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ARTÍCULO DE INVESTIGACIÓN

Environmental impacts generated by the hydroelectric power plant El Quimbo - Colombia. An ex-post evaluation

Impactos ambientales generados por la hidroeléctrica El Quimbo - Colombia. Una evaluación ex-post

Impactos ambientais gerados pela central hidroelétrica de El Quimbo - Colômbia. Uma avaliação ex-post

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Abstract

Introduction: Hydroelectric power plants are the most demanded source of electrical energy worldwide after the year 2000. **Objective:** This article identified the environmental impacts generated by the construction and operation of the El Quimbo hydroelectric power plant in the area of influence in southern Colombia from an ex-post perspective. **Methodology:** The study was of a mixed nature, under the deductive and descriptive method using information gathering techniques such as documentary analysis, open and participatory reconnaissance and the Delphi survey. **Results**: A total of eighty-eight (88) environmental impacts were identified in the physical, biotic and socioeconomic spheres. In the physical dimension, aspects such as decreased river flow and land flooding were found; in the biotic dimension, aspects such as increased displacement of terrestrial fauna and increased mortality of native species of terrestrial flora and fauna were identified; and in the socioeconomic field, decreased agricultural employment and increased cost of living were highlighted. **Conclusions:** We conclude with the identification of a greater number of negative impacts in the socioeconomic dimension compared to the impacts in the physical and biotic fields.

Keywords: Environmental changes; Environmental impact, Hydropower, Reservoirs[1]

Resumen

Introducción: Las hidroeléctricas son la fuente de energía eléctrica más demandada a nivel mundial después del año 2000. **Objetivo:** Este artículo identificó los impactos ambientales generados por la construcción y operación de la central hidroeléctrica El Quimbo en el área de influencia en el sur de Colombia desde una perspectiva ex-post. **Metodología:** El estudio fue de carácter mixto, bajo el método deductivo y descriptivo utilizando técnicas de recolección de información como el análisis documental, el reconocimiento abierto y participativo y la encuesta Delphi. **Resultados:** En total, se identificaron ochenta y ocho (88) impactos ambientales en los ámbitos físico, biótico y socioeconómico. En la dimensión física, se encontraron aspectos como la disminución del caudal de los ríos y la inundación de terrenos; en la dimensión biótica, se identificaron aspectos como el aumento del desplazamiento de la fauna terrestre y el aumento de la mortalidad de especies nativas de flora y fauna terrestre; y en el campo socioeconómico, se destacaron la disminución del empleo agrícola y el aumento del costo de vida. **Conclusiones:** Se concluye con la identificación de un mayor número de impactos negativos en la dimensión socioeconómica frente a los impactos en los ámbitos físico y biótico.

Palabras clave: Cambios ambientales; Embalses; Energía hidroeléctrica; Impacto ambiental.

1 Tesauro UNESCO (Ciencias Sociales y Humanidades)

Resumo

Introdução: As centrais hidroeléctricas são a fonte de eletricidade mais procurada em todo o mundo após o ano 2000. **Objetivo:** Este artigo identificou os impactos ambientais gerados pela construção e operação da usina hidrelétrica El Quimbo na área de influência no sul da Colômbia a partir de uma perspetiva ex-post. **Metodologia:** O estudo foi de natureza mista, sob o método dedutivo e descritivo, utilizando técnicas de recolha de informação como a análise documental, o reconhecimento aberto e participativo e o inquérito Delphi. **Resultados:** No total, foram identificados oitenta e oito (88) impactos ambientais nas esferas física, biótica e socioeconómica. Na dimensão física, foram encontrados aspectos como a diminuição do caudal dos rios e a inundação de terrenos; na dimensão biótica, foram identificados aspectos como o aumento da deslocação da fauna terrestre e o aumento da mortalidade de espécies nativas da flora e fauna terrestres; e no domínio socioeconómico, destacaram-se a diminuição do emprego agrícola e o aumento do custo de vida. **Conclusões:** Concluímos com a identificação de um maior número de impactos negativos na dimensão socioeconómica comparativamente aos impactos nos domínios físico e biótico.

Palavras chave: Alterações ambientais; Energia hidroelétrica; Impacto ambiental; Reservatórios.

INTRODUCTION

Dams for power generation or hydroelectric purposes entered the world scene towards the end of the 19th century as a consequence of the global demand for electrical energy in a capitalist economic system that was in the process of consolidation (McCully, 2004); However, during the second half of the 20th century, the largest number of dams in the world were built (World Commission on Dams, 2000), reaching around 45,000 by the year 2000 distributed in more than 140 countries (Gutiérrez & Villalobos, 2020).

In contrast, during the first decades of the 21st century, in Europe and the United States, numerous old hydroelectric dams were dismantled, while in the southern hemisphere, many projects to generate electricity from water re-sources were planned and carried out (Habel et al., 2020).

Hydroelectric plants generate extensive social and environmental impacts, especially negative ones on the environment in which they are implemented (Arantes et al., 2023). However, they report positive economic consequences, which is why many countries build them with the hope of contributing to the fulfillment of their economic and productive objectives (Moran et al., 2018).

For example, in Africa, they have been built to supply water for agricultural and industrial use and have boosted the growth of the local economy (Richter et al., 2010), while in other regions strong social and negative environmental impacts have been reported (Wu et al., 2019) such as the alteration of river flow (Forsberg et al., 2017), the decrease in water quality (Gobeze et al., 2023), climate change (Lu et al., 2020), fragmentation and interruption of river flows (Harper et al., 2020; Yang et al., 2022), affectation of the fishing resource (Keppeler et al., 2022), loss of vegetation cover (Nickerson et al., 2022), thermal stratification (Poff et al., 2007), and the decrease in sedimentation (Arnaud et al., 2019), among others.

By tradition, environmental impact studies are carried out prior or ex-ante to the construction of the reservoirs, so the nature of the studies is predictive, while they try to guess the number, nature and intensity of the impact generated. On the other hand, although less popular and more effective, are the ex-post environmental impact studies or after construction and operation, which identify the impacts and assess their intensity in the environment. World-wide, some studies were established that carried out studies of ex-post impacts associated with hydroelectric plants in which they discussed the expected impacts in ex-ante analysis. Thus, the studies by Nhiakao et al. (2022) in Laos, Udayakumara and Gunawardena (2018) in Sri Lanka, Aledo et al. (2015) in Brazil, Fu et al. (2010) and Xu et al. (2013) in China, and Siciliano et al. (2015) in Cambodia, among others.

South America is a subcontinent where a significant number of dams are concentrated, especially for power generation purposes, and they acquire relevance to the extent that there are many studies that project large hydroelectric dams on rivers of obvious importance such as the Amazonas, Madeira, Xingu, Cauca, and Magdalena, among others (Andrade & Olaya, 2021). Countries such as Brazil, Peru, Chile, Ecuador, and Colombia have experienced a growing trend in the construction of hydroelectric plants to increase their electricity generation capacity.

In the Colombian case, since the end of the 20th century, there have been multiple energy expansion initiatives in the country. Since the launch of the Electricity Expansion Plan in 1990, a dynamic of dam construction was entered to generate hydroelectricity. In 2010, the Mining and Energy Planning Unit - UPME, a dependency of the Ministry of Mines and Energy, projected through the Generation -

Transmission Reference Plan 2010-2024 a generation potential of 79,000 MW (UPME, 2010). Along the same lines, there is the "Master Plan for the Use of the Magdalena River" entrusted to the interstate Hidrochina by the Colombian Government, in which, among other aspects, the potential for the generation of electrical energy was raised, with the proposal of construction of 17 large dams located in the upper part of the Magdalena river basin, the country's main river, of which 8 would be located in the vicinity of the department of Huila (Hidrochina Corporation, 2013). Likewise, since 2007 there has been a hydroelectric exploitation project that contemplates 31 small hydroelectric plants in Huila (UPME, 2007; 2010).

Andrade & Olaya (2023) identified, from an extensive review, many positive and negative socioeconomic, bio-tic, and abiotic (physical) impacts caused by hydroelectric plants in Colombia. In the study, the negative impacts stood out more than the positive impacts. Among the most repetitive negative impacts were the decrease in biodiversity, the fragmentation of ecosystems, the interruption of fish reproduction cycles, the decrease around vegetation cover, the loss of river connectivity, the flooding of lands and the deterioration of the water quality of the river downstream of the reservoir. On the other hand, among the most relevant positive impacts were the increase in the availability of water for crop irrigation, the decrease in flooding downstream of the reservoir, and the increase in the availability of water for human consumption.

The case of the El Quimbo hydroelectric plant, one of the most ambitious in the last decade, with an estimated investment of USD 1,093 million, has an area of approximately 8,586 ha, located in southern Colombia, this construction began in 2008 and was completed around 2015, due to multiple social and legal inconveniences, where around 300,000 people were directly affected (Licencia ambiental N° 0899 de 2009, ANLA).

The construction of the project caused the flooding of around 5,300 ha of land used for agricultural and livestock production, including 2,000 ha of land belonging to former smallholders who were beneficiaries of the programs of the Colombian Institute of Agrarian Reform -INCORA (Molano-Bravo, 2009a). The remaining 3,286 ha corresponded to hydraulic works, roads, security zones and protected areas, among others (INGETEC, 2008). According to the environmental license for El Quimbo and other studies carried out by the Inter-American Institute for Agricultural Cooperation - IICA, 5,227 ha of the area allocated to the reservoir belonged to classes III and IV, corresponding to land suitable for agriculture, and 1,987 ha corresponded to types VI and VII land suitable for livestock, permanent crops, and reforestation (Viviescas-Santana, 2014; Motta-Delgado, 2010; INGETEC, 2008).

Even though, in the environmental impact study and the environmental license, the impacts generated by the hydroelectric plant were identified, the unreliability of these studies has been determined because they are carried out ex-ante, that is, prior to the construction of the work, so they are guided by the projection of probable impacts. In other words, since the impacts have not happened, these studies contain a high level of speculation and probability, which is why they end up underestimating, overestimating, or omitting real impacts, which can only be verified with studies after the construction and operation of the hydroelectric plant (Andrade & Olaya, 2021).

Because of the problems generated by the construction of El Quimbo, there are many studies that have been carried out, especially during its construction, with the aim of establishing the impacts generated by the dam; However, the studies carried out focus on particular and isolated phenomena. Based on the

above and considering the weakness of the environmental impact studies conducted ex-ante, due to the high degree of uncertainty they have, there is a lack of knowledge about the real environmental impacts generated by this megaproject. Consequently, the objective of this study is to identify the socioeconomic, biotic and abiotic (physical) impacts generated by the construction of the El Quimbo hydroelectric power plant from an ex-post perspective, that is, the identification of the environmental impacts after the construction and operation of the hydroelectric power plant.

For Colombian legislation, specifically in Decree 1076 of 2015, the environmental impact is "any alteration in the biotic, abiotic and socioeconomic environment, that is adverse or beneficial, total or that can be attributed to the development of a project, work or activity" (Decreto 1076 de 2015, p.12).

On the other hand, the Organización Internacional de Normalización, also called the International Organization for Standardization (ISO), defines it as a "change in the environment, whether adverse or beneficial, as a total or partial result of environmental aspects of an organization" (Organización Internacional de Normalización – ISO, 2015, p.4). In this understanding, the environmental aspects of an organization include the activities, products or services of an organization that interact with the environment.

Wathern (1988) states that from 1960 the term environmental impact acquired a connotation of strong and harmful action. Thus, it was given a meaning of effect produced in the environment and natural processes by human activity in each space and time. In this sense, it can be inferred that the environmental impact includes the adverse effects on ecosystems, the climate and society due to human activities, such as the excessive extraction of natural re-sources, the inappropriate disposal of waste, the emission of pollutants and the change in land use, among others (Perevochtchikova, 2013).

Pardo (2002) draws attention to the distinction between the terms impact and effect, although he warns about their indiscriminate use as synonyms in academic, research and practical fields. However, the effect corresponds to a phenomenon directly generated by a cause, while the impact is a bit more complex since it includes elements such as the assessment and relative importance for the community that experiences it. Likewise, he differentiates the consequences from the effects, in the sense of the first, although they are produced by an action or agent, they do not come directly from them, that is, it can be affirmed that they are of second or third order.

The concept of environmental impact does not necessarily have a negative connotation, some are positive. However, tradition has sought to anticipate negative impacts and their correction or mitigation. On the other hand, the positive impacts, although they are identified by the studies, are hardly developed or the use of opportunities is sought. This can occur since generally the owners of the projects seek authorization for their construction (Pardo, 2002).

André et al. (2004) recognize that environmental impacts are classified between direct and indirect (because of the secondary effect of the previous ones), which have common dimensions of magnitude, importance, and significance. Secondary effects are generated and propagated by existing links in the system (environment or environment). Thus, for example, the biophysical means of a community are generally linked to its economic livelihood resources.

For Pardo (2002) the secondary impacts are more difficult to identify and problematic to quantify,

even more complicated than the primary ones. Its evaluation requires a detailed analysis and study of the structural and functional characteristics of the environment. Despite the foregoing, special attention should be paid to these since on many occasions they are more relevant to the community than the primary impacts.

The magnitude refers to the quantitative dimension of the alteration caused. In ex-ante environmental impact studies, the magnitude is approximated based on certain projections. The magnitude is not related to the fact that the impact is positive or negative.

Likewise, the Instituto Latinoamericano y del Caribe de Planificación Económica y Social - ILPES (1993, p.1) defines ex-post evaluation:

The ex-post evaluation is the evaluation of the project during its operation phase once the investments have been completed. That is, the project is in its fully operational phase and the benefits may be measurable. In the ex-post evaluation, the execution, the results, the beneficiaries, and the goals obtained from a project are carefully analyzed.

In accordance with the previous definition, González (2000) considers that the ex-post or ex-post facto environ-mental evaluation is an analysis of the effects and consequences of a project after it has been executed and completed.

Ex-post studies are a retrospective evaluation, based on facts; opposite to ex ante, which is prospective in nature, based on assumptions and is developed before the event occurs or the activity is carried out. Normally an ex-post study is done to verify a forecast and assess the adequacy of the mitigation and control mechanisms used. Its purpose, in addition to identifying failures to apply the necessary corrective measures, is to highlight the lessons learned (Departamento Nacional de Planeación - DPN, 2004).

One of the advantages of ex-post studies is the opportunity to identify unobserved impacts before the construction of a project. The usefulness of the evaluation derives from knowing and understanding the differences between what was planned and what was achieved, to improve the quality of management, ensure the appropriate allocation of resources and draw lessons from experience (Ministerio de Economía y Finanzas del Perú y Agencia de Cooperación Internacional de Japón, 2012).

Despite the importance of ex-ante studies, as they allow predicting and anticipating with a certain level of certainty the impacts that the development of a project can generate, it is important to highlight that the evidence shows the high margin of inaccuracy that they can have regarding the impacts observed during the construction and operation phases.

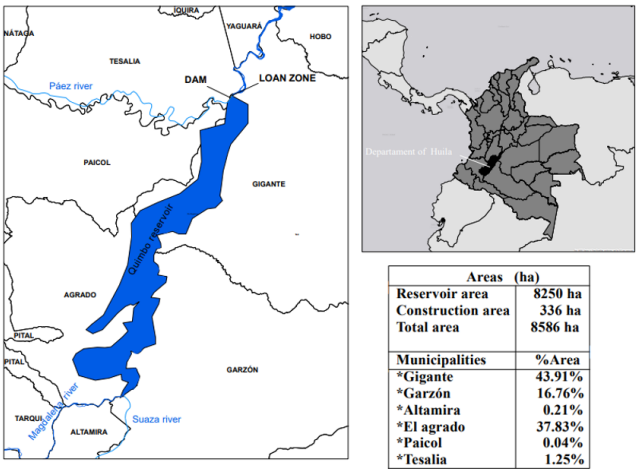
2. METHODOLOGY

Study area

The study was carried out in the department of Huila, located in the south of Colombia, in South America, on the area of direct influence, consigned in the Environmental License Resolution 0899 of the

year 2009 issued by the National Authority of Environmental Licenses, which includes the municipalities of Gigante, El Agrado, Garzón, Tesalia, Altamira and Paicol, which present the highest rates of affectation by flood area (ANLA, 2009) (see Figure 1).

Figure 1.
Reservoir for the El Quimbo hydroelectric plant, department of Huila, Colombia.



Areas (ha)	
Reservoir area	8250 ha
Construction area	336 ha
Total area	8586 ha
Municipalities	**%Area**
*Gigante	43.91%
*Garzón	16.76%
*Altamira	0.21%
*El agrado	37.83%
*Paicol	0.04%
*Tesalia	1.25%

Method and type of research

The research was of a mixed nature since, according to Hernández-Sampieri and Mendoza (2008), it represents a set of systematic, empirical, and critical research processes and implies the collection and analysis of quantitative and qualitative data. Likewise, Chen (2006), cited by Hernández-Sampieri & Mendoza (2008), de-fines the mixed cut as the systematic integration of quantitative and qualitative methods in a single study to have a more complete vision of the phenomenon.

On the other hand, the research method used for the development of this research was the deductive-inductive method, since it allowed going from general statements to other specific ones and vice versa, until approaching the concrete reality through indicators or empirical references. In other words, it is the process of reasoning that goes from the universal to the specific, that is, it consists of obtaining conclusions from universal laws. For the case, understanding the phenomenon of the environmental impacts of the El Quimbo hydroelectric plant, its causes and consequences, requires a previously defined framework of understanding.

Information collection

Documentary analysis: Peña & Pirela (2007) conceptualize documentary analysis as the selection of informatively relevant ideas from a document, with the aim of expressing its content without ambiguities to recover the information contained in it. On the other hand, they consider documentary analysis as a process devised to organize and represent the knowledge recorded in documents.

The documentary sources that were used for the investigation were the environmental impact studies, environmental licenses and environmental management plans of the dams built in the country and the world. Be-cause of technological advances, there is a significant amount of this type of document that is freely

accessible on the Internet. In the national case, the Autoridad Nacional de Licencias Ambientales – ANLA has a physical and digital repository with information related to El Quimbo and other hydroelectric plants in the national territory, to which public access was had, such as the minutes of the public hearings held with reason for hydroelectric pro-jects. Likewise, in the repositories of national and international universities, degree works, master's studies and doctoral theses were identified with research related to the impacts of El Quimbo and other hydroelectric plants on their areas of direct and indirect influence. Likewise, in databases of great scientific and academic impact (v.g. Scopus).

Recognition of open and participatory field: The open and participatory field recognition consists of a technique that allows the collection of information and identification of impacts, opportunities, and threats, based on direct and open observation on the ground, within the framework of which the participants can freely elaborate their statements. The technique makes it possible to identify, weigh and prioritize negative impacts, resources or opportunities and restrictions or threats. Unlike other methods, it requires the participation of experts in various disciplines or trades, in addition to the basic team that prepares the final field reports.

In the development of this technique, we proceed to form an interdisciplinary team made up of professionals from different disciplines, with preferences in economic, administrative, and environmental sciences with knowledge of environmental impacts. The team was made up of a number that oscillated between 6 and 8 people in the different sessions. Subsequently, they were informed of the impacts identified for the El Quimbo hydroelectric plant with the previously used technique, for them to ratify the impacts identified so far and provide new im-pacts. Four days of field recognition were scheduled that included meetings with people belonging to associative groups of those affected, social and political leaders, producers in the area and businessmen, among others. The members of the team of experts kept records of the information they collected, and, at the end of the day, a debate was held to consolidate the results through consensus.

The sessions allowed for interaction (conversations) with the community and direct observation (visual inspection) around influence of the project, touring the perimeter areas of the reservoir, visiting different businesses, and informally interviewing multiple residents of the area.

Delphi method: The Delphi is a prospective tool based on experts (Ortega, 2008; Turoff & Linstone, 1976) that is defined as a "systematic and iterative process aimed at obtaining the opinions and, if possible, the consensus of a group of experts" (Landeta, 2005, p.468) considering that the people consulted "have a close relation-ship on the issue, sector, technology or object of research" (Landeta, 2002, p.82).

For García-Ruiz and Lena-Acebo (2018) there are multiple ways to use the Dephi (Rowe & Wright, 1999). In almost all cases, it begins with a round structured and organized by the study monitoring panel, through one or two interactions depending on the degree of agreement between the panelists (Rowe & Wright, 1999) until the judgments of the participants are refined.

The application of the tool was established in seven fundamental stages: 1) Design of the questionnaire by the coordinating group based on the variables identified in the determined dimensions; 2) Selection of the panel of experts; 3) Obtaining the responses of the panel of experts; 4) Interpretation of responses and evaluation of actions; 5) Modification of the questionnaire by the coordinating group; and 6) Obtaining the responses of the panel of experts.

For the case, the Delphi was built with the information coming from a list of impacts built with the documentary review, which is previously refined and adjusted, and was strengthened with the new contributions from the expertise of the participants to determine and hierarchize, from the global impacts, those that apply in the case of El Quimbo.

The panel of experts to whom the Delphi survey was applied were officials from the local and national environmental authority, politicians from the departmental and municipal order, social communicators, environ-mental activists, academics and multidisciplinary researchers, and people affected by the hydroelectric plant. ten (10) experts were selected. The criteria for the selection of the experts corresponded to a single person representing each identified interest group.

The first phase of the study included a generic search for impacts of dams at the global, national and local levels based on the analysis of documentary sources, with the aim of constructing a checklist. Subsequently, open and participatory field reconnaissance was used to identify environmental impacts in the field through visits to the area of influence of the hydroelectric plant. Finally, the Delphi technique was used to reaffirm or discard the impacts generated by El Quimbo previously identified in influence.

3. RESULTS

Below are the environmental impacts generated by the construction and operation of the El Quimbo hydroelectric plant in the area of influence in the southern region of Colombia. For a better understanding, and in accordance with Colombian legislation, they were established in three dimensions: physical, biotic, and socioeconomic.

Likewise, for each of the impacts, the source of information was listed, i.e., it was indicated whether they were identified from the documentary review (in which case the reference is mentioned), from the field reconnaissance or from the Delphi survey.

Table 1 shows the environmental impacts identified in the multiple ex-post documentary sources analyzed for the El Quimbo hydroelectric project, discriminated in the physical, biotic, and socioeconomic spheres. In that order, sixteen (16) physical, seven (7) biotic and sixty-five (65) socioeconomic were identified, for a total of eighty-eight (88) environmental impacts.

Table 1.
Impacts identified ex post of El Quimbo

Dimension	Impact	Classification
Physical	Land flood (INGETEC, 2008; Salcedo & Cely, 2015)	(-)
	Loss of intraregional communication and connectivity (Actualidad, 2012; Dussán, 2017)	(-)
	Decrease in plant cover (David, 2020; Ruíz, 2019)	(-)
	Alteration of the microclimate of the area (ANLA, 2021; Hermosa, 2018)	(-)
	Decrease in the landscape attractiveness of the area (Dussán, 2017; Hermosa, 2018)	(-)

Dimension	Impact	Classification
Physical	Increase in unpleasant odors (Ambiente, 2019; Archivo, 2016; David, 2020; Región, 2015)	(-)
	Increased air pollution (Identified by Delphi survey)	(-)
	Decreased river water quality (Comisión Interncional de Juristas, 2016; Betancurt, 2016; Tribunal del Huila ratifica autorización para operación en El Quimbo, 2016)	(-)
	Decrease in the quality of the reservoir waters (Comisión Internacional de Juristas, 2016)	(-)
	Increase in the availability of water for crop irrigation (Identified by Delphi survey)	(+)
	Increase in the availability of water for industrial use (Identified by Delphi survey)	(+)
	Increased geological instability (Cortés et al., 2012; Noticias Uno Colombia, 2011; Salazar, 2016)	(-)
	Increased noise level (Resolución 1096, 2011)	(-)
	Decrease in river flow downstream of the reservoir (Identified through field reconnaissance)	(-)
	Water table rise (Identified through field reconnaissance)	(+)
	Reduction of reserve areas (Dussán, 2017; Resolución 1814, 2010)	(-)
	Loss of river connectivity (Identified through field reconnaissance)	(-)
Biotic	Decline of terrestrial habitats (Identified through field reconnaissance)	(-)
	Increase in the displacement of terrestrial fauna (ANLA, 2021a; 2021b)	(-)
	Increase in the mortality of native species of terrestrial fauna (Comisión Internacional de Juristas, 2016; Dussán, 2017)	(-)
	Increase in the mortality of native species of terrestrial flora (Comisión Internacional de Juristas, 2016; Dussán, 2017)	(-)
	Increase in the mortality of native species of aquatic fauna (Cultura, 2015)	(-)
	Disruption of fish reproductive cycles (Identified through field reconnaissance)	(-)
Socioeconomic	Increased human displacement (Barreiro & Martínez, 2019; Dussán, 2017; Naranjo, 2014)	(-)
	Decreased infrastructure [roads, bridges, housing, etc.] (Granados, 2015)	(-)
	Loss of cultural practices (Ballén, 2014)	(-)
	Increase in social conflicts caused by the project (Ballén, 2014; Actualidad, 2016)	(-)
	Decrease in the area of agricultural economic activities (Gutiérrez & Pinzón, 2018; Naranjo, 2014)	(-)
	Decrease in agricultural employment (Comisión Internacional de Juristas, 2016)	(-)
	Decrease in agricultural income (ANLA, 2021a)	(-)
	Decline in fishing sites (Identified through field reconnaissance)	(-)
	Decrease in the fishing resource (Identified by Delphi survey)	(-)
	Decrease in community organizations of agricultural producers (Identified by Delphi survey)	(-)
	Decrease of agro-industrial establishments (ANLA, 2021a; 2021b)	(-)
	Decrease in industrial establishments (ANLA, 2021a; 2021b).	(-)
	Increase in human rights violations (Sentencia T-135, 2013; Dussán, 2017; HUILA, 2012; Polémica, 2012; Nación, 2012)	(-)
	Decrease of smallholdings (Investigación, 2020)	(-)
	Decrease in traditional economic activities – mining (Identified by Delphi survey)	(-)

Dimension	Impact	Classification
Socioeconomic	Decrease in the area of fertile land (Identified through field reconnaissance)	(-)
	Decrease in subregional productivity (ANLA, 2009; Gobernación del Huila, 2016; HUILA, 2016; Molano-Bravo, 2009b; Nación, 2012)	(-)
	Decrease in sites for the extraction of materials from the river (ANLA, 2021a)	(-)
	Increased emigration of the local population to other regions (LA NACIÓN +, 2013)	(-)
	Increase in grassroots community organizations (Lesmes, 2010; Archivo, 2015; Actualidad, 2012; HUILA, 2013; Investigación, 2015)	(+)
	Increase in temporary employment in the project (ENDESA, 2015; Finanzas, 2015b)	(+)
	Increase in infrastructure works in the area (Instituto Nacional de Vías, 2015; Finanzas, 2015a)	(+)
	Cost of Living Increase – Zonal Inflation (Comisión Internacional de Juristas, 2016; Mas Regiones, 2012)	(-)
	Increased immigration of people to the area of influence (Naranjo, 2014)	(-)
	Increased pressure on public services in the area (Mas Regiones, 2012)	(-)
	Increase in the creation of businesses providing restaurant and bar services (Investigación, 2016)	(+)
	Increase in prostitution (Mas Regiones, 2012)	(-)
	Increase in drug addiction and alcoholism phenomena (Mas Regiones, 2012)	(-)
	Increase in income of territorial entities from transfers (Tovar, 2015; ENEL, 2017)	(+)
	Increase in economic activities associated with tourism (Investigación, 2016)	(+)
	Increase in commercial networks in the area (Tovar, 2015)	(+)
	Increase in the price of land (Identified through field reconnaissance)	(+)
	Increase in teenage pregnancies (Identified by Delphi survey)	(-)
	Population growth in the area (Identified by Delphi survey)	(+)
	Increase in public health diseases (ANLA, 2021a; 2021b)	(-)
	Loss of tangible cultural heritage (Atarraya Film, 2015; Comisión Internacional de Juristas, 2016; Archivo, 2012)	(-)
	Loss or deterioration of archaeological sites (Atarraya Film, 2015; Comisión Internacional de Juristas, 2016; Archivo, 2012)	(-)
	Increase in forced expropriations of land (Dussán, 2017; HUILA, 2014; Resolución 321 de 2008; Resolución 328 de 2011)	(-)
	Increase in social discontent (Castillo, 2016; Macías, 2013)	(-)
	Decrease in labor available for agricultural activities (ENDESA, 2015; Finanzas, 2015b)	(-)
	General increase in wages in the area (Identified through field reconnaissance)	(+)
	Increase in the abandonment of agricultural activities (ENDESA, 2015; Finanzas, 2015b)	(-)
	Increase in the creation of small businesses (neighborhood stores, fast food, clothing and footwear businesses, etc.) (Investigación, 2016)	(+)
	Appearance of foreign cultural practices (Ballén, 2014; Hermosa, 2018; NEIVA, 2015)	(+)
	Loss of spaces for social and community interaction (Ballén, 2014; Actualidad, 2016)	(-)

Dimension	Impact	Classification
Socioeconomic	Increase in the number of divorces and dysfunctional families (Región, 2016)	(-)
	Increased stigmatization of social and environmental movements (Dussán, 2017; HUILA, 2012; Polémica, 2012; Nación, 2012)	(-)
	Increase in corruption in public institutions (Dussán, 2017)	(-)
	Decrease in the income of the relocated population (ANLA, 2021b; Chronos Maker, 2020)	(-)
	Decrease in the income of the displaced population (Sobre el Quimbo, 2011).	(-)
	Increased destruction of third-party property (ANLA, 2021a)	(-)
	Increase in the illegal invasion of third-party properties (ANLA, 2021a)	(-)
	Increase in the invasion of properties, homes, and crops by displaced animals (ANLA, 2021b)	(-)
	Increase in cases of attacks on people by wild animals (Identified through field reconnaissance)	(-)
	Increase in death of people by immersion (Identified through field reconnaissance)	(-)
	Increase in informal and illegal tourism businesses (Identified through field reconnaissance)	
	Increase in the invasion of properties around the reservoir (Identified through field reconnaissance)	(-)
	Increase in respiratory diseases (Identified through field reconnaissance)	(-)
	Emergence of sports sailing (Identified through field reconnaissance)	(+)
	Increase in reforestation activity (Identified through field reconnaissance)	(+)
	Increased risk of flooding downstream of the reservoir (Identified by Delphi survey)	(-)
	Increase in the mortality of fish farms downstream of the reservoir (Identified by Delphi survey)	(-)
	Increased demand for goods and services (Mas Regiones, 2012)	(+)
	Increase in the closing of businesses of agricultural inputs (ANLA, 2021a; 2021b).	(-)
	Increased military presence in the area (Dussán, 2017; HUILA, 2012; Polémica, 2012; Nación, 2012)	(+)

4. DISCUSSION

The identification of impacts in an ex-post way showed a total of eighty-eight (88) environmental impacts in the physical, biotic and socioeconomic fields, with a negative majority, especially in the socioeconomic field. In the physical sphere, among the impacts identified ex post, aspects such as decreased river flow, land flooding, decreased river water quality, decreased water quality of the reservoir, alteration of the microclimate of the zone, increase in the water table, increase in the availability of water for crop irrigation and increase in the availability of water for industrial use, among others.

Likewise, in the biotic sphere, aspects such as the increase in the displacement of terrestrial fauna, increase in the mortality of native species of terrestrial flora and fauna, and in-crease in aquatic ecosystems were identified. Finally, in the socioeconomic sphere, the decrease in agricultural employment, increase in the cost of living, decrease in infrastructure, decrease in the area of fertile land and de-crease in the

area of agricultural economic activities, generalized increase in wages in the area, decrease in agricultural income, increase in the mortality of fish crops downstream of the reservoir, increase in the abandonment of agricultural activities, increase in the destruction of property to third parties, increase in forced expropriations of land, decrease in labor available for agricultural activities, increase in commercial networks in the area, decrease in community organizations of agricultural producers, decrease in smallholdings, increase in infrastructure works in the area, decrease in agroindustrial establishments, increase in the illegal invasion of third-party properties, increase in the invasion of properties , homes and crops due to displaced animals, increased closure of agricultural input businesses, increased demand for goods and services, increased land prices, and decreased regional productivity, among others.

This situation allows ex-post studies to be of great practical utility to identify and manage the impacts caused by the construction and implementation of large energy projects. The increase in the number of impacts identified ex post is explained by the abundant number of documentary sources (journalistic articles, videos, re-ports, research articles, graduate, and postgraduate projects, among others) that analyzed different phenomena within the area of influence. hydroelectric, specifically due to the social, economic, ecological, and legal problems that its construction implied. In this regard, this type of situation involving energy projects with high levels of social problems generally attracts the attention of multiple interest groups, including the media and academia, which is why related study material proliferates. Similar cases occurred at the Tres Gargantas hydroelectric plant in China, Belo Monte and Itaipú in Brazil, Francisco Morazán "El Cajón" in Honduras, Chixoy in Guatemala, and Urrá I in Colombia, among others.

In general, what was found is in line with the dominant trend, in recent years, within the scientific literature and academic fields to focus their studies on the impacts of negative connotations in the environmental, social and economic fields. Likewise, they highlight aspects such as the underestimation of some previously identified impacts and the discovery of other impacts that had been omitted in the ex-ante environmental impact studies. As Xu et al. (2013) found an underestimation of human displacement in previous studies; Sicilian et al. (2015) established a greater negative impact on the income of residents; Alrajoula et al. (2016) found that the levels of the river, downstream of the reservoir, were well below what was projected; Sivongxay et al. (2017) found an improvement in the road infrastructure in the area with the construction of the dams, among others, our study established the underestimation of multiple negative and positive socioeconomic effects and, in some cases, the identification of "new" impacts.

Pardo (2002) considers that this focus on impact management focused almost exclusively on negative consequences, has its genesis in developed countries such as the United States, due to the emphasis placed on its prevention, mitigation, correction and compensation, paying attention to the negative aspects. Indeed, North American legislation has served as a guideline for many less advanced countries in environmental matters, such as South American countries.

On the other hand, the predominance of socioeconomic and negative impacts may be related to the high volume of documentary sources (videos, books, news, press articles, etc.) whose objective was to expose the negative impacts generated by hydroelectric plants on the communities; In other words, it is likely that more socioeconomic and negative impacts will be identified because the number of documents that exposed them was greater. Thus, the scarcity of scientific studies on the biotic component is directly proportional to the number of exposed and recognized impacts. Therefore, it is necessary to delve into the study of biotic impacts to expand the inventory established as a consequence of the hydroelectric plant.

On the other hand, it should be noted that the open and participatory field reconnaissance allowed reaffirming the identification of impacts related to the documentary review, especially those of a socioeconomic nature. Thus, this technique facilitated, through field visits, the recognition of negative phenomena such as the increase in cases of wild animal attacks on people, the death of people by immersion, the appearance of informal and illegal tourist businesses, the invasion of properties around the reservoir and the increase in respiratory diseases. Positive impacts related to the emergence of sport fishing, reforestation activities, and an increase in land prices were also identified.

The results of the Delphi survey were useful because they confirmed the presence of impacts that had previously been identified in the documentary review or in the field reconnaissance in the area of influence.

Finally, the work carried out has two great contributions to knowledge. The first corresponds to the notable number of environmental impacts that were identified, becoming one of the investigations with the largest number of sources studied at the national level and becoming a world reference as a guide for the identification of environmental impacts caused by dams. Indeed, the list of consolidated impacts that will serve as a reference and starting point for multiple studies and research related to the identification and evaluation of environmental im-pacts stands out. The second contribution corresponds to the scheme that was used, that is, to establish the obligation of ex-post evaluation in large and complex energy projects, which could well become a benchmark for the regions affected by the construction of dams to the extent that the environmental evaluation is not exhausted with the ex-ante evaluation in the process of the environmental license, on the contrary, the scheme used proposes an alternative for future action based on the real impacts generated. This situation allows ex-post studies to be of great practical utility to identify and manage the impacts caused by the construction and implementation of large energy projects.

5. CONCLUSIONES

The objective of our study was to identify the environmental impacts of the socioeconomic, biotic, and physical spheres generated by the El Quimbo hydroelectric plant from an ex-post perspective, that is, after the construction of the reservoir. The results show the identification of 88 environmental impacts between socioeconomic, biotic, and physical, with a predominance of socioeconomic impacts and negative connotations. The extensive documentary review allowed for establishing an inventory of impacts generated by the construction and operation of the hydroelectric plant. Said inventory was later purified and fed back with the information coming from the open and participatory recognition of the field and the application of the Delphi survey.

The results obtained constitute the first document that systematizes the environmental impacts caused by the construction of this large dam in the southern region of Colombia, since there are different studies that address the impacts in an isolated manner and with little rigor of analysis. Thus, this is the first benchmark in a country that has invested in the construction, sometimes with a low level of environmental forecasting, of hydro-electric plants in its main rivers.

This study constitutes the starting point for the identification and assessment of environmental impacts generated by El Quimbo, since at no time was it intended to establish the intensity of the impacts, but rather to identify their existence.

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Conflicts of Interest

The authors declare that there are no possible conflicts of interest.

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