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DRUGS AND THE ENVIRONMENT

WORLD DRUG REPORT 2022

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Comments on the report are welcome and can be sent to:

Research and Trend Analysis Branch
United Nations Office on Drugs and Crime
PO Box 500
1400 Vienna
Austria

E-mail: wdr@un.org
Website: www.unodc.org/unodc/en/data-and-analysis/world-drug-report-2022.html

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World Drug Report
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PREFACE

Drugs can kill.

Addiction can be an unending, agonizing struggle for the person using drugs; suffering is needlessly compounded when people cannot access evidence-based care or are subjected to discrimination. The consequences of drug use can have ripple effects that hurt families, potentially across generations, as well as friends and colleagues. Using drugs can endanger health and mental health and is especially harmful in early adolescence. Illicit drug markets are linked with violence and other forms of crime. Drugs can fuel and prolong conflict, and the destabilizing effects as well as the social and economic costs hinder sustainable development.

The whole of the international community shares the same goals of protecting the health and welfare of people everywhere. But too often in the debate on drug policy approaches, we forget this basic and shared understanding, which is rooted in the fact that drug use for non-medical purposes is harmful.

We all want our children and loved ones to be healthy, and we want neighbourhoods and countries to be safe. As policymakers, we can see that illicit drug cultivation offers no way out for impoverished communities in the long run, that the drug trade has environmental impacts, and that drug trafficking along with associated corruption and illicit flows undermine the rule of law and stability.

Solutions to these shared threats and challenges to achieve our shared goals must also be shared and based on evidence. It is in this spirit that I am proud to present the World Drug Report 2022 from the United Nations Office on Drugs and Crime.

This is the first World Drug Report of the post-pandemic world. While countries continue to grapple with COVID-19 and its consequences, we have emerged from cycles of lockdowns to confront a “new normal”. And we have found that the world post-pandemic remains one in crisis, faced with multiple conflicts, a continuing climate emergency and threat of recession, even as the multilateral order is showing troubling signs of strain and fatigue.

World drug challenges further complicate the picture. Cocaine production is at a record high, and seizures of amphetamine and methamphetamine have skyrocketed. Markets for these drugs are expanding to new and more vulnerable regions.

Harmful patterns of drug use likely increased during the pandemic. More young people are using drugs compared with previous generations. People in need of treatment cannot get it, women most of all. Women account for over 40 percent of people using pharmaceutical drugs for non-medical purposes, and nearly one in two people using amphetamine-type stimulants (ATS), but only one in five in treatment for ATS is a woman.

In the face of these multiple crises, we need to show greater care.

Care starts with evidence-based prevention and addressing perceptions and misperceptions of risk, including by taking a hard look at the messages our societies are sending to young people. UNODC research has shown that perceptions of cannabis harms have decreased in areas where the drug has been legalized. At the same time, the proportion of people with psychiatric disorders and suicides associated with regular cannabis use has increased, together with the number of hospitalizations. Some 40 per cent of countries reported cannabis as the drug related to the greatest number of drug use disorders.

Whole-of-society approaches are needed to ensure that people, young people most of all, have the information and develop the resilience to make good choices and that they can access science-based treatment and services for drug use disorders, HIV and related diseases when they need it.

There can be no effective prevention or treatment without recognition of the problem and the necessary funding to address the problem. Public resources are stretched to the limit by competing demands, but we cannot afford to let commitment wane. We need to promote compassion and better understanding.

Care in crises means ensuring services and essential medicines for all, including people in emergencies and humanitarian settings; people left behind in the pandemic; and people facing barriers of stigma and discrimination.

Care is also manifested in shared responsibility, and we need to renew international cooperation to sustainably reduce illicit crop cultivation and tackle the criminal groups trafficking drugs.

The World Drug Report seeks to offer the data and insights to inform our joint efforts. This year's edition delves into the interplay between drugs and conflict, the impact of drugs on the environment and the effects of cannabis legalization, and identifies dynamics to watch, from the opiate market in light of developments in Afghanistan to dark web drug sales.

I hope the report serves as a basis for effective responses, and generates the support we need to continue shedding light on different aspects of the world drug problem, and assisting Member States to take action and save lives.

Ghada Waly, Executive Director
United Nations Office on Drugs and Crime

WORLD DRUG REPORT 2022

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Content overview
Chloé Carpentier
Angela Me

Research, analysis and drafting
Juanita Barrera
Liliana Dávalos
Erik Emke
Jorrit Kamminga
Thomas ter Laak
Nicholas Magliocca
Mariana Ortega
Pim de Voogt

Mapping
Coen Bussink
Lorenzo Vita

Graphic design and production
Anja Korenblik
Suzanne Kunnen
Kristina Kuttnig
Maria Moser
Lorenz Perszyk

Internal coordination and research assistance
Harvir Kalirai

Editing support
Leon Addie

Administrative support
Andrada-Maria Filip
Iulia Lazar

Review and comments
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Jonathan Caulkins
Paul Griffiths
Marya Hynes
Vicknasingam B. Kasinather
Charles Parry
Afarin Rahimi-Movaghar
Peter Reuter
Alison Ritter
Francisco Thoumi

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Ahcene Sahtout (Algeria), Djazia Dehimi (Algeria), Mohamed Oundi (Algeria), Olimpia Torres Barros (Andorra), Adrián Betti (Argentina), Andres Quintana (Argentina), Diego Ruiz (Argentina), Armenuhi Chilingaryan (Armenia), Andrew Courir (Australia), Raphael Bayer (Austria), Wolfgang Pfneiszl (Austria), Said Asadli (Azerbaijan), Terrance Fountain (Bahamas), Abdulrahman Ahmed Showaiter (Bahrain), Galina Pyshnik (Belarus), Olegovich Pruchkovskiy (Belarus), Katia Huard (Belgium), Lies Gremeaux (Belgium), Nele Van Tomme (Belgium), Stéphanie Ovaere (Belgium), Sonam Tashi (Bhutan), Tsheringc Choden (Bhutan), Ivan Aliaga Casceres (Bolivia (Plurinational State of)), Richard Jesús López Vargas (Bolivia (Plurinational State of)), Wilson Salinas Olivares (Bolivia (Plurinational State of)), Elis Viviane Hoffmann (Brazil), Lívia Faria Lopes dos Santos Oliveira (Brazil), Rodrigo Bertoglio Cardoso (Brazil), Viviane Hoffmann (Brazil), Aimi Jamain (Brunei Darussalam), Hardiyamin Barudin (Brunei Darussalam), Radi Ignatov (Bulgaria), Slaveika Nikolova (Bulgaria), Amanda Pinke (Canada), Bobby Chauhan (Canada), Christina Arruda (Canada), Saeid Roushan (Canada), Daniel Diaz (Chile), Emilse Pizarro (Chile), Jose Marin (Chile), Luis Medel Espinoza (Chile), Monserrat Aranda (Chile), Yan Zheng (China; China, Hong Kong SAR), Kitty Hon (China, Hong Kong SAR), Hon Wai (China, Macao SAR), Oscar Ricardo Santa Lopez (Colombia), Andrés Rodríguez Pérez (Costa Rica), Beatriz Murillo Paz (Costa Rica), Roger Badou N'Guessan (Côte d'Ivoire), Hrvoje Paljan (Croatia), Lara Jezic (Croatia), Smilja Bagaric (Croatia), Gavriel Efstratiou (Cyprus), Ioanna Yiasemi (Cyprus), Nasia Fotsiou (Cyprus), Katerina Horackova (Czechia), Viktor Mravcik (Czechia), Lars Petersen (Denmark), Gilda Maria Francisco Espinal (Dominican Republic), Moises Gomez Trabous (Dominican Republic), Samanta Almeida (Ecuador), Sahar Ahmed Mohamed Farag (Egypt), Alma Cecilia Escobar de Mena (El Salvador), Carmen Morena Batres de Gracias (El Salvador), Heli Laarmann (Estonia), Katri Abel- Ollo (Estonia), Sanna Rönkä (Finland), Claire Jounet-Arenes (France), Joséphine Affres (France), Roland Hein (Germany), Saskia Jensen (Germany), Charles Oblitei Commey (Ghana), Godlove Vanden-Bossche (Ghana), Rosemond Agbefu (Ghana), Argyro Andaraki (Greece), Danae Manousaki (Greece), Gerasimos Papanastasatos (Greece), Ioannis Marouskos (Greece), Ioulia Bafi (Greece), Manina Terzidou (Greece), Mario Sierra (Guatemala), Roberto Maldonado (Guatemala), Rachel Victoria Ulcena (Haiti), Paola Cristina Girón Serrano (Honduras), Anna Péterfi (Hungary), Gergely Csaba Horvath (Hungary), Ibolya Csákó (Hungary), Peter Foldi (Hungary), Agus Irianto (Indonesia), Mohammad Narimani (Iran (Islamic Republic of)), Seyed Hamzeh Madani (Iran (Islamic Republic of)), Imad Abdel Raziq Abdel Gani (Iraq), Stephen Murphy (Ireland), Eti Kahana (Israel), Andrea Zapparoli (Italy), Elisabetta Simeoni (Italy), Yuki Maehira(Japan), Jamil Alhabibeh (Jordan), Malak Al-mahirah (Jordan), Alma Agibayeva (Kazakhstan), Stephen Kimani (Kenya), Akyl Amanov (Kyrgyzstan), Agnese Zile-Veisberga (Latvia), Diana Vanaga-Araja (Latvia), Ieva Pugule (Latvia), Zeinab Abbass (Lebanon), Jurgita Žilinskaite (Lithuania), Michel Goergen (Luxembourg), Nadine Berndt (Luxembourg), Rita Cardoso Seixas (Luxembourg), Nikmat Yusop (Malaysia), John Testa (Malta), Victor Pace (Malta), Corceal Sewraz (Mauritius), Martha Vazquez (Mexico), Valeria Solis (Mexico), Jasna Sekulic (Montenegro), Nevena Markovic (Montenegro), Valentina Bodven (Montenegro), Abdelhafid EL Maaroufi (Morocco), Abderrahim Matraoui (Morocco), Ayoub Aboujaafer (Morocco), EL Maaroufi Abdelhafid (Morocco), Mustapha El alami El Fellousse (Morocco), Nadia Chouaib (Morocco), Myint Aung (Myanmar), Zaw Lin Oo (Myanmar), Guus Cruts (Netherlands), Martijn Mulder (Netherlands), Vincent van Beest (Netherlands), Blair Macdonald (New Zealand), Lauren Bellamore (New Zealand), Manuel García Morales (Nicaragua), Abdoul Aziz Garba Yayé (Niger), Hamidou Amadou Insa (Niger), Ibiba Jane Odili (Nigeria), Ngozi Vivian Oguejiofor (Nigeria), Daniel Bergsvik (Norway), Ola Bilgrei (Norway), Mahmood Al Abri Sultante (Oman), Mohamed Amin (Oman), Sayed Sijjeell Haider (Pakistan), Daysi Vargas (Panama), Rubielys Saladana (Panama), Tatiana Tesis (Panama), Crhistian Gomez (Paraguay), Juan Pablo Lopez (Paraguay), Laura Reinoso (Paraguay), Lillian Portillo (Paraguay), Mathías Jara (Paraguay), Sandra Morales (Peru), Corazon P. Mamigo (Philippines), Johanna Rosales (Philippines), Michael P. Miatari (Philippines), Rebecca F. Arambulo (Philippines), Yvonne B. San Pascual (Philippines), Lukasz Jedruszak (Poland), Ana Sofia Santos (Portugal), Elsa Maia (Portugal), Quatar ARQ (Qatar), Donghyun Kim (Republic of Korea), Yongwhee Kim (Republic of Korea), Victor Tacu (Republic of Moldova), Ciprian Zetu (Romania), Oleg Lozhkin (Russian Federation), Saud Alsabhan (Saudi Arabia), Dusan Ilic (Serbia), Evelyn Low (Singapore), Melvina Niroshini Andrew (Singapore), Thamaraichelvan Meyappan (Singapore), Eva Debnarová (Slovakia), Ivana Bucková (Slovakia), Jože Hren (Slovenia), Staša Šavelj (Slovenia), Vathiswa Dlangamandla (South Africa), Elena Alvarez Martín (Spain), Thamara Darshana (Sri Lanka), Frida Nyman (Sweden), Jennie Hagelin (Sweden), Joakim Strandberg (Sweden), Johan Ragnemalm (Sweden), Julia Ahlin (Sweden), Barbara Walther (Switzerland), Diane Buechli (Switzerland), Marc Wittwer (Switzerland), Verena Maag (Switzerland), Saidzoda Firuz Mansur (Tajikistan), Prang-anong Saeng-arkass (Thailand), Mouzinho T. 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EXPLANATORY NOTES

The designations employed and the presentation of the material in the *World Drug Report* do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations concerning the legal status of any country, territory, city or area, or of its authorities, or concerning the delimitation of its frontiers or boundaries.

Countries and areas are referred to by the names that were in official use at the time the relevant data were collected.

Since there is some scientific and legal ambiguity about the distinctions between "drug use", "drug misuse" and "drug abuse", the neutral term "drug use" is used in the *World Drug Report*. The term "misuse" is used only to denote the non-medical use of prescription drugs.

All uses of the word "drug" and the term "drug use" in the *World Drug Report* refer to substances controlled under the international drug control conventions, and their non-medical use.

All analysis contained in the *World Drug Report* is based on the official data submitted by Member States to the UNODC through the annual report questionnaire unless indicated otherwise.

The data on population used in the *World Drug Report* are taken from: *World Population Prospects: The 2019 Revision* (United Nations, Department of Economic and Social Affairs, Population Division).

References to dollars ($) are to United States dollars, unless otherwise stated.

References to tons are to metric tons, unless otherwise stated.

The following abbreviations have been used in the present booklet:

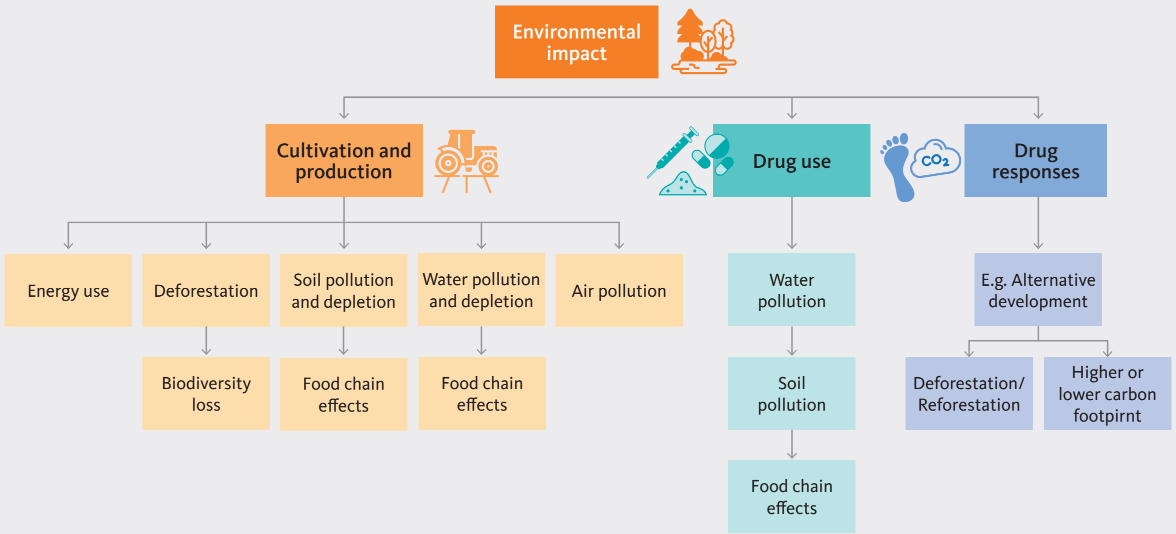
BIOREDD+	Biodiversity – Reduced Emissions from Deforestation and Forest Degradation
BMK	benzyl methyl ketone
BVOC	biogenic volatile organic compounds
CO2	carbon dioxide
CO2e	carbon dioxide equivalent
EMCDDA	European Monitoring Centre for Drugs and Drug Addiction
ES	environmental service
Europol	European Union Agency for Law Enforcement Cooperation
GIZ	German Agency for International Cooperation
ha	hectares
HVAC	heating, ventilation and air conditioning
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
MDMA	3,4-methylenedioxymethamphetamine (MDMA, commonly known as "ecstasy")
P-2-P	1-phenyl-2-propanone
REDD+	Reducing Emissions from Deforestation and Forest Degradation in Developing Countries
UNODC	United Nations Office on Drugs and Crime

SCOPE OF THE BOOKLET

Constituting the fifth part of the *World Drug Report 2022*, the present booklet contains a deep dive into the nexus between drugs and the environment. The aim is to provide a comprehensive overview of the current state of research into the direct and indirect effects of illicit crop cultivation, drug manufacture and drug policy responses on the environment, in order to assist Member States in anticipating and addressing environmental challenges and in mitigating risks.

The booklet starts with a general overview of how illicit drugs and the environment are linked within the bigger picture of the Sustainable Development Goals, climate change and environmental sustainability. It highlights direct and indirect linkages and gives examples of the significant local and individual-level impact that drugs can have on the environment. This is followed by a more in-depth overview of the latest scientific evidence for plant-based drugs and for synthetic drugs. For plant-based drugs, for example, this includes an analysis of the relationship between illicit crop cultivation and deforestation. For synthetic drugs, it includes an analysis of waste composition, volumes, and dumping and discharge, as well as the relation with wastewater treatment. The booklet also contains, at the end, detailed descriptions of the environmental harm related to the production of cannabis (both indoor- and outdoor-grown), other plant-based drugs and synthetic drugs.

THE THREE ROUTES OF ENVIRONMENTAL IMPACT



Source: UNODC elaboration.

THE BIG PICTURE: DRUGS AND THE ENVIRONMENT

Setting the scene

Scientific research into the linkages between illicit drug economies and the environment is a relatively limited and recent endeavour.[1,2] Compared with other fields of study related to illicit drugs, there are only limited data and relatively few academic studies. As with all aspects of illicit economies, data are also incomplete or unavailable owing to the underground nature of the phenomenon, which makes it difficult to draw sharp conclusions. While drugs may account for a small contribution to the total environmental footprint at the global level, the illicit drug industry can have important local environmental effects.

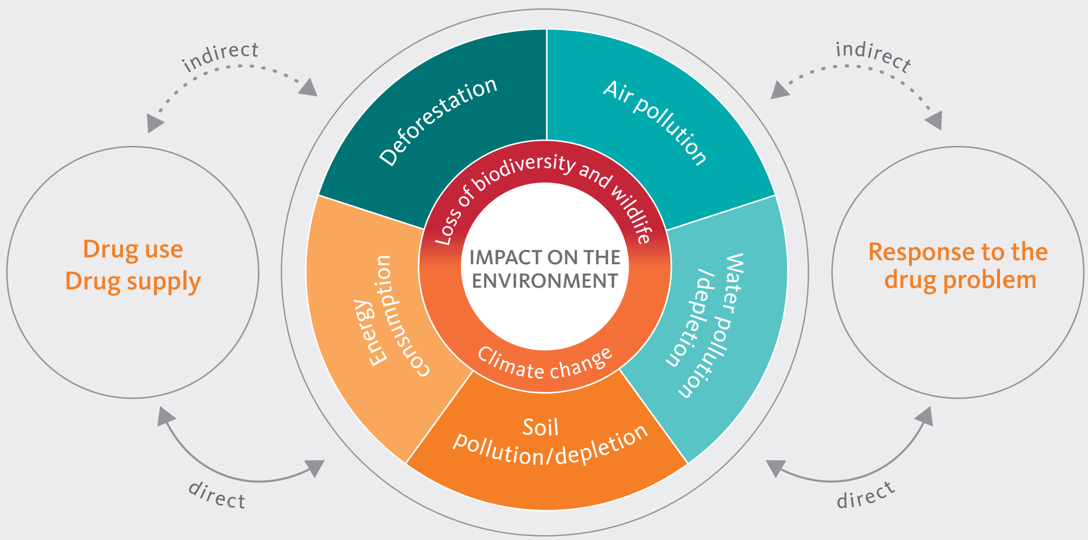
The present booklet gives an overview of the current state of scientific research on the direct and indirect links between drugs and the environment and provides analyses that can inform targeted responses. It covers many aspects but does not pretend to be exhaustive.

The booklet examines whether and how drug policy and drug use and supply have an impact on the environment and quantifies that impact wherever possible. It also includes a comparison of the impact of various drugs and of comparable licit activities. It approaches the environmental impact of the illicit drug economy from a scientific angle in order to properly assess the world drug problem within the broader debate about climate change and environmental sustainability.

Framework for drugs and the environment

The present analysis of the links between drugs and the environment is structured according to the framework set out below.

ANALYTICAL FRAMEWORK FOR DRUGS AND THE ENVIRONMENT



Source: UNODC elaboration.

Note: Based in part on discussions during the expert meeting on drugs and the environment organized by UNODC and GIZ on 20 and 21 September 2021.

Main conclusions

General impact. While the global environmental impact of illicit crop cultivation and drug manufacture is relatively small compared with that of the legal agricultural or pharmaceutical sector, the effects can be significant at the local, community and individual levels.

Location as a key differentiating aspect. One of the key differentiating aspects of the environmental impact of illicit crop cultivation and drug manufacture is the location of such cultivation and production. Illicit crop cultivation generally takes place in remote, thinly populated areas, far from any governmental presence. Those areas can be home to highly diverse and fragile ecosystems, such as those found in forest reserves and natural parks. Similarly, synthetic drug manufacture often takes place on remote locations and results in dumping or discharge of drug-related waste in forests, rivers or directly into sewage systems. The location can also determine the opportunities for mitigation of this impact. The effects of discharges in wastewater can, for example, be higher in countries and communities with no or poor wastewater treatment systems.

Illicit cultivation of plant-based drugs. As with other agricultural crops, the cultivation of plant-based drugs can affect the soil and water, and their final production, including chemical processing and waste, can also affect the air. The heavy use of fertilizers and pesticides can have negative effects on the environment and on organisms living in the water and soil. Certain types of irrigation can accelerate soil salinization, that is, the excessive accumulation of salts in the ground. Illicit cultivation is also found in protected environmental areas, such as national parks and forest reserves, where ecosystems are particularly fragile. The carbon footprint of plant-based drugs depends on the cultivation methods used and the subsequent processing, transportation and marketing of the product. The carbon footprint of indoor cannabis cultivation is considerably larger than that of outdoor cultivation (i.e. 16 to 100 times larger). In outdoor settings, including greenhouses, an important determinant of the carbon footprint can be deforestation or other forms of land-use change. The carbon footprint per kg of cocaine manufactured is significantly larger than that of other, licit agricultural crops, such as coffee, cocoa beans and sugar cane (e.g. 30 times greater than for cocoa beans and 2,600 times greater than for sugar cane), and it is mainly determined by coca bush cultivation (60 per cent), alkaloid extraction (24 per cent) and waste disposal (14 per cent). The estimated total carbon emissions of global cocaine manufacture amount to 8.9 million tons of CO_2e per year, which is equivalent to the average emissions of more than 1.9 million gasoline-powered cars driven in the course of one year, or more than 3.3 billion litres of diesel fuel consumed.

Illicit production of synthetic drugs. The environmental impact of the production of synthetic drugs is partly determined by the methods of production and the corresponding waste patterns. It is also determined by the way in which the waste is disposed of afterwards. The use of pre-precursors and pre-pre-precursors increases the volume of waste. As production tends to be localized, the dumping and discharge of waste can have significant effects on the soil, water, and air, as well as indirect effects on organisms, animals, and the food chain. The waste produced during the process of synthesizing drugs such as amphetamine, methamphetamine and MDMA ("ecstasy") is between 5 and 30 times the volume of the end product. For law enforcement operations, this creates important challenges when dismantling seized laboratories. For local governments and citizens, it can bring about significant costs, both in terms of the financial costs of clean-up operations and the health costs resulting from pollution. Wastewater treatment can reduce the environmental impact of dumped and discharged waste, but the capacity to treat water is distributed unevenly around the world. The majority of the global manufacture of amphetamine and methamphetamine is typically carried out in remote areas with no water treatment, and for some substances, such as MDMA, the removal rates are relatively low.

Deforestation. Illicit crop cultivation can affect deforestation directly and indirectly. According to data from two regions in Colombia, the illegal cultivation of coca bush could directly cause or be indirectly associated with 43 to 58 per cent of all deforestation in those regions. If illicit cultivation involves prior deforestation, it can result in a significant additional carbon footprint, as CO_2 is released into the atmosphere when trees are cut down, and they no longer absorb carbon. New research covering the western Amazon region shows that illicit cultivation of coca bush drives deforestation but to a lesser extent than other agricultural practices (20 per cent less in Bolivia (Plurinational State of), 6 per cent less in Colombia and 2 per cent less in Peru). Illicit drug cultivation can also trigger deforestation by providing the resources to expand human settlements and other agricultural activities. Drug trafficking can also indirectly lead to deforestation when its proceeds are laundered through cattle ranching and other activities that require vast amounts of land.

Energy use. For indoor cannabis cultivation, the carbon footprint is determined especially by energy use, including for HVAC equipment to maintain temperature and humidity and for growing lights. Taken together, such climate control measures represent more than 80 per cent of the carbon footprint. Drug trafficking can also be indirectly related to energy use if cryptocurrencies are used in online sales.

Alternative development. There are examples of alternative development projects that have included environmental protection components, such as reforestation and agroforestry. More recently, projects have also started focusing on integrating environmental policy instruments such as carbon credits and schemes involving payment for environmental services.

Research gaps. In general, the links between illicit drugs and the environment remain underresearched and underreported. Despite growing attention to the topic, research remains limited and is often focused on isolated studies that show local or specific impact without extrapolating what it could mean at the global level. In addition, there is a lack of gender-sensitive data and an overall lack of knowledge on the role of women in illicit drug economies.

The linkages between illicit drugs and the environment are approached from two main perspectives: from the production (supply) and use of (demand for) drugs, and from drug policy responses. From both of those perspectives, there is a direct and indirect relationship with five areas of environmental harm, namely air pollution, deforestation, energy consumption, soil pollution and depletion and water pollution and depletion.

The various relationships between drugs and the environment cannot be analysed in complete isolation. They can be considered only within a broader context in which environmental policies and their effects also play a role. Environmental sustainability is among the three dimensions of the 17 Sustainable Development Goals, along with economic and social development.[3] It is a cross-cutting element of all of the Goals, but it is more directly reflected in certain objectives. For example, Goal 13 is about combating climate change and its impacts, while Goal 15 is about promoting the sustainable use of land and forests.[4] Drug use, the illicit drug economy and the responses to those phenomena are also linked to various Goals, such as Goal 1 (poverty reduction), Goal 2 (food security), Goal 3 (health) and Goal 16 (just, peaceful and inclusive societies).[5]

Since the adoption of the Sustainable Development Goals, important global commitments have been made to reduce climate change. In its April 2022 report, the Intergovernmental Panel on Climate Change (IPCC) called for further action, including reductions in fossil fuel use, structural shifts to renewable energy, and investments in carbon dioxide removal.[6]

DRUGS AND THE ENVIRONMENT IN RELATION TO THE SUSTAINABLE DEVELOPMENT GOALS		
Sustainable Development Goal	**Impact of drugs on the environment**	**Relationship with drug policy responses**
1: No Poverty		› Alternative development interventions can involve a trade-off between environmental protection and sustainable development and livelihoods.
2: Zero Hunger	› Illicit crop cultivation can have a detrimental effect on soil conditions (e.g. salinization) that may affect the cultivation of food crops. › Dumping and discharge of synthetic drug related waste may affect agricultural lands used for food crops.	
3: Good Health and Well-being	› Illicit crop cultivation and drug manufacture can have negative health effects for those involved in the production process (e.g. exposure to chemicals or volatile organic compounds).	› The handling and disposal of chemicals or waste related to illicit drug manufacture can have health-related consequences (e.g. for law enforcement personnel).
4: Quality Education		› Training of law enforcement can provide the necessary skills for cleaning up clandestine drug laboratories, for the safe handling and proper disposal of chemicals used in the illicit manufacture of drugs, and for reducing the environmental impact of the illegal manufacturing of drugs.
6: Clean Water and Sanitation	› Illicit crop cultivation and drug manufacture may affect the quality of (drinking) water, the behaviour of aquatic organisms as well as aquatic ecosystems in general. › Most drug manufacture happens in remote areas with either no or poor water treatment systems, so remnants of the illicit manufacture of drugs and their metabolites remain in the water, potentially impacting aquatic ecosystems and biodiversity.	

DRUGS AND THE ENVIRONMENT IN RELATION TO THE SUSTAINABLE DEVELOPMENT GOALS		
Sustainable Development Goal	**Impact of drugs on the environment**	**Relationship with drug policy responses**
7: Affordable and Clean Energy	> Indoor cannabis cultivation is highly energy intensive. The total carbon footprint depends to a significant extent on the mix of energy sources used.	> Using clean energy in alternative development projects can decrease the carbon footprint of alternative crops. > Clean energy can be important to decrease the significant environmental impact of cryptocurrency mining, which is related to drug trafficking.
8: Decent Work and Economic Growth		> Alternative development interventions that promote economic activities in the legal economy can address their environmental impact.
12: Responsible Consumption and Production		> Alternative development programmes can increase the environmental sustainability of production by including agroecology and other sustainable production methods.
13: Climate Action	> The carbon footprint of illicit crop cultivation and drug manufacture can be substantial, especially when land-use change or extensive climate control is included.	
14: Life Below Water	> Illicit drugs and their metabolites may have an impact on organisms in aquatic ecosystems. Laboratory simulations suggest that the species affected include brown trout, crayfish, zebra fish and zebra mussels. > Research is limited when it comes to the (long-term) effects on aquatic organisms and ecosystems.	
15: Life on Land	> Illicit crop cultivation and drug manufacture may affect the quality of soils (e.g. soil pollution or salinization) and biodiversity (e.g. through deforestation).	> Alternative development programmes can include agroforestry and reforestation components.

Link between drugs and the environment

In parallel to the growing importance of the Sustainable Development Goals, the relationship between illicit drugs and development has attracted some more attention in recent years, but they remain underresearched.[7] Environmental sustainability is an integral and indivisible part of the relationship between illicit drugs and development. From the 1980s onward, increasing attention was paid to the link between illicit drugs and the environment, but initially that connection was established predominantly through the perceived impact of drug cultivation on tropical deforestation.[8] While there is a link between coca bush cultivation and deforestation, the scale of the impact is limited. For example, in two areas of Colombia, namely the Amazonía region and the region of Catatumbo (part of the Department of Norte del Santander), the deforestation directly caused by illicit coca bush cultivation between 2005 and 2014 came to only 2 and 4 per cent, respectively, while the largest share of deforestation was directly related to other activities, such as cattle farming and agriculture.[9]

Later, from the 2000s onward, the link with drug policy responses was frequently highlighted, especially in relation to the aerial spraying of illicit crops in Colombia.[10] Research included a broad focus on health and the environment, but with attention to the impact on biodiversity, for example, in relation to bird and fish species.[11] While such studies help to quantify environmental effects, they often do not put them into perspective in relation to other sources of environmental harm.

More recently, the environmental impact of the drug problem was highlighted in the outcome document of the thirtieth special session of the General Assembly, held in 2016, entitled "Our joint commitment to effectively addressing and countering the world drug problem", as an effect of illicit cultivation and production, and in a call for environmental protection considerations in drug policy responses.[12]

Despite increased attention to the nexus between drugs and the environment, little is known about the effects that illicit drugs, their metabolite residues and the drug waste produced have on the environment or about the risks involved for public health and biodiversity. Environmental impact studies are often local or limited to laboratory experiments and they rarely explore the gender dimension of drugs and the environment. Similarly, while wastewater analysis is an important measure of drug use in some countries, the effects on the environment remain under-researched. Wastewater treatment capacity varies significantly from country to country, as does the ability to detect drug-related contamination. In addition, there is little research linking drug-related contaminants with environmental harm. Those gaps in the research limit the capacity to comprehensively understand the scale and scope of the problem.

Significant local and individual-level impact

The limited global environmental impact of illicit drugs can be illustrated in various ways. For example, illicit crop cultivation takes place on a relatively small percentage of total agricultural land. Adding up the estimated areas of illicit crop cultivation of opium in 2021 (246,800 ha) and coca bush in 2020 (234,000 ha) results in a total of nearly half a million hectares.[13] In 2019, the estimated total agricultural land used for all crops globally was 1.6 billion ha, or more than 3,000 times the area used for illicit crop cultivation.[14] This difference in size – three orders of magnitude – also has implications for the relative environmental impact of the use of precursor chemicals, pesticides and other agricultural inputs for illicit crop cultivation as compared with the overall agricultural sector.

Similarly, the global production of synthetic drugs is equivalent in volume to only a small fraction of, for instance, the total licit production of pharmaceutical drugs. While estimates vary, the global annual production of the common medicine aspirin may be as much as 40,000 tons.[15] This results in a far smaller environmental footprint globally and usually also locally, except in places where synthetic drug production is geographically concentrated. For example, wastewater analysis has revealed extremely high concentrations of pharmaceuticals in areas of India where the production of medications is concentrated.[16] Despite such localized production-related agglomerations, it is likely that the amount of pharmaceuticals and their metabolites reaching the environment through human excretion or improper disposal is larger than the sum of the discharges at those pharmaceutical production sites.[17] Although data are lacking, the same is probably true for illicit drugs as well, which means that any production-related contamination data represent only one part of the broader environmental impact.

Nevertheless, the impact of illicit drug production and drug use on the environment can have significant knock-on effects at the local and individual levels. That is not only because of a lack of environmental regulations in the illicit supply chain, but also because the illicit drug economy affects multiple dimensions of development and biodiversity. That impact is linked to broader patterns of marginalization, underdevelopment, fragility and conflict,[18, 19] in which even relatively small issues of environmental degradation can have important spillover effects for local communities in development areas, such as poverty, food security or even social stability. This type of environmental impact is, for example, visible in illicit cultivation located in isolated areas with little State presence and a lack of official land-use or development planning, where the vulnerability to environmental shocks may be higher and have an important impact on the affected communities. Similarly, where the production and use of drugs are concentrated in small geographical areas, the environmental impact can be significant for the ecosystem, and local communities bear the burden of that impact.

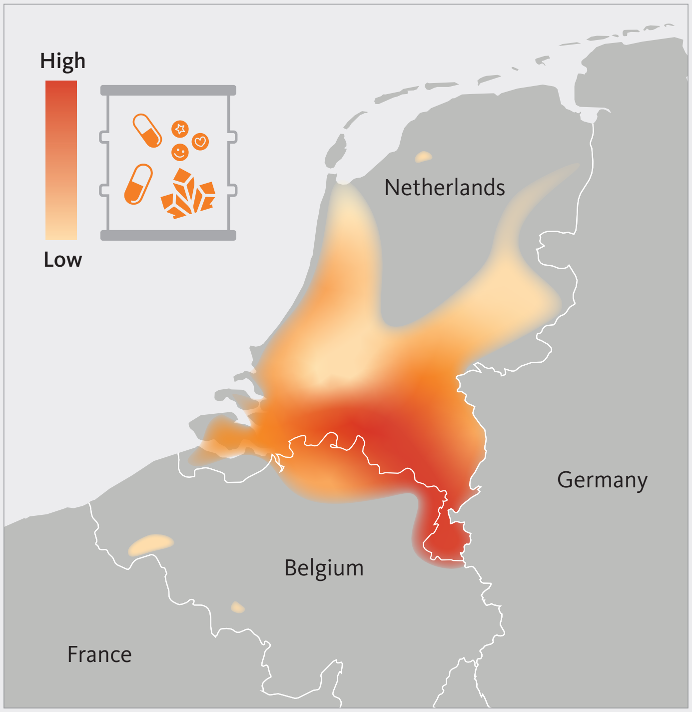
In the Rif area of northern Morocco, where most of the country's cannabis is cultivated, increasingly intensive, often monoculture, illegal cannabis farming in recent decades has resulted in increased environmental pressure on an already fragile ecological system in the form of deforestation, water scarcity and loss of biodiversity.[20] The intensive cannabis cultivation in the Rif has turned the area into the largest user of fertilizers and pesticides in the country's broader agricultural sector; however, no research has been conducted to measure the effects in terms of water pollution.[21]

In certain areas of Afghanistan, such as the southern province of Helmand, for example, opium poppy cultivation has resulted in salinization because of poor drainage during irrigation.[22] The profits from the illegal opium economy pushed the agriculture frontier toward the desert areas through investments in deep wells and diesel-powered pumps.[23]

When it comes to synthetic drug production, the local impact can also be significant, as production takes place in concentrated geographical areas. For example, some dumping sites of waste from the manufacture of synthetic drugs are concentrated in the southern parts of the Netherlands and the northern parts of Belgium, and their impact on soil and water contamination is significant in that relatively small geographical area. On two separate occasions, for example, MDMA was determined in samples taken from corn grains.

CONCENTRATION OF DUMPING SITES OF WASTE FROM SYNTHETIC DRUG PRODUCTION

IN BELGIUM AND THE NETHERLANDS (2015–2017)



Source: EMCDDA and Europol, *EU Drug Markets Report 2019* (Luxembourg: Publications Office, 2019).

The negative environmental impact of illicit drugs may also have different implications at the individual and community levels. In addition to individual health risks, local communities could be affected in different ways: from poor communities faced with water or soil pollution in fragile ecosystems to farmers in more developed countries who are faced with the costs of cleaning up their lands after the dumping of synthetic drug waste.

Environmental impact of illicit drug activities versus legal activities

Although their impact is small in absolute terms, when compared with the licit economy, illicit drug activities can have a greater environmental impact per unit produced. For example, licit industries could, in principle, cause greater contamination in absolute terms, but, in general, those industries have mechanisms in place to minimize their environmental impact because they are bound by national and international environmental regulations.

Because of the illegal nature of the drug business, drug production and trafficking are often located in remote areas, where their environmental impact could be particularly significant. For example, in Colombia, nearly half of all illicit coca bush cultivation was carried out in areas with special protection status in 2020.[24] In line with a longer-term trend, cultivation increased in national parks and continued to affect other territories with special environmental regulations, including forest reserves, indigenous reserves and lands reserved for the Afro-Colombian population.[25] The environmental impact identified in national parks includes water and soil contamination and deforestation.[26] In Nigeria, illegal cannabis cultivation generally takes place in remote tropical forest areas, far away from major roads and urban areas.[27]

The effects of the illegality of drug production and trafficking are often not clear-cut or unidirectional in terms of causality. For example, illicit cultivation may result in deforestation, but licit cultivation and other economic activities may have the same effect. Similarly, efforts to reduce the illicit supply of drugs by introducing alternative crops may not necessarily decrease the impact on the environment, as the substitute crops may have an equal or worse carbon footprint.

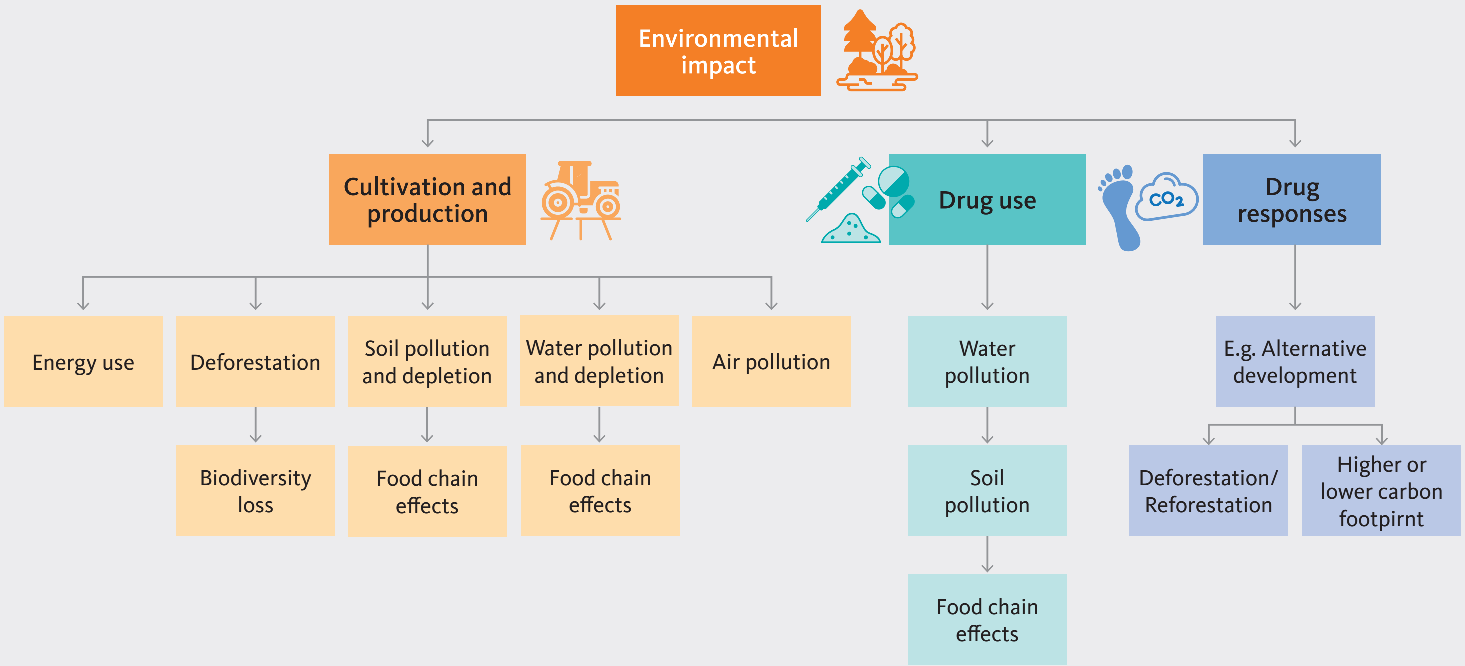
No general conclusions can be drawn about the relative environmental impact of legal versus illegal crop cultivation or production. However, the clandestine nature of illicit crop cultivation has meant that part of the economy has traditionally taken place largely outside of the policy frameworks related to environmental protection, sustainable development, and public health.

Research shows that legal activities, such as the cultivation of medical cannabis, provide authorities with opportunities for environmental protection, regulation, monitoring and compliance mechanisms.[28, 29] However, the market for medical cannabis and the expanding cultivation of cannabis in jurisdictions where it has been legalized can also have a significant carbon footprint, especially if those activities result in indoor cultivation with extensive climate control. Research has also shown that the cultivation of cannabis in jurisdictions where it has been legalized, does not necessarily ensure compliance with environmental regulations.[30] As with other legal agricultural crops, negative environmental effects can also be exacerbated if cultivation leads to intensive monoculture farming or favours larger growing operations over smaller ones.[31, 32]

Production harm pathways

The illicit production and manufacture of drugs, be they plant-based or synthetic, can be harmful to the environment in different ways. Besides drug policy responses, the two main routes through which drugs harm the environment are cultivation and production and drug use.

THE THREE ROUTES OF ENVIRONMENTAL IMPACT



Source: UNODC elaboration.

In order to provide a clearer picture of how production affects the environment, three production-related harm pathways have been identified.[a] They are based on harm arising from the following:

a) Illicit indoor cannabis cultivation;

b) Illicit outdoor drug crop cultivation;

c) Illicit synthetic drug production.

It is important to note that these harm pathways can often be subdivided into additional or more specific sub-pathways. For example, while the discussion below includes the use of agricultural inputs and precursor chemicals in the illegal cultivation and production stages, respectively, separate harm pathways arise from the production and transportation of the (mostly legal) fertilizers, pesticides, and precursor chemicals themselves. Especially when the production of those chemicals takes place far away from the area of their use, the environmental footprint can be expanded significantly.

All production stages generate waste in different amounts, which means that the environmental footprint also depends on whether and how that waste is treated and discarded. In general, waste production is an important indicator for comparing the environmental footprint of legal and illegal production, especially as the volume of waste may be much larger than the volume of the end products involved.

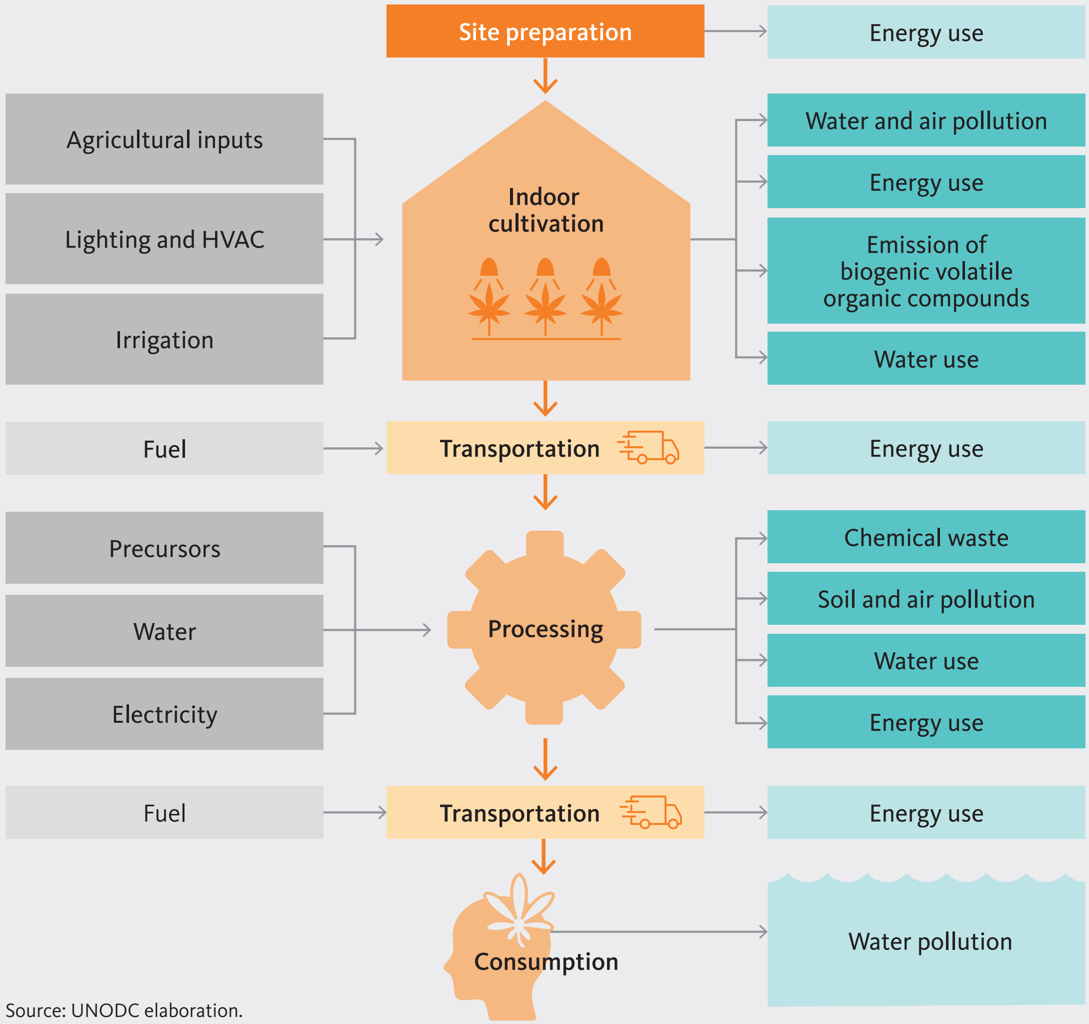
a For more detailed descriptions of the three harm pathways, please see the Annex of the present booklet.

Key findings in detail

While the global environmental impact of illicit crop cultivation and drug production is relatively small compared with that of the legal agricultural or pharmaceutical sector, the effects can be significant at the local or individual level. In relative terms, the impact can also be higher than that of some legal industries given the lack of environmental regulation associated with illegal drug production.

In general, the links between illicit drugs and the environment remain underresearched and underreported. Despite growing attention to those links, research remains limited and is often focused on isolated studies that reveal local or specific impact without extrapolating what it could mean at the global level. Even when more data become available, the estimate of the carbon footprint is limited to only a few studies that are frequently referenced but not often used as a basis for new or more precise research.[33]

ILLICIT INDOOR CANNABIS CULTIVATION HARM PATHWAY

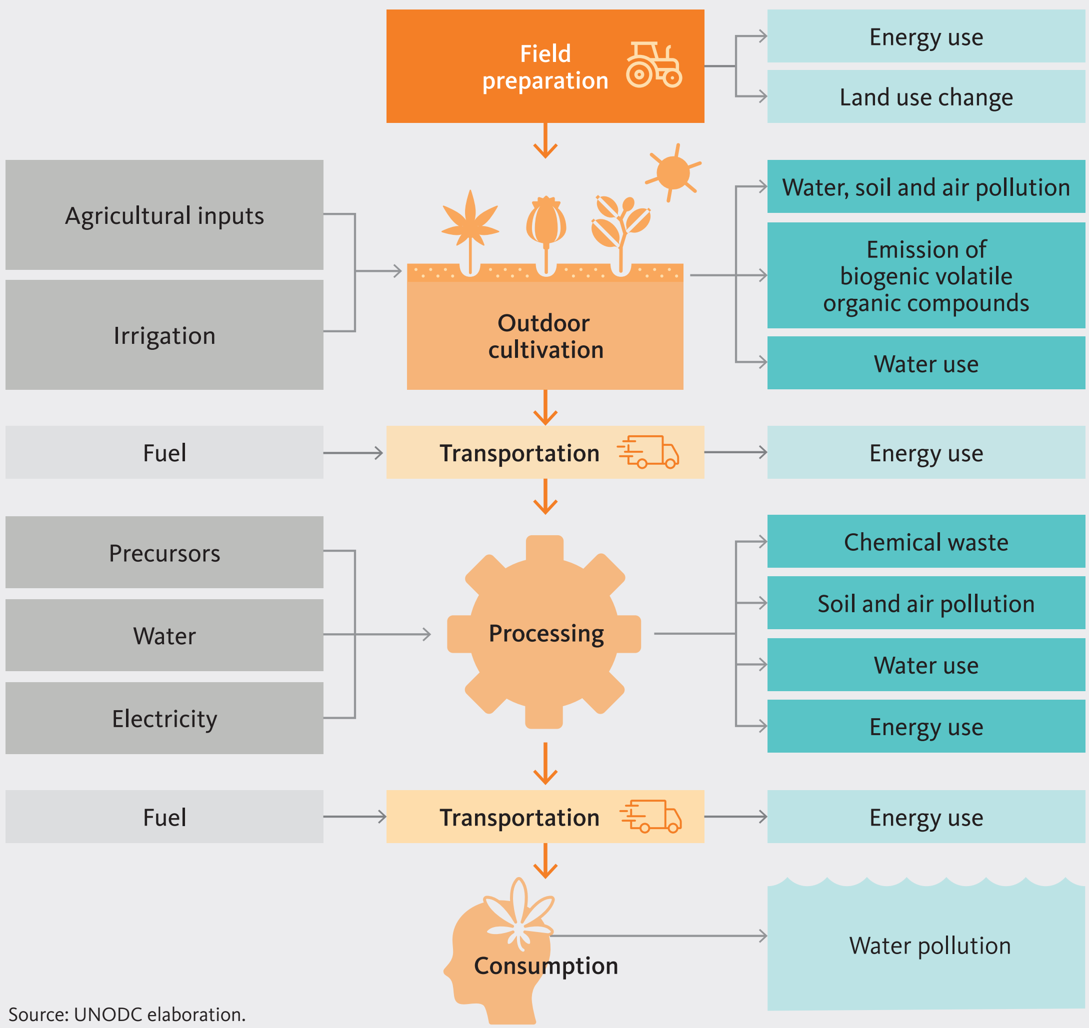


Source: UNODC elaboration.

When it comes to plant-based drugs, the carbon footprint of indoor cannabis cultivation is mostly determined by energy use, especially for controlling climate parameters.[34] This includes HVAC equipment to maintain temperature and humidity, as well as growing lights. Taken together, those climate control measures represent more than 80 per cent of the carbon footprint of indoor cannabis cultivation.[35] While the largest contributors to the carbon footprint of conventional outdoor agricultural production are fertilizers, herbicides, and land preparation activities, they represent less than 5 per cent in total for indoor cannabis. Another typical contributor in indoor cultivation is the injection of CO_2 to accelerate plant growth.

For the outdoor cultivation of any plant-based drugs, the highest potential environmental impact relates to land-use change, for example, when forests are cleared for the illicit cultivation of drugs. Deforestation has been associated with illicit crop cultivation for decades, but research has only recently started to provide more insights into the extent to which illicit cultivation is

ILLICIT OUTDOOR DRUG CROP CULTIVATION HARM PATHWAY



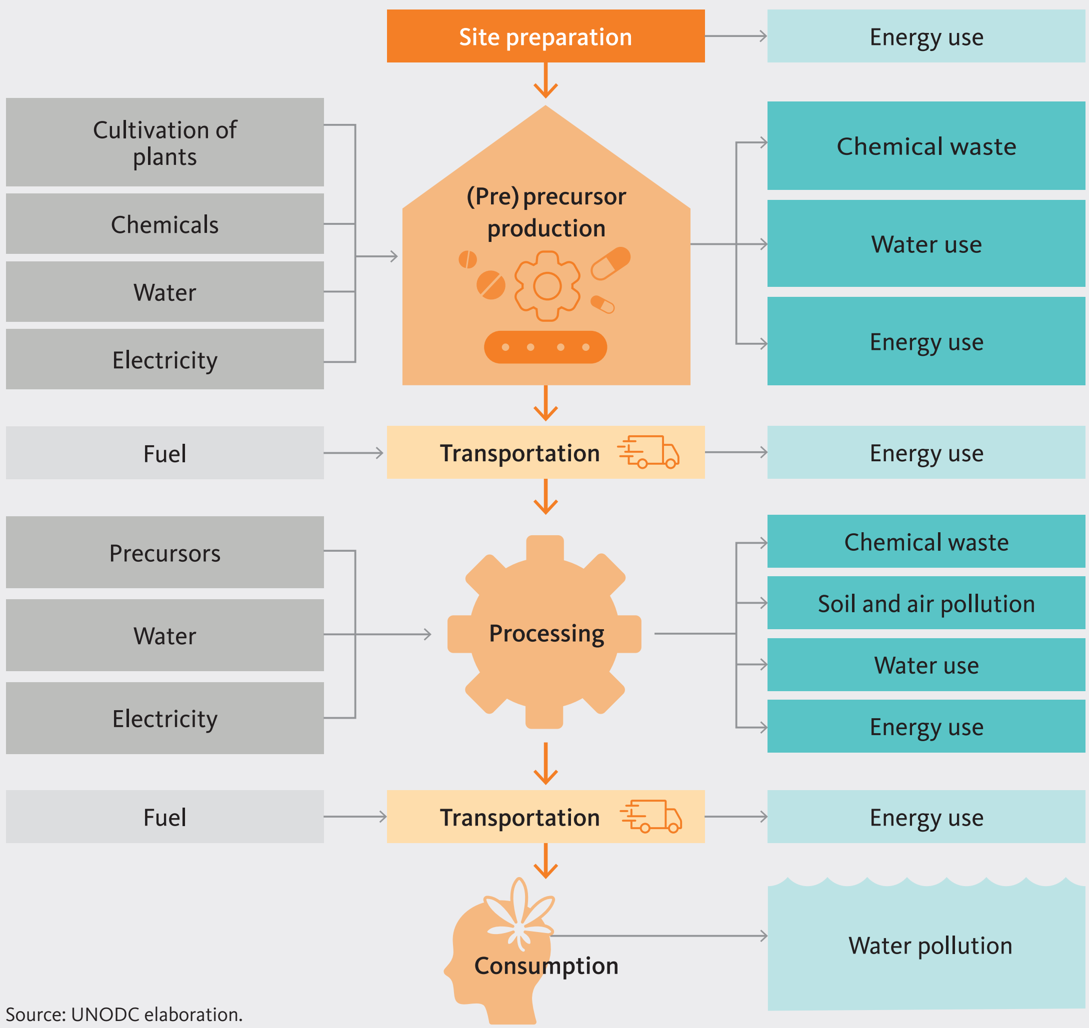
Source: UNODC elaboration.

a direct cause of deforestation or a more indirect driver of economic activities that expand the agricultural frontier. Drug trafficking can also have an environmental impact on land, for example, through money-laundering-related investments in cattle ranching.[36]

While the environmental impact of plant-based drugs is generally quantified on the basis of the end product, the environmental impact of synthetic drugs often focuses on waste, which is estimated to be at least five times the weight of the end product.[37, 38, 39] With incomplete data on the production of synthetic drugs such as amphetamine, methamphetamine or MDMA, accurate waste estimates cannot be computed at the global level. Applying the estimated waste production ratios to quantities seized, for which aggregate figures based on official country reporting are available, provides a minimum estimate.

Local wastewater analysis can monitor both drug consumption trends and measure the environmental load

ILLICIT SYNTHETIC DRUG PRODUCTION HARM PATHWAY



Source: UNODC elaboration.

of drug-related substances. While such analyses have provided evidence as to the concentrations of drug remnants and metabolites in various local areas around the world, they are mostly carried out in Europe and a few other high-income countries, including Australia, Canada and the United States of America,[40] and so far they have been used more to monitor trends in drug consumption rather than to assess environmental impact. While various wastewater studies have shown the negative effects of drug use on biodiversity, research on the topic is still often limited to laboratory settings and has so far produced little insight into possible long-term effects.

The following specific findings can be formulated:

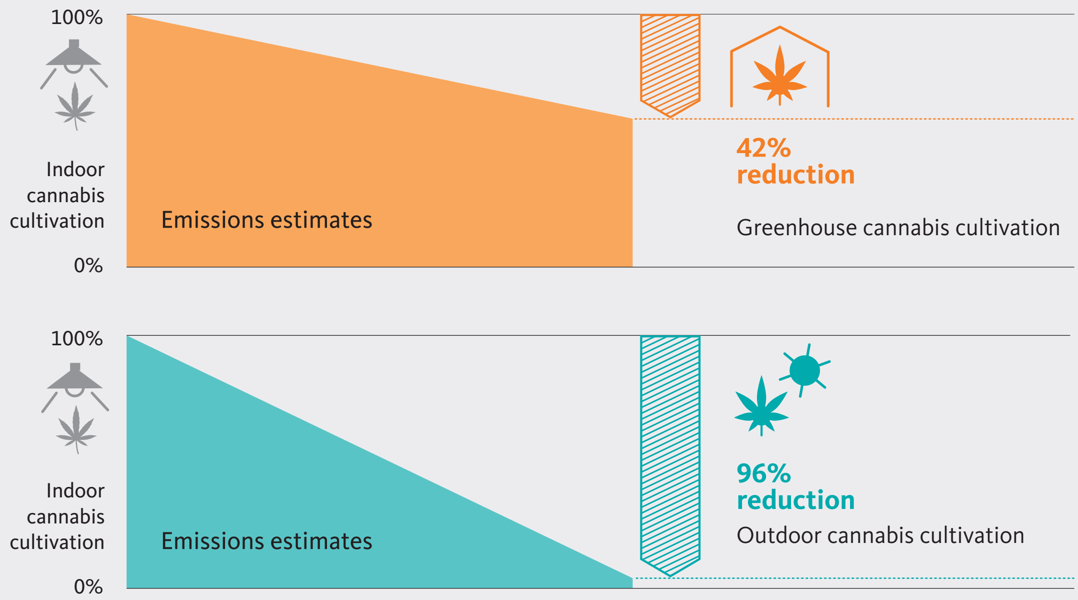
Alternative development interventions

Substituting illicit crops with alternative crops can bring about a higher or lower carbon footprint, depending in part on the geographical location, the agroclimatic conditions, the methods of cultivation, the use of fertilizers, pesticides and other agricultural inputs, and the marketing of the end products.

Biodiversity

- Drugs and their metabolites may have an impact on wildlife, especially in aquatic ecosystems. Laboratory simulations suggest that the species affected include brown trout, crayfish, zebra fish and zebra mussels.[41]
- However, little research has been conducted on the effects of long-term or chronic exposure in those ecosystems[42] and on potential food chain effects.
- Similarly, there is a research gap when it comes to the effects of local deforestation or forest fragmentation on endemic species distributed within small areas (endemism).

ESTIMATED EMISSION REDUCTIONS FROM CHANGES IN CANNABIS CULTIVATION METHODS

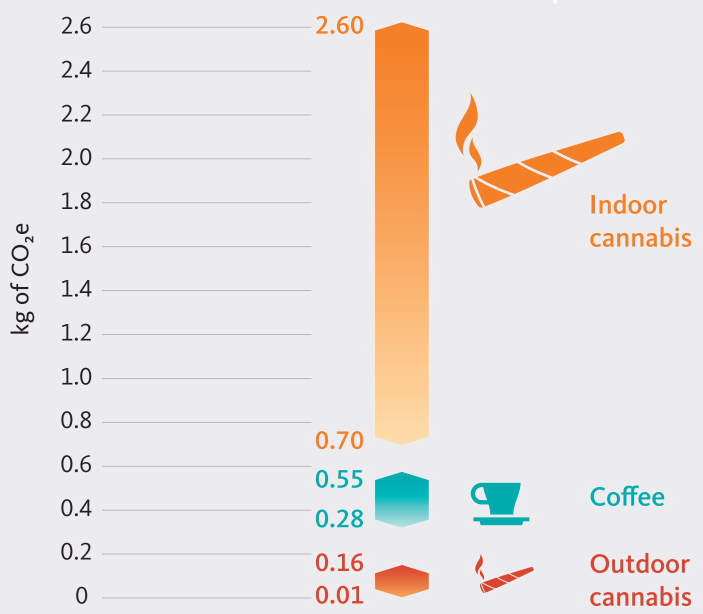


Source: Hailey M. Summers, Evan Sproul, and Jason C. Quinn, 'The Greenhouse Gas Emissions of Indoor Cannabis Production in the United States', *Nature Sustainability* 4, no. 7 (July 2021).

Cannabis

- The total carbon footprint of indoor cannabis cultivation has been estimated at 2,300 to 5,200 kg of CO_2e per kg of dried cannabis flower.[43] For outdoor cannabis, the estimates range from 22.7 to 326.6 kg of CO_2e per kg of dried flower.[44] The impact per user is lower and depends on patterns of cannabis consumption. Energy use is by far the largest part of the carbon footprint generated by indoor cannabis cultivation.
- For outdoor cannabis, the clearing of forests prior to cultivation can be the single largest source of environmental impact.
- In high-technology settings, both indoors and outdoors (greenhouse farming), the carbon footprint is mainly driven by climate control (HVAC) and the use of growing lights.
- The limited research available suggests that, compared with indoor cultivation, greenhouse cannabis cultivation and outdoor cultivation generate 42 per cent and 96 per cent less CO_2 emissions, respectively.[45]
- Studies on the environmental impact of cannabis cultivation in countries where cannabis was legalized suggest that indoor cannabis cultivation requires substantial amounts of energy to control the climate, which may represent some 80 to 85 per cent of the total carbon footprint.
- The average carbon footprint of a typical cannabis dose (a joint) is substantially higher than that of a cup of coffee if the cannabis has been grown indoors, while it is lower if the cannabis has been produced outdoors.
- For outdoor cannabis cultivation, the amount of water used for irrigation purposes is small compared with the quantity required for alternative crops, such as almonds. However, depending on the location, cannabis cultivation can still have an important environmental impact.[46]

CARBON FOOTPRINT COMPARISON OF A CUP OF COFFEE AND A JOINT (kg of CO_2e per "joint"/cup)



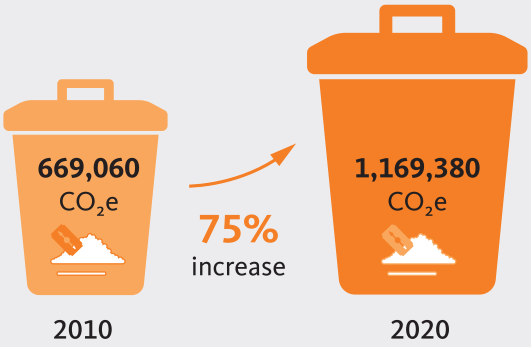
Sources: Carmen Nab and Mark Maslin, 'Life Cycle Assessment Synthesis of the Carbon Footprint of Arabica Coffee: Case Study of Brazil and Vietnam Conventional and Sustainable Coffee Production and Export to the United Kingdom', Geo: Geography and Environment 7, no. 2 (July 2020); Hailey M. Summers, Evan Sproul, and Jason C. Quinn, 'The Greenhouse Gas Emissions of Indoor Cannabis Production in the United States', *Nature Sustainability* 4, no. 7 (July 2021).

Note: The coffee figures are based on carbon footprint estimates related to coffee produced in Brazil and Vietnam and exported to the United Kingdom. The numbers of indoor and outdoor cannabis cultivation are based on the United States and do not include exportation.

Carbon footprint of other plant-based drugs

- In relative terms, drug supply chains can have a considerable carbon footprint per kg of product. For example, cannabis and cocaine have a larger carbon footprint per kg than other products, such as green coffee beans, cocoa beans or sugar cane. However, in absolute terms, the latter crops have a much larger total footprint owing to the different scale of global production.
- Low alkaloid yields from coca leaves amplify the environmental impact of cocaine production. One ton of coca leaves yields 1.41 kg of cocaine hydrochloride.

ANNUAL GLOBAL FOOTPRINT FROM COCAINE MANUFACTURING CALCULATED ON THE BASIS OF ESTIMATES OF TOTAL MANUFACTURE



Sources: Juanita Barrera-Ramírez, Valentina Prado, and Håvar Solheim, 'Life Cycle Assessment and Socioeconomic Evaluation of the Illicit Crop Substitution Policy in Colombia', *Journal of Industrial Ecology* 23, no. 5 (October 2019); UNODC estimates of cocaine manufacture.

- Based on a carbon footprint of 0.51 kg of CO_2e for 1 kg of coca leaves, the footprint of 1 kg of cocaine is an estimated 590 kg of CO_2e, if land use change is not considered, which is equivalent to using 250 litres of gasoline. At the level of the individual user, the average carbon footprint is much less significant given the smaller average consumption amounts involved.
- By comparison, the estimated carbon footprint of 1 kg of green coffee beans is about 7 kg of CO_2e, while 1 kg of cocoa beans produces around 20 kg of CO_2e.
- The carbon footprint increases once land-use changes are taken into account. For Colombia, it was estimated that the footprint increases by about 7 to 10 times.
- Based on the available carbon footprint estimates and 2020 global production data, the global carbon footprint of cocaine is equivalent to 1.17 million tons of CO_2e without taking into consideration land use change. This is equivalent to the average emissions of more than 250,000 gasoline-powered cars being driven in the course of a year, or around 435 million litres of diesel fuel consumed.
- Research into the carbon footprint of cocaine production in two areas of Colombia: the Department of Putumayo and the region of Catatumbo, shows that if land-use change occurs (e.g. when forest land is turned into cropland, which releases a large amount of carbon into the atmosphere), the resulting emissions could be as high as 4 to 6 tons of CO_2e per kg of cocaine, which suggests that the effect of land-use change could easily be the single most important impact of cocaine production.[47]
- Substantial data gaps hinder accurate estimates of the global carbon footprint of outdoor cannabis cultivation for dry flower and/or resin. In order to enable such estimates, one would need production data that allow the quantification of yields, fertilizer inputs, processing energy and the effects of land management on, for example, soil and water systems.
- The data gaps are even larger for opium cultivation and production. The closest estimate of its carbon footprint was for a portion of the supply chain and limited to the cultivation of opium poppy for the legal production of medical morphine. A single study published in 2016 suggested that almost 90 per cent of the carbon footprint of morphine ready for medical use was related to the final stages of production, especially to sterilization and packaging.[48]
- For plant-based drug production, direct and indirect links between policy responses and the environment can be established through programmatic activities and support, for example in alternative development projects.
- There are only a few environmental policies, such as the designation of protected environmental areas, in which an indirect link with (potential) illicit crop cultivation is established. Apart from those cases, environmental policies generally do not seem to consider the specific environmental issues related to illicit crop cultivation, production or trafficking.

Deforestation

- In terms of hectares of cultivation, direct deforestation from illicit crops is generally not significant compared with other sources of deforestation, such as those associated with other crops or cattle ranching. However, illicit crop cultivation is linked to the expansion of the agricultural frontier and other drivers of deforestation, which may include socioeconomic underdevelopment and inequality, armed conflict, or a lack of effective agricultural development policies.[49]

- Illicit coca bush cultivation can be a driver of deforestation. However, new research on the western Amazon region shows that deforestation driven by the illicit cultivation of coca is slower and causes less forest loss than that driven by other agricultural practices, although the impact varies by country in terms of hectares of cultivation. For the Amazon region in the Plurinational State of Bolivia, the total rate of forest loss due to illicit coca bush cultivation was 20 per cent lower than that caused by other agricultural activities. In the Amazon region of Colombia, the rate was 11 per cent lower.

- Research continues to be focused predominantly on the effects of cultivation, with much less attention given to the effects of drug trafficking, which can, through money-laundering-related investments (e.g. in agriculture or cattle ranching), produce an additional environmental impact. Evidence from many locations involved in the transnational cocaine supply chain demonstrates the transformative power of illicit capital in agricultural frontier landscapes, which can drive significant indirect land-use change and degradation that may be equal to or greater than direct cultivation-related impacts.[50, 51, 52] The link between drug trafficking and deforestation has now been firmly established in research. However, there is still a research gap when it comes to understanding how the size, scope and dynamics of that link affect environmental degradation and identifying opportunities for drug policy responses and broader policies to address the problem.

- With regard to Central America, research into trafficking networks in Guatemala and Honduras has shown that not only changes to land use and land cover are relevant, but also changes to land control.[53] Changes in the ownership of land can result in other forms of environmental harm that go beyond land-use change, including, for example, illegal logging and wildlife trafficking.[54]

MINIMUM GLOBAL WASTE FROM SYNTHETIC DRUGS: ESTIMATES OF WASTE GENERATED BY THE MANUFACTURE OF QUANTITIES OF DRUGS SEIZED

"Ecstasy"	Amphetamine	Methamphetamine
69.6–116 tons	1,152–1,728 tons	1,233–2,466 tons

Source: UNODC, responses to the annual report questionnaire.

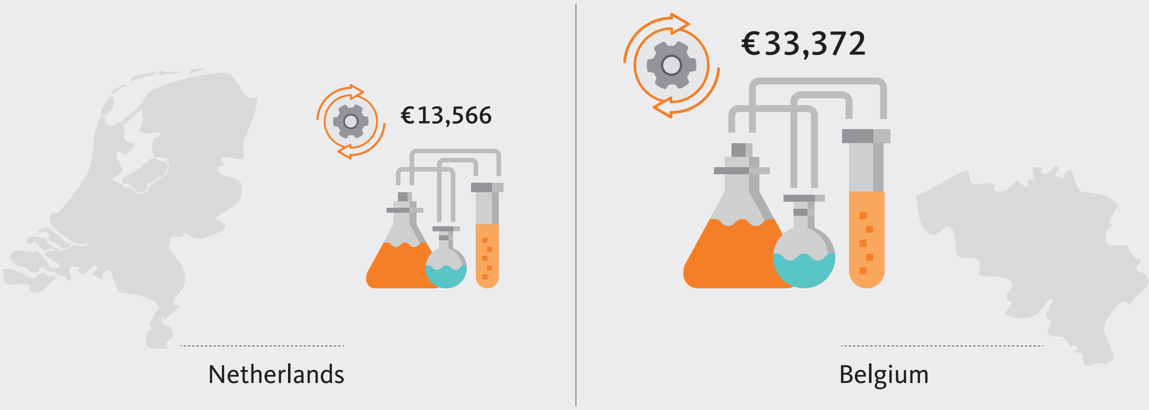
- Besides the direct effects of deforestation, illicit cultivation may contribute to forest fragmentation with indirect, longer-term effects on biodiversity through the fragmentation of habitats and a decrease in the support capacity of ecosystems.[55]

Synthetic drugs

- The dumping and discharge of synthetic drug waste often go undetected; together with a lack of global production data, this makes it difficult to estimate the environmental impact of synthetic drug production.
- As in other chemical processes, the amount of drug waste created during synthetic drug production is at least five times the amount of the end product.[56, 57, 58] For some drugs and drug production methods, it can be as much as thirty times.[59]
- Although global waste production figures are unknown, a minimum estimate can be calculated on the basis of known quantities of synthetic drugs seized. Calculated on the basis of annual quantities seized, the total global waste per year for amphetamine is between 1,152 and 1,728 tons. For methamphetamine, it is between 1,233 and 2,466 tons, and for MDMA it is between 69.6 and 116 tons. Given the large amounts of undetected end products, however, the actual total global waste production can be expected to be several orders of magnitude higher.
- Apart from precursor control, policy responses to synthetic drug production are mostly reactive in nature, ranging from the detection and dismantling of clandestine laboratories to wastewater analysis, clean-up operations on production or waste dumping sites and the proper disposal of confiscated drugs.
- The costs of cleaning up synthetic drug production sites, storage and dump sites can be substantial. Available estimates from Belgium and the Netherlands amount to an average of €33,372 and €13,566, per site, respectively.
- In the Netherlands, provincial governments provide subsidies for cleaning up contaminated soil or surface water.

AVERAGE COST OF DISMANTLING AND CLEANING UP SYNTHETIC DRUG PRODUCTION, STORAGE AND WASTE DUMPING SITES

IN BELGIUM AND THE NETHERLANDS



Source: Maaike Claessens et al., *An Analysis of the Costs of Dismantling and Cleaning up Synthetic Drug Production Sites in Belgium and the Netherlands,* Background Paper commissioned by the EMCDDA for the EU Drug Markets Report 2019 (Lisbon: EMCDDA, 2019).

PLANT-BASED DRUGS AND THE ENVIRONMENT

Setting the scene

On the basis of quantities seized, the most trafficked drugs globally in terms of weight are cannabis, cocaine and opiates. In the period from 2017 to 2019, those drugs accounted for 76 per cent of the total quantity of global seizures.[60] They are all plant-based substances that depend on agriculturally suitable land for cultivation, but the total area used for their cultivation is very small compared with the area used for major agricultural staples. While cannabis can theoretically be grown anywhere in the world, opium poppy and coca bush require more specific climatic conditions. The resulting geographical distribution of the plants also determines the regional variations in their environmental impact.

The illicit cultivation of plants such as cannabis, coca bush and opium poppy affects the environment in similar ways as the cultivation of other plants. It produces emissions of greenhouse gases at various stages: pre-cultivation (e.g. through land-use change, such as deforestation), cultivation (e.g. energy use) and post-cultivation (e.g. processing and transportation). Like licit agriculture, illicit drug cultivation also uses agricultural inputs, such as seeds, energy, fertilizers, and pesticides. Overall, however, illicit cultivation accounts for a very small share of total human emissions.

Differentiating factors

The clandestine nature of illicit drug cultivation means that the environmental impact may be less visible and more difficult to measure and control.

The illegal processing of plant-based drugs also distinguishes them from other crops in terms of environmental impact. For example, in cocaine manufacturing, the use of organic solvents such as kerosene and (sulphuric) acids in the extraction process causes a waste pattern that is quite specific to the substance.[61] However, the total weight of cocaine manufactured annually (estimated at 1,982 tons in 2020) is rather small compared with the production volume of other crops; so, the greater harm per kg is mitigated by the very small total volume involved. For example, global coffee production in 2019 and 2020 was estimated at some 10.2 million tons.[62]

The big picture

In absolute terms, the carbon footprint of legal agriculture is much larger than that of all illicit cultivation combined. For 2019, global emissions related to agricultural food production alone were estimated at 16.521 billion tons of CO_2e per year.[63] While there is no similar estimate for the total emissions arising from illicit cultivation, they are much lower by comparison.

General overview of key linkages and factors involved

The environmental impact of illicit cultivation is always a combination of effects, most of which relate directly to soil and water. The overall impact depends on the local context and on a number of factors, including, in particular, the farming methods involved and the size of the area under cultivation. However, the net environmental impact is often difficult to estimate. For example, there is no clear understanding of the different impact of “inefficient” traditional agriculture and “efficient” modern agricultural practices. In the Rif region in Morocco, traditional cannabis farming is still predominantly reliant on the heavy use of synthetic fertilizers, while the introduction of modern (irrigation) techniques and high-yield varieties has put increased pressure on the water resources of the region’s fragile ecology.[64]

In Nigeria, there is a clear relationship between cannabis cultivation and deforestation. A total of 39 per cent of all cannabis fields detected in 2019 were cultivated on former forest land that had been cleared in the same year, although the total area of cannabis cultivation (8,900 ha) represents only about 0.02 per cent of the country's arable land.[65] Cannabis fields are established in dense, tropical areas, most often by burning down the forests in the area. While cannabis cultivation contributes to ongoing deforestation, a much larger part of deforestation is caused by other factors, in particular by licit agriculture.[66]

Illegality and its implications for environmental impact

The impact of legal and illegal cultivation cannot be assessed in two neatly separated categories. Their effects depend on the location, scope and methods of cultivation, and on whether or not mitigation measures are implemented. The legal and illegal cultivation of crops can take different forms. For example, small-scale coca bush cultivation may sometimes resemble organic farming with low environmental impact, while the large-scale intensive legal cultivation of crops can have far-reaching consequences for the environment.

Nevertheless, there is one area in which the illegal cultivation of drugs can have a markedly different environmental impact. When cultivation is legal, for medical or scientific purposes or in jurisdictions where cannabis production has been legalized, the farming process is subject to environmental protection measures, such as the specific requirements related to licensing of cannabis cultivation in the State of California in the United States. Those requirements are in addition to general compliance with other conditions imposed under State,[67] county and local regulations. The nature of some of the restrictions results partly from the traditional practices of illegal cannabis cultivation, for example, the diversion of water from streams and springs.[68]

The regulations not only regulate individual cannabis farms, but also take into consideration the aggregated geographical impact of the industry. For example, the State Water Resources Control Board or the California Department of Fish and Wildlife can notify the California Department of Food and Agriculture when the overall cultivation of cannabis in certain watersheds or geographical areas is causing significant adverse impacts on the environment.[69] In such cases, there would be a temporary suspension of the issuance of new cultivation licences or no increase in the total number of licences issued.

There is limited research available to understand whether the regulations reduce the environmental impact of cannabis cultivation as compared with the impact of its illegal cultivation. A study conducted in California in 2018 found high rates of noncompliance with the cannabis cultivation regulations,[70] suggesting that not all cannabis cultivation sites in jurisdictions where cannabis has been legalized fully apply environmental protection measures. A study in the States of Oregon and Washington, United States, found that the legalization of cannabis had significantly contributed to a reduction in the number of illicit cannabis cultivation sites in protected national forests in Oregon, but had no impact in the forests of Washington State, suggesting that the effects may differ according to the type of legalization model applied or other factors not related to cannabis legislation.[71]

The most substantial environmental impact of cannabis cultivation is likely to be associated with industrial agriculture, which affects the scale and location of both licit and illicit cultivation. However, in jurisdictions where cannabis cultivation has been legalized, farmers can more easily move to the cultivation area of their choice, and the environmental impact of such cultivation differs according to varying conditions in different areas.[72] In addition, the overexploitation of ecological resources may be exacerbated, as farming, in a competitive market, tends to move towards either extensification (the maximization of production areas) or intensification (more dense plantations and increased use of agricultural inputs).[73]

While environmental regulations can mitigate, at least partially, environmental impacts in areas where cannabis cultivation is legal, tight regulations may incentivize the parallel illegal industry, making it challenging to measure the differential impact of legal and illegal cultivation.

ENVIRONMENTAL SAFEGUARDS RELATED TO CANNABIS CULTIVATION LICENCES IN THE STATE OF CALIFORNIA, UNITED STATES	
Requirements	**Environmental harm that the requirement addresses**
Evidence that the applicant has the legal right to occupy and use the proposed location	> Cultivation in protected areas
Evidence of fulfilling waste discharge requirements with the State Water Resources Control Board or the appropriate regional water quality control board	> Illegal or irregular waste disposal
Compliance with the California Environmental Quality Act	> Improper management of natural resources and waste disposal > Unhealthy or unsafe environments for people
Identification of all power sources for cultivation, including but not limited to lighting, heating, cooling and ventilation	> Improper energy use
Compliance with the Water Code as implemented by the State Water Resources Control Board, Regional Water Quality Control Boards or the California Department of Fish and Wildlife	> Improper water use > Harm to fish and wildlife
Lake and streambed alteration agreement (or exemption) issued by the California Department of Fish and Wildlife	> Substantial diversion or obstruction of a river, stream or lake > Improper deposit or disposal of debris, waste or other material
Identification of all relevant available water sources	> Improper water use
Evidence that the proposed premises are not located in a watershed or other geographic area that has been determined to be "significantly adversely impacted by cannabis cultivation"	> Further harm to already degraded or fragile areas
Compliance with all pesticide laws and regulations enforced by the Department of Pesticide Regulation	> Improper storage, use and disposal of pesticides

Source: State of California, California Code of Regulations, title 3. Food and Agriculture, division 8. Cannabis Cultivation, chapter 1. Cannabis Cultivation Program (2019).

HEALTH RISKS ASSOCIATED WITH INDOOR AND OUTDOOR CANNABIS PRODUCTION SITES			
Type of risk	**Description of risk**	**Type of potential harm to health**	**Level of potential impact on health**
Physical	Booby traps put in place by plantation or site owners[i]	Physical injury	High; but not often encountered[ii]
	Electrical shocks or electrical fire[ii]	Electrocution; burns	Relatively high[iii]
Chemical	Fertilizers or growth regulators	Eye or skin irritation	Low[iv]
	Pesticides	Nervous system alterations; allergic reactions; eye or skin irritation[iv]	Low; not often used in indoor settings
	Toxic gases caused by the use of CO_2, which is injected to artificially stimulate plant growth	Dizziness; unconsciousness; suffocation	Low
Biological risks	Fungal growth caused by high temperatures and humidity levels and lack of ventilation, mainly indoors but also found outdoors[v]	Higher exposure to bioaerosols; allergic reactions	Medium
	Emission by cannabis plants of volatile organic compounds (terpenes), which can, for example, result in harmful compounds of ozone and formaldehyde[vi]	Irritation; allergic reactions; nausea; headaches; dizziness and hypotension	Low, but the effects remain underresearched[vi]

i Jan Tytgat, Eva Cuypers, Patrick Van Damme, Wouter Vanhove, *Hazards of illicit cannabis cultivation for public and intervention staff* (KU Leuven, Universiteit Gent, 2017).

ii Darryl Plecas, Aili Malm, Bryan Kinney, *Marihuana Growing Operations in British Columbia Revisited (1997-2003)* (Abbotsford: Department of Criminology and Criminal Justice, University College of the Fraser Valley, 2005).

iii Neil McManus, 'Marijuana Grow Operations' (Fall Symposium of the Occupational Hygiene Association of Ontario, North Vancouver, 2011).

iv Jan Tytgat, Eva Cuypers, Patrick Van Damme, Wouter Vanhove, *Hazards of illicit cannabis cultivation for public and intervention staff*.

v Brett J. Green et al., 'Microbial Hazards during Harvesting and Processing at an Outdoor United States Cannabis Farm', *Journal of Occupational and Environmental Hygiene* 15, no. 5 (4 May 2018).

vi Vera Samburova et al., 'Dominant Volatile Organic Compounds (VOCs) Measured at Four *Cannabis* Growing Facilities: Pilot Study Results', *Journal of the Air & Waste Management Association* 69, no. 11 (2 November 2019).

Health-related impact

While the body of scientific research about the health-related impact of drug use is well developed and constantly evolving, the available research on the health-related consequences of illegal crop cultivation and drug production is much more limited. With regard to cannabis, most of the research was initially focused on the respiratory effects of hemp fibre production.[74]

The limited research shows that law enforcement personnel may suffer health consequences as a result of entering illegal indoor cannabis plantations.[75] Research conducted in Belgium in 2015 showed that 60 per cent of the 221 respondents working in law enforcement had had at least one health-related symptom upon or immediately after entering a plantation.[76] The most direct health-related effects were headaches, nose and/or eye irritation and skin irritation.[77] Hardly any of these and other symptoms were medically treated.[78] While such research is useful for determining some of the immediate health-related consequences for those exposed to illegal cannabis cultivation, it is less clear what the longer-term consequences might be, for example, those related to exposure to illegal pesticides and other chemicals.

In comparison with law enforcement officers, workers handling or harvesting cannabis at production sites have a more prolonged and intensive exposure to these risks.

Illicit drug crop cultivation and environmental impact

The environmental effects of illicit drug crop cultivation have been documented extensively, particularly in the Americas. Illicit coca bush cultivation in Bolivia (Plurinational State of), Colombia and Peru has been associated with deforestation, soil erosion and depletion, water pollution, biodiversity loss and other environmental harms.[79, 80]

In the United States, illicit cannabis cultivation in national parks has shown to have resulted in various harmful environmental effects, including loss of native vegetation, the diversion of rivers, agrochemical pollution, the dumping of waste and the poaching of wildlife.[81]

Carbon footprint analysis

Often, the impact of illicit crop cultivation is described in general terms without clear indications of its severity and extent. One way to quantify the impact of the cultivation of cannabis, coca bush or opium poppy is to estimate its carbon footprint. To do this, a life-cycle assessment methodology can be implemented (see the box below), following standard practice applied to the licit cultivation of other crops.

Carbon footprint of indoor cannabis cultivation

Carbon footprint studies of cannabis are scarce. Only two studies, from 2012[82] and 2021,[83] respectively, have established estimates based on calculations related to indoor cannabis production in the United States.

Both studies show that the carbon footprint of indoor cannabis cultivation is driven by the use of electricity for climate control and the use of growing lights. To a lesser degree, this is also the case for outdoor cultivation (e.g. in greenhouses), which means that any changes in the energy grid or climatic conditions can greatly impact the overall carbon footprint.[84, 85]

The 2021 study shows the importance of location in estimating the carbon footprint of cannabis cultivation. The study calculated the cradle-to-gate carbon footprint of indoor cannabis cultivation across the United States, accounting for geographical variations in meteorological and electrical grid emissions data.[86] The resulting carbon footprint estimate ranged from 2,283 to 5,184 kg of CO_2e per kg of dried flower, with the main contributors being the consumption of electricity and natural gas for lighting and microclimate control.[87]

In these estimates, the combined factors of lighting and HVAC amount to 81 per cent (between 1,849 and 4,199 kg of CO_2e) of the carbon footprint. In the case of indoor cultivation, by including CO_2 injections to increase foliage in the estimate, the combined factors can amount to as much as 96 per cent (between 2,192 and 4,977 kg of CO_2e) of the carbon footprint.

Carbon footprints and life-cycle assessment

A carbon footprint is a measure of the systemic greenhouse gas emissions, represented as carbon equivalents, resulting from economic activities in terms of "functional units", which are the products or functions generated by the activities.[i] The selection of the functional unit can vary widely depending on the purpose and scope of the assessment.[ii] For example, an assessment of the carbon footprint of coffee production might be based on a functional unit of 1 kg of coffee at a farm site, 1 kg of roasted, ground and packaged coffee in a destination market or one cup of espresso at a café. Different practices, such as harvesting techniques and production practices, can also be incorporated in the analysis.

Another important element of a carbon footprint analysis is the selection of system boundaries, which help to define the scope of assessment.[iii] These are defined on a case-by-case basis, but typically follow either "cradle-to-gate" or "cradle-to-grave" models. Both approaches start by covering the initial raw material extraction phases (the "cradle"); the assessment can be carried out up to the final stage of manufacturing or processing (e.g. to the factory gate) or all the way through to the product's use and final disposal (to its "grave"). In the coffee example, a cradle-to-gate assessment would include the phases of land preparation, growing, harvesting, and processing into the defined format (toasted, ground and/or packaged). In addition, a cradle-to-grave study would also include subsequent transportation, processing, preparation, consumption, and disposal of waste.

Internationally accepted standard procedures for measuring carbon footprints are codified in the International Organization for Standardization (ISO) standard ISO 14067.[iv] They are commonly applied to consumer products for organizations seeking to understand and manage the climate change impacts associated with a specific economic activity and/or goods. Carbon footprint assessments follow a life-cycle assessment framework (specified in the ISO 14040 standard) that is aimed at accounting for all direct and indirect emissions throughout the cradle-to-grave life cycle of a system, with a focus on carbon-related emissions.

The main limitation of a carbon footprint assessment is its narrow coverage of environmental issues.[i] Aspects such as water use, toxicity and biodiversity are not considered in a carbon footprint estimate, therefore, such estimates do not represent overall measures of environmental impact. Carbon footprint analysis incorporates analysis of fossil fuel use and land use, both of which are relevant to the cultivation of drugs indoors (in relation to humidity and temperature control) and outdoors (in relation to extensive cultivation areas and possibly deforestation). Impacts related to waste disposal and wastewater treatment practices typical in the production of synthetic drugs do not typically contribute substantially to a carbon footprint.

The challenge in estimating the carbon footprint of the illicit cultivation of drug crops is the lack of data on many of the aspects related to the carbon footprint due to the illegal nature of the drug supply chain.[i] Another limitation is the high degree of variability. Cultivation practices may differ greatly between regions, and if carbon footprint estimates refer to different production pathways, they may not be comparable.

i Juanita Barrera and Mariana Ortega, Literature review of carbon footprint of cannabis and cocaine for the World Drug Report, study commissioned for the present report (March 2022).

ii Ioannis Arzoumanidis et al., "Functional Unit Definition Criteria in Life Cycle Assessment and Social Life Cycle Assessment: A Discussion," in *Perspectives on Social LCA*, ed. Marzia Traverso, Luigia Petti, and Alessandra Zamagni, SpringerBriefs in Environmental Science (Cham: Springer International Publishing, 2020), 1–10.

iii Anne-Marie Tillman et al., "Choice of System Boundaries in Life Cycle Assessment," *Journal of Cleaner Production* 2, no. 1 (January 1994)

iv Clare Naden, "Reducing Carbon Footprint Made Easier with New International Standard, ISO Online News Story," accessed June 9, 2022, https://www.iso.org/news/ref2317.html.

AVAILABLE CARBON FOOTPRINT ESTIMATES OF INDOOR CANNABIS PRODUCTION

Source: Hailey M. Summers, Evan Sproul, and Jason C. Quinn, 'The Greenhouse Gas Emissions of Indoor Cannabis Production in the United States', *Nature Sustainability* 4, no. 7 (July 2021).

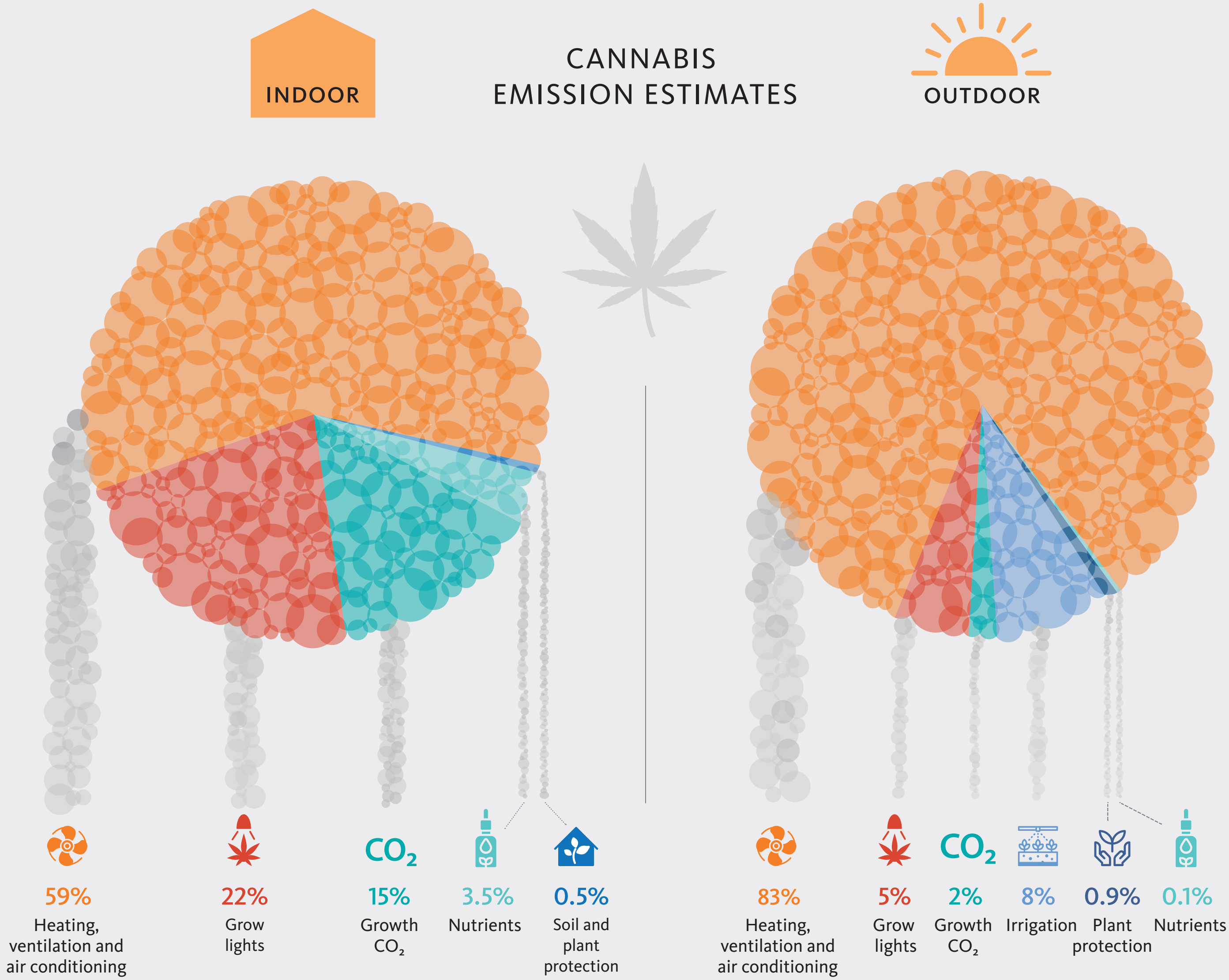
Note: While only focusing on cannabis cultivation in the United States, the study from which these data are drawn currently gives the best available rough estimate of the carbon footprint of indoor cannabis cultivation.

The carbon footprint estimates could increase by up to 50 per cent in cases where off-grid diesel-fuel power generation is used,[88] for example, in cases where the indoor operation is located in a remote area to avoid detection or where there are constraints on the supply of electricity.

Given the lack of a reliable global estimate of cannabis production, it is not possible to extrapolate from these studies the global carbon footprint of cannabis cultivation. Furthermore, without reliable estimates of the scale of indoor cannabis production in the United States, it is difficult to extrapolate the total global environmental impact of indoor cultivation. The carbon footprint attributed to energy consumption can vary substantially depending on the power source and grid mix involved.[89] The annual average electricity intensity required for cannabis cultivation has been estimated in other studies to range from 78 megajoules per square metre (MJ/m2) (outdoors) to 10,152 MJ/m2 (indoors). This last estimate is quite high when compared with ranges of 600–2,827 MJ/m2 for greenhouse cultivation of vegetables and flowers in Canada, Europe and North Africa.[90]

What the 2021 study clearly showed is that the carbon footprint also depends on the local conditions at the indoor sites. For instance, in the United States, the need to control humidity is much more prevalent in the State of Hawaii than in the city of Portland, Oregon.

While the main contributors to the carbon footprint of indoor cannabis cultivation are energy consumption and associated greenhouse gas emissions, there are other concerns associated with such cultivation, such as high use of fertilizers.[91] Moreover, studies found that cannabis plants can emit a significant amount of biogenic volatile organic compounds, which could affect



Source: Hailey M. Summers, Evan Sproul, and Jason C. Quinn, 'The Greenhouse Gas Emissions of Indoor Cannabis Production in the United States', *Nature Sustainability 4*, no. 7 (July 2021).

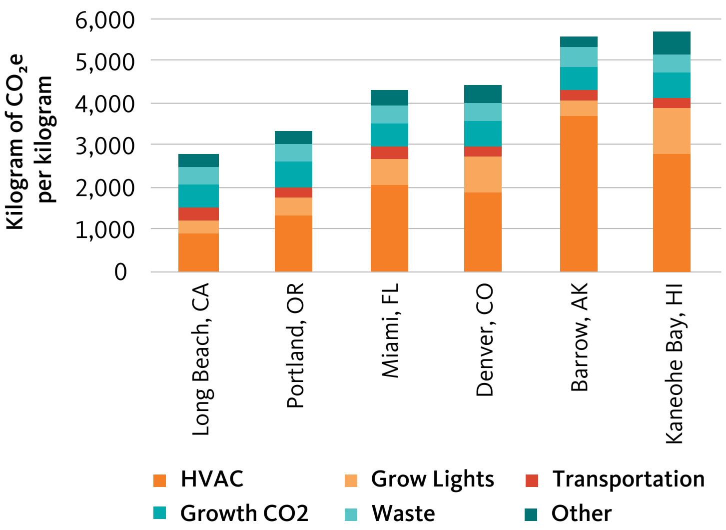
Note: "Growth CO_2" represents combustion fuel used to produce on-site CO_2.

indoor air quality and worker safety.[92, 93] Likewise, pesticide residues on cannabis products can potentially have an impact on human health.[94]

Carbon footprint of outdoor cannabis cultivation

Assessments of the overall carbon footprint of outdoor cannabis cultivation, including in greenhouses, can be informed by studies carried out in the United States, in jurisdictions where cannabis had been legalized. Available estimates from those studies indicate that the carbon footprint was between 22.7 and 326.6 kg of CO_2e per 1 kg of dried flower.[95, 96] All available estimates were made by calculating the carbon footprint in terms of kilograms of end product. It is important to note that the footprint will be different if calculated on the basis of an average consumer's daily, monthly or annual dose.

FIG. 1 Distribution of factors contributing to the carbon footprint of indoor cannabis cultivation in various locations, United States



Source: Data from Hailey M. Summers, Evan Sproul, and Jason C. Quinn, 'The Greenhouse Gas Emissions of Indoor Cannabis Production in the United States', *Nature Sustainability* 4, no. 7 (July 2021).

Note: The totals represent individual simulation results based on the input parameters specific to each location. The label "HVAC" includes heating and cooling, as well as humidity management. "Other" includes additional equipment that helps to maintain optimal environmental conditions inside grow rooms. The total footprint values differ from those of the original study, as carbon sequestration data are excluded here.

Although the estimate for outdoor cannabis cultivation is probably less reliable than that for indoor cultivation, it is clear that outdoor cultivation has a lower impact than indoor cultivation, provided that in outdoor cultivation there is less or no need for climate control, even when cultivation in greenhouses is considered a form of outdoor cultivation. These estimates seem to indicate that the level of impact of outdoor cannabis cultivation is one or two orders of magnitude lower than that of indoor cultivation (about 100 times lower if using the lowest estimates for both types of cultivation and 16 times lower if using the highest estimates), but its impact may nevertheless be higher than that of the cultivation of some energy-intensive food crops.

The available estimates, however, require further research.[97] For example, it appears that land-use considerations, which are often among the more significant contributors to the carbon footprint of agricultural products, are missing. The yield of cannabis cultivated outdoors assumed in the 2021 study was 3,034.35 kg of dried flower per year, but additional studies are required to ensure more reliable estimates of outdoor production.

Outdoor production can also be energy-intensive, for example, if powered irrigation systems are used. Although outdoor cultivation reduces the need for temperature and humidity controls in some climates, the main concern about such cultivation has been water sourcing and depletion. The use of water to irrigate cannabis crops in dry, sunny areas in California, for example, has been found to be highly dependent on groundwater.[98, 99, 100] It was calculated that, during a typical growing season (150 days), an outdoor cannabis plant requires up to 22.7 litres of water per day.[101, 102]

Nevertheless, in the United States, the consumption of water for outdoor cannabis irrigation is relatively low compared with that of other crops, such as almonds.[103] Given that some of those crops are grown in much higher volumes, the environmental impact of the use of water for cannabis cultivation is less a matter of the overall extent of cultivation and more a matter of spatial distribution.[104]

Keeping that broader picture mind, in the United States case modelled in 2021, the carbon footprint of cannabis production in high-technology settings, both indoors and outdoors, is mainly driven by the use of climate control (HVAC) and growing lights. For outdoor cultivation, this relates mainly to cultivation in greenhouses. While CO_2 input represents 15 per cent of the carbon footprint in indoor conditions, in outdoor conditions it accounts for just 2 per cent. Irrigation is especially important for outdoor cultivation. In both cases, the use of nutrients makes a small contribution in relation to the other inputs. This does not mean that the use of agrochemicals is low, only that its share of the impact is smaller in relation to other inputs.

COMPARISON OF THE ESTIMATED CARBON FOOTPRINTS OF INDOOR AND OUTDOOR CANNABIS CULTIVATION

Source: Hailey M. Summers, Evan Sproul, and Jason C. Quinn, 'The Greenhouse Gas Emissions of Indoor Cannabis Production in the United States', *Nature Sustainability* 4, no. 7 (July 2021).

The findings on outdoor cannabis cultivation in the United States could be extended to cannabis cultivation in other regions of the world with greenhouse cultivation and similar conditions regarding land-use change and polyculture, where there is no need for lighting, climate control and industrial CO_2 injections. Land-use change may represent an important share of emissions in outdoor cannabis cultivation around the world, as many cannabis farms are located in remote areas or protected spaces, or along agricultural frontiers. As is the case with most agricultural products, if land-use change is involved, it could represent one of the main factors impacting the carbon footprint of cannabis cultivation. The clearing of forests prior to the cultivation of cannabis can be the single largest source of impact.

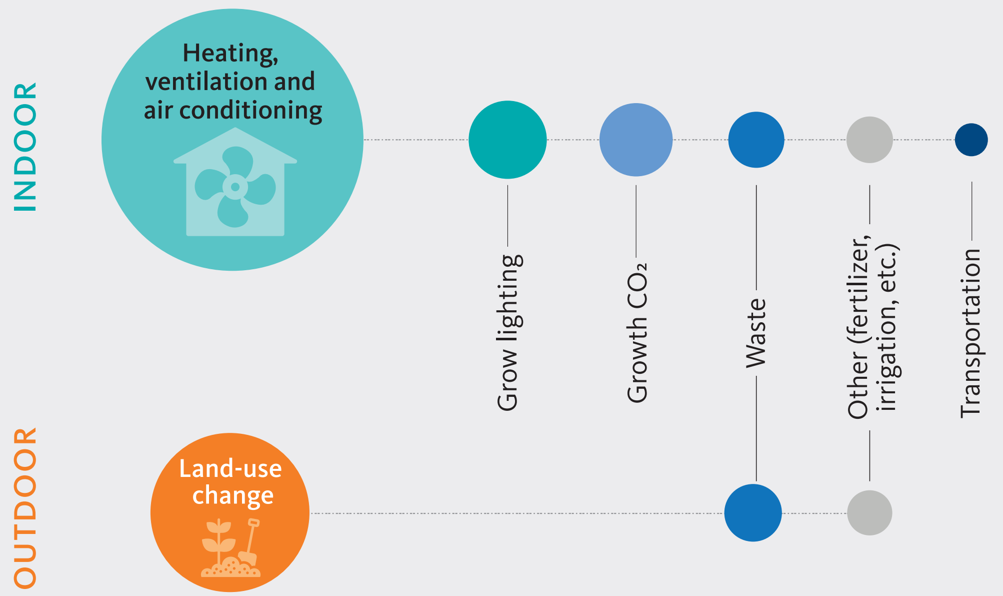
Outdoor cultivation occurs under diverse circumstances. It can be energy-intensive and involve land-use change, but that depends on the context of each country and the specific locations within a country. Some processes involve a nursery stage, while others rely on feral plants gathered from the wild.[105] In Nigeria, for instance, many aspects of outdoor cultivation, such as clearing, ploughing, planting, weeding, harvesting, packing, ensuring the security of the fields, and even fetching water, are labour-intensive, thus greenhouse gas emissions resulting from the use of fuels and electricity might be minimal. Outdoor emissions can also vary through the year, with more energy being used for irrigation in the dry season than in the rainy season.

In later stages of the supply chain, depending on the location and the terrain, a cradle-to-grave life-cycle assessment would need to take into account transportation. Drug sellers may choose different means of transportation. In Nigeria, for example, transportation can involve two-, three- or four-wheeled vehicles and animals,[106] which exemplifies the variety of potential scenarios that have not yet been scientifically studied using a life-cycle assessment approach. Given the lack of data, it is not possible to determine if the findings from carbon footprint studies in the United States can be easily extrapolated to areas outside the United States, but it can reasonably be expected that minimal microclimate controls (e.g. no or limited equipment for lighting, heating or air conditioning, even in greenhouses) would greatly reduce energy impacts and thus carbon impacts.

Depending on how well it is optimized, the application of organic or synthetic fertilizers can affect the carbon footprint; excessive application can lead to nitrate emissions.

In comparing estimates of the carbon footprints of outdoor and indoor cannabis production, one should consider that the resulting products can be quite different. For example, in outdoor, non-greenhouse settings, both the yield and quality of the cannabis may be different from that cultivated in technology-intensive indoor grow rooms. In outdoor production, it is more difficult to control the pollination and fertilization stages of the plant life cycle, which can result in plants with lower yields and fewer active ingredients.[109] Additionally, if plants are sun-dried, their potency is reduced.[110] Outdoor yields vary from as low as 47 grams per m² for feral or semi-cultivated varieties grown without irrigation in difficult climates, to as high as 500 grams per m² in well-tended gardens.[111] Indoors, yields per harvest range from just over 300 grams per m2 to a high of just under 800 grams per m².[112] Although

ESTIMATES OF THE DISTRIBUTION OF FACTORS CONTRIBUTING TO THE CARBON FOOTPRINTS OF OUTDOOR AND INDOOR CANNABIS CULTIVATION



Source: Hailey M. Summers, Evan Sproul, and Jason C. Quinn, 'The Greenhouse Gas Emissions of Indoor Cannabis Production in the United States', *Nature Sustainability* 4, no. 7 (July 2021).

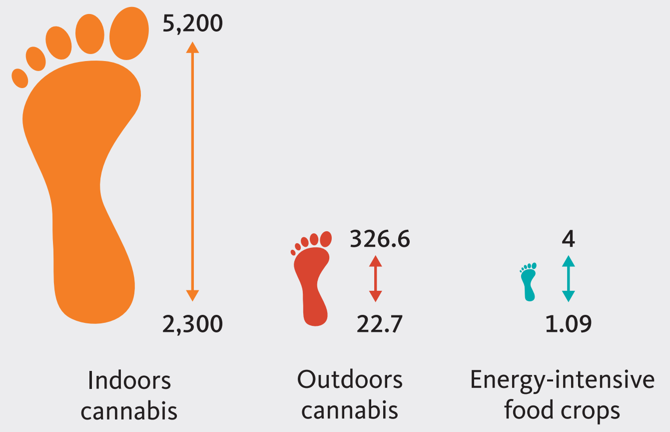
Notes: The figure combines data from Summers et al. (2021) with worst-case conditions in a hypothetical outdoor cultivation scenario involving land-use change. The distribution of the indoor total carbon footprint is based on conditions in Miami, Florida. The distribution of the outdoor carbon footprint assumes maximum carbon release due to deforestation. For the outdoor scenario, emissions resulting from land-use change were calculated on the basis of IPCC Guidelines for National Greenhouse Gas Inventories,[107] taking into consideration the change from forest land to cropland with a range of carbon content in soil and biomass in forest ecosystems (24–231 tons of carbon per ha) and in cropland (10–70 tons of carbon per ha); a range of outdoor cannabis yields, as reported by UNODC, was also considered (47–500 grams per m²).[108] The results show that, if land-use change occurs, emissions could be on the order of 10–1,200 kg of CO_2 per 1 kg of dry cannabis. Although land-use change can also occur under legal conditions, it does not typically involve a change from carbon-rich forest land to cropland, but rather a change from degraded forest land or grassland to cropland, thus emissions would be lower.

available life-cycle assessments on cannabis have focused on indoor production, so far they have only produced partial results and have not modelled potential variations in yield or potency or compared the situation with regard to legality.

As a way to place the available estimates in context, the carbon footprints of indoor and outdoor cannabis cultivation can be compared with those of certain energy-intensive food crops, such as cucumber, tomato, eggplant and strawberry. A comparison with such crops is relevant, as they are often grown in heated greenhouse conditions. While those crops are quite different and cannot be compared directly in terms of use and impact, the research indicates a large difference in scale compared with indoor and, to a lesser extent, outdoor cannabis cultivation.

Greenhouse gas emissions of cannabis cultivated indoors are 900 to 3,600 times higher than those of indoor-cultivated energy-intensive food crops. This difference is mainly related to the fact that lighting and climate control are not used or are used less in outdoor greenhouse settings.

COMPARISON OF THE CARBON FOOTPRINTS OF CANNABIS PRODUCED INDOORS AND OUTDOORS AND OF SELECTED FOOD CROPS



Sources: Hailey M. Summers, Evan Sproul, and Jason C. Quinn, 'The Greenhouse Gas Emissions of Indoor Cannabis Production in the United States', *Nature Sustainability* 4, no. 7 (July 2021). Data on food crops was retrieved from the World Food Database (see Thomas Nemecek et al., *World Food LCA Database: Methodological Guidelines for the Life Cycle Inventory of Agricultural Products*, Version 3.0 (Lausanne and Zurich: Quantis and Agroscope, 2015)); and Ecoinvent, *Ecoinvent Database,* Version 3.8 (Zurich: Ecoinvent, 2021).

Note: The energy-intensive food crops consisted of a 1-kg basket of selected crops grown under heated greenhouse conditions and included cucumber, eggplant, strawberry, and tomato.

Carbon footprint of cocaine production

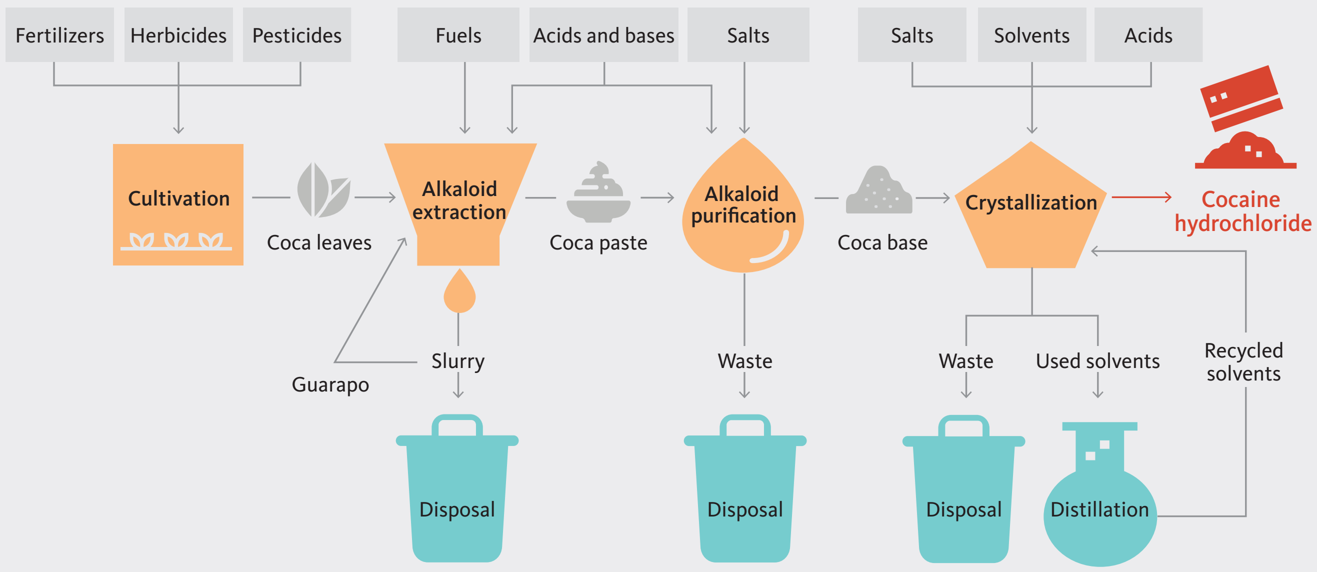
Although the environmental impact of illicit coca bush cultivation has been compared with that of commodities used in coca substitution interventions, research on that impact is still very limited. Only one study, conducted in 2019, assessed the carbon footprint of cocaine production "from cradle to gate"; the assessment was based on an evaluation in two areas of Colombia: Catatumbo and Putumayo.[113]

In Catatumbo, located in north-eastern Colombia, 10,779 ha of coca were cultivated in 2015. In 2020, the quantity of coca cultivated increased to 40,116 ha.[114, 115] In Putumayo, in south-western Colombia, 20,068 ha of coca were cultivated in 2015 and 22,041 ha in 2020.[116, 117] The terrain of these areas ranges from tropical rainforest and wetlands to densely forested mountains, with a large variety of endemic ecosystems and high biodiversity.

The study examined coca bush cultivation, cocaine processing, and the disposal of waste generated in the production process. It found that the manufacture of 1 kg of cocaine generated, without considering land use change, 590 kg of CO_2e, which is equivalent to the emissions generated by an average gasoline-powered car driven 2,358 km, or 220 litres of diesel fuel consumed. According to the study, this footprint was about 84 and 30 times higher, respectively, than that of the potential alternative crops of green coffee beans and cocoa beans. The 24 per cent of the footprint accounted for alkaloid extraction was attributed to the use of fertilizers and chemical precursors and the discharge of gasoline used in the processing stage.

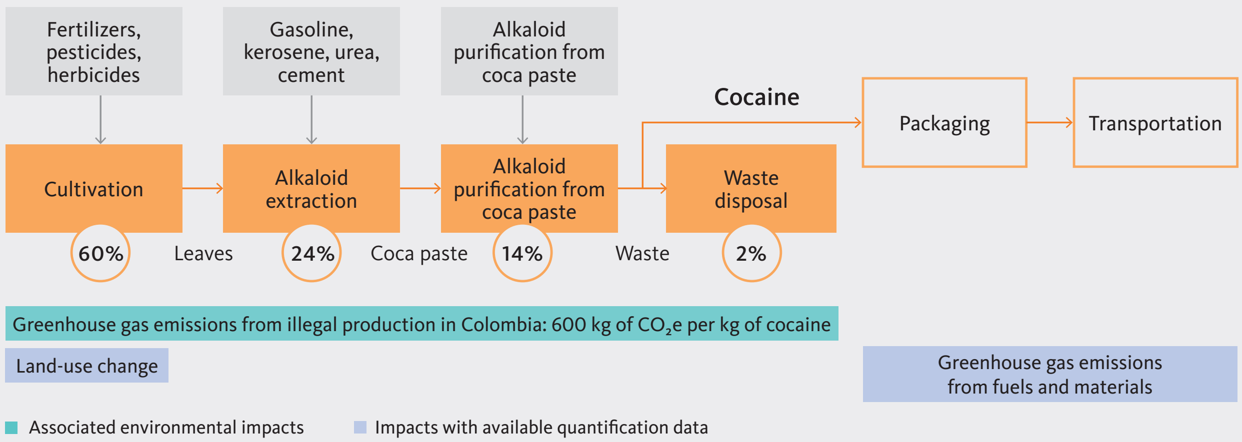
Large quantities of agrochemicals are used in the phases of coca bush cultivation and cocaine manufacture. Fertilizers, herbicides, and pesticides are the main inputs for coca bush cultivation, while the alkaloid extraction process involves the use of cement, urea,

INPUTS AND WASTE RELATED TO THE PRODUCTION OF COCAINE



Sources: Juanita Barrera-Ramírez, Valentina Prado, and Håvar Solheim, 'Life Cycle Assessment and Socioeconomic Evaluation of the Illicit Crop Substitution Policy in Colombia', *Journal of Industrial Ecology* 23, no. 5 (October 2019); UNODC, *Cocaine – a Spectrum of Products, Cocaine Insights 2* (Vienna: United Nations publication, 2021).

ESTIMATED DISTRIBUTION OF FACTORS CONTRIBUTING TO THE CARBON FOOTPRINT OF COCAINE PRODUCTION IN COLOMBIA



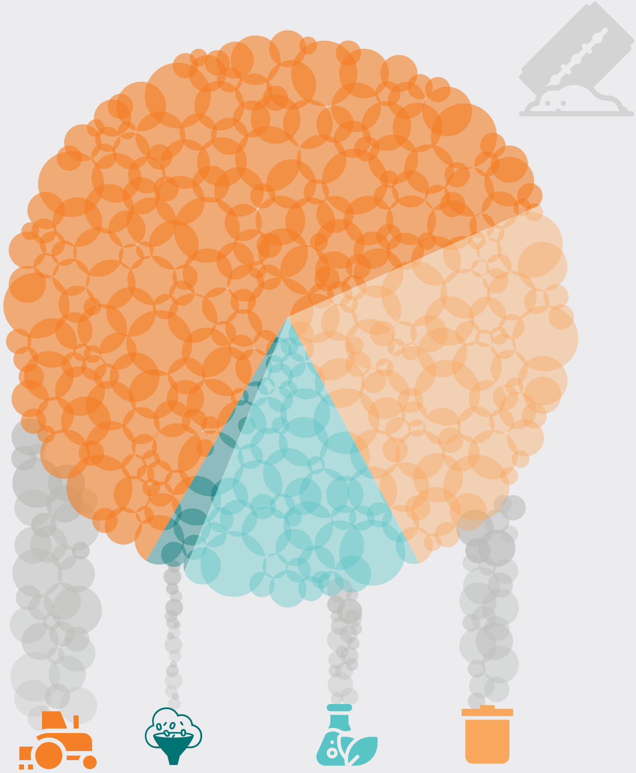
Source: Research for the present World Drug Report. Total emission estimate taken from Juanita Barrera-Ramírez, Valentina Prado, and Håvar Solheim, 'Life Cycle Assessment and Socioeconomic Evaluation of the Illicit Crop Substitution Policy in Colombia', *Journal of Industrial Ecology* 23, no. 5 (October 2019).

Note: The carbon footprint of 1 kg of cocaine was found to be about 600 kg of CO_2e, considering conditions in Colombia. Cultivation accounted for an estimated 60 per cent of the carbon footprint of the cocaine production process, while alkaloid extraction accounted for 24 per cent; waste disposal and alkaloid purification accounted for 14 per cent and 2 per cent, respectively. Data on the impact of the other stages of the supply chain were not available.

gasoline or kerosene to process the leaves and to obtain the cocaine alkaloid during coca paste manufacture.[118, 119] The carbon footprint calculation for this study assumed a yield of 1.41 kg of cocaine hydrochloride per ton of fresh coca leaves.[120]

DISTRIBUTION OF FACTORS CONTRIBUTING TO THE CARBON FOOTPRINT OF COCAINE PRODUCTION

IN THE REGIONS OF CATATUMBO AND PUTUMAYO, COLOMBIA



Source: Juanita Barrera-Ramírez, Valentina Prado, and Håvar Solheim, 'Life Cycle Assessment and Socioeconomic Evaluation of the Illicit Crop Substitution Policy in Colombia', *Journal of Industrial Ecology* 23, no. 5 (October 2019).

Note: Land-use change is not included in the data.

Given the importance of land-use change in the total environmental impact, rough estimates of its impact can be established for the two regions of Colombia included in the 2019 study.[121]

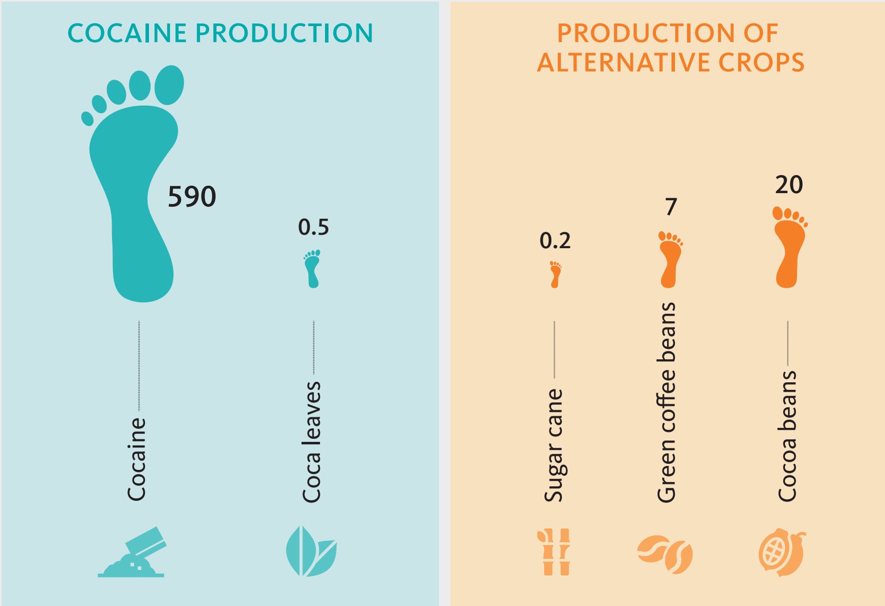
The results of the study show that, if land-use change occurs, the resulting emissions could be approximately 4–6 tons of CO_2e per kg of cocaine; thus, the effect of land-use change could easily represent the single most important factor contributing to the environmental impact of cocaine production.

Even without considering land-use change, the estimates of the carbon footprint of cocaine production shown above suggest that its footprint is at least 30 times higher than that of substitute crops. The carbon footprint of coca leaf production is 0.51 kg of CO_2e per kg of leaves harvested.

Using the available carbon footprint estimates for cocaine, it is possible to estimate the total global environmental impact of cocaine production. Taking into account the global production estimate for 2020 of 1,982 tons of cocaine and a carbon footprint of 4,500 kg of CO_2e per kg of cocaine produced (considering land use change) gives a rough estimate of the total emissions amounting to 8.9 million tons of CO_2e per year if land-use change is involved. This is equivalent to the average emissions of more than 1.9 million gasoline-powered cars driven in the course of one year, or more than 3.3 billion litres of diesel fuel consumed.

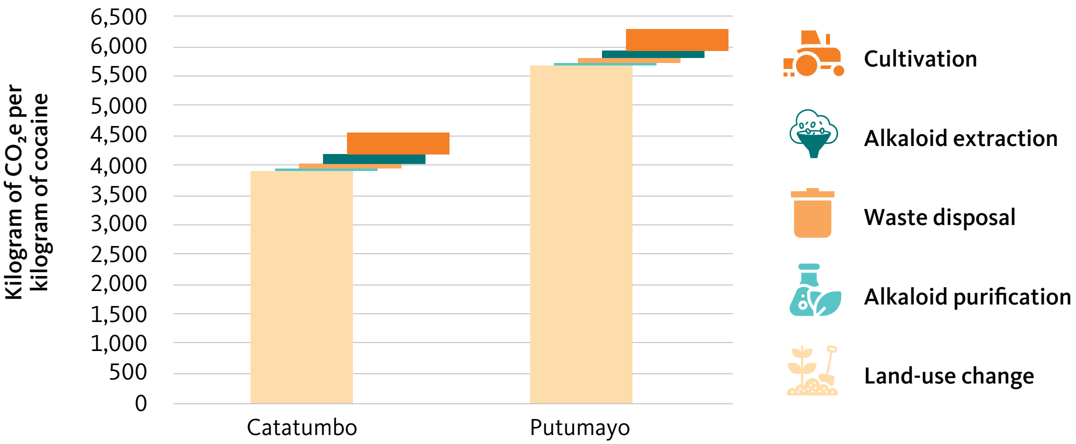
If land-use change is not considered, the total carbon footprint amounts to about 1.17 million tons of CO_2e. This is equivalent to the average emissions of more than 250,000 gasoline-powered cars driven in the course of one year, or about 435 million litres of diesel fuel consumed. As not all coca bush cultivation involves land-use change, however, the actual figure will be somewhere between these two aggregated figures.

CARBON FOOTPRINT OF COCAINE PRODUCTION COMPARED WITH THE CARBON FOOTPRINT OF THE PRODUCTION OF A SELECTION OF ALTERNATIVE CROPS (kg of CO_2e per kg)



Source: Data from Juanita Barrera-Ramírez, Valentina Prado, and Håvar Solheim, 'Life Cycle Assessment and Socioeconomic Evaluation of the Illicit Crop Substitution Policy in Colombia', *Journal of Industrial Ecology* 23, no. 5 (October 2019).

Note: Land-use change is not taken into account.



Source: Data from Juanita Barrera-Ramírez, Valentina Prado, and Håvar Solheim, 'Life Cycle Assessment and Socioeconomic Evaluation of the Illicit Crop Substitution Policy in Colombia', *Journal of Industrial Ecology* 23, no. 5 (October 2019).

Note: Land-use change is defined here as a change from forest land with maximum carbon content to cropland. Emissions resulting from land-use change were calculated on the basis of IPCC Guidelines for National Greenhouse Gas Inventories,[122] taking into consideration the change from rainforest land to cropland with a carbon content in soil and biomass of 231 tons (rainforest land) and 70 tons (cropland) of carbon per hectare, respectively, with carbon stocks reaching equilibrium after 20 years. The yields of coca leaves per hectare and cocaine per quantity of coca leaves correspond to the values used by Barrera-Ramirez et al.[123]

ESTIMATED GLOBAL ANNUAL CARBON FOOTPRINT OF COCAINE MANUFACTURE				
Crop	Global production (tons per year)	Type	Carbon footprint (kg of CO_2e per kg of cocaine manufactured)	Global impact (tons of CO_2e per year)
Cocaine	1,982	Without land-use change	590	1.17 million
		With land-use change	4,500	8.9 million

Source: Juanita Barrera-Ramírez, Valentina Prado, and Håvar Solheim, 'Life Cycle Assessment and Socioeconomic Evaluation of the Illicit Crop Substitution Policy in Colombia', *Journal of Industrial Ecology* 23, no. 5 (October 2019).

Note: The carbon footprint is calculated using the data for Catatumbo and Putumayo, Colombia. For the estimate that includes land-use change, the lowest total footprint value found for Catatumbo was used.

Carbon footprint of opium

With regard to opium, few life-cycle assessments have been carried out. One study of legal opium poppy cultivation on farms in Australia assessed the environmental life cycle from poppy farming through to the production of 100 mg of packaged morphine (for intravenous usage).[124] It was concluded that 100 mg of morphine had a carbon footprint of 204 grams of CO_2e. For 1 kg of morphine, this would amount to a carbon footprint of 2,040 kg of CO_2e. In the study, the environmental impact of poppy cultivation accounted for only 3 per cent of the total footprint. Almost 90 per cent of the total impact related to the final stages of morphine production, in particular sterilization and packaging.

Illicit opium cultivation in Afghanistan is likely to produce a different carbon footprint since the environmental impact depends on the location and methods of poppy cultivation. There are accounts of a specific environmental impact caused by illicit opium cultivation in the former desert areas in south-western Afghanistan. In a study undertaken between 2011 and 2017, it was observed that the use of herbicides and pesticides enabled more extensive poppy cultivation, while irrigation methods shifted from the use of diesel fuel-powered pumps and generators to the reliance on solar power.[125] In the short term, poppy cultivation enabled the production of other agricultural crops in dry areas, while in the long term, salinization, decreasing groundwater levels and reduced yields caused farmers to migrate to other areas.[126]

Deforestation

The big picture

Deforestation is part of a broader process of environmental change that is primarily driven by human population growth, demographic trends and economic development.[127] There are many direct and indirect drivers of global deforestation, such as unsustainable agricultural practices, invasive species, low resource use and efficiency, and overexploitation.[128] Illicit activities, including illegal logging, wildlife trafficking and illegal crop cultivation, have also driven deforestation, but drug production accounts for a relatively minor share.

Link between drugs and deforestation

While illicit cultivation has been associated with deforestation, more recent studies emphasize that there is both a direct and an indirect relationship. For example, in Colombia, government data for 2020 showed that 12,939 ha of deforested land (7.54 per cent of the total land deforested in that year) could be attributed directly to illicit coca cultivation.[129] A much larger area

Cryptocurrencies and energy use

A study conducted in 2019 estimated that approximately one quarter of all bitcoin users (26 per cent) and close to one half of global bitcoin transactions (46 per cent) were linked to illegal activities, including drug trafficking.[i] While only limited data are available, in a report issued in December 2021, officials from the Cyber Crimes Center of the Homeland Security Investigations component of the United States Department of Homeland Security stated that 80 to 90 per cent of the sales on the dark web that they had been monitoring were related to the trafficking of drugs.[ii] The same report showed a five-fold increase between 2017 and 2020 in suspicious activity reports filed with the United States Financial Crimes Enforcement Network relating to virtual currencies and drug trafficking.[ii, iii]

The proportion of cryptocurrency transactions related to illicit drug trafficking suggest some environmental impact related to drugs. Bitcoin is one of the cryptocurrencies that rely on cryptocurrency mining (also known as bitcoin mining), which generally involves the use of specialized computers with high levels of computational power to perform calculations.

Since 2014, when the use of cryptocurrencies started to expand significantly, there has been an exponential rise in the estimated amount of electricity consumption associated with cryptocurrency mining. The Cambridge Bitcoin Electricity Consumption Index shows a sharply increasing trend in electricity consumption related to bitcoin mining.

Another index, the Bitcoin Energy Consumption Index, estimated that, as of 27 March 2022, the annual energy footprint of bitcoin-related activity amounted to 204.50 terawatt-hours, which is equivalent to the average energy consumed by approximately 19 million gasoline-powered cars driven in the course of one year, or the electricity used by more than 17 million houses in the course of one year. A study conducted in 2022 related to this index estimated that this footprint represented 65.4 megatons of CO_2e.[iv] A study conducted in 2018 even projected that bitcoin alone could, in less than three decades, produce enough CO_2 emissions to push global warming above 2 degrees Celsius, if it followed the rate of adoption of other technologies.[v] As bitcoin accounted for about 38 per cent of the cryptocurrency market in the last quarter of 2021,[vi] it can be assumed that the total electricity consumption resulting from cryptocurrency mining is much higher for the cryptocurrency market as a whole.

The total global carbon footprint associated with bitcoin and other cryptocurrencies is difficult to establish, as it depends on the location where the cryptocurrency mining takes place and the composition of the electricity sources used. For example, the degree to which renewable sources are part of the mix of energy sources used for electricity production differs from location to location and can change over time.

i Sean Foley, Jonathan R. Karlsen, and Tālis J. Putniņš, 'Sex, Drugs, and Bitcoin: How Much Illegal Activity Is Financed through Cryptocurrencies?', *The Review of Financial Studies* 32, no. 5 (1 May 2019): 1798–1853.

ii United States Government Accountability Office (GAO), *Virtual Currencies: Additional Information Could Improve Federal Agency Efforts to Counter Human and Drug Trafficking*, Report to Congressional Requesters, 2021.

iii See also Booklet 2 of the present report, entitled *Global overview of drug demand and drug supply*.

iv Alex de Vries et al., 'Revisiting Bitcoin's Carbon Footprint', *Joule* 6, no. 3 (March 2022): 498–502.

v Camilo Mora et al., 'Bitcoin Emissions Alone Could Push Global Warming above 2°C', *Nature Climate Change* 8, no. 11 (November 2018): 932.

vi Statista, *Distribution of Bitcoin and Other Crypto in the Overall Market from 2nd Quarter of 2013 to 4th Quarter of 2021* (Statista, 2022).

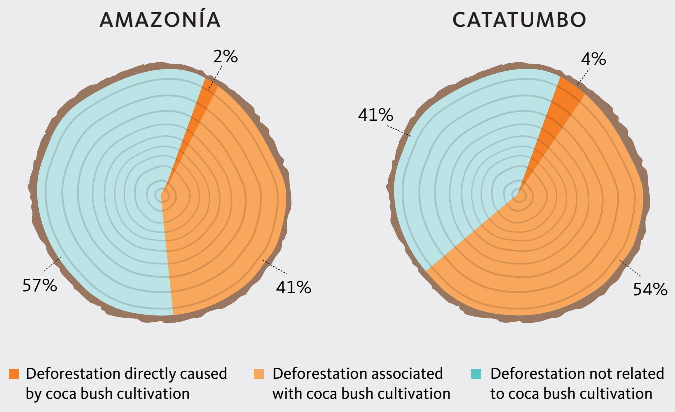
of 38,449 ha (22.4 per cent) was considered to be indirectly associated with such cultivation, owing to its close proximity to areas under coca bush cultivation (less than 1 km distance).[130] That means that, in addition to the forest lands lost to illicit coca cultivation, there are other, possibly larger areas that were deforested as a result of other activities that might be connected to such cultivation.[131] In two regions of Colombia, direct and indirect deforestation related to illicit coca cultivation have been observed over a long period of time.

In Amazonía and Catatumbo in Colombia, where deforestation studies were undertaken in relation to illicit coca cultivation, the direct contribution of illicit coca cultivation was minor in the period studied (2 and 4 per cent of total deforestation, respectively), but increased significantly when taking into account degraded forests, which are areas where the quality of the forest ecosystem has been diminished by economic activities.[132] The largest share of deforestation by far is directly related to other activities such as cattle ranching and agriculture, even though coca cultivation may in some cases, enable further deforestation and economic development. Overall, coca cultivation in Colombia may trigger the expansion of the agricultural frontier, but generally it is not the ultimate or direct cause of deforestation.[133, 134]

Deforestation associated with coca bush cultivation

While coca bush cultivation can directly cause deforestation, it can play a bigger role as a catalyst for the process. Beyond what is taken away for the illicit cultivation of coca bush itself, illicit cultivation of coca bush can eventually provide farmers with a stable and competitive income and access to informal credit, therefore allowing them to further expand into the forest for the cultivation of food crops, pastures, and housing construction. This associated deforestation can eventually be larger than the deforestation directly caused by illicit cultivation of coca bush.

TOTAL DIRECT AND INDIRECT DEFORESTATION RELATED TO ILLICIT COCA BUSH CULTIVATION IN THE REGIONS OF AMAZONÍA AND CATATUMBO, COLOMBIA, 2005–2014



Source: *UNODC, Comunidad, Bosque y Coca: Un Camino Para La Acción* (Bogota: United Nations publication, 2018).

Note: Totals may not add up due to rounding.

The link between drugs and deforestation goes beyond illicit cultivation. Deforestation can also be associated with drug trafficking. The impact of drug trafficking on deforestation has traditionally been overshadowed by the focus on the effects of illicit crop cultivation but has recently received more attention from scholars.[135]

A study conducted in 2020 using remote sensing and geographic information system analysis examined land-use and land-cover change in the Maya Biosphere Reserve in Guatemala and found that cattle ranching was responsible for most of the deforestation of the reserve.[136] In the vast majority of cases, those activities were linked to drug trafficking organizations that invested in cattle ranching for the purpose of money-laundering, drug smuggling or territorial control.[137] This research suggests that the environmental impact of money-laundering related to drug trafficking can be much higher than the impact of small-scale subsistence farming in the same areas.

TOTAL DIRECT AND INDIRECT DEFORESTATION RELATED TO ILLICIT COCA CULTIVATION IN AMAZONÍA AND CATATUMBO, COLOMBIA, 2005–2014				
Region	Deforestation directly caused by coca cultivation (hectares)	Deforestation indirectly associated with coca cultivation (hectares)	Deforestation not related to coca cultivation (hectares)	Total deforestation (hectares)
Amazonía	17,564 (2%)	298,474 (41%)	412,508 (57%)	728,546
Catatumbo	2,205 (4%)	28,719 (54%)	21,909 (41%)	52,833

Source: UNODC, *Comunidad, Bosque y Coca: Un Camino Para La Acción* (Bogota: United Nations publication, 2018).

Note: Percentages relate to the total amount of deforestation. "Deforestation associated with coca cultivation" refers to deforested areas that are within 1 km of coca fields and that are considered to be the result of the role of coca cultivation as a "catalyst activity" along the agricultural frontier. "Deforestation not related to coca cultivation" includes, for example, agriculture and cattle ranching.

How the spatial dynamics of drug trafficking networks affect the environment

To identify and anticipate the spread and intensity of environmental harms, it is important to understand the spatial dynamics involved in drug trafficking networks. High-resolution territorial sensing can be applied to track changes over time and explore the link with deforestation.

The shifting presence of drug trafficking networks has an impact on deforestation through three main pathways: (a) directly, through territorial control and informal infrastructure development (e.g. controlling land for the construction of clandestine landing strips or land routes in forests); (b) indirectly, through money-laundering using cattle ranching or land-based investments (e.g. palm oil plantations) as a cover; or (c) indirectly, through the creation of informal and speculative land markets that open otherwise intact and remote forest frontiers. A growing body of research[i] on the situation in Central America suggests that drug trafficking can indirectly have an effect on land-use change through illicit capital and land control practices that accelerate deforestation. When drug traffickers seize and control land in areas, such as land in protected areas or indigenous territories, it opens previously inaccessible areas to new types of investment (e.g. speculative trading in land) and extractive activities (e.g. cattle ranching, agriculture, mining and logging), as part of and/or cover for illegal activities.[ii] Through these mechanisms, indirect environmental impacts may be larger than the direct impact of drug trafficking networks.

i Nicholas Magliocca et al., 'Shifting landscape suitability for cocaine trafficking through Central America in response to counterdrug interdiction', *Landscape and Urban Planning* 2219; Beth Tellman et al., 'Narcotrafficking and Land Control in Guatemala and Honduras,' *Journal of Illicit Economies and Development* 3 no. 1 (2021); Jennifer Devine et al., 'Narco-degradation: Cocaine trafficking's environmental impacts in Central America's protected areas', *World Development*, 144 (2021); Beth Tellman et al., 'Illicit Drivers of Land Use Change: Narcotrafficking and Forest Loss in Central America', Global Environmental Change 63 (July 2020).

ii Presentation by Nicholas Magliocca at the expert meeting on drugs and the environment organized by UNODC and GIZ, held on 21 September 2021.

New findings on deforestation in the western Amazon region

Illicit coca cultivation often takes place at or near to the agricultural frontier as it encroaches into forests. The spatial relationship between illicit coca bush cultivation and deforestation has often been interpreted as causal (e.g. coca cultivation drives deforestation), but how much deforestation can be attributed to this illicit cultivation remains unclear. To better determine the relationship between illicit cultivation and deforestation, research was conducted in the western Amazon region applying spatial analysis.

Earlier studies[i, ii, iii] based on geospatial analysis tended to show a direct link between coca bush cultivation and forest loss, while earlier macro-socioeconomic and demographic analyses (that considered for example population size and road density) identified illicit coca bush cultivation as an indirect driver of deforestation, mostly related to general patterns of economic development that cause deforestation.

These earlier studies[iii, iv, v] have often linked coca cultivation to the rate of deforestation or have incorporated sociodemographic data only at the municipal scale, which created distortions in the analysis of very large municipal areas in the Amazon-Andes region. The more recent study in the western Amazon region[vi], including the Amazon-Andes, offered a more detailed spatial approach by studying a total of 419,073 deforestation clusters cross-referenced with population and road density data between 2010 and 2020.

Overall, the study provided a more granular picture of the link between illicit coca bush cultivation and deforestation. Illicit coca cultivation was found to increase the frequency of forest clearing, confirming its role as an initial driver or pioneering crop of deforestation, particularly in Colombia. In a given year, areas with illicit coca bush cultivation were 48 per cent more likely to experience deforestation than areas that did not have illicit coca cultivation, with an average rate of overall forest clearing per deforestation cluster per year of 1.035 ha.

However, despite more frequent clearing associated with illicit coca cultivation, deforestation clusters with illicit coca cultivation were significantly smaller - often more fragmented - and had lower forest loss rates than areas without illicit coca bush cultivation. The strength of the effect of the presence of illicit coca bush cultivation varied per country. The total forest loss rate for the Plurinational State of Bolivia in areas affected by illicit coca bush cultivation was 20 per cent lower than in areas without coca bush cultivation, 6 per cent lower for Colombia, and 2 per cent lower for Peru.

The average size of deforestation clusters was also smaller in areas affected by illicit coca bush cultivation. On average, these clusters were 33 per cent smaller in the Plurinational State of Bolivia when coca was present. In Colombia, they were about 11 per cent smaller and in Peru about 3 per cent smaller.

There may be different explanations for the lower rate of forest loss and smaller size of deforestation caused by illicit coca bush cultivation. The illegal market related to coca cultivation may be more stable than the markets for other agricultural commodities, which are subject to surges in demand and may rapidly lead to clusters of deforested areas, especially near roads.

i Kenneth R. Young and Blanca León, Peru's Humid Eastern Montane Forests. *An Overview of Their Physical Settings, Biological Diversity, Human Use and Settlement, and Conservation Needs, DIVA Technical Report, Nr. 5* (Centre for Research on the Cultural and Biological Diversity of Andean Rainforests (DIVA), 1999).

ii Timothy J. Killeen et al., "Thirty Years of Land-Cover Change in Bolivia," *AMBIO: A Journal of the Human Environment* 36, no. 7 (November 2007).

iii Liliana M. Dávalos et al., "Forests and Drugs: Coca-Driven Deforestation in Tropical Biodiversity Hotspots," *Environmental Science & Technology* 45, no. 4 (February 15, 2011): 1219–27.

iv Ana María Sánchez-Cuervo and T. Mitchell Aide, "Consequences of the Armed Conflict, Forced Human Displacement, and Land Abandonment on Forest Cover Change in Colombia: A Multi-Scaled Analysis," *Ecosystems* 16, no. 6 (September 2013): 1052–70.

v T. Mitchell Aide et al., "Deforestation and Reforestation of Latin America and the Caribbean (2001-2010)," *Biotropica* 45, no. 2 (March 2013): 262–71.

vi Liliana M. Dávalos and Nicholas R. Magliocca, Western Amazon Deforestation Analyses, study commissioned for the present report (June 2022).

Ongoing policy responses

Community responses

In different settings and contexts, community-based groups have often played an important role in drug policy responses related to the production of plant-based drugs. For example, in evaluations of alternative development projects, community participation has generally been identified as vital for the success and sustainability of the project.[138] In addition, the United Nations Guiding Principles on Alternative Development recommend the empowerment of the community and local authorities to sustain the achievements of projects and programmes.[139]

Community groups can also play a role in environmental protection and resilience. In Thailand, for example, resource management groups, including village water management and forestry management committees, have promoted sustainable resource use and have enhanced community self-governance capabilities in the context of drug policy-related programmes.[140]

Community-based resource management groups in northern California in the United States have promoted best practices in cannabis farming, fostered restraints on water use and helped eradicate illegal cultivation on public lands.[141] However, this example also indicates the vast challenges that the continued illegal cultivation of cannabis, especially on public lands, poses to local governments and community-based resource management groups in their efforts to effectively address environmental resilience.[142]

State responses

Dismantling and destruction of laboratories

As part of law enforcement efforts, drug processing laboratories are either dismantled or destroyed. While several Governments have guidelines on how to clean up clandestine drug laboratories and the United Nations offers guidelines[b] for the safe handling and proper disposal of chemicals used in the illicit manufacture of drugs, responses vary from country to country and may involve the burning of drug laboratories.

Crop eradication

Forced crop eradication policies and related law enforcement policies have different environmental effects depending on the location and context of illicit cultivation and the methods used. For example, eradication might temporarily slow deforestation. In the Plurinational State of Bolivia in the 1990s, an intensive interdiction policy decreased deforestation associated with indigenous farmers by about a third.[143]

Eradication may also increase deforestation, as law enforcement efforts could displace farmers looking for new plots where they can illicitly cultivate drug crops. This, however, might not be the case in all circumstances. A 2011 study of Colombia found that eradication had neither an effect on population density in coca-growing municipalities nor an effect on deforestation in general, which meant that a causal link between crop eradication and deforestation seemed unlikely.[144] Deforestation is generally not caused by migrants being forced to go from one area to the next because of eradication. Although studies indicate that population density and deforestation rates are linked in coca-growing municipalities, it is not illicit coca cultivation that drives or influences this relationship but rather poor rural economic development.[145]

Aerial spraying of areas under illicit coca cultivation was implemented in Colombia until 2015. Since 1994, most of the coca bush eradication had been conducted by means of aerial spraying with the herbicide glyphosate.[146] For many years, aerial spraying has been the topic of health and environmental concerns, turning its possible impact on the environment into a long-debated and controversial issue in Colombia and elsewhere. While considerable research has been conducted, including on the effects of the substance glyphosate, spraying mixtures and the precision of spraying, there is still no conclusive evidence about the size and scope of its impact on the environment.[c]

b See UNODC, *Guidelines for the Safe Handling and Disposal of Chemicals Used in the Illicit Manufacture of Drugs* (New York: United Nations publication, 2006).

c An updated literature review is available in the methodological annex.

The "balloon effect"

The term "balloon effect" has traditionally been used to describe the displacement of illegal activities as the result of interdiction or other measures. In the context of illicit crop cultivation, the balloon effect is sometimes discussed as a driver of deforestation, as local eradication efforts could push illicit cultivation into new areas, which could eventually increase deforestation in frontier areas.

Research on the likelihood that eradication triggers a balloon effect is mixed. A 2013 study[i] related to Colombia established a positive relationship between aerial crop eradication in a municipality and coca cultivation in adjacent municipalities the year after. It contributed to the understanding of the "balloon effect" by showing that the geography of coca production is not shifted from one area to the next because of eradication, but rather gets diffused across municipalities. However, the study did not show causality, but rather association between eradication and shifting cultivation.

A 2019 study[ii] on Colombia used annual data for 1,116 contiguous municipalities between 2001 and 2010. The study suggests that manual eradication does not affect new coca cultivation, while aerial spraying actually reduces coca cultivation, in terms of new cultivation following eradication, and generates spillover effects: cultivation also decreases in neighbouring areas where spraying activities have not been undertaken. On average, eradication efforts in a municipality reduce new coca cultivation by 8 per cent in that area, while reducing it by 3 per cent in adjacent municipalities. The latter confirms that, at least in the Colombian municipalities analysed, there was, on average, no sign of a "balloon effect", but rather the opposite. The study introduces a spatial econometric technique to address spatial dependence and to estimate the spillover effects of forced eradication activities from one municipality to the next. There are no studies of this kind in other countries, and it is not possible to understand the impact of forced eradication and whether it triggers a balloon effect in locations outside of Colombia.

i Alexander Rincón-Ruiz and Giorgos Kallis, 'Caught in the Middle, Colombia's War on Drugs and Its Effects on Forest and People', *Geoforum* 46 (May 2013).

ii Eleonora Dávalos and Leonardo Fabio Morales, 'Is There a Balloon Effect? Coca Crops and Forced Eradication in Colombia', CIEF Working Paper - *Economy and Finance* 19, no. 8 (2019).

Alternative development

The General Assembly, at its twentieth special session, held in 1998, defined alternative development as a process to prevent and eliminate the illicit cultivation of plants through specifically designed rural development measures in the context of sustained national growth and sustainable development efforts in countries taking action against drugs, recognizing the particular sociocultural characteristics of the target communities and groups.[147]

Alternative development is an approach aimed at reducing the vulnerabilities that lead to involvement in illicit crop cultivation by offering farmers and farming communities viable and legal livelihood alternatives in areas with illicit cultivation to help promote rural development and discourage illicit cultivation in the future.

Alternative development is a means to an end: it is aimed at contributing to an enabling environment for long-term rural development without illicit crop cultivation.[148] In that process, alternative development projects act as catalysts, boosting development in areas with particular challenges related to the illicit drug economy.[149] Some alternative development interventions have an explicit objective to mitigate or address the environmental impact related to illicit crop cultivation or the implementation of the intervention itself.

For example, an ongoing alternative development project in Myanmar promotes the sustainable cultivation of coffee and avocado, while it also invests in reforestation, as well as in complementary initiatives such as furniture, bamboo handicraft and honeybee keeping.[150]

But often, this objective has not been a leading factor. In recent years, the emphasis of alternative development has often been on creating commercially viable agricultural or agroforestry activities with connections to profitable markets and the private sector. The most visible link with the environment has been the aim of balancing sustainable alternative livelihoods with the protection of forests, which, for example, is a focus of projects in Peru.

Alternative development can, in principle, broadly contribute to environmental protection in two ways: it can include components of the "do no harm" principle to minimize the environmental impact of alternative development projects, and it can proactively contribute directly or indirectly to the protection of the environment, biodiversity and climate change mitigation.[151]

Over the past decade, the link between alternative development and the environment has been emphasized more strongly. The United Nations Guiding Principles on Alternative Development, adopted by the General Assembly in 2013, recommend that programmes include measures to protect the environment at the local level through the provision of incentives for conservation, proper education and awareness-raising.[152] They also recommend that impact assessments include environmental indicators.[153] At the special session of the General Assembly on the world drug problem held in 2016, it was recommended that drug policy responses address the environmental impact of illicit cultivation and production, and that measures to prevent illicit cultivation and eradicate crops take into account the protection of the environment.[154]

As part of standards for the design and implementation of alternative and rural development projects, one study stressed the importance of including forest and soil protection efforts in programme design, especially in ecologically sensitive areas.[155] It also suggested that coca monocultures should not be substituted with other large-scale monocultures that create the risk of similar environmental impacts, including soil erosion, desertification and biodiversity degradation.[156]

A challenge in designing alternative development programmes is to precisely identify alternative produce that has a lower environmental footprint than the illicitly cultivated crop. Making this comparative assessment is complex as it depends on various factors, including the geographic location of the programme, agroclimatic conditions, the scale and methods of cultivation, the use of fertilizers, pesticides and other agricultural inputs, as well as the marketing of the crop. A 2019 life-cycle assessment conducted in Putumayo and Catatumbo, Colombia, showed different results for different alternative crops and for each area.[157] For example, while the overall environmental impact of coca bush cultivation was greater, the comparative impact of the alternative produce depended significantly on the methods used, with coffee having an especially negative impact (due to fertilizer use) as well as sugar cane (due to pesticide use), and cacao having a positive impact.[158]

Environmental policies

It is difficult to achieve a comprehensive overview of the degree of interaction between environmental policy and drug policy. Some environmental provisions are included in drug programmes at the local level, but they may not be fully integrated at the national level. Even at the project level, only some environmental aspects may be considered. For example, the mitigation of the environmental impact of the cultivation of alternative crops might address some aspects of environmental protection, but it may fail to address underlying causes related to suboptimal, intensive or monoculture farming.

There are examples of existing environmental policies that have a link with the drug problem or are integrated into drug policy interventions. The present section highlights four of these environmental policies: protected areas, carbon credit schemes, payments for environmental services and agroecology. While these should not be considered an exhaustive list, they present valid examples of how environmental protection programmes could interact with the drug problem, depending on the local context and requirements. All four policies have already been considered in relation to drug policy responses, either directly or indirectly.

Protected areas

Designating protected areas can have positive outcomes for the environment,[159] but they may not shield these areas from illicit crop cultivation. In 2020, nearly half of all illicit coca bush cultivation in Colombia was located in areas with special regulations.[160] That same year, in the Plurinational State of Bolivia, four of the six protected areas with illicit coca cultivation had significant increases in coca bush cultivation.[161] In total, the area under coca cultivation in those areas grew to 454 ha, which was a 44 per cent increase from 2019.[162] In Peru, two of six protected areas with a history of illicit coca cultivation saw significant increases in 2017 (a natural park and a protected forest), which contributed to an overall increase in the total area of coca cultivation within protected areas of 228 ha, compared with 168 ha in 2016.[163] While the overall area under cultivation inside protected natural areas is limited in Peru – especially compared with cultivation in the surrounding areas – its relevance is greater given the fragility of the ecosystems that those areas protect, for example, in terms of biomass and biodiversity.

While there isn't enough research to understand the underlining reasons for the expanding illicit cultivation in protected areas, it can be speculated that expansion of such cultivation in protected areas may be a strategy to avoid eradication because regulations for protected areas limit interventions against illicit cultivation; but it may also be related to other factors such as underdevelopment.

Carbon credit schemes

Some alternative development projects addressing deforestation and forest degradation have integrated carbon credit schemes. An example was the BIOREDD+ programme in Colombia (2011–2015), which worked with Afro-Colombian and indigenous communities to support sustainable development while conserving forests and biodiversity in the Pacific region.[164] While this programme was a forest preservation programme and did not directly address illicit crop cultivation, it worked in areas where communities are partly dependent on illicitly cultivated crops. To respond to the challenge of deforestation, the programme was, for example, implemented in cooperation with two community councils in the region of Tumaco: Bajo Mira y Frontera and Rio Patia Grande Sus Brazos y Ensenada Acapa.[165] Earlier projects of sustainable forestry and timber production proved to be unsuccessful owing to the high costs of the timber produced and competition from the much cheaper production of the illegal timber industry. Agreements with local communities were subsequently reached to conserve the forests through direct payments and technical assistance on the sustainable management of the forests. The funding for this support partly came from the sale of carbon credits.

Carbon credit schemes have also been used to complement alternative development projects in Thailand. For example, the "You Protect Forests; We Protect You" project active since 2019 links forest conservation to financial awards through the use of carbon credits.[166] The project managed to obtain the participation of various private sector organizations, including national energy, steel and beverage companies.[167] Similarly, a development project in the Province of Chiang Rai in Thailand focuses on sustainable forest management, and it is expected to result in a reduction of 106,788 tons of CO_2 per year during a 20-year period (2016–2033).[168]

Payments for environmental services

Payments for environmental services can be defined as "a positive economic incentive where environmental service (ES) providers can voluntarily apply for a payment that is conditional either on ES provision or on an activity clearly linked to ES provision."[169] The incentive is generally used to compensate landholders for activities or services with environmental benefits to society but which imply reduced profits for themselves.[170]

In essence, payments for environmental services awards environmental stewardship. As such, it is not a new environmental policy instrument. It was introduced under the label of "agri-environmental policies" in the European Union from the mid-1980s onward and has an even longer history in the United States.[171]

Carbon credit markets

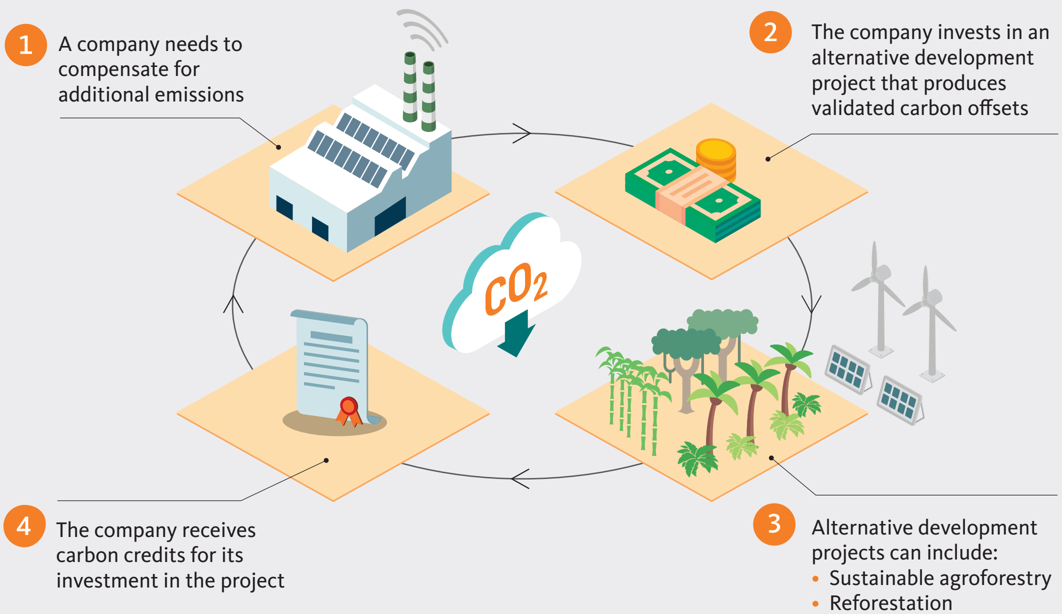
The carbon credit market helps entities that want or need to reduce their emissions by giving them the option to buy carbon credits to offset their own greenhouse gas emissions.[i] A carbon credit allows to generate a fixed amount of 1 ton of carbon emissions (CO_2e). Those carbon credits originate, for example, in companies or projects that store, avoid or reduce greenhouse gas emissions by, for example, preserving and restoring forests.

To ensure these projects actually reduce emissions, a standard is used to certify emission reductions, such as the Verified Carbon Standard. Accurate carbon and biomass estimates are established for the project area, which results in verified carbon credits that can be sold on the market.

For the BIOREDD+ programme in Colombia, for example, the technology to estimate the carbon and biomass values was developed with a geospatial intelligence company.[ii]

There is a voluntary market where business and individuals can buy credits, as well as a mandatory market in which companies and Governments trade emissions on the basis of commitments made internationally within the framework of the United Nations Framework Convention on Climate Change. The current reduction targets were set in the Paris Agreement adopted in 2015, which was last updated by the Conference of the Parties in the Glasgow Climate Pact (at "COP 26") in November 2021.[iii]

CARBON OFFSETS THROUGH ALTERNATIVE DEVELOPMENT PROJECTS



Source: UNODC elaboration.

i UN Climate Change, "About Carbon Pricing," accessed June 9, 2022, https://unfccc.int/about-us/regional-collaboration-centres/the-ciaca-initiative/about-carbon-pricing#eq-7.

ii USAID, *Biodiversity - Reduced Emissions from Deforestation and Forest Degradation Program: Final Report* (Washington D.C.: USAID, 2015).

iii UN Climate Change Conference UK 2021, "The Glasgow Climate Pact," accessed June 9, 2022, https://ukcop26.org/the-glasgow-climate-pact/.

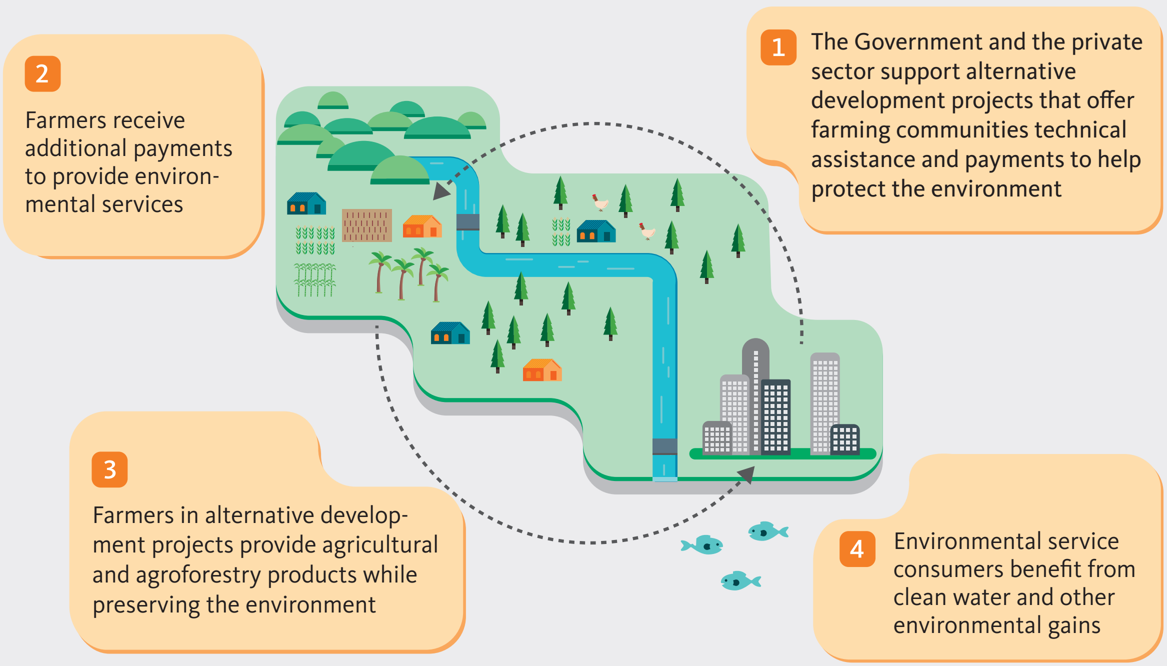
Through the European Union's Common Agricultural Policy, farmers receive payments in return for environmental services such as environment-friendly land management.

In the Colombian Department of Valle del Cauca, payments for environmental services have been integrated into a pilot alternative development project within forest reserve zones.[172] The pilot project involved providing support to farming families growing bananas, cocoa, citrus fruits, coffee and plantain. The key environmental service identified was the provision of water and water quality. To ensure this service, beneficiaries committed to forest protection and to more environment-friendly agricultural practices, such as the use of organic fertilizers. To further promote this use, some farms are in the process of obtaining certification for good agricultural practices. As a result of the pilot project, monthly household incomes increased on average by 42 per cent.

Agroecology

Agroecology represents a shift away from large-scale industrialized agriculture towards more socially just, environmentally resilient and localized food production systems.[173] As such, the approach goes beyond a set of environment-friendly agricultural practices by, inter alia, also focusing on social relations, the empowerment of farmers, climate change adaptation and the conservation of natural resources and biodiversity.[174] Some alternative development projects already seem to incorporate elements of agroecology, for example, in Myanmar, where the project, in addition to focusing on agroforestry, also aims to improve the relationship of rural communities with the environment.[175]

PAYMENTS FOR ENVIRONMENTAL SERVICES IN ALTERNATIVE DEVELOPMENT PROJECTS



Source: UNODC elaboration.

SYNTHETIC DRUGS AND THE ENVIRONMENT

Setting the scene

The biggest difference between plant-based drugs and synthetic drugs is that the former are often dependent on certain climatic conditions, which means their cultivation is limited to certain geographical zones. Synthetic drugs, on the other hand, are location-independent. Some basic conditions are prerequisites for synthetic drug production, such as the availability of electricity and water, but if there is no network available supplying those services, they can be supplied by using, for example, solar panels and water tanks.

Another substantial difference is that the plant-based drug market is relatively stable in terms of its end products (e.g. cannabis, cocaine, heroin and opium), while the synthetic drug market is rapidly and constantly evolving, with more than 1,000 new psychoactive substances emerging on illicit drug markets in recent years.[d] All these new substances are, however, still part of a niche market. The bulk of synthetic drug production is related to three drugs: methamphetamine, amphetamine and MDMA ("ecstasy"). Like for plant-based drugs, there are many factors that define the environmental impact of synthetic drugs.

The production of plant-based drugs has patterns of environmental impact similar to those of synthetic drugs as, in both cases, a variety of precursor chemicals and other inputs are used to produce the final product. But the type of precursors used in the manufacture of synthetic drugs is more dynamic as traffickers adapt to regulations, with the tendency to move to the use of pre-precursors (chemicals that are not regulated and that can produce precursors that are internationally controlled).[176]

It is important to note that the manufacture of synthetic drugs is not completely separate from the agricultural domain. For some synthetic drugs, such as "ecstasy", the main raw materials are plant-based precursors such as safrole, which is extracted from various plants, in particular from the sassafras tree.[177] The cultivation of these precursors adds to the carbon footprint of synthetic drugs in similar ways as do synthetic precursors. However, there is an additional, specific negative impact on fragile ecosystems in countries such as Cambodia and Myanmar due to the distillation process, which requires a large amount of wood for fuel.[178, 179]

The risk of environmental harm varies significantly according to the availability and sophistication of water and waste management. The capacity to treat and analyse water can be very different from country to country, which means that, for example, methamphetamine manufacture has different patterns of impact in Afghanistan, Myanmar and the Netherlands.

The big picture

Similar to plant-based drugs, the manufacture of synthetic drugs is small compared with the global market of licit chemicals or medicines. It is, however, a growing market within the segment of illicit drugs.[180] While the concentrations of controlled drugs and their metabolites in the environment are relatively low compared with other chemical substances, some substances such as amphetamine and MDMA have strong pharmacological activities, which can create specific toxicity in soil, surface and groundwater.[181] These bring risks to public health and biodiversity that may be small in relation to other national or global risks but nevertheless may be important at the local level.[182]

The environmental impact of synthetic drugs can be divided into two main spheres of activity: manufacture and consumption. The immediate impact of illicit drug manufacture is often quite local, while the impact of consumption can be more widely spread and global in nature. Consumption affects the environment mainly through human excretion, by which drugs or their active metabolites are discharged directly into the

d See also Booklet 4 of the present report, entitled *Drug market trends: Cocaine, Amphetamine-type stimulants*.

wastewater.[183] Among the substances most often detected at wastewater treatment plants in countries where such monitoring exist, are amphetamine, benzoylecgonine, ecgonine methyl ester, MDMA, methamphetamine and morphine.[184]

Relationship between production and waste

Clandestine drug laboratories are encountered in many countries. Methamphetamine, illicitly manufactured in clandestine laboratories, is the most commonly manufactured amphetamine-type stimulant worldwide.[185] The manufacture of synthetic drugs is widely spread. Laboratories for the illicit manufacture of synthetic drugs have been dismantled in all regions of the world. A large amount of methamphetamine manufacture is concentrated in North America and South-East Asia, with a trend of increasing manufacture in South-West Asia and Northern Europe; amphetamine manufacture is prevalent in the Middle East (in the form of "captagon"); and "ecstasy" manufacture in Northern Europe.[e]

Each step in the synthesis process of synthetic drug manufacture creates its specific chemical signature with a range of chemical compounds, that is, (pre-) precursors and related impurities, and synthesis by-products. All of these can be called synthesis markers. In most cases, the composition of the impurities generated during the synthesis process is known, but for some precursors, it is still unknown.

The composition of the drug waste is determined by many factors, including the used (pre-)precursors, reaction steps, reaction conditions and duration, the installations and equipment used and the experience of the producer. This means that the production waste can be variable in volume and composition. Based on recipes found at illicit laboratories in the Netherlands, indicative figures on the composition of the waste can be given.[186]

Synthetic drug production and environmental impact

The environmental hazard of synthetic drug production and human consumption has different elements. The environmental impact of human consumption of drugs is usually small and related to the emission of the parent drugs and human metabolites into surface waters via wastewater treatment plants. The environmental impact associated with the dumping of chemical waste from illicit drug manufacturing can be substantial and is mostly caused by the bulk chemicals, such as solvents (acids, bases, organic solvents) and by specialty chemicals. The latter include precursors, end products, intermediates and by-products and in some cases catalysts. The routes of emissions of drug production waste are diverse, as detailed below.

In addition to the production and transport of precursors, the environmental impact of synthetic drugs is mostly due to the toxic waste generated during the production process. The producers of synthetic drugs typically dispose of this waste in two ways: through dumping and discharges. Dumping is the disposal of synthetic drug waste in some kind of container (e.g. a plastic barrel or a metal drum), while discharges are the liquid waste directly or indirectly discarded onto land or into water.

The distinction between dumping and discharge is important from an environmental harm perspective. Dumped containers are visible and can eventually be identified, while discharges are more invisible.[187] Discharges are also seen as a more direct cause of harm as human beings and nature are more directly exposed to the toxic substances involved[188] at the same time as the substance's invisibility limits the knowledge and data availability.[189]

Production-related waste generation

At the production stage, the greatest environmental impact is created by the chemical waste, consisting of chemical precursor substances that are used in the manufacturing process. This waste is proportionally high compared with the end product. The production of 1 kg of MDMA (or "ecstasy") is estimated to produce between 6 and 10 kg of waste.[190] For other synthetic

e See also Booklet 4 of the present report, entitled *Drug market trends: Cocaine, Amphetamine-type stimulants.*

AMOUNT AND INDICATIVE COMPOSITION OF CHEMICAL WASTE GENERATED BY THE PRODUCTION OF SYNTHETIC DRUGS			
Synthetic drug	Amount of waste generated by 1 kg of final product (in kg /kg)[i]	Examples of type of waste[ii, iii, iv]	Composition of waste[v]
MDMA	6–10[vi] >12[vii]	> Ethanol/isopropyl alcohol, methylamine; HCl, acetone, NaOH, Hg, $Al(OH)_3$, diethyle-ther, MeOH; (pre-) precursors	> Major part of the total waste composition: Aqueous acidic and alkaline solutions, organic solvents and reactants > Minor part: (Pre-) precursors, by-products, end product and catalysts
Methamphetamine	5–6[viii] 6–10[ix] 5–7[ix]	> From ephedrine: NaOH, I_2, P, organic solvents (e.g. ether, acetone, thinner, xylene); H_2SO_4, HCl, HI, methylamine > From BMK: Ammonia, NaOH, LiOH, metals (Li), solvents (e.g. ether, acetone, DCM)	> Major part: Aqueous acidic and alkaline solutions, organic solvents and reactants > Minor part: (Pre-) precursors, by-products, end product and catalysts
Amphetamine	20–30[vi] >16[vii]	> Alkaline waste, formic acid, formamide, N-formylamphetamine, NaOH, NH4Cl, phenyl acetic acid, MeOH, H_2SO_4, H_3PO_4, acetone, ammonia; (Pre-) precursors	> Major part: aqueous acidic and alkaline solutions > Minor part: (Pre-) precursors, by-products and end product > No data: Organic solvents and reactants

i Amounts are expressed in kg per 1 kg of final product, unless otherwise indicated.

ii Minnesota PCA (2021) (Minnesota Pollution Control Agency).

iii Felix Brongers, 'Vaten En Fauna. Een Groen Criminologisch Onderzoek Naar de Milieuschade Als Gevolg van Synthetisch Drugsafval' (Rotterdam, Erasmus Universiteit, 2021).

iv Not all chemicals are found in the waste in or from every laboratory. Reaction materials used depend upon the method of production. The solvent(s) used in manufacture may vary owing to availability, the trafficker's preference, etc.

v The chemical components of waste can be roughly divided into minor and major parts of the total waste. This is partly based on unpublished results estimates; residues of (pre-)precursors, by-products and final product are not often studied. However, some information is available about residues that are left in the reaction mixtures.

vi Pardel et al., 2021.

vii Riemersma, 2021 . Waste is expressed per kg of precursor.

viii Lukas 1997, cited in Scott et al., 2003.

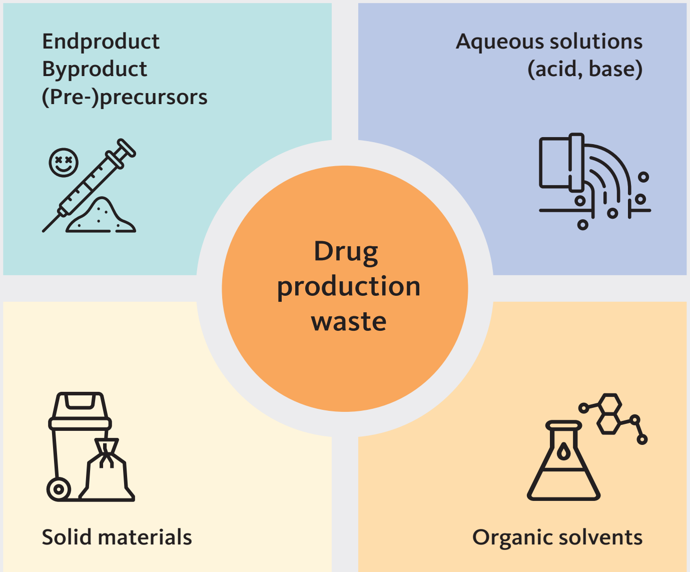
ix White 1998, cited in Scott et al., 2003.

drugs, the estimates may be significantly higher. For example, the production of 1 kg of amphetamine is estimated to generate between 20 kg and 30 kg of waste.[191]

Depending on the drug produced and the synthesis route used, the volume and composition of chemical waste vary, together with the associated environmental impact. The volume of waste produced can vary depending on the number of individual steps in a particular manufacturing route. The use of unregulated pre-precursors or precursor alternatives often adds additional steps to the actual synthesis and therefore produces more waste.

Given that a global estimate of the volume of synthetic drugs manufactured is not available, it is not possible to compute a global estimate of waste generated by the manufacture of synthetic drugs. Estimates of chemical waste based on seizures provide a minimum estimate of waste, because much more has been produced than what has been seized, but those estimates can provide a reliable order of magnitude of the minimum impact.

COMPOSITION OF SYNTHETIC DRUG PRODUCTION WASTE

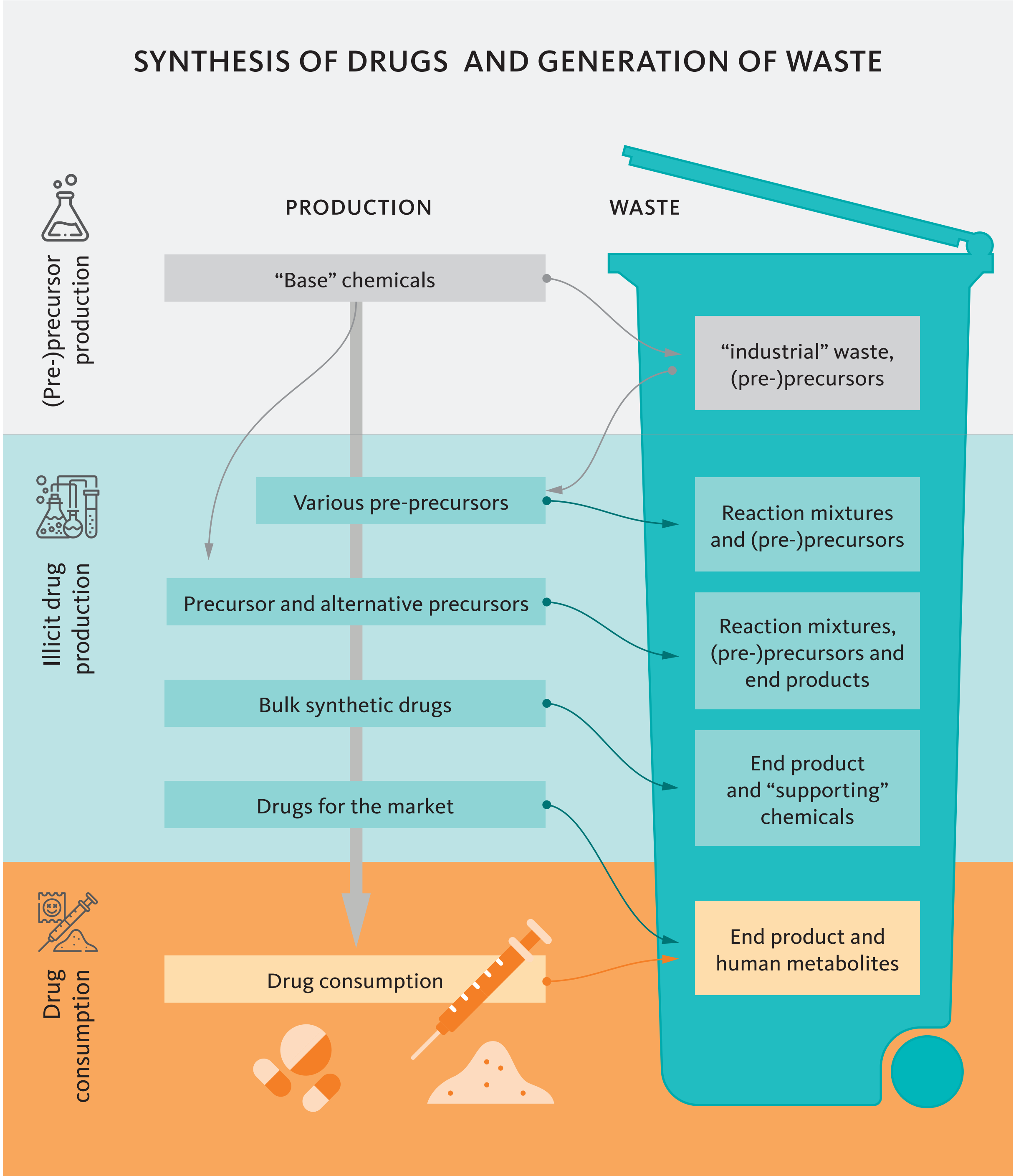


Source: KWR and UNODC elaboration.

MINIMUM ANNUAL AMOUNT OF GLOBAL CHEMICAL WASTE GENERATED IN THE MANUFACTURE OF SYNTHETIC DRUGS BASED ON SEIZURES, 2016–2020

Synthetic drug	Reported average annual seizures (tons)	Waste output per ton produced	Composition of waste[v]
Amphetamine	57.6	20-30	1,152–1,728
Methamphetamine	246.6	5-10	1,233–2,466
MDMA	11.6	6-10	69.6–116

Sources: For amphetamine and MDMA: EMCDDA and Europol, *EU Drug Markets Report 2019* (Luxembourg: Publications Office, 2019); For methamphetamine: Scott Lukas, *Proceedings of the National Consensus Meeting on the Use, Abuse and Sequelae of Abuse of Methylamphetamine with Implications for Prevention, Treatment and Research. Substance Abuse and Mental Health Services Administration* (Dpt. Of Health and Human Services Publication, 1997); J. White, 'Clandestine Labs: The Lethal Workplace' (Cited in Caldicott, 2005), *Police Association Journal* 64 (1998); Tim Scott et al., 'Effect of Amphetamine Precursors and By-Products on Soil Enzymes of Two Urban Soils', *Bulletin of Environmental Contamination and Toxicology* 70, no. 4 (April 2003).



Source: KWR and UNODC elaboration.

Impact of waste on the environment

The environmental impact of discharged waste varies. The impact of a spilled or dumped acidic solution, alkaline solution or solvent may vary with the physical and chemical properties of the natural surface onto which it has been spilled and the dilution it undergoes. When water is present in the soil environment, for example, the waste can more easily spread, while its concentration decreases through dispersion and diffusion.[192]

Judging by the recipes found in clandestine laboratories, amphetamine waste is dominated by acidic aqueous solutions, with a major part (50 per cent) of waste from amphetamine synthesis consisting of very strong acids (pH≈0).[193] For MDMA, organic solvents, reactants and alkaline aqueous solutions make up a relevant part of the waste. In addition, the conversion of various pre-precursors to precursors and subsequent conversion and isolation of the end product result in significant losses for both amphetamine and MDMA. This is due to both incomplete and imperfect conversions and losses due to incomplete separation of reaction mixtures and products. This means that the waste contains significant residues of the pre-precursors, precursors and impurities, as well as the end product.

The manufacture of amphetamine-type stimulants also produces volatile organic compounds, including acetone, toluene and ether. The primary environmental hazard of volatile organic compounds is the possible contamination of groundwater. In great enough quantities, those compounds may injure or kill the bacterial growth that provides sewage treatment in a drain field. Methamphetamine lab-related wastes are primarily fuels and solvents like those used at home for activities such as cleaning and automobile work. The waste can also contain smaller amounts of various metals such as lithium or mercury which act as catalysts for reactions.

Methamphetamine can be produced through a variety of synthetic routes. These routes may include precursors such as ephedrine or phenylacetone (also known as *P2P) or* benzyl methyl ketone (BMK). If phenylacetone is used as a precursor, the pathway to produce this precursor is identical to the production of amphetamine, mainly using acidic aqueous solutions. Subsequently, reductive amination is performed using N-methylamide or methylamide as a reactant and aluminium coated with mercury as a catalyst. When ephedrine is used as a precursor, alkaline solutions, various organic solvents, iodine and phosphorus are required.

Although amphetamine synthesis generates a larger volume of waste than the synthesis of methamphetamine or MDMA, the synthesis of the latter two drugs may generate the highly toxic, metallic mercury.[194] Depending on the synthesis route used, amphetamine manufacture can generate lead and mercury as by-products.

Environmental exposure to acid and alkaline waste and to organic solvents (e.g. acetone, ethyl ether, methanol or isopropanol) used in illicit drug manufacture is generally a localized, immediate risk. The harm is largely a function of the volume that enters the soil or surface waters. Longer-term exposure is less likely to occur as, over time, acidic and alkaline solutions are diluted and buffered by the water and rain and/or are neutralized by the buffering capacity of soils, while organic solvents either evaporate into the air or are relatively rapidly biodegraded by microbes in wastewater treatment or the environment. However, these substances can have indirect environmental effects such as the presence of heavy metals in soil. This may affect groundwater quality and organisms within soils or sediments. In addition, it can lead to high chemical oxygen demand and oxygen depletion in water, high sulphate loadings, and salinity.[195]

Organic solvents may evaporate or be transported with water to underground waters. In the provinces of Noord-Brabant and Limburg of the Netherlands (in which provinces most of the clandestine laboratories in that country are located), for example, about 20 per cent of the dumps for discharge waste discovered were in groundwater protection areas.[196] These areas are protected as aquifers and are used for the production of drinking water.

SYNTHESIS OF THE ENVIRONMENTAL IMPACT OF WASTE CONSTITUENTS FROM ILLICIT MANUFACTURE OF SYNTHETIC DRUGS						
Substances found in waste	**Environmental behaviour (surface water)**	**Environmental behaviour (soil)**	**Environmental impact (surface water)**	**Environmental impact (soil)**	**Other impacts (surface water)**	**Other impacts (soil)**
Aqueous acidic or alkaline solutions	Local (short-lived/ diluted)	Local, medium-term	High, local	High, local	Infrastructure damage (e.g. jetties, ships)	Release of sorbed metals
Organic solvents	Local (short-lived/ degraded or evaporated)	Local, short-lived (evaporation)	Medium to high, local	Medium to high, local	Odour	Odour
Catalysts	Regional (persistent)	Local, long-lived	Low to medium	Low (immo-bilization)	Bioaccumulation in food chain, contamination of sources of drinking water	Bioaccumulation in food chain
Pre-precursors, precursors, by-products	Variable	Generally more persistent			Contamination of sources of drinking water	Possible uptake in crops, contamination of sources of drinking water
End product	Variable	Generally more persistent			Contamination of sources of drinking water	Possible uptake in crops, contamination of sources of drinking water

Analysis of production-related waste in the Netherlands

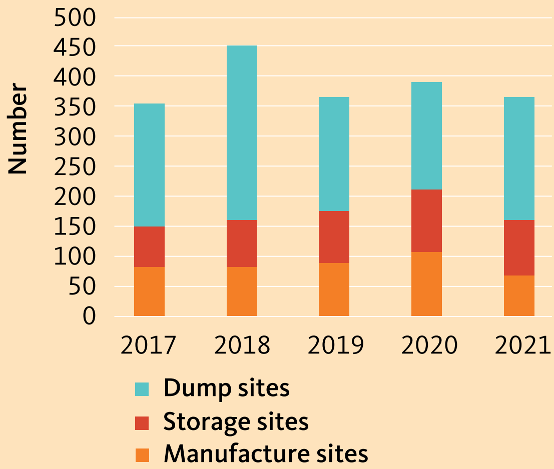
Based on a 2018 report estimating the production of amphetamine and MDMA in the Netherlands,[i] it has been estimated that the waste generated in these production processes in the country result in over 6,000 and 1,000 tons of drug production waste annually, for amphetamine and MDMA, respectively.[ii] This may include some synthetic drug waste from clandestine laboratories in Belgium that may have been dumped intentionally in southern provinces of the Netherlands.[iii]

The national police of the Netherlands publish annual overviews of synthetic drug production locations, storage facilities for synthesis hardware and chemicals, and dumps of waste from production sites.

While the number of both the production sites and the storage facilities increased from 2017 to 2020, the number was again lower in 2021. The number of discovered dump sites decreased from 2018 to 2020, followed by a substantial increase in 2021. Most of the production and storage facilities were encountered in the eastern and south-eastern parts of the Netherlands, and the majority of dump sites were located in the same areas and in the south-western province of Zeeland.

i Pieter W. Tops et al., *The Netherlands and Synthetic Drugs: An Inconvenient Truth* (The Hague: Eleven International Publishing, 2018).

FIG. 2 **Dismantled manufacture, storage and dump locations related to synthetic drugs, the Netherlands, 2017–2021**



Source: Dutch National Police, *Nationaal Overzicht Drugslocaties 2021, Version 1.6* (Driebergen: Dutch National Police, 2022).

ii E. Emke, 'Invloed van Drugsproductie Afval Lozingen Op Grondwaterwinningen - Een Scenariostudie' (Nieuwegein: KWR Water Research Institute, 2020).

iii F. De Middeleer et al., 'Illegale Drugsmarkten in België En Nederland: Communicerende Vaten?' (Ghent, Belgium: Belgian Science Policy Office (BELSPO), 2018).

Low level of media reporting on the environmental harm of synthetic drug production in Belgium

A 2021 study[i] that focused on the reporting of Flemish language newspapers in Belgium on drug waste dumping and drug production sites in Belgium shows that little attention is paid or little is known about the environmental harm caused by manufacture of synthetic drugs.

The study analysed media reports in the period 2013–2020 of about 69 cases of dumping (in 90 news articles) and 38 cases involving the detection of drug production labs (in 57 news articles). The study found that the media hardly reported on the environmental harm involved. Only in 10 cases involving dumping sites and 3 cases of clandestine laboratories did the news articles include some mention of specific environmental effects (e.g. related to soil or water pollution). Hardly any details were included about the nature or the scale of the environmental harm caused by the clandestine laboratories. As the researchers admit, however, those details might not have been fully known at the time of detection.

i Mafalda Pardal, Charlotte Colman, and Tim Surmont, "Synthetic Drug Production in Belgium – Environmental Harms as Collateral Damage?," *Journal of Illicit Economies and Development* 3, no. 1 (October 4, 2021).

Harm pathways

Two decades ago, a study already signalled the potential environmental pollution caused by chemicals associated with clandestine drug laboratories due to chemicals often disposed of covertly into soil, sewage systems or public waste management facilities.[197]

Based on what was observed in the Netherlands, illegal dumping, or fly-tipping, can take many forms, including burying, dumping on land or in surface waters, or storage in basements, mixing with manure or other chemical waste, incineration, illegal deposition at local recycling centres, and direct or indirect dispersal through indoor plumbing drains that drain either into a city sewer system or individual sewage treatment system.[198] Drug synthesis waste can also be collected in vessels, jerry cans or large intermediate bulk containers and stored in the production facilities or in vans that may subsequently be abandoned or set on fire.

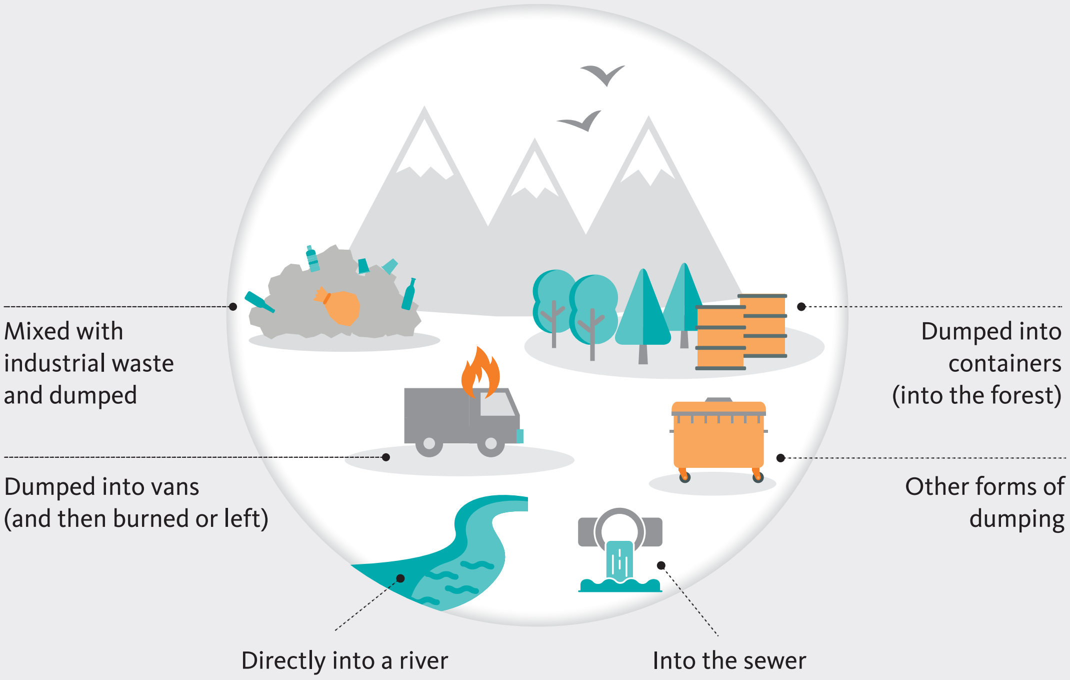
Direct discharges on land

The waste stored in plastic vessels, jerry cans or intermediate bulk containers can be dumped on private and public land (agricultural fields, forests, nature reserves), resulting in adverse effects on all aspects of agriculture and the environment. Drug waste has also been found buried in pits[199] and filled water wells.

Direct discharges into surface waters

Direct discharge of synthetic drug production waste into surface waters can also take place through the deliberate emptying of jerry cans and other containers. In addition, clandestine laboratories can make use of drains to directly introduce liquid waste into ditches, streams and canals. The primary (local) threats for the aquatic environment consist of acidification (in the case of amphetamine waste) or oxygen depletion (in the case of MDMA waste containing ethanol or methanol).[200] For chemical waste from methamphetamine

METHODS OF DUMPING AND DISCHARGE OF SYNTHETIC DRUG-RELATED WASTE



Source: KWR and UNODC elaboration.

production dumped into surface waters, it was demonstrated in laboratory experiments, combined with model calculations, that in the immediate term, the waste is likely to be harmful to aquatic organisms because of the depletion of oxygen. A mixture of the individual waste components was found to consume more oxygen than the individual chemicals. The waste was likely to remain in the water tank for 15 to 37 days.[201]

Direct discharges into sewer systems

When acidic or alkaline waste is discharged into the sewer system, it can damage the sewer infrastructure (for example, by damaging sewage pipes) and can affect the bacteria used in wastewater treatment plants to clean the water. In the Netherlands, for example, there have been reports of multiple malfunctions in a small sewage treatment plant as a result of chemical waste from amphetamine synthesis that had been dumped into the sewer.[202] In a model study involving 23 small to moderately sized wastewater treatment plants, it was shown that liquid waste from even a small batch of amphetamine (40 kg) could cause malfunction in all 23 of those treatment plants.[203]

In addition to the bulk solvents and chemicals (acids, bases) used in the production of synthetic drugs and that end up in the chemical waste, the waste often contains residues of the end product, which may also end up in the sewer system. Such residues in wastewater often exceed the levels resulting from excretion after human consumption of the drug.

A 2014 study on the manufacture and consumption of pharmaceuticals, suggests that the risks associated with the environmental impact of discharges from the manufacture of illicit drugs differ in several respects from the risks associated with the excretion of drug residues after consumption.[204] This is primarily due to the differences in exposure levels. Concentrations of illicit drug residues due to excretion in municipal sewage effluents are low because drugs are used by a small fraction of the population each day. Moreover, high volumes of water are generally used in flushing the toilet and result in an initial high dilution of faeces and urine. Discharges of chemical waste from

Impact of waste on agricultural crops and the food chain

The dumping of drug waste in or near manure pits and cellars can have an important additional environmental impact. If not detected before the manure is used in the agricultural process, fields may become indirectly contaminated. The mixture of manure and waste can be distributed to the fields, and crops grown in such fields may contain residues of the chemicals, as can the end products. In the Netherlands, amphetamine and MDMA were found to be present in corn harvested from such fields.

In the Netherlands, corn plants from an agricultural field that had been fertilized with manure contaminated with waste from synthetic drug production was analysed and found to contain synthesis-related products. Although results were only indicative, levels of 8 µg/kg of dry weight (dw) of amphetamine and up to 60 µg/kg dw of MDMA were found in corn.[i] These levels were considerably higher than the maximum level of MDMA in corn-based fodder that could be fed to cows, established to prevent acute or chronic effects in humans through milk consumption and to avoid effects in the cows themselves.

In an additional study, MDMA was detected in samples taken from another field in 2017: concentrations were found to be 12–17 µg/kg in silage maize and up to 10 µg/kg in corn grains[ii]. Contrary to the previous study, this study concluded that no harmful effects were to be expected from the levels observed.

i NVWA and RIKILT, *Beoordeling 3,4-methylenedioxy-n-methamphetamine (MDMA) in maïs* (7 December 2015)

ii NVWA, *Advies over MDMA in mais* (1 March 2018).

synthesis of illicit drugs, where they occur, usually have much higher concentrations, including of the end products.[205, 206]

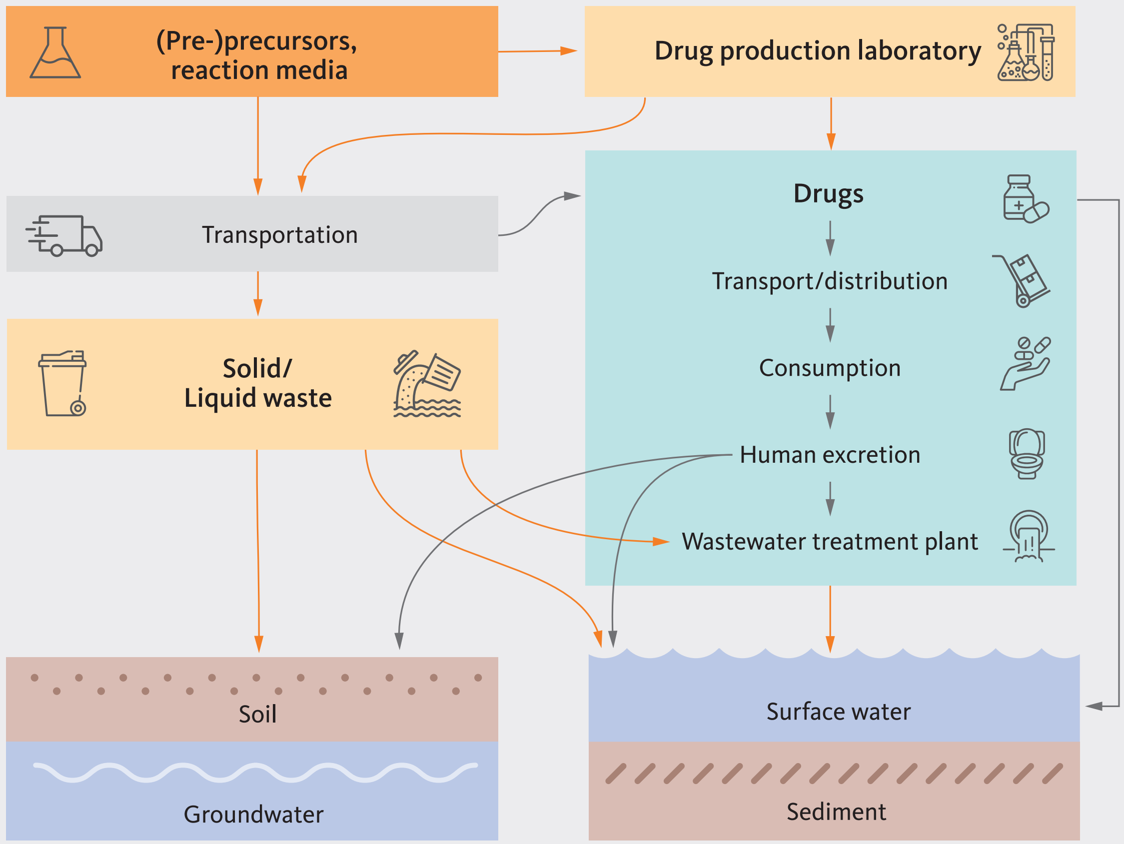
A useful way to distinguish the incidental presence of discharges from illicit manufacturing in sewer systems is to monitor the ratio of certain biomarkers of commonly consumed drugs of abuse in wastewater influents. For example, extremely high loads of amphetamine and MDMA compared with "normal" consumption-related loads as recorded in the sewer system of the city of Eindhoven, the Netherlands,[207] were indicative of manufacture-related dumps into the sewer system.

Other sources of synthetic drug residues in the environment

Consumption

Illicit drugs themselves can also reach the environment after human consumption when drug residues excreted by the human body end up in wastewater, and the subsequent treatment in the wastewater treatment plant fails to completely remove the residues.

ROUTES OF SYNTHETIC DRUG PRODUCTION WASTE TO THE ENVIRONMENT



Source: KWR and UNODC elaboration.

When assessing the impact of drug consumption and production on water in a sewage system, it is important to look at the efficiency of water treatment systems in removing substances from the water. In general, where wastewater treatment is available, amphetamine and methamphetamine can be largely removed by the treatment applied, but removal rates for MDMA are low. For MDMA, even negative removal rates have been reported,[208, 209] implying that the concentrations in effluents of wastewater treatment plants may exceed those of the corresponding influents. Wastewater treatment plants receiving high loads of MDMA may subsequently serve as single localized sources of MDMA for receiving surface waters.

Temporary high levels of synthetic drug residues in sewers can also result from music festivals where the consumption of drugs is often higher than in the general population. While the combined waste from the urinals used at such festivals can be legally discharged into sewer systems, leading to temporary high loads, festival attendees may not always use the urinals provided, and the subsequent run-off from nearby soil may temporarily increase the levels in surrounding surface waters.[210]

Health-related issues

Manufacturing synthetic drugs generates a variety of noxious solvents and gases (e.g. hydrogen chloride, phosphine and, in the case of crystal methamphetamine, the drug itself).[211] Police and firefighters report breathing problems and headaches when they dismantle crystal methamphetamine labs. Anyone who is present during synthetic drug processing is exposed to those and likely other toxicants. In some cases, that exposure could have fatal consequences. People living near production locations can be exposed to evaporating solvents and toxic fumes. Humans may be accidentally exposed to the bulk chemicals when they encounter chemical dumps.

Impact of drug-related waste on biodiversity

Ecotoxicity refers to the potential for biological, chemical or physical agents to affect ecosystems, and thereby, indirectly, biodiversity. When synthetic drugs or chemical residues enter the soil or water, they change the pH level, which may affect the ecosystems of living organisms.[212] This can affect aquatic organisms, but also, for example, livestock, when surface water is used for irrigation or as drinking water for animals.[213]

There is a lack of studies on the behaviour and environmental impact of synthetic drugs and the by-products of their synthesis.

THE ROUTE OF ILLICITLY PRODUCED DRUGS AND THEIR METABOLITES THROUGH WASTEWATER

Source: Based on Mayana Karoline Fontes, Luciane Alves Maranho, and Camilo Dias Seabra Pereira, 'Review on the Occurrence and Biological Effects of Illicit Drugs in Aquatic Ecosystems', *Environmental Science and Pollution Research* 27, no. 25 (September 2020).

RATES OF REMOVAL OF SYNTHETIC DRUGS IN WASTEWATER TREATMENT PLANTS			
Synthetic drug	**Removal efficiency (percentage eliminated)**	**Location**	**Source**
MDMA	0–27	Netherlands	Bijlsma, 2012
	13–36	Global	Yadav, 2017
Methamphetamine	54.5	United States	Loganathan, 2009
	44–99	Spain	Huerta-Fontela, 2008
	99	Spain	Bijlsma, 2009
	33–100	Global review	Yadav, 2017
Amphetamine	52–99	Spain	Huerta-Fontela, 2008
	85	Spain	Bijlsma, 2009
	87–99	Netherlands	Bijlsma, 2012
	0–99	China	Deng, 2020
	33–100	Global review	Yadav, 2017

Sources: L. Bijlsma et al., 'Investigation of Drugs of Abuse and Relevant Metabolites in Dutch Sewage Water by Liquid Chromatography Coupled to High Resolution Mass Spectrometry', *Chemosphere* 89, no. 11 (2012); Meena K. Yadav et al., 'Removal of Emerging Drugs of Addiction by Wastewater Treatment and Water Recycling Processes and Impacts on Effluent-Associated Environmental Risk', *Science of the Total Environment* 680 (25 August 2019); Bommanna Loganathan et al., 'Contamination Profiles and Mass Loadings of Macrolide Antibiotics and Illicit Drugs from a Small Urban Wastewater Treatment Plant', *Chemosphere* 75, no. 1 (March 2009); Maria Huerta-Fontela, Maria Teresa Galceran, and Francesc Ventura, 'Stimulatory Drugs of Abuse in Surface Waters and Their Removal in a Conventional Drinking Water Treatment Plant', *Environmental Science & Technology* 42, no. 18 (15 September 2008); L. Bijlsma et al., 'Simultaneous Ultra-High-Pressure Liquid Chromatography-Tandem Mass Spectrometry Determination of Amphetamine and Amphetamine-like Stimulants, Cocaine and Its Metabolites, and a Cannabis Metabolite in Surface Water and Urban Wastewater', *Journal of Chromatography* A 1216, no. 15 (2009); Yanghui Deng et al., 'Occurrence and Removal of Illicit Drugs in Different Wastewater Treatment Plants with Different Treatment Techniques', *Environmental Sciences Europe* 32, no. 1 (26 February 2020).

The effects on the environment are clearest when high concentrations are involved. For example, dumps of chemical waste from illegal synthesis have led to several local environmental incidents in the Netherlands. These include mass killings of fish, amphibians and invertebrates in a small creek in the province of Limburg after discharge of waste from MDMA synthesis.[214]

Beyond such local spikes of contamination, there are contrasting data about the ecotoxicity and behaviour of amphetamine-type stimulants in the environment. One study found that amphetamine precursors and by-products do not have harmful effects on important microbiological activities at concentrations below 1,000 µg/g.[215] Methamphetamine and MDMA levels in effluents from Australian wastewater treatment plants amounted to 200 and 60 ng/l, and were found to pose low risks to the receiving waters.[216]

However, even at relatively low concentrations, residues of synthetic drugs may pose risks for ecosystems. Water bodies are highly susceptible for contamination by drugs and associated compounds.[217] Aquatic organisms, including bacteria, algae, invertebrates and fishes, have receptors that make them potentially sensitive to controlled drugs entering the ecosystem.[218] Concentrations of methamphetamine were found to affect the health of fish.[219] Methamphetamine and amphetamine were found to accumulate in zebra fish. [220] At 0.1 µg/l, MDMA was also found to bring about effects in zebra fish.[221] A mixture of controlled drugs similar to that found in real environmental conditions was found to induce effects in zebra mussels.[222] A 2021 study reported that methamphetamine causes addiction and behaviour alteration in brown trout (*Salmo trutta)* at environmentally relevant concentrations (1 µg/l).[223]

The potential environmental harm of the more stable compounds depends on the concentrations reaching groundwater or surface water, for which few data exist. A monitoring study in the Netherlands[224] involved establishing predicted no-effect concentrations for the ecosystem, which represent the threshold below which

Music festivals

Music festivals can provide interesting insights into the environmental effects of synthetic drugs in higher concentrations and during short time frames, as those concentrations are difficult to measure in settings where drug consumption is more dispersed. Some examples are given below.

Glastonbury Festival, United Kingdom, 2019 (203,000 attendees)[i]

The Glastonbury Festival is located at a confluence of the Whitelake River, providing an easy way to monitor the impact of synthetic drug consumption on the local environment. At the time of the festival, concentrations in the river were significantly higher downstream of the festival. MDMA mass loads were 104 times greater downstream compared with measurements taken upstream of the festival. The concentration of MDMA reached its highest level during the weekend after the festival, totalling 322 ng/l. That concentration is deemed harmful to aquatic life and provides evidence of continuous release after the festival due to MDMA draining away from the site.

Decibel Outdoor, Netherlands, 2017 (75,000 attendees)[ii]

During the Decibel Outdoor Festival, the load to a small wastewater treatment plant in the area was 56 times the normal daily value for MDMA as compared with the daily load due to consumption reported for the city of Utrecht, the Netherlands, in the same period. During the days of the festival, loads were recorded that suggested a total consumption of 2.6 kilo of pure MDMA, which is the equivalent of around 16,230 pills. Most of this waste was likely discharged in the receiving surface water owing to the poor efficiency of removal of MDMA at the wastewater treatment plant.

Balaton Sound, Hungary 2017, 2018 and 2019 (154,000, 165,000 and 172,000 attendees, respectively)[iii]

The lake Balaton was monitored prior to, during and after the festivals held in 2017, 2018 and 2019, attended by 154,000, 165,000 and 172,000 people, respectively. The detection of controlled drugs peaked immediately after each event. MDMA was found consistently over the years, and a risk quotient (a ratio of estimated exposure and estimated effects) of 0.4 was observed, which is considered a medium environmental risk.[iii]

i Dan Aberg et al., 'The Environmental Release and Ecosystem Risks of Illicit Drugs during Glastonbury Festival.', *Environmental Research* 204 (March 2022).

ii Erik Emke, 'Rioolwateronderzoek Decibel, Rioolwateranalyse Op de Aanwezigheid van Drugs' (Nieuwegein: KWR Water Research Institute, December 2017).

iii G. Maasz et al., 'Illicit Drugs as a Potential Risk to the Aquatic Environment of a Large Freshwater Lake after a Major Music Festival', *Environmental Toxicology and Chemistry* 40, no. 5 (2021).

no harmful environmental effects of exposure are measured.[225] For amphetamine, methamphetamine and MDMA, these amounted to 4.9, 1.5 and 1.6 µg/l, respectively.[226] In a subsequent monitoring campaign, concentrations of MDMA were found in effluent-receiving water bodies close to wastewater treatment plants that approached the estimated safe levels. For amphetamine and methamphetamine, levels were far below the safe values.

In a simulation study, a worst-case scenario was applied in order to evaluate the possible effects of the dumping of amphetamine or MDMA waste in a drinking water abstraction area. MDMA levels as a result of the simulated dumping of chemical waste from its synthesis were shown to exceed the existing limit values and toxicological thresholds.[227]

Effect of methamphetamine on drug addiction in fish

A 2021 study[i] involving laboratory experiments examined the effects of exposure of the brown trout (Salmo trutta) species to methamphetamine. During eight weeks, the fish were exposed to concentrations of residuals of methamphetamine production similar to those found in rivers after the water has been treated. After that exposure, they went through 10 days of withdrawal. The fish were then exposed to a choice arena with methamphetamine and a control arena.

The result was a change of behaviour and movement preference of the fish exposed to methamphetamine during the withdrawal period. The findings indicate that environmental concentrations of methamphetamine alter fish brain metabolomes. Overall, the study concluded that the emissions of controlled drugs into freshwater ecosystems can cause addiction in fish. One of the impacts observed is a change in habitat preferences potentially leading to adverse consequences for individual fish and the population at large (e.g. related to foraging and mating). The context of the experiment involved wastewater treatment. In many parts of the world where such treatment is poor or non-existent, methamphetamine manufacture may have an even larger impact on fish.

i Pavel Horký et al., ‘Methamphetamine Pollution Elicits Addiction in Wild Fish’, *Journal of Experimental Biology* 224, no. 13 (1 July 2021).

Ongoing policy responses

With regard to synthetic drug production, in addition to precursor control, the policy responses are mostly reactive in nature, ranging from the detection and dismantling of clandestine laboratories to wastewater analysis, to cleaning operations on production or waste dumping sites, and the proper disposal of confiscated drugs.

Wastewater analysis

Wastewater analysis serves various purposes, from public health protection and the monitoring of drug consumption trends[228] to environmental protection and law enforcement.[229] Worldwide, wastewater analysis has detected controlled drugs and their metabolites. For example, a literature review conducted in 2020 found wastewater analysis studies in at least 23 countries for opioids, 15 countries for cannabinoids and 17 for synthetic drugs.[230] However, most of these studies come from Europe and North America (Canada and the United States), with only a few countries represented in other regions: in Asia, China, the Republic of Korea and Taiwan Province of China; in Latin America, Brazil, Colombia, Costa Rica, Martinique, Mexico and Uruguay; and in Africa, only Egypt and South Africa.[231] Most of the wastewater analysis conducted is currently related to monitoring drug consumption or drug production trends.

Law enforcement

In addition to determining environmental impact, wastewater analysis can support law enforcement, as waste profiles may be used to identify ongoing drug production in the wastewater catchment area.[232] It could also help to identify trends, for example, in terms of geographical location, the types of precursors used and the drugs produced. When precursors are also used for licit purposes, wastewater analysis to identify illicit manufacture becomes very challenging. This is also the case for some processed plant-based drugs. For example, it is difficult to detect heroin because its main metabolite, morphine, is also an indicator of commonly used medicines.[233] The same applies to cannabis, for which there are currently no suitable biomarkers to be detected in wastewater.[234]

In the Netherlands, in a 2016 study of dumping cases that led to arrests, two thirds of those cases resulted in prison sentences.[235] Those sentences varied from 165 days to three-and-a-half years in prison.[236]

Cleaning

While it is difficult to estimate the total environmental impact of synthetic drug production worldwide, there are estimates for the financial cost of cleaning up the waste created by drug labs and dump sites. This represents only a fraction of the true costs involved but does give an idea of the economic burden that synthetic drug production places on Governments and individuals responsible for mitigating the environmental impact.

The costs of cleaning up synthetic drug production and waste dump sites have been estimated in detail for Belgium and the Netherlands. The costs vary widely from site to site, depending on the local conditions, the size of the site and other factors.

While other estimates of clean-up costs for drug laboratories have been much lower, for example, in the United States, an average of $2,200 per clean-up in the fiscal year 2009,[237] such estimates are often limited to only the costs of the cleaning operation and do not include, for example, the costs of law enforcement officers or other local government agencies involved. While the latter, additional costs are ultimately costs paid by the taxpayers, the former costs are paid primarily by the homeowner or landowner. In most cases, property owners or lien holders are responsible for the direct costs of the clean-up itself.

As costs related to drug waste clean-ups can be substantial, in the Netherlands, subsidies are available under the provincial-level "subsidy regulation for clearance of drug waste" (2021–2024).[238] These subsidies cover activities related to the decontamination of soil and surface water, as well as the removal of dumped drug waste.

Monitoring

Monitoring of illicit drug concentrations is useful for three broad purposes: to assess the nature and scope of drug consumption over time; to identify trends in drug consumption; and to identify control and mitigation strategies that can help protect the environment from biologically active substances.[239] While little is yet known about the actual magnitude of environmental harm, monitoring can help inform future policy responses to address the environmental effects of the production and dumping of synthetic drugs.[240]

MINIMUM ESTIMATED COST OF DISMANTLING/CLEANING-UP SYNTHETIC DRUG PRODUCTION SITES, STORAGE AND WASTE DUMP SITES, BELGIUM AND THE NETHERLANDS, 2016

Country	Number of sites	Total cost	Composition of waste (euros)
Belgium	42	1,401,634	33,372
Netherlands	322	4,368,294	13,566
Total	**364**	**5,769,928**	**15,851**

Source: Maaike Claessens et al., *An Analysis of the Costs of Dismantling and Cleaning up Synthetic Drug Production Sites in Belgium and the Netherlands*, Background Paper commissioned by the EMCDDA for the EU Drug Markets Report 2019 (Lisbon: EMCDDA, 2019).

Note: The cost estimations are based on the working hours, training hours and materials used by all the actors involved. This includes the police, a specialized police synthetic drug lab dismantling team, the fire department, civil protection services and private companies. As there was often no standardized system for recording data, the estimated costs should be considered to be the minimum cost.

HARM PATHWAYS

TABLE 1: OVERVIEW OF ENVIRONMENTAL HARM ARISING FROM ILLICIT INDOOR CANNABIS CULTIVATION				
Production stage	**Activity**	**Direct environmental impact**	**Examples**	**Indirect environmental impact**
Pre-cultivation	Site preparation	Energy use	Installation of equipment or construction work on the cultivation facility	If non-renewable, the energy used contributes to abiotic resource depletion and climate change
Cultivation	Use of agricultural inputs: fertilizers	Water pollution: eutrophication;[i] air pollution: ammonium toxicity	Fertilizers high in nitrogen and phosphorus are sometimes applied exorbitantly to plants	Climate change
	Use of agricultural inputs: pesticides and herbicides	Toxicity to humans and ecosystems	Pesticide residues can be found on carbon filter cloths and on equipment;[ii] the impact may be higher if the pesticides used have been banned for environmental reasons[iii]	Health risks for people involved in cultivation and harvesting, or in dismantling installations
	Emission of biogenic volatile organic compounds	Air pollution: ozone formation	Concentrations of highly reactive terpenes above plants[iv, v]	Air quality effects on human health: reduced health and increased burden of diseases
	Lighting, HVAC and dehumidification	Energy use and risk of air pollution	Use of high-intensity grow lights and other indoor tools that can maintain temperatures or other environmental conditions needed for cannabis cultivation[vi]	Risk of fire, especially when lights are poorly installed; fires create air pollution and more waste; if non-renewable, the energy used contributes to abiotic resource depletion; stratospheric ozone depletion if HVAC equipment uses old refrigerant technologies
	Irrigation	Fresh water use; energy use	Automatic drip irrigation systems[vii]	Soil and water pollution
Distribution	Transportation	Air pollution; energy use		

TABLE 1 (CONTINUATION): OVERVIEW OF ENVIRONMENTAL HARM ARISING FROM ILLICIT INDOOR CANNABIS CULTIVATION				
Production stage	**Activity**	**Direct environmental impact**	**Examples**	**Indirect environmental impact**
Processing	Use of precursor chemicals and other substances (e.g. gasoline)	Discarding of (untreated) chemical waste	Some methods used to extract psychoactive substances use large amounts of chemical solvents[vii, viii]	Soil and water pollution (e.g. through dumping)
	Use of water	Fresh water use		
	Use of electricity	Energy use	For equipment used during the drying or extraction process; occurs during various stages of drying (if electric drying ovens and dehydrators are used), extraction and production (e.g. during purification and crystallization)	
Marketing	Transportation	Air pollution		
Consumption	Drug use	Water pollution	Contamination of wastewater as cannabinoids such as tetrahydrocannabinol and 11-Nor-9-carboxy-Δ^9-tetrahydrocannabinol (THC-COOH), or benzoylecgonine and norcocaine (for cocaine) are excreted[ix]	Potential impact on aquatic ecosystems and biodiversity

i Eutrophication is the gradual increase in the concentration of phosphorus, nitrogen and other plant nutrients in aquatic ecosystems.

ii Eva Cuypers et al., 'The Use of Pesticides in Belgian Illicit Indoor Cannabis Plantations', *Forensic Science International* 277 (August 2017): 59–65, https://doi.org/10.1016/j.forsciint.2017.05.016.

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iv Chi-Tsan Wang et al., 'Potential Regional Air Quality Impacts of Cannabis Cultivation Facilities in Denver, Colorado', *Atmospheric Chemistry and Physics* 19 (20 November 2019): 19373, https://doi.org/10.5194/acp-19-13973-2019.

v Vera Samburova et al., 'Dominant Volatile Organic Compounds (VOCs) Measured at Four Cannabis Growing Facilities: Pilot Study Results', *Journal of the Air & Waste Management Association* 69, no. 11 (2 November 2019).

vi Hailey M. Summers, Evan Sproul, and Jason C. Quinn, 'The Greenhouse Gas Emissions of Indoor Cannabis Production in the United States', *Nature Sustainability* 4, no. 7 (July 2021).

vii While water use is on average lower than in outdoor settings, it is still high compared with other crops. See, for example, Zhonghua Zheng, Kelsey Fiddes, and Liangcheng Yang, 'A Narrative Review on Environmental Impacts of Cannabis Cultivation', *Journal of Cannabis Research* 3, no. 1 (December 2021): 3. and Houston Wilson et al., 'First Known Survey of Cannabis Production Practices in California', *California Agriculture* 73, no. 3 (September 2019).

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TABLE 2: OVERVIEW OF ENVIRONMENTAL HARM ARISING FROM ILLICIT OUTDOOR DRUG CROP CULTIVATION				
Production stage	**Activity**	**Direct environmental impact**	**Examples**	**Indirect environmental impact**
Pre-cultivation	Field preparation	Energy use; land-use change with risk of environmental effects	Deforestation and forest fragmentation; uprooting of other plants	Soil erosion, biodiversity loss, indirect effects of forest fragmentation (e.g. on biodiversity and ecosystem support functions[i]), disruption of the water cycle, etc.; climate change
Cultivation	Use of agricultural inputs: fertilizers	Water pollution: eutrophication; air pollution: ammonium toxicity	Fertilizers high in nitrogen and phosphorus are sometimes applied exorbitantly to plants	Climate change
	Use of agricultural inputs: pesticides[ii] and herbicides	Human and ecosystem toxicity	Contamination of watersheds;[iii] the impact may be higher if the pesticides used have been banned for environmental reasons	Health risks for people involved in cultivation and harvesting or in dismantling plantations; biodiversity loss through the food chain[iv]
	Emission of biogenic volatile organic compounds	Air pollution in the form of ground-level ozone emissions[v]		Air quality effects on human health: reduced health or increased burden of diseases
	Irrigation	Fresh water use; energy use	Increased salinization and decreased groundwater levels in Afghanistan because of the use of pumps and deep wells in dry areas[vi]	Soil and water pollution; water depletion
Marketing	Transportation	Air pollution		

TABLE 2 (CONTINUATION): OVERVIEW OF ENVIRONMENTAL HARM ARISING FROM ILLICIT OUTDOOR DRUG CROP CULTIVATION

Production stage	Activity	Direct environmental impact	Examples	Indirect environmental impact
Processing	Use of precursor chemicals and other substances (e.g. gasoline)	Discarding of (untreated) chemical waste	Some methods used to extract psychoactive substances use large amounts of chemical solvents[vii, viii]	Soil and water pollution (e.g. through dumping)
	Use of water	Fresh water use		
	Use of electricity	Energy use	For equipment used during the drying or extraction process; occurs during various stages of drying (if electric drying ovens and dehydrators are used), extraction and production (e.g. during purification and crystallization)	
Marketing	Transportation	Air pollution		
Consumption	Drug use	Water pollution	Contamination of wastewater as cannabinoids such as tetrahydrocannabinol and 11-Nor-9-carboxy-Δ⁹-tetrahydrocannabinol (THC-COOH), or benzoylecgonine and norcocaine (for cocaine) are excreted[ix]	Potential impact on aquatic ecosystems and biodiversity

i Jenny Zambrano et al., 'Investigating the Direct and Indirect Effects of Forest Fragmentation on Plant Functional Diversity', ed. Berthold Heinze, *PLOS ONE* 15, no. 7 (2 July 2020).

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TABLE 3: OVERVIEW OF ENVIRONMENTAL HARM ARISING FROM ILLICIT MANUFACTURE OF SYNTHETIC DRUGS				
Production stage	**Activity**	**Direct environmental impact**	**Examples**	**Indirect environmental impact**
Pre-production	Site preparation	Energy use	Installation of equipment and construction of laboratories	If non-renewable, the energy used contributes to abiotic resource depletion and climate change
Production	Precursor conversion	Chemical waste by-products and energy use	Heating of chemical mixtures	
	Synthesis/ cooking	Chemical waste by-products and energy use		
	Separation of drug base	Chemical waste		
	Purification of crude base oil	Chemical waste and energy use		
	Crystallization	Chemical waste	Use of sulphuric acid and hydro-chloric acid	
	Product finalization	Energy use	Drying or processing into tablets	
Distribution	Transportation	Air pollution		
Consumption	Drug use	Water pollution	Contamination of wastewater with remnants of drugs and their metabolites	Potential impact on aquatic ecosystems and biodiversity

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GLOSSARY

amphetamine-type stimulants — a group of substances composed of synthetic stimulants controlled under the Convention on Psychotropic Substances of 1971 and from the group of substances called amphetamines, which includes amphetamine, methamphetamine, methcathinone and the "ecstasy"-group substances (3,4-methylenedioxymethamphetamine (MDMA) and its analogues).

amphetamines — a group of amphetamine-type stimulants that includes amphetamine and methamphetamine.

annual prevalence — the total number of people of a given age range who have used a given drug at least once in the past year, divided by the number of people of the given age range, and expressed as a percentage.

coca paste (or coca base) — an extract of the leaves of the coca bush. Purification of coca paste yields cocaine (base and hydrochloride).

"crack" cocaine — cocaine base obtained from cocaine hydrochloride through conversion processes to make it suitable for smoking.

cocaine salt — cocaine hydrochloride.

drug use — use of controlled psychoactive substances for non-medical and non-scientific purposes, unless otherwise specified.

fentanyls — fentanyl and its analogues.

new psychoactive substances — substances of abuse, either in a pure form or a preparation, that are not controlled under the Single Convention on Narcotic Drugs of 1961 or the 1971 Convention, but that may pose a public health threat. In this context, the term "new" does not necessarily refer to new inventions but to substances that have recently become available.

opiates — a subset of opioids comprising the various products derived from the opium poppy plant, including opium, morphine and heroin.

opioids — a generic term that refers both to opiates and their synthetic analogues (mainly prescription or pharmaceutical opioids) and compounds synthesized in the body.

problem drug users — people who engage in the high-risk consumption of drugs. For example, people who inject drugs, people who use drugs on a daily basis and/or people diagnosed with drug use disorders (harmful use or drug dependence), based on clinical criteria as contained in the Diagnostic and Statistical Manual of Mental Disorders (fifth edition) of the American Psychiatric Association, or the International Classification of Diseases and Related Health Problems (tenth revision) of WHO.

people who suffer from drug use disorders/people with drug use disorders — a subset of people who use drugs. Harmful use of substances and dependence are features of drug use disorders. People with drug use disorders need treatment, health and social care and rehabilitation.

harmful use of substances — defined in the International Statistical Classification of Diseases and Related Health Problems (tenth revision) as a pattern of use that causes damage to physical or mental health.

dependence — defined in the International Statistical Classification of Diseases and Related Health Problems (tenth revision) as a cluster of physiological, behavioural and cognitive phenomena that develop after repeated substance use and that typically include a strong desire to take the drug, difficulties in controlling its use, persisting in its use despite harmful consequences, a higher priority given to drug use than to other activities and obligations, increased tolerance, and sometimes a physical withdrawal state.

substance or drug use disorders — referred to in the Diagnostic and Statistical Manual of Mental Disorders (fifth edition) as patterns of symptoms resulting from the repeated use of a substance despite experiencing problems or impairment in daily life as a result of using substances. Depending on the number of symptoms identified, substance use disorder may be mild, moderate or severe.

prevention of drug use and treatment of drug use disorders — the aim of "prevention of drug use" is to prevent or delay the initiation of drug use, as well as the transition to drug use disorders. Once a person develops a drug use disorder, treatment, care and rehabilitation are needed.

REGIONAL GROUPINGS

The *World Drug Report* uses a number of regional and subregional designations. These are not official designations, and are defined as follows:

AFRICA

- East Africa: Burundi, Comoros, Djibouti, Eritrea, Ethiopia, Kenya, Madagascar, Mauritius, Rwanda, Seychelles, Somalia, South Sudan, Uganda, United Republic of Tanzania and Mayotte
- North Africa: Algeria, Egypt, Libya, Morocco, Sudan and Tunisia
- Southern Africa: Angola, Botswana, Eswatini, Lesotho, Malawi, Mozambique, Namibia, South Africa, Zambia, Zimbabwe and Reunion
- West and Central Africa: Benin, Burkina Faso, Cabo Verde, Cameroon, Central African Republic, Chad, Congo, Côte d'Ivoire, Democratic Republic of the Congo, Equatorial Guinea, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Mauritania, Niger, Nigeria, Sao Tome and Principe, Senegal, Sierra Leone, Togo and Saint Helena

AMERICAS

- Caribbean: Antigua and Barbuda, Bahamas, Barbados, Cuba, Dominica, Dominican Republic, Grenada, Haiti, Jamaica, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, Trinidad and Tobago, Anguilla, Aruba, Bonaire, Netherlands, British Virgin Islands, Cayman Islands, Curaçao, Guadeloupe, Martinique, Montserrat, Puerto Rico, Saba, Netherlands, Sint Eustatius, Netherlands, Sint Maarten, Turks and Caicos Islands and United States Virgin Islands
- Central America: Belize, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua and Panama
- North America: Canada, Mexico, United States of America, Bermuda, Greenland and Saint-Pierre and Miquelon
- South America: Argentina, Bolivia (Plurinational State of), Brazil, Chile, Colombia, Ecuador, Guyana, Paraguay, Peru, Suriname, Uruguay, Venezuela (Bolivarian Republic of) and Falkland Islands (Malvinas)

ASIA

- Central Asia and Transcaucasia: Armenia, Azerbaijan, Georgia, Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan
- East and South-East Asia: Brunei Darussalam, Cambodia, China, Democratic People's Republic of Korea, Indonesia, Japan, Lao People's Democratic Republic, Malaysia, Mongolia, Myanmar, Philippines, Republic of Korea, Singapore, Thailand, Timor-Leste, Viet Nam, Hong Kong, China, Macao, China, and Taiwan Province of China
- South-West Asia: Afghanistan, Iran (Islamic Republic of) and Pakistan
- Near and Middle East: Bahrain, Iraq, Israel, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syrian Arab Republic, United Arab Emirates, Yemen and State of Palestine
- South Asia: Bangladesh, Bhutan, India, Maldives, Nepal and Sri Lanka

EUROPE

- Eastern Europe: Belarus, Republic of Moldova, Russian Federation and Ukraine

- South-Eastern Europe: Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Montenegro, North Macedonia, Romania, Serbia, Türkiye[f] and Kosovo[g]
- Western and Central Europe: Andorra, Austria, Belgium, Cyprus, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Liechtenstein, Lithuania, Luxembourg, Malta, Monaco, Netherlands, Norway, Poland, Portugal, San Marino, Slovakia, Slovenia, Spain, Sweden, Switzerland, United Kingdom of Great Britain and Northern Ireland, Faroe Islands. Gibraltar and Holy See

OCEANIA

- Australia and New Zealand: Australia and New Zealand
- Polynesia: Cook Islands, Niue, Samoa, Tonga, Tuvalu, French Polynesia, Tokelau and Wallis and Futuna Islands
- Melanesia: Fiji, Papua New Guinea, Solomon Islands, Vanuatu and New Caledonia
- Micronesia: Kiribati, Marshall Islands, Micronesia (Federated States of), Nauru, Palau, Guam and Northern Mariana Islands

f Further to the communication dated 31 May 2022 from the permanent mission addressed to the Executive Office of the Secretary-General, the country name was changed from the former name of the Republic of Turkey (former short form: Turkey), with immediate effect. The *World Drug Report 2022* was prepared before that date and thus uses the former name in its reporting and analysis, except for the maps that were finalized more recently.

g References to Kosovo shall be understood to be in the context of Security Council resolution 1244 (1999).

UNODC
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UNODC Research

Vienna International Centre, PO Box 500, 1400 Vienna, Austria
Tel: +(43) (1) 26060-0, Fax: +(43) (1) 26060-5866, www.unodc.org

Consisting of five separate booklets, the *World Drug Report 2022* provides an in-depth analysis of global drug markets and examines the nexus between drugs and the environment within the bigger picture of the Sustainable Development Goals, climate change and environmental sustainability.

Booklet 1 summarizes the four subsequent booklets by reviewing their key findings and highlighting policy implications based on their conclusions. Booklet 2 provides an overview of the global demand for and supply of drugs, including an analysis of the relationship between illicit drug economies and situations of conflict and weak rule of law. Booklet 3 reviews the latest trends in the global markets for opioids and cannabis at the global and regional levels, and includes a discussion of the potential impact of changes in opium poppy cultivation and opium production in Afghanistan, and an analysis of early indications of the impact of cannabis legalization on public health, public safety, market dynamics and criminal justice responses in selected jurisdictions. Booklet 4 presents the latest trends in and estimates of the markets for various stimulants – cocaine, amphetamines and "ecstasy" – and new psychoactive substances, both at the global level and in the most affected subregions, including an analysis of different coca bush eradication strategies and a focus on the expansion of the methamphetamine market in South-West Asia. Booklet 5 delves into the nexus between drugs and the environment, providing a comprehensive overview of the current state of research into the direct and indirect effects of illicit drug crop cultivation and drug manufacture, as well as drug policy responses on the environment.

The *World Drug Report 2022* is aimed not only at fostering greater international cooperation to counter the impact of the world drug problem on health, governance and security, but also, with its special insights, at assisting Member States in anticipating and addressing threats from drug markets and mitigating their consequences.

The accompanying statistical annex is published on the UNODC website:
www.unodc.org/unodc/en/data-and-analysis/world-drug-report-2022.html

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