Alluvial gold exploitation
Evidences from remote sensing 2016
May 2018
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Colombian Geological Survey
National Mining Agency
Ministry of Interior
National Army, Brigade against Illegal Mining
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National Department of Planning - DNP

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Mining community of the Municipality of San José del Fragua (Caquetá)
Mining community, civil and military authorities of the municipalities of: Guapi (Cauca), Barbosa and Santa Rosa de Osos (Antioquia)

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Unless another is specified, all the graphs, tables, illustrations, and figures in this report are sourced from the Government of Colombia within the context of the Monitoring System supported by UNODC.

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Cover image: Alluvial gold exploitation in Municipality Nóvita (Chocó)
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EXECUTIVE SUMMARY

With this report, UNODC and the Colombian Government, represented by the Ministry of Mines and Energy, provides an update of the status of alluvial gold exploitation that can be observed with remote sensing (EVOA, by its Spanish acronym) in the Colombian territory in 2016. The focus of this study is on those EVOA that use machinery on land. A similar study with the same methodology was conducted in 2014 with the support from the Ministry of Justice and Law and serves as a baseline.

Colombia is one of the main gold producers in Latin America. In 2016, the National Mining Agency, which administers the permits for gold mining, reported a national production of 61,805 kg. Nevertheless, given the informal and illegal nature of a significant proportion of gold exploitation in Colombia, these figures are most probably an underestimate.

The objective of this study is to provide national entities with an objective measurement of the areas affected by EVOA in Colombia, and an analysis of the geographic characteristics, the permits and authorizations required for gold mining, and linkages with other activities in these territories.

The results of the detection of EVOA that use machinery on land in 2016 show that 14 of the 32 departments in Colombia, were affected by this type of exploitation. In total, 83,620 hectares were affected by EVOA, of which 76% was concentrated in two departments, Chocó (39%) and Antioquia (37%). A comparison of the results of 2014 and 2016, reveals an increase of 6% (4,681 ha).

Although Chocó remains the department with the largest detected area of EVOA, according to the National Mining Agency, the highest gold production is recorded in Antioquia: the latter contributes 41% of the total national production while Chocó contributes 23.5%. These differences in relative importance may have been caused by: i) additional extraction and production of alluvial gold using machinery in water ii) regional differences in productivity due to different levels of gold content of the minerals, iii) some gold production is not recorded officially in the same regions; iv) or gold is not registered at all. For example, miners interviewed by UNODC in Cauca, Chocó, and Guainia, reported that the gold they extracted was registered in the city of Medellin in the department of Antioquia.

47% of the EVOA was observed by the study in so-called special zones (National Parks, Indigenous Reserves, Afro-Colombian Community Councils). Particularly, the Afro-Colombian Community Councils were affected: 67 of 158 of these showed EVOA in 2016, representing about 42% of the total area with EVOA. Less than 1% of the detected area in 2016 was in Indigenous Reserved Areas, affecting mainly the Emberá Katio group, which is one of the 84 indigenous groups registered on Colombian territory.

Concerning EVOA in National Natural Parks, four out of 52 parks in Colombia were affected. More importantly, the area with EVOA in National Natural Parks doubled in 2016, from 47 ha in 2014 to 111 ha in 2016. The Puinawai National Nature Reserve continued to be the most affected with 57 hectares, located mainly in the Serranía de Naquén.

In total, out of the 131 municipalities affected by EVOA in 2016, 74 also had coca crops. In Nariño, Putumayo and Caquetá, coca was grown in more than 80% of the territories detected with EVOA.

When overlaying the EVOA findings in 2014 with 2016, the total affected territory in these years sums up to 107,649 ha. 54,910 ha (66%) of EVOA territory in 2016 already existed in 2014; 24,029 ha (29%) of
EVOA in 2016 showed signs of abandonment; and 28,710 ha (34%) were new EVOA sites that were not observed in 2014.

Gold mines in Colombia require, firstly, a mining title and, secondly, an environmental authorization to obtain a full exploitation permit. In this study, a geographical analysis was made on the legal status of each EVOA, indicating the fulfilment of requirements to obtain a full exploitation permit. The analysis revealed that only 7% of the detected EVOAs had obtained an environmental license and therefore had all necessary authorizations for legal exploitation; these areas were concentrated in their entirety in the department of Antioquia. 20% of the EVOAs detected in 2016 had “Amparo de Título” only, lacking the environmental license. Another 7% of the detected evidences fall in the category “request for legalization”, which means they are in the process of getting permits and licenses. Also, it is worth mentioning that observed EVOA owning a mining title are not always exploited by the same owners of the title. The remaining 66% of the EVOAs, does not fall under any of the former legal statuses. In addition, the study shows that the magnitude and nature of the detected EVOA areas, independent of whether they have a legal status or not, have a strong impact on the landscape which suggests a lack of compliance with the environmental obligations.

In 2016, the Colombian Government conducted 1,708 control operations against gold exploitation without any legal status, which included confiscation of machinery and equipment (hoses, boats, vehicles, shovels). The control operations were mostly carried out by operational teams of the Military and Police. In some cases, depending on the nature of the crime, other institutions were part of these operations, like the Office of the Attorney General of the Nation, the Technical Investigation Team (CTI), Regional Autonomous Corporations, among others. Of the total number of operations, 355 were carried out by the National Army, 285 by joined operations between National Army and Police and two in coordination with the National Army of Perú.

Most of the control operations (45%) concentrated on machinery and equipment, which included seizures of engines, motor pumps, dredgers, excavators, crushers, among others. 15% of the control operations focused on illegal exploitation and exploration and involved arrests (870 for the year 2016). Finally, less than 7% of these operations were related to seizure of explosives.

Finally, a case study was conducted for the detection of EVOA which use machinery in water, using spectral indexes from satellite images. The methodology showed promising results for the detection of mines using the reflectance of water caused by pollution. This could be used as an additional tool for the Government to collect evidence of illegal mining.

With this second report, the Ministry of Mines and Energy and UNODC hope to contribute to a better understanding of the alluvial gold exploitation activities in the country, offering objective information that can be used in the formulation of more specialized public policies on this phenomenon.

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1 Corresponds to other associated uses in the area, holding a mining title that has administrative protection as by Colombian law. This is a literal concept from Spanish and it is used throughout the document.
### SUMMARY RESULTS

Evidences of alluvial gold exploitation with use of machinery on land

#### Departments affected by EVOA

<table>
<thead>
<tr>
<th>Department</th>
<th>EVOA 2014 (ha)</th>
<th>Total national percentage 2014 (EVOA)</th>
<th>EVOA 2016 (ha)</th>
<th>Total national percentage 2016 (EVOA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chocó</td>
<td>36,185</td>
<td>46%</td>
<td>33,024</td>
<td>39%</td>
</tr>
<tr>
<td>Antioquia</td>
<td>26,323</td>
<td>33%</td>
<td>30,897</td>
<td>37%</td>
</tr>
<tr>
<td>Bolívar</td>
<td>7,361</td>
<td>9%</td>
<td>7,820</td>
<td>9%</td>
</tr>
<tr>
<td>Cauca</td>
<td>1,408</td>
<td>2%</td>
<td>3,702</td>
<td>4%</td>
</tr>
<tr>
<td>Córdoba</td>
<td>3,544</td>
<td>4%</td>
<td>3,592</td>
<td>4%</td>
</tr>
<tr>
<td>Nariño</td>
<td>1,676</td>
<td>2%</td>
<td>2,677</td>
<td>3%</td>
</tr>
<tr>
<td>Valle del Cauca</td>
<td>1,570</td>
<td>2%</td>
<td>1,023</td>
<td>1%</td>
</tr>
<tr>
<td>Others</td>
<td>872</td>
<td>1%</td>
<td>885</td>
<td>1%</td>
</tr>
</tbody>
</table>

#### Municipalities with greater impact by EVOA 2016

<table>
<thead>
<tr>
<th>Municipality</th>
<th>Department</th>
<th>EVOA (ha)</th>
<th>Percentage of national participation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zaragoza</td>
<td>Antioquia</td>
<td>6,186</td>
<td>7%</td>
</tr>
<tr>
<td>Nechí</td>
<td>Antioquia</td>
<td>5,916</td>
<td>7%</td>
</tr>
<tr>
<td>Nóvita</td>
<td>Chocó</td>
<td>4,797</td>
<td>6%</td>
</tr>
<tr>
<td>El Cantón de San Pablo</td>
<td>Chocó</td>
<td>4,385</td>
<td>5%</td>
</tr>
<tr>
<td>El Bagre</td>
<td>Antioquia</td>
<td>4,377</td>
<td>5%</td>
</tr>
</tbody>
</table>

#### Special Management Areas

- **Afro -Colombian Community Territories**: 34,858 (42%)
- **National Natural Parks**: 111 (Less than 1%)
- **Other Areas of the National System of Protected Areas - SINAP**: 3,776 (4.5%)
- **Indigenous Reserves**: 780 (1%)

#### National Natural Parks con EVOA

<table>
<thead>
<tr>
<th>Park</th>
<th>Department(s)</th>
<th>EVOA inside PNN (ha) 2014</th>
<th>EVOA inside PNN (ha) 2016</th>
</tr>
</thead>
<tbody>
<tr>
<td>Puinawai Guainía</td>
<td></td>
<td>25</td>
<td>57</td>
</tr>
<tr>
<td>Paramillo</td>
<td>Antioquia, Córdoba</td>
<td>14</td>
<td>31</td>
</tr>
<tr>
<td>Los Katios</td>
<td>Antioquia, Chocó</td>
<td>5</td>
<td>19</td>
</tr>
<tr>
<td>Selva de Florencia</td>
<td>Caldas</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>45</strong></td>
<td><strong>111</strong></td>
</tr>
</tbody>
</table>

#### EVOA under legal figures

- **Without figures of law**: 66%
- **Environmental licenses**: 7%
- **Amparo de títulos**: 20%
- **Requests for legalization**: 7%

#### Dynamics of EVOA 2014 - 2016

- **Stable**: 54,910
- **Abandoned**: 24,029
- **New**: 28,710
- **Affected territory**: 107,649
INTRODUCTION

One of the great challenges for the Government and Colombian society is transforming the rural territories that historically have been excluded from the development that the country has achieved. To transform them, it is necessary to comprehensively understand the situation in the midst of which, communities have developed strategies for their own survival in territories where various traits converge, both state deficiencies that have exacerbated vulnerabilities, and illegality strategies that take advantage of these vulnerabilities to support highly lucrative illicit business.

The United Nations Office on Drugs and Crime - UNODC field office in Colombia, and the Ministry of Mines and Energy; with the support of the Embassy of the United States in Colombia; present the document “Alluvial gold exploitation. Evidences from remote sensing 2016”, as a contribution to improve knowledge on those territories.

The report constitutes an update of the baseline 2014, for the year 2016. The methodology is based on the use of satellite images in detecting evidences of alluvial gold exploitation - EVOA. From the EVOA, the geographic dimension is incorporated into the phenomenon of illegal exploitation of minerals (gold), and the integration of this phenomenon into a spatial database is made possible, which also includes secondary information on the affected territories, and on the mining activity itself.

While the document focuses on alluvial gold mining exploitation with the use of machinery on land; it also includes an evaluation of the evidences of alluvial gold exploitation with use of machinery in water in the Apaporis River, specifically in the sector of the Serranía del Chiribiquete National Natural Park. It is important to mention that detecting evidence of gold exploitation of reef is still under investigation.

The document is made up of 4 sections:

The first one is dedicated to the reference framework, where the main background of the research is collected, the Colombian mining sector is framed within a territorial approach, highlighting the legal figures as a geographic instrument to evaluate the formal activity against the EVOA as a geographic instrument to distinguish authorized from unauthorized activity.

The second section is devoted to the main findings, including the EVOA for machinery on land and for machinery in water (Apaporis case); this section emphasizes the relationship of the EVOA with the territories and offers data on the dynamics of the phenomenon when comparing the situation observed with that reported in 2014.

The third section is destined to studies that complement the baseline; it presents the information model for the integration of the mining dimension in land use planning (Guapi case), the research model to identify the most outstanding features related to the dynamics of alluvial gold exploitation (Antioquia case), the social and economic characterization of rural communities in the area of gold exploitation of the Colombian Pacific and the dynamics of chemical substances related to the gold exploitation (mercury and cyanide). This section presents the basis for implementing an integrated model to monitor the gold exploitation in Colombia.

Finally, the fourth section is dedicated to the methodological aspects with emphasis on detecting EVOA in both water and land, and in integrating that information into the framework of areas to monitor the phenomena of illegality in the territory.

The document is based on the experience of the SIMCI project, which has monitored the phenomenon of illicit crops for more than 15 years in Colombia and the experience of the Ministry of Mines and Energy (head of the mining sector and rector of the country’s mining policy), who studies mineral exploitation; a synergy that paves the way for the implementation of a monitoring system focused on illegal exploitation of minerals and that promotes a greater understanding of the complexities of the territories affected by illegal activities in Colombia.
The first section is dedicated to reference framework; it includes the main background of the research and presents the Colombian mining sector framed within a territorial approach. The section highlights the figures of law as a geographical instrument to evaluate formal activity; this information is contrasted with the EVOAs, which are used as geographical instruments to detect unauthorized activity.
The gold exploitation in Colombia contemplates two types of deposit in accordance with the geological conditions of formation: i) primarily, known as reef or vein2, characterized mostly by underground exploitation, and, ii) secondary or alluvial3, with strip mining type exploitation [1] [2] [3]. The Colombian Mining Information System - SIMCO4 [4] reports that during 2011 18% (10.06 tons) of gold5 production in Colombia came from vein exploitation and 82% (45.84 tons) of alluvium exploitation. Along the same line, in respect of the legality nature of exploitation in both types of deposits, from the data reported by the mining census, it can be deduced that 95% of the alluvial mines counted have no mining title6, while the percentage without qualification for reef mines is 77%.

The exploitation of the deposits, both vein and alluvial, has two basic modalities in terms of exploitation and benefits according to the level of technology employed: i) it is performed by manual means, without the use of machinery, and ii) rudimentary techniques and tools. Subsistence mining corresponds to the first modality, and is carried out by people, i.e. natural persons, who dedicate their work force to the exploitation of some mineral by manual methods to generate subsistence income; this type of mining is considered as subsistence mining [5]. This activity does not use specialized machinery (backhoes, dredges, etc.) but instead it is the hand of man that extracts the mineral in a very traditional way and in small quantities [6]; some modalities of this mining are the barequeo7 and the crushing7 [4]. For the case of barequeo8, it is stated that it is a subsistence exploitation under environmentally friendly conditions, since it should not use any chemicals for the recovery of the gold and the intervened area is imperceptible. Subsistence mining is a frequent phenomenon and it is not addressed in the present study [7]. Consequently, the type of exploitation, the tools and machinery used generate physical9 evidence in the territory: In the case of underground type exploitation, they are identified mainly as those derived from air, noise, water pollution and destabilization of the underground environment (Subsidies), while strip mining generates physical evidence on terrestrial cover, with strong visual impact due to changes in the surrounding landscape, related to alterations in water bodies, deforestation and to soil degradation, among others.

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2 Primary deposits refer to mineral deposits in situ.
3 Secondary deposits are those that after the weathering processes of a primary reservoir there is a natural mechanical disintegration and by the action of the water the gold particles are transported to certain distances they tend to concentrate in water channels, giving rise to the known “auriferous pleasures” [103].
4 Colombian Mining Information System, which contains the integrated, reliable and timely information of the Colombian mining sector and also provides the official statistics of the sector. The Administrator is the Ministry of Mines and Energy [6].
5 The reported productions do not discriminate the legal or illegal nature of the exploitation since informal or illegal miners may register fictitious production in a different municipality from which the exploitation took place in order to evade control by the authorities [104].
6 Reference is made to the mining title in the modalities of exploration and exploitation indistinctly for the use of mineral resources.
7 Barequeo" in rivers and streams, the “crushing” in sites of exploitation with residual deposits in situ or as surpluses of the batteries of sterile of mining of greater spread, the “monitoring” of terraces and alluviums [51].
8 (Article 155 of the Mining Code). Popular activity of the inhabitants of current alluvial lands”. According to the aforementioned legal precept, this activity is exclusively subject to the washing of sand by manual means, being prohibited the use of machinery or mechanical means for its exercise. Barequeo mining has the specific objective of separating and collecting precious metals contained in these sands [9].
9 Physical evidence is any significant sensitive material that is perceived with the senses and that is related to an event [105].
The physical evidence can be detected by “in situ” techniques and by remote sensing\(^\text{10}\) techniques according to the study’s objective. The techniques “in situ” focus on specific areas and studies of air and water pollution due to the high cost of implementation. On the other hand, remote sensing offers tools that allow, among others, greater coverage of territory at lower cost, with short visit times that enhance its usefulness in monitoring studies. The applicability of this technique in mining-related studies ranges from the detection of potential areas in minerals (with the use of hyper-spectral images), to the detection and monitoring of the dynamics of exploitation activities based on physical evidence on the landscape.

The report focuses on updating the EVOA detection baseline by using satellite images. The updated information is integrated into the SIMCI project area framework, which provides information on the territories affected by EVOA; additionally, the available information on the legal figures that regulate mining in Colombia is also integrated into the geographic database.

The study has defined scopes regarding the coverage of the phenomenon gold mining exploitation; in particular, it is important to highlight the following:

- Only alluvial gold mining is covered; the methodology to detect illegal exploitation of underground gold is still under investigation.
- The alluvial gold exploitation with machinery in water is covered only in the Apaporis River.
- The alluvial gold exploitation is identified with machinery on land that leaves evidence in the landscape; in this sense, small exploitations or those that are carried out under adequate management conditions, will not leave very detectable traces.
- The temporal analysis contemplates the years 2014 and 2016.
- The analysis of the legal figures is limited to those that have a geographic registry in the Mining Cadastre. SIMCI made adjustments in the topology of some geographic databases consulted to facilitate the integration of information.

Illustration 1. Distribution of production by type of deposit (SIMCO Source).

\(^{10}\) Remote sensing is defined as the science and art of obtaining useful information about objects, areas or phenomena under investigation through analysis of data acquired by devices that are not in physical contact with them through images that offer periodic observation and a broad perspective of the earth’s surface. Satellite images have become a valuable source of information for numerous applications, such as the inventory of natural resources, urban and rural planning, monitoring and management of the environment, agriculture, infrastructure, civil works, mining exploration, rapid response to disasters and military operations, among many others [106].
The project detects physical evidence characterized by landscape changes generated in land holdings with backhoe type machinery and defines the methodological guidelines to detect EVOA in water bodies with alteration of suspended sediments, resulting from the use of dredge type machinery. Detecting EVOA generated by both types of exploitation is addressed by remote sensing techniques.

Although the most characteristic visible physical evidence of the use of heavy duty machinery on land is the alteration of the landscape surrounding the water bodies or in alluvial lands, the nature of the exploitation (removal of material, benefit with water, etc.) alters the sediments in suspension in the aquatic environment; this means that mining activities employing machinery on land leave evidence that can be detected both by visual interpretation and by spectral indexes 11.

11 The spectral indexes are based on the algebraic combination of bands with corrected and radiometrically calibrated spectral values (reflectances); the objective is to group and minimize the different responses of the sensors in a single value per pixel, which can be successfully related to a phenomenon to be investigated [90].
Illicit Exploitation of Minerals, as stipulated by Law 685 dated 2001 (Code of Mines), is defined as:

“Article 159. Exploration and illicit exploitation. Illegal exploration and exploitation of mineral deposits, constituting the offense contemplated in article 244 of the Penal Code, is configured when exploration, extraction or capture of minerals of national ownership or private ownership is carried out, without the corresponding mining title in force or without the authorization of the owner of said property”.

In addition, it establishes the powers over the control of Illicit Exploitation of Minerals, thus:

“ARTICLE 306. MINING WITHOUT TITLE. The mayors will proceed to suspend, at any time, ex officio or by notice or complaint of any person, the exploitation of minerals without title registered in the National Mining Registry. This suspension will be indefinite and will not be revoked until the operators present said title. The omission by the mayor of this measure, after receiving the notice or complaint, will make him subject to disciplinary sanction for serious misconduct”.

Strengthening and complementing the above, we find in “the National Code of Police and Coexistence”, Law 1801 of 2016, TITLE X, “MEASURES TO CONTROL THE EXPLOITATION AND ILLICIT USE OF MINERALS”, the power to apply preventive and corrective measures environmental and mining (articles 96 and 97); as well as, the exhaustive enunciation of mineral exploitation activities are contrary to mining and, consequently, are subject to control and give “… place to corrective measures or to the imposition of preventive measures referred to in Law 1333 of 2009, according to the case and without prejudice to those of a criminal or civil nature that derive from them …” (Art. 105).

Additionally, we find that Illicit Exploitation of Minerals is classified as an offense in the Penal Code, “ARTICLE 338. ILLEGAL EXPLOITATION OF MINING DEPOSIT AND OTHER MATERIALS. Whoever, without the permission of a competent authority or in breach of the existing regulations, exploits, explores or extracts a mining deposit, or exploits sand, stony or trawl material from rivers and river banks by means capable of causing serious damage to natural resources or the environment, will incur prison …”.

Illicit Exploitation of Minerals is a phenomenon that mutates in its practices over time, it is floating, which complicates its monitoring in real time and leaves innumerable negative impacts in economic, environmental, social, health and in some cases it brings with it scenarios that affect public safety.

It is imperative to consider that the mining business takes place in different stages, not necessarily involving the same actors or places; in this sense, it is inevitable that all those related in some link of the chain, supporting the supply of inputs, such as fuel, machinery, equipment, explosives, chemicals, wood, among others; the actors involved in the development of activities such as exploitation, the benefit of mining, transportation, the commercialization of inputs and minerals, provide inputs such as mercury, cyanide,
are also linked as major actors in the control of illicit exploitation of minerals.

Additionally, the areas where the minerals are mined must be considered in more detail areas that are often restricted or excludable for the development of legal mining activities, which do not have enough infrastructure for transportation in their area, restricting access to their populations.

**Strategies designed, coordinated or developed in support by the Ministry of Mines and Energy and other entities for the control of Illicit Exploitation of Minerals**

The formalization of small mining in many areas of the country is developed as a strategy to control illegality, because here it is possible to differentiate traditional small-scale miners, who require support to do things right, within the legal framework, to be able to strengthen them so that they maintain their status as legality and meet the standards required to perform well-made mining.

In this sense, after being identified or characterized the mining production units in the regions, if the extractive activity is developed without the framework of legality, but the actors that carry it out, are traditional and want to work under the protection of a title mining, the *regularization* stage begins; which is the preliminary stage when entering the formalization program, where the production units are accompanied in the evaluation of the different mechanisms established by the current regulations, so that they can work under the protection of a mining title and be part of the program of mining formalization.

The mining formalization program is a set of actions or activities developed by the Ministry of Mines and Energy, focused on mining production units of small mining that work under the protection of a mining title and have an environmental instrument or have it in procedure. The beneficiaries of these mining production units must first commit themselves to comply with the standards established in the formalization policy, in order to achieve the best mining practices.

On the other hand, this Ministry has been working and supporting the development of the different strategies of the National Government to advance in the control of the illegal exploitation of minerals and related crimes from the following actions:

- Support in the generation of a regulatory framework for the control of the illegal exploitation of minerals, as follows:

**Tools proposed in the Development Plans:**

**Law 1450 of 2011:** In the period from 2011 to 2014, the National Development Plan was included.

Article 106, which states: "CONTROL OF ILLICIT EXPLOITATION OF MINERALS; as of the validity of this law, the use of dredges, mini-cranes, backhoes and other mechanical equipment in mining activities without mining title registered in the National Mining Registry is prohibited throughout the national territory. Failure to comply with this prohibition, in addition to the corresponding criminal action and without prejudice to other sanction measures, will result in the confiscation of said assets and the imposition of a fine of up to one thousand minimum legal monthly salaries in force, which will be imposed by the corresponding police authority. The National Government will regulate the matter".

**Law 1753 of June 9th, 2015**, whereby the National Development Plan 2014-2018 "TODOS POR UN NUEVO PAIS" is issued in its Article 5 defines the Transversal Strategies and Objectives of the Investment Plan, and considers the Mining and Energy sector as one of the components of the strategy of competitiveness and infrastructure. Said Law 1753 of 2015, maintains the validity of Article 106 “Control of Illicit Exploitation of Minerals”, related in the previous paragraph.

Mechanisms were generated for work under the protection of a mining title: legal tools were established with mechanisms so that traditional small-scale miners could develop mining activity under the protection of a mining title and thus achieve the separation of the traditional mining community from the opportunists, who only want to extract the metals or minerals, without the adequate technical, social and environmental management, in this sense the following article was included:

- Article 19 includes the mechanisms for the work of a degree in small-scale mining.

Subcontract of mining formalization.

Return of areas for mining formalization.
The following articles were also included:

- Article 20. Reserve areas for formalization.
- Article 21. Classification of Mining. To implement a differential public policy, mining activities will be classified into subsistence mining, small, medium and large.
- Article 152. Custody of gold by the Bank of the Republic.

- Support mechanisms and work strategies at National and International level, from which the Ministry of Mines and Energy developed joint actions with other authorities and countries, having:
  
  **Andean Committee Against Illegal Mining:**
  Decision 774 of July 30th, 2012 of the CAN, establishes and adopts the “Andean Policy to Combat Illegal Mining”, where some control measures were developed, such as the destruction of heavy machinery that is being used in the exploration and exploitation of minerals without the corresponding mining title registered in the National Mining Registry. The National Police is the Competent Authority to execute said action. The above in the framework of Decree 2235 of 2012.

As a result of this decision, promulgated within the framework of the international articulation of policies for the control of the illegal exploitation of minerals, the following was regulated:

**Decree 2235 of 2012:** “By which are regulated Article 6 of Decision No. 774 of July 30th, 2012 of the Andean Community of Nations and Article 106 of Law 1450 of 2011 in relation to the use of heavy machinery and its parts in activities mining companies without the authorizations and exigencies foreseen in the law”, is the National Police the competent authority to execute said action.

**Decree 723 of April 10th, 2014:** By which measures are established to regulate, register and control the import and mobilization of machinery classifiable in the subheadings and other provisions are dictated.

**Law 1658 of 2013:** By means of which provisions are established for the commercialization and use of mercury in the different industrial activities of the country, requirements and incentives are established for its reduction and elimination and other provisions are dictated. In its Article 11, the tools for Mining Formalization, Subcontracting, and the return of areas for this purpose were established.

- **Decree 480 of March 6th, 2014:** By which the conditions and requisites for the celebration and execution of the subcontracts of mining formalization are regulated.

- In mining, **Decree 0933 of 2013 was issued (Today with provisional suspension declared by the Council of State).** With this Decree it was sought to provide a legal solution for the evaluation of legalization applications filed under Article 12 of Law 1382 dated 2010 declared unenforceable. These requests are suspended and therefore cannot exploit minerals in the framework of this process.

- In environmental matters, there is **Law 1333 of 2009 “By which the sanctioning environmental procedure is established and other provisions are issued”**.

- Control (operational) mechanisms generated by the Ministry of National Defense in coordination with the Ministry of Mines and Energy together with other entities to counteract the problem of the illegal exploitation of minerals.

**Law 1801 of 2016,** Whereby the National Code of Police and Coexistence is issued, where it establishes in its Title X, control measures for activities that are developed outside the regulatory framework of mining and the powers in this area are extended to the National Police.

**Decree 1421 of September 1st, 2016,** “By which the Single Regulatory Decree of the Mining and Energy Administrative Sector, 1073 of 2015, is added and modified in respect of the adoption of measures related to the Profit and Commercialization of minerals and the Sole Regulatory Decree of the Environment Sector is added and modified and Sustainable Development, 1076 of 2015, regarding environmental licensing for profit plants”
Decree 2133 of December 22nd, 2016, “By which control measures are established for the import and commercialization of mercury and the products that contain it, within the framework of what is established in article 5 of Law 1658 of 2013”.

Decree 1102 of June 27th, 2017, “By which is added and modified the Single Regulatory Decree of the Administrative Sector of Mines and Energy, 1073 of 2015, regarding the adoption of measures related to the Marketing of Minerals”.

As a preventive strategy, for the development of a well-made mining, with standards in technical, environmental, social, labor and other aspects, regardless of the size of its development, the National Mining Policy was established, defining it as follows:

### NATIONAL MINING POLICY:

Resolution No. 40391 of April 20th, 2016, whereby the National Mining Policy is adopted, through which pillars and lines of action are defined to promote mining regularization and that mining activity takes place under conditions of legal, technical, labor, environmental, economic, and social formality. In it, the details that are evaluated for each type of mining, both in diagnosis and in supply, are developed.

As a necessity for the organization of the mining sector, Decree 1666 of October 21, 2016 was issued, “Whereby the Single Regulatory Decree of the Mining and Energy Administrative Sector, 1073 of 2015, related to the mining classification is added”.

Resolution 40103 of February 9th, 2017, by which the maximum production volumes are established in subsistence mining.

### Table 1. Maximum volumes of subsistence mining production.

<table>
<thead>
<tr>
<th>MINERAL AND / OR MATERIALS</th>
<th>AVERAGE MONTHLY VALUE</th>
<th>MAXIMUM ANNUAL PRODUCTION VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precious Metals (Gold, Silver, Platinum)</td>
<td>35 grams (g)</td>
<td>420 grams (g)</td>
</tr>
<tr>
<td>Sand and river gravel (for the construction industry)</td>
<td>120 cubic meters (m³)</td>
<td>1,440 cubic meters (m³)</td>
</tr>
<tr>
<td>Clays</td>
<td>80 Tons (ton)</td>
<td>960 Tons (ton)</td>
</tr>
<tr>
<td>Precious stones</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Emeralds</td>
<td>50 carats</td>
<td>600 carats</td>
</tr>
<tr>
<td>Whitebait</td>
<td>1,000 carats</td>
<td>12,000 carats</td>
</tr>
<tr>
<td>Semi-precious stones</td>
<td>1,000 carats</td>
<td>12,000 carats</td>
</tr>
</tbody>
</table>
Bill No. 169 of 2016 to control Illicit Exploitation of Minerals. Establishes measures against the illegal exploitation of minerals. The Government set before the Congress of the Republic a bill that will provide legal tools to prosecute the illegal exploitation of minerals in all the links of the criminal chain: exploitation, profit, transportation and commercialization. The strategy will be focused on fighting the mafias. It does not seek to persecute the small miners or stigmatize the activity.

• Prevention and Control Strategy
  • Investment Project “Control of Illicit Exploitation of Minerals Colombia” validity 2017.

The Ministry of Mines and Energy, formulated the Investment Project: “Control of the illegal exploitation of minerals Colombia”, which seeks to support control and prevention actions of the different competent authorities through the provision of information or evidence of the activity of the illegal exploitation of minerals and facilitate decision-making, which includes, among others, the following three related activities:

— Record georeferenced information of the zones defined in the flight lines, with equipment and defined logistic organization.

— Identify cases of illegal exploitation of minerals subject to operational intervention by the competent authority.

— Support coordination actions for the development of prevention and control operation of illegal mineral exploitation.

To materialize the above, Inter-administrative Cooperation Agreements were held, in order to articulate and develop aerial activities to identify the places destined for the illegal exploitation of mining deposits, also the Ministry supports the strengthening of the Police units, by means of the supply of indispensable technical instruments for the detection of substances, elements or chemical inputs used in the mining activity, and all the technical and legal support necessary for the execution of operations and judicial actions carried out by the competent authorities in the national territory.

The agreements signed in the framework of the investment project “Control of Illicit Exploitation of Minerals Colombia” are:

• AGREEMENT GGC 196 OF 2014:
  OBJECT: Join forces between the parties for the prevention and control of the illegal exploitation of minerals, through the use of aero-photography, aerial reconnaissance, analysis and interpretation of information from the Ministry of National Defense - Colombian Military Forces - Colombian Air Force, and the joint use of said information with the Ministry of Mines and Energy, as input in different processes for the competent authorities, related to the purpose of coordination for the control that the Ministry must develop.
  START: August 13th, 2014,
  FINALIZATION: December 31st, 2015.

• AGREEMENT GGC 277 OF 2015:
  OBJECT: Join forces between the Ministry of Mines and Energy and the National Police for the articulation and development of helicopter activities for the prioritization of cases of illegal exploitation of minerals, subject to intervention by the competent authorities, in order to generate control actions to this scourge in the national territory.
  START: July 31st, 2015,
  FINALIZATION: April 30th, 2016.

• AGREEMENT GGC-207 OF 2016:
  OBJECT: Support the Ministry of Mines and Energy, according to their needs, with the information, product of their capacity of aero-photography, aerial reconnaissance, analysis, and interpretation of information. Joint efforts between the parties for the prevention and control of the illegal exploitation of minerals, through the use of the capacity of aero photography, aerial reconnaissance, analysis, and interpretation of the information of the Ministry of National Defense - Military Forces of Colombia - Colombian Air Force, and the joint use of said information with the Ministry of Mines and Energy, as input in different processes for the competent authorities, related to the purpose of coordination for the control that the Ministry must develop.
  START: May 5th, 2016,

• AGREEMENT GGC-232 OF 2016:
  OBJECT: To join technical and administrative efforts, between the Ministry of Mines and Energy
and the National Police, for the articulation and development of aerial activities for the identification and prioritization of cases of illegal exploitation of minerals subject to intervention by the competent authorities, with the order to generate control actions in the national territory.


• AGREEMENT GGC-284-2017:
OBJECT: Bring together technical, human, financial and logistical efforts between the mines and energy ministry, and the National Police through the Carabineros and Rural Security Directorate - the National Unit against Illegal Mining and Anti-terrorism UNIMIL, and the Anti-narcotics Directorate - Aircraft Police Aviation, for the development of actions of coordination, prevention and control of the illegal exploitation of minerals, in order to protect natural resources.


• INTERNATIONAL COOPERATION AGREEMENT 243 OF 2017:
OBJECT: Join efforts between the Ministry of Mines and Energy and the office of the United Nations against drugs and crime (UNODC) to establish mechanisms of technical and economic cooperation, to help control the illegal exploitation of minerals by expanding the line base of information related to the alluvial gold exploitation (EVOA), and the research structure to support an integrated system of monitoring illicit gold exploitation with a territorial approach and a case study.

START: April 7th, 2017, In action.

• AGREEMENT GGC 549 of 2017, signed on November 28th, 2017, between the Attorney General of the Nation, the National Mining Agency and the Ministry of Mines and Energy, whose purpose is: To join institutional, technical, technological, human and logistic efforts in order to facilitate the access to the computer tools and databases of the ANM and the Ministry, which are necessary to support the missionary activity of the Office of the Prosecutor, by providing and/or allowing the most efficient access possible to the information that these entities manage regarding mining and hydrocarbons.

Trainings to competent local authorities as a prevention instrument

The Ministry of Mines and Energy, in coordination with the Attorney General’s Office, Technical Investigation Team - CTI, National Natural Parks of Colombia, National Mining Agency - ANM, National Police, Ministry of Defense, ANLA, Migration Colombia, and DIAN develop coordination and training sessions in the different regions of the country in order to make known the skills, procedures, clarify concerns, and support the control tasks to the illegal exploitation of minerals.

• TRAINING
Training for Communities
In the regions where small-scale mining activity is being carried out traditionally and no greater environmental impacts are generated and those who develop it do not know the legal framework that could apply to them to carry out their activities legally, they are given training or awareness days, in many occasions requested by the regional authorities, to explain to the community the options or existing mechanisms to work under the protection of a title and in another way, the legal administrative or criminal implications for not fulfilling these requirements in the development of their work.

Training to Local Authorities
With the purpose of coordinating and clarifying concepts to the competent authorities in the control of the illegal exploitation of minerals in order to facilitate decision-making and the exercise of their competences in the regions, the Ministry of Mines and Energy with the inter-institutional support of entities such as the National Mining Agency, the National Police, the Military Forces, the Ministry of Defense, the Directorate of National Taxes and Customs, the Ministry of the Environment, the National Authority of Environmental Licenses, the Office of the Attorney General of the Nation, etc., they impart the training called “Mining, Environmental Aspects and Competencies in the Control of Illicit Mineral Exploitation”.

REFERENCE FRAMEWORK
The training usually lasts three (03) days and covers the following topics:

<table>
<thead>
<tr>
<th>TITLE OF THE BLOCK</th>
<th>CONTENTS</th>
</tr>
</thead>
</table>
| MINING BLOCK       | Mining Regulations  
|                    | Competencies Authorities  
|                    | Mechanisms to work under the protection of mining title  
|                    | Right to explore and exploit (Excludable, Restricted and Reserved Zones / Mining Zones Ethnic Groups)  
|                    | Mining Regional Situation  
|                    | Administrative Protection  
|                    | Sole Registry of Mineral Traders - RUCOM  
|                    | DIAN - Customs Police  
|                    | Police Code - Title X (Miner) |
| ENVIRONMENTAL BLOCK| Environmental Licensing Regime (Competencies Authorities)  
|                    | Law 1333/2009 - Environmental Sanction  
|                    | National Environmental System - SINA  
|                    | National Natural Parks System - SPNN  
|                    | Specific cases of the region  
|                    | Strengthening in Own Government |
| ADMINISTRATIVE BLOCK| Decree 2235 of 2012 - Destruction of Machinery  
|                     | Seizure of Machinery  
|                     | Police Code - Title IX (Environmental)  
|                     | Regulation Hydrocarbons  
|                     | Hydrocarbon Control Procedures  
|                     | Procedures Use and Control of Explosives  
|                     | Directive 004 of 2017 |
| CRIMINAL BLOCK     | Immigration Regulations (Integrate with cases in the exercise of it)  
|                     | What is a crime?  
|                     | Environmental crimes (contests and casuistry)  
|                     | First Responsible and its Importance  
|                     | Judicial Police - Management of the scene - Aspects of Interest  
|                     | Judicialization  
|                     | Expert Part: Technical Test - General aspects - Mercury  
|                     | Practical Exercise - CASUISTRY |

Table 2. Thematic blocks for training local authorities.
In 2017, training was given to territorial authorities in the following areas:

<table>
<thead>
<tr>
<th>DEPARTMENT</th>
<th>DATE</th>
<th>TARGET POPULATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAQUETÁ</td>
<td>May 17th to 19th, 2017</td>
<td></td>
</tr>
<tr>
<td>BOYACÁ</td>
<td>August 24th, 2017</td>
<td></td>
</tr>
<tr>
<td>CHOCÓ</td>
<td>August 29th to 31st, 2017</td>
<td></td>
</tr>
<tr>
<td>CUNDINAMARCA</td>
<td>September 14th, 2017</td>
<td>Territorial Administrative Authorities</td>
</tr>
<tr>
<td>RISARALDA</td>
<td>September 22nd, 2017</td>
<td></td>
</tr>
<tr>
<td>ANTIOQUIA</td>
<td>September 27th to 29th, 2017</td>
<td></td>
</tr>
<tr>
<td>MAGDALENA</td>
<td>December 5th to 7th, 2017</td>
<td></td>
</tr>
<tr>
<td>AMAZONAS</td>
<td>November 29th to December 1st, 2017</td>
<td></td>
</tr>
<tr>
<td>CAUCA</td>
<td>December 11st to 13rd, 2017</td>
<td></td>
</tr>
</tbody>
</table>

Table 3. Timeline of training to territorial authorities in 2017.

Photo 1. National Police training.
AFFECTED AREAS WITH ILLEGAL MINERAL EXPLOITATION IN COLOMBIA

It is necessary to reiterate that the phenomenon of the illegal exploitation of minerals in Colombia is a floating phenomenon, due to the geological gold mining potential in Colombia, the variation of the tenors means that unauthorized operators move between different points or enriched areas, where there is greater and better production of metals, minerals or high value materials.

Bearing in mind the above, it is necessary to affirm that in Colombia there is talk of the problem that exists with the illegal exploitation of minerals in many areas of the country, but in reality, there is no official diagnosis of the state of the operations carried out (without Amparo de título), the magnitude of the areas intervened, the use of machinery, deforestation in the territories, the community involved, among many other factors that are required, since this activity takes place in an itinerant way, it does not have a constant determined area, nor is developed by means of a specific exploitation method, in that sense monitoring is the best and quick tool we need to size part of the problem in the territory.

However, there is a census carried out by the Ministry of Mines and Energy in the years 2010 - 2011, which shows some mineral exploitations developed without mining title for that time, but the number and areas have increased abysmally.

Statistics (2010 Mining Census)

Of the 14,357 Mining Production Units-UPM registered in the 23 departments, 63% have no mining title and it is observed that in ten departments this percentage is above 80% with worrying cases such as Chocó, Bolívar, Córdoba, and Antioquia, due to the importance of the exploitations located in these entities in the national aggregate.

At that time, in the department of Antioquia, 59% of small-scale mining UPMs do not have a mining title, followed by medium-scale mining UPMs of which 20% do not have a mining title.

Regarding the department of Boyacá, the behavior of the UPM in titling and size is different from that of Antioquia, since in Boyacá 50% of small-scale UPMs have a mining title, likewise 17% of medium-sized UPMs Scale have title. It is worth noting that in this department there is a high level of mining qualification, since for both large UPMs as for medium and small ones, the percentage of degree is close to 70%.

Contrary to what happens with the department of Boyacá, in which there is a high level of legality in the UPM censuses, in the department of Chocó the census figures reported that close to 100% of the UPM do not have a mining title, which 55% belong to UPM of medium scale and 44% to UPM of small scale and, only three units of large-scale mining production were registered, of which two do not have title.

As for the department of Bolívar, 50% of small scale UPMs have a mining title, while 26% of them do not have this. Similarly, a significant percentage, 17% of medium-scale UPM have a mining title. In terms of degree and size, the behavior of the department of Bolívar is very similar to that of Boyacá in which there are high levels of titling, especially at the level of small scale UPM.

Finally, in the department of Cundinamarca, 33% of small-scale UPMs do not have a mining title,
while 22% of them do have this. Regarding the medium-sized UPM, the behavior is different since the percentage of those with a mining title is higher (26%), while 16% of the medium-sized UPM do not have a title. In general, it is observed that the mining titling in the UPM registered in Cundinamarca is close to 50%.

<table>
<thead>
<tr>
<th>DEPARTMENT</th>
<th>UPM TOTALS</th>
<th>Without mining title</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antioquia</td>
<td>2,025</td>
<td>1,601</td>
</tr>
<tr>
<td>Atlántico</td>
<td>266</td>
<td>237</td>
</tr>
<tr>
<td>Bolívar</td>
<td>1,432</td>
<td>1,347</td>
</tr>
<tr>
<td>Boyacá</td>
<td>2,649</td>
<td>845</td>
</tr>
<tr>
<td>Caldas</td>
<td>203</td>
<td>148</td>
</tr>
<tr>
<td>Cauca</td>
<td>544</td>
<td>476</td>
</tr>
<tr>
<td>Córdoba</td>
<td>303</td>
<td>289</td>
</tr>
<tr>
<td>Cundinamarca</td>
<td>1,391</td>
<td>696</td>
</tr>
<tr>
<td>Chocó</td>
<td>527</td>
<td>523</td>
</tr>
<tr>
<td>La Guajira</td>
<td>282</td>
<td>277</td>
</tr>
<tr>
<td>Magdalena</td>
<td>564</td>
<td>559</td>
</tr>
<tr>
<td>Norte de Santander</td>
<td>858</td>
<td>394</td>
</tr>
<tr>
<td>Risaralda</td>
<td>161</td>
<td>133</td>
</tr>
<tr>
<td>Santander</td>
<td>1,055</td>
<td>578</td>
</tr>
<tr>
<td>Tolima</td>
<td>316</td>
<td>187</td>
</tr>
<tr>
<td>Valle del Cauca</td>
<td>249</td>
<td>199</td>
</tr>
<tr>
<td>Putumayo</td>
<td>501</td>
<td>322</td>
</tr>
<tr>
<td>Caquetá</td>
<td>219</td>
<td>12</td>
</tr>
<tr>
<td>Cesar</td>
<td>135</td>
<td>14</td>
</tr>
<tr>
<td>Huila</td>
<td>418</td>
<td>110</td>
</tr>
<tr>
<td>Meta</td>
<td>109</td>
<td>45</td>
</tr>
<tr>
<td>Arauca</td>
<td>45</td>
<td>26</td>
</tr>
<tr>
<td>Casanare</td>
<td>105</td>
<td>23</td>
</tr>
<tr>
<td>Otros</td>
<td>1,031</td>
<td>230</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>15,388</strong></td>
<td><strong>9,271</strong></td>
</tr>
</tbody>
</table>

Table 4. Mining Production Units without mining title. Source: 2011 Mining Census.

In addition, in 2016, the United Nations-UNODC, in cooperation with the Ministry of Justice and with the support of the Ministry of Mines and Energy, the Ministry of Environment and the Ministry of National Defense, conducted a study where, through remote sensing, it was possible to demonstrate in many areas, alluvial gold operations with onshore machinery, clarifying that the information reported there can be developed under different conditions of the legal framework, complying or not with the provisions of the regulations before the mining and environmental authorities.

Finally, it is necessary to highlight that due to security factors in some areas of the national territory, where the scourge of illicit exploitation of minerals takes place, it has been the National Police and the Colombian Military Forces, which through their intelligence work, with the support of some means provided through agreements and others, are monitoring the phenomenon, to identify the areas where the non-authorized extractive activity takes place, in order to prioritize and comply with the pertinent control actions.
LAW FIGURES IN THE STUDY

The methodology used for the detection of EVOA is not intended to characterize the activity of alluvial gold exploitation nor the legality of it; however, the framework of Colombian regulations confers on the mining dimension particularities and scope that must be observed in order to get a territorial view of this phenomenon.

This scope seeks that the competent entities responsible for the formulation of public policy, management, administration and control of resources, have objective information to improve the characterization of the phenomenon and therefore the integral vision of the affected territory.

Figures authorized by the normativity

The study addresses the relationship between the EVOA and legal figures, which count as the official source to the National Mining Agency - ANM, which is the entity in charge of administering the mineral resources of the State efficiently, effectively, and transparently through the development, the promotion, the granting of titles, and the monitoring and control of mining exploration and exploitation, in order to maximize the contribution of the sector to the integral and sustainable development of the country [2]. In this context, the study has official information from the ANM regarding Amparo de títulos, contract proposals and requests for legalization.

Regarding environmental licenses, the source is the National Authority of Environmental Licenses - ANLA, as the entity responsible for the projects, works or activities subject to environmental licensing, permit or processing, comply with environmental regulations, in such a way that they contribute to the environmental sustainable development of the Country (Decree 3573) [3].

Environmental licenses

Authorization granted by the competent environmental authority, through an administrative act to a person, for the execution of a project, work or activity that, in accordance with the law and regulations, may cause serious deterioration to renewable natural resources or the environment or introduce considerable or notorious modifications to the landscape, and in which are established the requirements, obligations and conditions that the beneficiary of the environmental license must comply with to prevent, mitigate, correct, compensate and manage the environmental effects of the project, work or authorized activity. (Decree 1753 of 1994, article 2).

Amparo de títulos of exploitation and exploration

In the Mining Code, the mining Title is defined as the document in which the right to explore and exploit the soil and the subsoil is granted. The mining titles are classified in: i) exploration and exploitation licenses, ii) mining contributions, iii) mining contracts [4].

Contract proposals

Those requests submitted by individuals to the State in order to carry out a mining concession contract for the execution of studies, works and exploration works of state-owned minerals in places where mining deposits are not yet carried out [5].

Requests for legalization

Those requests made by state-owned mines operators, without mining title registered in the National Mining Registry, and that carry out mining deposits and/or fields prior to August 17th, 2011 [6].
Under this framework, Article 165 of Law 685 dated 2001\textsuperscript{13}, contemplates the legalization by concession to the exploiters of mines on state property without title inscribed in the National Mining Registry. On the other hand, under the rule of Law 1382 dated 2010\textsuperscript{14}, Article 12, contemplates the legalization by concession, of the operators, groups and associations of traditional mining that exploit mines on State property without title inscribed in the National Mining Registry; as long as the requested area is free to contract, and it is proven that the mining works have been progressing continuously, since before the effectiveness of Law 685 dated 2001 and the required form and fund requirements are met. However, it is important to mention that as of 2016 the processes in force under this modality were suspended\textsuperscript{15}.

\textsuperscript{13} Law 685 dated 2001 established special mining and community development projects in order to promote the legalization and technical training of small-scale miners.

\textsuperscript{14} Law 1382 dated 2010 reformed Law 685 dated 2001 and granted a term of two years for traditional miners to request their formalization and be granted a mining concession contract as a result of a verification process of the traditionality of the mining works. This regulation was regulated by Decree 1970 of 2012.

\textsuperscript{15} By virtue of the Order of April 20th, 2016 of the State Council, the Mining Authority will not be able to resolve any of the requests for formalization of traditional mining that are under study and verification of the traditionality of the mining works, based on Decree 933 of 2013. In addition, the holders of such requests must suspend any mining activity that they are carrying out in the area to be formalized, under penalty of incurring illegal exploitation of mines, and becoming creditors of the measures provided for in articles 161 (confiscation) and 306 (suspension) of Law 685 dated 2001 and the sanctioning environmental actions determined in the legislation [80].
STRUCTURING AND INTEGRATING INFORMATION RELATED TO THE FRAMEWORK OF UNODC MONITORING SYSTEM AREAS AND GOVERNMENT OF COLOMBIA

In recent years, the research model of the SIMCI project has evolved from the construction of data on the phenomena and problems present, such as hectares sown with coca crops, sprinkled area and eradicated area, to become a research model where the integrating axis is the territory. This change of focus, associated with the incorporation of risk theory, has shown that the integration of information about threats and vulnerabilities allows one to understand in a more consistent and productive way the dynamics present in the territories.

The construction of this model requires the integration of information and the standardization of data to guarantee the temporal and geographical comparability of any phenomenon in the territory. The basis for SIMCI information integration, as well as other sources, is the framework of areas. The 1-kilometer square grids that can be grouped to form larger grids according to the research needs constitute this framework. It consists of a series of polygons (square grids of 5km and 1km) that are not dependent on changes in the territory; that is, the change in the administrative limits or the creation of new territorial entities does not alter the results obtained in the framework; therefore, space-time analysis can be carried out in a comparable and simple way.

In the previous context, the official geographic information available (secondary information) regarding alluvial gold mining exploitation has been incorporated into the framework. The official data was provided by the Ministry of Mines and Energy. Entities such as the National Mining Agency (ANM), the National Authority of Environmental Licenses (ANLA), the Directorate of Carabineers and Rural Security (DICAR), the Autonomous Corporations, and the Armed and Police Forces, officially submitted the data to the Ministry.

The topological validation of the information provided allowed one to detect that in some areas of the country, the layers present overlaps and duplicity of information that may alter the results presented. To avoid duplication in the reported area, the topology of the layers was restored and filtered for only gold-related mining data.

For spatial analyzes, priority was given to the information of legal figures in the following scale:
1. Environmental licenses. 2. Amparo de títulos

National Mining Agency – ANM

The ANM is the institution in charge of managing the State’s mineral resources and is responsible for the granting titles and control of mining exploration and exploitation. In compliance with its mission, the ANM generates geographic information with the location of titles, contract proposals, mining applications, limited areas of mining, restricted. Requests for legalization, delimitation of Special Reserve Areas, among others. For the analysis,
these data are considered as figures of law and the Colombian Government. The files delivered are of vector type.

**National Authority of Environmental Licenses - ANLA**

The National Authority of Environmental Licenses ANLA is responsible for the projects, works or activities subject to licensing, permit or environmental procedure comply with environmental regulations, in such a way that they contribute to the sustainable environmental development of the Country (Decree 3573) [3] . This data comes in vector files. The table below presents the consolidated files delivered to UNODC.

Summary of the available geographic information of the ANM and ANLA:

<table>
<thead>
<tr>
<th>Name</th>
<th>Geometry type</th>
<th>Format</th>
<th>Characteristics</th>
<th>Geographic Coverage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amparo de títulos</td>
<td>Polygon</td>
<td>Vector Shape</td>
<td>It contains the mining titles discriminated by modality, mineral and holder. Information for 22 departments. Antioquia, Bolivar, Boyacá, Caldas, Cauca, Cesar, Córdoba, Chocó, Huila, La Guajira, Magdalena, Nariño, Norte de Santander, Quindío, Risaralda, Santander, Sucre, Tolima, Valle del Cauca, Putumayo, Guainía, Vaupés. Number of records: 1,601 related to gold (86% of the national total).</td>
<td></td>
</tr>
<tr>
<td>Contract proposals</td>
<td>Polygon</td>
<td>Vector Shape</td>
<td>It contains the proposals with attributes such as modality, type of mineral and holder. Information for 29 departments. Only Sucre, Arauca and the Archipelago of San Andrés, Providencia and Santa Catalina have no information. Number of records 2,270 related to gold (75% of the national total).</td>
<td></td>
</tr>
<tr>
<td>Nombre</td>
<td>Geometría tipo</td>
<td>Format</td>
<td>Características</td>
<td>Cubrimiento geográfico</td>
</tr>
<tr>
<td>--------</td>
<td>----------------</td>
<td>--------</td>
<td>-----------------</td>
<td>-----------------------</td>
</tr>
<tr>
<td>Requests for legalization (Law 685 and Decree 0933 of 2013)</td>
<td>Polygon</td>
<td>Vector Shape</td>
<td>Contains applications for legalization with attributes such as modality, type of mineral and applicant. Information for 23 departments. Antioquia, Bolívar, Caldas, Caquetá, Cauca, Cesar, Córdoba, Cundinamarca, Chocó, Huila, Magdalena, Meta, Nariño, Quindío, Risaralda, Santander, Tolima, Valle del Cauca, Putumayo, Amazonas Guainía, Vaupés, Vichada</td>
<td></td>
</tr>
<tr>
<td>Environmental licenses</td>
<td>Polygon</td>
<td>Vector Shape</td>
<td>It contains environmental licenses with attributes such as modality, type of mineral and holder. Information for 1 department, Antioquia. Number of records 30 related to precious metals.</td>
<td></td>
</tr>
</tbody>
</table>

*Table 5. Summary of the available geographic information of the ANM and ANLA.*
The model designed in coordination with the Government of Colombia by UNODC during 2015, is based on a methodological scheme for the detection and monitoring of alluvial gold exploitation activities. This model was adopted by the Ministry of Mines and Energy and constitutes the structural basis for the implementation of the components of detection, information integration and geographic analysis. Likewise, it is consolidated as the methodological pillar for the implementation of a monitoring model that generates information based on technical evidence and that improves the frame of reference of the phenomenon for decision making and the formulation of public policy.

The model starts from the identification and geo-referencing of the physical manifestations of the phenomenon, in particular the exploitation of the mineral with the use of machinery on land (backhoes and bulldozers); it continues with the integration into the study framework of the related official primary and secondary information, which constitutes the scenario on which to design investigations that improve the characterization of the activity and allow the platform to be fed back, and finally, it ends with the availability of the data.

The methodological model adopted by the Government of Colombia headed by the Ministry of Mines and Energy in partnership with UNODC consists of two phases:

**PHASE I:**

This phase, the subject of this report, has a mainly geographical emphasis. It implements the methodology designed in the previous study [1] for i) the detection of evidence of alluvial gold exploitation with the use of machinery on land (national scope) and use of machinery in water (study - case); ii) the integration of primary and secondary information; iii) the geographical analysis for the characterization of the phenomenon.

**DETECTION**

The spatial dimensioning of the alluvial gold exploitation phenomenon is based on the detection, by remote sensing, of the physical evidences of the exploitation activities of the alluvial gold and verification overflights. This stage constitutes the basis for the geographical characterization of the phenomenon in the territory.

The alluvial gold exploitation with the use of heavy machinery in the Colombian territory, is carried out in two general modes: exploitation through the use of machinery on land (backhoes) and exploitation through the use of machinery in water (dredges, dragons, rafts). Each mode of exploitation causes different disturbances, which generate physical evidence of different nature according to the medium in which they manifest themselves.

The methodology for the detection of evidence of alluvial gold exploitation with the use of machinery on land, EVOA, is based on remote perception through the use of satellite images, through two methodological lines that present a common axis, but that address specific processes according to the nature of the evidence,

The exploitation in the bed of the water bodies through the use of machinery in water generates “ephemeral evidences”, characterized by the alteration of sediments suspended in the water, which are related to the moment of exploitation and are not durable. These changes are not accurately detected by traditional satellite image interpretation techniques, and are addressed by specialized information extraction techniques, such as band algebra (spectral indexes).

Illustration 2. Physical evidence detected through the use of spectral indexes generated by the use of machinery in water. Left satellite image RGB 453 in which NO perturbations are observed in the water medium. Right, spectral index applied to the image, the areas of the river in orange or red, indicate alterations in the sediments. Apaporis River.

On the other hand, the evidences generated by the exploitation activities through the use of machinery on land are considered “lasting evidences” due to their permanence over time and are characterized by changes of visual impact in the landscape surrounding the water bodies; these changes are caused by the removal of the vegetation layer, the proliferation of bare soils, the alteration of channels, and the appearance of benefit lagoons, among others. Lasting evidence is detected through remote sensing using traditional satellite image interpretation techniques.

The following illustration presents the detection scheme:

Illustration 3. Detection of changes with Landsat 8 satellite images (displayed in false color RGB 543. Visible physical evidence on the landscape, generated by the use of machinery on land EVOA in light blue tone with benefit lagoons. Municipality López, department of Cauca.
Illustration 4. Outline model of detection based on remote sensing.
• **INFORMATION INTEGRATION**

It refers to the standardization and consolidation of primary (detection) and secondary information, related to the phenomenon of gold exploitation in the SIMCI database. The consolidated data allow access to structured information of a multidisciplinary nature, collected by SIMCI for more than 15 years in the monitoring of phenomena of illegality in the territory, and facilitates, among others, the updating of the geographic reference framework for the affected territory by the phenomenon of alluvial gold exploitation developed in a non-technical manner.

The SIMCI project has integrated geographic information into a system of square grids of 5 km and 1 km; this grid is known as the area frame. Each grid has associated attributes information such as municipality and department, special management area and forest reserve area, among others. Historical data on areas planted with coca crops, studies on the production of the coca leaf transformation to cocaine hydrochloride, multi-temporal analyzes of land cover, and now the EVOA data, are found in this unique grid of reference, and they allow among others, i) to establish the relationships between the phenomena and between these with different elements in the territory, ii) the development of multi-temporal analyzes for the establishment of the geographical origin and trends of the phenomenon, iii) the design of various research models, that contribute to improve the frame of reference and knowledge about the dynamics of the phenomena of illegality in the territory, iv) the construction of a sampling frame for statistical and probabilistic exercises.

• **GEOGRAPHICAL ANALYSIS**

The geographical characterization of alluvial gold exploitation not only involves its location and dimensioning, but also requires an integral look at the various phenomena present in the territory, in such a way that it allows acquiring knowledge and understanding of the changes associated with its distribution and location, its spatial and temporal dynamics, and the relations of association with other economic and social processes. For this study, the spatial dynamics of the phenomenon is addressed, based on the findings found in the previous study [1].

**PHASE II:**

This phase oriented to the implementation of a monitoring system, will be developed in two stages, the first to be developed during 2018, has a more integral approach, and involves the following dimensions:

- Detection, includes the update of the baseline of EVOA in land 2017 and the extension of the base line of EVOA in water to the region of Orinoquia and Amazonia of the Colombian territory.
- Socioeconomic, involves the implementation of quantitative and qualitative\(^\text{16}\) methodologies with a vulnerability approach, to reach the territory and deepen the characterization and dynamics of the phenomenon.
- Administrative, involves information models for the inclusion of the mining variable in the development plans of the municipalities, as well as for the regularization of exploitation activities in communities of traditional exploitation.

The second stage, with emphasis on the implementation of the Monitoring System of the phenomenon, involves, among others, the scope of the methodological framework, the periodicity of information capture, identification of complementary variables, establishment of monitoring indicators and users of the system. This Monitoring System will allow the government to have permanent, objective information based on evidence for the decision-making processes, management and formulation of public policy.

\(^\text{16}\) These methodologies have been designed and validated in the framework of the development of the Alliance with the Ministry of Mines and Energy for the approach to communities in the territory affected by the phenomenon.
SECTION
FINDINGS
EVIDENCES OF ALLUVIAL GOLD EXPLOITATION

From the reference framework, the main findings are presented in this section. The section includes the findings related to the EVOA for both onshore machinery and machinery in water (Apaporis case). The relationship of the EVOA with the territories is presented and data on the dynamics of the phenomenon are presented when comparing the situation observed with that reported in 2014.
EVIDENCES OF ALLUVIAL GOLD EXPLOITATION USING MACHINERY ON LAND, IN THE COLOMBIAN TERRITORY

The results of the detection of EVOA 2016, strip mining using machinery on land, indicate that by 2016, in 14 of the 32 departments of the country that evidence alluvial gold exploitation have detected using machinery on land. Of them, 83,620 hectares were identified, which is 6% more than what was detected in 2014; 77% of the EVOAs in the country are concentrated in two departments, Chocó (39%) and Antioquia (37%).

<table>
<thead>
<tr>
<th>Department</th>
<th>EVOA 2014</th>
<th>EVOA 2016</th>
<th>% of the 2016 national total</th>
<th>% change 2014-2016</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chocó</td>
<td>36,113</td>
<td>33,024</td>
<td>39</td>
<td>-9</td>
</tr>
<tr>
<td>Antioquia</td>
<td>26,237</td>
<td>30,897</td>
<td>37</td>
<td>17</td>
</tr>
<tr>
<td>Bolívar</td>
<td>7,405</td>
<td>7,820</td>
<td>9</td>
<td>6</td>
</tr>
<tr>
<td>Cauca</td>
<td>1,405</td>
<td>3,702</td>
<td>4</td>
<td>163</td>
</tr>
<tr>
<td>Córdoba</td>
<td>3,541</td>
<td>3,592</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Nariño</td>
<td>1,671</td>
<td>2,678</td>
<td>3</td>
<td>60</td>
</tr>
<tr>
<td>Valle</td>
<td>1,566</td>
<td>1,023</td>
<td>1</td>
<td>-35</td>
</tr>
<tr>
<td>Putumayo</td>
<td>365</td>
<td>537</td>
<td>1</td>
<td>47</td>
</tr>
<tr>
<td>Others</td>
<td>507</td>
<td>347</td>
<td>0</td>
<td>-31</td>
</tr>
<tr>
<td>TOTAL</td>
<td>78,939</td>
<td>83,620</td>
<td>100</td>
<td>6</td>
</tr>
</tbody>
</table>

Table 6. EVOA with use of machinery on land (hectares) by department.

Cauca, with 18 of its 42 municipalities affected by EVOA (43%), has the largest increase compared to the 2014 measurement with 163%, however, the municipalities of Bolívar, Guachené, Guapi, which concentrate the expansion and report increases above 800%, Piamonte, Timbiquí, and López de Micay recorded increases of over 200%.

The second place in terms of EVOA expansion area is occupied by Nariño with a 60% increase, concentrated in the municipalities of El Charco, Santa Bárbara, Barbacoas, Magüí Payén, and Roberto Payán. Tumaco reports stability in the detected area.

The following graph shows the EVOA area obtained in the present study, in relation to the gold production record by department [7].

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17 The EVOA 2014 file was interpreted in the reference system (Bogotá Transverse Mercator) used by the SIMCI project for 15 years. In order to carry out the dynamics analysis of EVOA 2014-2016, it was necessary to re-project this file to the new system used by the official entities and by UNODC (Magna SIRGAS). This procedure changes the geometries of the interpreted polygons. According to the above, the dynamics data in some departments and municipalities may differ from those published in the previous study.
Although Chocó continues to occupy the first place with the highest percentage of EVOA detected (39%), Antioquia has the highest production, with a share of 41.04% (25.37 tons) in the total national production; followed by Chocó with 23.50% (14.53 tons) [7][8][9].

It is striking that Córdoba with an EVOA area very similar to Cauca, only reports 1% (0.62 tons) of participation in the national production; Cauca reports 6% (3.71 tons). On the other hand, Chocó, which ranks first in EVOA detection in the two study periods, reported approximately half of what was reported in Antioquia.

Unlike Chocó, Nariño marks an inverse behavior in its EVOA-Production relationship, which may be supported by reef operations located mainly towards the western slope of the Galeras volcano. In the case of Huila, Caldas, Tolima, Valle del Cauca, Risaralda and Santander, grouped in the “Other” category, the available information registers a predominance of exploitation activities associated with reef [9].

The fact that there is no strong relationship between EVOA and participation in the National production, may be due, among other reasons, to the incidence of production from reef or alluvium (see graph 2) with the use of machinery in water, to differences in productivity, because gold is not always recorded in the exploitation zone, or because, as it was possible to verify by means of information obtained in the territory, gold simply does not register. In this regard it is worth mentioning that miners interviewed by UNODC in Cauca, Chocó and Guainia, reported Medellín as the final destination of the gold they extracted.

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18 The National Production Report is obtained based on the collection of royalties supported by the Basic Mining Format, which is a government control tool, where the owner indicates, among others, the volumes produced every six months and annually. However, this information is not fully consolidated by the mining authority [81].

19 In light of the interpretation of the data, it is necessary to mention that the reported production refers to both alluvial deposits and reef deposits.
The affectation by EVOA covers 131 municipalities (12%) of the total of 1,127 in the country. Antioquia has affected 30% of its 125 municipalities, and ranks first in the number of affected municipalities with 38. The EVOAs are concentrated there in 10 municipalities: Zaragoza, Nechí, El Bagre, Cáceres, Caucasia, Tarazá, Segovia, Remedios, Anorí, and Amalfi, which contribute 94% of the department’s EVOAs and 35% of the national data.

On the other hand, 23 municipalities of Chocó, 77% of the total of municipalities of the department report evidences of the phenomenon. The EVOAs are concentrated in 10 municipalities: Nóvita, Cantón del San Pablo, Istmina, Unión Panamericana, Río Quito, Condoto, Medio Atrato, Quibdó, Medio San Juan, and Tadó. In these municipalities, there is 86% of the total detected in the department and 34% of the total EVOA detected in the country.

The problematic phenomenon in the national realm is strongly concentrated. 52% of the national detection is located in 10 municipalities in the departments of Antioquia, Chocó, Córdoba and Bolívar.

---

20 The EVOA 2014 file was interpreted in the reference system (Bogotá Transverse Mercator) used by the SIMCI project for 15 years. In order to carry out the dynamics analysis of EVOA 2014-2016, it was necessary to re-project this file to the new system used by the official entities and by UNODC (Magna SIRGAS). This procedure changes the geometries of the interpreted polygons. According to the above, the dynamics data in some municipalities may differ from those published in the previous study.

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**Concepts**

- **Affected municipality:** municipality with EVOA detection with use of machinery on land by remote sensing.
- **Evidence:** footprint or signal detected through interpretation and digital processing of satellite images and characterized by alteration of the landscape in alluvial lands.

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**Photo 2. Alluvial gold exploitation in Antioquia.**

**Photo 3. Alluvial gold exploitation in Nariño.**
Antioquia and Chocó contribute four municipalities each to this list, with 25% and 20% of the affected national area, respectively. Zaragoza and Nechí, in the department of Antioquia, are the municipalities with the largest reported area 6,186 ha and 5,916 ha respectively, representing 14% of the national total, followed by Nóvita and El Cantón del San Pablo in Chocó, with a participation in the national total of 11%. The department of Bolívar is integrated into this list with the municipality of Montecristo, and the department of Córdoba with Ayapel. All these municipalities, except Ayapel and Unión Panamericana, are also affected by the presence of coca crops.

Dynamics of the phenomenon 2014-2016

The study indicates that the territory affected by EVOA considering the baseline 2014 and the 2016 update, is 107,649 ha. 43% of the national territory affected is concentrated in Chocó with 45,711 ha. Antioquia ranks second with 37,066 ha representing 34% of the national territory affected by EVOA.

The affected territory is made up of stable areas, new areas, expanding areas and areas with indications of pastures and grasslands. 30% of the EVOA 2014, show signs of pastures and grasslands, considered within the initial stages of plant succession. However, it must be borne in mind that, in these stages, the requirement of germplasm or genetic material to initiate succession is less demanding in diversity and species richness in respect of the higher stages of plant succession. In this sense, the successful completion of a succession process will depend, among others, on the quantity, viability, and diversity of the germplasm, as well as on the physical and chemical conditions of the soil [10]. Therefore, it is not possible to ensure that the areas under this category advance towards a recovery of the original conditions of forest cover.

Concepts

**Affected territory 2014-2016**: geographical sum of the EVOA 2014 and EVOA 2016 detection.

**Stable area**: area with permanent EVOA, detected in the 2014 study and in the 2016 update.

**New area**: area with EVOA detected in 2016, but not in 2014.

**Expanding area**: area with EVOA detected in 2014 with the largest area affected in 2016.

**Area with indications of grasses and grasslands**: areas with EVOA detected in 2014, but which in 2016 are found with low herbaceous or stubble vegetation, characteristic of initial stages of plant succession

**Area without information**: areas with EVOA detected in 2014, but which are under cloud cover in 2016.

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21 The grassland category indicates that there is spectral response related to incipient vegetation of plant succession, however, this does not imply that the process of succession continues until maturity, so this category should be taken with caution.
Table 7. Territory affected by EVOA 2014-2016.

<table>
<thead>
<tr>
<th>Department</th>
<th>EVOA 2016 (ha)</th>
<th>Stable Area (ha)</th>
<th>New area (ha)</th>
<th>Expanding area (ha)</th>
<th>Area with indications of grasses and grasslands (ha)</th>
<th>Affected territory 2014-2016 (ha)</th>
<th>% of affected territory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chocó</td>
<td>33,024</td>
<td>23,426</td>
<td>2,327</td>
<td>7,271</td>
<td>12,687</td>
<td>45,711</td>
<td>43%</td>
</tr>
<tr>
<td>Antioquia</td>
<td>30,897</td>
<td>20,068</td>
<td>2,359</td>
<td>8,469</td>
<td>6,169</td>
<td>37,066</td>
<td>34%</td>
</tr>
<tr>
<td>Bolívar</td>
<td>7,820</td>
<td>5,267</td>
<td>700</td>
<td>1,853</td>
<td>2,138</td>
<td>9,957</td>
<td>9%</td>
</tr>
<tr>
<td>Cauca</td>
<td>3,702</td>
<td>991</td>
<td>1,981</td>
<td>731</td>
<td>414</td>
<td>4,117</td>
<td>4%</td>
</tr>
<tr>
<td>Córdoba</td>
<td>3,592</td>
<td>3,027</td>
<td>45</td>
<td>519</td>
<td>514</td>
<td>4,106</td>
<td>4%</td>
</tr>
<tr>
<td>Nariño</td>
<td>2,677</td>
<td>1,239</td>
<td>731</td>
<td>708</td>
<td>432</td>
<td>3,110</td>
<td>3%</td>
</tr>
<tr>
<td>Valle del Cauca</td>
<td>1,023</td>
<td>613</td>
<td>205</td>
<td>205</td>
<td>953</td>
<td>1,976</td>
<td>2%</td>
</tr>
<tr>
<td>Putumayo</td>
<td>537</td>
<td>167</td>
<td>165</td>
<td>206</td>
<td>198</td>
<td>735</td>
<td>1%</td>
</tr>
<tr>
<td>Others</td>
<td>348</td>
<td>112</td>
<td>132</td>
<td>103</td>
<td>524</td>
<td>871</td>
<td>1%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>83,620</strong></td>
<td><strong>54,910</strong></td>
<td><strong>8,645</strong></td>
<td><strong>20,065</strong></td>
<td><strong>24,029</strong></td>
<td><strong>107,649</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>

Regarding the new areas, the dynamics identified indicates that 10% (8,646 ha) of the EVOA detected in 2016 had not been detected in 2014. Of these, 77% are concentrated in Chocó, Antioquia and Cauca. On the other hand, the areas in expansion represent 24% of the 2016 EVOA and are mainly focused on Antioquia with 42% and Chocó with 36%.
The following graph illustrates the departmental percentage distribution around the EVOA 2016 detection; Córdoba is the department with the greatest stability in the phenomenon, with 84% of the detection concentrated in stable areas.

![Graph 4. EVOA dynamics by department, 2014-2016.](image)

Cauca, Putumayo and Nariño report increases of over 50% in new areas. It is striking that the expansion of this phenomenon coincides with the increase in the area sown with coca crops (45%, 25% and 43% respectively)\(^\text{22}\). These departments contain 55% of the territory affected by coca crops in the national scope and although they represent only 8% of the detection of EVOA 2016, it is configured as a national alert, due to the activation of the dynamics of two illegal phenomena, which they associate directly with the conditions of vulnerability in the territories.

Similarly, it is striking that during the recent field surveys, it was observed that the removal of material to reach the alluvial deposit, stopped being superficial to make way for deeper excavations and reach older\(^\text{23}\) alluvial deposits; in the following photograph it is possible to observe the dimension of the depth reached by the machinery, a factor that acquires great importance when evaluating the environment in which it is made a few meters from the wall of the river bed, leaving a very thin layer of containment of it.

The dynamics of the exploitation of gold with the use of machinery on land, without complying with environmental regulations, increases the vulnerability of the natural environment due to destabilization of slopes, overload and increase in the water table. This condition has direct implications in flash floods and landslides.

\(^{22}\) Between 2015 and 2016 Cauca went from 8,660 ha to 12,594 ha of coca crops, Putumayo from 20,068 ha to 25,162 ha and Nariño from 29,755 ha to 42,697 ha.

\(^{23}\) Formed by detrital sediments transported by the river and deposited at points along its floodplain [55]. These sediments usually change in thickness in relation to the level of their site, prevailing in its composition either crystalline material of remote antiquity or substances of recent volcanic formation. In general, gold is accompanied by heavy-gauge, reddish rock, composed of granite and crystalline schists, since it comes from the auriferous veins of quartz that such rocks contain and that, on the other hand, due to its greater weight, requires for its drag a water force equal to that which rocks of size would also be able to carry [82].
Illustration 6. Aerial reconnaissance photographs where the depth of exploitation is observed. 

a) Deep excavation and close to the wall of the riverbed. 

b) Surface excavation.
Dynamics of EVOA in Colombia, 2014-2016 period

ONE OF THE PUBLIC POLICY EMPHASIS PROMOTED BY THE COLOMBIAN GOVERNMENT IS THE RECOGNITION OF THE PARTICULARITIES OF THE TERRITORY AND THE NEED FOR PUBLIC POLICIES TO INCORPORATE THESE PARTICULARITIES. THE OBSERVATION OF THE ZONES OF SPECIAL MANAGEMENT CONTRIBUTES TO THE FOCUSING OF EFFORTS, BUT ABOVE ALL TO THE DESIGN OF SPECIFIC STRATEGIES TO FACE PROBLEMS IN THESE TERRITORIES. THIS DOCUMENT PRESENTS DATA ON EVOA FOR FOUR AREAS OF SPECIAL MANAGEMENT: INDIGENOUSRESERVES, AFRO-COLOMBIAN COMMUNITY TERRITORIES, NATIONAL PARKS, AND OTHER AREAS OF THE NATIONAL SYSTEM OF PROTECTED AREAS SINAP.

47% OF THE EVOA (39,175 HA) IS IN ONE OF THESE CATEGORIES. IN PARTICULAR, AFRO-COLOMBIAN COMMUNITY TERRITORIES ARE STRONGLY AFFECTED: 67 OF 158 TERRITORIES REPORT EVOA FOR 2016 AND 42% (34,858 HA) OF THE TOTAL AREA WITH EVOA IS IN THIS CATEGORY. ALTHOUGH ABOUT 1% OF THE DETECTION FOR THE YEAR 2016 IS IN AREAS OF INDIGENOUS RESERVES (780 HA), IT IS STRIKING THAT ALMOST ALL AFFECT THE EMBERA KATÍO GROUPS.

**National Natural Parks**

The areas that make up the National Natural Park System (SNPNN) declared and delimited, in accordance with current regulations for the protection and development of renewable natural resources or the environment, are considered excludable areas of mining, according to Article 34 of the Code of Mines (Law 685 dated 2001) that is to say that in these areas mining activities cannot be executed, not even of subsistence.

Notwithstanding the foregoing, the destruction of these protected areas has increased alarmingly in recent years due to various pressure fronts, among which illicit exploitation of minerals stands out. According to the environmental justice atlas 2014 (Environmental Justice Organizations, Liabilities and Trade), Colombia is the country that faces the most environmental conflicts in the continent [11].

The EVOAs detected in areas of National Natural Parks provide information on alerts due to the presence of the activity and vulnerability to the phenomenon, which will allow the competent institutions to improve the characterization of the phenomenon in these areas of high biodiversity richness and the supply of services environmental.

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24 Excludable for mineral exploitation: National Natural Parks and other categories of protected areas registered in the RUNAP. Restricted mineral exploitation: Indigenous Reserves, Afro-Colombian Community Territories and Mining Areas of ethnic communities.

25 The geographical coverage of Indigenous Reserves corresponds to information reported by the IGAC for 2015.

26 The geographical coverage of the lands of the Afro-Colombian Community Territories corresponds to the geographical delimitation reported by the IGAC for 2015.

27 The geographic coverage of National Natural Parks corresponds to official information of UAESPNN for 2017.

28 The geographic coverage of the National System of Protected Areas, SINAP, corresponds to official information of UAESPNN for 2017.
Of the 59 National Natural Parks, in four of them EVOA was detected with the use of machinery on land in 2016, totaling 111 hectares that represent 0.13% of the total national area detected. The presence of EVOA in the SNPNN, regardless of its magnitude, generates alerts not only because of the presence of the activity and because of the territory’s vulnerability to the phenomenon, but because of the environmental effects that impact the ecosystems\textsuperscript{29}. These alerts constitute a call to the competent institutions for the design of strategies and public policy for the protection of these areas of great biodiversity and offer of environmental services.

Although only in four SNPNN parks were evidences of direct alteration of the landscape, it is noteworthy that in respect of 2014 the area doubled. The Puinawai National Nature Reserve\textsuperscript{30} continues to register the highest impact with 57 hectares located mainly in the Serranía de Naquén and representing 51% of the total detected in the SNPNN.

When considering the proximity of the EVOAs to the PNNs, the strong pressure being exerted by the fronts of the phenomenon on these territories is evident, aggravating more the environmental panorama of the same. The following table presents the PNN with EVOA in three proximity ranges: a) within the parks, (b) within 10 km of their boundaries, and (c) at a distance between 10 km and 20 km from the boundaries.

\begin{table}[h]
\centering
\begin{tabular}{|l|c|c|c|}
\hline
National Natural Park & Area (ha) EVOA in PNN & Area (ha) EVOA in ZI_10Km & Area (ha) EVOA in ZI_20Km \\
\hline
Puinawai & 57 & 0 & 6 \\
Paramillo & 31 & 89 & 458 \\
Los Katios & 19 & 0 & 78 \\
Selva de Florencia & 4 & 70 & 0 \\
Munchique & 0 & 140 & 399 \\
Las Orquídeas & 0 & 0 & 25 \\
Los Farallones de Cali & 0 & 461 & 125 \\
Serranía de los Churumbelos & 0 & 191 & 210 \\
Yaigojé Apaporis & 0 & 17 & 15 \\
Complejo Volcánico Doña Juana Cascabel* & 0 & 0 & 3 \\
Plantas medicinales Orito Ingi Ande** & 0 & 0 & 15 \\
Tatamá & 0 & 0 & 56 \\
Acandí, Playón y Playona & 0 & 0 & 45 \\
Alto Fragua Indi-Wasi & 0 & 0 & 50 \\
\hline
Total & 111 & 968 & 1,485 \\
\hline
\end{tabular}
\caption{EVOA detected in PNN 2016 and in different proximity ranges.}
\end{table}

\textsuperscript{29} The concept of affectation in parks is proposed due to the environmental impact it generates in these protected territories.

\textsuperscript{30} Puinawai National Nature Reserve.
EVOA in areas of influence (0 - 20 km) of the National Natural Parks, 2016

**Map 4. EVOA in zones of influence of the PNN, 2016.**
The results reveal that four additional parks are at risk of affectation, for presenting EVOA less than 10 km and six more parks to include the category of 10 to 20 km. The presence of EVOA in these areas of influence also increased in respect of the areas detected in 2014.

Two parks generate an alert when registering a strong increase in the EVOA detected in the zones of influence; the PNN Munchique went from 145 ha in 2014 to 539 ha in 2016 (+ 272%) and the PNN Serranía de los Churumbelos presents a similar situation when reporting a 208% increase in these areas.

However, when contemplating that the vulnerability of the PNN associated with the presence of EVOA does not depend only on the distance proximity to the park, but on the fluvial connectivity\(^\text{31}\) of the same. It is observed that, in addition to the previously mentioned parks, the EVOAs in areas near Los Farallones de Cali, Selva de Florencia, and Tatamá parks, increase the risk of affectation by being directly connected to the interior of the parks through some rivers or its tributaries, as presented in the following table.

### Table 9. Fluvial connectivity between EVOA detected and PNN.

<table>
<thead>
<tr>
<th>National Natural Park</th>
<th>Fluvial connectivity</th>
<th>NOMSZH(^\text{32}) Sub-basin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Selva de Florencia</td>
<td>River Samaná and tributaries, Quebrada Las Mercedes</td>
<td>River La Miel (Samaná)</td>
</tr>
<tr>
<td>Munchique</td>
<td>River Micay and tributaries, River Chuaré</td>
<td>River San Juan del Micay</td>
</tr>
<tr>
<td>Los Farallones de Cali</td>
<td>River Anchicayá</td>
<td>Anchicayá</td>
</tr>
<tr>
<td></td>
<td>River Mallorquín, River Cajambre, River Guapi, Quebrada Juan López, Quebrada Don Carlos</td>
<td>River Cajambre - Mallorquín - Raposo</td>
</tr>
<tr>
<td>Serranía de los Churumbelos</td>
<td>River Mandiyaco, River Caquetá and tributaries</td>
<td>Alto Caquetá</td>
</tr>
<tr>
<td></td>
<td>Quebrada Pacayaco and Santa Lucía</td>
<td></td>
</tr>
<tr>
<td>Tatamá</td>
<td>Tributaries of River Tamaná</td>
<td>River Tamaná and other direct</td>
</tr>
<tr>
<td></td>
<td></td>
<td>San Juan</td>
</tr>
</tbody>
</table>

### Other categories of protected areas registered in the RUNAP\(^\text{33}\)

In addition to the National Natural Parks’ System, in Colombia there is a great variety of figures for the protection of areas. As part of the National System of Protected Areas - SINAP\(^\text{34}\), these areas are registered in the National Registry of Protected Areas - RUNAP, therefore they are defined geographically and are designated, regulated and managed in order to achieve specific conservation objectives.

### Table 10. EVOA detected in other categories of the SINAP, 2016.

<table>
<thead>
<tr>
<th>Name Protected Area</th>
<th>% EVOA of the total in these areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>National Protective Forest Reserve River Escalarete and San Cipriano</td>
<td>3%</td>
</tr>
<tr>
<td>National Protective Forest Reserve River Anchicayá</td>
<td>5%</td>
</tr>
<tr>
<td>District of Integrated Management of Natural Resources of the Ayapel Wetland Complex</td>
<td>92%</td>
</tr>
</tbody>
</table>

\(^{31}\) Information obtained through the mining community, in the framework of this study, indicates that the axis of exploitation and operation is concentrated in the water current, framed within the natural limits of the watersheds.

\(^{32}\) NOMSZH: Name Hydrographic Subzone, IDEAM.

\(^{33}\) In order to have a national consolidation of the areas that make up the SINAP, the Ministry of Environment and Sustainable Development through Decree 2372 dated 2010 created the National Registry of Protected Areas - RUNAP, a platform administered by the National Natural Parks Unit of Colombia. On the RUNAP platform is the information entered by the environmental authorities on the protected areas of its jurisdiction that includes at least the category of management, its location, geographical extension, conservation objectives and destination of use, supported in its administrative acts of declaration, homologation, re-categorization, or subtraction for the case of public protected areas and registration for private protected areas (Natural Reserves of Civil Society).

\(^{34}\) Set of protected areas, social actors and strategies and management instruments that articulate them, to contribute as a whole to the fulfillment of the country’s conservation objectives. It includes all protected areas of public, private or community governance, and the scope of national, regional or local management. (Article 2.2.2.1.1.3 of Decree 1076 of 2015).
For 2016, 3,776 ha of EVOA were detected in these territories. The most affected area is the Integrated Natural Resources Management District of the Ayapel Wetland Complex, where 92% of the total EVOA detected in these areas is concentrated.

This Complex is of great ecological interest because it has different aquatic and terrestrial biotopes; it is home to a great biological diversity and supports a series of environmental services, which constitute it as the natural capital of the region and the country [12].

It should be noted that wetlands are highly productive ecosystems due to their natural dynamics and functional structure, which allows them to offer a suitable habitat for biological diversity and configure an environment with significant services for human communities [13]. However, the indiscriminate use of the resources of this wetland complex and the way in which the productive activities of gold exploitation have expanded in the region, continually attack the sustainability of this ecosystem and the welfare of those who depend on it [14].

Among the environmental services provided by a wetland are: the storage and purification of water; control of the microclimate; CO₂ sinks; flood mitigation; refuge and permanent or transient habitat of migratory bird species; and areas of reproduction, spawning, growth and feeding of fish and other aquatic species [13].

35 The Wetland Complex of Ayapel is located in the department of Córdoba, in the upper and middle part of the San Jorge River. Its hydrographic basin is part of the North Atlantic plain of Colombia macro system of wetlands and flood zones of the Momposina Depression, which covers areas of the departments of Córdoba, Sucre, Magdalena and Bolívar (83).
EVOA detected in the DMI Wetland Complex of Ayapel

Map 5. EVOA detected in the Integrated Management District (DMI) of the Ayapel Wetland Complex.
**Indigenous Reserves**

The 5% (35) of the total of Indigenous Reserves in the country is affected by EVOA; 780 hectares of EVOA were identified in these territories for 2016. Reserves in Chocó are the most affected, with 336 hectares (43%) distributed in 29 reserves. The second place in affectation corresponds to the department of Cauca, with 190 ha (24%) distributed in 5 reserves. In third place is Guainía with 117 ha (15%). Strong increase is registered in Cauca, going from 96 ha in 2014 to 190 ha in 2016, which represents an increase of 97 percentage points.

![Graph 5](image)

**Graph 5. Percentage distribution of ethnic groups in indigenous reserves affected by EVOA 2016.**

It is worrisome that 81% of the territory affected by EVOA in reserves is located in territories of the Embera and Embera Katío ethnic groups. The 10 most affected reserves gather 84% (655 ha) of EVOA detected, and are located in the departments of Chocó, Antioquia, Cauca, and Guainía.

![Graph 6](image)

**Graph 6. The 10 Indigenous Reserves with the greatest impact of EVOA with the use of machinery on land 2016.**
Afro-Colombian Community Territories

The EVOA detected in Afro-Colombian Community Territories\textsuperscript{36} report 34,858 ha for the year 2016; this figure represents 42\% of the total detected throughout the national territory, which warns of the need to design strategies and public policies around the problem of illegal exploitation, taking into account the particularities of these territories.

The Afro-Colombian Community Territories of Chocó are the most affected with 84\% of the EVOA area detected in these special management zones. Of the 67 Afro-Colombian Community Territories of the department, 17 (25\%) present evidences of the phenomenon. The most affected are Mayor del Cantón de San Pablo “ACISANP”, Istmina y parte del Medio San Juan, and Mayor del Medio Atrato Acia, these three territories group 38\% of the EVOA detected in this department.

81\% of the territory affected in these territories is focused on 10 community councils located in the department of Chocó. It is important to highlight that of the evidences detected in Chocó, 94\% are in these territories that, being part of the Chocó Biogeographic, are characterized because their ecological structure ensures in time the conservation of biodiversity, its functionality and the provision of ecosystem services that sustain the well-being of the population present in the territory [15].

In these territories, water sources are in many cases the only transport route for communities located in their area of influence, as well as the means of

\begin{table}[h!]
\centering
\begin{tabular}{|l|c|}
\hline
\textbf{Afro-Colombian Community Territories} & \textbf{EVOA 2016 (ha)} \\
\hline
Mayor del Cantón San Pablo “ACISANP” & 4,698 \\
Istmina & Parte del Medio San Juan & 4,514 \\
Mayor del Medio Atrato ACIA & 4,151 \\
Acadesán & 3,395 \\
Mayor de Unión Panamericana & 2,929 \\
Mayor de Nóvita & 2,916 \\
Mayor del municipio de Condoto e Iró & 2,566 \\
Paimadó & 1,203 \\
Mayor de Alto San Juan “ASOCASAN” & 1,184 \\
Cértegui & 839 \\
\hline
\textbf{Total} & \textbf{28,395} \\
\hline
\end{tabular}
\caption{The 10 Community Councils with the largest EVOA area in the national territory.}
\end{table}

According to interviews conducted by SIMCI during the year 2015 in the Pacific region, the hydrographic basin is the primary territorial axis for carrying out alluvial gold exploitation activities in this region. Rivers act as hubs of connectivity between exploitation zones and supply sites and constitute a nucleus for the advancement of the phenomenon. In this sense, the Basin must be observed as a base territory to understand the dynamics of the phenomenon.

In this context, according to [15], the water sources of the region fulfill a socio-cultural function, since the communities settled in its low-lying areas depend on the resources they obtain and transport through their channels, since they are mainly dedicated to fishing activities, wood extraction and consumer agriculture practiced in river valleys.

\textsuperscript{36} DECREE 1754 of 1995. Article 3\textsuperscript{\textordfракtus}. A black community may be constituted as a Community Council, which as a legal entity exercises the highest authority of internal administration within the lands of the Black Communities, in accordance with the constitutional and legal mandates that govern it and the others assigned by the legal system proper to each community.

In the terms of number 5, article 2 of Law 70 of 1993, Black Community is the set of families of Afro-Colombian descent that have their own culture, share a history and have their own traditions and customs within the field-town relationship, that reveal and conserve awareness and identity that distinguish them from other ethnic groups [102].
obtaining the natural resources necessary for their subsistence and a predominant factor in their productive cultural practices [15].

In this sense, access and movement through the territory presents serious limitations; more than half of the municipalities are not connected by road network, and although the water network is wide and allows communication within the basins, it presents draft restrictions for the vessels, so that an important part of the territory can be connected only by means of low capacity boats [16].

This factor limits the access of development and control actors to the territory, facilitates the establishment of illegal phenomena and increases the conditions of vulnerability.

Mining areas of ethnic communities

In the territories of Afro-Colombian Community Territories Lands or Indigenous Reservation (i.e. “Resguardos”), the Government established three special figures: mining areas of black communities, indigenous mining areas and mining areas of mixed communities. These are delimited by the mining authority and grant them a right of priority over third parties at the time of being requested a mining title in that area [17].

Additionally, the delimitation of these zones entails the right of priority, so that the mining authority grants a concession over mining beds and deposits located in an indigenous mining area or in a mining area of Afro-Colombian Community Territories [18]. Said delimitation does not grant the right to explore or exploit in accordance with article 34 of the Mining Code.

There are 41 mining areas of Afro-Colombian Community Territories located in the Pacific region in which 81% of the EVOAs are located in areas of special management of Afro-Colombian Community Territories.

On the other hand, there are three mining areas of Indigenous community, Chorrobocón, Delicias, Canoas, and Yaberaradó that present EVOA and group 10% of the evidences detected in Reserves.

It is important to mention that the presence of EVOA in these territories indicates that the use of the resource is not carried out under the special conditions of protection and participation of the communities, which give rise to the regulations and which tend to preserve their cultural and economic characteristics.
Map 6. Distribution EVOA in indigenous mining areas and mining areas of Afro-Colombian Communities, 2016.
Forest Reserve Areas

One of the government tools for the development of forestry economy and protection of soil, water and wildlife is oriented in the seven (7) Forest Reserve areas constituted by the issuance of Law 2 dated 1959 [19]. These areas are framed in a zoning and ordering process, with the purpose of establishing the general guidelines to guide environmental management processes within these areas, serving as a planning and guidance input in environmental matters for the different productive sectors of the country [20]. It is appropriate to clarify that although these areas “are not protected areas”, there are areas within the National System of Protected Areas SINAP and collective territories.

Under the condition of not constituting itself a protected area, the competent environmental authority may authorize the theft of areas from these areas for multiple purposes.

49% (40,834 hectares) of the national EVOA total is located in Forest Reserve areas. The Forest Reserve of the Pacific registers the greater affectation with 69% of the total detected in this figure.

Graph 8. EVOA 2016 participation percentage in Forest Reserves.

Although the Amazonia Forest Reserve (0.4%) reports very low affectation, it should be taken as a national alert due to the affectation of this important region in the world level because it constitutes a strategic mega biological corridor of high value in the conservation of global biodiversity, mitigation and adaptation to climate change [21]. The maintenance of the supply of ecosystem services lies precisely in its connectivity and conservation [22]. Consequently, this alert calls for deepening knowledge of the vulnerabilities of this territory for the design, development of control strategies and policy formulation according to the particularities of this ecosystem.

The Forest Reserve areas established in Law 2 dated 1959 and other national forest reserves may be subject to realinderation, subtraction, zoning, ordering, recategorization, incorporation, integration, and definition of the regime of uses, by the Ministry of Environment and Development Sustainable based on technical, economic, social and environmental studies [89]; except the National Protective Reserve Zones.

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37 A zoning system integrates a hierarchical process with multi-criteria analysis techniques, which allows generating decision alternatives related to land use and where different actors participate [84].
The study allows one to identify that of the EVOA detected in the Pacífico Reserve, 0.8% is in the SINAP territories, 0.2% in the PNN zones, specifically in the Los Katios PNN and Paramillo PNN, and another 0.6% in areas of National Protective Forest Reserves, River Anchicayá and Rivers Escalarete and San Cipriano.

<table>
<thead>
<tr>
<th>Forest Reserve</th>
<th>PNN ha</th>
<th>SINAP ha</th>
<th>Outside of protected areas ha</th>
<th>Total ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amazonia</td>
<td>57</td>
<td>96</td>
<td></td>
<td>153</td>
</tr>
<tr>
<td>Central</td>
<td>48</td>
<td></td>
<td></td>
<td>48</td>
</tr>
<tr>
<td>Magdalena</td>
<td>12,436</td>
<td>12,436</td>
<td></td>
<td>24,872</td>
</tr>
<tr>
<td>Pacífico</td>
<td>50</td>
<td>173</td>
<td>27,975</td>
<td>28,198</td>
</tr>
</tbody>
</table>

**Table 12. Areas of the SINAP in Forest Reserve Areas affected by EVOA.**

On the other hand, 96% of the EVOA detected in the Pacífico Forest Reserve, are concentrated in Chocó with 87%. While in the Magdalena Reserve, Bolívar and Antioquia concentrate the entire EVOA with 59% and 41% respectively. Finally, in the Amazonía Reserve, the department of Guainia registers 77% of the EVOA detected in this reserve. It is striking that the Puinawai Natural Reserve located in the department of Guainia concentrates 37% of the detection in this Forest Reserve.

Regarding the dynamics of these zones, in relation to the expansion of the phenomenon, the study detects that the Pacífico and Magdalena Reserves group 33% of the national detection, with 22% and 12% respectively. However, when considering the Forest Reserve Zones individually, in the Amazonia Reserve, 84% of the detection of EVOA for 2016 corresponds to expansion of the phenomenon or new areas in respect of the study carried out at the end of 2014, this dynamic again calls the attention the exercise of control of sovereignty in this region.

<table>
<thead>
<tr>
<th>Forest Reserve Zone</th>
<th>2016 ha</th>
<th>EVOA Stable ha</th>
<th>EVOA New ha</th>
<th>% EVOA Stable</th>
<th>% EVOA New</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amazonia</td>
<td>153</td>
<td>25</td>
<td>128</td>
<td>16</td>
<td>84</td>
</tr>
<tr>
<td>Central</td>
<td>48</td>
<td>27</td>
<td>21</td>
<td>56</td>
<td>44</td>
</tr>
<tr>
<td>Magdalena</td>
<td>12,436</td>
<td>7,649</td>
<td>4,787</td>
<td>62</td>
<td>38</td>
</tr>
<tr>
<td>Pacífico</td>
<td>28,198</td>
<td>19,103</td>
<td>9,096</td>
<td>68</td>
<td>32</td>
</tr>
</tbody>
</table>

**Table 13. New and stable areas in Forest Reserve Areas.**

The municipalities of Río Quito (4%), Nóvita (3%) and Cantón del San Pablo (2%) in the Pacífico Reserve occupy the first three places in new areas of EVOA for the total detected in Forest Reserve Areas, while the municipality of Montecristo in the Magdalena Reserve occupies the fourth place with 2%.
UNODC has been supporting, for 17 years, the analysis of the permanence of coca crops on the national territory; the monitoring of this phenomenon has made it possible to identify links with other illegal activities such as the alluvial gold exploitation without complying with the requirements by the law. These illegal activities converge in the same territory as a consequence, among others, of the conditions of vulnerability that favor their establishment.

The territories affected by coca crops are characterized by conditions of poverty, marginality, weak institutional presence and the presence of armed outlaw groups [23]; under these same conditions the phenomenon of alluvial gold exploitation has been configured as a threat not only to strategic natural ecosystems but as a trigger for social and economic conflict.

The spatial analysis of the territories affected by coca crops and EVOA for 2016 on a framework of square grids of 5 km, indicates that the geographical coincidence of the two phenomena increased by 4 percentage points compared to what was identified in 2014, going from 38% to 42%. In the coinciding territories, the presence of 83,620 ha of EVOA and 11,880 ha of coca was identified. In a departmental approach, Antioquia and Putumayo reflect a significant increase in spatial coincidence compared to what was observed in 2014.

**Graph 9.** Matching territories affected by EVOA and coca crops, 2016.
In the coinciding territories for the two phenomena, a concentration of 29% of the evidence of alluvial gold and 8% of the area sown with coca for 2016 is identified.

52% of EVOA 2016 is concentrated in 10 municipalities, which are part of the departments of Antioquia, Chocó, Bolívar, and Córdoba. Zaragoza, is the municipality with the greatest impact by EVOA. In these affected territories, the presence of 2% of the total area sown with coca was identified for the same period; within this ranking, Cáceres, in Antioquia, which ranks seventh in the area affected by EVOA, with 4,096 ha, has the greatest impact on coca with 1,131 ha.

In total, of the 131 municipalities affected by EVOA in 2016, it is reported that 74 are affected by the presence of coca crops for the same period. The municipality with the greatest impact due to coca in 2016 was Tumaco with 23,148 ha and with EVOA an impact of 54 ha is reported.

In Nariño, Putumayo, and Caquetá, there is a spatial coincidence between areas affected by EVOA and coca in more than 80% of the territories detected with EVOA. As opposed to what was identified in 2014, Putumayo shows an increase from 81% to 91% in coinciding territories. These three departments are increasing both in the area reported with coca and with EVOA.

The municipalities of Barbacoas, Magüí Payán, and Santa Bárbara in Nariño have the highest values of EVOA and values of significant affectation for coca. In Putumayo, the municipalities of Puerto Guzmán, Puerto Caicedo, and Orito present an important coincidence of the two phenomena, and in Caquetá, the activity of EVOA grew significantly compared to what was observed in 2014 and the spatial coincidence with areas with coca presence in the municipalities of Curillo and San José del Fragua.

Timbiquí, López de Micay, and Guapi are the municipalities most affected by EVOA in Cauca; these municipalities present a significant increase in the area occupied by EVOA compared to what was observed in 2014, as well as for the area with coca in the period 2015-2016. The spatial relationship of these two phenomena is maintained at 70% and is concentrated in the areas of the Pacific coast.
Although Chocó is the department with the highest detection of EVOA in 2016, it presented a slight reduction compared to that observed in 2014, originated by the establishment of grasses and herbaceous vegetation in previously affected areas; the territories coinciding with the presence of coca crops were also reduced, going from 35% to 25% in 2016. The municipalities that have the greatest impact on the two phenomena are Nóvita, El Cantón de San Pablo and Itsmina; these municipalities, both for coca and for EVOA, have variable dynamics. In the north of the country, in Bolívar, the spatial coincidence between coca crops and EVOA was reduced by 3 percentage points, going from 45% in 2014 to 42% in 2016. In the department, there was a slight increase in the area with EVOA and for coca crops in 2015, there was a significant reduction but for 2016, the area with coca increased again. The municipalities with the highest coinciding impact are Montecristo, Santa Rosa del Sur and Simití.

Antioquia presents a growth of the area affected by EVOA and a significant increase of the area with coca between 2014 - 2016; territories with a spatial relationship for both phenomena increased from 33% to 40% in 2016. The municipalities of Zaragoza, Nechí, and El Bagre have the highest values of affection for the two activities. In Córdoba, the percentage of coincidence for coca and EVOA is low, 3%; 96% of the area affected by EVOA has no spatial relationship with coca.

In Antioquia and Putumayo there is an increase in the area sown with coca as well as an increase in the affected area with EVOA, in turn, there is an increase in the territories with spatial correlation for the two activities.

In Guainía and Magdalena there is affectation due to the presence of coca crops, however, this activity is not close to the affectation by EVOA. The departments of Caldas, Huila, Quindío, and Risaralda are not affected by coca crops.
Affected territory by EVOA and coca crops, 2016

RELATIONSHIP BETWEEN EVOA AND LAW FIGURES

The methodology used for the detection of EVOA, does not pretend to characterize the activity of alluvial gold exploitation nor the legality of it. The objective is to strengthen the competent entities responsible for the administration, management and control of resources, with information to improve the characterization of the phenomenon in the territory. For this purpose, observing the spatial nature of the EVOAs and the zones under law frameworks related to the gold exploitation such as, environmental licenses, *amparo de títulos*, contract proposals and requests for legalization allows obtaining a territorial vision of this variable.

The information related to *amparo de títulos*, contract proposals and requests for legalization in the Colombian territory, has as its source the National Mining Agency - ANM, which is the entity in charge of managing the mineral resources of the State in an efficient, effective and transparent through the promotion, granting of titles, and the monitoring and control of mining exploration and exploitation, in order to maximize the contribution of the sector to the integral and sustainable development of the country [2].

However, it is worth noting that since 2012, Antioquia, through the Ministry of Mines, is the only department that operates as a mining delegation, with delegated functions of development and mining development, mining titling and supervision, following the guidelines of the Ministry of Mines and Energy and intervening directly in the territory [24]. Consequently, the Secretariat of Mines of Antioquia is the entity that provided the information of the department, regarding *amparo de títulos*, contract proposals and requests for legalization.

On the other hand, for environmental licenses, the source is the National Authority of Environmental Licenses - ANLA, as the entity in charge of ensuring that the projects, works or activities subject to environmental licensing, permit or processing, comply with environmental regulations, in such a way that they contribute to the environmental sustainable development of the Country (Decree 3573) [3].

Although the study deals in a general way with four legal figures, it is necessary to mention that the spatial crossing of the EVOA detected with these figures entails a different interpretation in two dimensions:

1. **Regulatory framework for the start of mining activity**: it implies the fulfillment of requirements to obtain the exploitation permit (mining title).

2. **Environmental regulatory framework**: it involves obtaining the environmental permit for the start of exploitation, but also involves a series of obligations, requirements and environmental conditions to which the owner has committed to guarantee the good environmental performance of the mining activity.

At this point, it should be pointed out that the magnitude and nature of the detected evidences, independently of being located under a law, imply a strong impact on the landscape that suggests the non-compliance of these environmental obligations.

- **Environmental licenses**: to advance the work of assembly and usufruct a mine, must have the mining title of exploitation and, subsequently, have obtained an environmental license [25]. Therefore, this figure refers to titles that have an environmental license, and is considered the only figure under which exploitation activities would be carried out within the framework of the law.

- **Amparo de títulos**: this figure, *Amparo de títulos*, although it is consolidated into one of the final
requirements for exploitation under the law, do not have the environmental permit granted by the environmental license. In this sense, when carrying out the spatial crossing with the EVOA detected, they are considered outside the framework of the law to carry out exploitation activities. However, at this point it is necessary to clarify that inconsistencies may arise in the licensing file due to lack of updating in the ANLA of the reports generated by the competent environmental authorities.

- **Contract proposals:** this figure only includes the areas that have been the subject of a request to enter into a mining concession contract between the State and individuals for mineral exploitation. However, the very nature of the figure implies the non-performance of mining operations, until the proposal triggers in the figure of Amparo de títulos and later environmental license. By following any evidence detected under these figures is considered outside the framework of the law

- **Requests for legalization:** under this figure are the applications under Law 685 dated 2001. It should be noted that, under this law, illicit gold exploitations are included that have made application for legalization and have prerogatives to exploit, however, the use of machinery is not allowed until the respective mining title is granted; therefore, the interpretation of the spatial crossing of the EVOA detected with this figure implies exploitations outside the framework of the law, but that have initiated a process for their legalization. Additionally, under this figure are also contemplated the applications covered by Decree 0933 of 2013, which are suspended and cannot develop exploitation activities.

By superimposing the EVOA with information provided by the ANM, the Secretariat of Mines of Antioquia and the ANLA, the spatial relationship of intersection between them was established.

The following graph illustrates the percentage relationship between EVOA and the related law figures:

Within the framework of the law (legal and environmental) it is established as a final requirement for the start of exploitation having obtained the approval of the environmental license that establishes the fulfillment of requirements, terms, conditions and obligations to prevent, mitigate, correct, compensate environmental effects of the project, among which a) severe deterioration to renewable natural resources, b) to the environment, c) notorious modifications to the landscape.

In this context, a national alert is generated, since, the EVOAs detected in the framework of this study, under the context of spatial crossing with figures of law or without them, focus on changes and notorious modifications in the landscape, which do not harmonize with the essence of environmental regulations, and show flaws in the monitoring and control of exploitation activities.

For 2016, 34% of the EVOA area coincides with some of the legal figures and the remaining 66% is not spatially associated with any figure. In this category, 23% is under the figure of “contract proposals” which by its very nature must not register any exploitation.

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39 The information of the ANM has a cut-off date of December 2016. The attached table does not differentiate exploitation methods or types of deposits, since the archives represent the universe of the figures of law around the exploitation of gold without differentiation by reef, or alluvium.

40 The information provided by the Secretariat of Mines of Antioquia has a cut-off date of September 2017 and, like that provided by the ANM, does not differentiate the type of exploitation.

41 The information provided by ANLA has a cut-off date of December 2016.

42 The first document [1], reports individually that 60% of the EVOA detected is not associated with any statute, additionally 4% is under the figure of contract proposals. In this sense, it should be considered that 64% of the EVOA detected in the previous study, were not under any figure of law.
These proposals are mainly focused on Chocó (37%), Antioquia (34%) and Bolívar (11%). On the other hand, 20% of the detected area is under the modality of “amparo de títulos”, a figure that remains stable in respect of 2014 and is again concentrated in the departments of Antioquia (56%), Chocó (20%), and Bolívar (19%).

Regarding “requests for legalization”, 7% of the detected evidences cross spatially with this figure, where 6.5% correspond to requests under Decree 0933 of 2013 and 0.5% to requests under Law 685 dated 2001, the latter, although they have prerogatives to exploit, they cannot use, machinery for their exploitation. Of the total contemplated under this figure, 54% is focused on Chocó, followed by Antioquia and Bolívar with 18% and 16% respectively. Cauca, Nariño and Putumayo also present EVOA under this figure.

Finally, 7% of the evidences detected are under the figure of “environmental licenses”, and are concentrated in their entirety in the department of Antioquia. It is striking that no other department registers environmental licenses for exploitation. However, there may be problems in the ANLA base due to lack of updating by the Regional Autonomous Corporations.

In the context of the legal and environmental framework established to initiate exploitation operations, this figure would comply with all the requirements. However, the evidences detected show a strong imbalance in compliance with management, monitoring and environmental control measures established by the competent authority for the granting of environmental licenses.

Additionally, despite geographical congruence, it is not possible to determine that exploitation is being done in a full formality framework. There is another figure that links the formality of these titles with disturbances in them, administrative protection. For the study it was not possible to access this information.

The following graph shows the percentage distribution of the EVOA under legal figures.

According to what can be observed in the graph, more than 50% of the EVOA detected in Caquetá, Guainía, Valle del Cauca, Nariño, Huila, Putumayo, Córdoba, and Chocó are outside any legal figure and the outlook is darkened even more when evidencing that although there are evidences under legal figures, they do not guarantee the fulfillment of the commitments and obligations acquired with the management and protection of resources.

The following map summarizes the departmental results (ha) of EVOA by nationally authorized figure.

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43 The administrative protection action is intended to prevent the illegal exercise of mining activities, the de facto occupation or any other disturbing act, current or imminent against the right that enshrines the title. The nature of this guarantee of mining rights against acts of disturbance or de facto occupation is reflected in a procedure foreseen by the legislator in which there is no vision or articulation of any confrontation between the individual and the State, but rather protection of the rights of a private subject in the face of the disturbing acts of another or others, all of which makes it a process of an eminently police nature [85].
Map 9. Departmental distribution of EVOA (ha) in relation to legal figures.
In 2016, the intervention of the Colombian Government against gold exploitations not protected under any law, was 1,708 operations in the country, including 1,018 operations reported by the National Army, and 690 police operations44; these include intervention to mines - pitheads, seizure of related machinery, and equipment, implements (stack of boards, hoses, boats, vehicles, spades, shovels), ammunition and explosives, solid and liquid inputs used during mining activities; among others.

The intervention operations are carried out by the operational groups of the Military Forces and the National Police; in some cases, according to nature, it is carried out in accompaniment with other institutions such as the Attorney General’s Office, the Technical Investigation Team (CTI), Regional Autonomous Corporations, SIJIN, among others.

For the operations reported by the National Police, in charge of the UNIMIL - National Unit against Illegal Mining -, 661 operations were carried out, involving 2,546 mines and captures of 2,067 people linked to illegal activities related to the exploitation of illegal mining. Among the machinery destroyed in the operations, 154 heavy-duty machines and 52 dredgers and dragons are counted; in relation to seized machinery, a total of 1,664 machines are registered, where 60% represent engines and motor pumps and 15% backhoe loaders. Finally, UNIMIL records the seizure of 51,344 gallons of hydrocarbons and 1,880 kg of mercury used in the exploitation and benefit activities.

As for the operations reported by the Brigade against the Illegal Mining of the National Army, of the total operations, 355 were made by the National Army, 285 as a whole National Army and National Police and two with the National Army of Perú. In general terms, it was identified that 45% of the interventions carried out are concentrated in the machinery and equipment category, which includes seizures of engines, motor pumps, dredgers, excavators, crushers, among others. In a second place, there are control operations for illegal exploitation and exploration with 15% of the national total; this action is directly related to the capture of people; 870 for the year 201645. They are followed with less than 7% representation, the operations related to seizure of explosives (Anfo, Indugel, slow wick, black powder) and mines intervened.

According to the information provided by the National Army, the department of Antioquia ranks first in number of operations with 37% of the national total (381 operations); Tolima follows with 11% (112 operations) and Valle del Cauca, 10.5% (109 operations). In Antioquia, operations are concentrated in the seizure of machinery and equipment with 37% of the total departmental; in order of importance continue the seizure of explosives, the entanglement (only present in this department) and the illegal exploitation and exploration that led to the capture of 222 people.

In Tolima and Valle del Cauca, operations related to the confiscation of machinery and equipment and illegal exploitation and exploration are the most representative; the latter allowed the capture of 64 people in Tolima and 99 in Valle del Cauca.

44 The data includes 29 coordinated operations.
45 The captured persons are prosecuted under the charges of illegal exploitation of deposits and environmental pollution; if the investigation process is extended to a criminal network, it proceeds to open investigations into related crimes such as money laundering, trafficking in persons, among others.
In 2016, Buriticá, in the department of Antioquia, is the municipality with the largest number of operations, with 223, representing 22% of the national total; where the most representative actions are those related to machinery and equipment, seizure of hose, explosives and woodworks. The second municipality in number of operations is Cali, in Valle del Cauca, with 54 operations that represented 5% of the national total.
EVIDENCE BASELINE OF ALLUVIAL GOLD EXPLOITATION USING MACHINERY IN WATER, BASED ON SPECTRAL INDEXES. STUDY CASE APAPORIS RIVER, PNN SERRANÍA DE CHIRIBIQUETE

This chapter deals with the results obtained through the application of the methodological model based on spectral indexes to detect alterations with suspended sediments in waterbodies, attributable to activities of gold exploitation using machinery in water. It should be noted that this methodology was validated through a pilot study on the Inírida River, department of Guainía [1].

The study area corresponds to the Apaporis River between the Dos Ríos and Puerto Penalito communities in shared boundaries between the municipalities of Solano in the department of Caquetá, Miraflores in the department of Guaviare, and Pacoa in the department of Vaupés. In this segment, the river constitutes the northern limit of the Serranía del Chiribiquete National Natural Park. The findings found in the present and previous study constitute the baseline for the monitoring of the phenomenon under the modality of exploitation with use of machinery in water, in these territories.

Before entering with the results obtained, it is pertinent to make an approach to the national and global connotation of the area bordering the Apaporis River, the PNN Serranía de Chiribiquete.

PNN Serranía de Chiribiquete

The Serranía de Chiribiquete National Natural Park has, in 2016, an area of 2,782,354 ha and is the conservation unit of the National Park System with the greatest extension in Colombia. It is located in the western end of the biogeographic Province of Guayana, which transcends the physical limits of the equally named Escudo (Shield) de la Guayana, which is one of the oldest rock formations on the planet. Due to the large area covered and access difficulties, it is believed that only a minimal part of the park has been investigated [26].

The Guyana Shield is characterized by: i) the presence of rock formations of approximately 2,000 million years old, known as Tepuyes ii) is one of the most biodiverse points in the world where you can find unique ecosystems still unexplored with endemic wild fauna iii) has a rock sample of prehistoric disappeared from the north of South America, and iv) place where the first men who inhabited America are kept intact and is the current shelter of at least four indigenous groups that remain in isolation and belong to the Huitoto, Caribbean language families and Arawak[27].

This natural and cultural wealth of the park has a connotation of global importance, for which UNESCO has under study its declaration as a world heritage site. The declaration of a good as patrimony of the humanity contemplates 10 criteria, the first six obey to goods of cultural character and the last four to goods of natural character. Among these, the PNN Serranía de Chiribiquete has connotation in the following:
In 1987, Carlos Castaño, director of National Parks, at that time, in a casual flight between San José de Guaviare and La Araracuara, overflowed the then unknown place and marveled at the Precambrian formations, after two hours of flight, he was convinced to include this cultural and emblematic manifestation of the country in the system of National Natural Parks. Thus, after two years of work, in September, 1989 it became official that Chiribiquete would become the largest reserve in the country with an area of 1,200,000 hectares, at that time [91].

Through Resolution No. 1038 of August 21st, 2013, issued by the Ministry of Environment and Sustainable Development, with the support of the Colombian Academy of Physical and Natural Sciences [92]. Recently the Colombian Government announced that by 2018 the park area will be increased to 4.5 million ha.

**Criterion I:** As the largest, densest and most impressive pictographic archaeological complex in northern South America, and represents a masterpiece of human creative genius due to the aesthetic refinement of the paintings and a monument of universal value because of the anthropological importance of the representations of hunting, dancing and mythological scenes.

**Criterion III:** The paintings of Chiribiquete are an exceptional testimony of a cultural tradition that has disappeared, but that is related to the cosmo-vision of the indigenous peoples existing in the central and eastern Amazon region of Colombia. The paintings of Chiribiquete are of great importance for ethnohistory and for the cosmologies of the surrounding indigenous groups and constitute a cornerstone for the understanding of past human migrations, war and the traditional use of the land, in the northeastern Amazonian zone.

**Criterion VIII:** It constitutes an outstanding example of geologic relics testimonies and of the physiographic characteristics of the most western part of the biogeographic Province of Guyana. Nowhere, to the west of the Roraima complex in Venezuela and northern Brazil, is there such widespread, high and fully conserved testimony of this ancient formation.

**Criterion X:** It contains a great diversity of biological communities with Andean, Guyanese and Amazonian elements due to its geological history and its geographical position at the junction of the Andean highlands, the Pantepuy in Venezuela and Brazil and the lowlands of the Amazon. It includes at least five endemic species and more than ten vulnerable or critically endangered species. Due to its great extension and state of conservation, it guarantees the perpetuation of these ecological characteristics, better than any other area in the Colombian Amazon [26].

Although the ecological integrity of the area, its large extension and difficult accessibility facilitate the dynamics of natural processes in ecosystems, alerts have recently been generated due to evidence of involvement due to activities surrounding illegal economies such as the presence of coca crops [28]46, [23]47, alluvial gold exploitation with the use of machinery in water48 and deforestation. These recent dynamics require the focusing of efforts and the design of specific strategies oriented to the natural conservation and maintenance of sovereignty in these isolated territories but of great cultural and natural richness.

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46 The study generated alert for expansion of the phenomenon towards the park, following the course of the Tacumena River.
47 In 2016, satellite monitoring and joint work with the Risk Management Office of National Natural Parks identified and verified the presence of coca crops within the park between the Tacumena and Macaya rivers, with additional interventions associated with recent logging.
48 Information supplied by illegal mining control entities reported the destruction of two rafts dedicated to gold mining in the Apaporis river bed, one of the natural limits of the park.
National Natural Park Serranía de Chiribiquete

Map 10. Serranía de Chiribiquete National Natural Park.

Source: Government of Colombia - Monitoring system supported by UNODC; for National Parks: National Natural Parks of Colombia. The limits, names and titles used in this map do not constitute recognition or acceptance by the United Nations.
BASELINE NATURAL SPECTRAL BEHAVIOR OF SUSPENDED SEDIMENTS APAPORIS RIVER

The results for the detection of alteration of suspended sediments related to the use of machinery in water for the gold exploitation in the Apaporis river channel, start from the identification of the baseline that reflects the natural spectral behavior of the river, this is, without being affected by external factors, such as the gold exploitation.

The construction of this baseline is based on specialized remote sensing tools, through the use of spectral indexes; for more methodological detail (see Annex 2).

Under this framework, the construction of the baseline was performed with satellite images corresponding to the year 1988, a period during which the channel was not affected by the alluvial gold exploitation. According to the results obtained in the previous study, the spectral index evaluated was the MNDWI, since it showed greater sensitivity to the registration of the index, since it takes advantage of the use of the range of the medium infrared electromagnetic spectrum, which makes it possible to differentiate and highlight places where the water content is affected by some alteration; this was selected for both the characterization of the baseline and for the analysis of the sediments [29].

It is worth noting that, in this study, the sensitivity of other indexes to the detection of the phenomenon was evaluated, but the MNDWI again showed to be the most robust for the detection of these alterations in the hydraulic body.

Baseline:
5 Path Row (Landsat Grid) 461, 560, 561, 659, and 660 were processed and interpreted, covering beyond the study area and comprising the Apaporis River path from the area called Dos Ríos in the department of Guaviare, up to the border with Brazil. The temporality of the images comprises from December to January.

Dynamics of the spectral behavior of the Apaporis River in the study area:
For the evaluation of the dynamics, the Path Row, which covers the study area, 0659 and 0660, were evaluated. With a total of 16 satellite images distributed in the years 1991, 1996, 2001, 2006, 2009, 2016, and 2017. Temporality of the images comprises from December to February.

<table>
<thead>
<tr>
<th>INDEX</th>
<th>DESCRIPTION</th>
<th>FORMULA</th>
<th>VARIABLES</th>
<th>AUTHOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>MNDWI Modification for Normalized Difference Water Index</td>
<td>This index is designed to discriminate the digital values between the waterbodies and the reflectance of the soils making use of the medium infrared band.</td>
<td>$\text{MNDWI} = \frac{\rho_{\text{Green}} - \rho_{\text{MIR}}}{\rho_{\text{Green}} + \rho_{\text{MIR}}}$</td>
<td>$\rho_{\text{Green}} = \text{visible green band.}$</td>
<td>[30]</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>$\rho_{\text{MIR}} = \text{infrared shortwave}$</td>
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</table>

Table 14. MNDWI spectral index.
The interpretation of the index indicates that values close to 1, reflect clear waters or without affecting the alteration of sediments, while values close to zero, show higher concentrations of suspended sediments. For the case study, the natural behavior of the river is in the index range between 1.0 and 0.5; values below this range show alteration in the sediment load.

When looking at the graph there is a sudden drop in the value of the index at point 20 of measurement. This particular point reflects an atypical behavior in the identified natural range, which is geographically related to a waterfall or cascade. For this specific case, the fall in the value of the index corresponds to the natural behavior of the river and is explained by the accumulation of sediments in the bowl or basin area [31].

The detection of changes must consider this natural condition for the identification of alterations at this point.

The baseline ensures that the satellite image of the river represents pixel values corresponding to the absence of anthropic activity over the course of the river; this one, when compared with other periods of study, marks the base point for the evidence of the alteration in the sedimentation of the river.

The graph shows the curve resulting from the application of the index for the construction of the baseline, which was validated by analyzing the congruence of the spectral response at the reading points of the index and the secondary information provided by territorial control organisms, as per the institutions present in the region. The behavior curve obtained was evaluated taking into account sensitivity for detection, and sensitivity to changes over time.

**Graph 12.** Top image Landsat RGB 547. Down Range “natural” spectral base line index MNDWI, 1988.
The following map represents the spectral natural base of the MNDWI index corresponding to a transect of the Apaporis River in the study area. Although the representation of the reading of the index on the map, it ranges from dark blue for waters without disturbance of sediments, to red for waters with strong alteration of sediments, in 1988, period of establishment of the baseline of natural spectral behavior, the index adopts the dark blue hue, that is to say, waters without disturbance of light blue sediments for natural sedimentation zones.
DETECTION OF CHANGES IN NATURAL BEHAVIOR BY OBSERVATION AND SPECTRAL INDEX ANALYSIS

The index application was made in the images identified for each follow-up period. The years evaluated correspond to 1991, 1996, 1998, 2001, 2006, 2009, 2016, 2017. The construction of the curves starts from the following premises in the identification of reading points: i) the points must cover the entire area of study (it is important to note that these points are the same as those used for the construction of the curves at all times of the study); ii) the reading points are systematically distributed every 1.5 km, taking into account the availability of information during the study periods, i.e., the analysis of null information due to the presence of clouds is avoided.

The table below shows the points (highlighted in red) that recorded alteration in the reading of the indexes in the different years of evaluation.

<table>
<thead>
<tr>
<th>Sample Point</th>
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<th>MNDWI 1988</th>
<th>MNDWI 2009</th>
<th>MNDWI 2016</th>
<th>MNDWI 2017</th>
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</tbody>
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50 The years 1991, 1996 and 2001 are not displayed in the table given that they are in the range of the natural spectral behavior of the river.
51 The names of the communities were obtained from Google Earth Pro, 2017.
### ALLUVIAL GOLD EXPLOITATION

<table>
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<th>Sample Point</th>
<th>Community nearby</th>
<th>MNDWI</th>
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<td>36</td>
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</tr>
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<td>37</td>
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<tr>
<td>41</td>
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<td>0.6430</td>
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<td>Vereda</td>
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<tr>
<td>83</td>
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<td>103</td>
<td></td>
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<tr>
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<tr>
<td>204</td>
<td></td>
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</tr>
<tr>
<td>210</td>
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<td>211</td>
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<td>0.5756</td>
</tr>
<tr>
<td>213</td>
<td></td>
<td>0.5837</td>
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</table>

<table>
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<tr>
<th>Sample Point</th>
<th>Community nearby</th>
<th>MNDWI 1988</th>
<th>MNDWI 2009</th>
<th>MNDWI 2016</th>
<th>MNDWI 2017</th>
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<td>216</td>
<td>Berlin</td>
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<td>0.6369</td>
<td>0.3359</td>
<td>0.8763</td>
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<tr>
<td>217</td>
<td></td>
<td>0.6627</td>
<td>0.5560</td>
<td>0.3089</td>
<td>0.8621</td>
</tr>
<tr>
<td>218</td>
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<tr>
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<td>0.1480</td>
<td>0.7066</td>
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<tr>
<td>225</td>
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<td>0.6158</td>
<td>0.4864</td>
<td>0.8838</td>
</tr>
<tr>
<td>226</td>
<td></td>
<td>0.6525</td>
<td>0.5968</td>
<td>0.4530</td>
<td>0.8177</td>
</tr>
<tr>
<td>227</td>
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<td>0.6985</td>
<td>0.5968</td>
<td>0.3188</td>
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<tr>
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<td>0.3950</td>
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</tr>
<tr>
<td>229</td>
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<td>0.6388</td>
<td>0.5379</td>
<td>0.4542</td>
<td>0.8532</td>
</tr>
<tr>
<td>232</td>
<td></td>
<td>0.5837</td>
<td>0.5637</td>
<td>0.1986</td>
<td>0.4422</td>
</tr>
<tr>
<td>233</td>
<td></td>
<td>0.5837</td>
<td>0.6180</td>
<td>0.4665</td>
<td>0.8120</td>
</tr>
</tbody>
</table>

## Graph 13. Curve of the spectral behavior of suspended sediments by application of the MNDWI index, Apaporis River. The segments outside the black limit correspond to alterations in the suspended sediments.
ALLUVIAL GOLD EXPLOITATION

For 1991, 1996 and 2001 the values of the index do not report alteration in the natural spectral behavior of the river; the year 2006 recorded an atypical behavior by extreme values in the dry season [32], which may affect the interpretation of sediment behavior in this period; due to this, this year is not considered for the analysis of results.

For 2009, alteration of the suspended sediments is evidenced in areas between the Dos Ríos and Puerto Penalito communities. In 2016, specific spots (hot spots) were observed on the upper Apaporis River in points near the communities of Dos Ríos, Macayari, El Morichal, Cornelio, and Tolima, and in the vicinity of Puerto Suárez, Puerto Penalito, and Berlín; for the 2017 alteration in the suspended sediments it is concentrated in points near the communities of Dos Ríos, Macayari, El Morichal, Cornelio, Tolima, Veracruz, Puerto Penalito, and Berlín.
VALIDATION BY ASSOCIATION OF DATA OBTAINED WITH SECONDARY INFORMATION

As part of the validation of the results obtained, information was obtained corresponding to overflight operations in the study area by the Colombian Air Force - FAC\(^\text{52}\) and operations of interdiction and control of the Army and the National Police. The results of the spatial correspondence analysis between the findings provided by the MNDWI index and the secondary information validate the results obtained.

In the specific case of the information provided by the Colombian Air Force - FAC, although it is true, there were no dredges in mineral exploitation activity, but three specific points with slabs for the support of the machinery, associated with the exploitation activity, were evidenced. These evidences detected in the overflight, locate anchoring sites of the machinery when it is not in operation, which are at a distance of approximately 4 km to the detection sites of the hot spots.

The exploitation of alluvial gold in water is not carried out in a static mine, because dredges and similar machinery move along the body of the river in search of the mineral. Moreover, they only stay when they find profitable production volumes.

\(^{52}\) According to the overflight made by the Colombian Air Force in August 2017, Apaporis River, three infrastructures are identified that correspond to platforms for the exploitation of gold.

On the other hand, information provided by the Colombian Army on operations to control illicit exploitation of minerals carried out during 2016, allowed to validate the congruence in the findings of the hot spots detected in the vicinity of the El Morichal Community.

According to results obtained in the previous study for the gold exploitation, “research” tasks are carried out (the rafts explore along the river in search of gold); once the exploitation site is identified, they are established during the time they consider that the production of gold is profitable, according to the size of the deposit they can last from days to months, the persistence in the alteration of sediments in the stretches of the river between the communities of Macayarí, Morichal, Cornelio, and Tolima, allow us to infer that they are large alluvial deposits, which favor the persistence of the exploitation activity in the area.

As a result, these hot spots of exploitation activities detected in the study area, bordering the Serranía de Chiribiquete Natural Reserve, in the process of being declared a “World Heritage Site”, increase the warning initially generated by the presence of illicit crops in the periphery, and within the Reserve [28], as well as the increase in fellings and now by alluvial gold exploitation in the Apaporis River.

It should be noted that this type of exploitation, without control, directly affects the ecosystem function of the water body by altering its physical characteristics and by contamination due to substances used in the benefit of gold. In this aspect, the repercussions on the fish resource, terrestrial fauna and population health are highlighted. It is striking that although alluvial gold is “free gold” and does not require the use of mercury for its benefit, it is used for speed and economy over clean techniques.

The application of this methodological model confirms again that the evidence of alluvial gold exploitation with the use of machinery in water, depending on the alteration of the sediments in the water body due to the disturbance of the bed during the exploitation operations, can be detected through the application of spectral indexes. In agreement, with the methodological validation obtained in this study and the one related to the Inírida River, the methodology allows to identify with certainty sites of alteration by exploitation activities that should be considered as alerts in this exploitation modality.

In the following map, it is possible to view sectors of the river where the alteration of sediments for 2017 is evident; the blue color represents the natural behavior, while the range from yellow to red reflects from minor to major alteration of the suspended sediments respectively.

In auriferous alluviums formed by natural mechanical concentration, gold is released in its entirety from its accompanying particles, such as quartz, carbonates, clays, and even sulfides; the gold lamellae disintegrate into granules with the appearance of scales and seeds; in this state the gold is for its recovery in the form denominated as “free gold”.

The mining of the gold of subsistence and of small scale mistakenly uses mercury for ease, rapidity and economy in the recovery of the free gold, for which it prefers in many cases the amalgamation on other techniques [51].

53 In interdiction operations carried out in November 2016, between the Colombian Army and the National Police, the destruction of two dredges and the prosecution of materials used for the benefit, among them, mercury, were carried out.
Detection of suspended sediments alteration by spectral indexes MNDWI 2017 and secondary information registers - FAC.

**Map 12.** Detection of suspended sediments alteration by spectral indexes (MNDWI - 2017) and secondary information registers FAC August 2017.
This section presents the basis for the implementation of an integrated model to monitor the gold exploitation in Colombia, through four complementary studies.

Beyond the actual results, the studies seek the design of methodological guides applicable in the context of other regions.
Related Studies

Within the framework of the cooperation agreement between the United Nations Office on Drugs and Crime (UNODC) and the Ministry of Mines and Energy (MME), it has sought to contribute to the development of studies focused on the dynamics of gold exploitation under the territorial approach. We present here a synthesis of the research model for the identification of the most outstanding features in the dynamics associated with the gold exploitation in its different dimensions with territorial ordering approach, carried out with a pilot case in the municipality of Guapi (Cauca), and whose development will be published later.

The general objective, the identification of the information requirements that facilitate the inclusion of the mining variable in the planning and territory management instruments. To this end, a methodology was developed for the collection of primary information in the municipality of Guapi, the dynamics associated with mineral exploitation in the municipality were analyzed, and on this basis, recommendations were made for the integration of the energy mining dimension in the municipal EOT.

The model starts from the integration of landscape information in terms of land cover, mining potential and expectation and vision of the communities and institutions present in the territory around the gold exploitation activity. The first component was addressed by multi-temporal analysis of landscape coverage transformation from remote sensing tools in three periods of time 2010, 2014 and 2016. The second component is supported in the available official cartographic information and the third component is addressed through interviews and workshops54 with focal groups of the municipal government and other institutions, with representatives of the Afro-Colombian Community Territories and other community organizations in the municipality.

Both with the institutions and with the communities, the problems were addressed from a territorial analysis approach, using as a main tool the social cartography, which allows identifying the location of diverse phenomena in the territory, and facilitates the establishment of spatial relationships that frequently they cannot be identified by means of classical quantitative analyzes. In this way, the social, economic, environmental, cultural, and security dimensions are integrated around the gold exploitation.

Main findings

Composition and distribution of the population in the territory

Based on the DANE projections, the municipality of Guapi has approximately 29,797 inhabitants, of whom 61% are located in the municipal seat and 39% in rural areas. The population is mostly Afro-descendant, and there is a small Eperara Siapidara community organized in two indigenous councils, although there is no collective shelter territory.

54 The workshops were carried out by a team composed of members of UNODC and MME.
Most of the municipal territory corresponds to Afro-Colombian Community Territories, established in Community Councils as detailed below:

<table>
<thead>
<tr>
<th>Community Council</th>
<th>Area (ha)</th>
<th>Productive activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consejo Comunitario de la comunidad negra del Alto Guapi</td>
<td>103,742</td>
<td>Agricultural production. Gold exploitation.</td>
</tr>
<tr>
<td>Consejo Comunitario Guapi Abajo</td>
<td>43,196</td>
<td>Agricultural production. Fishing.</td>
</tr>
<tr>
<td>Consejo Comunitario de la comunidad negra del río Napi</td>
<td>47,007</td>
<td>Agricultural production. Gold exploitation.</td>
</tr>
<tr>
<td>Consejo Comunitario de Chanzará</td>
<td>3,144</td>
<td>Agricultural production. Fishing.</td>
</tr>
</tbody>
</table>

Table 16. Guapi Community Councils.

Along with the Community Councils, there are several civil society organizations that have been developing works to promote development in various areas; some of the most outstanding organizations are the following:

<table>
<thead>
<tr>
<th>Organization</th>
<th>Mission</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooperativa de mujeres productivas de Guapi - COOPMUJERES</td>
<td>Established in 1992, it seeks to solve the social and economic problems of women in the territory.</td>
</tr>
<tr>
<td>Pastoral Social del Vicariato de Guapi</td>
<td>Evangelization and Christian formation. Accompaniment to the communities in the development of social works.</td>
</tr>
<tr>
<td>Asociación de Consejos de Guapi - ASOCONGUAPI</td>
<td>Defense of the interests and solution to the problems of the Community Councils of the municipality.</td>
</tr>
<tr>
<td>Fundación Chiyangua</td>
<td>Rescue of cultural practices, equity and gender in the Guapi river high and low basin.</td>
</tr>
<tr>
<td>Empresa comunitaria de mujeres rurales de Guapi “Ríos Unidos”</td>
<td>Organizational strengthening and productive projects of women in the municipality.</td>
</tr>
<tr>
<td>Asomanos negras</td>
<td>Ethnic-political work in San Francisco river, Guapi river high and low basin.</td>
</tr>
</tbody>
</table>

Table 17. Social organizations in Guapi.

Security dimension

The municipality of Guapi has registered a historic presence of the FARC - EP (Front 29), the ELN (Warrior Front of Sindagaua), and various criminal organizations. The recent demobilization of the FARC - EP has led to an increase in the presence of the ELN and criminal organizations associated with drug trafficking, as well as the illegal gold exploitation. The ELN is located in a mobile corridor in the area where the Guajuí and Napi rivers converge, where the two Vive Digital kiosks are also located that the municipality has, four of the seven meeting centers of the Community Councils, and three zones of alluvial gold exploitation with active machinery. Likewise, a point of possible settlement of this guerrilla was identified on the border with the municipality of Timbiquí.
In the municipality, the National Navy, the National Army, and the National Police have presence and regular activities. The Navy has patrol and control jurisdiction up to 20 km from the coastline, and operates with the Infantry Battalion No. 42 that is part of the Second Marine Infantry Fluvial Brigade. For its part, the National Army is present with the Twenty-Ninth Brigade through the Tactical Unit of the Infantry Battalion No. 56 Francisco Javier González. The National Police operates with a station located in the urban area, and performs occasional actions in the rural area of the municipality. The Air Force has Juan Casiano Airport for the development of military and humanitarian operations.

The public entities perceive that there are weaknesses in the coordination of the different entities of the Public Force, and they would expect a greater presence and control in the territory. In particular, the increase in the presence of the ELN in some areas of the municipality generates concern in the authorities and the communities, which is why they expect a more regular presence of the National Army.

The communities raised the need to expand the scope of action of the National Police, since it has no presence in the municipal administrative units and hamlets. Likewise, they stated that the controls on the passage of machinery for gold exploitation in the rivers of the municipality are not operating effectively, and expressed their concern since the communities cannot contain the passage of this machinery, often associated with illegal armed actors.

The Directorate of Narcotics - DIRAN of the National Police, identified in 2016 trafficking routes of illegal arms and explosives that follow their route to the Argelia municipality; they also discovered a route for the entry of chemical substances and products used in the production of cocaine hydrochloride, as well as a route for the departure of cocaine shipments to Central America.

The integration of the information reported by the institutions in the workshop carried out by UNODC is presented in the map 13.

**Economic dimension**

**Situation of public finances**

For the period between 2011-2015, the municipal added value has constituted less than 2% of the departmental total in all the years of the series.

The municipality of Guapi registers a Fiscal Performance Index of 57% for 2015. The municipality has remained in fiscal risk condition for the last 15 years. In the national ranking of the performance index for 2015, Guapi is ranked 1,054 out of 1,101 in the country, ranked 169 out of 178 in the Pacific region, and 39 out of 42 in the department of Cauca.

The fiscal management presents high risk, mainly explained by the low level of own resources, dependence on the transfers of the Nation and the low capacity to generate own savings and resources for investment.
Integration of the mining dimension for the municipality of Guapi

Map 13. Systematization of the workshop with institutions. Source: participants to the workshop conducted by UNODC on July 18th, 2017.
The municipality faces great difficulties to guarantee its financial solvency in the long term. However, its rating improved, going from 48.5% in 2014 to 56.9% in 2015.

**Unsatisfied Basic Needs (NBI) in Guapi**

The NBI for the municipality of Guapi is 67%, twenty percentage points above the departmental average, and 2.5 times above the national average. In the head-municipal, the NBI register 23%, while in the rural area they reach 73%. Additionally, according to the 2012-2015 Development Plan, 32.5% of the population of the municipality lives in extreme poverty, and it is estimated that more than 85.6% of households do not cover basic expenses.

Based on the 2012-2015 Development Plan, 32.5% of the population of the municipality lives in extreme poverty, and it is estimated that more than 85.6% of households do not cover basic expenses.

### Land use and agricultural production in the municipality

According to the results of the National Agricultural Census, 80% of the land in the municipality corresponds to natural forests, 14.1% to agricultural production, and 5.5% to other uses. The registry of cultivated area in the municipality provided by the municipal evaluations carried out by the Ministry of Agriculture indicates a significant decrease in the agricultural production of the municipality in the last decade, going from 2,176 ha in 2007, to 1,090 in 2016. The most important crops in the municipality, by area planted, are oil palm, banana, and coconut. The coca crops in the municipality presented their highest peak in 2008, with 1,912 ha.

![Graph 15. Unsatisfied Basic Needs (NBI) Guapi. Source: DANE.](image)

Although in 2016, Guapi occupies the third place in percentage participation (19%) in the department with evidences of alluvial gold exploitation, occupies the first place in expansion of the phenomenon, going from 81 ha in 2014 to 722 ha in 2016.

### Gold exploitation in the municipality

The record of the volumes of production of gold for the period 2002-2016, shows that in the last two years the exploitation of this mineral has increased sharply, going from 128,454.34 gr in 2014, to 717,978.95 gr in 2015. Note that there is a high risk of under-registration of municipal production, while a seemingly important fraction of the product is marketed in Medellín and other cities.

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55 The municipal seat is a term used in the context of the census of the National Administrative Department of Statistics - DANE in Colombia. Corresponds to the most densely populated area of the municipality and where the headquarters of the municipal Mayor’s Office. Its geographical area is defined by an urban perimeter, whose limits are established by “agreements” of the Municipal Council (100).

The methods of exploitation of alluvial deposits include subsistence mining, the use of small machinery in systems of low technification, and the use of heavy machinery on land (backhoes), in irregular, informal, or illegal conditions. In this regard, it should be noted that during the period 2014-2016, in the municipality there was an increase in the EVOA of 900%, from 80 to 722 hectares during this period.

The representatives of institutions estimate that from 20 to 25% of the population obtains resources from the exploitation of minerals, and mainly from gold. Currently 6,811 people are registered in the registry of barequeros that the municipal mayor’s office holds. There are two requests for assignment of Mining Zones of Afro-Colombian Communities, but they have not been formalized so far.

In the cultural sphere, barequeo is a popular community art and activity that has historically been exercised to search for gold in the municipality rivers as a means of subsistence. There is a wide range of practices and cultural expressions that still survive.

57 Rice, coconut, corn, oil palm and banana.
59 Subsistence mining allows only strip mining activities and is limited to the extraction and collection of sands, river gravel, (destined to the construction industry), clays, precious metals, precious, and semi-precious stones, as well as to work of barequeo.
in the municipality, which could be recovered and exalted at the local and regional level as part of the cultural heritage of Guapi and the department of Cauca.

The development of extractive activity has been generating clashes between some representatives of the Afro-Colombian Community Territories and organizations of the territory, since there are positions in favor and against the gold exploitation in the municipality. Additionally, there are weaknesses in the boundaries of some of the collective territories, which have led to clashes between the communities, mainly related to the gold exploitation.

The transformation of traditional mining to exploitation with the use of heavy machinery in the municipality brought with it a number of related social conflicts, associated with the control of the business, the participation of communities in the benefits of exploitation, and environmental and of health that are associated with this form of exploitation. Additionally, the operation with machinery is organized by illegal armed groups; the modalities of participation of these groups are “grammage” (percentage share in the product) or financing of operations by third parties.

The presence of these has generated extortion to small and medium miners, threats and selective killings of social leaders defending traditional mining, displacement of communities where there were large gold deposits, and the feeling of fear, insecurity, and loss of ownership of the territory by the communities.

The recent bonanza of the gold exploitation has led to the establishment of places of prostitution and the increase in the consumption of alcohol and drugs in the territories surrounding the exploitation areas, a situation that has generated social conflicts in the territories.

Recommendations on integrating the mining-energy dimension in the EBOT

1. Integrate the mining-energy dimension in the local government structure, either through the establishment of a specialized secretariat, or through the integration of this axis of development in another related secretariat (agriculture or economic development).

In this way, the institutional architecture can be developed by incorporating specialized personnel to facilitate compliance with the regulations, and the appropriate treatment of the processes of regularization and formalization of mining activity in the municipality.

2. Determine mining exclusion zones in the municipality, related to the protection of strategic environmental assets, and ecotourism development zones.

3. Define the Mining Zones of Afro-Colombian Community Territories of the municipality, through concertation processes with the Community Councils and the municipal Mayor’s Office, accompanied by the Ministry of Mines. These processes must be accompanied by training and formation processes, both of the communities and of the responsible institutions, in order to ensure a harmonious process in which the determinations are viable and can be effectively fulfilled.

4. Design and implement a strategy to control illicit gold exploitation in a joint manner between the institutions of the public force, from zoning based on control competencies, and the location of the potential mining area. Given the presence of the ELN and organized crime actors, the participation of the National Army is recommended through regular operations, as well as the study of possible points of location of a police station.

5. Together with the above, the analysis of the population concentration around the traditional gold mining centers deserves the study of the location of communications points that facilitate the interconnection of the communities with the head and the rest of the country, and of another part that facilitates the processes of denunciation of incursions of illicit exploitation in the basins of the rivers within the zone of mining development of the Municipality.
Within the framework of the cooperation agreement between the United Nations Office on Drugs and Crime (UNODC) and the Ministry of Mines and Energy (MME), it has sought to contribute to the development of studies focused on the dynamics of gold exploitation under the territorial approach. There is here a synthesis of the research model for the identification of the impact of mining activity in two municipalities of the department of Antioquia.

The general objective of the study, still in execution, is to characterize the effects that two modalities of realization of gold exploitation activity have had in two municipalities of the department of Antioquia. In the first case (Santa Rosa de Osos), the intervention of an international company that has implemented an environmentally sustainable exploitation and exploitation model, accompanied by a corporate social responsibility component, is analyzed. In the second case (Barbosa), the effect of mining activity is examined in a municipality where the extractive process has intensified without the presence of international agents, mainly due to the expansion of exploitation with machinery on land, and in association with a migratory process driven by the presence of gold in the territory.

The methodology consisted of carrying out case studies, applied under the framework of the territorial approach. The study addresses the social, economic, environmental, cultural, and security dimensions around the gold exploitation.

For the collection of information, recollection and documentary analysis was used, interviews with relevant actors in the municipality, and in the institutions related to the subject. Workshops were also held with focus groups of gold producers in the municipality. The workshops were carried out by a team composed of members of UNODC and MME.

Some of the preliminary findings are the following:

Santa Rosa de Osos
(Traditional and formalized mining activity)

1. Economic impacts of the mining activity: The mining activity in the municipality of Santa Rosa de Osos has resulted in the following impacts perceived as positive by the communities and the local government:
   a. Hiring of local personnel as unskilled labor.
   b. Increases in family income.
   c. Boost to the commercial dynamics.
   d. Technical and training support for traditional miners.
   e. Reinvestment of resources generated by mining activity in the improvement of agricultural production.
   f. Improvement of the tertiary road network in some villages.

2. Social impacts of mining activity: Primarily positive impacts have been detected; the most outstanding are the following:
   a. Expansion of employment sources.
b. Generation of income for the municipality, both for the taxes paid by the mining company and for those derived from the activation of local commerce.

c. Articulation of communities in social projects of the corporate social responsibility program applied by the mining company.

d. A negative impact is registered, related to the expansion of gambling houses, which are generating complex problems in some families of the municipality.

e. Economic dependence of the community towards the company.

Barbosa (Traditional, non-traditional mining activity with the use of machinery for alluvial exploitation, not formalized)

1. Economic impacts: The main economic impacts in this municipality can be summarized as follows:

a. Increase family income of families.

b. Activation of the commercial sector, and particularly associated with services for extractive activity.

c. Activation of commerce and consumption.

2. Social impacts: In the case of Barbosa, both authorities and traditional producers perceive a deterioration of social conditions in the municipality, associated with the exploitation activity, which are expressed in the following elements:

a. Massive migration processes that cause congestion in the provision of public and social services of the municipality (education, health, etc.).

b. Migrants have no appreciation for the territory or sense of belonging, so they do not care for natural resources in the exploitation areas and generate significant environmental damage.

c. Increase in prostitution, alcohol consumption, and associated street brawls.

d. Increase in sites for games of chance.

e. Increase in insecurity, mainly due to street theft.
During 2015, UNODC, in coordination with the Ministry of Justice and Law, developed a comprehensive research model aimed at characterizing the socioeconomic situation of rural communities in areas of gold exploitation and coca cultivation in the Colombian Pacific. Next, a synthesis of it is presented.

The quantitative study included conducting field surveys. The design of the applied survey was based essentially on the methodology of “Area Agricultural Sampling”. Which consists in dividing without duplication or omission the total area to be investigated in “N” small pieces called Sample Segments (SM), which make up the universe population; this division was made by square grids of 1 km. A total of 624 surveys were conducted.

Based on this methodological design, different possible scenarios were analyzed, which allowed a socio-economic characterization in territories with EVOA and coca crops. The surveys were distributed in three typologies, technically known as substrata, depending on the spatial crossing with some figure of law for exploitation.

Formalized Exploitation Activity: Grids in which an environmental license or amparo de títulos is registered, including or not EVOA or coca crops.

Request (Future Formal Exploitation Potential): Grids in which there was no presence of coca crops, EVOA amparo de títulos. But there could be contract proposals; by not registering EVOA, it is assumed that the exploitation activity with the use of machinery on land is not active.

Exploitation Activity outside figures of the law: Grids in which there is no record of License or Mining Title but which have the presence of coca crops and / or EVOA.

The findings were analyzed in the framework of the following dimensions:

- **Characterization of tenure and land use**
  It was found that more than 70% of the Units of Agricultural Production and / or Minerals (UPAM) surveyed in the Pacific region are occupied without title deed; just a little more than 10% have property titles, and the rest is under other tenure modalities (sharecropping, leasing, another form). It should be noted that the high percentage of occupation of land without title in the region, is due to the fact that in this region of the country, the form of tenure is governed by the collective tenure schemes provided in Law 70 of 1993.

In territories where the activity is formalized, it is observed that there is a considerable participation of land use for forests, around 33%, while in territories where the activity is not formalized a lower participation is observed, around 23%, which it may be associated with the fact that the illegal gold exploitation can develop with greater environmental impact to the extent that it is not controlled. Another aspect to be highlighted is a noticeable increase in the intensity of use and ownership of the land as the exploitation area is reduced, specifically in UPAM with small areas (less than three hectares), which dedicate a considerable proportion of the soil to the sowing of permanent crops, associated with
agricultural production for self-consumption and / or for commercial purposes.

- **Sociodemographic characterization of the population**

Undoubtedly, knowing the living conditions of the communities that are located in territories with formalized and non-formalized exploitation activity, become an elementary factor to comprehensively understand the dynamics around this activity. Among the most outstanding results, it was found that in territories where the formalized exploitation activity takes place, half of the surveyed population in the region considered that they do not study because they need to work (50.3%), whereas where it is developed the non-formalized activity showed that a little less than half considered the same ratio (44.8%). As for other reasons why the people who make up the home of the PAM do not study (different from the need to work), regardless of the substratum, the population aged between 19 and 24 years considered that the costs are the main reason for not study.

On the other hand, according to the results of the surveys, the armed conflict stood out as one of the main reasons for migrating to other departments, as manifested by the surveyed population where formal exploitation takes place as well as where it is not formalized. While in territories with request (potential for future formal exploitation), the main reason to migrate to these territories was due to work or business opportunities.

- **Economic conditions of the Agricultural and / or Mineral Producer (PAM) and labor market.**

The labor and occupational characterization of households in areas with mining influence and illicit crops is especially relevant if we consider that, a large part of the income of households comes from work. Under this understanding, it was evidenced that the barequeo, the licit agricultural production and the assistance in mineral exploitation activities were the most frequent occupational positions in the study population. It is noteworthy that the great weight that these occupational positions have corresponds to the high level of informality that exists in the labor market of the region, and in general, they are associated with low quality jobs and, therefore, with low remuneration.

In this sense, the gold exploitation in the Pacific region is consolidated as the main economic activity and the main source of household income. Likewise, it is observed that the UPAM present in the region have maintained a traditional subsistence system, that is, where agricultural activities and small-scale fishing are maintained, alternating with the gold exploitation. However, the proportion of people engaged in fishing showed a significant decrease.

In the case studied, the substratum where the highest levels of informality were recorded presented the lowest profitability. The average income in territories with non-formalized exploitation activity registered the lowest income compared with the other two substrata. This can be associated to several factors, among which stand out:

(i) that in this substratum the highest levels of unemployment were registered,

(ii) the development of illicit activities in this substratum, makes the income fluctuating for those who exercise this type of work (illicit gold exploitation, sowing of illicit crops, among others),

(iii) the population surveyed in this substratum is probably did not accurately report the income received in the reference period for any circumstance.

In the specific case of the substratum where the non-formalized exploitation activity is recorded, the profitability is low compared to those strata where there is a greater formality, which according to the study may be associated to the following factors:

(i) PAMs sell their production to local intermediaries (which can be illegal armed groups, investors with criminal capital, who do not pay the “fair” price,

(ii) The labor force is not qualified and offers its labor at any price,

(iii) The prices of the basic basket rise, making the standard of living of the population more expensive,

(iv) In this substratum, a high unemployment rate (6.0%) was registered.

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60 UPAM: Unit dedicated totally or partially to the development of agricultural activities and / or exploitation of minerals, which may be composed of one or more farms, located in one or more zones of the same municipality, provided that all are under administration or management and they share the same set of means of production, such as labor, machinery and work animals, regardless of the level of formalization of the property or size.
Finally, in the substratum with future formal exploitation potential, the highest average monthly profitability levels were registered, compared to formalized and non-formalized exploitation territories in the region.

- **Characterization of the perception of security and trust in institutions**
  
  Among the most outstanding results, it was found that the highest perception of safety occurs in the areas with formalized exploitation activity with 45%, followed by the territories with non-formalized exploitation activity with 29.6% and in the substratum with application (future formal exploitation potential) with 27.2%. Regarding the level of trust in the institutions, it was evident that in the region there is confidence on the part of the communities of the region, mainly in the National Government and in the Military Forces. In the substratum with formalized exploitation activity, according to the results of the surveys, there is a high distrust in the Governorates and the municipal Mayors; this same situation was identified in the sub-contract with request (future formal exploitation potential). On the other hand, in the territories with non-formalized exploitation activity, there was distrust in the City Halls followed by the National Police.

- **Environmental characterization of mining activity according to the perception of PAM**
  
  The results showed that the main environmental problems according to the perception of PAM, regardless of the substratum where they are found, are the contamination of water and rivers. For this it must be taken into account, that the second main source of water of the inhabitants of the region are the rivers, streams, springs, becoming a sanitary risk. According to UPAM’s perception, it is highlighted that despite the fact that the population recognizes the adverse effects of gold exploitation; considers that the activity should continue to operate in the territory. This result can mainly be due to two factors: (i) mining activity has become the main source of income; becoming a representative line in the economy of the region and (ii) there are other potential sources of income that do not present functional articulation to markets.

**Graph 18. Analysis of profitability by substratum in the Pacific region.**
DYNAMICS OF CHEMICAL SUBSTANCES (MERCURY, CYANIDE AND INPUTS) CORRELATED WITH GOLD EXPLOITATION ACTIVITIES

The difficulties to exercise more efficient mechanisms of control in the exploitation operations, has determined that the illegal exploitation systems employ invasive and disproportionate techniques for the exploitation process; it has been demonstrated that they resort to the intensive use of dredging and removal of soil supplemented by the uncontrolled use of chemical substances, with a high level of toxicity, to facilitate the gold exploitation. This scenario generates great concern regarding the impact on unique and diverse ecosystems, as evidenced in the departments of Chocó and Antioquia.

Chemical substances such as nitric acid, sulfuric acid, some solvents; ammonium nitrate, fuel oil for Diesel motor, ammonia explosives such as ANFO, fuels such as gasoline, cyanide and mercury salts enter the exploitation process. In the development of these activities there is a lack, on the part of the miners, in the control of the waste generated in the gold activity, as well as in the mechanisms of final disposal. Although the majority of these substances are used in the exploitation process, the cyanide and metallic mercury salts are relevant to the extent that they facilitate the obtaining of gold; in this context, these chemicals play an important role in the profitability of the gold mining process, being perhaps the main reason for its large-scale use, both in industrial mining and in small and subsistence exploitation.

First, cyanide salts (especially sodium cyanide and calcium cyanide) are used intensively, in low-concentration aqueous solutions, to recover the gold from the removed material.

The use of cyanide is associated with large gold mining operations (industrial gold exploitation or vein), which, in general, have technical and operational mechanisms that contribute to minimize the environmental impacts that could potentially be generated from their use.

Secondly, metallic mercury is used as a medium that allows metal to adhere to gold (amalgamation) in order to facilitate its capture.

From the review of documentation on the subject and thanks to the approach to the territories influenced by the gold mining activity, it was identified that metallic mercury is the chemical substance that the majority of mining producers use inadequately in the country, in any of the following processes:

a) The amalgamation process in which mercury is added during the grinding, milling or washing of the extracted mineral;

b) The concentration in tray: method in which making use of trays are generated rotating movements of the mixture of free gold and a specific amount of mercury in order to facilitate its identification;

c) The gutter: technique of concentration of the mineral that allows in a simple way to extract the gold by means of a system that allows to perform blows of water and to concentrate the minerals that are mixed with mercury;

Metallic mercury in the environment generates a high impact on water sources; from a chemical perspective, in aquatic environments, elemental

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61 Different strategies of approach to the territory were carried out in order to understand the dynamics of the mining activity, among which the following stand out: conducting surveys of agricultural and/or mining producers in areas of influence of the alluvial gold mining activity as well as the conducting workshops and interviews with local authorities and non-regulated mining producers. These strategies were executed within the framework of the Cooperation Agreement No. 589 between the United Nations Office on Drugs and Crime, through the Integrated Illicit Crop Monitoring System (SIMCI) and the Ministry of Justice and Law, Strategic and Analysis Sub-Directorate.
mercury, due to various highly complex factors in which even biogeochemical cycles act, is transformed into organic mercury, specifically methyl and dimethylmercury $\text{CH}_3\text{-Hg}$ and $(\text{CH}_3)_2\text{-Hg}$, highly neurotoxic molecules that have the characteristic of bioaccumulate and biomagnify, initially in fish fauna tissues. Therefore, the immersion of metallic mercury can increase the methylmercury that biomagnifies in the trophic chain up to one million times from its initial entry into the food cycle [33].

The use of mercury in communities close to the gold exploitation zones can cause affectation, given that it is a potentially mutagenic and teratogenic chemical; it can negatively affect the immune and reproductive systems of consumers of contaminated products and, in addition, neurotoxic and genotoxic effects have been proven, as well as inhibits the synthesis of proteins in organisms. A series of negative effects of this element on humans have been reported and documented, which can be classified mainly in:

- Damage to the central nervous system.
- Damage to brain functions.
- Damage to DNA and chromosomes.
- Allergic reactions, skin irritation, fatigue, and headache.
- Negative effects on reproduction, damage to sperm, birth defects and abortions.

In Colombia, different studies have been carried out to estimate the potential amount of metallic mercury used in the production of gold; however, these exercises present limitations insofar as different methods of exploitation and benefit of the metal have been documented, which determine that the miner uses discretionally the amount of metallic mercury in each process. The information gathered from the interviews with unregulated mining producers indicates that the grams of mercury consumed in the recovery of gold from alluvium or vein to obtain a gram of gold, vary in a wide range that can be between 0.5 grams to 30 grams of mercury; this wide margin of use of this chemical substance makes it difficult, considerably, to estimate the quantity used from the available statistics. The use of metallic mercury in alluvial gold mining can be reduced even to approximately 3 Hg/g of gold recovered in case of exploitation with mini dredgers, which use concentration in gutters and amalgamation in small gutters or buckets and in the case of dragons modified and amalgamating plates and / or amalgamation of concentrates in small gutters, with the use of backhoes to feed the mineral to a size classification system.

The estimation of the amount of mercury consumed by the main gold producing departments in Colombia was made taking into account all the limitations of the case and in it the important aspects that were previously discussed are weighted. The results are shown in the following table:

<table>
<thead>
<tr>
<th>Departament</th>
<th>Mercury consumed (average annual tons for 2013)</th>
<th>Gold production 2013 (in tons)</th>
<th>Gold production 2014 (in tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antioquia</td>
<td>129.2</td>
<td>26.5</td>
<td>28.1</td>
</tr>
<tr>
<td>Chocó</td>
<td>24.3</td>
<td>15.2</td>
<td>11.3</td>
</tr>
<tr>
<td>Cauca</td>
<td>16.9</td>
<td>4.4</td>
<td>4.3</td>
</tr>
<tr>
<td>Bolivar</td>
<td>15.7</td>
<td>2.2</td>
<td>2.7</td>
</tr>
<tr>
<td>Nariño</td>
<td>5.0</td>
<td>3.6</td>
<td>5.2</td>
</tr>
<tr>
<td>Córdoba</td>
<td>2.0</td>
<td>0.5</td>
<td>0.5</td>
</tr>
</tbody>
</table>


In the previous calculation, according to the Ministry of Mines and Energy, it is possible to observe that in Antioquia, one of the areas of the country with the highest mining activity, in 2013, 129.2 tons of the 193.1 tons calculated for the country of mercury, and therefore, is the most affected department by...
the harmful effects of mercury on the health of living beings and the ecosystem. Finally, to have a correlation between the gold produced and the mercury used by the department, the following table shows a relation of the mercury use per gram of gold produced in 2013 and the estimate of the mercury consumption for 2014.

However, it is important to note that the country is working on the design of mechanisms to regulate, or eliminate, the use of mercury, so on July 15th, 2013, Law 1658 is issued, where among others, requirements and incentives are established for the reduction and elimination of mercury; according to these guidelines this year the Ministry of Environment and Sustainable Development built the guidelines for the National Strategic Plan for the reduction and elimination of the use of mercury in artisanal and small-scale mining scale - MAAPE [34].

For its part, Antioquia has proposed an ordinance project that seeks to control the import, marketing and use of mercury throughout the department of Antioquia. According to the Government of Antioquia, this department consumes 100-120 tons of mercury annually [35]. The project, which was filed on June 1st, 2017, has the purpose of prohibiting the use of mercury in the department in mining activities, establishing legality controls for those who use this chemical for industrial activities. If this initiative is approved, natural or legal persons who use mercury in the department, will have to declare it before the Department Health Secretary and before Departmental Rents [36].

<table>
<thead>
<tr>
<th>Departament</th>
<th>Gram relation of gold produced per gram of mercury consumed (average in kilograms per year for 2013)</th>
<th>Mercury consumed (average annual kilograms for 2014)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antioquia</td>
<td>4.88</td>
<td>137,207.38</td>
</tr>
<tr>
<td>Chocó</td>
<td>1.60</td>
<td>18,141.94</td>
</tr>
<tr>
<td>Cauca</td>
<td>3.80</td>
<td>16,394.49</td>
</tr>
<tr>
<td>Bolívar</td>
<td>7.02</td>
<td>19,267.73</td>
</tr>
<tr>
<td>Nariño</td>
<td>1.40</td>
<td>7,280.75</td>
</tr>
<tr>
<td>Córdoba</td>
<td>3.99</td>
<td>1,982.32</td>
</tr>
</tbody>
</table>

SECTION IV
METHODOLOGICAL ANNEXES
ANNEX 1. METHODOLOGY INTERPRETATION EVIDENCE OF ALLUVIAL GOLD EXPLOITATION WITH USE OF MACHINERY ON LAND

To characterize the phenomenon of alluvial gold exploitation with the use of machinery on land, a research model was implemented that includes detection, integration of information, synthesis, findings and analysis.

This model is based on the detection of EVOA, based on images from remote sensors and with the application of an interpretation key designed for that purpose. Subsequently, this information (interpreted EVOAS) is integrated with secondary information (from official sources) in a research framework. The data obtained are processed and quantified (synthesis), giving rise to the main findings that will finally be analyzed.

This model confers on the results obtained the census character in that it complies with the following premises: i) enumeration, the detection of the EVOA is done individually and visually, following defined and structured criteria according to a key interpretation; ii) universality, focuses on the entire universe of study (EVOA with use of machinery on land) throughout the Colombian territory, iii) simultaneity or defined reference period, based on the temporality of the EVOAS, “Durable evidence”\(^\text{62}\), has a reference period for the capture of information (January 2016 to May 2017).

\(^{62}\) The evidences generated by the exploitation activities are considered permanent over time due to the deterioration of the vegetation layer and the soil.
Remote sensing

One of the most relevant contributions of remote sensing is its ability to monitor dynamic processes. The information acquired by satellite images constitutes an important and valuable source to study the changes that occur in the Earth surface, either due to natural factors or by human action. The orbital characteristics of the Earth observation satellites allow us to acquire periodic images of any place, under comparable conditions of observation, which is ideal to study the dynamics and trends of expansion of phenomena of interest.

Some specific advantages of the use of satellite images as a source of information on natural resources and the environment are: i) covering scenes allow obtaining a synoptic view of large areas of the Earth surface, which enables a better understanding of the organization space; ii) the periodicity of takings allows the checking and monitoring of dynamic processes, with this characteristic, it is possible to perform spatial and temporal analysis by comparing two or more images of the same place in different dates (multi-temporal analysis); iii) the ability to capture data in different wavelength ranges facilitates the identification and discrimination of the coverage analyzed in the image and allows access to information that our vision does not capture, such as the infrared bands; iv) rapid updating of the information by the periodicity of the takings (temporary resolution); v) territorial coverage, which allows access to data in isolated areas, which makes them less expensive per unit area than aerial photographs or information taken on the ground [38]; vi) availability of images of several remote sensing systems free of charge.

The techniques of digital image processing facilitate the application of the theoretical and algorithmic bases through which information can be extracted from the real world from the image analyzed. This exploitation of information can be done through visual interpretation and digital classification. The differences between the two techniques are based on the methodology. The visual interpretation is made based on the prior knowledge of the observed territory and the application of identification techniques based on the pictorial-morphological characteristics of the image. On the other hand, the digital classification is based on digital levels (ND), which allow to group equal values of visualization in scales of gray.

The methodology for the detection of evidence of alluvial gold exploitation with the use of machinery on land is based on the visual interpretation of satellite images and covers the following stages:

- **Selection and acquisition of satellite images**

The EVOA coverage was obtained with the interpretation of medium resolution images of the Landsat remote sensing system, as they had previously been used to identify coca crops and their dynamics. In this sense, optimization and efficiency in the use of resources was obtained. These images, widely known and used for the monitoring of the areas planted with coca since 2001, present adequate conditions of periodicity, availability, coverage, spectral resolution and gratuity, which represent a valuable tool for carrying out studies of the dynamics of natural resources, facilitating the sustainability of the implemented monitoring.

For the update of the national baseline of EVOA with the use of machinery on land, an approximate time window of one and a half years was taken (2016-2017). The data obtained do not have adjustments for areas without information or temporality.

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63 Remote sensing is commonly defined as the process of acquiring information at a distance, without physical contact between the source of information (object) and the receiver of the same (sensor) [70].

64 The constellation of satellites LANDSAT (LAND = Earth and SAT = satellite), that initially were called ERTS (Earth Resources Technology Satellites), was the first mission of the United States for the monitoring of the terrestrial resources. Its maintenance and operation is in charge of the National Aeronautics and Space Administration (NASA), while the production and commercialization of the images depends on the United States Geological Survey (USGS).
Minimization of areas without information

The strategic position of the Colombian territory in the tropical zone favors condensation and, therefore, formation of clouds, which implies loss of information captured by the satellite. To reduce these areas without information and depending on the temporality of the evidence, a permanent search was made of the images available on the download portals and mosaics were built from images of the same area with dates between January 2016 and May of 2017. A total of 274 Landsat 8 (LDCM) images covering 58 Path Row from all over the country were downloaded and processed, reducing the area without information to only 2% of the entire territory affected by EVOA in 2016.

Illustration 9. Coverage of Landsat 8 satellite images used for the interpretation of EVOA. Composition RGB 5,6,4.

Illustration 10. Example of minimization of areas without information.

From a Landsat 7 ETM + (a) image and by selecting and adding information available in other Landsat images (c, d, e, f, g and h) a final image is obtained.

• Pre-processing images

The pre-processing of images groups a series of techniques oriented to: i) correct or remove effects in the image due to sensor errors or environmental factors, ii) enhance the contrast to facilitate interpretation, iii) increase the spatial resolution to improve the delimitation and object detection.

The techniques used for the initial processing of the selected images are summarized in the following illustration:

Co-registration

The project has adopted the World Geodetic System 1984 (WGS 84) as a spatial reference frame; this system has the same ellipsoid as the one used by the Agustín Codazzi Geographic Institute for Colombia, which will allow the UNODC / SIMCI data to be linked to another type of geographic information officially produced in the country. The interpretation of the EVOA area is carried out in its entirety with Landsat 8 OLI images that are received in this projection system. The interpretation of the EVOA area is carried out in its entirety with Landsat 8 OLI images that are received in this projection system.

To facilitate the work of interpretation, a mosaic was built for the whole country that is defined as the base of geo-referencing of each of the images. From a co-registration operation, it is guaranteed that each image that is downloaded is adjusted pixel by pixel, ensuring that there is no displacement, rotation or distortion. Consequently, each image used as an input within the project is spatially referenced in the same way to this base matrix, which improves the temporal comparability for the different analyzes.

Illustration 11. Image preprocessing techniques.

95% of the points detected in verification overflights were identified by the methodology proposed and cover an area of 17,000 ha, 20% of evidence for 2016.

• Visual interpretation of evoa with use of ground machinery

The gold exploitation that takes place in alluvial terraces includes the following stages: preparation and access to the area, operation, benefit or transformation of the ore; transport of the material and abandonment of the mine (these last two activities are not addressed in this study) [39], [40], [41]. More information in [1].

This methodological line was made using as a base input the detection of EVOA in 2014, overflights of recognition and photographic documentation.

In the process of interpretation, those characteristics present in the image that serve as evidence for the identification of objects and their differentiation are taken into account [42]. Some authors define them as pictorial-morphological features and include the analysis of shape, size, tone, color, pattern, texture and geographical position [43].

The visual interpretation of EVOA is carried out by systematically sweeping the images with emphasis on the water network and alluvial landscapes.
The identification is carried out by means of delimitation of the polygons that circumscribe these areas, which are digitized on the screen with the help of manual (bitmaps⁶⁶) and semi-automatic software tools (seedling or automatic grouping of pixels).

To update the EVOA coverage in 2016, the detection made in 2014 (EVOA 2014) was used as a base input, and with the visual interpretation of the selected images 2016, the changes in the affected areas were identified in four categories:

I) Stable EVOA: area affected by EVOA in 2014 and identified again in 2016.

II) New EVOA: area affected by EVOA in 2016 that was not present in 2014. It may be a consequence of the expansion or new exploitation fronts.

III) EVOA abandoned: area affected by EVOA in 2014 that changed coverage in 2016.

IV) EVOA 2014 affected by clouds in 2016: area affected by EVOA in 2014 that could not be identified due to the presence of clouds in 2016, despite the minimization of areas without information. The study reports that 2,150 ha of EVOA 2014, could not be interpreted by cloud cover in the study period.

Landsat image 1056 RGB 5,6,4.

⁶⁶ A bitmap or Bitmap acts as a graphic layer that can be used to create masks of regions in images for various purposes.
• Aerial reconnaissance

Once the EVOA interpretation stage has been completed, the methodology contemplates verification overflights. This recognition is based on visual inspection of the terrain of areas affected by the phenomenon from an aircraft. The overflights have photographic record and vector information of this phenomenon, since 2012. With the findings found in the overflights, the interpretation of the EVOA is adjusted if required.

• Quality control

Finally, and transversal to all stages, process quality control is carried out. Quality control seeks to guarantee the standardization of procedures, so that the data generated meet the standards of quality, accuracy and comparability required by the Government of Colombia and the users of the information.

In general, this quality control is based on specific evaluations of the different activities involved in the detection of EVOA, especially in the interpretation processes. The quality is controlled in:

• Image selection and coverage: the area without information is reduced to the minimum possible using several images of the same area and forming mosaics. Images of the entire territory under study are obtained.

• Interpretation: to validate this parameter, a validation of the data is performed between interpreters in different areas. Subsequently, a comparison of the information obtained through field verification in overflights, secondary information and validation with high resolution images of the World Imagery gallery that provides the Esri maps service is performed.

The Esri gallery provides high resolution satellite images of GeoEye, IKONOS, QuickBird and WorldView that can be viewed with the ArcGis Add Basemap tool.

These images are only used to support interpretation, because in many areas of the country only images are available before 2010. However, they provide a good point of comparison.

Illustration 13. Comparison Satellite image (Landsat 8 1058 RGB 564) (left) - high resolution image GeoEye - 1 (center) and traditional photograph (right) taken in SIMCI reconnaissance flyby. Municipality of Timbiquí - Sector Coteje. Cauca.
The high resolution images allow to improve the delimitation of the areas with evidence and to clear cases of spectral confusion\textsuperscript{72} with other coverage present in the area such as hamlets, bare soils or another type of mineral exploitation.


The detection of EVOA using interpretation tools is based on the pictorial-morphological characteristics that define the spectral behavior of the evidence. However, this spectral behavior alone does not guarantee the reliability of the interpretation, since other coverings or elements on the landscape present a similar spectral behavior that generates overlap. In this sense, the methodology includes in this stage, the use of an interpretation\textsuperscript{73} key developed for that purpose by SIMCI, in order to minimize and resolve those cases that may present spectral confusion.

Interpretation key for EVOA detection

In accordance with the above, the identification of evidence of alluvial gold exploitation in the open with the use of machinery on land (EVOA) by remote sensing uses a key interpretation, in this case a decision tree to interpret those areas of the territory that are or were affected by this activity and that are detectable in satellite images. The use of this allows to objectively differentiate different coverages that can generate confusion when observing the satellite images due to the overlapping of the spectral response, these coverages are called confounding factors.

In the general scheme of the interpretation key, two moments are established: identification of confounding factors and structuring of the key.

\textsuperscript{72} A more detailed description of these cases is available in the “Interpretation Code” section.

\textsuperscript{73} Tool based on the characteristic or combination of characteristics of a particular element that allows its identification based on its shape, size, color, texture, etc. [52]. The use of these tools guarantees the reduction of the margin of subjectivity when interpreting images from remote sensors.
Confusing factors

They are the outputs resulting from the decision tree other than EVOA, and they present pictorial-morphological characteristics similar to the EVOA in the satellite image, which can generate erroneous decisions when the interpreted coverage is classified without a defined guide. For this reason, the substantial differences between these confounding factors and the EVOAs are established in order to generate the correct decision in the interpretation key:

<table>
<thead>
<tr>
<th>Coverage</th>
<th>Confusing factor</th>
<th>Differences</th>
<th>Satellite image</th>
<th>Photography</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sandbanks</td>
<td>They present bright tonalities and colors equal to EVOA, irregular shapes and are found over the course of rivers.</td>
<td>Fine textures and absence of dark objects inside (benefit lagoons).</td>
<td>EVOA Sandbanks</td>
<td>Sandbanks EVOA</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Landsat 8 RGB-654</td>
<td>Overflight SIMCI</td>
</tr>
<tr>
<td>Populated centers, hamlets</td>
<td>They present bright tones and colors similar to EVOA, irregular shapes in some cases, thick textures.</td>
<td>Internal geometric patronage that makes up the road network.</td>
<td>EVOA Populated center</td>
<td>Populated center EVOA</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Landsat 8 RGB-547</td>
<td>Overflight SIMCI</td>
</tr>
<tr>
<td>Landslides</td>
<td>They present bright tones and colors similar to EVOA, medium and thick textures.</td>
<td>Absence of dark objects inside (benefit lagoons), occur in areas of high slope (although erosion can reach the terraces).</td>
<td>EVOA Landslides</td>
<td>EVOA Landslides</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Landsat 8 RGB-654</td>
<td>Overflight SIMCI</td>
</tr>
<tr>
<td>Erials 74</td>
<td>They present brilliant tonalities and colors similar to EVOA, fine and medium textures.</td>
<td>Absence of dark objects inside (benefit lagoons), internal presence of small areas with red (RGB-547), orange (RGB-564) or green (RGB-654) vegetation.</td>
<td>EVOA Erial</td>
<td>EVOA Erial</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Landsat 8 RGB-547</td>
<td>Overflight SIMCI El Tiempo Newspaper</td>
</tr>
<tr>
<td>Fish ponds</td>
<td>They present groups of objects with dark tones (pools of water) in the middle of areas with bright shades and colors similar to EVOA.</td>
<td>They have a geometric shape and a uniform distribution pattern, generally.</td>
<td>Fish ponds EVOA</td>
<td>Fish ponds EVOA</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Landsat 8 RGB-562</td>
<td>Overflight SIMCI ICA</td>
</tr>
</tbody>
</table>

74 Dry areas subject to wind erosion with incipient vegetation of low development and no use [56], have a geological origin different from bare soils due to the formation times [94].
They present groups of objects with dark tones (waterbodies) with an irregular pattern. They are usually surrounded by colored herbaceous vegetation in the range of greens in RGB-547, RGB-564 and RGB-654. Typical in areas of savannah where livestock activity predominates.

Bare Soil

They present bright tones and colors similar to EVOA.

Fine textures and absence of dark objects inside (benefit lagoons), in some cases may be far from the course of rivers.

Agricultural preparation areas

They present bright tones and colors similar to EVOA.

Polygons with defined shapes and regular patterns.

Mangroves

They present in their interior groups of objects with dark tonalities (mirror of water) with an irregular pattern, thick texture.

Around the water there is tall vegetation (red in RGB-547, orange in RGB-564 and green in RGB-654).

Table 20. Confounding factors in the interpretation of EVOA.

Structuring the key

Once the possible confounding factors have been identified, the levels or hierarchies in the key are defined. The interpretation of EVOA consists of the following levels: i) landscapes, ii) pictorial-morphological characteristics, iii) reference information and iv) validation, high spatial resolution images. On the other hand, the outputs resulting from the questions referred correspond only to two types of decision: EVOA or Not EVOA.

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75 Depressions on the ground that allow the storage of water from surface runoff [62].
76 Coverage of trees and shrubs adapted to colonize land flooded with salt water [65].
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- **Landscapes**

The detection of EVOA by remote sensing includes the visual identification of some characteristic elements of the landscape in the areas where these coverings are presented, in such a way that the interpretation process is considerably facilitated by discarding other landscapes and the universe of exploration is reduced. Next, the contemplated landscape elements are described:

<table>
<thead>
<tr>
<th>Landscape</th>
<th>Content</th>
<th>Photo View</th>
<th>Satellite image view</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alluvial plains</td>
<td>They correspond to flat or slightly flat areas that border a river, and that have been formed by accumulation of sedimentary materials derived from fluvial processes where there are flows in motion [44]. Among the sedimentary materials deposited there are the gravitational concentrations of valuable and heavy minerals, such as gold [45].</td>
<td><img src="image" alt="Overflight SIMCI" /></td>
<td><img src="image" alt="Landsat 8 RGB-654" /></td>
</tr>
<tr>
<td>Alluvial valleys</td>
<td>They are plains or depressions elongated and inclined by which there are water currents, which reach either the ocean or other rivers of greater hierarchy. They are characterized by being located in the middle of mountains or other formations of greater height [44]. On the terraces closest to the rivers, sedimentary materials are deposited, among which are the gravitational concentrations of valuable and heavy minerals, among them gold [45].</td>
<td><img src="image" alt="Overflight SIMCI" /></td>
<td><img src="image" alt="Landsat 8 RGB-564" /></td>
</tr>
</tbody>
</table>

**Table 21. Landscapes of influence of the EVOA.**

- **Pictorial-morphological characteristics**

Also known as interpretation elements, they allow interpreting an object in an image due to the particular behavior of the EVOA in terms of shape, size, brightness, color, texture and pattern. The integration of these characteristics makes it possible for the EVOA to be differentiated from other coverings, by virtue of the transformation of the original covers in the plains and alluvial valleys (removal of the vegetation layer, soil excavation and establishment of benefit lagoons), which leaves a certain evidence on the earth’s surface for several years and establishes an approach for the detection of the EVOA.

In some cases, the same element of interpretation may vary in respect of the EVOA, depending on the region of the country where it is located, the intensity of the activity and the stage in which the exploitation is located.

- **Reference information**

One of the essential conditions of the decision tree is the geographic information available about the alluvial gold exploitation. There are two types of reference information used in the EVOA detection process: primary information and secondary information.

SIMCI has information regarding three processes for recording data on the phenomenon of strip alluvial gold exploitation: i) specific evidence of the phenomenon through verification overflights since 2011, ii) national EVOA 2014 baseline and iii) spatial dynamics of coverage around EVOA in the Pacific region for the periods 2001-2006-2011-2014.

For its part, there is information generated by other sources (National Mining Agency, Ministry of Mines and Energy, National Army) which contains georeferenced data from the Mining Census, law figures for the alluvial gold exploitation, and operations of the Public Force against illegal mining.
• Validation, high spatial resolution images

There are some cases in which it is necessary to go to the consultation of images of high spatial resolution to make the decision to classify an area where there are doubts about the presence of EVOA or not, since, even following the initial conditions of the tree decision (landscapes, pictorial-morphological characteristics and reference information), it is not possible to arrive at a response with security. Generally, this happens with i) very small hamlets located on the margin of the rivers where there is no road network, so their identification in the images is difficult and ii) with some landslide areas in the alluvial valleys, or iii) with exploitation of other minerals other than gold that have a similar dynamic.

Decision tree for the interpretation of EVOA

The structured integration of the aforementioned information defines the inputs, conditions and outputs resulting from the interpretation key, according to the excluding statements for the EVOA identification and its discrimination of similar coverage. For this, it is necessary to generate a flow chart that guides the decision making following the order of criteria established in the key, so this way the interpretation and classification process, besides being facilitated, is objective.

Initially, a guide flow diagram is established with the logical sequence of the aspects to be taken into account in the interpretation process of EVOA, in which the partial results are determined in each level of participation. With this, the interpretation progresses from the general to the particular until arriving at a conclusive result that classifies a coverage as EVOA and the difference of the confounding factors.

Illustration 15. Flow diagram for the construction of interpretation key EVOA.

Next, the final result of the integration process that provides the tool for the detection of EVOA by remote sensing is presented:
ANNEX 2

METHODOLOGY DETECTION OF ALTERATION OF SUSPENDED SEDIMENTS BY SPECTRAL INDEXES

The methodology for detection of suspended sediment alterations was developed within the framework of agreement 589 of 2015, between the Ministry of Justice and Law and the United Nations Office on Drugs and Crime - UNODC. In this agreement, a methodological approach was carried out for the detection of alluvial gold exploitation with the use of machinery in water based on evidence of remote sensing. This methodology was validated through a pilot study on the Inírida River, in the sector between the “El Zancudo” and “Morroco” communities, in the department of Guainia. The model is based on the identification of changes in the natural behavior of sediments in rivers that can be measured through changes in the spectral indexes and that can be associated with alluvial gold exploitation activities. For the application of the model, the MNDWI (Modification for normalized difference water index) index was selected.

The model begins with the establishment of the baseline of natural spectral behavior, that is, without affecting exploitation activities, continues with the application of spectral indexes to detect alteration in suspended sediments, for the identification of the dynamics of changes and ends with the validation of the data.

The detection of the evidence generated by the alluvial gold exploitation with the use of machinery in water, is approached from the identification of alteration in suspended sediments, through remote sensing tools with the use of band algebra (indexes spectral). The model involves four stages:

i) Identification of the general framework of the area.
ii) Construction of the baseline for the river in which the “natural” spectral behavior is guaranteed, that is, without the intervention of exploitation activities.
iii) Detection of changes in natural behavior through analysis of spectral indexes.
iv) Validation of the findings through secondary information, elements of association of the detection of sediment alteration.

On the other hand, the model addresses the detection taking into account the following premises to ensure comparability:

• Spatial comparability, application of geometric correction technique, co-registration of images and systematic point sampling.
• Spectral comparability, use of atmospheric correction tools.
• Comparability in terms of water flow, window of time corresponding to the dry season based on the following premises: i) the lower flow facilitates the
The model of detection of evidence of exploitation by use of machinery in water, based on spectral indexes, is oriented to the identification of “hot spots” or active points of alteration of suspended sediments. This means that it identifies zones in the water body that have exploitation activity through the use of machinery in water, at the time of the satellite image.

detection of alterations in suspended sediments; ii) the rainy season represents a strong precipitation regime, which leads to an increase in transported sediments, generated both by the rain regime and by other factors inherent to landslides and material haulage, and iii) secondary information acquired by institutions present in the zone reports that the greater flow makes access to the deposit difficult for the machinery used.

However, the methodological model also allows the application in the rainy season, as the alteration of the sediments in these periods affect the water flow uniformly and the “hot spots” of suspended sediments caused by the exploitation can be detected by the sensitivity of the index and by statistical correlation adjustments.

General framework: this stage addresses: i) identification of the study area, ii) selection of images, and iii) evaluation of the rainfall regime [46]. Regarding the latter, the premise of the dry season is maintained, to reduce the noise in the results, because of the alteration in the sediments due to natural factors.

In accordance with the above, the establishment of the spectral natural baseline of the river is defined, in the dry period, to guarantee the reading of the index without any exogenous alteration caused by external factors, landslides among them.

In accordance with the regional scale of the methodological model and considering the temporal, spectral and spatial resolution of the images; the use of Landsat images 5, 7 and 8 is recommended, as they have homologous bands that capture information in the visible and infrared spectrum range.

Illustration 17. Diagram of a methodological model for the detection of alteration of suspended sediments by spectral indexes.
On the other hand, the infrared bands facilitate the separation between soil, vegetation cover and water bodies, this allows discrimination or separation of the elements present in the land cover, due to differences in moisture, heat or temperature contents [38]. The combination by spectral indexes of these groups of bands allows to enhance and provide information on a specific coverage, in this way it is possible to obtain objectively and precisely quantitative information of the object of study.

**Baseline construction of natural spectral behavior**

The methodology emphasizes the establishment of a baseline of normal suspended sediments in the waterbody, which allows comparability over time to detect changes. It is noteworthy that the waterbodies in the satellite images are among the elements that best explain the optical properties of reflectance, transmittance and absorption; water absorbs or transmits most of the visible radiation it receives, and its absorptivity^77^ is greater the longer the wavelength. The greater reflectivity^78^ of clear water occurs in the range of the electromagnetic spectrum, which ranges from 0.45 to 0.52 μm, in which its value gradually decreases towards the near infrared, where it is practically null. Reflectivity is affected by factors such as chlorophyll content, suspended sediments, surface roughness, and depth [47].

The following illustration presents a comparison between the behavior of the reflectivity in clear water (without turbidity) and turbid water affected by suspended sediments, where it is observed that the greater the amount of suspended solids, the greater the reflectivity [48].

The construction of the baseline for the river establishes the “natural” spectral behavior, that is, without affecting gold exploitation activities. In this way, it guarantees that the results of the comparison with the indexes in different periods of time are related to alterations of the suspended sediments. The validation of the obtained spectral curves is carried out through a congruence analysis in respect of secondary^79^ and qualitative information, related to the presence of the activity in the region during the study periods.

**Detection of changes in the “natural” spectral behavior of the river**

Once the range of the spectral natural behavior of the river under study has been identified, the methodology allows to evaluate the dynamics of the elements in suspension in different periods of time, by reading the index and comparing it with the

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^77^ In the process of remote sensing, the relationship between the incident flow and the one that absorbs a surface.

^78^ In the remote sensing process, the relationship between the incident and reflected flow on a surface.

^79^ Information from the Military Forces and Police of Colombia, descriptive documents of the historical dynamics of the mining activity in the study areas and information from the different entities of the Colombian State.

**Illustration 18. Water spectral behavior (Source: Aligarh Muslim University).**
baseline of natural spectral behavior. In this stage, the methodology emphasizes the analysis of possible external sources that imply alteration in the results.

In this sense, prior to the identification of the “hot spots” of suspended sediment alteration, an analysis is made with coverage information and secondary information from communities, which allows to discard false “hot spots”, among these, landslides, avalanches, recent fellings on the banks and active erosive processes. Once the external alterations have been ruled out, the spectral dynamics are identified.

In the following illustration, we can observe, in blue color, the curve of expected spectral behavior in a period with natural behavior, without alteration by the exploitation activity; the other curves reflect the behavior of the index in different periods of time with exploitation activities. The horizontal axis represents the points \(^80\) for reading the index taken on the satellite image along the stretch of the river under study. The vertical axis represents the value of the index.

As observed, the spectral behavior curve generates a warning in two dimensions i) in time, when the alert appears and ii) space in which geographical location. Alerts are consolidated when the value of the index is below the range of spectral behavior (yellow box).

**Validation of the findings through secondary information, elements of association and verification overflights**

As part of the validation of the findings, spatial crossings are made through spatial correspondence with secondary information from official\(^81\) institutions and workshops with communities on exploration and exploitation sites, where the findings obtained by the methodological application are corroborated or validated. So far, two case studies have been carried out, with validation of successful findings, one in the Sipí-Chocó river, in 2013 and the other in river Inirida-Guainía, in 2014.

Finally, it is worth noting that the corroboration of the findings is not always recorded by the detection of machinery in flagrancy, but by elements of association that allow to infer with certainty their relationship with the exploitation activity (rafts hidden in adjacent pipes, containers of substances used for the benefit, base slabs for the support of the machinery in the water, etc.).

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\(^80\) The reading points are generated taking into account all the areas with information in the periods of analysis

\(^81\) Operations of control and interdiction of Military and Police Forces.

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**Graph 19. Expected curves of affection, values close to 1.0 indicate clear waters, without alteration in the sediments.**
ANNEX 3
FRAMEWORK OF MONITORING MODEL AREAS FOR ILEGALITY PHENOMENA IN THE TERRITORY

Since 2001, SIMCI has obtained primary information about the presence of coca crops in the territory. From 2012, by means of verification overflights, geographic congruences were identified in some areas of the territory, with the presence of two activities of illegality, coca cultivation and alluvial gold exploitation with the use of machinery on land.

The information from EVOA, since 2014, as well as the data on coca crops has been collected with similar methodologies based on remote sensing that facilitate comparability and monitoring in the territory. In this way the integration of information of both phenomena becomes feasible, which allows analyzing trends and determining possible relationships between the activities.

Currently, the project has a database of structured primary information of both phenomena, as well as information concerning other phenomena of illegality such as the one provided by the Directorate for Integral Action against Antipersonnel Mines (DAICMA), currently Descontamina Colombia, referring to mines antipersonnel; by the Ministry of Environment and Sustainable Development relative to deforestation and by the Geographical Institute Agustín Codazzi (IGAC), regarding administrative limits.

The basis for putting SIMCI’s geographic information (coca crops and EVOA) as well as other sources, is the framework of areas. This framework consists of a series of polygons (square grids of 5km and 1km) that are not directly related to changes in the territory, that is, the change in administrative limits or the creation of new territorial entities does not alter the results obtained in the framework, for which, space-time analysis can be carried out efficiently and simply.

By incorporating data from other sources of information into the framework of areas and at the same time that of administrative limits and special management zones, it is possible to create tables and dynamic reports useful for the analysis and verification of the congruence of the data and the spatial analysis, at the same time, it has the information of the territorial units of importance for the National Government as municipality and department. On the other hand, it is known that research and work from other sectors are created at the municipal level; official territorial minimum unit defined for decision making82. Finally, the area framework offers a sampling universe with the possibility of incorporating useful probabilistic criteria for research based on sampling.

This chapter presents the technical processes carried out by integrating information into the framework of areas, in order that a user can define the scope and limitations of the area framework. As mentioned, when using a geometric figure (grid) to represent the Colombian territory, it is necessary to take into account some considerations.

The information integrated into the framework can be divided into three groups; the first, related to the presence of illegal activities in the territories (primary and secondary information), the second with the official information of territorial entities and administrative limits, and the third, with spatial analyzes developed using the framework of areas.

82 To cite some cases, the production reports of the transformation of coca leaf to cocaine hydrochloride, multi-temporal analysis of coverage, threat index due to the presence of coca crops (SIMCI), seizures of drugs and chemical substances (Ministry of Defense), deforestation (Ministry of Environment) are on this scale.
Presence of illegal activities

In this group of information, the data is classified not only of the presence of illegal activities in the territory, but also the secondary information related to the subject, for example, the data of the actions carried out by the government of Colombia to deal with the problematic, or legally constituted zones that are reported by the institution in charge to perform activities, such as gold exploitation.

In the first place, there are data on illicit crops such as: hectares sown with coca crops, - period 2001-2016, hectares of manual eradication of illicit crops, hectares of aerial spraying operations with glyphosate, territories with biophysical, historical conditions and favorable spectral for the sowing of poppy or marijuana and territories intervened by alternative development programs.

Second, there is information related to EVOA, for this case EVOA 2014 and EVOA 2016, evidence dynamics 2014-2016 and legal figures for exploitation.

Finally, information on antipersonnel mines where data is available on: frequency of MAP / MUSE83 events, threats due to presence of anti-personnel mines, vulnerability associated with the movement of people in the territories and risk due to the presence of anti-personnel mines.

83 Antipersonnel mines / Unexploded ammunition.
Events of antipersonnel mines and unexploded ammunition (MAP/MUSE)

The process of integrating the MAP/MSUE data into the grid base begins with the intersection between the events for each year and the 1 kilometer square grid; afterwards the frequency of occurrence for each grid is calculated and this calculation allows to determine how many and what type of events were presented per year in each grid. As a reference to 2017, MAP/MSUE information is available at the cut-off date of December 31st, 2015. The aforementioned procedure must be carried out every year, since antipersonnel mines events can change their typology; therefore, the data for the grids varies in respect of the cutoff date.
Grids type 1: accidents\textsuperscript{84} in the last 6 years.

Grids typology 2: no reports of accidents by MAP/ MSUE in the last 6 years (2010 - 2015). They have records of accidents in years prior to 2010.

Type 3 grids: there is no report or record of accidents by MAP/ MSUE. There have been incidents\textsuperscript{85}.

Type 4 grids: there are no historical reports of events by MAP/ MSUE.

EVOA 2016

Illustration 22. Information of the DAICMA in the framework of areas.

**Official information of territorial entities and administrative limits**

Although analyzes and calculations of areas are carried out through the grids of a square kilometer, it is necessary to generate data at the municipal, departmental national scale, and by other types of administrative entities of interest. To fulfill this objective, the boundaries information was integrated into the area framework\textsuperscript{86}: municipal (IGAC 2016), departmental (IGAC 2016), National Natural Parks (PNN 2016), Second Law (Ministry of Environment and Sustainable Development 2014), Community Councils and Indigenous Reserves (IGAC 2016).

This information is updated according to the availability of the data of each institution.

- **Municipal and departmental administrative limits**

During 2017, the Geographical Institute Agustín Codazzi delivered the municipal administrative limits updated to 2016. The assignment of the administrative limits and other territorial entities was made by crossing the coordinates of the center of the grid and the polygon of administrative boundary. This procedure was executed in 2010, when the grid was created.

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\textsuperscript{84} According to the National Glossary of Terms for Comprehensive Action against Antipersonnel Mines-AICMA, “accident” is an unwanted event caused by anti-personnel mines or unexploded ammunition that causes physical and/or psychological damage to one or more persons [108].

\textsuperscript{85} According to the National Glossary of Terms for AICMA, an incident is an event related to anti-personnel mines or unexploded ammunition, which may increase to an accident or have the potential to lead to an accident [108].

\textsuperscript{86} The assignment is made by the centroid of the grid.
In 2017, the municipal boundaries were updated. When taking into account the new administrative limits, EVOA 2014 - 2016 data are 98% comparable on a national scale. For departmental scales, the percentage remains in the same range, with the exception of Nariño (93%) and Caldas (92%) where the greatest differences were found.

The Colombian continental territory consists of 1,190,675 square grids of 1 km or 47,627 grids of 5 km. The following example presents the differences between the original data of administrative limits (left) and the result in grids (right). In the same way, the information of special territorial entities such as PNN, Indigenous Groups, Forest Reserves of the Second Law and Afro-Colombian Community Territories is incorporated.

Assignment of information of administrative boundaries through the coordinates of the center of the grid (a):

The Colombian continental territory consists of 1,190,675 square grids of 1 km or 47,627 grids of 5 km. The following example presents the differences between the original data of administrative limits (left) and the result in grids (right). In the same way, the information of special territorial entities such as PNN, Indigenous Groups, Forest Reserves of the Second Law and Afro-Colombian Community Territories is incorporated.

Assignment of information of administrative boundaries through the coordinates of the center of the grid (a):

The main limitation of the grid is related to territorial delimitation; since there are grids that share administrative limits with two or more territorial entities, called edge grids. For 2017, 106,632 grids present this situation in respect of the municipal limits, of which only 1,321 have EVOA in 2014 or 2016. For the last EVOA detection, 10,873 hectares are in edge grids, which corresponds to 13% of the total.

Spatial analysis in the framework of areas

By having unrepeatable units with regular geometry, it is possible to perform spatial analysis exercises in an agile and simple way, given that all the information presented is added in each of the grids, spatial analysis applies to all the variables. For example, to know the distance of coca crops to the land borders, when performing the spatial analysis exercise, it is necessary not only to know the relationship between coca crops and borders, but at the same time to have the relationship of MAP / MUSE, EVOA, manual eradication and aerial spraying in respect of borders. In essence, the area framework behaves like a geographic database, but easy to use for a non-expert user in geographic information systems. With this, it is sought that experts from different fields use the information concerning illegal activities in the territory.

With the data of the IGAC in scale 1: 100,000 and the framework of areas of 1 kilometer several spatial analyzes have been carried out, among them, distance of crops to population centers, road and water density. On the other hand, distance exercises between land borders, maritime borders and coca crops among others.

• Coverage of the predominant land for the grid

The historical series of coverage of coca influence zones 2001-2014 is available. For the interpretation of hedges, 18 classes of land cover87 were defined. To define which coverage to assign in each grid, it is defined that the predominant class will be the one that defines its coverage. The latest version of land cover that SIMCI has developed corresponds to 2014.

87 For more information, consult: Multi-temporal analysis of coca crops, SIMCI, 2001.
• **Average height above sea level**

The incorporation of altitude data on sea level is based on the digital elevation model built by the Ministry of Economy, Trade and Industry (METI by its acronym in English) of Japan, and the National Administration of Aeronautics and Space (NASA). The Model GDEM V2 was built in 2011\(^8\). The resulting data is the calculation of the average of the heights of the digital elevation model per grid.

In conclusion, the area framework behaves as a single entity with fixed geographical characteristics; it does not change its position in time, nor its form; the update of the presented information can be done with the described methodology. Additionally, this framework allows integrating geo-referenced data regardless of the source of information. This characteristic facilitates the monitoring, verification and evaluation of the interventions carried out on the territory.

88 https://asterweb.jpl.nasa.gov/gdem.asp
**Affected territory.** Square grids of the 1km area framework, which present EVOA according to the established methodology based on remote sensing [1].

**Alluvial deposits.** Detrital material (formed or composed of fragments) transported by a river and deposited in sectors along its floodplain [55].

**Alluvial plain.** Flat or slightly flat areas bordering a river that have formed due to the accumulation of sedimentary materials derived from fluvial processes where there are flows in motion [44].

**Alluvial valley.** Plains or depressions elongated and inclined by which generally occurs the course of a river either towards the ocean or other rivers of greater hierarchy, and are characterized by being located in the middle of mountains or other formations of greater height [44].

**Amalgamation.** Process in which excesses are linked to previously classified minerals (can be inside water ponds or in gutters), in such a way that the physical property of mercury is used to bond easily with precious metals, a process in which obtains a combined paste (mercury and gold) that is exposed to fire to release the mercury in the form of vapor [51].

**Band.** Wavelength interval within the electromagnetic spectrum. By extension, each of the data acquisition channels of a sensor system is called a band [38].

**Cartographic projection.** Graphic representation system that establishes an ordered relationship between the points of the curved surface of the Earth and those of a flat surface (map), for this uses mathematical transformations [38].

**Color.** A basic element of the visual interpretation of images, it originates from the different wavelengths that capture the eyes as a characteristic of the selective reflectivity of things. For example: if an object reflects wavelengths from 0.5 to 0.6 μm, then what is seen will be green [53].

**Color composition.** Process of forming a color image by composing three bands, each of which is matched by one of the primary tones of red, green and blue [54].

**Decision tree.** Set of conditions organized in a multi-way hierarchical guide structure, in such a way that the final decision to be taken can be determined by following the conditions that are fulfilled from the root of the tree to some of its leaves [50].

**Digital Elevation Model - DEM.** Numerical data structure representing the spatial distribution of the altitude of the land surface [66].

**Digital level.** Discrete numerical value that translates the radiometric intensity received by an electro-optical sensor. It is also known as gray level, luminance, digital number, pixel value, etc [68].

**Digital Processing of Satellite Images.** Discipline that develops the theoretical and algorithmic bases through which information can be extracted from the real world, automatically, from an observed image. Such information can be related to the recognition of objects, three-dimensional descriptions, position and orientation of them or the measurement of any spatial property such as the distance between two well-defined points or the cross-section of the object [43].

**Erial.** Dry areas subject to wind erosion with incipient vegetation of low development, without use [56].

**Filter.** Local operator by means of which the information contained in an image is highlighted or suppressed selectively to highlight some of its elements, or also to hide anomalous values [57].

**Floodplains.** Floodplains are areas adjacent to rivers, subject to recurrent flooding [64].
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**Framework of areas.** Set of grids with national coverage with a systematic and cartographic arrangement of geospatial units of one and five square kilometers, built by the SIMCI - UNODC project to facilitate the geographical continuity of the spatial and statistical analysis of illicit crops in Colombia [1].

**Geographic Information Systems (GIS).** In its broadest sense, a GIS is a group of procedures used to store and manipulate geographically referenced data, either manually or based on a computer [73].

**Georeferencing.** It is the procedure by which a digital image is mapped valid by geometrically correcting the position of the cells and assigning them coordinates in some reference system [58].

**Hot spot.** Anglicism frequently used in Spanish is a point or zone of high activity within a greater area of low activity. The term applies to different things in different contexts [59].

**Interpretation.** Formally, interpretation is defined as “explaining or declaring the meaning of something” [61]. In the context of remote sensing, the interpretation consists in the use of techniques, systems and processes of image analysis by trained personnel, to give safe and detailed information about the natural or artificial objects contained in the surface whose image is analyzed, and determine the factors that imply the presence, condition and use of them [43].

**Interpretation key.** It refers to the characteristic or combination of characteristics, which enable the identification of a particular object, for example the size, shape, tone, color [52].

**Jagüey.** Depression on the ground that allows the storage of water from surface runoff [62].

**Land cover.** Formed by different types of objects or bodies that are on the Earth (vegetation, soil, water, among others) that receive the energy signal from the energy source and reflects or emits according to their physical and chemical characteristics [53].

**LandSat.** Civil satellite information program. The constellation of satellites LANDSAT (LAND = Earth and SAT = satellite), that initially were called ERTS (Earth Resources Technology Satellites), was the first mission of the United States for the monitoring of the terrestrial resources. Its maintenance and operation is in charge of the National Aeronautics and Space Administration (NASA), while the production and commercialization of the images depends on the United States Geological Survey (USGS) [57].

**Lixiviation.** Process based on the use of tanks with cyanide solutions and filtering media, where mixed amalgamation tails are added to facilitate the generation of cyanidation precipitates by gravity that subsequently must be melted at a slow fire to finally separate the gold [63].

**Mangrove swamp.** Coverage of trees adapted to colonize land flooded with salt water [65].

**Multispectral.** Image acquired optically in more than one spectrum or wavelength range. Each individual image is usually of the same physical area and scale but of a different spectral band [67].

**Multitemporal analysis.** It is a spatial type assessment that consists in identifying not only the changes that a particular phenomenon has in itself, but also in relation to terrestrial coverage, through observations or readings that are made in different periods of time [49].

**Panchromatic.** Image collected within the wide range of visible wavelengths but produced in black and white. The term has historically been referred to black and white photographic emulsion sensitive to all visible colors, although not necessarily uniformly [67].

**Pan-Sharpening.** It is the acronym for “panchromatic sharpening” process in which a high resolution panchromatic image is used to adjust a multispectral image by increasing its spatial resolution [1].

**Pattern.** Spatial arrangement of a set or association of similar objects, as well as the systematic repetition of forms. It takes into account the particular spatial organization of the objects of a cover [53].

**Patterning.** Term used in remote sensing to relate the behavior of an object in the image (pictorial-morphological characteristics) with the reality of the terrain [1].

**Pictorial-morphological characteristics.** It refers to those elements present in an image that serve as evidence for the identification of objects, including shape, size, shadows, tone, color, spatial patterns, texture and association [43].

**Radiance.** It is the amount of energy radiated from one object in the unit of time per unit of solid angle and unit of surface of the object perpendicular to the direction of propagation [38].
Radiometric resolution. It refers to the ability of the sensor to detect variations in light or radiation translated into gray levels. In this way, it can be concluded that among more bits, more shades of gray equivalent to a higher radiometric resolution. This feature allows for sufficient contrast in the images, making pattern discrimination easier [57].

Raster. Form of treatment and spatial representation of the entities by means of the arrangement of cells or pixels in the form of a numerical matrix of Digital Levels [38].

Reference system. Set of properly modeled conventions and concepts that allow defining the orientation, location and scale of three coordinate axes (x, y, z) [58].

Reflectance. Measurement of the capacity of a surface to reflect electromagnetic energy in a certain wavelength. It is the existing ratio between the reflected flow and the incident on said surface. Applied to the visible spectrum, it is usually spoken of albedo [38].

Remote sensing. This science refers to the “process of acquiring information at a distance, without physical contact between the source of information (object) and the receiver of the same (sensor)”[70].

Satellite Images. They are passive sensor products and work in the optical range of the electromagnetic spectrum from 0.4 μm to 15 μm. The information capture system is combined with an optic similar to that of photography and an electronic detection system [57].

Shape. It is defined as “external configuration of something”. The shape of a certain object is a key determinant to identify it, since its contour allows assimilating it to one of the patterns that are familiar [38].

Shapefile. Vector representation format developed by ESRI (Enviromental Systems Research Institute). It consists of a variable number of files, in which the location of the geographical elements is stored digitally (file shape * .shp) together with its attributes or characteristics (dBase table * .dbf) [23].

SIMCI. Project framed in the World Program for the Monitoring of Illicit Crops established by the General Assembly of the United Nations whose main objective is to determine the extent of coca cultivation in Colombian territory through satellite images and field verification [72].

Size. The size of an object is one of the most useful clues that lead to its identification. By the measurement of an object, the interpreter can eliminate much of the possibility of confusion from his consideration [43].

Spatial resolution. This term designates the smallest object that can be distinguished on an image [57]. In other words, it is the distance that corresponds to the minimum unit of information included in the image (pixel). Thus, the smaller the pixel size, the greater the spatial resolution, which implies that the sensor will obtain more detail of the objects.

Spectral index. Algebraic combinations of two or more bands that serve to spectrally enhance certain coverage. The result of these operations allows to obtain a new image where certain pixels related to parameters of the coverage analyzed are highlighted [60].

Spectral resolution. It indicates the number and width of the spectral bands that the sensor can discriminate [71]. The more bands in the spectrum discriminate a sensor system, the higher its spectral resolution. This feature facilitates the identification of certain characteristics in an image, since it discriminates information depending on the wavelength between the visible and the infrared, which allows to determine spectral signatures of the terrestrial coverages [38].

Spectral response. Also defined as spectral signature or spectral signature, it is the expression of an object on the Earth surface that allows it to be recognized in a satellite image according to its own characteristics that configure its interaction with electromagnetic energy and its wavelengths [38].

Temporary resolution. It refers to the periodicity with which the sensor acquires images of the same portion of the Earth surface. This cycle is a function of the orbital characteristics of the platform (height, speed, angle, time of capture, inclination), as well as the design of the sensor [57].

Texture. The texture of an image is referred to the spatial contrast between the different elements present in the image and comes from the relationship between the size of the objects and the resolution of the sensor. It is related to the apparent roughness or softness of a region of the image [43].

Tone. It is defined as the degrees of variation of gray that exists between black and white [50].
The United Nations Educational, Scientific and Cultural Organization (UNESCO) is an international organization whose mission is to contribute to the consolidation of peace, the eradication of poverty, sustainable development and intercultural dialogue through the education, science, culture, communication and information. Currently, UNESCO has 193 Member States and 6 Associate Members [74].

**World Heritage.** It is the title conferred by UNESCO to specific sites (be it forest, mountain, lake, cave, desert, building, architectural complex, cultural route, cultural landscape or city) that fulfill a function of landmarks on the planet, of symbols of the conscience of States and peoples about the meaning of those places and emblems of their attachment to collective property, as well as the transmission of that heritage to future generations. These sites have been proposed and confirmed for inclusion in the *World Heritage List* [69].

**World Reference System (WRS).** It is a global numbering system that allows the user to obtain the location of a satellite image obtained by Landsat satellites from any part of the planet, by specifying the ordered pair of the scene (image) that is defined by the PATH (approximate orbit of the satellite) and ROW (nominal center of the scene or image) [38].
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