Market on the exploitation of dragging materials in Boyacá (Colombia): a documentary analysis of regulatory, business and socio-environmental dynamics

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Abstract

The exploitation of dragging materials represents one of the main activities associated with the supply of aggregates for infrastructure works, urban expansion and development of the construction sector in Colombia. In the department of Boyacá, this activity has acquired increasing importance due to the presence of industrial corridors, road projects and strategic water systems that concentrate extractive processes related to sand, gravel and other alluvial materials. However, the increase in these dynamics has also generated environmental and territorial concerns related to water deterioration, erosion of riverbeds, landscape transformation and conflicts over land use.

The purpose of this research was to analyze the exploitation of dragging materials in Boyacá from a comprehensive perspective, considering regulatory, territorial, environmental and socioeconomic components. To this end, a qualitative descriptive-documentary research was developed based on a review of scientific literature, current Colombian regulations, environmental and territorial planning instruments, as well as technical and institutional documents related to mining, sustainability and water management.

The results showed that extractive activity is directly related to urban growth, regional demand for construction materials, and the strengthening of industrial corridors associated with the Alto Chicamocha. Similarly, problems related to mining informality, limitations of institutional control, and environmental effects on watersheds and riparian ecosystems were identified. Although the country has a broad legal framework to regulate the exploitation of dragging materials, difficulties persist in the processes of institutional articulation, territorial

monitoring, and effective application of environmental and mining instruments.
It is concluded that the exploitation of dragging materials in Boyacá constitutes a phenomenon where economic interests, business dynamics and challenges associated with environmental sustainability and territorial governance converge. In this sense, the study provides a useful interdisciplinary approach to strengthen environmental planning, regulation and management processes in territories with high extractive pressure.

Keywords: Drag materials, legal and regulatory framework, value chain and socioeconomic and environmental impacts

1. INTRODUCTION

Dragging materials, made up of sand, gravel and rock fragments transported and deposited in riverbeds, are an essential resource for the development of the construction sector. Their use has become increasingly important in developing economies, where the expansion of infrastructure and housing is steadily increasing the demand for stone aggregates. (Lara Brochado et al., 2025)

In Colombia, these materials represent the main source of inputs for civil works and infrastructure projects, which gives them a strategic role in the regional economic dynamics. According to the National Mining Agency, the exploitation of construction materials, including dragging materials, is one of the most representative activities of the non-metallic mining sector, with a high incidence in the generation of employment and in the supply of the construction production chain. (Lara Brochado et al., 2025; Pérez-Herrera, 2021) (ANM, 2021)

According to the information provided by the Agustín Codazzi Geographic Institute, at the territorial level, the department of Boyacá presents particularly favorable conditions for the development of this activity, due to its water wealth and the availability of alluvial deposits. However, the exploitation of dragging materials in this region is developed in a context characterized by the coexistence of productive units with different levels of formalization and technical capacity. According to the , a large part of the extractive activities in Colombia are developed under small-scale schemes, a condition that limits the incorporation of technology, reduces the operational capacity of the productive units and makes it difficult to comply with regulatory and environmental requirements. (IGAC, 2021) (Aguilar et al., 2006) (Ministry of Mines and Energy, 2016) (Murillo- Baltan , 2017)

Likewise, an important part of these extractive dynamics is developed in municipalities belonging to the upper basin of the Chicamocha River, a strategic territory for regional environmental planning and integrated management of water resources. In this area, mining, industrial and urban processes converge that increase the pressure on river ecosystems and surface and underground water sources. (CAS 2015; Corpoboyacá 2006, 2014, 2015b) (Corpoboyacá, 2014, 2021; MinAmbiente , 2026)

From the environmental component, the exploitation of dragging materials in waterways represents one of the main challenges for the sustainability of river ecosystems. Various studies have shown that this type of activity can modify the natural structure of rivers, alter sediment transport and significantly affect aquatic ecosystems, especially when extractive processes are developed without technical

controls or adequate environmental management measures. These transformations not only impact the ecological dynamics of water bodies, but also generate cumulative effects on the territory and nearby communities. In the regional context of Boyacá, these processes acquire special relevance in territories associated with the upper basin of the Chicamocha River, where environmental planning and water management instruments recognize the need to strengthen actions for the conservation, protection and sustainable use of the resource (Dan Gavriletea , 2017) (Dan Gavriletea, 2017; Padmalal , 2014) (Corpoboyacá, 2021) (IGAC, 2021) (Corpoboyacá, 2014, 2021)

Faced with this situation, the Ministry of Environment and Sustainable Development, through the , established guidelines aimed at strengthening the processes of planning, monitoring and environmental control in extractive activities, promoting measures aimed at the prevention and mitigation of the impacts derived from the use of natural resources. (MMADS, 2026) (Decree 1076 of May 26, 2015)

In response to these challenges, Colombia has consolidated a regulatory framework that integrates mining, environmental and territorial provisions for the development of this activity. Regulations such as the Mining Code, and the technical guidelines issued by the National Mining Agency establish requirements related to obtaining mining titles, environmental licenses and the implementation of management plans. However, different institutional reports indicate that difficulties still persist in the effective application of these provisions, particularly in territories where small-scale extractive activities and low levels of formalization predominate. (Law 685 of August 5, 2001) (Decree 1076 of May 26, 2015) (ANM, 2021) (Murillo- Baltan , 2017)

In the case of the department of Boyacá, the environmental management and supervision of the activity falls mainly on the entity in charge of assessing impacts, granting licenses and verifying compliance with environmental regulations. However, the geographical characteristics of the territory and the dispersion of the productive units make it difficult to permanently monitor the extractive activity, favoring in some cases the continuity of informal practices and the appearance of socio-environmental conflicts. In this sense, the Regional Environmental Management Plan (PGAR) 2021–2031 establishes guidelines aimed at the environmental management of the territory, the prevention of environmental deterioration and the integrated management of water resources as strategic axes for regional sustainability. (Government of Boyacá, 2026) (Corpoboyacá, 2026a) (Corpoboyacá, 2021)

Despite the economic importance of the exploitation of dragging materials for the construction sector and infrastructure development, the scientific literature shows that a large part of the research has approached this activity from sectoral approaches, concentrating mainly on environmental impacts, regulatory processes or production dynamics independently. In this context, numerous studies have been oriented to the analysis of the geomorphological and ecological alterations derived from the extraction of sediments in river channels, especially in relation to the erosion of riverbanks, the modification of sedimentary dynamics and the loss of aquatic biodiversity. (Dan Gavriletea, 2017; Kondolf et al., 2018; Padmalal

, 2014) (Condolf et al., 2018; Padmalal , 2014)

On the other hand, research related to mining governance and small-scale mining has emphasized aspects associated with formalization, regulatory compliance, and institutional limitations for the control of extractive activities, particularly in developing countries. From an economic and business perspective, some authors have analyzed the relevance of construction materials within regional value chains and their impact on the competitiveness of the infrastructure sector. However, there are limited studies that simultaneously integrate the regulatory, business, and socio-environmental dimensions in the same analysis, especially in regional scenarios where multiple actors, institutional interests, and complex territorial dynamics converge. (Hilson, 2002; Hilson & McQuilken, 2014) (Garza-Esquivel, 2020; Ministry of Mines and Energy, 2016)

This fragmentation of knowledge makes it difficult to build a comprehensive vision of the exploitation of trawling materials, limiting the understanding of the relationships between environmental sustainability, business management, and territorial governance. In departments such as Boyacá, where extractive activity is closely linked to regional economic development and the use of strategic water systems, it is necessary to promote research that articulates these dimensions from interdisciplinary and territorial perspectives (Corpoboyacá, 2026a; Government of Boyacá, 2026) .

Under this panorama, the purpose of this study is to analyze, from a qualitative approach of documentary review, the regulations, management and business dynamics associated with the exploitation of dragging materials in the department of Boyacá, in order to understand their relationship with the socioeconomic and environmental impacts reported in recent literature.

In this context, this study provides a comprehensive approach to the analysis of the exploitation of dragging materials in Boyacá, articulating regulatory, environmental, territorial and business components from an interdisciplinary perspective. Likewise, the research contributes to the understanding of the existing relationships between mining governance, environmental sustainability and territorial planning in extractive corridors associated with strategic watersheds of the department.

1. Framework of Reference

The exploitation of dragging materials has acquired increasing relevance in recent decades due to the sustained increase in global demand for aggregates for the construction sector and infrastructure development. According to , the increase in urbanization and territorial expansion processes has generated significant pressure on sedimentary resources used in civil works, a situation that has led various authors to consider sand and gravel as strategic resources for contemporary economies. Along the same lines, recent research published in the Journal warns that the growing extraction of aggregates is one of the main current challenges in terms of sustainability and governance of natural resources. (Zhong et al., 2022) (Nat. Geosci, 2024)

From a conceptual perspective, the dragging materials correspond to sediments of alluvial origin, mainly sand and gravel, transported and deposited naturally in river channels, whose use is essential for activities related to the production of concrete, asphalt mixtures and infrastructure projects. Its economic importance has been

widely recognized in developing countries, where urban growth and the expansion of public works have considerably increased the demand for stone materials. (Padmalal , 2014) (Environmental Development, 2014)

In Colombia, the exploitation of construction materials represents one of the most dynamic activities of non-metallic mining, particularly because of its contribution to the supply of the construction sector and the development of road and urban infrastructure. However, recent research indicates that a large part of these activities continue to be carried out under small-scale schemes and limited technification, a situation that hinders both productive efficiency and compliance with the environmental and administrative requirements demanded by current regulations. (Ministry of Mines and Energy, 2016) (Hilson & McQuilken, 2014; Oliveira et al., 2024)

In departments such as Boyacá, the exploitation of dragging materials has particular characteristics associated with the availability of water systems and alluvial deposits suitable for their use. However, the coexistence of formal and informal extractive units, added to the limitations in technical capacity and institutional control, has generated complex scenarios in terms of environmental sustainability and territorial governance (Corpoboyacá, 2026).

From the environmental component, multiple studies have shown that the extraction of sediments in river channels can produce significant alterations in the geomorphological dynamics of rivers. Classic studies developed by , showed that the intensive removal of materials can cause deepening of channels, erosion of banks and modifications in the natural transport of sediments. These effects not only alter the physical balance of river ecosystems, but also generate cumulative impacts on biodiversity and hydrological stability. (Kondolf et al., 2018; Mathias Kondolf , 1994)

The most recent research complements this perspective by pointing out that the impacts derived from sand mining have increasingly complex environmental, economic and social implications. They argue that the intensive extraction of river materials is related to the degradation of aquatic ecosystems, the increase in turbidity and the loss of riparian habitats, especially in contexts where there are weaknesses in environmental control mechanisms. Similarly, they emphasize that the exploitation of sand and gravel cannot be analyzed only from an economic dimension, because its effects have a direct impact on local livelihoods, territorial governance and ecological sustainability. (Rentier & Cammeraat , 2022) (Marschke & Rousseau, 2022)

At the international level, recent literature has also begun to address the so-called "global sand crisis", associated with the accelerated growth in the demand for aggregates and the expansion of informal extraction markets. According to , these dynamics have favored the emergence of poorly regulated extractive activities, making it difficult to trace the resource and increasing socio-environmental risks in territories with limited institutional capacity. (Nat. Geosci, 2024) (Oliveira et al., 2024)

From the regulatory perspective, Colombia has consolidated a regulatory framework that articulates mining, environmental and territorial provisions to regulate the exploitation of dragging materials. The Mining Code establishes the obligation to have a mining title for the legal use of the resource, while the and (Law 865 of August 5, 2001) (Law 99 of December 22, 1993) the (Decree 1076 of May 26,

2015) incorporate criteria related to licensing, monitoring and environmental management of the (Ministry of Mines and Energy, 2016) .

However, different studies on mining governance agree that the existence of a robust regulatory framework does not necessarily guarantee its effective application, especially in regions where small-scale extractive activities and high levels of informality predominate. This situation is related to institutional limitations, supervisory difficulties, and administrative barriers that affect both regulatory entities and productive units. (Hilson, 2002; Hilson & McQuilken, 2014)

From the business perspective, the exploitation of dragging materials can be understood as a value chain made up of extraction, transport, processing and marketing activities, whose competitiveness depends on the efficient articulation between its links. However, recent studies show that many companies dedicated to the exploitation of aggregates face limitations associated with low technification, high logistics costs and reduced incorporation of sustainability criteria in their management processes. (Garza-Esquivel, 2020) (Garza-Esquivel, 2020; Niyonyungu et al., 2025)

In this context, the scientific literature shows the need to promote comprehensive approaches that allow understanding the exploitation of dragging materials from an interdisciplinary perspective, articulating environmental, business and regulatory dimensions. This integration is especially relevant in complex territorial scenarios such as Boyacá, where economic interests, institutional dynamics and environmental transformation processes associated with the use of natural resources converge.

2. Methodology

This research was developed under a qualitative approach, because it was oriented to the analysis and interpretation of documentary information related to the exploitation of dragging materials in the department of Boyacá, considering its regulatory, business, territorial and socio-environmental dimensions. This approach allowed to understand the dynamics associated with the extractive activity from the review of technical, regulatory, institutional and scientific documents, favoring a comprehensive approach to the phenomenon studied. According to , qualitative research seeks to interpret phenomena within their natural context, analyzing meanings, relationships and characteristics present in the reality studied. (Bernal Torres, 2016; Hernández-Sampieri et al., 2014; Medina et al., 2023) (Hernández-Sampieri et al., 2014)

The study was based on a documentary research design, understood as a systematic process of collection, organization, analysis and interpretation of information from secondary sources. According to , documentary research allows the examination of previously existing knowledge through the critical consultation of books, scientific articles, institutional documents, technical reports and regulations related to the object of study. In this sense, the methodology was aimed at identifying the main regulatory, territorial, business and environmental elements associated with the exploitation of dragging materials in Boyacá. (Bernal Torres, 2016)

Likewise, the research adopted a descriptive-analytical scope, because initially it sought to characterize the dynamics of exploitation of dragging materials and later to interpret the existing relationships between the normative, economic and socio-environmental components identified in the reviewed literature. According to ,

descriptive studies allow detailing properties, characteristics and behaviors of a phenomenon, while the analytical component facilitates understanding the interactions and effects derived from it. (Bernal Torres, 2016; Medina et al., 2023)

For the development of the research, the documentary review technique was used, through the consultation and analysis of different types of sources of information. Among the main sources reviewed were indexed scientific articles, specialized books, technical reports, institutional documents, mining and environmental legislation, Watershed Planning and Management Plans (POMCA), Territorial Planning Plans (POT), guidelines of the National Mining Agency, documents issued by Corpoboyacá, as well as information related to mining governance and environmental sustainability. (Bernal Torres, 2016; Hernández-Sampieri et al., 2014; Medina et al., 2023)

The search for information was carried out through academic databases and institutional repositories such as Scopus, ScienceDirect, Google Scholar, Springer, ResearchGate, official documents of the Ministry of Mines and Energy, the Ministry of Environment and Sustainable Development, the National Mining Agency, the Government of Boyacá and Corpoboyacá. To do this, keywords related to "dragging materials", "sand and gravel mining", "environmental impacts", "mining value chain", "Boyacá", "mining exploitation" and "environmental governance" were used.

Documents published mainly between 1974 and 2026, research related to the exploitation of dragging materials, non-metallic mining, socio-environmental impacts, mining regulations and territorial management, as well as studies with relevance to the Colombian and regional context, were considered as inclusion criteria. Likewise, legal norms and institutional documents relevant to understanding the regulation of extractive activity in Colombia and Boyacá were incorporated. On the other hand, documents without technical or academic support, duplicate sources and publications that were not directly related to the object of study were excluded.

Subsequently, the information collected was organized through documentary analysis matrices, which allowed the information to be classified according to thematic categories related to: i) mining regulatory framework and regulation, ii) value chain and business dynamics, and iii) socioeconomic and environmental impacts associated with the exploitation of dragging materials. This organization facilitated the identification of patterns, coincidences, recurring problems and relationships between the different components analyzed.

The analysis of the information was developed through a process of thematic and comparative interpretation of the findings identified in the reviewed sources. This procedure made it possible to build a comprehensive vision of the dynamics of exploitation of dragging materials in the department of Boyacá, integrating territorial, environmental, institutional and business elements associated with this extractive activity.

3. Results

3.1 Regulatory framework for the exploitation of dragging materials in Colombia

The exploitation of dragging materials in Colombia is regulated by a broad set of constitutional, mining, environmental, water and territorial provisions that seek to guide the sustainable use of natural resources and reduce the impacts derived from extractive activities on ecosystems and communities. In the case of the department of Boyacá, the application of this regulatory framework acquires special relevance due to the presence of mining-industrial corridors, strategic watersheds and areas with high pressure on water resources and the territory.

In this context, the regulation of sand, gravel and other alluvial materials involves the participation of multiple national, regional and municipal entities in charge of planning processes, environmental licensing, mining inspection, land use and water control. Instruments such as the Mining Code, the Single Regulatory Decree of the Environment Sector, the POMCA, the POTs and the guidelines issued by Corpoboyacá are fundamental elements to guide the development of extractive activity under criteria of environmental sustainability and territorial governance.

Table 1 presents an updated synthesis of the main legal, environmental and administrative instruments in force applicable to the exploitation of dragging materials in Colombia and Boyacá. The regulatory selection was made through documentary review in official sources, including the Public Function Regulatory Manager, the Ministry of Environment and Sustainable Development, the National Mining Agency, the National Environmental Licensing Authority ANLA and the institutional normogram of Corpoboyacá, prioritizing provisions related to mining regulation, water management, environmental licensing, territorial planning and sustainability of extractive activities.

Table 1: ***National legal and regulatory framework applicable to the exploitation of dragging materials in Colombia.***

No.	Level	Standard / Instrument	Year	Issuing / responsible entity	Main content	Application to Drag Materials	Implications for Boyacá and extractive activity
1	National	Political Constitution of Colombia (Arts. 8, 79, 80 and 332)	1991	National Constituent Assembly	It establishes environmental protection and state ownership of non-renewable natural resources.	It is the basis for the regulation of sand, gravel and alluvial materials.	It underpins state control and environmental and mining obligations in Boyacá.
2	National	Decree 2811 National Code of Renewable Natural Resources	1974	Presidency of the Republic	It regulates the sustainable use of natural resources.	It controls the intervention on water bodies and riverbeds.	It requires environmental prevention and mitigation measures in river farms.
3	National	Decree 1541	1978	Presidency of the Republic	It regulates the use of water, channels and beds.	Defines requirements for extraction in rivers and streams.	It requires permits for the occupation of riverbeds and water control in Boyacá.
4	National	Decree 2222 Mining Safety Regulations	1993	Ministry of Mines and Energy	It regulates open-pit mining safety and hygiene conditions.	It applies to alluvial mining and aggregate exploitation.	It requires industrial safety and occupational health protocols.
5	National	Law 99 of 1993 – National Environmental System (SINA)	1993	Congress of Colombia	It creates the Ministry of Environment and the Regional Autonomous Corporations.	Introduces mandatory environmental licensing.	Defines Corpoboyacá's competencies for environmental monitoring and control.

6	National	Constitutional Court Ruling T-243	1994	Constitutional Court	It recognizes the relationship between a healthy environment, health, and the protection of fundamental rights in the face of environmental impacts.	It supports the need for environmental control over activities with an impact on ecosystems and communities.	It reinforces the importance of preventing environmental effects derived from extractive activities and water pollution.
7	National	Law 141 – Royalty Regime	1994	Congress of Colombia	It regulates economic considerations derived from mining exploitation.	Applies to construction and drag materials.	It generates economic and tax obligations for exploiters in Boyacá.
8	National	Resolution 181847	2001	Ministry of Mines and Energy	Adopts mining legalization forms.	It facilitates mining formalization processes.	It favors business and mining regularization in the department.
9	National	Law 685 of 2001 – Mining Code	2001	Congress of Colombia	It regulates mining exploration and exploitation in Colombia.	Recognizes drag materials as building materials.	It requires a mining title, PTO and payment of royalties.
10	National	Law 685 of 2001 – Articles 11 and 338	2001	Congress of Colombia	It defines construction materials and illegal exploitation.	It includes sand, gravel and alluvial materials.	Increases control and sanction over illegal extraction in Boyacá.
11	National	Decree 2390	2002	Presidency of the Republic	It regulates traditional mining legalization processes.	Applies to historical exploitation of dragging materials.	It favors formalization processes in regional small-scale mining.
12	National	Law 756	2002	Congress of Colombia	Modifies the mining royalties regime.	Regulates economic settlement of construction materials.	Increases financial and tax obligations.
13	National	Decree 2191 – Mining Technical Glossary	2003	Ministry of Mines and Energy	Defines technical mining concepts.	Establishes official definition of dragging materials.	Standardizes technical and legal criteria applicable in Boyacá.
14	National	Law 1333 – Environmental Sanctioning Procedure	2009	Congress of Colombia	It regulates environmental sanctions.	It applies to environmental breaches and illegal exploitation.	It increases sanctioning and economic risks for exploiters.
15	National	Decree 4134	2011	Presidency of the Republic	Creates the National Mining Agency (ANM).	It centralizes mining administration and supervision.	It strengthens technical and legal control over extractive activities.
16	National	Law 1450 – National Development Plan	2011	Congress of Colombia	It introduces mining traceability mechanisms.	It gives rise to the Single Registry of Mineral Marketers RUCOM.	Strengthens control over the commercialization of dragging materials.
17	National	Presidential Directive 10	2013	Presidency of the Republic	It establishes guidelines on prior consultation.	It applies to extractive projects with possible ethnic impact.	It increases social and territorial demands in mining projects.
18	National	Law 1682 on Transportation Infrastructure	2013	Congress of Colombia	It regulates road infrastructure projects.	It allows temporary extraction authorizations for public works.	It facilitates the supply of aggregates for regional projects.
19	National	Decree 276 – RUCOM	2015	Presidency of the Republic / ANM	It regulates the Single Registry of Mineral Marketers.	It requires traceability and legal accreditation of the material.	It reduces illegal marketing and strengthens market control.
20	National	Decree 1066 of 2015	2015	Presidency of the Republic	It compiles regulations on prior consultation and ethnic affairs.	It regulates procedures associated with extractive projects.	It strengthens social and territorial requirements in mining.
21	National	Decree 1076 of 2015 – Single Regulatory	2015	Ministry of Environment and	Compiles Colombian	It regulates licenses, permits for the	Demands PMA and permanent environmental

		Decree of the Environment Sector		Sustainable Development	environmental regulations.	occupation of riverbeds and environmental management.	monitoring in Boyacá.
22	National	National Mining Policy	2016	Ministry of Mines and Energy	It defines guidelines for sustainability and mining formalization.	He recognizes informality and low technification of the sector.	It encourages sustainability and business strengthening.
23	National	Resolution 40103	2017	Ministry of Mines and Energy	It defines mining classification and sectoral technical guidelines.	It applies to extractive projects and mining activities.	Strengthens technical criteria for mining exploitation and supervision.
24	National	Resolution 143	2017	National Mining Agency	Adopt mining terms and technical guides.	Defines applicable technical and environmental guidelines.	It increases technical suitability requirements.
25	National	Resolution 299	2018	National Mining Agency	It regulates standards of mineral resources and reserves.	Includes construction and drag materials.	It strengthens technical and financial standards in the extractive sector.
26	National	Resolution 883	2018	Ministry of Environment and Sustainable Development	Regulates discharge parameters.	It applies to extractive activities that affect water quality.	It demands monitoring and control of discharges in rivers in Boyacá.
27	National	Law 1955 – National Development Plan	2019	Congress of Colombia	It strengthens guidelines for mining formalization and sustainability.	It incorporates mining control and traceability measures.	It favors articulation between mining, sustainability and regional development.
28	National	Resolution 1170	2023	ANLA	Defines terms of reference for the preparation of Environmental Impact Assessments (EIAs).	Applies to extractive projects with environmental licensing requirements.	Standardizes technical and environmental requirements for mining and extractive projects.
29	National	Resolution 100	2020	National Mining Agency	It regulates the presentation of mineral resources and reserves.	Applies to construction materials titles.	It requires periodic updating of technical information.
30	National	Good Practice Guide for Drag Materials	2021	National Mining Agency	It presents technical and environmental guidelines for sustainable exploitation.	It includes sediment management and environmental recovery.	It favors sustainability and business formalization in Boyacá.
31	Regional	POMCA – Watershed Planning and Management Plans	Current	Corpoboyacá	They regulate the management and conservation of watersheds.	Restrictions are determined for extraction in rivers and streams.	They limit areas of exploitation and condition environmental licenses.
32	Regional	Regional Environmental Licenses	Current	Corpoboyacá	They evaluate impacts and authorize extractive activities.	They apply to farms located in Boyacá.	They demand compliance with environmental measures and permanent monitoring.
33	Regional	Channel occupation permits	Current	Corpoboyacá	They regulate intervention on bodies of water.	Required for extraction in rivers and alluvial terraces.	They control intervention in water ecosystems.
34	Regional	Environmental Management Plans (EMP)	Current	Corpoboyacá	They establish prevention, mitigation and environmental compensation measures.	They apply to mining and extractive projects in the department.	They increase technical obligations and operating costs.
35	Regional	Mining environmental monitoring and control	Current	Corpoboyacá	Supervises environmental compliance and impact control.	It monitors the exploitation of dragging materials in Boyacá.	It favors environmental control and mining formalization.
36	Regional	Regulation of discharges and water quality	Current	Corpoboyacá	It regulates discharges and effects on bodies of water.	It applies to extractive activities that affect water quality.	It requires monitoring and management of sediments in regional basins.

37	Regional	Agreement 023	2009	Corpoboyacá	Establishes parameters for environmental assessment and monitoring collection.	It applies to extractive projects subject to environmental control.	Increases economic obligations and environmental technical monitoring.
38	Regional	Agreement 014	2014	Corpoboyacá	It adopts regional environmental management and conservation instruments.	Strengthens environmental planning on intervened areas.	It promotes sustainability and ecosystem control in extractive areas.
39	Regional	Agreement 003	2016	Corpoboyacá	Adopt tariffs for water use.	It applies to extractive activities with the use of water resources.	It increases obligations related to water use.
40	Regional	Resolution 3646	2016	Corpoboyacá	Adopts a procedure for reporting captured and discharged flows.	Applies to farms with water impact.	Strengthens water monitoring and regional environmental control.
41	Regional	Resolution 4327	2016	Corpoboyacá	Regulates requirements for bulk material collection centers.	Applies to the storage and handling of dragging materials.	Increases environmental and technical control over stone aggregates.
42	Regional	Resolution 0630-0049	2016	Corpoboyacá	Reorganizes committee for the planning and management of watersheds.	Strengthens water management and environmental planning.	Reinforces the articulation of POMCA and control over river exploitation.
43	Regional	Resolution 0070	2016	Corpoboyacá	It regulates the use of water supply during climatic phenomena.	Applies to activities with intervention on bodies of water.	It reinforces water control in periods of environmental vulnerability.
44	Regional	Regional mining inspection	Current	National Mining Agency	It carries out technical and legal control over mining titles.	Verifies legality and compliance of farms.	It increases the requirements for formalization and legal production.
45	Municipal / Regional	POT – Land Use Plans	Current	Municipal mayors	They regulate land use and economic activities.	They define permitted or restricted areas for mining.	They condition the territorial viability of extractive projects.
46	Regional	Environmental and mining guidelines applied in Boyacá	Current	ANM and Corpoboyacá	They guide good environmental and technical practices.	They promote sustainable management of dragging materials.	They promote sustainability and reduce environmental impacts.
47	Departmental	Departmental Development Plan of Boyacá	Current	Government of Boyacá	It defines guidelines for economic development and territorial sustainability.	It includes strategies related to mining and infrastructure.	It guides public policies and institutional articulation.
48	Departmental	Departmental mining and environmental management	Current	Government of Boyacá	It coordinates actions between municipalities and environmental and mining entities.	It supports formalization and territorial monitoring of extractive activities.	It favors institutional articulation and territorial control.
49	Departmental	Departmental road infrastructure plans and programs	Current	Government of Boyacá	It promotes infrastructure and road maintenance projects.	Regional demand for stone aggregates increases.	It energizes extractive activity and the regional supply chain.
50	Regional	Regional Environmental Management Plan (PGAR) 2021–2031	Current	Corpoboyacá	It guides long-term regional environmental planning.	It integrates sustainability, water management and environmental control.	Strengthens environmental governance and territorial sustainability in Boyacá.

Note. The table integrates the main constitutional, mining, environmental, water, territorial and administrative instruments in force applicable to the exploitation of dragging materials in Colombia and the department of Boyacá. The regulatory selection was made through documentary review in official sources, including the Public Function Regulatory Manager, the National Mining Agency, the Ministry of

Environment and Sustainable Development, the ANLA and the institutional normogram of Corpoboyacá, considering criteria of validity, thematic relevance and territorial application on extractive activities, water management, environmental sustainability and territorial planning. Own elaboration based on (CAS, 2015; Office of the Comptroller General of Boyacá, 2008; Corpoboyacá, 2021, 2025, 2026b; Decree 276 of February 17, 2015; Decree 291 of August 4, 2003; Decree 1066 of May 26, 2015; Decree 1541 of July 28, 1978; Decree 2222 of November 5, 1993; Decree 2390 of October 24, 2002; Decree 2811 of December 18, 1974; Decree 4134 of November 3, 2011; Presidential Directive of November 10 of November 7, 2013; Law 99 of December 2, 1993; Law 141 of June 28, 1994; Law 756 of July 23, 2002; Law 1333 of July 21, 2009; Law 1450 of June 16, 2011; Law 1682 of November 22, 2013; Law 1955 of May 25, 2019; Resolution 100 of March 17, 2020; Resolution 143 of April 3, 2017; Resolution 299 of June 13, 2018; Resolution 883 of May 18, 2018; Resolution 1170 of June 8, 2023; Resolution 40103 of February 9, 2017; Resolution 181847 of December 28, 2001; Judgment 243 of May 20, 1994; IGAC, 2021; MinAmbiente , 2026; MinVivienda , 2025; Murillo- Baltan , 2017)

3.2 Value chain of dragging materials in Boyacá

The documentary review allowed us to identify that the value chain of dragging materials in the department of Boyacá is made up of different productive links and territorial actors that participate in the processes of extraction, transport, processing, commercialization and regulation of extractive activity. The results show that these dynamics are mainly concentrated in municipalities associated with the industrial and mining corridor of Alto Chicamocha, as well as in areas near strategic watersheds of the department.

Similarly, the information collected made it possible to recognize the participation of extractive companies, transporters, processing plants, marketers, environmental entities and territorial administrations, whose functions are articulated within the supply chain of stone aggregates destined for the construction sector and regional infrastructure. In this context, **Table 2** presents the territorial and operational structure of the value chain of hauling materials in Boyacá, including the main actors, areas of greatest presence, productive dynamics and business aspects identified in the documentary review.

Table 2: ***Value chain of dragging materials in Boyacá***

N	Chain Link	Main activity	Actors involved	Municipalities and areas with the greatest presence	Identified production dynamics	Problems and challenges identified	Business and territorial aspects
1	Primary extraction	Obtaining sand, gravel and sediments in alluvial channels and terraces	Extractive companies, small producers, formal and informal mining operators	Tunja, Paipa, Duitama, Sogamoso, Nobsa, Corrales, Tópaga, Tibasosa and Puerto Boyacá; riparian areas of the Chicamocha River basin and associated tributaries	Predominance of small and medium-sized farms; coexistence of formal and informal mining; mechanized and manual extraction	Mining informality, erosion of riverbeds, sedimentary alteration and pressure on river ecosystems	High dependence on urban, industrial and road growth of the Alto Chicamocha corridor)
2	Exploitation in	Use of sedimentary deposits	Extractive operators, riverine	Basins of the Chicamocha River, Suárez River, Garagoa	Concentration of extractive activities near	Risks of sedimentation, loss of vegetation	Environmental restrictions condition

	strategic basins	and alluvial terraces	owners and local communities	River and sectors associated with Lake Tota; municipalities such as Paz de Río, Socha, Socotá, Tasco, Gámeza, Betéitiva and Sativanorte	water corridors and historic mining areas	cover and water impact	continuity and expansion of extractive projects)
3	Transport and logistics	Mobilization of aggregates to urban centers and infrastructure projects	Transporters, logistics operators and dump truck owners	Tunja–Paipa–Duitama–Sogamoso road corridor; connections to Santander, Casanare and Magdalena Medio; industrial routes of the Alto Chicamocha	High flow of dump trucks and dependence on regional road infrastructure	Increased logistics costs, road deterioration and congestion	The geographical position of the industrial corridor favors regional distribution of aggregates)
4	Processing and transformation	Shredding, sorting and washing of materials	Shredding plants, collection centers and processing companies	Industrial and peri-urban areas of Nobsa, Duitama and Sogamoso	Significant differences in technification and installed capacity	Low technological modernization in small farms	Competitiveness depends on technological investment and operational efficiency)
5	Marketing	Distribution and sale of stone aggregates	Marketers, intermediaries and distributors	Regional markets of Tunja, Duitama, Sogamoso, Paipa and municipalities with urban expansion	Marketing associated with the growth of the construction and public works sector	Price intermediation and limited traceability of the material	Regional Infrastructure and Housing Projects Unit
6	Resource End Use	Application of aggregates in civil works and infrastructure	Construction companies, contractors and public entities	Road and urban development projects developed in the provinces of Sugamuxi, Tundama, Central and Western Boyacá	High demand for materials for road maintenance and urbanization	Economic dependence on the behaviour of the construction market	The extractive sector consolidates itself as a strategic regional supplier
7	Mining Regulation	Technical and legal inspection of farms	National Mining Agency, mayors' offices and territorial entities	Municipalities with mining titles and registered exploitation: Nobsa, Sogamoso, Tópaga, Corrales, Paz de Río, Tasco and Puerto Boyacá	Increased controls on mining formalization and traceability	Persistence of informal extractive activities and territorial dispersion	Formalization conditions operational continuity and access to markets
8	Environmental regulation	Monitoring and granting of environmental permits	Corpoboyacá, ANLA and mayors' offices	Municipalities included in POMCA of the Chicamocha River, Lake Tota, Garagoa River and Suárez River; especially Tunja, Duitama, Paipa, Sogamoso, Nobsa, Tibasosa and Tota	Supervision of discharges, channel occupation and environmental management	Monitoring difficulties due to geographical dispersion and industrial pressure	Environmental control has a direct impact on sustainability and project permanence
9	Territorial management and planning	Territorial planning and institutional articulation	Government of Boyacá, municipal mayors and environmental authorities	Municipalities with POTs associated with mining areas and industrial corridors: Tunja, Duitama, Sogamoso, Nobsa, Tibasosa, Paipa and Puerto Boyacá	Integration between mining, urban expansion and infrastructure	Conflicts over land use and pressure on strategic ecosystems	The POTs and POMCA condition the expansion of extractive activities
10	Socio-environmental management	Environmental prevention, mitigation and recovery	Environmental authorities, communities and extractive companies	Riparian sectors of the Chicamocha River and areas with a history of erosion and water deterioration in Nobsa, Corrales, Tibasosa, Sogamoso and Paz de Río	Implementation of PMA, revegetation and water monitoring	Risks of contamination, sedimentation and landscape deterioration	Corporate sustainability increasingly depends on environmental compliance)

Note. The table integrates the territorial value chain of dragging materials in the department of Boyacá, identifying municipalities, extractive corridors, watersheds, business dynamics and areas of mining and environmental regulation derived from the documentary review and the territorial dynamics associated with the industrial and mining corridor of the Alto Chicamocha. Own elaboration based on (Bonilla-Benítez et al., 2017; CAS, 2015; Office of the Comptroller General of Boyacá, 2008; Corpoboyacá, 2006, 2014, 2015a, 2015b, 2021, 2026b; Corpoboyacá, 2026a; Fajardo et al., 2024; Government of Boyacá, 2012; IGAC, 2021; MinAmbiente , 2026; MinVivienda , 2025; Rojas, 2018; All of Colombia , 2019)

3.3 Socio-economic and environmental impacts of the exploitation of dragging materials

The documentary review identified that the exploitation of dragging materials in the department of Boyacá generates various environmental and socioeconomic impacts associated with both the extraction processes and the productive, logistical and territorial dynamics linked to this activity. The results show that these impacts are more intense in municipalities located on mining and industrial corridors and strategic watersheds, especially in sectors associated with the Chicamocha River and its areas of influence.

Likewise, the information analyzed shows that the effects identified are not limited only to the environmental component, but also involve aspects related to employment, road infrastructure, territorial conflicts, quality of life, and pressure on natural resources. In this context, **Table 3** summarizes the main environmental and socioeconomic impacts reported in the literature, as well as the areas of the department where there is a higher incidence of these extractive dynamics.

Table 3: ***Impacts associated with the exploitation of dragging materials.***

No.	Dimension	Type of impact	Description of the impact identified	Municipalities and areas with the highest incidence	Evidence and findings identified	Territorial, environmental and socio-economic implications
1	Environmental	Alteration of riverbeds and river dynamics	The extraction of sand and gravel modifies the natural shape of rivers, alters hydraulic flow and generates changes in sediment transport	Upper and Middle Basin of the Chicamocha River; Sogamoso, Nobsa, Tibasosa, Duitama, Paipa and Tópaga	Corpoboyacá Environmental Diagnostics Identify Geomorphological Alterations and Sedimentary Changes in the Chicamocha Basin	Increased erosion, deterioration of water rounds and impact on riparian ecosystems
2	Environmental	Soil erosion and degradation	The constant removal of sediments and vegetation cover favors erosive processes and loss of slope stability	Nobsa, Corrales, Tibasosa, Paz de Río, Socha and Tasco	The POMCA and environmental studies report accelerated erosion and soil degradation in mining and riparian areas.	Loss of productive land, landscape deterioration and increased environmental vulnerability
3	Environmental	Sedimentation and increased turbidity	Extractive activity increases the presence of suspended sediments and modifies the physical-chemical quality of the water	Chicamocha River, Suárez River, Jordan River and sectors associated with Lake Tota	The environmental reports of the Chicamocha River show sedimentation processes and water affectation associated with extractive and industrial activities. (Corpoboyacá, 2026b)	Decrease in water quality and impact on domestic, agricultural and ecosystem uses
4	Environmental	Water Resource Pollution	The combination of mining, industrial dumping and urban activities generates deterioration of bodies of water	Tunja, Duitama, Nobsa, Sogamoso and Chicamocha River Basin	Impacts associated with industrial dumping, waste and mining exploitation on the Chicamocha River are reported.	Pressure on water sources and aquatic ecosystems
5	Environmental	Loss of vegetation cover	Intervention on riparian areas and exploitation areas reduces natural cover and transforms the landscape	Paz de Río, Corrales, Tasco, Socha, Socotá and mining-industrial corridor	Environmental investigations show an impact on vegetation and ecosystems associated with extractive activities.	Ecosystem fragmentation and reduction of environmental services
6	Environmental	Affecting strategic ecosystems	Extractive activities generate pressure on moorlands, water roundabouts and	Chicamocha Basin, moors near Paz de Río, Tasco and Socotá	Studies on mining in Boyacá link extractive activities with pressure on strategic ecosystems.	Biodiversity risk and regional water regulation

			high Andean ecosystems			
7	Environmental	Risk of floods and natural hazards	The alteration of channels and occupation of ring roads increases susceptibility to floods and landslides	Chicamocha River Basin and associated sub-basins	POMCA identify threats from erosion, flooding and loss of stability in intervened areas	Increased vulnerability for communities and infrastructure near rivers
8	Environmental	Air emissions and particulate matter	Dump truck traffic, crushing and processing generate dust emissions and deterioration of air quality	Nobsa, Corrales, Sogamoso, Duitama and the industrial corridor of the Upper Chicamocha	Environmental studies report air pollution associated with mining and cement industry.	Impact on air quality and negative perception of communities
9	Environmental	Noise and vibrations	Operation of heavy machinery and constant transportation generates noise pollution	Tunja–Paipa–Duitama–Sogamoso Corridor and industrial municipalities	Extractive activity and the flow of dump trucks have impacts on urban and rural environments	Alteration of quality of life and conflicts with communities
10	Environmental	Landscape Transformation	Extraction visually modifies riparian environments and exploitation areas	Chicamocha River Basin, Nobsa, Corrales and Paz de Río	Environmental impact studies report transformation of the natural landscape and visual degradation	Loss of landscape value and impact on territorial identity
11	Socioeconomic	Generation of local employment	The exploitation of dragging materials generates direct and indirect employment	Tunja, Duitama, Sogamoso, Nobsa, Puerto Boyacá and mining municipalities	Regional mining continues to be an important source of employment and economic activity.	Economic dependence on communities linked to the extractive sector
12	Socioeconomic	Regional economic dynamization	Aggregate supply strengthens infrastructure, housing, and trade sectors	Tunja–Paipa–Duitama–Sogamoso Corridor and municipalities with urban expansion	Extractive activity is articulated with regional production chains and road projects.	Economic strengthening of sectors associated with construction and infrastructure
13	Socioeconomic	Dependence on the construction sector	The demand for materials depends on urban growth and public investment	Municipalities with urban expansion and regional infrastructure projects	The exploitation of aggregates responds to the behaviour of the construction sector	Economic variability and dependence on public and private investment
14	Socioeconomic	Land use conflicts	Mining expansion generates tensions with agricultural and environmental activities	Lake Tota, Chicamocha basin and mining municipalities	POMCA identify territorial conflicts over water use and land occupation	Pressure on ecosystems and disputes between territorial actors
15	Socioeconomic	Mining informality	Farms persist without sufficient technical or environmental control	Municipalities with dispersed mining and regional small-scale mining	The studies reviewed show limitations in institutional formalization and follow-up	Difficulties in traceability, environmental control and economic collection
16	Socioeconomic	Deterioration of road infrastructure	The continuous traffic of heavy vehicles accelerates the deterioration of the roads	Tunja–Paipa–Duitama–Sogamoso Corridor and rural secondary roads	High circulation of dump trucks associated with the transport of aggregates is reported	Increased road maintenance costs and regional congestion
17	Socioeconomic	Impacts on quality of life	Communities report nuisance associated with dust, noise and heavy traffic	Nobsa, Corrales, Duitama, Tibasosa and Sogamoso	Inhabitants and regional reports show perception of environmental deterioration and social inconvenience	Community conflicts and negative perception of extractive activities
18	Socioeconomic	Pressure on water resources	The intensive use of water and the alteration of channels generate pressure on water availability	Chicamocha Basin, Jordan River and sectors of Tunja and Sogamoso	Environmental diagnoses report increasing pressure on regional water resources.	Risks to water supply and environmental sustainability
19	Socioeconomic	Expansion of industrial and mining corridors	Extractive activity drives industrial and urban growth in certain areas	Nobsa, Duitama, Sogamoso, Corrales and Paz de Río	The Alto Chicamocha corridor concentrates industrial, mining and logistics activities	Territorial transformation and consolidation of productive corridors
20	Socioeconomic	Increased institutional and	Extractive growth increases the need	Municipalities with the	Corpoboyacá and environmental entities	Need to strengthen environmental

	environmental pressure	for state control and monitoring	presence of mining titles and active exploitation	face challenges of monitoring and territorial control	governance and institutional control

Note. The table integrates the main socioeconomic and environmental impacts associated with the exploitation of dragging materials in the department of Boyacá, identified through documentary review of environmental diagnoses, POMCA, environmental impact studies, academic research and institutional reports related to the extractive dynamics present in the Chicamocha river basin and mining-industrial corridors of the department. Own elaboration based on (Bonilla-Benítez et al., 2017; CAS, 2015; Office of the Comptroller General of Boyacá, 2008; Corpoboyacá, 2006, 2014, 2015b, 2015a, 2021, 2026b; Corpoboyacá, 2026a; Fajardo et al., 2024; Government of Boyacá, 2012; IGAC, 2021; Marschke & Rousseau, 2022; MinAmbiente , 2026; MinVivienda , 2025; Pérez-Herrera, 2021; Rentier & Cammeraat , 2022; Rojas, 2018; All of Colombia , 2019)

4. Discussion

The results obtained show that the exploitation of hauling materials in the department of Boyacá represents a strategic activity for the supply of aggregates for road infrastructure, urban expansion and industrial development. This dynamic coincides with what has been stated by , who point out that construction materials continue to play an essential role within regional economies due to their direct relationship with urban growth and the consolidation of civil works. In the Colombian context, the National Mining Agency also recognizes that hauling materials constitute one of the most representative segments of non-metallic mining, especially due to their impact on regional production chains and public infrastructure processes. (Lara Brochado et al., 2025; Pérez-Herrera, 2021) (ANM, 2021)

However, the strengthening of this extractive activity has also increased the pressure on strategic ecosystems associated with the upper basin of the Chicamocha River and other water sources in the department. The findings obtained show effects related to riverbank erosion, sedimentation, geomorphological alteration and deterioration of water quality, particularly in municipalities such as Nobsa, Tibasosa, Sogamoso and Paz de Río. These conditions are related to what has been proposed by , who argue that the intensive extraction of sediments in river channels modifies the natural dynamics of rivers and can generate cumulative impacts on riparian ecosystems and nearby communities. (CAS, 2015) (Dan Gavriletea, 2017; Kondolf et al., 2018; Padmalal , 2014)

From the territorial perspective, the results show that a large part of the extractive activity is concentrated in industrial and urban corridors linked to the Alto Chicamocha, especially in municipalities such as Tunja, Duitama, Paipa, Nobsa and Sogamoso. This trend coincides with what has been reported by the , entities that identify a growing relationship between urban expansion, regional infrastructure and increased demand for stone aggregates in Boyacá. Likewise, the proximity of these exploitations to road corridors and urban centers favors the consolidation of logistics and commercial networks, although it simultaneously increases conflicts associated with land use, landscape deterioration and pressure on strategic natural

resources. (Corpoboyacá, 2006, 2015b) (Corpoboyacá, 2014; IGAC, 2021)

In relation to the value chain identified in the research, the participation of multiple institutional, business and territorial actors was observed, including mining operators, transporters, marketers, environmental authorities and municipal administrations. This structure coincides with what was pointed out by , who states that the competitiveness of the aggregates sector depends to a large extent on the articulation between extraction, logistics, transformation and marketing. However, the results also show that an important part of the productive units present in Boyacá continue to operate under small-scale schemes and limited technification, a situation that hinders the adoption of good environmental practices and reduces the capacity to comply with regulatory and administrative requirements. (Fajardo et al., 2024; Government of Boyacá, 2026; All of Colombia , 2019) (Garza-Esquivel, 2020)

Similarly, the documentary review identified the persistence of mining informality scenarios and weaknesses in institutional monitoring processes. These findings coincide with the approaches of , who maintain that small-scale mining faces significant financial, technical, and administrative limitations to move towards effective formalization processes. In Boyacá, this situation is reinforced by the geographical dispersion of exploitations, the coexistence between legal and informal activities, and the difficulties associated with permanent territorial control by the competent authorities. (Hilson, 2002; Hilson & McQuilken, 2014) (Oliveira et al., 2024; Resolution 100 of March 17, 2020)

Regarding the regulatory component, the research showed that Colombia currently has a relatively broad legal framework to regulate the exploitation of dragging materials, integrating constitutional, mining, environmental, water and territorial provisions. Instruments such as the establish guidelines related to environmental licensing, mining formalization, occupation of riverbeds and environmental monitoring. At the regional level, tools such as the POMCA, the POTs and the Regional Environmental Management Plan (PGAR) strengthen the processes of territorial planning and water protection in Boyacá. In this sense, it recognizes the need to consolidate environmental management mechanisms aimed at reducing the impacts associated with extractive activities developed on strategic ecosystems and watersheds in the department. (Decree 1076 of May 26, 2015; Law December 99, December 22, 1993; Law 685 of August 5, 2001) (Corpoboyacá, 2025; Corpoboyacá, 2026a; Government of Boyacá, 2026; MinAmbiente , 2026) (Corpoboyacá, 2026a)

Despite the existence of this regulatory framework, the findings show that the multiplicity of procedures, competent entities and technical requirements continues to represent a major difficulty for small extractive units. This situation coincides with what is stated by , who points out that a large part of small-scale mining in Colombia faces administrative and economic barriers that limit full compliance with legal and environmental requirements. Consequently, regulatory complexity can become a factor that favors scenarios of informality and weakens the institutional capacity for territorial control. (Oliveira et al., 2024) (Murillo- Baltan , 2017) (Oliveira et al., 2024)

From the environmental component, the impacts identified in the research show that the effects derived from the exploitation of dragging materials transcend the physical modification of river channels and involve broader ecological, social and economic dimensions. Aspects related to loss of vegetation cover, atmospheric

emissions, water pollution and landscape deterioration reflect processes of cumulative pressure on strategic ecosystems and territories with increasing anthropic intervention. These results coincide with , who argue that sand and gravel mining requires comprehensive approaches capable of articulating environmental sustainability, territorial governance and social well-being. (Marschke & Rousseau, 2022; Rentier & Cammeraat , 2022)

In the socioeconomic field, the research established that the exploitation of dragging materials continues to be an important source of employment and regional economic dynamization, especially in municipalities associated with industrial corridors and infrastructure projects. However, this economic dependence also increases the vulnerability of communities to fluctuations in the construction sector and changes in regional public investment. These dynamics reflect the close relationship between economic growth, territorial expansion and environmental pressure, widely documented in recent studies on non-metallic mining and territorial sustainability. (ANM, 2021; Murillo- Baltan , 2017) (Nat. Geosci, 2024; Niyonyungu et al., 2025)

On the other hand, the conflicts identified around land use and the use of water resources show the need to strengthen mechanisms of articulation between territorial planning, environmental management and mining regulation. The results show that instruments such as the POTs and the POMCA play a decisive role in the delimitation of extractive areas, environmental restrictions and territorial planning processes, particularly in municipalities where industrial activities, urban expansion and strategic ecosystems converge. (Corpoboyacá, 2006, 2014, 2015b, 2021, 2025, 2026b; MinAmbiente , 2026; MinVivienda , 2025; Rojas, 2018)

In correspondence with the above, the findings obtained allow us to broaden the understanding of the extractive dynamics associated with dragging materials in regional contexts where economic interests, environmental problems and territorial governance processes converge. In this sense, the research provides an interdisciplinary perspective that integrates regulatory, environmental, business and territorial components, contributing to the analysis of mining sustainability and the integrated management of water resources in regions with high extractive pressure such as the department of Boyacá.

5. Conclusions

Conclusion 1. The exploitation of dragging materials in the department of Boyacá has been consolidated as an activity closely linked to urban growth, infrastructure development and the regional supply of stone aggregates. The research showed that municipalities located on the industrial corridor of Alto Chicamocha concentrate a large part of these extractive dynamics, configuring scenarios where economic interests, territorial expansion and intensive use of natural resources converge. However, it was also identified that the permanence of informal practices, the low technification of some productive units and the limitations of institutional control continue to generate significant pressures on strategic ecosystems and water systems in the department.

Conclusion 2. The documentary analysis made it possible to establish that Colombia has a broad set of legal and environmental instruments aimed at regulating the

exploitation of dragging materials from mining, territorial and water approaches. Regulations such as Law 99 of 1993, Law 685 of 2001 and Decree 1076 of 2015, together with regional tools such as the POMCA, the POT and the PGAR of Corpoboyacá, constitute fundamental elements to guide environmental sustainability and territorial planning of extractive activity. However, the results show that the existence of regulation does not guarantee efficient management of the territory by itself, especially in contexts where monitoring difficulties, institutional fragmentation and operational limitations for mining formalization persist.

Conclusion 3. The findings show that the impacts associated with the exploitation of dragging materials are not limited only to the physical modification of river channels, but also involve environmental, social and economic transformations of a cumulative nature. Problems related to riverbank erosion, sedimentation, water deterioration, loss of vegetation cover and conflicts over land use reflect the growing pressure exerted on territories with high extractive intervention. Even so, this activity continues to be an important source of employment and economic revitalization for various municipalities in Boyacá, a situation that highlights the need to strengthen management models capable of balancing environmental sustainability, economic development and territorial governance.

Conclusion 4, Practical implications. The results of this research provide useful elements for environmental entities, mining authorities, municipal administrations and business actors involved in the exploitation of dragging materials in Boyacá. The normative, territorial and socio-environmental characterization developed in the study can contribute to the strengthening of planning processes, environmental monitoring, mining formalization and integrated management of water resources. Similarly, the findings allow the identification of priority territories where it is necessary to consolidate strategies aimed at the prevention of environmental deterioration, the reduction of territorial conflicts and the implementation of extractive practices with higher levels of sustainability.

Conclusion 5, Future implications. The research shows the need to continue developing interdisciplinary studies related to non-metallic mining, environmental sustainability, and territorial planning in regional contexts with high extractive pressure. Future research could delve into geospatial analysis, water quality monitoring, cumulative impact assessment, and community perception studies of extractive activities. It is also pertinent to move towards research focused on ecological restoration, circular economy, mining traceability, and technological modernization, with the purpose of strengthening more sustainable use models compatible with the conservation of Boyacá's strategic ecosystems.

6. Bibliographic References

1. Aguilar, C., León, N., & Meléndez, M. (2006). Cuadernos de Fedesarrollo, Number Twenty. https://repository.fedesarrollo.org.co/handle/11445/1916
2. ANM. (2021). Guide to good practices for the exploitation and estimation of resources and reserves of dragging materials.
3. Bernal Torres, C. Augusto. (2016). Research Methodology: Administration, Economics, Humanities, and Social Sciences. (Pearson, Ed.). Pearson Educación de

Colombia S.A.S. https://www.academia.edu/53015080/LIBRO_BASE_Metodologia_de_la_investigacion_4ta_Edicion_Cesar_A_Bernal

4. Bonilla-Benítez, M. L., Lizarazo-Goyeneche, O., & Chacón-Rodríguez, M. (2017). Analysis of the management in the decontamination of the Upper Basin of the Chicamicha River in the Department of Boyacá during the Period 2010 – 2016. https://repository.udistrital.edu.co/server/api/core/bitstreams/b0beba32-9d0f-450a-a1b0-1925a7866896/content
5. CAS. (2015). Chicamocha River Technical Report. https://www.bing.com/search?q=INFORME+TECNICO+RIO+CHIMOVHA&src=
6. Office of the Comptroller General of Boyacá. (2008). Environmental Report of Boyacá. https://cgb.gov.co/ARCHIVOS-2025/Direccion%20de%20Obras%20y%20ambiente/informes%20ambientales/INFORME%20SOBRE%20EL%20ESTADO%20DE%20LOS%20RECURSOS%20NATURALES%20Y%20DEL%20AMBIENTE%20BOYACA%202007-2008.pdf?utm_source=chatgpt.com
7. Corpoboyacá. (2006). Environmental Management Plan for the Upper Chicamocha River Basin. https://www.corpoboyaca.gov.co/cms/wp-content/uploads/2015/11/diagnostico-capitulo-3-pomca-chicamocha.pdf?utm_source
8. Corpoboyacá. (2014). Environmental Management Plan of the Tunja Aquifer System (in 14 municipalities of the Upper Chicamocha River Basin).
9. Corpoboyacá. (2015a). Socio-Economic Aspects. https://www.corpoboyaca.gov.co/cms/wp-content/uploads/2016/03/Aspectos-Socio-Economicos.pdf?utm_source
10. Corpoboyacá. (2015b). Water Resources Management Plan for the Upper and Middle Basin of the Chicamocha River. https://www.corpoboyaca.gov.co/cms/wp-content/uploads/2019/09/informe-porh-chicamocha.pdf?utm_source=chatgpt.com
11. Corpoboyacá. (2021). Regional Environmental Management Plan. https://www.corpoboyaca.gov.co/cms/wp-content/uploads/2025/02/Plan-de-Gestion-Ambiental-Regional-PGAR-2021.pdf
12. Corpoboyacá. (2025, February 7). Regional Environmental Management Plan PGAR 2021-2031. https://www.corpoboyaca.gov.co/nuestra-gestion/planes/plan-de-gestion-ambiental-regional-pgar-2021-2031/
13. Corpoboyacá. (2026a). https://www.corpoboyaca.gov.co/
14. Corpoboyacá. (2026b, May 5). Water Resources Management Plan – PORH. https://www.corpoboyaca.gov.co/plan-de-ordenamiento-del-recurso-hidrico-porh/?utm_source=chatgpt.com
15. Dan Gavriletea, M. (2017). Environmental impacts of sand exploitation. Analysis of sand market. In Sustainability (Switzerland) (Vol. 9, Number 7). MDPI. https://doi.org/10.3390/su9071118
16. Decree 276 of February 17, "By which measures related to the Single Registry of Marketers - RUCOM are adopted" (2015). https://www.funcionpublica.gov.co/eva/gestornormativo/norma.php?i=61176

17. Decree 291 of August 4, "By which the Technical Mining Glossary is adopted". (2003). https://www.funcionpublica.gov.co/eva/gestornormativo/norma.php?i=64907
18. Decree 1066 of May 26 of , "By means of which the Single Regulatory Decree of the Administrative Sector of the Interior is issued" (2015). https://www.funcionpublica.gov.co/eva/gestornormativo/norma.php?i=76835
19. Decree 1076 of May 26, "By means of which the Single Regulatory Decree of the Environment and Sustainable Development Sector is issued". (2015). https://www.minambiente.gov.co/documento-normativa/decreto-1076-de-2015/
20. Decree 1541 of July 28, which regulates Part III of Book II of Decree-Law 2811 of 1974: "On non-maritime waters" and partially Law 23 of 1973." (1978). https://www.funcionpublica.gov.co/eva/gestornormativo/norma.php?i=1250
21. Decree 2222 of November 5, By which the Regulation of Hygiene and Safety in Open Pit Mining Work is issued. (1993). https://www.anm.gov.co/sites/default/files/decreto_2222_de_1993.pdf
22. Decree 2390 of October 24, "By which article 165 of the Mining Code is regulated". (2002). https://www.funcionpublica.gov.co/eva/gestornormativo/norma.php?i=7166
23. Decree 2811 of December 18, "By which the National Code of Renewable Natural Resources and Environmental Protection is dictated." (1974). https://www.funcionpublica.gov.co/eva/gestornormativo/norma.php?i=1551
24. Decree 4134 of November 3, which creates the National Mining Agency, ANM, determines its objective and organizational structure. (2011). https://www.suin-juriscol.gov.co/viewDocument.asp?id=1542244
25. Desarrollo ambiental. (2014). Sand, rarer than one thinks. Environmental Development, 11, 208–218. https://doi.org/10.1016/J.ENVDEV.2014.04.001
26. Presidential Directive November 10 7 De, Guide for the Realization of Prior Consultation. (2013). https://www.suin-juriscol.gov.co/viewDocument.asp?id=30021326
27. Fajardo, C., In Figures -2024, B., Researchers, /, Hermes, C., Fajardo, Y., & Pérez, G. (2024). Boyacá in Figures. https://cctunja.org.co/wp-content/uploads/2025/09/Boyaca-en-Cifras-2024.pdf?utm_source
28. Garza-Esquivel, Y. (2020). The five forces in strategy. https://www.academia.edu/48952246/Ensayo_Las_cinco_fuerzas_en_la_estrategia_2020_Yolanda_Garza_Esquivel
29. Government of Boyacá. (2012, June 21). Boyacense Hydrography. https://www.boyaca.gov.co/hidrografia-boyacense/
30. Government of Boyacá. (2026). https://www.boyaca.gov.co/
31. Hernández-Sampieri, R., Fernández-Collado, C., & Baptista-Lucio, M. del P. (2014). Research Methodology (Mc Graw Hill, Ed.; Sixth). https://www.academia.edu/31726822/Sampieri_6ta_pdf_Libro_metodologia_6ta_edicion
32. Hilson, G. (2002). Small-scale mining and its socio-economic impact in developing countries. Natural Resources Forum, 26(1), 3–13. https://doi.org/10.1111/1477-8947.00002
33. Hilson, G., & McQuilken, J. (2014). Four decades of support for artisanal and small-scale mining in sub-Saharan Africa: A critical review. The Extractive Industries and

Society, 1(1), 104–118. https://doi.org/10.1016/j.exis.2014.01.002
34. IGAC. (2021). Geographical Dictionary of Colombia Department of Boyacá. https://diccionario.igac.gov.co/?Boyac%C3%A1
35. Kondolf, G. M., Schmitt, R. J. P., Carling, P., Darby, S., Arias, M., Bizzi, S., Castelletti, A., Cochrane, T. A., Gibson, S., Kummu, M., Oeurng, C., Rubin, Z., & Wild, T. (2018). Changing sediment budget of the Mekong: Cumulative threats and management strategies for a large river basin. Science of the Total Environment, 625, 114–134. https://doi.org/10.1016/j.scitotenv.2017.11.361
36. Lara Brochado, J. V., Choles Polo, L. E., & López Juvinao, D. D. (2025). Logistics Optimization Techniques in a Drag Materials Mine in Riohacha, Colombia. https://doi.org/https://doi.org/10.24050/reia.v22i43.1807
37. Law 99 of December 2, which creates the Ministry of the Environment, reorganizes the Public Sector in charge of the management and conservation of the environment and renewable natural resources, organizes the National Environmental System and other provisions (1993). https://www.funcionpublica.gov.co/eva/gestornormativo/norma.php?i=297
38. Law 99 of December 22 of the Ministry of the Environment (1993). https://www.funcionpublica.gov.co/eva/gestornormativo/norma.php?i=297
39. Law 141 of June 28 of , partially regulated by National Decrees 145, 620 and 1747 of 1995; 416 and 4192 of 2007; 851 of 2009 By which the National Royalties Fund, the National Royalties Commission (1994) are created. https://www.funcionpublica.gov.co/eva/gestornormativo/norma.php?i=9153
40. Law 685 of August 5, By which the Mining Code is issued and other provisions are issued". (2001). https://www.funcionpublica.gov.co/eva/gestornormativo/norma.php?i=9202
41. Law 756 of July 23, which modifies Law 141 of 1994, establishes distribution criteria and dictates other provisions. (2002). https://www.funcionpublica.gov.co/eva/gestornormativo/norma.php?i=9154
42. Law 1333 of July 21, which establishes the environmental sanctioning procedure and dictates other provisions. (2009). https://www.funcionpublica.gov.co/eva/gestornormativo/norma.php?i=36879
43. Law 1450 of June 16, "By which the National Development Plan, 2010-2014 is issued." (2011). https://www.funcionpublica.gov.co/eva/gestornormativo/norma.php?i=43101
44. Law 1682 of November 22, which adopts measures and provisions for transportation infrastructure projects and grants extraordinary powers. (2013). https://www.funcionpublica.gov.co/eva/gestornormativo/norma.php?i=55612
45. Law 1955 of May 25, by which the National Development Plan 2018-2022 "Pact for Colombia, Pact for Equity" (2019) is issued. https://www.funcionpublica.gov.co/eva/gestornormativo/norma.php?i=93970
46. Marschke, M., & Rousseau, J.-F. (2022). Sand ecologies, livelihoods and governance in Asia: A systematic scoping review. Resources Policy, 77, 102671. https://doi.org/10.1016/j.resourpol.2022.102671
47. Mathias Kondolf, G. (1994). Geomorphic and environmental effects of instream gravel mining. Landscape and Urban Planning, 28(2–3), 225–243. https://doi.org/10.1016/0169-2046(94)90010-8

48. Medina, M., Rojas, R., Bustamante, W., Loaiza, R., Martel, C., & Castillo, R. (2023). Research Methodology: Research Techniques and Instruments. In Research Methodology: Research Techniques and Instruments. University Institute of Innovation, Science and Technology Inudi Peru. https://doi.org/10.35622/inudi.b.080
49. MinAmbiente. (2026, May 8). Watershed Planning and Management Plans – POMCA. https://archivo.minambiente.gov.co/index.php/gestion-integral-del-recurso-hidrico/planificacion-de-cuencas-hidrograficas/cuenca-hidrografica/planes-de-ordenacion
50. Ministry of Mines and Energy. (2016). Mining Policy in Colombia. Bases for the Mining of the Future. https://www.minenergia.gov.co/documents/2423/Pol%C3%ADtica_Minera_de_Colombia_final.pdf
51. MinVivienda. (2025, December 2). Territorial Planning Plan. https://minvivienda.gov.co/viceministerio-de-vivienda/espacio-urbano-y-territorial/plan-ordenamiento-territorial/pot?utm_source=chatgpt.com
52. MMADS. (2026). https://www.minambiente.gov.co/
53. Murillo-Baltan, S. (2017). Dragging material extraction mining in the framework of sustainable development. https://ridum.umanizales.edu.co/items/6386a4ac-04ac-4e1b-9554-7b3738f811dd
54. Nat. Geosci. (2024). Finite sand resources need better governance. 17 (817). https://doi.org/https://doi.org/10.1038/s41561-024-01544-9
55. Niyonyungu, F., Ogra, A., & Ngcobo, N. (2025). Foundry Sand in Sustainable Construction: A Systematic Review of Environmental Performance, Contamination Risks, and Regulatory Frameworks. Construction Materials, 5(3), 57. https://doi.org/10.3390/constrmater5030057
56. Oliveira, L. S., Angulo, S. C., & John, V. M. (2024). Quantifying the informal sand market and its consequences: The case of Brazil. Environmental Development, 51, 101032. https://doi.org/10.1016/j.envdev.2024.101032
57. Padmalal, D. M. K. (2014). Sand Mining: Environmental Impacts and Selected Case Studies. Springer Nature. https://link.springer.com/book/10.1007/978-94-017-9144-1#accessibility-information
58. Pérez-Herrera, I. P. (2021). Evaluation of Environmental Liabilities generated by the exploitation of dragging material in the municipality of Morroa, Department of Sucre. https://ridum.umanizales.edu.co/items/ccc2f22a-93b6-4de9-a222-8d87c57e6d54
59. Rentier, E. S., & Cammeraat, L. H. (2022). The environmental impacts of river sand mining. Science of The Total Environment, 838, 155877. https://doi.org/10.1016/j.scitotenv.2022.155877
60. Resolution 100 of March 17, establish the conditions and periodicity for the presentation of information on the existing mineral resources and reserves in the concessioned area (2020). https://compilacionjuridica.antioquia.gov.co/compilacion/compilacion/docs/resolucion_anm_0100_2020.htm
61. Resolution 143 of April 3, by means of which Resolution number 428 of 2013 and other terms of the Mining Code (2017) are repealed. https://vlex.com.co/vid/resolucion-numero-143-2017-676164965

62. Resolution 299 of June 13, 2017 (2018). https://www.anm.gov.co/index.php/resolucion-no-299-de-junio-13-de-2018
63. Resolution 883 of May 18 of , "By which the parameters and maximum permissible limit values are established in punctual discharges to bodies of marine waters, and other provisions are dictated (2018).
64. Resolution 1170 of June 8, By which the expiration of the sanctioning power is declared and other determinations are adopted. (2023). https://vlex.com.co/vid/resolucion-n-1170-autoridad-936844504
65. Resolution 40103 of February 9, which establishes the maximum production volumes in subsistence mining. (2017).
66. Resolution 181847 of December 28, Ministry of Mines and Energy (2001). https://normativame.minenergia.gov.co/normatividad/5720/norma/
67. Rojas, A. M. (2018). Regional Urban Agglomeration Tunja - Duitama - Sogamoso. https://revistas.santototunja.edu.co/index.php/tarquitectura/article/view/1436
68. Sentence 243 of May 20, Right to a Healthy Environment/Right to Life- Threat due to overflow of river. (1994). https://vlex.com.co/vid/43558173
69. All of Colombia. (2019, February 21). Municipalities of Boyacá Political Division.
70. Zhong, X., Deetman, S., Tukker, A., & Behrens, P. (2022). Increasing material efficiencies of buildings to address the global sand crisis. Nature Sustainability, 5(5), 389–392. https://doi.org/10.1038/s41893-022-00857-0