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Challenges and Improvements in the Environmental Prosecution of Environmental Crimes in the Specialized Prosecutor's Office of Chachapoyas

Rosas Carranza Guevara

Victor Manuel Valdiviezo Sir*

Julio Arevalo Reategui

Adolfo Cacho Revilla

Dennis Brayan Baique Timaná

National University Toribio Rodríguez de Mendoza de Amazonas, Peru
**Corresponding Author*

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Abstract

Environmental justice in the Chachapoyas region faces structural limitations that hinder the effectiveness of forensic environmental procedures. This study employed a mixed-methods approach, combining semi-structured interviews with six environmental experts and eight prosecutors, along with structured surveys, to identify challenges and opportunities for improving forensic procedures. The findings highlight key obstacles, including the lack of standardized protocols, technological resource limitations, and insufficient training. Additionally, the absence of uniform forensic report criteria negatively affects the validity of evidence in judicial proceedings, making the prosecution of environmental crimes more challenging. The study recommends implementing strategies such as equipment modernization, the establishment of clear forensic standards, and continuous training programs for forensic experts. Furthermore, improving coordination between judicial and environmental institutions is essential to enhancing the applicability of forensic reports. These results provide a solid framework for strengthening environmental forensic management and may serve as a reference for other regions facing similar challenges. This research contributes to the advancement of environmental justice and the fight against environmental crimes in both the Peruvian and global contexts.

Keywords: *Environmental justice, environmental crimes, environmental expert assessment, environmental management*

1. Introduction

Environmental protection and justice have gained crucial importance in recent decades, particularly in contexts where urban expansion, natural resource exploitation, and intensified productive activities have accelerated environmental degradation and increased the incidence of ecological crimes. In the Chachapoyas region of Peru, these challenges manifest in crimes such as illegal logging, wildlife trafficking, and water body contamination (Falconi & Grenni, 2023; Herrador et al., 2022). In this scenario, optimizing environmental forensic procedures is essential for the collection and analysis of evidence in judicial processes related to environmental crimes (Bullard, 1994; Odum & Barrett, 2005; Suter, 2007).

However, the Environmental Specialized Prosecutor's Office of Chachapoyas faces various limitations that affect the quality and effectiveness of forensic reports. The lack of adequate equipment, the shortage of specialized personnel, and the absence of standardized protocols pose significant obstacles to the investigation of these crimes (Becker-Weinberg, 2023; García-Ramos et al., 2023). These deficiencies not only hinder criminal prosecution but also perpetuate impunity and exacerbate environmental degradation. Additionally, as highlighted by Ruiz Arias (2021), the most vulnerable communities are the most affected, facing double victimization due to their socioeconomic situation and the deterioration of their natural environment.

The challenges of environmental justice go beyond operational limitations and include the need to strengthen scientific cooperation and specialized training. A study conducted by Mäkelä et al. (2023) within the European Network of Forensic Science Institutes highlighted the urgency of standardizing environmental crime definitions and strengthening regulatory frameworks. Rodríguez Sánchez (2023) emphasizes that integrating environmental sciences with law has optimized forensic procedures, while Pereira et al. (2023) underscore the importance of precise methodologies in assessing ecological damage. Likewise, Costa Alves & Abba (2023) highlight the role of civil society in formulating sustainable strategies, while Díaz-Horna et al. (2022) and Casali et al. (2022) stress the influence of regulatory frameworks on the quality of forensic reports.

Previous studies have addressed the challenges of environmental forensics in different contexts. Garcia Guevara (2023) and Manríquez Zapata & Rascón (2020) have documented how methodological difficulties affect the accuracy of forensic reports on environmental crimes. Priya et al. (2023) emphasize the inherent complexity of these crimes due to their connection with other illicit activities, recommending the integration of specialized scientific approaches. Solodov & Zębek (2021) analyzed centralized and decentralized models of environmental forensics, assessing their advantages and disadvantages. Semi-structured interviews with experts and prosecutors, surveys of key actors and a documentary analysis of court files have been conducted. This mixed approach, supported by Creswell & Creswell (2018), has proven to be highly effective in investigating multidimensional phenomena. Mabon et al. (2020) argue that interdisciplinary collaboration between natural and social sciences enhances the effectiveness of environmental interventions, while Chacowry (2023) underscores the importance of governance and community participation in climate change adaptation projects. Watson & Emery (2003) suggest that international standards such as ISO 14000 can contribute to environmental regulation.

In the Amazonas region, structural deficiencies in environmental forensics include the absence of standardized protocols, a shortage of trained personnel, and limited access to specialized technology. This situation restricts authorities' ability to investigate and sanction complex environmental crimes, where interdisciplinarity is crucial to ensuring the accuracy and validity of forensic reports. Fernandes et al. (2024) suggest that incorporating environmental education into school curricula can foster greater awareness and sustainable action. González et al. (2021) and González et al. (2023) analyze how identifying environmental damage factors, such as pollution and deforestation, is key to mitigating negative impacts. Herrera Robles et al. (2022) emphasize the relationship between pollution and public health, recommending better coordination between environmental and health agencies. Finally, the Leopold Matrix (Leopold et al., 1971) has been consolidated as a fundamental tool for environmental impact assessment.

Given this context, this research poses the following central question:

What are the main limitations and opportunities for improving environmental forensic procedures in environmental crimes in Chachapoyas?

To answer this question, the specific objectives include:

- Identifying the most common environmental crimes in the region.
- Analyzing the technical and methodological challenges faced by forensic experts.
- Evaluating the impact of forensic reports on judicial decisions.
- Proposing concrete strategies to improve the effectiveness of environmental forensics.

From a multidimensional perspective, this study aims to generate a precise diagnosis and offer practical recommendations to strengthen the institutional framework responsible for prosecuting environmental crimes, aligning with the United Nations Sustainable Development Goals on environmental justice and ecosystem protection.

2. Literature Review

Environmental expertise is based on theoretical principles from various scientific disciplines, such as ecology, chemistry, biology, and geology. A key foundation is systems theory, which views the environment as an interconnected set of biotic and abiotic components interacting with one another (Odum & Barrett, 2005). This systemic perspective is essential for understanding the synergistic and long-term effects of environmental impacts. Another theoretical pillar is the concept of sustainable development, which emphasizes the need to meet the present generation's needs without compromising the ability of future generations to meet theirs (World Commission on Environment and Development, 1987). Environmental expertise contributes to this goal by providing scientific information to support decision-making that balances economic and social development with environmental protection.

Various studies have emphasized the need to strengthen regulatory frameworks and forensic procedures to enhance the effectiveness of environmental crime prosecution. Baltazar et al. (2024) highlight the strategic role of local authorities in mitigating environmental crimes through inter-institutional collaboration and the use of advanced technologies.

Furthermore, in the European context, Röck et al. (2021) have indicated that current environmental challenges require more robust strategies in forensic evidence collection and the application of international regulations. This approach is particularly relevant to improving procedural efficiency in countries with fragile ecosystems and high rates of environmental crimes. Similarly, in Asia, Hong-in et al. (2024) analyzed how land use changes have impacted ecological stability and increased environmental crime incidence, reinforcing the need to adapt forensic methodologies to specific contexts.

A study by Teed et al. (2023) analyzed the role of regulatory agencies in setting environmental standards in the United States, emphasizing the importance of clear regulations for identifying and penalizing environmental crimes. In Europe, Herrador et al. (2023) examined the impact of population growth and urbanization on ecological vulnerability, highlighting the need to update environmental protection policies to strengthen forensic capabilities. In China, Cao and Bian (2021) emphasize the role of environmental planning in mitigating negative impacts, demonstrating that predictive tools can improve the identification of environmental crimes before they occur. Meanwhile, Wang et al. (2024) study water management in arid regions, noting that inadequate resource allocation policies can increase environmental criminality. Meanwhile, Mao et al. (2020) highlight how the worsening of global ecological problems demands integrated strategies among international organizations to enhance environmental crime detection.

Furthermore, theories such as complex systems and ecological resilience have influenced the development of environmental expertise by highlighting the complexity and adaptability of socioecological systems (Gunderson & Holling, 2002; Levin, 1998). These theories emphasize the need for a holistic and adaptive approach to environmental management that acknowledges uncertainty and the nonlinearity of ecological processes.

2.1 Deforestation Dynamics in High-Biodiversity Regions

Deforestation dynamics in regions like the Amazon highlight the importance of addressing underlying factors driving environmental degradation. Dias et al. (2024) found that the area of permanent crops is the most influential factor in Brazilian deforestation, while increased public spending is associated with reduced deforestation rates. These findings underscore the need for conservation strategies that integrate economic factors with land-use patterns, which is particularly relevant for the Chachapoyas region, where illegal logging and land conversion are common issues.

2.2 Theories of Pollution and Environmental Degradation

The theory of environmental pollution explains how the introduction of substances, energy, or species alien to an ecosystem can disrupt its balance and generate adverse effects (Manahan, 2010). Concepts such as bioaccumulation and biomagnification from ecotoxicology describe how pollutants concentrate and amplify through trophic networks, affecting organisms at higher levels (Walker et al., 2012). On the other hand, the theory of environmental degradation analyzes processes such as deforestation, desertification, and biodiversity loss (Millennium Ecosystem Assessment, 2005). While these phenomena can result from natural factors, they are largely driven by unsustainable human activities.

Environmental expertise utilizes these theoretical frameworks to identify sources of pollution and degradation and assess their impacts. Additionally, theories such as ecosystem resilience and landscape ecology have enhanced understanding of environmental degradation processes and restoration strategies (Holling, 1973; Turner, 1989). These theories emphasize the importance of maintaining ecosystem integrity and functionality to ensure their recovery capacity after disturbances.

2.3 Theories of Environmental Justice and Nature's Rights

The theory of environmental justice asserts that all individuals have the right to a healthy and safe environment, regardless of race, social class, or geographic location (Bullard, 1994). This perspective challenges the unequal distribution of environmental risks and demands inclusive and transparent decision-making processes. Meanwhile, the theory of the rights of nature recognizes ecosystems and species as rights-bearing entities with intrinsic value beyond their utility to humans (Stone, 1972).

These ethical and legal theories have influenced the development of environmental expertise by broadening its scope beyond technical evaluation to address issues of justice and rights. Additionally, theories such as the environmentalism of the poor and post-development critique the conventional development model and propose alternatives rooted in environmental justice and the defense of local community rights (Escobar, 1995; Martinez-Alier, 2002). These theories highlight the importance of incorporating the voices and knowledge of marginalized groups into environmental expertise practices.

The application of environmental justice theories is particularly relevant in the studied region, where vulnerable communities are disproportionately affected by environmental degradation. According to Ruiz Arias (2021), these communities face dual victimization, underscoring the need to integrate equity principles into expertise procedures and policymaking.

2.4 Theories of Environmental Economic Valuation

Neoclassical economic theory considers environmental goods and services to lack value if they are not priced in the market (Pearce & Turner, 1990). However, alternative approaches like ecological economics recognize that the environment provides a wide range of benefits not reflected in conventional markets (Costanza et al., 1997). Environmental economic valuation theory seeks to assign monetary value to these benefits using methods such as contingent valuation and travel cost analysis (Hanley & Spash, 1993). While controversial, these approaches can help integrate environmental considerations into economic decision-making.

Environmental expertise can provide biophysical data to support these valuation analyses. Furthermore, theories such as the commons and degrowth economics challenge the premise that unlimited economic growth is compatible with environmental sustainability (Latouche, 2009; Ostrom, 1990). These theories propose alternative models based on the collective management of natural resources and reduced material consumption, with implications for environmental expertise in evaluating the feasibility and equity of development projects.

The protection of natural areas relies not only on effective public policies but also on community participation and government support. López de la Lama et al. (2023) identified critical limitations in South America's Private Protected Areas (PPAs), such as insufficient legal frameworks and vague guidelines for economic activities. In Peru, they highlighted the need to differentiate between community-managed and individually-managed PPAs due to their distinct goals and commitments. These observations are applicable to the Chachapoyas region, where strengthening the regulatory framework could enhance biodiversity conservation in areas facing high environmental pressure.

2.5 Theories of Environmental Risk and Impact Analysis

Environmental risk theory is based on the concept that exposure to stressors, such as pollutants or extreme events, can lead to adverse effects on ecosystems and human health (Suter, 2007). This theory employs probabilistic methods to quantify the magnitude and likelihood of these risks. Meanwhile, environmental impact analysis theory provides a methodological framework to predict, prevent, and mitigate the effects of projects and policies on the environment (Canter, 1996). Both theoretical approaches are fundamental to environmental expertise as they guide risk assessments and the preparation of environmental impact reports—key tools for informed decision-making.

Additionally, theories such as risk perception and risk communication have enhanced understanding of how individuals and communities perceive and respond to environmental risks (Covello & Sandman, 2001; Slovic, 2000). These theories underscore the importance of incorporating stakeholder perspectives into environmental risk assessment and management, with implications for public participation and transparency in environmental expertise practices.

3. Methodology

This study was conducted using a mixed-methods approach, designed to provide a comprehensive understanding of the challenges associated with environmental forensic procedures in the Chachapoyas region. This methodology integrated qualitative and quantitative techniques, allowing for data triangulation to enhance the validity and reliability of the findings.

The study followed a non-experimental, cross-sectional design, suitable for observing phenomena in their natural setting without manipulating variables, while capturing data at a specific point in time. As suggested by Hernández et al. (2006), this design is appropriate for descriptive and explanatory research, particularly when analyzing complex issues such as environmental crimes.

The study population consisted of all environmental experts and prosecutors involved in environmental crime cases handled by the Specialized Environmental Prosecutor's Office in Chachapoyas between 2020 and 2024. A purposive sampling technique was applied, selecting six environmental experts and eight prosecutors who were directly involved in resolving high-impact cases. This non-probability sampling method, recommended by Babbie (2017), enabled the identification of key informants with specialized knowledge and experience, ensuring the relevance and depth of the collected data. Participants were selected based on their experience in handling environmental expert reports, their participation in relevant court cases and their knowledge of current environmental regulations, ensuring adequate representation of key actors in the investigation.

For data collection, two main instruments were employed. First, semi-structured interviews were conducted to capture the perceptions and experiences of forensic experts and prosecutors regarding the technical, logistical, and training limitations faced in environmental forensic investigations. The interview guide focused on key themes such as the effectiveness of forensic methods, challenges in case resolution, and institutional constraints. The interviews were structured around four main axes: (1) technical challenges in environmental expert reports, (2) institutional barriers in evidence management, (3) strategies to improve the training of experts and (4) evaluation of the impact of expert reports on judicial decisions. Second, structured questionnaires were designed to collect quantitative data on the impact of environmental crimes and forensic procedures. Both instruments underwent expert validation and pilot testing to ensure clarity and appropriateness, following the methodological guidelines established by Hernández et al. (2006).

Data analysis was performed using qualitative and quantitative techniques. On the qualitative side, a thematic analysis was applied to categorize and synthesize interview responses, identifying recurring patterns and key challenges in forensic investigations. On the quantitative side, descriptive statistics—including frequencies and percentages—were used to characterize key study variables and explore significant relationships between them. This integrative analytical approach allowed for a comprehensive interpretation of the data, aligning with Yin's (2018) recommendations on mixed-methods research.

The research adhered to fundamental ethical principles. All participants were informed about the study's objectives and procedures, and informed consent was obtained before data collection to ensure voluntary participation. Additionally, strict confidentiality and anonymity measures were implemented to protect participants' identities and ensure compliance with ethical standards.

The methodology employed enabled a rigorous and structured approach to achieving the research objectives, providing valuable insights into the main limitations of environmental forensic procedures and offering a basis for designing effective strategies to improve their implementation within the framework of environmental justice in Chachapoyas.

4. Results

4.1 Main findings

Table 1 presents the main findings from the interviews conducted with environmental experts and prosecutors, organized according to the four main axes of analysis. The direct quotes provided illustrate the key challenges and perspectives identified during the investigation, offering firsthand insights into the current state of environmental forensic procedures in Chachapoyas. These findings reflect the complex interplay between technical limitations, institutional barriers, training needs, and the impact of expert reports on judicial decision-making.

Table 1. Main findings from interviews with environmental experts and prosecutors

Analysis Axis	Key Findings	Direct Quote
Technical Challenges in Environmental Expertise	Lack of adequate equipment and limited technological updates.	*"The lack of modern equipment affects the accuracy of our analyses."* (Expert 1)
	Difficulties in obtaining samples due to logistical restrictions.	*"We cannot always obtain samples in optimal conditions due to logistical restrictions."* (Expert 2)
	Lack of access to updated databases for comparative analysis.	*"Having access to reliable databases would be crucial to improving evidence comparison."* (Expert 3)
	Non-standardized procedures for forensic evidence collection.	*"Each expert has their own criteria for collecting samples, which affects standardization."* (Expert 4)

Analysis Axis	Key Findings	Direct Quote
Institutional Barriers in Evidence Management	Lack of effective communication between prosecutors and experts.	*"Many times, we do not know exactly what the prosecutor expects from our reports."* (Prosecutor 1)
	Difficulties in the admissibility of expert reports in trials.	*"Some judges doubt the validity of our reports because they do not follow a standardized format."* (Prosecutor 2)
	Lack of clear protocols for the chain of custody of evidence.	*"There are issues in the chain of custody that may compromise the validity of the evidence."* (Prosecutor 3)
	Limited access to financial resources to optimize forensic analyses.	*"Without adequate funding, we cannot perform high-complexity analyses."* (Prosecutor 4)
Strategies to Improve Expert Training	Insufficient training in specialized forensic techniques.	*"We learn more from experience than from formal academic training."* (Expert 5)
	Outdated knowledge of international regulations and their local application.	*"We are outdated in the application of new environmental regulations."* (Expert 6)
Evaluation of the Impact of Expert Reports on Judicial Decisions	Lack of continuous training programs for experts.	*"There are not enough programs to improve our technical skills continuously."* (Prosecutor 5)
	Low influence of expert reports in judicial decision-making.	*"Our reports rarely have a determining weight in sentences."* (Prosecutor 6)
	Prosecutors perceive expert reports as lacking technical robustness.	*"Some reports seem more like general descriptions than rigorous scientific analyses."* (Prosecutor 7)
	Need to improve the alignment between expert reports and judicial requirements.	*"If we improve the alignment between forensic work and judicial requirements, reports would be more effective."* (Prosecutor 8)

5. Main Environmental Crimes Evident in the Provinces of Bongará, Luya, and Rodríguez de Mendoza

5.1 Environmental Crimes

The analysis reveals a significant concentration in the trafficking and illegal possession of wildlife (50%), followed by pollution-related crimes (33%) and the illegal extraction of aquatic species (17%). This distribution suggests that crimes against biodiversity represent the greatest threat in the provinces studied, underscoring the need to strengthen monitoring and enforcement mechanisms specifically in these areas.

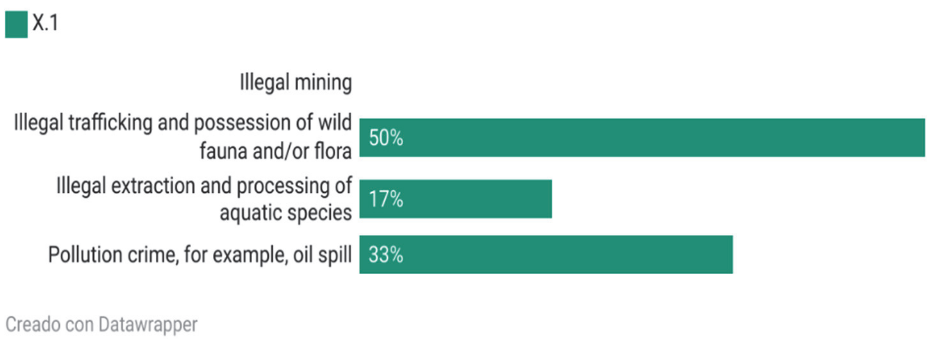

Figure 1. Environmental Crimes

5.2 Most common crimes

From a prosecutorial perspective, illegal logging of forest resources (62%) emerges as the predominant crime, followed by wildlife/flora trafficking (25%) and illegal extraction of aquatic species (13%). This distribution differs from the perception of the experts, suggesting possible gaps in the detection and prosecution of different types of environmental crimes.

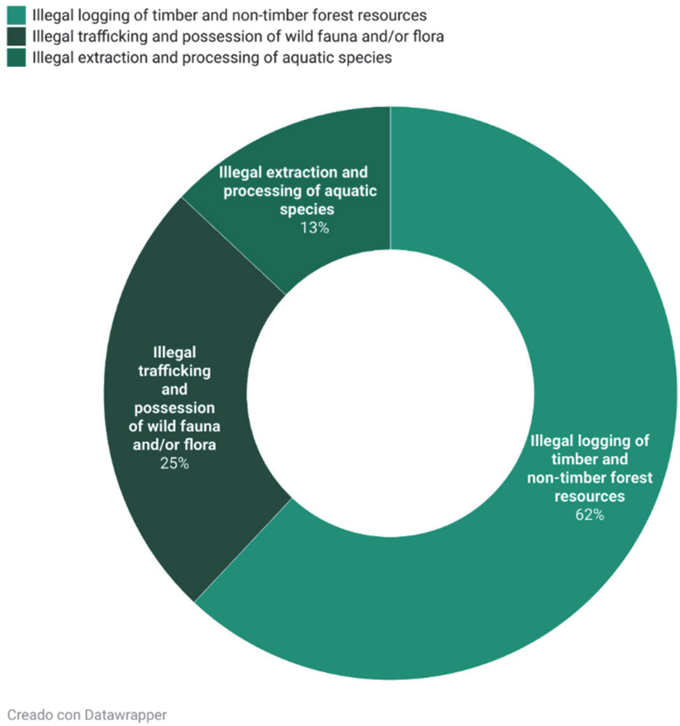

Figure 2. Most common crimes (fiscal perspective)

6. Main Difficulties Encountered in the Preparation of an Environmental Expert's Report

6.1 Status of expert procedures

The evaluation of the state of expert procedures shows a worrying situation: only 33% are considered adequate, while 50% are classified as regular and 17% as inadequate. These data suggest an urgent need for standardization and improvement in environmental expertise procedures, since more than two thirds of the procedures do not reach an optimal level. One of the most relevant difficulties identified in this study is the lack of homogeneous criteria for the interpretation of environmental crimes among prosecutors and experts. One prosecutor interviewed mentioned: 'There are differences in the way prosecutors and experts interpret environmental crimes, which generates conflicts in the presentation of evidence'. This suggests the need to standardise procedures and define clear guidelines to strengthen inter-institutional coordination.

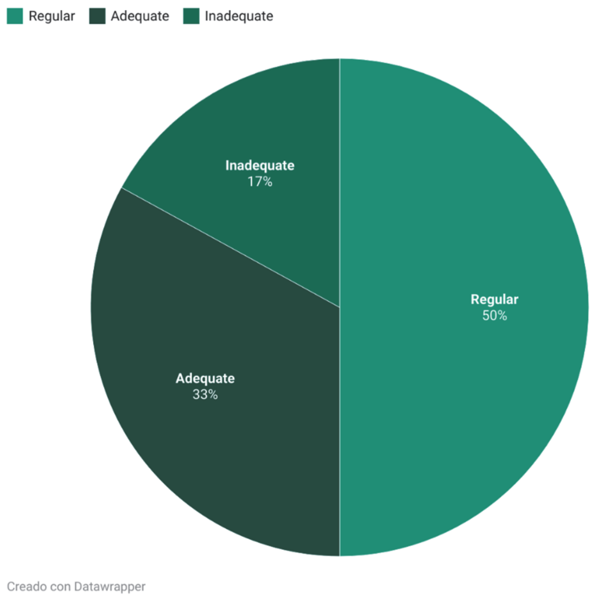

Figure 03. Status of expert procedures

6.2 Difficulties in expert reports

Technical limitations emerge as the main obstacle (32%), followed by an even distribution (17% each) between scientific complexity, insufficient information, limited financial resources and climatic changes. This pattern indicates that modernization of technical equipment and training should be priorities in improvement strategies. The results show that the main limitation in environmental assessments is the lack of adequate equipment, which prevents thorough analysis and compromises the validity of the expert assessments. In this regard, one expert noted: 'The lack of adequate equipment prevents us from carrying out accurate analyses, which affects the validity of the expert reports'.

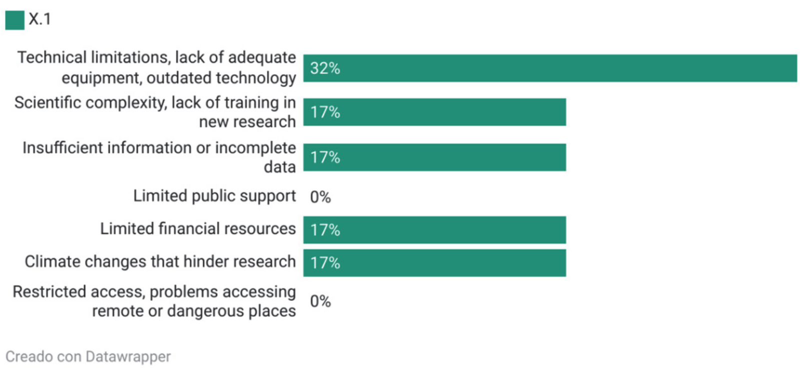

Figure 4. Difficulties in expert reports

6.3 Environmental Management System experience

The distribution of experience in EMS shows that 67% have moderate experience and 33% have high experience. While it is positive that there are no inexperienced experts, the predominance of moderate experience suggests the need for continuous training programs to raise the overall level of expertise. Another key finding is the lack of continuous training in environmental management systems and advanced expertise techniques. While some experts have received training, most rely on experience gained in the course of their work. As one expert put it: 'Without continuous training, the quality of expertise still depends more on individual experience than on a consolidated technical standard'.

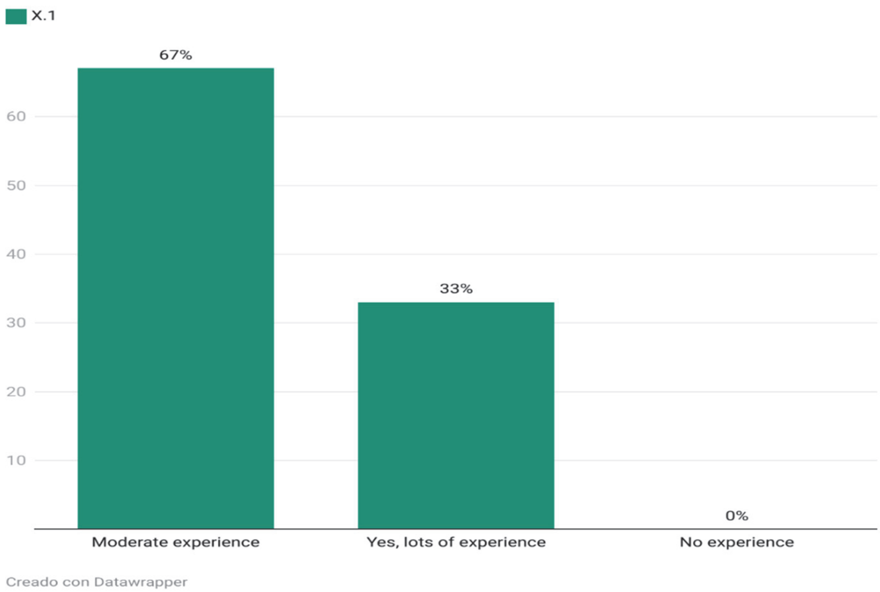

Figure 5. EMS experience

7. Impact of Expert Opinions

7.1 Usefulness of expert opinions

The valuation of environmental expert opinions shows significant support, with 63% considering them very relevant and useful, while 37% consider them not very relevant. This division suggests that, although expert opinions are generally valued, there is significant room for improving their effectiveness and relevance in judicial proceedings. Despite the importance of expert reports in the investigation of environmental crimes, their impact on prosecutions remains limited. One prosecutor interviewed noted: 'Expert reports are often not considered determinative in trials, which reduces their impact on the resolution of environmental cases'. This perception reinforces the need to improve the clarity and accuracy of the reports in order for them to be valued in court decisions.

Figure 6. Usefulness of expert opinions

8. Strategies for Optimizing Forensic Procedures in Environmental Crimes

8.1 Optimization of Environmental Expertise

The analysis of results reveals the pressing need to implement comprehensive and systematic strategies to optimize the effectiveness of environmental expertise in the provinces of Bongará, Luya, and Rodríguez de Mendoza. The research identified five key strategic areas requiring priority intervention:

a) *Strengthening Training and Resources for Environmental Experts:* The findings show that 67% of experts have only moderate experience in Environmental Management Systems (EMS), while a concerning 33% of forensic procedures are deemed inadequate. This situation justifies the urgent implementation of:
- Continuous training programs and specialization in advanced environmental analysis methodologies.
- Incorporation of advanced technology (drones, environmental sensors, specialized software).
- Establishment of centers of excellence in environmental expertise as regional reference points.

b) *Establishment of Protocols and Standards:* With 50% of forensic procedures rated as average and 33% of experts identifying technical limitations as the main obstacle, the following is proposed:
- Development and implementation of standardized protocols for every phase of forensic work.
- Creation of best-practice manuals based on scientific evidence.
- Certification systems for procedures and technical equipment.
- Specific methodological guidelines for each type of identified environmental crime.

c) *Comprehensive Monitoring and Evaluation System:* The diversification of environmental crimes detected (50% wildlife trafficking, 33% pollution, 17% illegal extraction) requires:
- Implementation of quantifiable performance indicators.
- Periodic evaluations by independent expert committees.
- A centralized digital platform for managing forensic information.
- Continuous feedback mechanisms for procedural improvement.

d) *Promotion of Interdisciplinary Collaboration and Community Participation:* The complexity of the documented environmental crimes demands:
- Formation of multidisciplinary teams composed of experts, prosecutors, and social science specialists.

- Community awareness and participation programs.
- Establishment of collaboration networks with academic institutions and specialized NGOs.
- Community-based early warning systems.

e) *Updating the Legal Framework:* Considering that 63% of prosecutors rate forensic work as highly relevant, the following is proposed:

- Revision and updating of regulations on forensic procedures.
- Strengthening of precautionary measures and sanctions.
- Improved alignment between the legal framework and technical procedures.
- Establishment of clear criteria for the judicial validity of forensic reports.

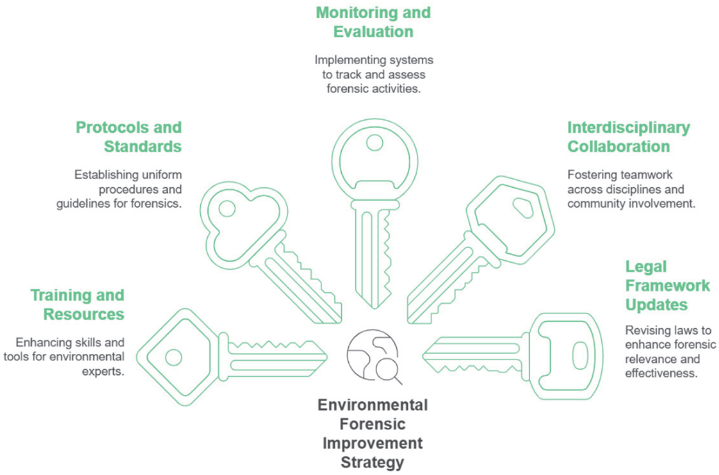

Figure 7. Optimization of Environmental Expertise

The systematic implementation of these strategies should be carried out in a coordinated and progressive manner, with specific follow-up indicators for each component. The results suggest that the integration of these five strategic axes could significantly improve the quality and effectiveness of environmental expert opinions, thus contributing to a better administration of environmental justice in the region.

The proposals presented are based on the empirical analysis of the deficiencies identified and are aligned with international best practices in environmental expertise. Their implementation requires a sustained institutional commitment and the allocation of adequate resources to ensure their long-term effectiveness.

Finally, the findings suggest that the modernisation of expert procedures is a critical aspect of improving the administration of environmental justice. As one interviewee stated: 'There is an urgent need to modernise procedures to ensure that evidence is accepted and valued in judicial processes'. This highlights the importance of implementing innovative methodologies and updating regulatory frameworks to improve the effectiveness of environmental expertise.

9. Discussion

The discussion of the results allows us to reflect on the inherent complexity of environmental crimes and the challenges facing environmental expertise in Chachapoyas. These findings reinforce the need to modernise expert procedures and strengthen the articulation between prosecutors and experts, in line with previous studies in other regions (Baltazar et al., 2024; Röck et al., 2021). The lack of technological resources and specialised training limits the accuracy of expert opinions, as also noted by García-Ramos et al. (2023) and Wang et al. (2024). Furthermore, the mixed perception of the usefulness of expert reports highlights the need to update methodologies and strengthen the validation of results in the judicial process (Cao & Bian, 2021).

The need to standardize definitions and legal frameworks related to environmental crimes is not exclusive to Chachapoyas, as noted by Mäkelä et al. (2023) in their analysis of European forensic institutions. These authors emphasize that scientific and educational collaboration is essential for optimizing the investigation of environmental crimes. Furthermore, Dias et al. (2024) demonstrate that economic factors, such as public spending, directly influence environmental conservation. These findings reinforce the study's proposal to integrate interdisciplinary efforts and strengthen the regulatory framework in the region.

The observed discrepancy in the identification of major crimes between experts (50% cited wildlife trafficking) and prosecutors (63% cited illegal logging) confirms the multifaceted nature of environmental crimes, as suggested by Priya et al. (2023). This divergence underscores the need to establish uniform criteria for categorizing and prioritizing these crimes, which would not only improve their detection but also enhance interinstitutional coordination for their management. Moreover, these results support Mabon et al.'s (2020) arguments about the importance of interdisciplinary collaboration, particularly between scientific and operational disciplines.

The identification of technical limitations as the main obstacle (33%) corroborates the observations of García Ramos et al. (2023) and Becker-Weinberg (2023) regarding the lack of technological resources and specialized training. The uniform distribution of other limitations, such as financial resources and scientific complexity (17% each), suggests systemic issues requiring comprehensive strategies that combine funding, equipment, and technical training. These findings complement concerns raised by Díaz-Horna et al. (2022) about the influence of insufficient regulatory frameworks on the effectiveness of environmental expertise.

The moderate level of experience in environmental management systems (67%) supports concerns raised by Watson and Emery (2003) regarding the need for coherent regulatory frameworks. However, the results reveal that deficiencies in professional training are a key factor insufficiently addressed in prior literature, underscoring the importance of strengthening experts' competencies through continuous and context-specific training programs.

The divided evaluation of environmental expertise (63% rated it highly relevant, 38% rated it less relevant) reflects a disparity between the perceived utility and practical effectiveness of forensic reports. This finding aligns with Solodov and Zębek's (2021) arguments about the need to optimize the accuracy and standardization of forensic procedures. Despite their relevance, the inadequate implementation of these procedures limits their practical impact, highlighting the need to enhance technical and institutional capacities in this area.

The results also highlight that 50% of forensic procedures were rated as "average," supporting Mabon et al.'s (2020) observations about the need for more robust interdisciplinary collaboration. Additionally, the identification of community-based early warning systems as a necessity reinforces Chacowry's (2023) recommendations regarding the importance of community participation in environmental management. These strategies must be formalized and adapted to the specific characteristics of the studied provinces.

The diversification of environmental crimes identified in the results aligns with the observations of Manríquez Zapata & Rascón (2020) and Díaz-Horna et al. (2022) regarding the importance of considering local contexts in environmental policies. However, the findings suggest that current technical capacities limit the effectiveness of these regulatory frameworks, emphasizing the need for more tailored and sustainable strategies.

The necessity of updating traditional methodologies, such as the Leopold matrix (Leopold et al., 1971), is evident in the face of emerging environmental crimes and current technological limitations. This point complements the arguments of González et al. (2021) and González et al. (2023), who advocate for more sophisticated and context-sensitive tools to identify environmental damage factors.

Finally, the findings underscore the importance of a holistic approach to environmental expertise, integrating technical, legal, and social dimensions. This multidisciplinary approach, as suggested by Herrera Robles et al. (2022), is essential to addressing the complexity of environmental crimes. By aligning with the Sustainable Development Goals and Bullard's (1994) theories of environmental justice, this comprehensive approach provides a solid foundation for proposing practical and sustainable solutions to optimize forensic procedures and strengthen the administration of environmental justice.

10. Conclusions

The research findings demonstrate that crimes against biodiversity represent the main threat in the provinces studied, with a marked discrepancy between the perceptions of experts and prosecutors regarding the prevalence of specific offenses. This divergence highlights the need to establish more uniform criteria for identifying and categorizing environmental infractions.

Difficulties in forensic procedures reveal a systemic problem that goes beyond technical limitations, encompassing aspects such as scientific complexity, financial resources, and climatic factors. The predominance of moderate experience in Environmental Management Systems underscores the urgent need for continuous training programs and specialization.

The divided assessment of the relevance of forensic expertise indicates a significant gap between its perceived usefulness and its practical effectiveness in judicial processes. This underscores the importance of implementing the proposed comprehensive strategies to strengthen both technical and operational aspects, as well as interdisciplinary collaboration and community participation.

The results emphasize the need to optimize forensic procedures through a holistic approach that integrates specialized training, technological modernization, protocol standardization, and the strengthening of the regulatory framework. This comprehensive approach would significantly improve the quality and effectiveness of environmental expertise, contributing to better environmental justice administration in the region.

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