise, creating a diversified environment. This classification allows for better decisions to be made regarding the allocation of resources for climate adaptation, but even more importantly, how they should be allocated to the most vulnerable areas of the country. The total number of mechanisms grouped by type clearly shows which group predominates in terms of financial mechanisms (See Figure 2). Private mechanisms are the most common, followed by public mechanisms and finally public-international mechanisms. Therefore, the imminent growth of the private sector in investment for climate adaptability in Colombia has been booming, with certain instruments such as investment funds, CSR, and public-private partnerships standing out. Figure 2 (a) illustrates the number of mechanisms by type and number of mechanisms by level and type.

Figure 2 (b) illustrates the cross-relationship between the type of mechanism and its level of operation, allowing us to identify the most dominant combinations, such as the high concentration of public mechanisms at the national level and the power of the absence of private international mechanisms. The analysis provides insights that reveal certain strategic gaps in the implementation of mechanisms and their

types, such as the limited internationalization of some private instruments, thereby enabling the strengthening of partnerships and new forms of joint financing



Another analysis to be carried out relates to concentration by type and level (See Figure 3). In Figure 3 (a), the distribution of mechanisms is concentrated in the private sector with 41.2%, which indicates that efforts should be made to increase participation in the international spectrum combined with the public sector, as this could achieve greater coverage and reach for those areas that require greater investment on a large scale. Meanwhile, in Figure 3 (b), the concentration of levels in the national context at 47.1% indicates that other levels, such as the international level, should be explored, since the combination of mechanisms there could bring greater benefits to territories vulnerable to the effects of climate change.



When it comes to financial mechanisms, analyses vary widely, as they contain key elements that deserve to be reviewed in light of the behavior of their variables. Some existing mechanisms that, in terms of structure, could prove beneficial for the implementation of climate adaptation strategies, are not reaching the areas that really need them. By 2030, according to estimates by the United Nations Environment Programme (UNEP), the cost of adaptation will reach between USD 140 billion and USD 300 billion per year, and by 2050, between USD 280 billion and USD 500 billion (Centro de investigaciones económicas, 2022). Colombia is one of the countries most vulnerable to climate change, and although it emits less than 1% of global greenhouse gases (Colombia check, 2025), its strategic position within the continental geography makes it vulnerable to the effects of climate change. This gives rise to the need to create adaptation strategies, but these cannot stand alone; they must be accompanied by financial instruments that leverage them and mobilize resources that are specifically needed to reach these areas and reduce the risk and vulnerability of these regions.

Public funds represent a great opportunity for action to finance climate adaptation in the country. Strengths such as flexibility in allocation, direct acquisition in the regions, the possibility of mobilizing large resources, and promoting innovation and community participation are key factors that these mechanisms can use to their advantage to boost financing in the most vulnerable areas of the country. However, it must be understood that many of these territories and their stakeholders are not prepared to adopt such instruments because, due to their high technical complexity and operational and administrative requirements, they demand considerable knowledge of these mechanisms, which sometimes prevents these communities from gaining real access to such financing. In terms of private mechanisms, it is undeniable that they enjoy an excellent reputation and are quite effective in mobilizing resources that contribute to innovation and projects that can be managed in these highly vulnerable territories.

The flexibility they maintain, as well as the potential alliances they can form between different instruments, has a significant positive impact on the socio-environmental dynamics of these areas. The potential impact that the mechanisms to be applied in vulnerable areas of the country may have corresponds to two fairly important variables: the first is local adaptation, and the second is coverage. PESs and the NAF are currently the most adaptable mechanisms with the best coverage, although it should be noted that subsidies that increase resilience also have an average level of adaptability and coverage. Public loans, for example, face major challenges. Although they have broad coverage, they are not sufficiently adapted, as are the national budget and mandatory compensation. Monitoring adaptation financing also relates to activities that address the current and expected effects of climate change, when such effects are material to the context of those activities (Funes et al., 2023).

The regional approach brings with it certain factors that are highly relevant to the implementation of financial mechanisms for climate stability. In Colombia, where territories are so different from one another, these factors are important because they personalize the different instruments that can be applied in these regions. However, it should not be forgotten that key success factors leverage this strategy. In the Pacific region, important factors such as community participation, coordination between institutions, ongoing technical assistance, and affordable financing are of great importance for a region that is highly vulnerable and rich in biodiversity. Meanwhile, the Andean region maintains a comprehensive approach to water management through watersheds, the implementation of a consistent regulatory framework, the strengthening of local governments, and the exchange of knowledge acquired across territories. In the Caribbean region, early warning systems, conservation of ecosystems such as mangroves, the design of infrastructure based on a resilience model, and access to financial incentives are becoming important elements for developing more effective mechanisms. In the Orinoquía region, where there is still much territory to explore, agroforestry practices, access to climate insurance, strengthening of existing capacities, and constant monitoring are key elements for the development of better financing strategies.

Finally, in the Amazon region, whose natural capital is so invaluable to the global environment, the participation of indigenous communities, ecosystem-based adaptation, long-term financing chains, and ongoing monitoring suggest greater effectiveness in the implementation of these mechanisms. Qualitative coding helps us understand which of all the mechanisms are most effective when applied. The mechanisms analyzed in large part function adequately; that is, they are highly prominent, described in great detail, and important for their application. However, other mechanisms require improvement in certain areas, such as focus, particularly for the NAF, NCCAP, and GCF, and subsidies for investment in resilient infrastructure, which have a clear and concise focus in terms of public instruments.

In private funds, one variable in which these instruments are not sufficiently robust is in typical projects, meaning that few have been implemented from which lessons can be learned. This suggests a greater combination of these instruments with public ones so that they become more robust, and the application of these mechanisms can be standardized across different territories vulnerable to climate change. Table 2 describes the criteria defined by the OECD to provide greater support for the prioritization of actions and the implementation of financing mechanisms. These criteria are efficiency, effectiveness, relevance, impact, and sustainability (Scientific and Technical Advisory Panel [STAP], 2017).

Table 2. Ranking criteria.

Criterion	Description	Evidence
Efficiency	Refers to the extent to which resources and inputs are economically converted into results.	This is demonstrated in the cost-benefit ratio of the mechanism implemented.
Effectiveness	It refers to how adaptation objectives are achieved following what has been proposed. It is used as an aggregate measure or judgment of the merit or value of an activity, that is, the degree to which an intervention has achieved, or is expected to achieve, its main relevant objectives effectively, sustainably, and with a positive institutional impact on development.	Consider reducing vulnerability or increasing resilience.
Relevance	It is defined as the consistency between the requirements defined for access to the mechanism, national needs, priorities, and public policies.	It considers the achievement of objectives appropriately, even when circumstances have changed the environment of intervention.
Impact	It is the effect, whether positive or negative, primary or secondary, that is produced directly or indirectly by an intervention to achieve a project or strategy.	Health effects of biodiversity, ecological connectivity, and gender approach.
Sustainability	This criterion considers whether the benefits are sustained over time, after an intervention or project has been completed.	Implementation of projects with environmental, social, and economic criteria that promote social ownership and financing, such as renewable energy management projects.

The increase in the revitalization of private mechanisms within climate adaptability financing strategies clearly shows a boom in private investment that strengthens the various instruments that mobilize resources from the private sector for climate resilience projects. The significant growth of the private sector in the climate change adaptation strategy is very much focused on what organizations in this sector have done and invested in to minimize these effects. Strategies based on social responsibility, partnerships with the public sector, and corporate social responsibility are key factors in the current boom in this mechanism. In terms of the operation of each of the mechanisms, the dominant combinations illustrate that, at the national level, public mechanisms and public-international partnerships are at the forefront, and that more work is needed at the mixed and international levels. This could be an area of opportunity for the country, taking advantage of the international window that Colombia has as a result of its natural wealth and the processes that have been underway to mitigate climate change.

Therefore, it is necessary to mobilize more resources from the public sector and strengthen international links that can be leveraged to improve the flow of investment. It is important that climate finance strategies leverage the combination of different mechanisms, as this could help vulnerable communities with limited access to resources to access greater resources that can contribute to reducing vulnerability

in their territories, since the combination of several mechanisms improves the flexibility of criteria and leads to stronger public policy. The private sector, is a growing area, because the opportunity to apply resources to investment dynamics in climate change issues lies in local and national development plans. In the institutional arena, the key players in local and national governance are those most involved in financial mechanisms. In all regions, the Ministry of Environment and Sustainable Development, provincial governments, municipal governments, and communities in each area of the country are the key players in channeling resources.

Conclusions

The findings of this study demonstrate that the effectiveness of climate finance in Colombia depends less on the quantity of available mechanisms and more on their capacity to align with the territorial, institutional, and social conditions of highly vulnerable areas. Although public mechanisms exhibit the widest coverage, instruments with the greatest adaptive contribution—such as Payments for Ecosystem Services (PES) and the National Adaptation Fund—are characterized by operational flexibility, alignment with community dynamics, and an ability to adapt to heterogeneous institutional contexts. Spatial analysis reveals a mismatch between the supply of financing and the territories exhibiting the highest levels of exposure and vulnerability, confirming the persistence of structural gaps in resource access.

Based on these results, the study concludes that climate finance in Colombia requires a transformation that overcomes institutional fragmentation, reduces technical barriers to entry, and strengthens multi-level governance. To advance toward more equitable and effective systems, it is necessary to recognize that financial mechanisms perform unevenly across territories; this disparity is explained not only by instrument design but also by differential institutional capacities, local governance models, and the actual availability of technical information. This research demonstrates that incorporating systemic attributes—such as flexibility, territoriality, and absorption capacity—enables the evaluation of existing mechanisms and constitutes a useful conceptual framework for analyzing climate finance effectiveness in other Latin American contexts.

In terms of practical implications, the findings indicate that public policies must shift toward schemes that prioritize adaptive mechanisms with greater community relevance, reduce the administrative burden in territories with low technical capacity, and promote hybrid instruments capable of facilitating collaboration between the public sector, the private sector, and local actors. This necessitates strengthening the country's institutional architecture through coordination platforms, the standardization of criteria, and technical assistance models that improve financial accessibility in vulnerable zones. From a theoretical perspective, the study contributes a replicable analytical framework integrating systemic attributes, territorial

analysis, and qualitative coding, offering a robust methodological foundation for comparative research and the development of indicators to contextualize financial effectiveness.

Finally, this work establishes several avenues for future research. The first involves developing standardized metrics to evaluate the adaptation impacts of funded projects, addressing the current lack of comparable indicators. A second line proposes applying the analytical framework to other countries in the region to contrast how multi-level governance and institutional capacity influence the distribution and effectiveness of climate finance. A third avenue suggests studying specific combinations of mechanisms—for instance, the link between Payments for Ecosystem Services, green bonds, climate insurance, and cooperation funds—to identify synergies that enhance adaptive impacts. These research paths can contribute to the development of a climate finance system that is more inclusive, efficient, and oriented toward territorial resilience.

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