Adaptation of the Calculator of Social and Environmental Impacts from Small-Scale Gold Mining in the Amazon

APPLICATION IN BORDER REGIONS BETWEEN BRAZIL, COLOMBIA AND PERU

JUNE 2023

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Adaptation of the Calculator of Social and Environmental Impacts from small-scale Gold-Mining in the Amazon: Application in Frontier Regions between Brazil, Colombia and Peru

This document contains the results of the consultancy commissioned by the Amazon Sustainable Landscapes Program (ASL), led by the World Bank and financed with resources from the Global Environment Facility (GEF). In the period between 2022 and 2023, this consultancy was carried out by Conservation Strategy Fund (CSF) in collaboration with the Foundation for Conservation and Sustainable Development (FCDS).

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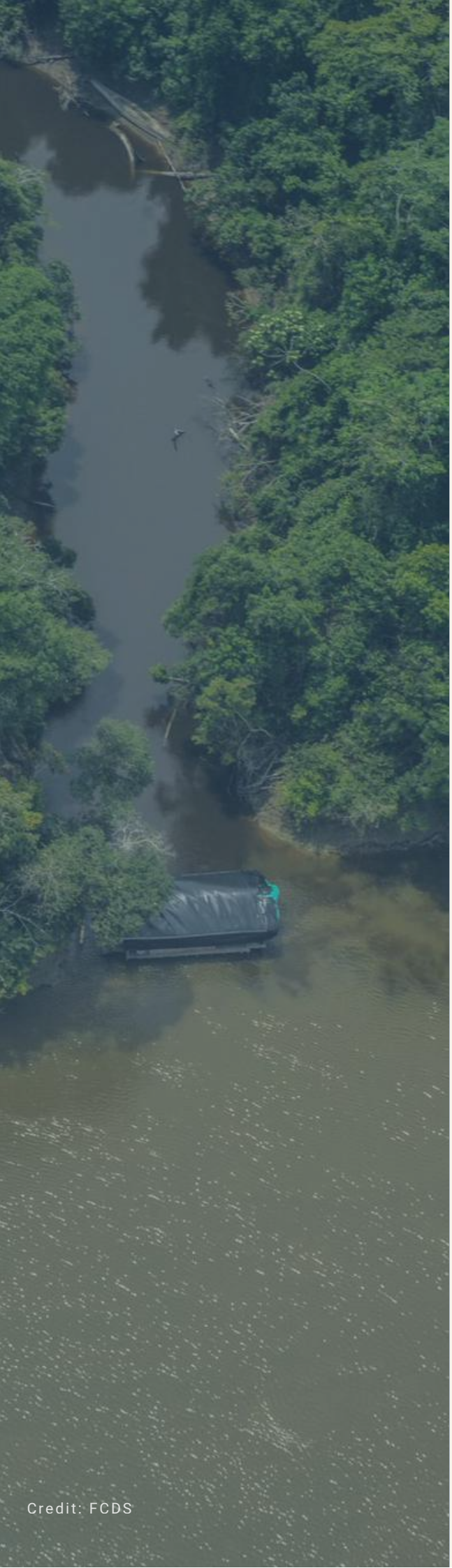

Credit: FCDS

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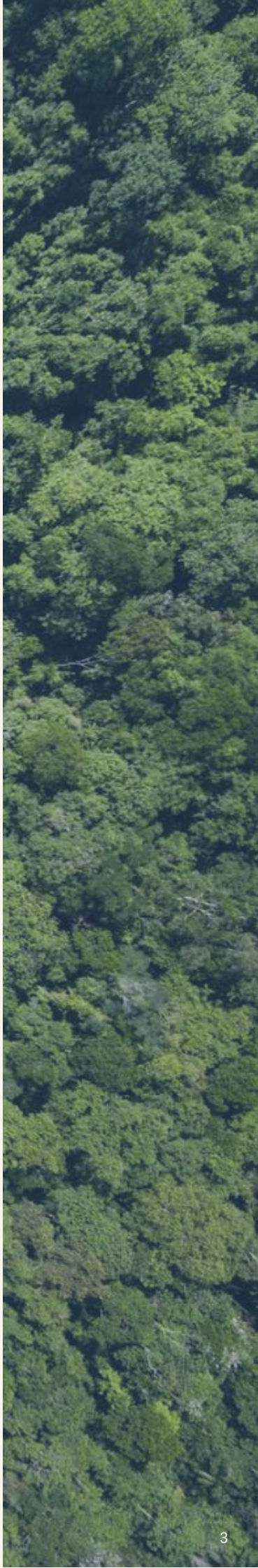
Acronyms

ARAIMO	The Regional Alliance for the Reduction of the Impacts of Gold Mining in the Amazon - *(Alianza Regional Amazónica para la Reducción de los Impactos de la Minería de Oro)*
ASL	Amazon Sustainable Landscapes Program
IQ	Intelligence quotient
CSF	Conservation Strategy Fund
FCDS	Foundation for Conservation and Sustainable Development - *(Fundación para la Conservación y el Desarrollo)*
GEF	Global Environment Facility
MPF	Public Prosecutor's Office - *(Ministério Público Federal)*
PNN	National Natural Parks
RAISG	The Amazon Network of Georeferenced Socio-Environmental Information - (*Rede Amazônica de Informação Socioambiental Georreferenciada)*



1 Introduction

Credit: FCDS

Over the past decade, illegal gold extraction has increased significantly in the Amazon region, partly due to the high international prices of this mineral, the less stringent attitude of some countries in relation to the environment and the pursuit of immediate economic opportunities. Furthermore, this illicit activity is closely intertwined with other illegal practices, such as drug trafficking, human trafficking, and the trafficking of endangered species. This has repercussions not just for the region's ecological wealth, but also for the physical well-being of those safeguarding their lands and the health of communities living in proximity to the extraction zones due to the contamination of their rivers and, consequently, their primary sources of food, such as fish.

Despite the international effort to recognize the socio-environmental repercussions of this activity, there are still gaps on this issue, mainly due to the economic losses that this activity represents.

Considering the above, Conservation Strategy Fund[1] (CSF), in partnership with the Public Prosecutor's Office (MPF) of Brazil, developed the first methodology for the economic valuation of the impacts of small- scale gold mining on deforestation, sedimentation and mercury pollution (Gasparinetti et al., 2021; Bakker et al., 2021). Based on this methodology, the "Gold Mining Impact Calculator"[2] was created. Subsequently, considering the experience of the calculator in Brazil, and by understanding the relevance of the process and seeking to scale it up, the Amazon Sustainable Landscapes (ASL) program, financed with resources from the Global Environment Fund (GEF) and under the leadership of the World Bank, commissioned CSF with the adaptation of the methodology for Colombia and Peru, using specific information for each country; as well as the implementation in pilot sites; and the organization of knowledge exchange spaces between Brazil, Colombia and Peru about the use of the calculator.

The calculator serves to understand and raise awareness about the social and environmental values of the impacts of small-scale illegal mining. Understanding these values can raise awareness of the impacts and their scale, define compensation and restitution payments, estimate efficient investment levels for impact planning and prevention, and support the decision process to invest in mercury-free technologies. This document summarizes the supported process with significant scaling potential.

The video presented here (in Spanish) reflects the results of this process:

1 Conservation Strategy Fund (CSF) is a private organization dedicated to advancing economically driven conservation solutions. Its mission is to use the economy for the benefit of people and nature. They have worked with governments, funders, conservationists, farmers and fishers, among others, to increase economic education around the world and create a better understanding of how economics can improve decision-making. It has offices in the United States, Bolivia, Brazil, Peru, Colombia, Indonesia and Africa (https://www.conservation-strategy.org/).

2 https://miningcalculator.conservation-strategy.org

2 Gold Mining Impact Calculator

The calculator, initially developed for Brazil, is an online analytical and pedagogical tool that economically assesses the social and environmental damages of gold mining considering three specific effects: deforestation, sedimentation and mercury contamination. The tool presents the step-by-step process of economic valuation and its results in an illustrated, accessible, and concise manner, catering to various contexts and audiences. All information can be generated in Portuguese, Spanish or English.

Access the Calculator:
www.calculadora.conservation-strategy.org


Credit: Shutterstock

The calculator is based on economic valuation methodologies, which are useful for estimating the variation in people's well-being as a result of changes in the quality or quantity of environmental goods and services (Da Motta, 1997). The tool calculates the results by synthesizing the relationship between biophysical damage and its impacts on the economy, society and the environment. It does so by drawing upon academic and specialized literature in the subject, as well as field data. All data used for the formulas were validated by relevant actors (government bodies, civil society, academia).

The calculator is applicable for different types of mining activities: alluvial,[3] raft[4] or adit/shaft.[5] Based on the available data, the calculator, for example, allows you to estimate how many hectares will be deforested to produce a certain amount of gold in adit/shaft (tunnel mining), how many m3 of soil will be sedimented in this extraction and how many people will be exposed to the additional risk of presenting neuropsychological problems, cognitive and cardiac effects resulting from exposure to mercury. The presentation of these relationships, from understanding the technical processes of mining to the economic valuation of its various impacts, is unprecedented in the literature and represents an important advance for the promotion of concerted and informed actions that address the problem of gold mining. The magnitude of these impacts is adjusted by contextual factors that influence economic values, such as the density and size of the affected population, the average consumption of contaminated fish and the logistical costs for recovering areas.

3 Extraction of ore by digging open trenches (cavities), generally on the banks of rivers. Also known as "gully mining", it is the most common type of illegal mining in the Amazon.

4 Ore extraction by dredging riverbeds. Carried out on rafts or floating boats, it does not generate deforestation, but has a greater impact due to the contamination of rivers by mercury.

5 Ore extraction through tunnels. It has minor impacts in terms of deforestation and erosion, but it also uses mercury in mineral processing.

The use of this methodology favors the population's awareness to increase consensus on the magnitude of environmental damage, influencing behavior and public policies. Likewise, the possibility of having monetary and non-monetary values and comparable results supports and expands the regional discussion on the effects of illegal mining activity in a strategic area such as the Amazon for the economic development of its countries. The tool contributes to the standardization of damage quantification processes, with the aim of reducing arbitrariness in calculating the values of penalties and indemnities (Gasparinetti et al., 2021; Bakker et al., 2021). It also allows to obtain a value that measures the total cost of these damages that affect public budgets.

2.1 Beginning of the Calculator in Brazil

The Brazilian experience, based on on its adoption by the country's control and justice bodies, has generated positive results that, when disseminated, have increased the interest of other Amazonian countries in adopting the calculator. The MPF adopted the methodology in 2021, and has been using it in several compensation actions that, to date, total more than US$1 billion. Furthermore, the Federal Police also uses the tool to carry out dozens of calculations of environmental and social damage.

The use of values related to mercury pollution is pioneering and has led to a nearly tenfold increase in fines issued by the Brazilian government compared to the previous estimates without the methodology. Due to the extended duration of the legal proceedings for these actions by the relevant entities and the relatively recent launch of the tool, there is still no record of completed cases that have used the methodology as a basis for sentencing.

3 Adaptation of the calculator for Colombia and Peru - Pilot application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The adaptation of the calculator to other countries was motivated by the interest of having the same economic tool and methodology, seeking its application to improve procedures and approaches to deal with cross-border problems related to mining and mercury contamination in the Amazon basin. Through this, the calculator becomes a technical tool that facilitates regional cooperation.[6]

The adaptation, commissioned by ASL, involved CSF, which, in cooperation with the Foundation for Conservation and Sustainable Development (FCDS)[7], initiated a series of inter-institutional coordination and dialogue events to disseminate the tool to potential users in Peru and Colombia. This process occurred in parallel with the collection of economic data for the adaptation of the calculator, and was a fundamental process to (i) awaken the interest of potential users, (ii) involve government entities in the socialization process, (iii) promote, in different instances, the need to have economic valuation methods that allow, in real time, to quantify the socio-environmental damage generated by gold mining, and (iv) build and strengthen institutional support for the future formal adoption of the tool as an official methodology. Once the first version of the calculator was completed for each country, the tool was presented to validate the data used for the formulas and receive feedback from relevant stakeholders in each country.

The adaptation process of the calculator was supported by workshops held with multiple stakeholders in Peru and Colombia, in addition to a regional exchange meeting, held in Lima, between September 2022 and March 2023. The workshops allowed sharing information about the effects of gold mining and mercury contamination in the countries involved and deepening the understanding of the environmental, social, cultural and economic impacts of mining in the Amazon.

6 *As of the date of this publication, Guyana and Suriname are also making progress in adapting, with resources from other funding sources, and Ecuador is making progress in adopting and implementing the tool.*

7 *FCDS is a non-governmental organization whose objective is to contribute to the sustainable and equitable development of human populations, especially rural populations, in harmony with the conservation of the natural base and social characteristics of territories.*

Likewise, opportunities for cooperation were identified in the actions necessary to manage the impacts of this illegal activity and information and input management mechanisms were established to operate the calculator in Colombia and Peru. Brazilian government officials participated in the workshops and shared their experiences and concrete applications of the calculator. They also contributed to the discussion of recommendations for future applications and scaling potential.

As part of the work with ASL, CSF created a **manual** (available in Spanish) that explains, using simple, step-by-step instructions, the use of the calculator and its functionalities. Additionally, **a video** is available. The work also allowed adjustments to be made to the calculator and its virtual platform, seeking to respond to the recommendations and needs of users from all countries. The summary of the results of these cases is presented below. The detailed methodological development (technical report) is found in the following links and includes specific information for **Colombia** and **Peru** (both available in Spanish). The detailed report of the use of the calculator for the case studies can be found at **this link** (available in Spanish).

Representatives from the environmental and health sectors of Brazil, Colombia, and Peru, participated in the workshops, as well as representatives from states, departments, or provinces, non-governmental organizations, media outlets, representatives from civil society, indigenous peoples' organizations, and academia. It was a collaborative process between the parties in which the positive aspects of the tool, its challenges, some possible modifications and the ways in which its benefits can be disseminated to the broaded public were discussed.

In addition to the workshops, to promote collaborative actions between the three countries, exemplify the applicability of this tool and show the results that can be obtained with its implementation, two case studies were prepared in the Amazon region: the first located on the border between Brazil and Colombia, formed by the Puré River, and the second on the triple border between Colombia, Peru and Brazil. These locations were prioritized by the Regional Alliance for the Reduction of the Impacts of Gold Mining in the Amazon (ARAIMO)[8] because of their transboundary nature, presence of indigenous communities, protected areas and because of the illegal mining activity registered in recent years, as well as their potential to propose joint actions.


Credit: Shutterstock

8 The Regional Alliance for the Reduction of the Impacts of Gold Mining in the Amazon (ARAIMO) is formed by organizations that, through community work, seek to reduce, prevent and restore the impacts of mining in the Amazon. Specifically, ARAIMO is composed of civil society organizations and institutions from Colombia, Peru and Brazil (Sociedade Zoológica de Frankfurt - FZS Colombia and Peru, GAIA Foundation Colombia, WWF Colombia, National Natural Parks of Colombia, Instituto Oswaldo Cruz - FIOCRUZ do Brasil , Amazonas Scientific Innovation Center - CINCIA from Peru, Amazon Conservation Team - ACT Colombia, University of Cartagena Colombia and FCDS Peru and Colombia.

3.1 Case 1 - Puré River (Brazil – Colombia border)

Map 1. Study area (2020). Source: IBGE, MMA, Maxar, Esri and DANE.

Historically, in Colombia, illegal exploitation of gold deposits has been concentrated in the departments of Bolívar, Antioquia and Chocó; but recently, the Amazon region (departments of Amazonas, Guainía, Caquetá, Putumayo, Vaupés, Guaviare) stands out as a new area of illegal exploitation. For example, according to the Amazon Network of Georeferenced Socio-Environmental Information (RAISG), in 2020, around 100 mines were found along the Caquetá, Putumayo and Cotuhé rivers.

The study area for the pilot tests of the adaptation of the calculator is a polygon that has 45,860 km2 and is located between the border of Brazil and Colombia (see Map 1). On the Colombian side, the area is within the limits of the department of Amazonas; while, on the Brazilian side, it is located in the municipality of Jarpurá. The region has low rates of deforestation and is bordered by the Puré, Juami, Japurá rivers and their tributaries.

In the region, on the Brazilian side, is the Juami-Japurá ecological station, where the Puré river flows. It is home to several indigenous peoples in a situation of voluntary isolation and who are endangered by the increase in mining activity in the region. The region is home to endangered species such as the woolly monkey (*Lagothrix lagotricha*), the executioner monkey (*Accipiter poliogaster*), the royal hawk (*Harpia harpyja*) and the spider monkey (*Ateles paniscus chamek*), among others. On the Colombian side of the pilot site is the Puré River National Natural Park (PNN).

The case study based its analysis on the illegal mining of rafts, since this type of extraction is predominant in this region, threatening its preserved character and natural exuberance. It is a remote area, difficult to access, with little deforestation, but with signs of impacts along the rivers. River mining by means of rafts allows for immediate displacement from one extraction point to another, as well as the ease of hiding in small tributaries or ravines, where vegetation cover makes it difficult to locate the barges using satellite images. On the Brazilian side, illegal mining has intensified since 2019, when 4 (four) rafts were identified. On the Colombian side, exploration using rafts began in 2016.

Through an investigation carried out by the FCDS team, several points of activity of barges for gold extraction in the study area were identified. The 2020 scenario was chosen for carrying out the calculations because it is the year with the highest number of illegal mining by means of rafts in recent years.

Furthermore, through a collaborative initiative between Maxar[9] and the National Natural Parks System (PNN) of Colombia, monitoring was carried out with high-resolution satellite images along 200,000 km2 of the Puré River, between the June 5th. and August 20th. of 2020 (Hettler, 2022). From the images, 26 rafts were identified operating in the Puré River PNN region, and four on the Brazilian side, close to the border with Colombia, totaling 30 rafts. To calculate the impacts, it was assumed that 30 rafts would operate for one year. The number of months of operation (360 months) is one of the input values for the calculation. Thus, the impacts were estimated using the calculator adapted for Colombian territory for the 26 rafts and applying the calculator for Brazilian territory for the remaining four.

To assess the impact that the 30 rafts had on the study area, it was first necessary to consider the non-monetary impacts of the activity. For this, the production of gold, the amount of sediment removed, which generates the solid product in suspension from dredging (plume), as well as the amount of mercury that the operation uses and that is released into the rivers, were estimated. Calculated monetary impacts include: sedimentation impacts, neuropsychological damage in prospectors, loss of IQ in fetuses, and increased risk of cardiovascular disease in the population. According to the studies and calculations performed, a total of 30,643 people could be affected, considering a radius of 100 km from the study area (Diringer et al., 2014).

The application of the calculator methodology in this pilot territory provided, evidenced and quantified the non-monetary and monetary damages caused by gold extraction with rafts in the study area, which can be found in the following tables (Tables 1 and 2). The tables show the results of the sedimentation and health impact. For this case, there are no results related to deforestation because mining is carried out using rafts and it is assumed that it does not cause deforestation.


Credit: FCDS

9 Maxar is a company that uses artificial intelligence and a complete mathematical model to increase the resolution of satellite images to contribute to national security, space exploration, research and solutions that improve sustainable practices in relation to the planet.

Table 1. Non-monetary impacts of illegal mining with rafts on the Puré River (2020)

Type of Impact	Colombia	Brazil	Total
Number of mining rafts	26	4	30
Total gold extraction (30 rafts operating for 1 year)	312	48	360
Gold production (kg)	131	21	152
Sediment removed (t)	5,86,972	844,102	5,931,074
Sediments generating plume (impact) (t)	38,067	2,988	41,055
Mercury used (kg) - 2.33 kg per kg of gold	305.32	50.66	355.99
Mercury released into rivers (kg) - 20%	61.06	10.13	71.20

Source: Elaborated by CSF based on the results of the case study.

Table 2. Monetary impacts of illegal mining using rafts on the Puré River (2020)

Type of Impact	Colombia (USD)	Brazil (USD)	Total (USD)
River sedimentation	492,643	169,992	662,635
Neuropsychological symptoms on illegal miners	3,932,013	266,002	4,198,015
Loss of IQ in fetuses	209,857	30,896	240,753
Risk of cardiovascular diseases	79,609,482	1,738,479	81,347,961
Total cost	**84,243,995**	**2,205,369**	**86,449,364**

Source: Elaborated by CSF based on the results of the case study.

The main impacts of river sedimentation are the contamination of river water resources, the release of heavy metals and increased water turbidity (Lobo et al., 2016; Swenson et al., 2011). The results of this process can be detected hundreds of kilometers from the impact site, in aquatic and terrestrial ecosystems (Sánchez-Cuervo et al., 2020). According to the case study, the sedimentation cost for Colombia is 0.6% of the total costs for the country, while for Brazil, these costs represent 7.7% of the total costs for the country.

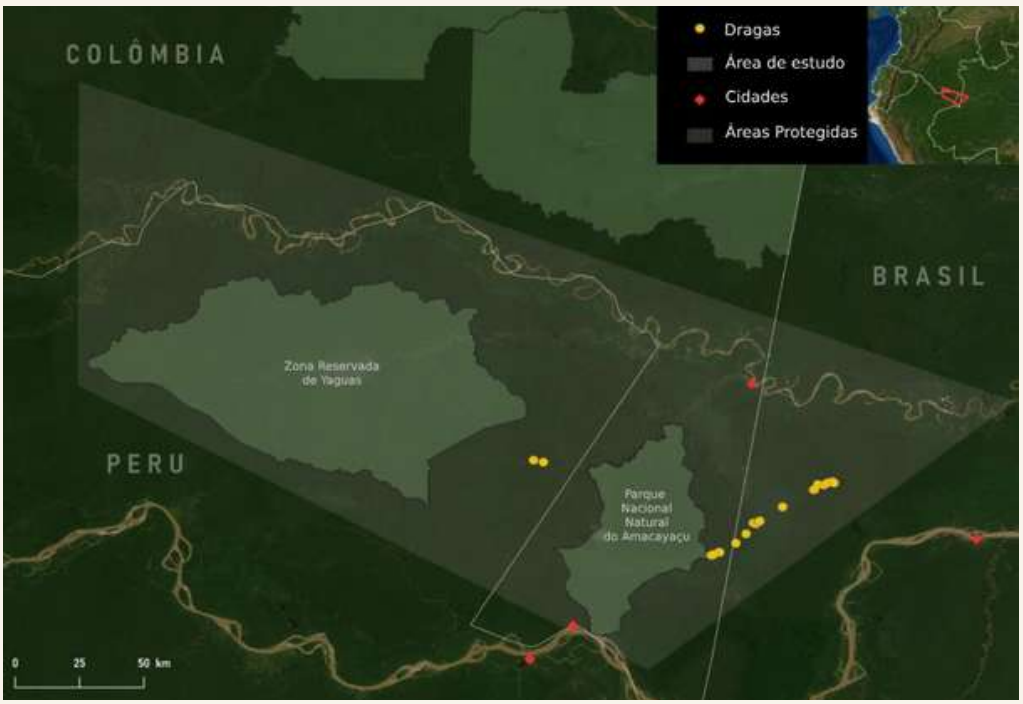
Regarding impacts on human health, there is evidence that links the development of myocardial infarction with the presence of methylmercury in fish consumed by the human population and from mining activities (Román et al., 2011). The majority of costs are health-related for the recovery of people with neuropsychological symptoms and cardiovascular disease. The difference in hospitalization and recovery costs between the two countries, which is higher in Colombia, is also taken into account.

The results show that the vast majority of costs come from this category (approximately 99.5% for Colombia and 93% for Brazil). Of the health impacts, the risks of cardiovascular disease are the highest.

The advance of mining in indigenous lands and protected natural areas has been highlighted in the literature and has promoted conflicts between traditional communities and these external agents (Rorato et al., 2020). In the case of the region studied, the future of indigenous peoples in a situation of voluntary isolation depends on the continuity of this isolation and the recognition of their right to live according to their customs. Despite the legal advances derived from Decree 1,232 of Colombian legislation, which establishes special measures to protect the rights of Indigenous peoples in voluntary isolation, concrete actions are necessary to guarantee the protection of these peoples against the impact caused by mining. Protection is even more necessary in the face of the invasion of PNN by illegal miners, destroying its resources, contaminating its waters and threatening its isolation.

In Brazil, a study carried out by Fiocruz (2020) showed the contamination levels of an indigenous population located close to alluvial mining sites and rafts. According to this study, mercury contamination in 57.9% of the community was at levels above 6 µg-g-1, the maximum safety level established by health agencies. The study also revealed that the community closest to the mining area had the highest levels of mercury concentration. Likewise, children presented higher levels of contamination, with 15% of them having neurological problems.

3.2 Case 2: Triple Border, Colombia, Peru and Brazil



Map 2. Study area (2020). Source: IBGE, MMA, Maxar, Esri and DANE.

In the case of Peru, gold mining has a long historical tradition and has been present for centuries in an artisanal way, but has exploded in recent decades due, among other things, to the increase in international demand for gold and other minerals. In this context, Peru became the sixth largest gold producer in the world (Tamayo et al., 2017).

This case study focuses on an area of 42,964 km2 located between the borders of Peru, Brazil and Colombia (see Maps 2 and 3). On the Colombian side, the area is within the limits of the department of Amazonas; on the Peruvian side, in the department of Loreto, and on the Brazilian side, it is located in the state of Amazonas.

Within the study area is the Yaguas National Park located in the provinces of Mariscal Castilla and Putumayo in Peru, and close to the borders with Colombia and Brazil. According to a report by the Amazonian Center for Anthropology and Practical Application (CAAAP) (2017), there is pressure in the region among illegal miners and loggers to develop these activities with the support of traditional communities. Illegal logging is mainly due to pressure from the extraction of cedar (*Cedrela odorata*), an Amazonian tree species with high added value and which occurs in large concentrations in the Park. In relation to mining, the study by Maldonado Rodríguez (2010) records that the northern region of the park is characterized by the activity of rafts for gold extraction. The report also points out that the area has high ecological relevance, as it is a breeding area for some endangered species, such as the pink dolphin (*Inia geoffrensis*), the South American manatee (*Trichechus inunguis*) and the river otter (*Pteronura brasiliensis*). Likewise, it has the largest number of hydrobiological species in all of Peru, in addition to an exuberant fauna and flora. Furthermore, it records more than 330 species of freshwater fish, which represents potential for research and bioprospecting in the region. Mining activity in the area has intensified since 2016, threatening natural resources (Finer & Manani, 2018). In addition to mining, the area is also infested with coca plantations for drug production and illegal deforestation (SZF, 2022).

Another ecologically and socially significant area within the study area is the Amacayacu National Natural Park (PNN Amacayacu), located in the Amazonas department of Colombia and established in 1975. With access to the Amazon River, the zone was created with the intention of controlling the illicit trade in resources natural resources with Peru (Maldonado Rodriguez, 2010). According to the Sula portal, the region is home to more than 5,000 species of plants and has the greatest diversity of primates on the planet, including the species *Callithrix pygmaea*, the smallest primate in the world. It is one of the areas with the greatest biodiversity in the entire Amazon jungle and according to Ungar and Strand (2012) it is one of the most used in the country by researchers for preparing articles and research on the environment.

It is worth mentioning that the Tikuna indigenous people reside within the park, who are also present in Brazil, given the park's proximity to the border, as well as indigenous people from the Yagua, Cocamas and Huitotos ethnic groups, but in smaller numbers.


Credit: Ministry of Environment of Peru

For the study and application of the calculator, FCDS identified several illegal mining sites in the region. Two years were considered for this analysis: 2021, as it was the year in which the highest concentration of rafts was detected, and 2022, as it had a more homogeneous distribution of illegal mining in the three territories. To account for the two characteristics observed, it was decided to carry out two separate analyses.

In 2021, two raft operating points were identified in the study area of Peru, 4 in Colombia and 15 in Brazil. In 2022, 51 rafts were identified on the Brazilian side and 10 in Colombia. Although the presence on the Peruvian side was not identified until 2022, studies indicate that the impacts of illegal mining extend more than 100 km from the extraction point (Gasparinetti et al., 2021).

As in case study 1, the results of applying the calculator methodology in case study 2 -the triple frontier- show the non-monetary (Table 3) and monetary (Table 4) damages caused by illegal mining activity with rafts during the two periods: 2021 and 2022. The impacts of deforestation do not apply to extraction by rafts as mentioned above.

3.2.1 Results of Case 2. 2021 Period

Table 3. Non-monetary impacts of illegal mining with rafts in the triple border (2021)

Type of Impact	Peru	Colombia	Brazil	Total
Number of mining rafts	2	4	15	21
Total gold extraction (rafts operating for 1 year)	24	48	180	240
Gold production (kg)	5.50	40.89	81.54	127.90
Sediment removed (t)	1,765,944	863,350	3,165,382	5,794,677
Sediments generating plume (impact) (t)	2,490	5,856	11,205	19,551
Mercury used (kg) - 2.33 kg per kg of gold	12.82	95	189.98	298
Mercury released into rivers (kg) - 20%	2.56	19.05	37.99	59.62

Source: Elaborated by CSF based on the results of the case study.

Credit: Shutterstock

Table 4. Monetary impacts of illegal mining with rafts in the triple border (2021)

Type of Impact	Peru (USD)	Colombia (USD)	Brazil (USD)	Total (USD)
River sedimentation	63,159	75,791	849,964	988,914
Neuropsychological symptoms on illegal miners	66,773	604,925	997,509	1,699,207
IQ loss in fetuses	6,996	35,883	113,082	155,961
Risk of cardiovascular diseases	440,549	10,144,737	7,206,071	17,791,357
Total Cost	**577,477**	**10,861,336**	**9,166,626**	**20,605,439**

Source: Elaborated by CSF based on the results of the case study.

The majority of costs (approximately 90% for Peru and Brazil and 99% for Colombia) are related to health and, more specifically, the recovery of people with neuropsychological symptoms and cardiovascular diseases. The impacts and, therefore, the costs are influenced by the power of the raft engines that extract the mineral from the river beds; that is, rafts with greater power and production capacity will remove greater sediment and use greater amounts of mercury. As in the first case, the difference in costs by country is also significant, with Colombia being the country with the highest recovery costs for health problems (both for fish consumers and miners) resulting from mining. Mercury exposure for miners is obviously more intense and represents a cost of US$1,669,207.

3.2.2 Results of Case 2. 2022 Period

Tables 5 and 6 show in this scenario the impacts of the increase in monetary and non-monetary costs of mining with the increase in the number of rafts. Compared to 2021, this scenario has 40 more lagoons identified between Colombia and Brazil (Peru was not included in this year of analysis).

Table 5. Non-monetary impacts of illegal mining with rafts in the triple border (2022)

Type of Impact	Colombia	Brazil	Total
Number of mining rafts	10	51	61
Total gold extraction (rafts operating for 1 year)	120	612	732
Gold production (kg)	50.4	277.2	327.6
Sediment removed (t)	1,956,528	10,762,301	12,718,829
Sediments generating plume (impact) (t)	14,641	38,097	52,738
Mercury used (kg) - 2.33 kg per kg of gold	117.43	645.96	763.39
Mercury released into rivers (kg) - 20%	23.49	129.19	152.69

Source: Elaborated by CSF based on the results of the case study.

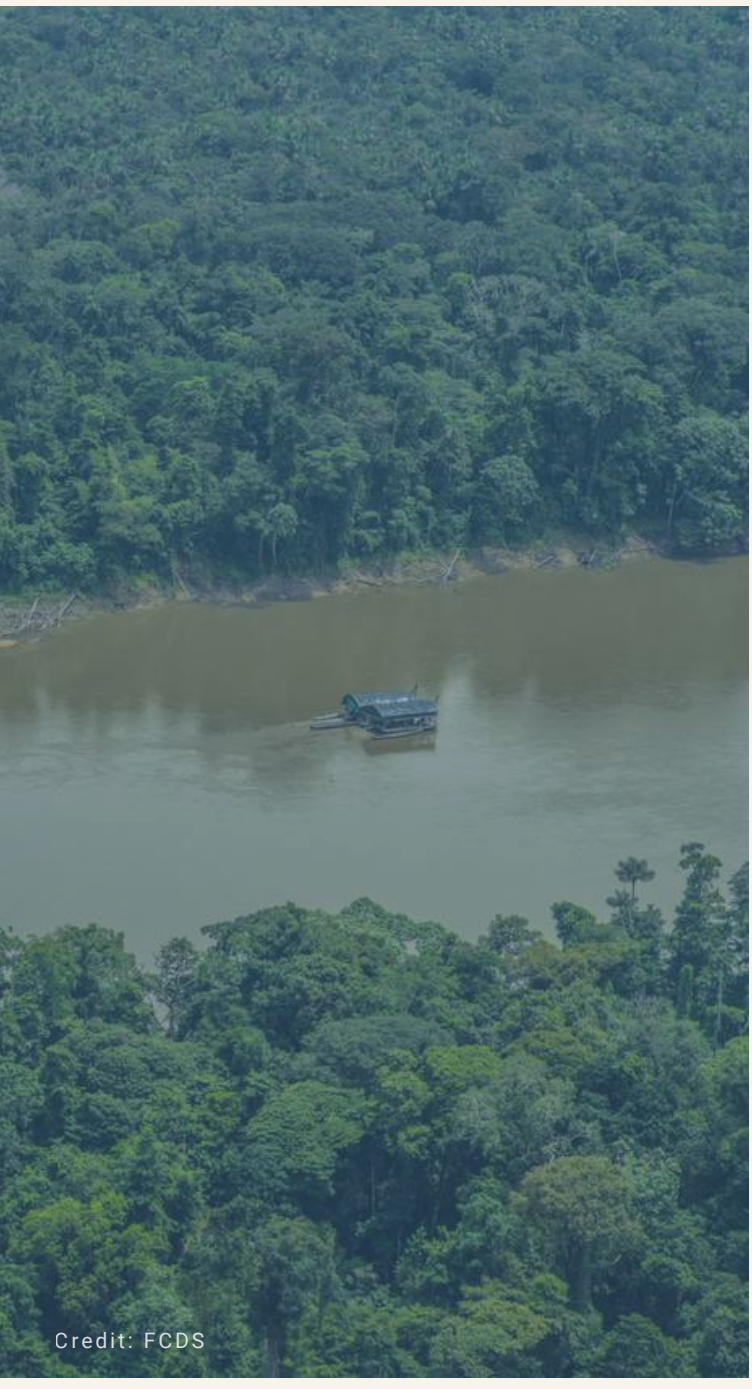
Table 6. Monetary impacts of illegal mining with rafts in the triple border (2022)

Type of Impact	Colombia	Brazil	Total
River sedimentation	189,478	2,167,409	2,356,888
Neuropsychological symptoms in illegal miners	1,512,314	3,391,533	4,903,847
Loss of IQ in fetuses	89,708	384,481	474,189
Risk of cardiovascular diseases	27,699,195	27,234,511	54,933,706
Total Cost	**29,490,695**	**33,177,935**	**62,688,631**

Source: Elaborated by CSF based on the results of the case study.

During the 2022 period, the majority of costs (more than 95% for both countries) are also health-related, mainly linked to the recovery of people with neuropsychological symptoms and cardiovascular diseases due to exposure to mercury used in mining. In addition to the contamination of the population, miners suffer from more serious problems due to direct exposure to the metal. This exposure represents a cost related to recovery and treatment of mercury neuropsychological symptoms.

4 General application results of the Calculator in pilot cases


Credit: FCDS

The calculator allowed to monetize the loss of society's well-being due to the impact of mining in these two selected regions. These numbers not only warn about the seriousness of the problem, but also encourage the formal adoption of the calculator to use the numbers, which are supported by scientific literature, in future judgments and sentences.

Overall, total economic damages for each case study ranged from USD20 million to USD86 million. The analysis of the results shows that damage to health shows the highest values. This value is derived from each country's hospitalization costs, which can vary substantially.

The process supported by the ASL also managed to strengthen the capacities of institutions in Brazil, Colombia and Peru to economically assess the socio-environmental impacts of gold mining. The use of economic tools, such as the Gold Mining Impact Calculator, has provided easily accessible economic information and reliable evidence-based interpretation to bring cases to court, strengthen decision-making processes, and raise awareness about the impacts of this activity. Furthermore, control bodies will be able to benefit from the tool in the planning processes for investments in control, surveillance and prevention, since the level of social costs that can be avoided if invested in this type of actions has been demonstrated.

5 Conclusions and Recommendations

5.1 Conclusions

With the increase of illegal mining in the Amazon region, there is a need for tools that allow to understand and deal with the issues, be it prevention, combat, mitigation or remediation. The Gold Mining Impact Calculator was born from the need to estimate the damage caused by this activity, and its implementation in Brazil, as well as case studies and pilot tests in sensitive areas of Peru and Colombia, demonstrated the usefulness and power of this tool.

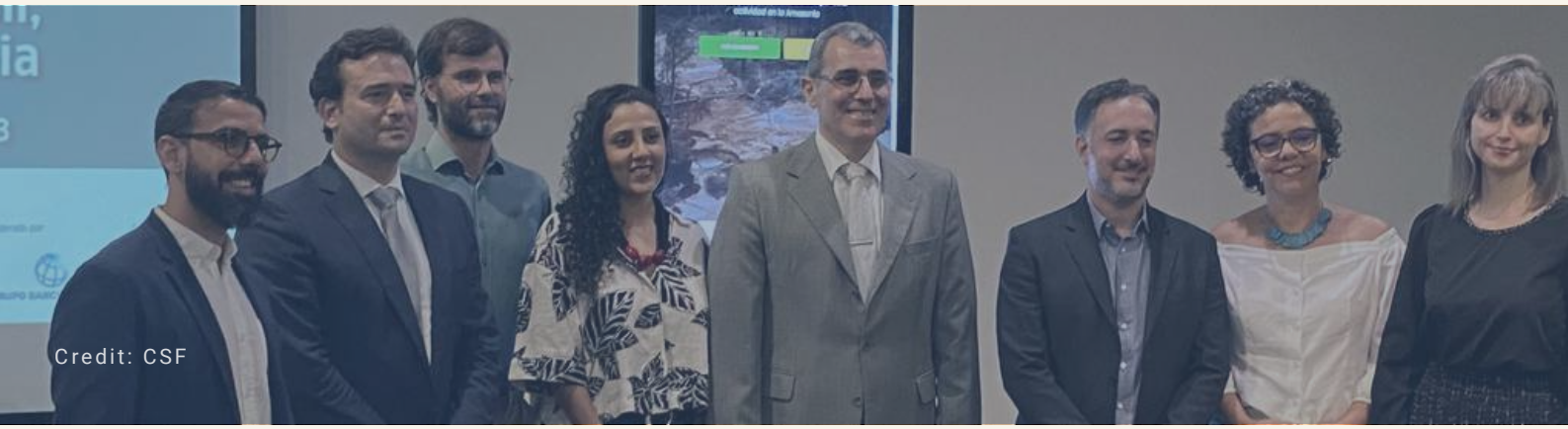
The calculator has great legal potential if it is integrated in an automated way into a raft detection system, such as the one used by the company Maxar and the Brazilian Federal Police. This way, it would be possible to assess the impacts of activities quickly, helping the work of supervising bodies and producing results in real time, and thus allowing to judge cases and rendering sentences supported by scientific literature.

But the scope of the calculator goes far beyond the legal issue when it comes to estimating the impacts on society's well-being. It has the potential to reflect the magnitude of the problem, contributing to greater formalization of artisanal mining operations. Indeed, by accounting for the negative effects of mercury on human health, especially in miners who carry out the activity, it can promote a change in behavior, such as the use of technologies that prevent the release of mercury, such as retorting, or even the adoption of mercury-free practices. Likewise, it can shed light on the health impact of consuming fish from waters contaminated with mercury, through educational campaigns so populations avoid this consumption. Finally, the calculator can draw attention to the threats faced by indigenous territories, protected natural areas and their inhabitants.


Credit: World Bank

5.2 Recommendations

The implementation of the Calculator in Brazil, the process of adapting the Calculator in Peru and Colombia, as well as the implementation of the tool in priority areas in the countries involved, yielded numerous lessons learned and recommendations, among which it is worth highlighting:


Credit: CSF

Expansion of the Calculator Scope

- Encourage the practical application of the tool in the formulation of new large-scale case studies across the Amazon and apply the calculator in other cross-border Amazon regions that are being threatened by the renewed outbreak of gold mining.

- Include calculator use in the assessment and evaluation of mercury-free techniques to demonstrate their socioeconomic benefits.

- Standardize the technical terminology applicable to the mining sector among the countries included in the calculator (for example, type of mining, materials used in the mining activity, techniques used in the field, among others).

- Promote new studies that evaluate the relationship between mercury ingestion and increased risk of harm to health, which provide more quantitative evidence in terms of variations in relative risks and fractions attributable to mercury, in addition to continuous monitoring of mercury contamination levels in the population.

- Carry out long-term monitoring studies that asses mercury concentrations in water, sediments and fish, specifically in the Amazon biome. These efforts can generate long-term data records that can be compared with forecasts. Without these studies, it is difficult to quantify environmental responses to a change in gold extraction and assess the time required for these responses to become evident.

- Promote greater knowledge sharing opportunities between national emergency management agencies and international prosecutors, especially among neighboring countries such as Peru, Ecuador, Colombia, and Brazil, particularly to coordinate actions in border areas.

- Continue promoting the exchange of experiences between Brazil and other countries benefiting from the calculator. From the organization of the workshops, it was found that despite the logistical challenges -in terms of distance and travel time- throughout the project there was ample availability and willingness of MPF representatives (attorneys and experts) to publicize the practical application of the calculator in the various events held. The exchanges were fundamental to the efforts to generate institutional interest, willingness to act collaboratively and share knowledge about good practices.

- Strengthen training in economics and concepts of economic valuation, especially aimed at justice operators, on the impact caused by illegal gold mining in the Amazon. It is recommended that training be continuous, given the high turnover of authorities. For this reason, it is important to ensure that the knowledge acquired by trained authorities can be hosted at the institutional level and transferred to competent staff. To ensure this, it will be necessary to constantly monitor how the knowledge acquired is being applied and how the calculator is being adapted in both countries. Local and indigenous communities directly affected by gold mining should also be an important target audience for this training, as it would assist them in obtaining economic arguments to support their demands.

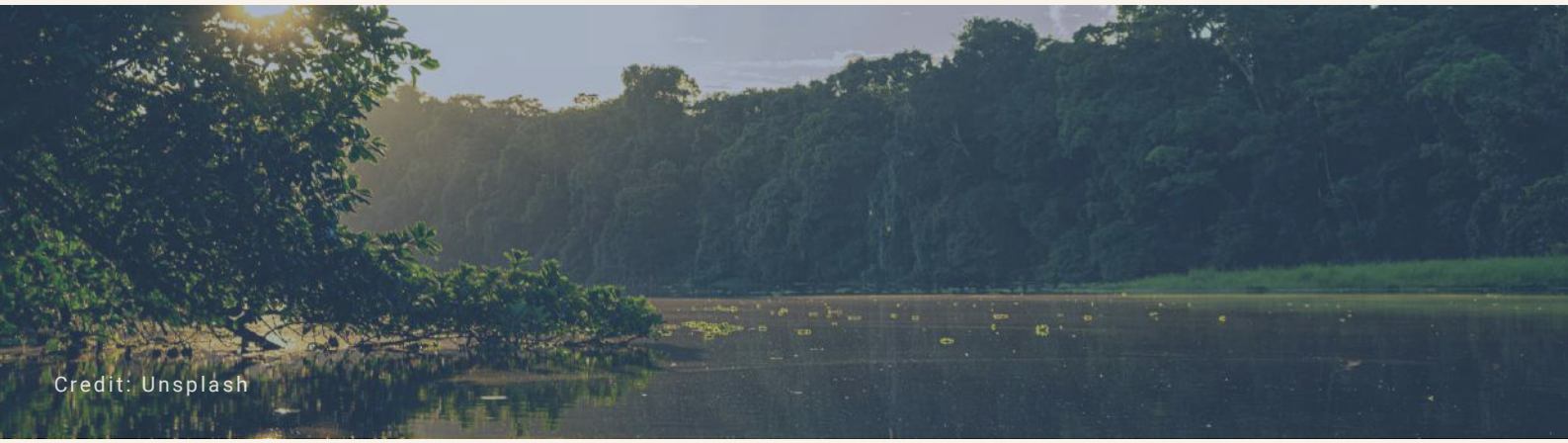
- Provide decentralized training to the competent authorities (Public Ministry, Public Environmental Ministry, Regional Governments, National Police, Ministry of Foreign Affairs, among others) in the regions/departments most affected by illegal mining. For regional events, it is advisable to make prior in-person visits to establish initial contact with the authorities to ensure a successful turnout.

- Develop communication campaigns to disseminate the calculator results to different audiences, from local communities and government authorities to the general public, to raise awareness and promote engagement. Such campaigns must be adapted to appropriate socio-cultural contexts and languages.

- Establish alliances with media outlets specialized in environmental issues, and especially in illegal mining, to promote training, dissemination and investigative journalistic reporting, that:
  - Provide assistance in interpreting the results of the calculator in the territories where it was applied.
  - Generate advice and/or analysis of new areas threatened by illegal mining and which have not yet been incorporated into the tool.

- Adapt the calculator to: (i) include other ecosystems in which gold mining activities also occur (and not only the Amazon region), (ii) consider other toxic substances used in gold mining activity, such as cyanide, (iii) evaluate the impact caused by legal mining, (IV) expand the use of the calculator for preventive purposes of illicit activities, and not only sanctions and repair of damages, and (V) expand to other environmental crimes.

Credit: Shutterstock


Credit: Unsplash

Interinstitutional, Amazonian and Larger-Scale Collaboration

- Articulate actions and agendas with different actors working on the same topic in the countries involved. This will help increase reach, work on a coordinated agenda, and avoid duplication of efforts. In this sense, it is important to highlight that the close coordination between CSF and FCDS, and in turn with the members of ARAIMO, contributed to articulating agendas given the thematic affinity and coincidence of interested actors.
- Incorporate the calculator into broader efforts to monitor in a detailed and coordinated way by neighboring countries the presence and intensity of mining activity in Amazon rivers. This monitoring would benefit from having open access protocols for recording information.
- Promote management aimed at incorporating the need to use robust and validated methodologies to calculate the social and environmental values of mining in corresponding policies and laws.
- Within each country and between countries, strengthen interagency collaboration among relevant environmental entities with information on the economic valuation of illegal gold extraction, whether in protected natural areas and/or in buffer zones.
- Formalize a cooperation mechanism between relevant government institutions on issues related to the impact of mining and that help improve informed decision-making. Involve the Amazon Cooperation Treaty Organization (ACTO) in these efforts, which may require arrangements and meetings between foreign ministries, and which may lead to regional adaptation of the calculator.
- The concrete implications that the experiences of using the calculator in Brazil, Colombia and Peru have highlighted have not only been relevant to the current situation of combating illegal mining in each country, but also allow us to think about the scope of the methodology for the future. The calculator facilitates the approval of procedures and, therefore, the development of joint actions to face a regional problem. It is part of a multisectoral process that allows regional and joint action to investigate the impacts of gold mining, but also to develop action plans to promote socio-environmental and economic benefits for the people living in the Amazon. This coordination between countries attracts international financing interested in promoting sustainable economic development in Latin America, something that will undoubtedly have a positive impact on the region's development at all levels.
- The Gold Mining Impact Calculator is an important step in a comprehensive effort to combat illegal activities. Understanding the costs of their impacts will be fundamental information for decision makers in national and cross-border scenarios.

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