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Comisión Nacional para el Desarrollo y Vida sin Drogas

INTERNATIONAL TARGETED POLICY ANALYSIS

Cocaine and the environment: building the foundations for measurement

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Introduction

Goals

The purpose of this report, prepared jointly by the European Union Drugs Agency (EUDA) and the *Comisión Nacional para el Desarrollo y Vida sin Drogas* (DEVIDA) ([1]), is to contribute to the development of tools to understand the negative impact that activities related to cocaine and connected markets may have on the environment. While cocaine is the primary focus of this report, it is developed with an awareness that similar processes and environmental impacts may arise across other illicit drugs and related markets. Although there is growing attention and evidence documenting these impacts, efforts to build a comprehensive framework to capture and measure drug-related environmental impacts remain at an early stage of development.

This analysis was guided by two specific objectives: (1) to understand the current approach to monitoring cocaine-related environmental impacts in Peru, and (2) to identify tools and metrics for measuring and monitoring cocaine-related environmental impacts more broadly. The analysis draws on a review of the literature and expert consultation, which we outline in more detail below.

Monitoring international drug developments that may pose a threat or have implications for the EU is a strengthened priority under the EUDA's new mandate ([2]) and is also reflected in its international cooperation framework ([3]). As such, the EUDA is developing a range of services that aim to enhance shared preparedness through stronger partnerships. This report is part of this institutional effort. It also contributes to the broader development of information management approaches by DEVIDA in Peru.

The analysis presented here will be of interest to policymakers and professionals working at the intersection of drug policy and environmental protection.

Why this matters

Illicit drug markets can generate environmental impacts, affecting soil, water, air quality and biodiversity. Some of these negative impacts stem directly from illicit activities such as soil degradation and water pollution caused by toxic waste dumping during the processing of drugs, while others may manifest indirectly: for instance, through the reinvestment of drug trafficking profits into other legal and illegal land use, which subsequently contributes to additional forest clearing ([4]). However, the current understanding of these dynamics remains limited, with existing research focusing primarily on specific segments of the supply chain for certain substances and examining impacts in a relatively small number of countries.

While historically environmental issues have received less attention than other aspects of drug policy, there has been increased attention to this area in more recent years. For instance, the 2021–2025 EU drugs strategy integrated environmental damage as a strategic priority for the first time ([5]). In 2024, the La Paz Declaration under the Coordination and Cooperation Mechanism on Drugs between

([1]) DEVIDA is the Peruvian government agency responsible for designing, coordinating and implementing the National Strategy against Drugs.

([2]) Regulation (EU) 2023/1322 of the European Parliament and of the Council of 27 June 2023 on the European Union Drugs Agency (EUDA) and repealing Regulation (EC) No 1920/2006 (OJ L 166, 30.6.2023, p. 6, ELI: http://data.europa.eu/eli/reg/2023/1322/oj).

([3]) EUDA, 'EUDA international cooperation framework – Acting today, anticipating tomorrow', https://www.euda.europa.eu/publications/work-programmes-and-strategies/euda-international-cooperation-framework_en.

([4]) United Nations Office on Drugs and Crime (UNODC), 'Drugs and the environment', in: *World Drug Report 2022*, UNODC, Vienna, 2022, https://www.unodc.org/res/wdr2022/MS/WDR22_Booklet_5.pdf.

([5]) Council of the European Union: General Secretariat of the Council, *EU Drugs Strategy 2021–2025*, Publications Office of the European Union, Luxembourg, 2021, https://data.europa.eu/doi/10.2860/736505.

the EU and the Community of Latin America and Caribbean States recognised environmental impacts as a shared bi-regional concern. Directive (EU) 2024/1203, the Environmental Crime Directive, also acknowledged the impact of illicit drug production and waste on the environment ([6]). More recently, the 2025 UN Commission on Narcotic Drugs Resolution 68/5 explicitly addressed the environmental impacts of illicit drug-related activities ([7]). Academic scrutiny has intensified too, with an expanding body of peer-reviewed research identifying and, to some extent, quantifying environmental impacts.

This issue is inherently global in scope. Drug-related environmental impacts transcend borders, with the potential to affect multiple countries and regions, regardless of where the specific activities are carried out. As such, the environmental impacts from illicit drug markets can be manifested at multiple scales, from localised pollution (e.g. contamination of a single waterway as a result of the dumping of drug-related toxic waste) to broader global environmental dynamics. Moreover, illicit drug markets are highly adaptable, with activities often being displaced to new regions, consequently relocating some of the more tangible or direct impacts of those activities. For instance, the 2026 European Drug Report notes the dismantling of several cocaine processing facilities, indicating a potential (and partial) shift in production to Europe, which could lead to some environmental impacts becoming intensified within the region ([8]).

Drug-related environmental impacts may often be unintended. For actors involved in the illicit production and trafficking of drugs, these impacts may largely be treated as collateral damage. At the same time, well-intentioned policies can also generate, even if unintentionally, negative environmental impacts. This underscores the importance of strengthening our understanding of these dynamics, making them more visible so that potential impacts can be better anticipated and mitigated.

How we have approached this issue

As part of its geostrategic services, the EUDA is conducting international targeted policy analyses (TPAs), in co-production with its international partners. An international TPA is a rapid, in-depth analysis of a targeted issue, with implications for the EU and our international partners. This type of analysis is intended to generate policy-relevant insights.

Key dimensions of an EUDA international TPA

- The analysis is driven by critical questions concerning a relevant, targeted and timely policy issue.
- The analysis may focus on a health-, safety- and/or security-related issue or focus on a critical question concerning a cross-cutting policy issue.
- The analysis may delve into a policy issue with likely or actual negative impacts for the EU, seek to identify and learn from practices in a non-EU country or address an issue of common concern.
- The analysis examines a policy issue in a non-EU country, with which the EUDA cooperates, contributing to increased knowledge gains between the EU and the international partner.
- The analysis draws on immersion and stakeholder engagement, relying primarily on qualitative and participatory methodologies.

([6]) Directive (EU) 2024/1203 of the European Parliament and of the Council of 11 April 2024 on the protection of the environment through criminal law and replacing Directives 2008/99/EC and 2009/123/EC (OJ L, 2024/1203, 30.4.2024, ELI: http://data.europa.eu/eli/dir/2024/1203/oj).

([7]) UN Commission on Narcotic Drugs, Addressing the impacts of illicit drug-related activities on the environment, Resolution 68/5, accessed September 2025, https://www.unodc.org/documents/commissions/CND/Drug_Resolutions/2020-2029/2025/Res_68_5.pdf.

([8]) EUDA, *European Drug Report 2026 – Trends and developments*, Publications Office of the European Union, Luxembourg, 2026, https://www.euda.europa.eu/publications/european-drug-report/2026_en.

This policy report is the result of the EUDA's first international TPA, undertaken in co-production with DEVIDA. The EUDA and DEVIDA have a longstanding partnership. Peru was the first Latin American country to establish a working arrangement with the EUDA, which provided a strong foundation for the development of this project. Peru's experience with illicit coca cultivation, as outlined throughout the report, and its efforts to monitor the environmental impacts associated with cocaine-related activities made it a relevant case to explore. While the analysis builds on the case of Peru, the results are not country-specific and are intended to have broader relevance, providing insights that can inform policy and practice in other contexts.

Conceptualisation of the research goals, data collection, analysis and the write-up were co-produced by the two institutions. The analysis relied on a mixed-methods approach, drawing on a targeted review of the literature (*n* = 72 sources reviewed), key informant interviews (*n* = 42), two in-person focus group sessions (*n* = 20 participants) and an online survey (*n* = 25). All data collection took place in 2025, drawing on insights from both Peruvian and international stakeholders with expertise on drug policy, environmental issues and/or data monitoring. This analysis took a comprehensive approach to the environmental impacts associated with the entire cocaine supply chain, from coca plant cultivation to end-consumer markets, and covered various cocaine products (e.g. coca plant, intermediate by-products, smokable forms of cocaine, powder cocaine) ([9]). In this report, the term 'cocaine-related activities' refers to the full set of phases, from illicit cultivation to processing, distribution and use. In addition, the phrase 'cocaine's environmental impacts' is used to describe the range of environmental consequences linked to those phases. Unless otherwise stated, 'environmental impacts' in this report refers to adverse environmental impacts. At the same time, a range of other activities (such as logging, cattle ranching and mining), conducted both legally and illegally, may in some cases be linked to the cocaine market and therefore also contribute to the broader environmental impacts associated with it. Where relevant, we incorporate evidence on the confluence of transnational criminal networks with a mixed portfolio of operations, drawing on analyses that explored how they are connected to cocaine-related activities. Key to this international TPA is understanding how environmental impacts linked to cocaine-related activities have been measured and considering ways to advance these tools and metrics.

The report starts by exploring the environmental impacts of cocaine-related activities and the limitations of existing evidence, including measurement challenges. Next, it maps a range of methodological tools for measuring these impacts, highlighting examples of their application. The following chapter narrows the focus to concrete metrics and indicators. The final chapter synthesises key findings and offers reflections on how to advance this critical area. Throughout the report, the concrete experience of Peru is highlighted.

([9]) The consideration of the full drug supply chain is also consistent with DEVIDA's notion of the 'drug trafficking business model', which captures activities from production to consumption.

Exploring the scope of cocaine's environmental impacts reveals a complex and interconnected picture

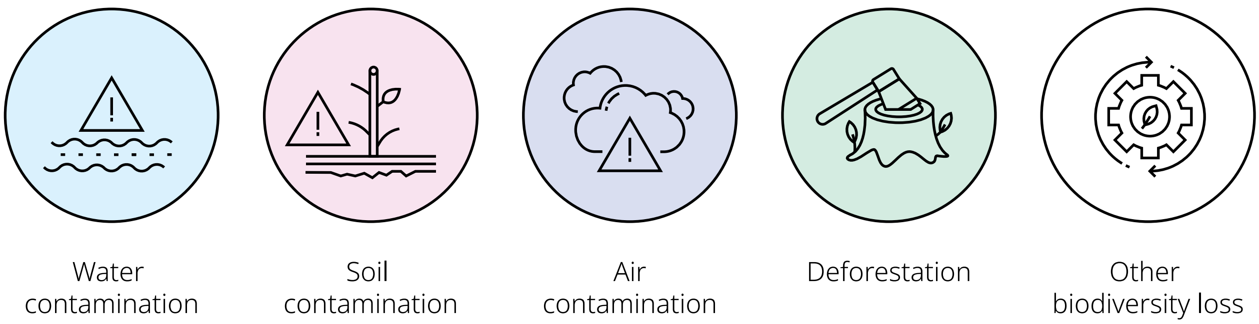
There have been documented efforts to identify and, in some instances, measure the range of environmental impacts associated with cocaine-related activities. At a high level, these include water, soil and air contamination, along with deforestation and other biodiversity loss, as illustrated in Figure 1, drawing on a review of the literature and expert consultation ([10]).

Beyond the more direct environmental impacts, cocaine-related activities may contribute to broader societal challenges. According to the experts consulted, these indirect effects – while not strictly environmental – may nevertheless be ripple effects linked to cocaine's environmental impacts. For example, they highlighted the potential for:

- heightened wildfire risks and further environmental degradation;
- public health threats from rising epidemic and infectious disease risks;
- economic losses due to reduced productivity;
- social disruption through community displacement and eroded social cohesion; and
- weakened public institutions.

Environmental impacts linked to cocaine-related activities are not limited to a single stage or activity, such as the cultivation of coca. Different activities along the chain can contribute to environmental

Figure 1. Key areas of environmental impact associated with cocaine-related activities



([10]) The available evidence often stems from one-off, highly localised measurements that might capture only specific aspects of a much broader chain of impacts, making comparability or generalisation difficult. There are ongoing efforts to aggregate and harmonise these data, but this work lies beyond the scope of this report. As such, this chapter focuses on the types of impacts examined in current studies rather than their reported magnitude.

Table 1. Summary of reported associations between cocaine-related activities and environmental impacts

Activity ↓ / Environmental impact →	Water contamination	Soil contamination	Air contamination	Deforestation	Other biodiversity loss
Cultivation	●	●		●	●
Processing	●	●		●	●
Distribution				●	
Use	●		●		

impacts. A systems view is therefore critical to understanding how cultivation, processing, distribution, use and other related activities may contribute to environmental impacts, as illustrated in Table 1. For ease of readability, the table refers only to broad categories of cocaine-related activities (e.g. cultivation, processing). These categories are intended to represent a wider range of smaller, related steps and activities (e.g. for cultivation, forest clearing and land preparation, and the use of materials to support crop growth, including fertilisers and pesticides, among others). It should be noted that the summary of the reported evidence depicted in the table is based on a review of the literature and expert consultation and is intended to illustrate possible relationships between cocaine-related activities and environmental impacts, without implying that these connections will always occur, that the list is exhaustive or that it captures the magnitude of the impacts.

Table 1 shows the documented environmental impacts associated with cocaine-related activities only, although, as acknowledged above, state responses and other market-related activities often connected to cocaine may also – even if unintentionally – add to these impacts. For example, police interventions, such as burning seized materials or destroying processing sites without adequate environmental protocols or trained personnel, can contribute to soil and water contamination. Moreover, other activities that may be associated with cocaine markets in certain settings, such as land grabbing or illegal mining, may further exacerbate environmental impacts. For instance, while illicit coca cultivation has been documented as a relatively limited driver of deforestation, in contexts where it is associated with other activities, the resulting deforestation may become more significant.

While some environmental impacts associated with specific cocaine-related activities are relatively well understood, many connections remain unclear. Indeed, the impacts associated with the illicit cultivation of coca seem to have received more attention to date, in comparison with other cocaine-related activities such as the processing, distribution or use of cocaine. Deforestation appears to be among the most extensively researched environmental impacts of cocaine-related activities. In contrast, evidence on other areas of impact is more limited.

The environmental impacts associated with cocaine-related activities can vary widely in their scale, intensity, and persistence. They may range from limited, site-specific effects to more sustained and geographically extensive consequences, with varying degrees of reversibility. For example, water contamination linked to cocaine use is typically associated with low concentrations of this substance in surface waters, whereas water contamination observed in connection with the chemical-intensive process of converting coca leaves into cocaine can involve significantly higher contamination levels in groundwater, which may persist for longer periods.

Furthermore, these impacts should not be understood in isolation, as they may be sequential or could be interconnected in different ways. For example, deforestation – often the initial environmental impact associated with illicit coca cultivation – may also trigger other environmental impacts. These cascading effects can ultimately contribute to broader ecosystem degradation, demonstrating how one impact can amplify or lead to others.

> 'Deforestation is the trigger – cut down that tree, and immediately a cascade of consequences unfolds. When you go to an area that has been deforested or degraded, where coca has been cultivated, you don't even hear the birds, right? [...] It becomes a chain reaction. And people often only see that the tree is gone, but it's the entire ecosystem services that are truly at stake.'
> (Expert interviewee)

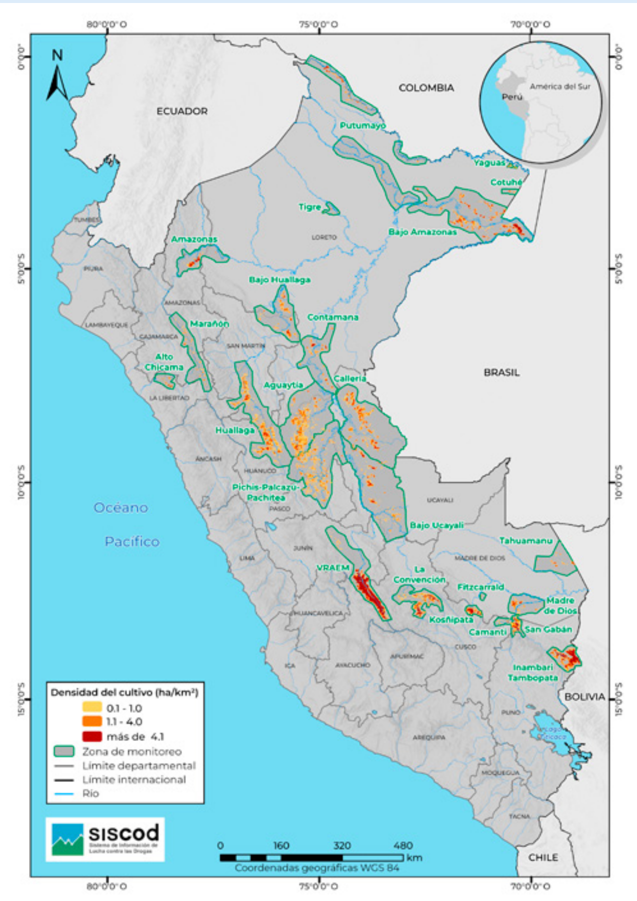
Highlights on Peru: coca and the environment

The regulation of coca leaf cultivation and commercialisation in Peru began in the 1950s. The use of coca was authorised for domestic consumption and export (with exports permitted exclusively through a state monopoly), as well as for medical and scientific purposes. Oversight was initially assigned to the *Estanco de la Coca* and later to the National Coca Company (*Empresa Nacional de la Coca* (ENACO)). The *Estanco de la Coca* was responsible for controlling coca planting, cultivation and harvesting, along with its distribution. ENACO is responsible for collecting and marketing coca leaves exclusively from registered cultivation areas and for licensing third parties for the commercialisation and industrialisation of coca leaves, provided that their intended use is limited to traditional consumption or the production of derivative goods that do not involve cocaine manufacturing. This legal framework enables a range of legitimate uses of coca leaves – such as infusions, flours, cosmetic products and medical applications – while recognising their cultural and economic importance in specific regions of the country. Within this framework, industrialisation for authorised domestic and export uses, including medical and scientific purposes, takes place under state oversight, while activities linked to cocaine production remain prohibited.

However, the rapid expansion in coca crops observed since the 1970s has significantly increased the difficulty of controlling the expansion of the coca market, particularly the growth of crops destined for illicit markets. In response, Decree Law 22095 was adopted, prohibiting the expansion of coca cultivation and updating the mandatory registration of coca producers with ENACO. Yet, there were challenges with the registration system, partly because it relied on producers' sworn declarations without additional verification mechanisms. In 2016, the government renewed efforts to establish a comprehensive registry of coca crops through Legislative Decree 1241, mandating local and regional governments to conduct registry surveys and georeferenced-registered coca plots. To date, regional governments have not been able to fully implement this mandate, adding to the challenge of distinguishing between licit and illicit coca cultivation.

Peru is currently the world's second-largest producer of coca leaf, following Colombia. According to the 2025 coca crop monitoring report by DEVIDA and UNODC, the country identified 24 coca-producing zones, encompassing an estimated total of 89 755 hectares under cultivation (2024 data) ([11]). This figure marks a reduction in the national cultivated area for the second consecutive year, following the peak figures recorded in 2022. DEVIDA estimates that approximately 92% of coca production is destined for illicit drug trafficking, underscoring the ongoing challenge of preventing the diversion of coca crops into illegal markets.

Figure 2. Density map of the areas cultivated with coca leaf in Peru, by monitoring zone, 2024



Beyond deforestation, cocaine-related activities that take place in the country may also contribute to a range of negative environmental impacts. For instance, illicit coca cultivation in the Peruvian Amazon has contributed to disrupting conservation efforts and indigenous communities' autonomy. Furthermore, in Peru, coca leaf processing into cocaine base / cocaine hydrochloride also takes place in ecologically sensitive areas, mainly through two main modalities: (1) using maceration pits, which is the more traditional method; and (2) more recently, using portable cylinder laboratories. Maceration pits are larger, fixed and highly visible structures that enable significant volumes of production. In contrast, cylinder-based processing is more discreet and mobile, allowing operations to be relocated quickly and making detection by authorities more difficult. Importantly, the use of one method or the other appears to vary across production zones. Both methods rely on a range of chemical inputs, including petroleum-based fuels and solvents (such as kerosene or gasoline) to extract alkaloids, strong acids (such as sulphuric and hydrochloric acid) to alter solubility and enable separation, bases and neutralising agents (such as lime, carbonates or ammonia) to precipitate alkaloids in solid form, and additional reagents used in later stages to purify and crystallise the product, converting coca paste into cocaine hydrochloride. When released or improperly managed, these substances may pose risks to surrounding ecosystems.

The illicitly produced cocaine products are typically transported via land, river and air routes to both domestic and international illicit markets. The region of the Valley of the Apurímac and the Ene and Mantaro rivers (VRAEM region) remains one of the country's primary zones for coca production and trafficking, accounting for more than one third of Peru's national yield and distribution activities.

([11]) DEVIDA (2025), *Monitoreo de cultivos de coca 2024*, DEVIDA, Lima, 2025, https://www.gob.pe/institucion/devida/informes-publicaciones/6868111-monitoreo-de-cultivos-de-coca-2024.

Measuring cocaine's environmental impacts remains challenging but different tools are available

Weighing technical, safety and resource considerations

Measuring cocaine's environmental impacts remains a challenge for several reasons. A first constraint relates to the limited accessibility of many cocaine-related activities, reflecting their covert and difficult-to-observe nature. Additional challenges arise in quantifying certain effects, as well as in establishing direct links between the observed impacts and specific drivers. For example, some of the agrochemicals that might be used for illicit coca cultivation might also be employed for the cultivation of other crops. This makes it difficult to, even when detected, attribute observed contamination to a specific source. Furthermore, there is often limited or no baseline data, which complicates comparisons between pre- and post- contamination conditions. At the same time, existing analyses are frequently fragmented, focusing on specific linkages and areas of impact. Regular monitoring of cocaine-related environmental impacts is limited and often does not occur on a routine basis, as acknowledged by the experts consulted, with notable exceptions such as the satellite-based monitoring programmes aimed at capturing coca cultivation. Below we take a closer look at Peru's approach to monitoring, with a particular focus on the various actors involved.

Measuring environmental impacts may require a choice about the methodological tools or approaches available to identify and quantify them. Table 2 shows the range of methods and tools that have been employed to assess environmental impacts linked to cocaine-related activities, drawing on a review of the literature. Although this review focused on methodologies more directly applied to understanding cocaine-related environmental impacts, there is scope to draw further lessons from environmental monitoring practices used in other sectors and activities, both licit and illicit.

Table 2. Key methodologies used in research measuring cocaine-related environmental impacts

Spatial and remote analysis
Spatial analysis and modelling
Laboratory analysis of environmental samples
Soil analysis
Water analysis
Air particulate analysis
Key informant elicitation approaches
Interviews
Surveys
Focus groups and workshops
Ethnography
Secondary data analysis
Analysis of secondary data

Highlights on Peru: key actors involved in the monitoring of environmental impacts

Different stakeholders are involved in monitoring cocaine's environmental impacts in Peru. At the national level, state institutions lead key initiatives, with a wide range of public entities, private institutions, civil society and international organisations contributing to data collection and analysis. As an example, DEVIDA's monitoring of the coca crops programme involves the biannual collection of data from institutions working in different fields, as illustrated in Table 1. These institutions, each with its own mandate, contribute to the development of evidence on territorial dynamics, environmental conditions and cocaine-related activities.

Institutions involved in data collection and reporting as part of DEVIDA's monitoring of coca crops programme:

Environmental actors and programmes

- National Service of Natural Protected Areas (SERNANP)
- Supervisory Body for Forest Resources and Wildlife (OSINFOR)
- National Forest and Wildlife Service (SERFOR)

Law enforcement and justice actors

- Special Project for the Control and Reduction of Coca Cultivation in the Upper Huallaga (CORAH)
- Ministry of Justice and Human Rights
- National Directorate of Criminal Investigation of the Peruvian National Police
- General Directorate against Organised Crime
- Coordination Liaison Office of the Specialised Drug Trafficking Prosecutor's Offices

Other domestic actors

- National Commission for Aerospace and Development (CONIDA)
- Ministry of Culture

International actors and programmes

- United Nations Office on Drugs and Crime — Sistema Integrado de Monitoreo de Cultivos Ilícitos (SIMCI)

In addition to these efforts, academic and private institutions, along with civil society organisations, have generated relevant data on cocaine's environmental impacts in Peru.

Qualitative approaches such as interviews or ethnographic fieldwork often require on-site presence for data collection, whereas others, including remote, quantitative or lab-based techniques, may reduce or eliminate the need for more extensive on-site presence. The experts consulted were supportive of relying on mixed-methods designs, integrating multiple methodologies for a more comprehensive analysis of the impacts.

'You need to socialise the pixel. You need to talk to people to understand what you are seeing. You need robust satellite images, but this needs to be integrated with on-the-ground perspectives.' (Expert interviewee)

However, beyond technical suitability, there are other factors to take into account. A critical concern, shared by the experts consulted, is the safety of researchers and local communities near impacted sites. On-site methods, while valuable for generating rich, context-specific insights into key drivers of environmental impacts, may inadvertently expose individuals to criminal actors, among other security risks. Methodological choices may also be shaped by the resources required to apply them. Some techniques, such as aerial overflights, are resource-intensive, which can affect cost and feasibility.

Methodological tools currently in use and their application

A range of methodological approaches has been used to explore cocaine's environmental impacts (Table 3). These approaches are introduced below, highlighting how they have been applied to study-specific linkages, i.e. to understand and measure environmental impacts associated with various cocaine-related activities.

Table 3. Overview of methodological approaches applied to the study of environmental impact areas across cocaine-related activities

Methodology	Water contamination				Soil contamination				Air contamination				Deforestation				Other biodiversity loss			
	Cultivation	Processing	Distribution	Use	Cultivation	Processing	Distribution	Use	Cultivation	Processing	Distribution	Use	Cultivation	Processing	Distribution	Use	Cultivation	Processing	Distribution	Use
1. Spatial analysis and modelling Spatial analysis and modelling are quantitative tools that leverage technologies such as satellite imagery, aerial overflights, drones, geographic information systems, cartography and georeferenced photography to detect spatial patterns, monitor land-use changes and build predictive models.													●	●	●		●			
2. Soil analysis Soil analysis refers to the measurement of the state of soil by means of laboratory analysis of soil samples. This type of analysis may focus on the concentration of contaminants, soil erosion, soil compaction, nitrogen levels, the level of nutrients found and pH value in a given area.					●															
3. Water analysis The quality of water can be analysed by assessing the presence of chemical compounds and other residues through laboratory testing of water samples. This type of analysis supports both the detection of target substances and the assessment of risk levels of environmental impacts for human and animal health.				●																
4. Air particulate analysis Air particulate analysis involves the collection and analysis of air samples to assess the presence of chemical compounds and particulates in the atmosphere. This approach uses extractive methods and a range of instruments to identify and measure target substance concentrations.												●								
5. Interviews Interviews are a qualitative research method that involves collecting data through in-depth conversations with individuals or experts, typically using structured, semi-structured or open questionnaires.	●	●			●	●							●	●	●					
6. Surveys Surveys provide insights into knowledge, attitudes and behaviours through the use of different question formats, supporting both quantitative and qualitative data analysis.					●								●				●			
7. Focus groups and workshops Focus groups and workshops are qualitative research methods that involve bringing together a small group of participants to discuss and share perspectives on a specific topic.	●	●			●	●							●		●		●			
8. Ethnography Ethnography is a qualitative method that entails the in-depth study of a group or culture by closely observing a community within its natural setting to understand beliefs, perceptions, behaviours and interactions ([12]).	●	●				●							●		●		●			
9. Analysis of secondary data Secondary data analysis involves using existing datasets collected for other purposes to examine patterns, trends or correlations (e.g. data on conflicts or areas of armed conflict, media data, livestock inventories, cocaine seizure data).													●		●		●			

([12]) This overview of main applications of this methodology includes studies that were explicitly identified by the authors as ethnographies, along with those that appeared to draw on ethnographic approaches, including fieldwork and on-the-ground observations.

This overview is based on a review of the literature. It is, however, not an exhaustive list of how this range of methodological tools has been or can be used. Instead, it is meant to highlight key applications and how these have advanced our knowledge of environmental impacts in this area.

The following highlight of Peru offers insights into the specific experience and approaches to monitoring in that country.

Highlights on Peru: approaches to monitoring of environmental impacts

In Peru, the state-wide monitoring of cocaine-related environmental impacts has been centred primarily on assessments of deforestation associated with coca cultivation, in particular by exploring data on the surface area of cultivated coca. The monitoring of coca bush cultivation is conducted through a systematic and periodic assessment, carried out by DEVIDA ([13]). Since 1999, this information has been gathered through the Illicit Crop Monitoring System in Peru (SIMCI-Peru project), implemented by UNODC. To establish a baseline of coca cultivation nationwide, maps were produced identifying coca crops in active production. This baseline was developed between 1999 and 2000, initially using photointerpretation of colour aerial photographs at a 1:2000 scale. In subsequent years, UNODC employed visual interpretation of satellite imagery to identify cultivation patterns and estimate the total area under coca cultivation. Once DEVIDA assumed responsibility for monitoring, supported technically by UNODC, this methodology has expanded to include complementary qualitative and quantitative data collected in the monitoring zones. The supplementary data are based on audiovisual and/or geographic records from field visits conducted via aerial surveys or ground travel, along with reports from state institutions documenting environmental impacts linked to illicit drug trafficking across the national territory.

In addition to analyses based on satellite imagery, academic research centred on Peru has largely focused on the impacts of coca cultivation on soil quality, drawing on soil sample analyses from highly localised areas (e.g. VRAEM, Ucayali, Huánuco) or other qualitative data collection approaches. Overall, the evidence base remains limited beyond deforestation, and, to a lesser extent, soil contamination associated with coca cultivation. Other environmental impacts and other phases of cocaine-related activities have received little attention.

([13]) Since 2008, the Peruvian government has independently produced national estimates of the area under coca bush cultivation. The estimates follow a standardised methodology that ensures data quality and enables temporal comparability.

Other strategies and opportunities to build on existing data collection efforts

Beyond these methodological tools, two additional ideas emerged from expert consultation that could help improve our understanding of cocaine's environmental impacts. The first relates to relying more on proxy data and analysis, which may offer opportunities to infer environmental impacts through indirect indicators. This strategy is particularly relevant given the challenges of directly measuring phenomena linked to cocaine-related activities. Experts highlighted examples from other conservation fields where the presence of specific animal species has been used as a sign of forest health. In such cases, researchers track a species directly or indirectly (e.g. by recording sightings, footprints or other traces) and use these observations to estimate how likely this species is to occupy a given area, subsequently monitoring changes over time. Similarly, identifying a species or ecological feature that depends on ecosystem quality or is sensitive to contaminants associated with cocaine-related activities could serve as an insightful indicator. Monitoring changes in such indicators, rather than attempting to track illicit operations directly, could provide an alternative pathway to assess environmental impacts.

The second idea concerns technology-driven approaches that could support both data collection and the analysis of large datasets, including through artificial intelligence. Remote sensing technologies, such as satellite imagery used to monitor deforestation, already play a role in this area. However, experts noted that there are further opportunities to complement and enhance current approaches. These could include exploring the use of drones to make observations in hard-to-reach areas, applying remote sensing tools to monitor proxy indicators (e.g. automated acoustic recognition and monitoring of specific bird species) and using AI to analyse datasets on forest loss or road network changes that could be linked to cocaine-related activities. AI could also help estimate the quantities of chemical precursors required for cocaine production (drawing on historical production data) and support the development of predictive models to identify likely hotspots for cocaine production, trafficking or discharge of cocaine-related materials. Several of these approaches have already been tried, but their full potential to support the measurement of cocaine-related environmental impacts could be further explored.

Furthermore, there appear to be opportunities to build on existing data and practices to expand our knowledge of cocaine-related environmental impacts. One potential approach is to leverage current monitoring efforts such as water and air quality analyses or fauna inventories. It may be useful to assess whether these activities already generate data that could shed light on cocaine-related environmental impacts, or whether adapting them for this purpose would require only limited additional effort. Other opportunities may also arise in situations where authorities intervene in contaminated sites from cocaine-related activities, to collect additional soil or water samples, in coordination with relevant actors, along with other relevant information.

As the case of Peru illustrates, several actors are likely to play a key role in gaining insights on this issue. Strong information sharing among them, including different government agencies, local communities and civil society, may be important. The experts consulted also emphasised the value of drawing on the knowledge and experience of local actors, such as park rangers or community representatives, who can provide context-rich and timely information. Further empowering local knowledge through training and support could, in turn, contribute to higher-quality data.

Building a systems view of cocaine's environmental impacts and the tools and metrics needed for their monitoring

Building on the key areas of environmental impact discussed earlier (e.g. water contamination, soil contamination), and drawing on insights from research and experts, it was possible to identify a set of more detailed metrics. Mapping these and potentially other relevant metrics helps translate broad impact areas into specific, observable features that can be monitored to assess whether environmental conditions are worsening, remaining stable or improving, following remediation efforts, for instance. In other words, these metrics offer a clearer picture of what might be measurable given current knowledge and approaches.

Table 4 provides an overview of a preliminary list of indicators, illustrating the possible range of aspects that may be examined, and how each could help measure different dimensions of the identified environmental impacts. For example, to better understand soil contamination, relevant metrics may include the volume or frequency of detected toxic residues, relevant stakeholders' perceptions of land-use change, observable alterations to ecosystems (e.g. the appearance of invasive species) or a combination of these. This list is not intended to be exhaustive or definitive. Rather, it brings together available knowledge and serves as a starting point for developing a more nuanced assessment of environmental impacts. Furthermore, individual indicators are unlikely, on their own, to provide a complete picture of environmental impacts within a given dimension. The value of mapping different metrics lies in illustrating how they may contribute to a broader analytical framework when used in combination.

'One needs to think of different layers and step by step: what kind of information do we have at the starting point, and then add different layers, connecting the information.' (Expert interviewee)

At the same time, the inclusion of the indicators in Table 4 does not imply a recommendation that these are integrated into future monitoring efforts. Instead, the selection of metrics and analytical tools should be guided by the specific monitoring objectives and the context in which it is carried out. Establishing a coherent set of indicators could facilitate comparative analysis and support the tracking of changes over time.

Table 4. Exploratory list of indicators per broad area of environmental impact associated with cocaine-related activities

Water contamination		Soil contamination		Air contamination		Deforestation	
Water quality and quantity degradation	**Loss of biodiversity in the aquatic environment**	**Soil quality degradation**	**Loss of biodiversity in the soil environment**	**Air quality degradation**	**Loss of biodiversity in the atmospheric environment**	**Land use change**	**Other forest change and biodiversity loss**
Concentration of contaminants (in surface water, waste water, groundwater, springs) (micrograms per litre)	Alterations in the ecosystem (e.g. loss of species, appearance of new predators or invasive species) (count or index of biodiversity)	Concentration of contaminants (micrograms per kilogram)	Alterations in the ecosystem (e.g. loss of species, appearance of new predators or invasive species) (count or index of biodiversity)	Concentration of contaminants (micrograms per cubic metre)	Alterations in the ecosystem (e.g. loss of species, appearance of new predators or invasive species) (count or index of biodiversity)	Area cultivated with coca per year (hectares, percentage of change over time, number of years of coca presence in given territory)	Biophysical factors of the area, including slope (degrees or percentage) and elevation (metres)
Concentration of cocaine metabolites (including benzoylecgonine) (micrograms per litre)	Perception of change in the availability of aquatic-based means of subsistence	Concentration of nutrients (micrograms per kilogram)		Concentration of cocaine in atmospheric particulate (micrograms per kilogram of particulate matter)		Clandestine laboratories detected per year (count, surface area)	Perception of change in the availability of forest-based means of subsistence
Percentage of change to the hydrological cycle per year (percentage)	Risk quotient for aquatic organisms (index or score)	Detected toxic residues (count; micrograms per kilogram)		CO2 emissions (kilograms of CO2)		Illicit maceration pits detected per year (count, surface area)	Outbreak of diseases associated with reduced forest cover (number of cases or incidents)
Visual alterations of aquatic bodies (e.g. water colour or clarity, vegetation, surface pollutants) (count)	Accumulation of cocaine on aquatic species (nanograms/ micrograms per gram of tissue)	Clandestine laboratories and/ or maceration pits detected per year (count, surface area)				Clandestine landing strips detected per year (count, surface area)	Predominant land use (percentage per main type of land use)
Outbreak of diseases associated with water contamination (number of cases or incidents)		Transport routes for illicit cocaine identified per year (count, surface area)				Transport routes for illicit cocaine identified per year (count, surface area)	Wildfire events (count, surface area)

Water contamination		Soil contamination		Air contamination		Deforestation	
Distance to detected clandestine laboratories and/or maceration pits (kilometres)		Soil erosion (tonnes per hectare per year)				Distance between waterways and illicit laboratories and/or maceration pits (kilometres)	Density of roads/tracks (kilometres per square kilometre)
Presence of unregulated boats (count)		Soil depletion (tonnes per hectare per year)				Location of seizures of cocaine products (geographic coordinates)	Risk quotient for jungle and avian wildlife (index or score)
Change in measure of water flow volume/rate (cubic metres per second per year)		Perception of change in land use				Perception of change in land use	Forest fragmentation (index)
Quantity of dumped toxic waste (tonnes or metric tonnes)		Predominant land use (percentage per main type of land use)					Biomass loss (metric tonnes per hectare)
		Quantity of dumped toxic waste (tonnes or metric tonnes)					

Other metrics		
Illicit cocaine market	**Other licit and illicit activities**	**Migration and people displacement**
Cocaine seizures per year (count, tonnes)	Illicit mining operations detected per year (count, surface area)	Number of internally displaced persons per year (count)
Location of seizures of cocaine products (geographic coordinates)	Illicit timber operations detected per year (count, surface area)	Presence of known organised crime/terrorist groups (count; number of incidents attributed to the group)
Number of cocaine shipments intercepted (count)		Number of conflict victims per year (count)

NB: The table presents three layers of information: broad environmental impact areas, the sub-aspects that make up each area and the indicators identified that may be used to monitor them. Some indicators may appear repeatedly under different areas of impact. In addition to the key areas of environmental impact, the list also includes other complementary and more transversal indicators, grouped under 'Other metrics'. As noted earlier, there may be other impacts to consider alongside those listed here, including from interconnected activities.

Zooming in on the long list of potential indicators for measuring cocaine's environmental impacts (Table 4), an online expert survey was used to rank them according to their perceived relevance across the different environmental impact areas. This prioritisation enabled a focus on indicators considered key by expert practitioners and researchers and allowed the shorter list to be aligned with the analytical building blocks of this analysis, consistent with a systems perspective. Table 5 brings together the main environmental impacts (e.g. deforestation, water pollution), the cocaine-related activities that may be associated with those impacts (e.g. cultivation, processing, distribution), the key indicators that could be measured (i.e. what one might measure) and the methodologies suitable for collecting such data (i.e. how one might measure it). By synthesising these components, Table 5 serves as a conceptual and methodological overview that provides a practical foundation for the development of a more coherent and integrated monitoring framework. This systems-oriented overview is not intended as a prescriptive framework but rather aims to illustrate how different methods and metrics may be combined to overcome siloed or fragmented assessments of cocaine-related environmental impacts.

At the same time, this overview can be seen as a preliminary roadmap for tailoring monitoring efforts to particular priorities. For instance, if the primary objective is to understand water contamination or biodiversity loss in aquatic environments linked to cocaine processing, measuring contaminant concentrations through water analysis together with examining ecosystem alterations may be appropriate. Conversely, if the focus lies on deforestation or forest fragmentation associated with coca cultivation, spatial analysis and modelling, along with more qualitative approaches such as interviews, ethnography, focus groups and workshops, may be more suitable. In contexts where multiple impacts or cocaine-related activities intersect, the structure provided in Table 5 offers a preliminary menu of metrics and methods that can be combined and tested to help strengthen the overall understanding of cocaine's environmental impacts. While this represents an initial step, it provides a basis for the further development of a more systems-oriented approach to monitoring drug-related environmental impacts.

The interpretation of results generated through such a framework would likely need to rely on reference points against which the impacts could be assessed. This may include a consideration of appropriate baselines, counterfactuals or comparators, recognising that environmental impacts are not measured against an abstract absence of activity, but are better contextualised in relation to land uses specific to the contexts being analysed. Further consideration will be needed on how impacts might be interpreted and graded, including the definition of relevant thresholds to reflect different levels and dimensions of impact (e.g. magnitude, geographical scale, duration, reversibility).

Table 5. Preliminary conceptual and methodological overview for the monitoring of cocaine-related environmental impacts

Environmental impact	Cocaine-related activity	Possible methodologies	Top ranked indicators
Water contamination Other biodiversity loss	Cultivation Processing Use	**Water analysis** *Interviews* Focus groups and workshops Ethnography	Concentration of contaminants (in surface water, waste water, groundwater, springs) (micrograms per litre) Quantity of dumped toxic waste (tonnes or metric tonnes) Alterations in the ecosystem (e.g. loss of species, appearance of new predators or invasive species) (count or index of biodiversity) Perception of change in the availability of aquatic-based means of subsistence
Soil contamination Other biodiversity loss	Cultivation Processing	**Soil analysis** *Interviews* Surveys Focus groups and workshops Ethnography	Quantity of dumped toxic waste (tonnes or metric tonnes) Soil depletion (tonnes per hectare per year) Concentration of contaminants (micrograms per kilogram) Detected toxic residues (count, micrograms per kilogram) Soil erosion (tonnes per hectare per year)
Air contamination	Use	**Air particulate analysis**	CO_2 emissions (kilograms of CO_2)
Deforestation Other biodiversity loss	Cultivation Processing Distribution	**Spatial analysis and modelling** Interviews Surveys Focus groups and workshops Ethnography Secondary data analysis	Area cultivated with coca per year (hectares, percentage of change over time, number of years of coca presence in given territory) Forest fragmentation (index)
Other illustrative metrics		Spatial analysis and modelling Secondary data analysis (law enforcement reports)	Location of seizures of cocaine products (geographic coordinates) Illicit timber operations detected per year (count, surface area)

NB: This table integrates findings from the literature review and expert consultation. Associations between activities and environmental impacts are based on the available evidence and may not capture all possible linkages (see Table 1). Methodological approaches are drawn from the literature and may not have been applied across all activity-impact linkages (see Table 3). Highlighted approaches reflect areas of consensus identified in focus groups; in addition, interviews were identified as a consensus approach for assessing 'other biodiversity loss' and are therefore highlighted across all relevant environmental impact areas. Priority indicators are derived from a survey-based ranking by impact area, and may not all be measurable through the listed methods. The indicators included received a combined relevance score above 90%; for air contamination, where no indicator met this threshold, the highest-scoring indicator (84%) is presented. The two top ranked other metrics are included for illustrative purposes, along with two suggested methodological approaches.

Final reflections

Cocaine-related activities can generate diverse environmental impacts. The available evidence highlights that the environmental impacts associated with cocaine-related activities extend beyond deforestation, including air, soil and water contamination, biodiversity loss and indirect impacts that require a more nuanced assessment. While the association between illicit coca cultivation and deforestation has received the most attention so far, it is clear that other cocaine-related activities – from processing a range of cocaine products to its consumption, along with activities from connected markets and state responses – can create and exacerbate negative environmental impacts.

Various methodological approaches have been employed in this area, but quantification of impacts remains challenging. There have been efforts to explore and measure cocaine-related environmental impacts that draw on a variety of designs and methodologies, ranging from spatial analysis and modelling to ethnographic fieldwork. These approaches capture rich data, yet challenges persist in isolating contributing factors, establishing attribution and securing baseline data or robust counterfactuals and comparators. Indirect indicators and emerging technological tools can offer complementary insights where direct measurement is difficult.

Systematic monitoring of cocaine-related environmental impacts is still limited. While the surface area of coca cultivation is regularly monitored in Peru and other countries in the region, which offers valuable insights to understand patterns of deforestation, systematic monitoring of other areas of impact remains limited or lacking. Medium- and long-term environmental effects, such as those related to broader climate change dynamics, pose further challenges and require integrated analytical frameworks that are fit for purpose.

On-the-ground experiences offer valuable entry points for building more integrated approaches to monitoring. This report highlights practical monitoring practices and the importance of information sharing among public, private and civil-society actors. Existing efforts, such as water and air quality monitoring, fauna inventories or sampling during site interventions, may already provide insights relevant to understanding cocaine's environmental impacts and could be explored in greater depth. Supporting the context-rich knowledge of local actors can further enhance data quality and insights.

The analytical approach developed in this report may be transferable beyond the case of cocaine. Although the analysis drew on the case of cocaine and was grounded in the Peruvian context, the conceptual approach and systems-oriented framing may also be relevant for the development of analytical frameworks for other substances and settings, particularly where crop-based production and chemical processing share comparable environmental pathways.

A clearer conceptual and analytical basis offers a practical foundation to improve the evidence base on cocaine-related environmental impacts. Acknowledging the complex dynamics between cocaine-related activities and their environmental impacts, this report offers an initial, systems-oriented point of reference for translating these dynamics into measurable elements, considering what could be measured and how. Rather than prescribing a single approach, the conceptual and methodological overview presented in the report is intended to support more coherent and targeted analysis in this area. As it spans all phases of cocaine-related activities, from cultivation and processing to distribution and use, it may be useful for monitoring efforts in a wide range of contexts and settings.

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About this report

Cocaine markets have the potential to generate environmental harms that extend far beyond deforestation, affecting water, soil, air quality and biodiversity across multiple regions and cocaine-related activities. This joint report by the European Union Drugs Agency (EUDA) and Comisión Nacional para el Desarrollo y Vida sin Drogas (DEVIDA) explores how these impacts can be better understood and measured. Drawing on the case of Peru and informed by literature review and expert consultation, it maps the range of cocaine-related environmental impacts, examines existing monitoring practices and identifies methodological tools, indicators and data opportunities to support more systematic assessment. By adopting a systems-oriented perspective, the report provides a practical foundation for strengthening the evidence base on drug-related environmental impacts and supports policymakers and practitioners working at the intersection of drug policy and environmental protection.