

4.1 Production

4.1.1 Challenges in estimating the production of pure cocaine HCl

For many years, UNODC has estimated the potential production of cocaine for each producing country with the purpose of providing information on the global supply of cocaine. Potential production refers to the amount of cocaine that would be produced if all the leaves harvested from the area under coca cultivation in one year would be converted into 100% pure cocaine hydrochloride (HCl).¹ The reference to 'potential' production underscores the fact that the recovery of cocaine from the leaves may not be absolute (that is, 100% recovery). The term *laboratory efficiency* is therefore employed as a measure of how efficient a particular process is. Coca paste and cocaine base (intermediate products of the transformation process from leaves to cocaine HCl) can also be marketed and consumed. In addition, these intermediate products and leaves may be seized before they are processed into cocaine.

Traditionally, the production of cocaine HCl includes three steps. The first is the conversion of the coca leaf into coca paste; this is almost always done very close to the coca fields to cut down on the transport of the coca leaves. The second phase is the conversion of coca paste into cocaine base. The final stage is conversion of base to HCl. In recent years, this process has been cut into two stages, where leaves are converted directly to cocaine base.

In order to estimate the total potential production of pure cocaine HCl, the following elements need to be measured:

- Cultivation
- Quantity of leaves per ha per year (yield)
- Quantity of leaves needed to produce 1 kg of 100% pure cocaine HCl. This includes the following elements:
 - Alkaloid content of leaves
 - Laboratory efficiency (the percentage of alkaloid content that can be extracted in the laboratory process)

1 In Peru and the Plurinational State of Bolivia, a certain amount of coca leaves (leaves harvested from 12,000 ha of coca bush grown under law 1008 in Bolivia and 9,000 mt of coca leaves in Peru are estimated to be used for traditional purposes) is subtracted from the calculation of potential cocaine production.

Over the years, UNODC has undertaken studies in the three producing countries of the Plurinational State of Bolivia, Colombia and Peru.² Of the three components needed to estimate the potential production of cocaine HCl, UNODC regularly measures cultivation and yield,³ but does not undertake any study to measure alkaloid content and laboratory efficiency. For this last step, it relies on an external source, the US Drug Enforcement Administration (DEA). The DEA is the only organization that has undertaken scientific studies to measure the alkaloid content of the coca leaves and laboratory efficiency in the Andean countries. In Colombia, the estimation process followed by UNODC differs from that used in the other two Andean countries. Using farmers' interviews, UNODC can estimate the quantity of cocaine base produced from the leaves, although it cannot estimate its quality.⁴ Furthermore, it needs to estimate the average purity of the cocaine base produced and the conversion factor between cocaine base and cocaine HCl.

There is a certain level of uncertainty in each of the three stages necessary to estimate potential cocaine production.

Estimating cultivation

Since 1999-2002,⁵ UNODC's Illicit Crop Monitoring Programme (ICMP) has been monitoring coca cultivation in three Andean countries, the Plurinational State of Bolivia, Colombia and Peru. The cultivation estimates provide the situation at the end of each year. All coca surveys use remotely sensed images, that is, satellite images or aerial photographs,⁶ which is the best means

- 2 In each country, UNODC has project teams to conduct the surveys with assistance from a team of experts at UNODC headquarters in Vienna.
- 3 Yield studies are carried out by UNODC in Colombia (provinces are covered every five years on a rotating basis), the Plurinational State of Bolivia (Yungas of La Paz, 2005) and Peru (three major growing regions in 2003). No yield studies have been so far carried out by UNODC in Chapare/Bolivia where DEA yield estimates are used.
- 4 Through farmers' interviews, UNODC can only estimate the quantity of cocaine base produced, not its purity, since farmers are unaware of the level of purity of what they produce.
- 5 Since 1999 in Colombia, 2000 in Peru and 2002 in the Plurinational State of Bolivia. Since 2006, ICMP has been monitoring coca in Ecuador as well; however the extent of coca cultivation found there is negligible.
- 6 There are differences between satellite images, for example, in the

to undertake a systematic monitoring of the insecure and often inaccessible cultivation areas.

Every year, UNODC purchases satellite images from commercial image providers of all the areas where coca is grown. It is often a challenge to get images that are cloud-free, and therefore, the images are acquired over a period of several months, tasking the satellites or searching in recent archives. After acquiring suitable images, a team of experts systematically digitizes all the fields with coca bushes.⁷ Identification of the crops can be challenging. Satellite images are taken at a height of hundreds of kilometres above ground and do not give the same detailed image as a snapshot taken from the ground. On the other hand, satellite images contain more information than a normal photo, since the satellites have extra sensors to register infrared colours. Precisely these infrared colours help to distinguish vegetation types.⁸

In the classification process, additional geographical information is used to judge whether the fields appearing in the satellite image are really coca fields. For example, information on the places that were eradicated or sprayed is used as well as information from former surveys or contextual information, such as typical shapes, sizes and locations of coca fields. The interpretation of this diverse set of criteria is difficult to automate and is mostly done by human interpreters. All interpreters have extensive experience in working with satellite images and they are all familiar with the coca cultivation areas. The interpreters follow so-called interpretation keys to avoid systematic errors or differences between the interpreters.⁹

Monitoring with satellite images should always be accompanied by ground control. Ideally these controls are performed by field visits throughout the monitored area. Since access to the ground in coca growing regions is often dangerous and difficult, UNODC performs ground 'truthing' by overflights with helicopters or small aeroplanes. Moreover, the results of the satellite interpretations are subject to independent quality controls with detailed aerial photos.

■ ■ detail ('spatial resolution' or 'pixel size') of the images. The more detailed, the more expensive the images. However, the area to be monitored in Colombia is about 20 times larger than the areas in Peru or the Plurinational State of Bolivia, and therefore, the type of images is not the same in the three countries.

7 The full coverage of all the areas helps the governments to have local information on changes and target specific crop reduction programmes.

8 Coca is a bush and the leaves can be harvested throughout the year. Therefore, the crop stage can vary by field but also within a field. At the time a satellite image is taken, a field can contain different crops in different growing stages, which gives a different appearance in the satellite images.

9 The keys were developed with the assistance of the University of Natural Resources and Applied Life Sciences in Vienna.

Estimating yield

Coca leaf yield is affected by unpredictable factors such as weather and plant diseases, as well as by eradication activities. The effect of these factors varies not only from year to year and during the course of a year but also from one cultivating region to the other. Since 2004, UNODC, in cooperation with the respective governments, has undertaken coca leaf yield studies in many coca growing regions in the Plurinational State of Bolivia, Colombia and Peru. In the Plurinational State of Bolivia, a yield study was carried out in 2005 in the Yungas region, where the annual yield was estimated at 1.3 mt of sun-dried leaves per hectare. In Chapare, the other cultivating region, UNODC relies on DEA estimates, which report a yield of 2.7 mt/ha. In Peru, UNODC undertook a yield study in 2003, estimating the annual average yield to 2.2 mt/ha of sun-dried leaves. In Colombia, starting in 2004-2005, UNODC/SIMCI fields a yearly yield study which covers one or two regions on a rotating basis. The core element of these studies is the controlled harvest of mature coca fields.

The challenges related to the estimation of the annual yield relate to the difficulties of measuring the different harvests occurring in one year (four on average) and capturing the variation that the yield may have from one year to another. Ideally, the yield should be measured every year, in order to consider the climatic and environmental changes. However, yield studies need substantial resources, and not all areas under coca cultivation are accessible to field researchers for security reasons.

Latest coca yield estimates

Source: UNODC studies

Country, region	Year of study	Yield (mt/ha)
Bolivia, Yungas	2005	1.3 mt/ha sun-dried
Bolivia, Chapare	2006 (Source: DEA)	2.7 mt/ha sun-dried
Peru	2003	2.2 mt/ha sun-dried
Colombia, Meta-Guaviare	2008	5.1 mt/ha fresh leaf
Colombia, Sur de Bolívar	2007	5.7 mt/ha fresh leaf
Colombia, Putumayo-Caquetá	2008	4.1 mt/ha fresh leaf
Colombia, Orinoco	2005	7.1 mt/ha fresh leaf
Colombia, Pacífico	2009	3.8 mt/ha fresh leaf
Colombia, Catatumbo	2007	4.2 mt/ha fresh leaf
Colombia, Sierra Nevada	2007	2.9 mt/ha fresh leaf

Conversion factors from coca leaves to cocaine HCl

Source: DEA scientific studies

Country	Year of DEA study	Conversion factor ¹¹ (quantity of leaves needed to produce 1 kg of 100% pure cocaine HCl)
Plurinational State of Bolivia	1993	370 kg sun-dried (Chapare) 315 kg sun-dried (Yungas)
Plurinational State of Bolivia	2007-2008	256 kg sun-dried (Chapare) 244 kg sun-dried (Yungas)
Peru	1994	400 kg sun-dried
Peru	2005	220 kg sun-dried

Conversion factor from coca leaves to cocaine

Estimating the conversion factor from coca leaves to cocaine requires two steps: i) measuring the alkaloid content of the leaves, and ii) calculating the efficiency used by traffickers in the laboratory conversion process where cocaine base is converted into cocaine HCl. The alkaloid content of the leaves can be measured by analysing the chemical composition of a sample of coca leaves from the field. Studies have shown that it varies across geographical regions, but it does not significantly change over time. Alkaloid content is highest in Peru and the Plurinational State of Bolivia, where it is about 0.7%, and lowest in Colombia, where it is about 0.53%.¹⁰

Laboratory efficiency is more difficult to measure as there are different influencing factors: quality of the raw material and precursor chemicals used, the technical processing method employed, the size and sophistication of laboratories, and the skill and experience of local workers and chemists. Studies to measure the efficiency are carried out by trying to simulate the real environment where traffickers process cocaine in a laboratory. According to these studies, there are two main methods to produce cocaine: the solvent extraction method and the acid extraction method. The solvent method is thought to be the most efficient; however, traffickers are making the acid extraction method very efficient in Peru, where this method is most used.¹¹

The impact of conversion factors in the production estimates for the three Andean countries

According to the scientific studies conducted by the DEA, in the last decade, there has been an increase in the efficiency of the clandestine laboratories employed in the three Andean countries, which has resulted in different conversion factors from leaves to cocaine. These changes are mainly due to the higher percentage of traffickers using more efficient methods to extract the cocaine.

Until 2009, UNODC used the conversion factors obtained by the DEA in its previous round of studies dated 1994 in Peru and 1993 in the Plurinational State of Bolivia. In recent years, the DEA obtained new conversion factors which lead to a higher estimate of cocaine production (showing the need for a lower amount of leaves to produce pure cocaine).

In Colombia as well, more recent information obtained by UNODC shows that the conversion from cocaine base to cocaine HCl requires updated parameters:

Process used by UNODC to estimate 100% pure cocaine HCl from cocaine base of unknown purity

Source: DEA scientific studies

Cocaine base to cocaine HCl	1:0.9 (1 kg of base needed to produce 0.9 kg cocaine HCl)
Cocaine HCl	85% purity

Revised process to estimate pure cocaine HCl from cocaine base of unknown purity

Source: DEA scientific studies

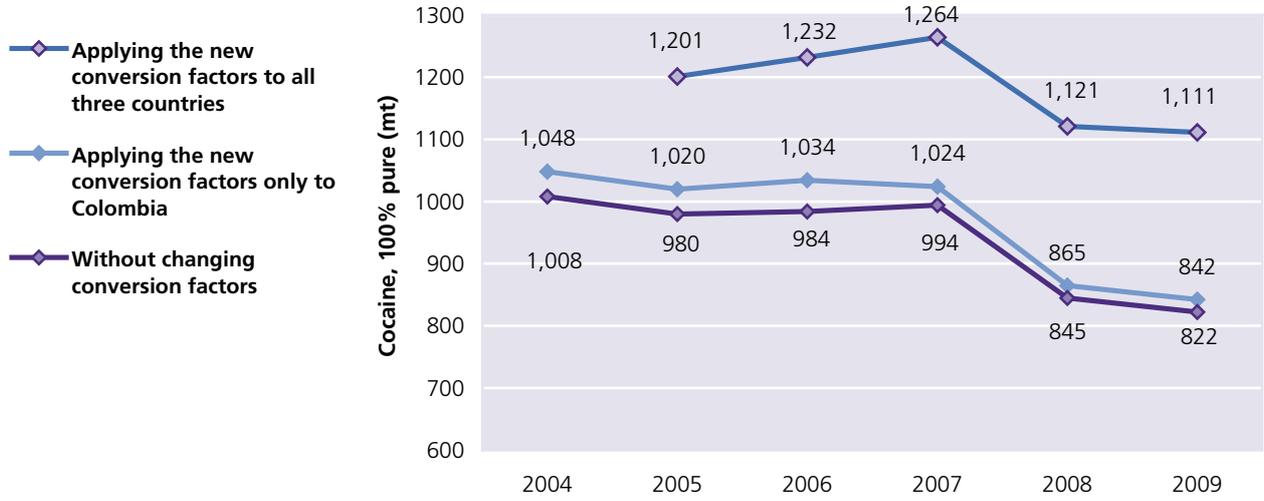
Average purity of cocaine base	81%
Cocaine base to cocaine HCl	1:1 (1 kg of base needed to produce 1 kg cocaine HCl)

¹⁰ Although these numbers represent a national average, they can not be used to calculate cocaine production at the national level since they hide very diversified alkaloid contents measured in different regions of the same country.

¹¹ Taking into consideration the alkaloid content of leaves and the laboratory efficiency.

Impact of conversion factors on global estimates of potential cocaine HCl production (mt)*

* Assuming that all other parameters remain unchanged.



Applying the results of the more recent DEA studies has an effect on the level of cocaine production estimated for the three Andean countries, as shown in the graph. UNODC is currently analysing in more detail these new conversion factors.