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OPERATIONS, INFORMATION & TECHNOLOGY | RESEARCH ARTICLE

Supply chains for illicit products: Case study of the global opiate production networks

John Miltenburg^{1*}

Abstract: In 2014, approximately 0.4% of the global adult population used illicit opiates (e.g. opium, heroin). Ninety five percent of these drugs were supplied by three global supply chains: the Afghanistan network, the Golden Triangle network, and the Mexico-Columbia network. The supply from these networks is insufficient to satisfy the demand. This paper analyzes the three supply chains (1) to understand how supply chains for illicit products operate and (2) to determine the elements in the supply chains that restrict the supply. Following the global production network (GPN) framework, the paper examines how product value is created and captured, markets and demand, networks, distribution routes, supply, inventory, and cost. The paper finds that the current high rate of seizures is the primary cause of the insufficient supply, that there is no easy way to increase supply, and that the most expedient solution is to boost the existing supply using additives (e.g. fentanyl). The paper gives insight into the characteristics of low capability supply chains and how increases in capability brought about by adapting to new conditions affects their design and operation.

Subjects: Operations Management; Supply Chain Management; Strategic Management; Management History; Pharmaceutical Industries; Economic Geography

Keywords: global supply chains; global production networks; case study: illicit drugs

1. Introduction

The United Nations Office on Drugs and Crime (2016a) reported that globally 1 in 20 adults (i.e. people between the ages of 15 and 64) used drugs in 2014 (i.e. 247 million people); 1 in 167 adults

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PUBLIC INTEREST STATEMENT

In 2014, approximately 0.4% of the global adult population used illicit opiates (e.g. opium, heroin). Ninety five percent of these drugs were supplied by three global production networks chains: the Afghanistan network, the Golden Triangle network, and the Mexico-Columbia network. The supply from these networks was insufficient to satisfy the demand. This paper analyzes the three networks to understand how networks for illicit products operate, and to determine the elements in the networks that restrict the supply. The paper finds that the current high rate of seizures is the primary cause of insufficient supply, that there is no easy way to increase supply, and that the most expedient solution is to boost the existing supply using additives (e.g. fentanyl). The paper gives insight into the characteristics of these low capability production networks.

suffered from drug use disorders (i.e. 29.5 million people); 1 in 1,000 adults were in drug treatment (i.e. 4.9 million people); and 1 in 24,000 adults had a drug-related death (i.e. 207,400 deaths). The UNODC reported that the number of adults who suffer from drug use disorders increased slightly during the period from 2006 to 2014. In 2006, it was 26 million adults or 0.6% of the adult population; in 2014 it was 29.5 million adults, which was still 0.6% of the adult population.

The UNODC also reported that globally in 2014 about 19 million adults used opiates (i.e. opium, heroin). This is 0.4% of the adult population and 8% of the adults who use drugs. By comparison about 0.4 and 3.8% of the adult population used cocaine and cannabis. The adults using opiates are supplied by three major opiate supply chains: the Afghanistan network, the Golden Triangle network, and the Mexico-Columbia network. The supply from these networks cannot satisfy the demand; the supply is too low. To increase supply the high-quality opiates produced by the networks are mixed with synthetic (i.e. man-made) additives, which are available and cost-effective. Fentanyl is a popular synthetic additive. Unfortunately when this is done, the purity and quality drop significantly.

The research problem in this paper is to analyze the three opiate supply chains: (1) to understand how production networks for illicit (i.e. illegal) products operate, and (2) to determine the elements in the production networks that restrict the supply and how this can be eased. The following methodology is used. The global production network (GPN) framework is used to assemble the elements that comprise the production networks. The elements are analyzed using data from the literature and from the United Nations Office on Drugs and Crime (UNODC). Because opiates are illicit, it is difficult to obtain this data; estimates and approximations must be used. United Nations Office on Drugs and Crime (2016b, 2017b) discuss these data and methodology issues.

This paper is organized as follows. Section 2 reviews the GPN framework. Sections 3–6 examine elements of the framework for the global opiate supply chains: how product value is created (Section 3), markets and demand (Section 4), networks, distribution routes, supply, inventory, and cost (Section 5), how product value is captured (Section 6). Discussion follows in Section 7. Section 8 gives a conclusion and describes areas where more research is needed. Appendix 1 gives a summary timeline of the activities, agents, costs, and profits in the global opiate supply chains.

2. The global production network (GPN) framework

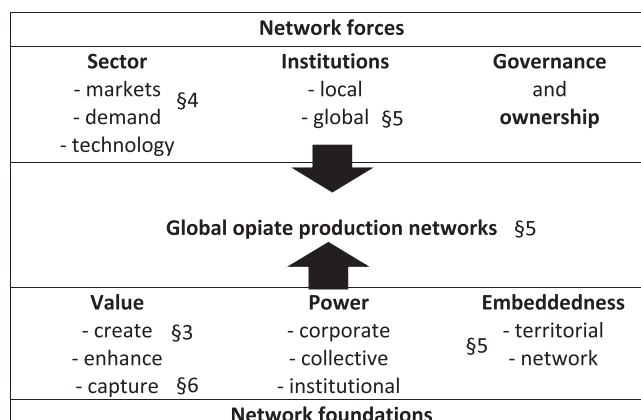
Various frameworks are used to analyze production networks. Friedli, Mundt, and Thomas (2014) give an over-review; see also Shi and Gregory (1998), Colotla, Shi, and Gregory (2003), Rudberg and West (2008), Jaehne, Li, Riedel, and Mueller (2009) and Miltenburg (2015). The framework used in this paper is called the global production network (GPN) framework. It was developed by economic geographers (Dicken, 2003; Henderson, Dicken, Hess, Coe, & Yeung, 2002) and is a familiar framework in social sciences (Coe, Dicken, & Hess, 2008; Reimer, 2007). Figure 1 shows the main elements in the GPN framework. The bottom of the figure shows three foundations on which a production network rests: (product) value, power, and embeddedness. The three forces at the top of the figure shape the design of the network: the (business) sector in which a production network operates, institutions impacting the network, and how power is exercised through governance and ownership structures.

There are three major global opiate production networks: the Afghanistan network, the Golden Triangle network, and the Mexico-Columbia network. In order to familiarize readers with the GPN framework, a brief overview of the foundations and forces in these three networks is now given. Detailed analyses of several foundations and forces follow in later sections as indicated by the § symbol in Figure 1.

2.1. Overview of network foundations

An activity or location is employed in a production network when it has characteristics that enable product value to be created, enhanced, or captured. Activities needed to create product value in a global opiate production network include: suitable land and climate for opium poppy cultivation, low cost labor, chemical supplies, opium and heroin processing laboratories, transportation, distribution,

Figure 1. Global production network (GPN) framework.



capital, and security. Capturing the value created requires accommodating government agencies and financial institutions. All of these are present in three locations: Afghanistan, the Golden Triangle, and Mexico-Columbia. They are also present along the distribution routes from these locations to global markets.

Where corporate, collective, and institutional power reside and how power is exercised affects network design. For opiates almost all corporate power resides in the (criminal) organizations that control distribution. Growers at the beginning of the supply chain and retailers at the end of the supply chain have very little (collective) power. Evidence of this are the decreasing prices growers receive for opium and the decreasing prices retailers charge for heroin. Wholesalers and distributors moving opiates from sources to markets are the supply chain members best able to capture high profits. Another type of power is institutional, which in the case of opiates is government. This power is moderate, as evidenced by the significant quantities of opiates that are seized by government agencies (currently between 20 and 25%). We will see that there were two occasions when government power was high: in 2001 when the government in Afghanistan halted opium cultivation, and between 2003 and 2007 when the governments of the United States and Columbia moved to stop opium cultivation in Columbia. However, this power could not be sustained: one year later in 2002 the government in Afghanistan fell and opium cultivation resumed, and, in Columbia, cultivation and production was simply moved from Columbia to Mexico.

Activities are not simply located in a particular place; often they are *embedded* in a place in the sense that the activities absorb and become absorbed by other activities in the place. This is called territorial embeddedness and it exists in Afghanistan, the Golden Triangle, and Mexico-Columbia. Opiate cultivation, production and distribution activities so affect the livelihood of large local populations that they are embedded in these places. But embeddedness is never so strong that it cannot be broken; as evidenced by the move of opium cultivation and processing from Columbia to Mexico. Another type of embeddedness is network embeddedness. This refers to the connections between members of the network. There is strong network embeddedness within and between criminal organizations and government agencies in all three networks.

2.2. Overview of network forces

Three forces further shape the production network: sector, institutions, and governance and ownership (Figure 1). Organizations in the same business sector serve similar markets and satisfy common demand, employ similar technology, and are affected by similar events. Local and global institutions such as governments, law enforcement, financial institutions, transportation services, and international agencies all influence the design and operation of the network. Governance and ownership structures affect how power is dispersed in the network. Many organizations comprise the production network. They may be owned or independent, be under short- or long-term agreement; they may differ in priorities, organizational structure, culture, attitude to others in the network, and so on.

In an opiate production network, the organizations controlling distribution exert the most power. Some of these organizations try to vertically integrate to extend their governance and increase their ownership over activities in the network.

3. Create product value

3.1. Opium

Opium is the name of the liquid produced inside the seed pods of the opium poppy plant. The opium liquid is comprised of morphine (about 12% in some poppy plant varieties), codeine (about 2%), thebaine, and other alkaloids. These chemicals as well as the seeds and other parts of the plant can be processed to produce powerful pain medication drugs. The morphine can also be processed into heroin.

Opium is a natural product. Vila, Martel, and Beauregard (2006) study a global production network for another natural product, softwood trees. However, their network is “divergent” whereas the networks in this paper are “convergent”. In a divergent network, the one raw material (softwood trees) becomes many different end products (different grades, dimensions, and lengths of lumber and wood chips). In a convergent network, the one raw material (opium poppy) becomes one or a small number of end products (heroin).

Table 1 shows the steps in the opium cultivation and heroin manufacture process. Step 1 is cultivation. There is one growing season each year. The opium poppy plant is planted in the spring, grows for three months, and flowers for two weeks. When the flower petals fall away, the seed pod (about the size and shape of a small egg) is exposed and the opium inside is ready for harvest. The opium is extracted by slitting the pod vertically several times. An opaque, milky liquid latex oozes out and dries on the outer surface of the pod. When the latex is semi-dried, it is scraped off the pod and is dried in open wooden boxes. The resulting product is called “dried opium latex”. The yield of dried opium latex from a single pod ranges from 10 to 100 milligrams (mg) and averages 80 mg. The yield of dried opium latex per hectare of cultivated land ranges from 8 to 60 kilograms (kg) and averages 20 kg. The dried opium latex is yellow-brown in color, bitter in taste, pungent in odor, and jelly-like in consistency. It is wrapped in plastic or leaves and is transported from the poppy fields to simple opium laboratories located nearby.

Step 2 in the figure is completed at the opium processing lab. Between 10 and 15 kg of dried opium latex are mixed with calcium oxide (i.e. lime) and 100 liters of boiling water in a steel drum.

Table 1. Steps in the opium cultivation and heroin manufacture process

Location	Processing step	Product	(a) Special chemicals used (b) Output quantity
Opium poppy field	Step 1	Opium plant	(a) none
		Dried opium latex	(b) 500 hectares of poppy plants produce 10,000 kilograms or 10 tonnes of “dried opium latex”
Opium lab	Step 2	Morphine base (morphine hydrochloride)	(a) hot water, calcium oxide (lime), ammonium chloride
			(b) 10 tonnes of dried opium latex yield 1 tonne of “morphine base”
Heroin lab	Step 3a	Diacetylmorphine	(a) acetic anhydride, chloroform, sodium bicarbonate (baking soda)
	Step 3b	Brown heroin base	(b) 1 tonne of morphine base yields 1 tonne of “diacetylmorphine”; 1 tonne of diacetylmorphine yields 1 tonne of “brown heroin base”
	Step 4	White heroin base	(a) hydrochloric acid, activated charcoal, ammonia solution
			(b) 1 tonne of brown heroin base yields 1 tonne of “white heroin base”
	Step 5	White heroin hydrochloride (No. 4 heroin)	(a) hydrochloric acid, acetone
			(b) 1 tonne of white heroin base yields 1 tonne of “No. 4 heroin”

Notes: (1) one metric tonne = 1,000 kilograms (kg). (2) Sources: Zerell, Ahrens, and Gerz (2005) and Opium - Poppy Cultivation, Morphine and Heroin Manufacture (2016). (3) The overall output from Step 1 to Step 5 is: 10 tonnes of opium (i.e. dried opium latex) yields 1 tonne of heroin (i.e. No. 4 heroin).

Waste sinks to the bottom and a morphine solution forms on the surface. This is drawn off, poured into large cooking pots, reheated with ammonium chloride, filtered, and heated again until it is reduced to a brown paste. The paste is called “morphine base” or “morphine hydrochloride”. The paste is poured and dried in molds to create brick-sized blocks (about 5 cm × 10 cm × 13 cm) weighing about 1.3 kg. Approximately 13 kg of dried opium latex (from about $13 \div 20 = 0.65$ hectares of land) are needed to make one 1.3 kg brick of morphine base. Morphine base is about 50% morphine. The bricks are bundled and packed for transport to a heroin lab. It takes about three weeks for a pack mule to transport 100 kg of bricks over 300 km of mountain trails from the simple opium labs to a larger heroin lab.

3.2. Heroin

Heroin labs are located in isolated areas where the strong odors produced by the lab’s chemicals are less likely to be detected (e.g. one chemical, acetic anhydride, has the pungent odor of pickles). In the next step (Step 3a), the morphine bricks are crushed and the dried powder is placed in enamel or stainless steel cooking pots. Acetic anhydride (a liquid) is added. The pot is heated for about two hours at a temperature of 85°C (but never boils). When the pot is cooled, the morphine and the acetic anhydride are chemically bonded, creating “diacetylmorphine”. Next (Step 3b), water and chloroform are added and the mixture is stirred and filtered to remove impurities. Sodium bicarbonate (i.e. baking soda) is added slowly. This causes carbon dioxide to form and bubble. When the bubbling stops, a crude form of heroin called “brown heroin base” has settled on the bottom of the pot.

In Step 4, the brown heroin base is dissolved in dilute hydrochloric acid. Activated charcoal is added. The solution sits for a time and is filtered. Dilute ammonia solution is added. The mixture is filtered; and the result is “white heroin base”. Next (Step 5) the base is dissolved in a solution of hydrochloric acid and acetone. The solution is filtered and sits for a time to allow the liquid to evaporate, leaving a white, fluffy, powder-like substance called “white heroin hydrochloride” or “No. 4 heroin”. It is 75–90% pure and can be inhaled (i.e. snorted), smoked, or injected.

The overall output from Step 1 to Step 5 is: 10 tonnes of dried opium latex yields 1 tonne of No. 4 heroin. (One metric tonne equals 1,000 kilograms, kg.) This is the standard average 10-to-1 conversion rate; i.e. 10 grams or kg or tonnes of opium yield 1 gram or kg or tonne of heroin. Skipping or replacing some of these steps in order to make processing easier, faster, or cheaper produces lower quality forms of heroin. An example is “black tar heroin”, which is produced in Mexico. After processing, this form of heroin still contains many impurities and is sometimes only 25–30% pure.

The heroin emerging from the heroin labs enters the distribution system (Section 5). The entire supply chain works as follows. Farmers grow opium poppy plants, harvest, and then produce the dried opium latex. They sell this to brokers for a price of \$140 US per kg. Brokers mark up the price 20% and sell to the opium lab (See also the summary timeline in Appendix 1). The opium lab sells to the heroin lab, which sells No. 4 heroin to wholesalers for a price of \$3,000 per kg. Wholesalers buy quantities of 20–100 kg. They transport these large quantities around the world, and then sell quantities of 1–10 kg for a price of \$30,000 per kg to local distributors who mix or “cut” the heroin and sell to retailers in quantities of 10–100 grams. Retailers also cut the heroin and sell to users in quantities of about 100 milligrams for a price of \$20 for 100 mg. (An average dosage for a user is 60 mg.) In this example, growers at the beginning of the supply chain receive \$140 per kg of opium (or $\$140 \times 10 = \$1,400$ for enough opium to produce one kg of heroin) and users at the end of the supply chain pay $\$20 \text{ per } 100 \text{ mg} \times 10^6 \text{ mg per kg} = \$200,000 \text{ per kg of heroin}$.

3.3. Production cost structure

In its 2005 report the UNODC reported that a typical poppy-cultivating farmer in Afghanistan had a 2.7 hectare farm of which 0.37 hectares was devoted to poppy cultivation; the rest of the land was for other crops (e.g. wheat and cotton) and for sheep pasture. Only a small fraction (about one-seventh) of a farmer’s land was cultivated with opium poppy plants. There are two reasons for this. Poppies deplete the soil; so they can only be grown once every five or more years in the same field.

In other years, they are alternated with the crops and sheep pasture. The other reason is the manual farm practices used. In 2003, for example, about 350 labor-days of work were required to cultivate 1 hectare of opium poppy (compared to 41 labor-days for wheat). 200 of the 350 labor-days were required during the 2–3 week harvest. This is $200 \text{ labor-days} \div (14\text{--}21 \text{ days}) \approx 10$ laborers per day to harvest 1 hectare. An average farm family is about seven members including about three who are too young or too old to work. So, a farmer using his own family can harvest $(7 - 3 = 4 \text{ laborers per day}) \div (10 \text{ labor-days per day to harvest 1 hectare}) = 0.4$ hectares of poppy plants. It is difficult to hire more laborers because the work is hard and relatively high-skilled. Therefore, a farmer cultivates opium poppy plants on only about 0.4 hectares.

If the yield is 20 kg of opium per hectare (Section 5.2), then an Afghan farmer on a 2.7 hectare farm with 0.37 hectares under opium poppy plant cultivation produces $0.37 \text{ hectares} \times 20 \text{ kg of opium per hectare} = 7.4 \text{ kg of opium per year}$. In 2014, the price for illicit opium in Afghanistan (i.e. the “farm-gate price”) was \$0.14 US per gram of opium. So farmer’s revenue is $7.4 \text{ kg of opium} \times 1,000 \text{ grams per kg} \times \$0.14 \text{ per gram of opium} = \$1,036$ per year for cultivating opium poppies. Now suppose the farmer’s other crops are wheat and cotton, that he plants one hectare of each, and that he leaves his remaining $2.7 - 0.37 - 1 - 1 = 0.33$ hectares for sheep pasture. Then for his wheat the farmer receives $1 \text{ hectare of land} \times 1,900 \text{ kg of wheat per hectare} \times \$0.41 \text{ per kg of wheat} = \780 ; and for his cotton he receives $1 \text{ hectare of land} \times 411 \text{ kg of cotton per hectare} \times \$1.5 \text{ per kg of cotton} = \617 . This production cost structure is one reason why opium poppies are such a valuable crop for small-scale farmers, and why opium poppy cultivation is deeply embedded in particular regions of the world, and, therefore, why it is difficult to eradicate opium poppy cultivation. Clemens (2008) gives other reasons why the possibilities for reducing opium cultivation and opiate production are low.

Note that in 2009, for example, when the farm-gate price for illicit opium in Afghanistan was \$0.075 per gram, the farm-gate price for licit (i.e. legal) opium in India was \$0.029 per gram (see Appendix 2). This indicates that the cost of opium poppy cultivation in Afghanistan (as described in the previous paragraph) is high relative to a nearby region like India. This suggests that if opium cultivation was legalized then it would be difficult for the (small scale, labor-intensive) Afghan farmers to be competitive with nearby, large-scale growers employing more modern farming practices.

3.4. Fentanyl

The term “opiates” refers to the products derived from the opium poppy plant. These are primarily opium, morphine and heroin. “Opoids” is a larger category. It includes the opiates and also includes synthetic (i.e. man-made) analogs of the opiates such as pharmaceutical drugs (e.g. oxycodone, hydromorphone, oxymorphone, fentanyl). Fentanyl is an opiod that is best known as a medication for chronic pain, especially for cancer patients. Pharmaceutical companies often produce it in the form of a patch that slowly releases pain medication through a patient’s skin. They also produce it as a powder and press it into pills. The cost to (illegally) purchase fentanyl from China is about \$10,000 per kg. If only the precursor chemicals are (illegally) purchased from China, then the fentanyl can be produced locally for a cost of about \$5,000 per kg. Fentanyl was legal in China until March 2017, when producing or selling it or its precursor chemicals became illegal.

Fentanyl is 15–25 times stronger than heroin. This means one kg of fentanyl can produce several kg of heroin-like products. For example, fentanyl can be pressed into pills that look like a prescription drug, e.g. OxyContin, which can be sold for about \$20 each. This can give a revenue of $50,000 \text{ pills} \times \$20 \text{ per pill} = \$1 \text{ million}$ for one kg of fentanyl (compared to \$200,000 for one kg of heroin). Fentanyl can also be mixed or cut into heroin so that one kg of “uncut heroin” becomes approximately 10 kg of “cut heroin”. If sold for the same price as uncut heroin, this would generate $10 \text{ kg} \times \$200,000 \text{ per kg} = \2 million of revenue. If sold at a lower price, then the revenue would be lower. In this way, fentanyl (or any other available inexpensive synthetic opiate) can be substituted for heroin if the price of heroin is high or if the supply is low.

4. Markets and demand

Figure 2 is a visual description of the types of drugs used in different regions of the world. The horizontal axis divides the world into regions: Africa, North America, etc. The vertical axis measures the proportion of adults in treatment for a particular drug disorder. The lengths of the bars indicate the types of drugs causing the disorder in three time periods: 2003, 2009, and 2014. For example, the bars for North America in 2014 indicate that 40-, 25-, 15-, 10-, and 10% of adults in treatment have problems with cannabis, opioids, cocaine, amphetamines, and other drugs, respectively. This data is used as an approximation or estimate of the demand for each type of drug in each region. Two patterns in the figure are important. First, there are differences between regions in the lengths of the bars. With respect to opioids there is a very high demand in Asia and all of Europe, and a lower demand in North America and Africa and Oceania. (Oceania is the region between Asia and the Americas that includes Australia.) Second, within each region the lengths of the bars do not change much from 2003 to 2014. These two patterns indicate that the variation in drugs used across regions is high, but the variation in drugs used across time in the same region is low.

Table 2 gives detailed data on the demand for opiates between 2000 and 2014. The first four columns give the number of adults (i.e. people between the ages of 15 and 64) who used opiates in 2000, 2007, and 2014 globally and in each region of the world. In 2000, for example, 14.94 million adults or 0.35% of the global adult population used opiates. Fourteen years later in 2014 the number of adults was 17.44 million people or 0.37% of the population. In North America, the number increased from 1.5 million people or 0.48% of the population in 2000, to 1.67 million or 0.50% in 2014. In general, the demand pattern did not change substantially between 2000 and 2014. Oceania appears to be an exception. However, the decrease in demand reported here is thought to be due to changes in how data is collected rather than to an actual decrease.

The second last column in Table 2 converts the demand from number of users to tonnes of heroin. We will see in Section 5.2 that the total global production of heroin in 2014 was 773 tonnes of which 25% or 193 tonnes were seized by government agencies, leaving $773 - 193 = 580$ tonnes of heroin available for global demand. If we assume that these 580 tonnes are consumed in proportion to the number of users, then the demands for heroin shown in the figure result. For example, North American users demand or consume $580 \times (1.67 \div 17.44) = 56$ tonnes of heroin. The last column in the figure shows the main source of heroin for each market. For example, Mexico is the largest source of heroin for users in North America (Section 5.1).

For many adult users, the daily dosage of heroin ranges from 5 to 100 mg per day and averages 60 mg per day. (Addicts use significantly more; 1 gram per day would not be unusual.) If an average

Figure 2. Drugs used in regions of the world during between 2003 and 2014.

Source: United Nations Office on Drugs and Crime (2016a, p. 9).

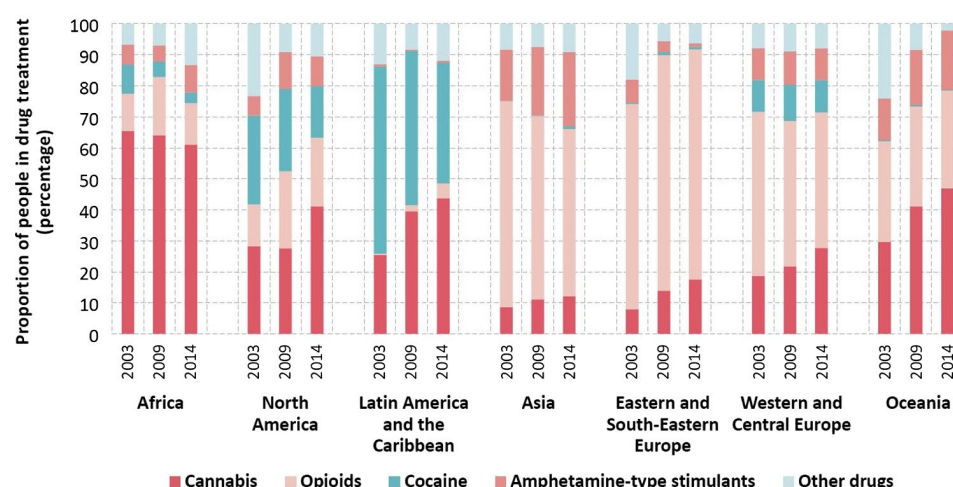


Table 2. Markets and demand for heroin in 2000, 2007, and 2014

Region/Market	Adult population using opiates number of people (millions); percent of population (%)			Production/ demand of heroin in 2014 (tonnes)	Largest source of heroin in 2014
	2000	2007	2014		
Global total	14.94; 0.35%	18.15; 0.40%	17.44; 0.37%	773	
North America (Canada, United States, Mexico, Caribbean)	1.50; 0.48%	1.41; 0.44%	1.67; 0.50%	56	Mexico
South America, Central America	0.36; 0.12%	0.85; 0.29%	0.42; 0.14%	14	Columbia
Eastern and South- Eastern Europe	2.99; 1.08%	2.37; 0.85%	1.89; 0.83%	63	Afghanistan
Western and Central Europe	1.57; 0.42%	1.38; 0.55%	1.31; 0.41%	44	Afghanistan
Africa	0.92; 0.20%	1.89; 0.35%	1.96; 0.31%	65	Afghanistan
Central Asia	7.46; 0.29%	0.34; 0.70%	0.45; 0.81%	15	Afghanistan
South Asia	Not available	3.64; 0.40%	2.89; 0.29%	96	Afghanistan
Near and Middle East Asia	Not available	2.30; 0.95%	3.47; 1.22%	115	Afghanistan
East and South-East Asia	Not available	3.89; 0.25%	3.35; 0.21%	111	Golden Triangle
Oceania	0.14; 0.63%	0.09; 0.40%	0.05; 0.20%	2	Golden Triangle

Sources: Compiled from UNODC, World Report on Drugs, documents published in 2001, 2008, and 2016.

adult user uses heroin four times a week, then they use $4 \times 60 = 240$ mg per week or 240 mg per week $\times 52$ weeks per year = 12.48 grams per year. Heroin is often sold in “bags” containing one tenth of a gram (100 mg) for \$20 US. So an average user may purchase three bags (300 mg) per week for \$60. This gives the following estimate of the global revenue: \$60 per week per user $\times 52$ weeks per year $\times 17.4$ million users = \$54.3 billion per year. In this calculation, the average demand is 12.48 grams per user per year and the global revenue is \$54.3 billion per year.

Another estimate of the average demand per user in 2014 would be: $(773 - 193)$ tonnes of heroin $\div 17.4$ million users = 33.33 grams per user per year. If the average retail price is \$100 per gram, then the average user spends $\$100 \times 33.33$ grams = \$3,333 per year on heroin and the resulting global revenue is $\$3,333$ per user $\times 17.4$ million users = \$58.0 billion per year. There are more sophisticated ways to estimate the average demand and the global revenue (United Nations Office on Drugs and Crime, 2016b). \$60 billion per year of global revenue and an average demand of 28 grams of heroin per user per year are reasonable, conservative estimates. These are the values used in this paper.

5. Opiate production networks

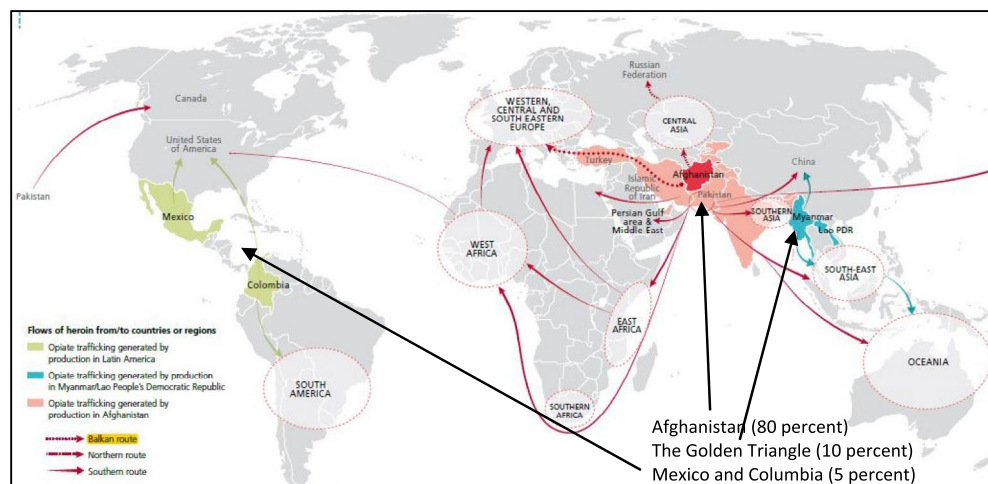
Heroin and opium are ideal trade products. Heroin is compact, does not need to be refrigerated, does not deteriorate, is easy to transport, and is easy to inventory. Profit margin is high and demand is steady and high. Heroin and opium have a long history of licit (i.e. legal) and illicit (i.e. illegal) global trade. Appendix 2 reviews that history and examines the effect that current globalization has on opiate trade.

5.1. Networks for illicit opiates

In 2016, approximately 6,380 tonnes of illicit opium were cultivated in about 49 countries. This was higher than 2015 but still 20% lower than the peak production in 2014. Three regions comprise the main sources of illicit opium (Figure 3): Afghanistan (Figure 4(a)), the Golden Triangle – about 950,000 square kilometers of mountainous terrain in Myanmar, Laos, and Thailand (Figure 4(b)), and Mexico and Columbia (Figure 4(c)). Corresponding to these main sources of supply are three major global

Figure 3. Main sources for illicit opium and heroin.

Source: United Nations Office on Drugs and Crime (2016a).



opiate production networks: the Afghanistan network, the Golden Triangle network, and the Mexico-Columbia network. Afghanistan is the largest network; in 2014 it produced about 80% of the world's illicit opium and heroin. The Golden Triangle is the second largest network, producing about 10%. Mexico and Columbia produce about 5% and are the largest suppliers to the United States market. The supply chain in each network is comprised of opium cultivation and processing, heroin processing, wholesale, distribution, and retail activities. A timeline for the supply chain is given in Appendix 1.

Opium and heroin leave Afghanistan along three main routes (Figure 4(a)): the Balkan route, the southern route, and the northern route. The Balkan route is the most important route. Opiates move through Iran, Turkey, south-eastern Europe, and then into markets in central and western Europe (Figure 3). The southern route moves opiates through Pakistan or Iran, by sea to the Gulf region, and into markets there and in southern Europe, or by sea to east Africa, overland to west Africa, and into markets in Africa and overseas to North America and Europe (Figure 3). It also moves opiates through Pakistan to markets in China. This route has grown in importance because of its ability to move opiates to markets in southern Europe and North America.

The northern route moves opiates north to neighboring states in central Asia (Turkmenistan, Uzbekistan and Tajikistan), to markets in the Russian Federation (Figure 3), and to markets in other countries in the Commonwealth of Independent States. This route declined in importance between 2008 and 2012, but regained its importance when the Russian economy improved.

Most of the heroin used in the world moves along the Balkan route (through Iran) and the southern route (through Pakistan). Evidence of this are the large quantities of opium and heroin seized in Iran and Pakistan. Figure 5(a) and (b) show data on seizures. Figure 5(a) shows that the total quantity of opium, morphine, and heroin seized annually from 2013 to 2015 is about 1,800 tonnes of opium or $1,800 \div 10 = 180$ tonnes of heroin. This is about 25% of the annual global production. The figure shows that the quantity seized peaked in 2011 and has remained fairly constant since then. The UNODC (2016a) reports that the average seizure rate was 10% from 1990 to 1997, 20% from 1998 to 2008, and 25% from 2009 to the present time. Figure 5(b) shows that the largest quantity of opiates seized is on the Balkan route (although not shown in the figure most of these seizures are in Iran), followed by Afghanistan (where the opium is grown and heroin is produced), and Pakistan (which is on the southern route), and in other parts of the southern route. About 80% of all global seizures are in these locations.

Figure 4. (a) Afghanistan is the largest source of illicit opium and heroin. Source: Business Insider (2014). (b) The Golden Triangle is the second largest source of illicit opium and heroin. Source: United Nations Office on Drugs and Crime (2017c). (c) Mexico is the third largest source of illicit opium and heroin. Source: Mexican Poppy Cultivation (2016).

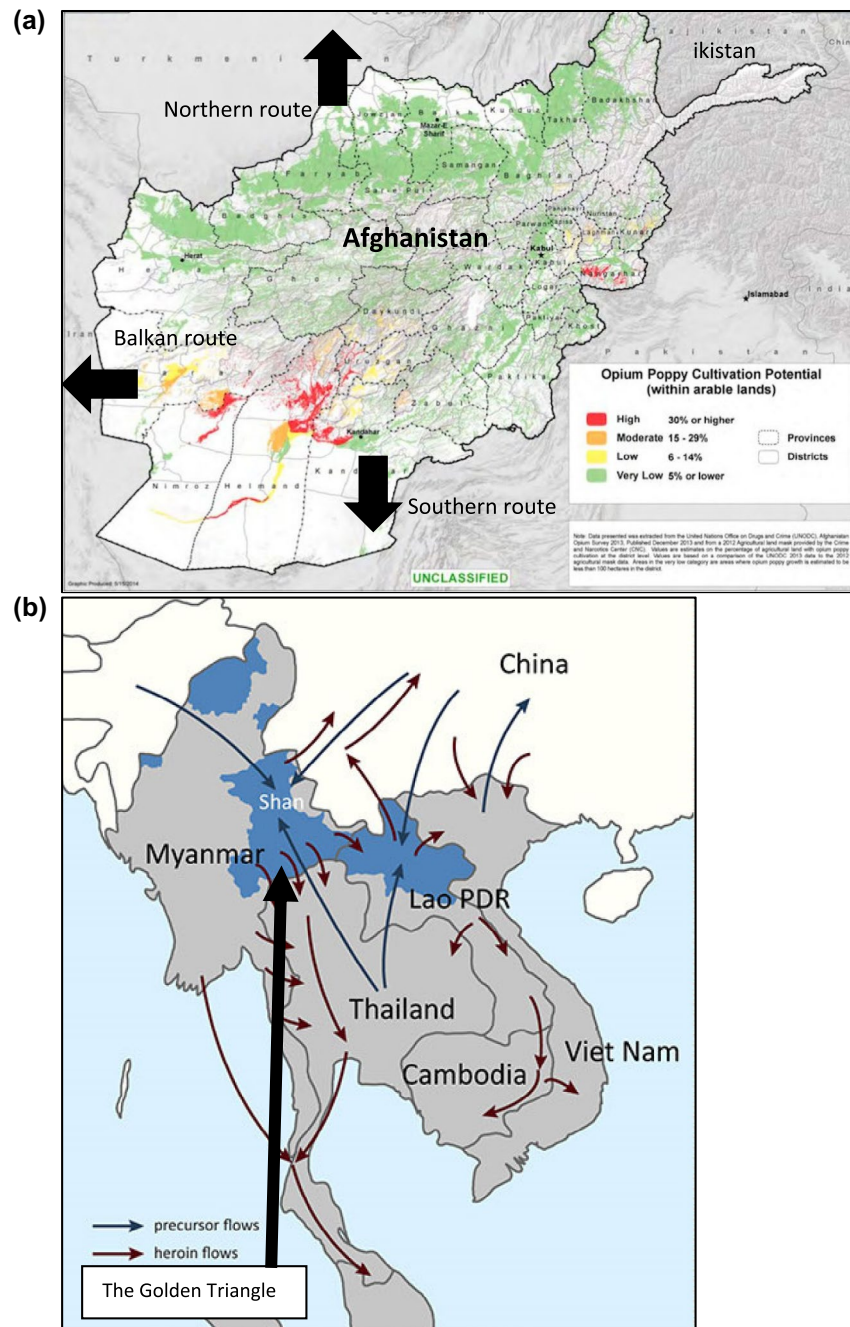


Figure 4. (Continued).



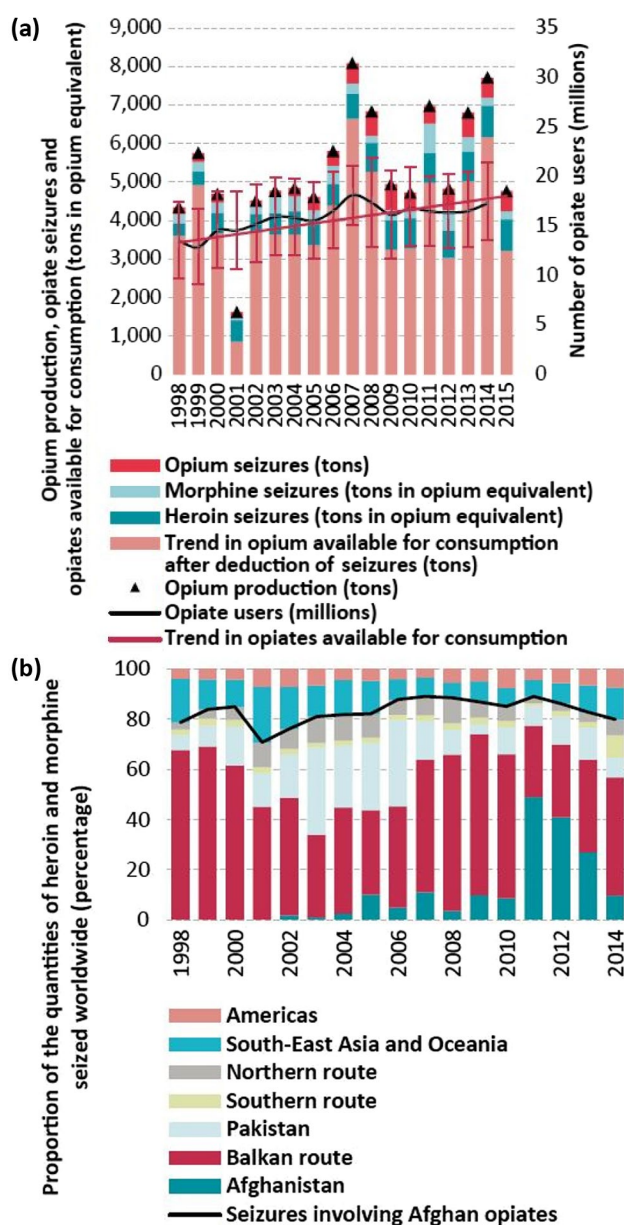
Opium poppy cultivation in Mexico (Figure 4(c)) is in the mountainous regions of the northern states of Chihuahua, Durango, Sinaloa, and Nayarit and the southern states of Guerrero and Oaxaca. From the poppy fields, dried opium latex is moved to opium and heroin labs at collection points in cities such as Iguala (at the crossroads of several highways including the interstate from Acapulco on the Pacific coast to Mexico City), and then to the points close to the Mexico–US border. There the heroin is moved by people and in vehicles across the border to markets in the United States. Heroin from Mexico supplies markets west of the Mississippi River and heroin from Colombia supplies markets east of the Mississippi River (Figure 4(c)).

5.2. Supply of illicit opiates

Table 3 describes the cultivation and production activities in the three opiate production networks and in the other areas of the world. The first column in the figure lists the sources of supply. They are Afghanistan, the Golden Triangle, Mexico-Columbia, and other areas of the world. The last row gives the total global values. The next four columns show the amount of land under opium poppy cultivation in 2000 and from 2013 to 2015. The amount of land peaked in 2014. Global cultivation of illicit opium poppy plants was 316,709 hectares. Of this total area, 224,000 hectares (71%) were in Afghanistan, 64,065 hectares (20%) were in the Golden Triangle, 17,000 + 387 = 17,387 hectares (5%) were in Mexico and Columbia, and the remaining 4% were elsewhere in the world. Notice that the land area in Columbia decreased dramatically (from 6,500 hectares in 2000 to 298 hectares in 2013) at exactly the same time as the land area in Mexico increased (from 1,900 hectares in 2000 to 11,000 hectares in 2013). The main reason for this was an opium cultivation eradication program in Columbia undertaken by the US and Columbia governments. In response, the drug cartels moved cultivation from Columbia to Mexico where it was easier to protect the poppy fields and to move heroin into the nearby US market. Since that time the land area under cultivation in Mexico has increased dramatically. Notice also that the land under opium poppy cultivation in other parts of the world increased significantly from 2000 to 2013. As we will see this was in response to the global shortage in the supply of heroin.

The next section of Table 3 show the tonnes of opium produced. Global production of opium peaked in 2014 before dropping dramatically in 2015. 2016 production rebounded to 6,380 tonnes (United Nations Office on Drugs and Crime, 2017a), about the same as the 2013 level. In 2014 in the Golden Triangle area 64,065 hectares of cultivated opium poppy produced 766 tonnes of opium. This gives a yield of $766 \div 64,065 = 0.012$ tonnes per hectare or 12 kg of opium per hectare of land. This is a low yield; the average global yield in 2014 was $7,732 \div 316,709 = 0.024 = 24$ kg per hectare, and the average yield in Afghanistan was $6,405 \div 224,000 = 0.029$ or 29 kg per hectare. (Recall that we used an average yield of 20 kg per hectare earlier in the paper. This was done to be conservative and

Figure 5. (a) Trends in the quantities of opiates seized. Source: United Nations Office on Drugs and Crime (2016a). (b) Where opiates are seized. Source: United Nations Office on Drugs and Crime (2016a).



to simplify the discussion.) The last section of the figure estimates the tonnes of heroin produced. For all sources of supply, opium production is converted to heroin production using the average conversion ratio of 10-to-1, 10 tonnes of opium yields 1 tonne heroin. For example, in 2014 in the Golden Triangle, 766 tonnes of opium produces $766 \div 10 = 77$ tonnes of heroin. Again we see that global heroin production peaked in 2014 before dropping dramatically in 2015 to a level not seen since about 2000. Heroin production in 2016 rebounded to about 638 tonnes (United Nations Office on Drugs and Crime, 2017a).

The actual heroin production in Afghanistan is less than what is stated in Table 3 because not all Afghanistan opium is processed immediately into heroin. About 25% of Afghanistan opium remains as opium. There are several reasons for this. Some users (e.g. in Iran) prefer smoking opium to using heroin. Some opium is inventoried and is processed in later years. Some is exported and processed later in other regions of the world; often because the chemicals needed for processing, especially

Table 3. Cultivation and production of opium and heroin in 2000 and 2013 to 2015

Source of supply	Hectares of opium poppy cultivation				Tonnes of opium production				Tonnes of heroin production (1)			
	2000	2013	2014	2015	2000	2013	2014	2015	2000	2013	2014	2015
Afghanistan	82,431	209,000	224,000	183,000	3,284	5,512	6,405	3,309	328	551	641	331
Golden Triangle	128,642	61,965	64,065	61,465	1,260	897	766	781	126	90	77	78
Mexico and Columbia	8,400	11,298	17,387	25,385	109	236	372	492	11	24	37	49
Mexico	1,900	11,000	17,000	24,800	21	225	360	475	2	23	36	47
Columbia	6,500	298	387	585	88	11	12	17	9	1	1	2
Other areas	2,479	13,028	14,257	11,214	38	165	189	184	4	16	18	19
Global cultivation/ production(2)	221,952	295,291	316,709	281,064	4,691	6,810	7,732	4,766	469	681	773	477

Sources: Compiled from UNODC, World Report on Drugs, documents published annually from 2001 to 2017. (1) Here the commonly used, average conversion rate of 10 tonnes of opium to produce one tonne of heroin is used. From time to time, there are instances where a different rate can be used. For example, in Afghanistan in 2000 a rate of 7 is sometimes used, and in Afghanistan in 2013 a rate of 9.6 is sometimes used. The rate depends on many factors, in particular the purity of the heroin just before it is exported from the region where it is produced. (2) Global cultivation/production is the sum of cultivation/production in the three main sources (Afghanistan, Golden Triangle, Columbia, and Mexico) plus all the other (smaller) cultivation/production areas in the world.

acetic anhydride and hydrochloric acid (Table 1), can be difficult to obtain in Afghanistan. The calculations in Table 3 overlook this issue and assume that all the opium grown in Afghanistan is processed immediately into heroin. This is normal and is done for two reasons. First, the total number of opiate users reported by the UNODC and others and shown earlier in Table 2 do not distinguish between opium users and heroin users. So if we use the values in Table 2 for the demand then we should use the values in Table 3 for the supply. Second, the actual supply of opiates in a particular year also depends on other factors, especially the quantity of opiates available in inventory from previous years' production. This is difficult to estimate (though we will try in the next section). Therefore, adjustments for other factors are not made in Table 3.

5.3. Global inventory of illicit opiates

Inventories of opium and heroin are held everywhere in the supply chain – by opium poppy growers, opium and heroin lab operators, and wholesalers and distributors. For example, several hundred thousand people in Afghanistan keep between 2 and 10 kg of opium, accumulated over several years, as personal savings. Recall that a typical farmer in Afghanistan produces about 7.4 kilograms of opium per year, so this is an inventory of $2 \div 7.4 = 0.3$ to $10 \div 7.4 = 1.4$ years of production. Large-scale wholesalers and distributors, defined as those who purchase two tonnes or more of heroin per year, keep an inventory of about one tonne of heroin (or $1 \div 2 = 0.5$ years of supply) for speculation purposes. The time required to move heroin from the opium poppy fields to the (foreign) markets is about one year, so the global pipeline inventory equals about one year of production. Since there is only one opium crop per year, the global cycle inventory is one half-year of production. Safety stock inventory is needed to cope with the uncertainty in the production process (e.g. weather, seizures by government agencies). It seems reasonable to suppose a safety stock inventory of one quarter-year of production.

All of this gives a total global inventory equal to about two years of production. This is calculated from: (savings + anticipation ≈ 0.5 years) + (pipeline + cycle ≈ 1.25 years) + (safety stock ≈ 0.25 years) ≈ 2 years. As a check recall from Appendix 2 that the inventory level for licit opium is one year of production. We expect the inventory for illicit opium to be higher than this because there is more uncertainty in the illicit network. The level of inventory in the global supply chain needs to be equal to about two years of production; a level lower than this makes it difficult for the supply chain to operate.

Table 4 shows an inventory calculation. The second and third columns in the figure show the annual global demand. The values in the second column are the total number of adults that use opiates (obtained from the UNODC reports). In 1999, global demand was 12.88 million adults; in 2016 it was 17.9 million. The values in the third column are the annual global demand in tonnes of heroin. They are calculated by multiplying the number of adults in the second column by an average demand rate of 28 grams of heroin per user per year (Section 4). In 1999, for example, the demand is 12.88×10^6 users per year \times 28 grams per user per year \div 10^6 grams per tonne = 361 tonnes of heroin.

The fourth column in Table 4 shows the inventory of heroin at the start of each year. Here, we assume that the total global inventory of heroin at the start of 1999 is equal to two years of production: $2 \times 576 = 1,152$ tonnes. The fifth and sixth columns show the annual production of opium and heroin. The values in the fifth column are the annual opium production values (obtained from the UNODC reports). The values in the sixth column are the values in the fifth column divided by 10, which is the standard conversion ratio of 10 tonnes of opium yields 1 tonne of heroin. For example, in 1999 the global production of opium was 5,764 tonnes, which gives $5,764 \div 10 = 576$ tonnes of heroin. The seventh column shows the seizure rate obtained from the UNODC reports (Section 5.1). For example, in 1999 heroin production was 576 tonnes and seizure rate was 20%. So the amount of heroin seized

Table 4. Calculation of global inventory from 1999 to 2016

Year	Demand		Starting inventory (tonnes of heroin)	Production		Estimated heroin seizures		Ending inventory (tonnes of heroin)
	Number of opiate users (millions of people)	Total annual demand (tonnes of heroin)		Annual opium production (tonnes of opium)	Estimated annual heroin production (tonnes of heroin)	Seizure rate	Seizures (tonnes of heroin)	
1999	12.88	361	1,152	5,764	576	0.20	115	1,252
2000	14.94	418	1,252	4,691	469	0.20	94	1,209
2001	15.2	426	1,209	1,630	163	0.20	33	913
2002	15.94	446	913	4,520	452	0.20	90	829
2003	15.84	444	829	4,783	478	0.20	96	767
2004	15.84	444	767	4,850	485	0.20	97	711
2005	15.60	437	711	4,620	462	0.20	92	644
2006	16.50	462	644	5,810	581	0.20	116	647
2007	18.15	508	647	8,091	809	0.20	162	786
2008	17.36	486	786	6,841	684	0.20	137	847
2009	16.16	452	847	4,953	495	0.25	124	766
2010	16.98	475	766	4,730	473	0.25	118	646
2011	16.50	462	646	6,983	698	0.25	175	707
2012	16.37	458	707	4,831	483	0.25	121	611
2013	16.50	462	611	6,810	681	0.25	170	660
2014	17.44	488	660	7,732	773	0.25	193	752
2015	17.67	495	752	4,766	477	0.25	119	615
2016	17.9	501	615	6,380	638	0.25	160	592
Mean		457		5,488	549		128	
Standard deviation		34.9			150.5			
Coefficient of variation		0.076			0.274			

Sources: Compiled from UNODC, World Report on Drugs, documents published annually from 2001 to 2017.

is $0.20 \times 576 = 115$ tonnes and the amount available to satisfy demand is $576 - 115 = 461$ tonnes. The ending inventory at the end of 1999 is: starting inventory + production less seizures – demand, which is $1,152 + (576 - 115) - 361 = 1,252$ tonnes. So the amount of inventory in the supply chain increased in 1999. But every year after that it decreased. In 2014, when production peaked most recently the ending inventory was 752 tonnes, which is a supply of $752 \div 773$ tonnes of production = 0.97 years. This is less than one year of production, which is likely not enough inventory to fill the pipeline and, therefore, leaves no inventory for safety stock, etc. After a year of very low production in 2015 and a moderate recovery in 2016, the inventory at the end of 2016 is $592 \text{ tonnes} \div 638 \text{ tonnes of production} = 0.93$ years. This is a very low level of global inventory; it is even less than the inventory for licit opium (Appendix 2).

The three rows at the bottom of Table 4 show that the average annual demand is 457 tonnes of heroin and the coefficient of variation (i.e. standard deviation divided by the mean) of the demand is 0.076. The average production minus the average seizure is $549 - 128 = 421$ tonnes per year. This average supply is insufficient to satisfy the average demand. This is the reason that global inventory dropped from two years of production at the beginning of 1999 to less than one year of production at the end of 2016.

In addition, there is more variation in the annual production than in the annual demand; the coefficient of variation for the annual production is 0.274. Notice, for example, the low production in 2001, 163 tonnes of heroin. In 2001, Afghanistan came under Taliban control, and the new government banned opium poppy cultivation. This eliminated almost all opium and heroin production, which reduced global production from 469 in 2000 to 163 tonnes in 2001. Global demand, however, did not decrease; rather it increased from 14.94 in 2000 to 15.2 million users in 2001. The ban caused great hardship for Afghan farmers and for the Afghanistan economy (see item 9 in Section 7). In late 2001 the Taliban government was overthrown and the ban was lifted. The next year, 2002, the previous production levels of opium and heroin were regained, about 452 tonnes. 2009, 2010, and 2012 were years when production was low. Poor weather conditions and a fungal infection called poppy blight in Afghanistan were the key reasons. Production was low again in 2015. This time drought in Afghanistan was the key reason. Drought (i.e. low rainfall) prompted some farmers to cultivate less land and also reduced the yield per hectare on the land that was cultivated. A production network needs safety stock to manage production fluctuations like these. Unfortunately, the global inventory level at the end of 2016 is so low that there is no safety stock.

Low inventory levels, the absence of safety stock, and high variation in annual production all suggest that there will be shortages at different times and in different locations in the world. The easiest way for the supply chain to cope with these shortages is for distributors and retailers to increase their supply of heroin by cutting (i.e. mixing) their heroin with additives. Another solution is to increase the amount of land under opium poppy cultivation or to increase the yield on the current land under cultivation. Unfortunately, neither of these is easy. Table 3 shows that the amount of land peaked in 2014 (316,709 hectares), then fell in 2015 (281,064 hectares), but increased in 2016 (304,000 hectares). We will discuss this again in Section 7.

6. Capturing value: The price of illicit opiates

In the 1970s and 1980s, the purity of the heroin exported from Afghanistan was high, about 60%; but the purity of the heroin sold by North American retailers was low, between 10 and 20%. Retailers would cut or mix additives with one gram of 60% heroin to produce, for example, three grams of 20% cut heroin. The retailer paid \$100 per gram for the 60% heroin but sold each gram of the 20% cut heroin for the same price, making a profit of $3 \times \$100 - \$100 = \$200$. The low purity heroin, however, was too weak to be inhaled or smoked; it had to be injected using dangerous intravenous needles. The uncertain additives were also dangerous. Then in the 1990s the purity of retail heroin rose to almost 50%, as retailers tried to expand their market beyond impoverished addicts to affluent recreational users who wanted purer heroin that could be inhaled and smoked. At about the same time oxycodone, a synthetic opioid drug, became available. It was marketed under many

names, including OxyContin, as a prescription medication for pain. Although more expensive and needing twice the dosage to get the same affect, users purchased it rather than heroin because there was less uncertainty about its purity and additives. To keep their users and gain new users, retailers were forced to increase the purity of their heroin.

Table 5 shows the price of heroin from 2003 to 2010. In 2009, for example, the global demand was 452 tonnes of heroin and the global production was 495 tonnes. The price paid to an Afghan farmer (the farm-gate price) was \$0.075 US per gram of dried opium latex, which is equivalent to $0.075 \times 10 = \$0.75$ per gram of heroin. Here, the standard conversion rate of 10 grams of opium yield one gram of heroin is used. After processing the opium into heroin, Afghan processors raised the price approximately three times to \$2.20 per gram of heroin. After the heroin was transported to global markets in, for example, Europe, the price increased approximately 14 times to \$31 per gram. Finally, the price doubled to \$72 per gram when retailers sold to users.

In 2009, demand (452 tonnes) exceeded production minus seizures ($495 - 124 = 371$ tonnes), and production (495 tonnes) was significantly less than the previous year's production (684 tonnes). In this situation, we expect prices to increase in 2009. But they did not; Afghan farm-gate price stayed the same and the Afghan processor and Europe wholesale and retail prices all decreased. It is clear that the connections between the global demand, global production, global seizures, and the price of opium or heroin in a particular region (e.g. Europe) are weak (Costa Storti & De Grauwe, 2009). This suggests that opium cultivation, and heroin production and distribution operate in separate markets where local rather than global conditions determine price. Other evidence of this comes from comparing the Afghan farm-gate price (fifth column of Table 5) and the Europe retail price (last column in the figure). Between 2003 and 2009, the Afghan farm-gate price dropped by more than 70% from \$0.28 to \$0.075 per gram while the Europe retail price stayed relatively constant at about \$72 per gram.

The last row at the bottom of Table 5 analyzes the supply chain in 2009. Total demand is 452 tonnes, total production is 495 tonnes, and total seizures are 124 tonnes. The value at the end of the row, \$26.712 billion, is (total production – total seizures) \times Europe retail price. This is a rough estimate of the global revenue generated by the 2009 production. Of this total revenue, the revenue paid to Afghan farmers is about \$0.075 per gram of opium \times 10 grams of opium per gram of heroin \times 495×10^6 grams of heroin = \$0.371 billion. This is $0.371 \div 26.712 = 1.4\%$ of the global revenue.

Table 5. Heroin prices from 2003 to 2010

Year	Global heroin			Afghanistan opium (farm-gate) US\$ per gram	Afghanistan heroin processor US\$ per gram	Europe wholesale US\$ per gram	Europe distribution & retail US\$ per gram
	Demand tonnes	Production tonnes	Seizures tonnes				
2003	444	478	96	0.280	na	30	70
2004	444	485	97	0.150	na	32	75
2005	437	462	92	0.130	na	32	73
2006	462	581	116	0.120	2.9	31	68
2007	508	809	162	0.100	2.6	32	74
2008	486	684	139	0.075	2.5	36	80
2009	452	495	124	0.075	2.2	31	72
2010	475	473	118	na	na	32	68
2009	452	495	124	$\$0.075 \times 10 \times 495 \times 10^6 = \0.371 billion; $0.371 \div 26.712 = 1.4\%$	$\$2.2 \times 495 \times 10^6 = \1.089 billion; $1.089 \div 26.712 = 4.1\%$	$\$32 \times 495 \times 10^6 = \15.840 billion; $15.840 \div 26.712 = 59.3\%$	$\$72 \times (495 - 124) \times 10^6 = \26.712 billion; 100%

Sources: Compiled from UNODC, World Report on Drugs, documents published annually from 2001 to 2017.

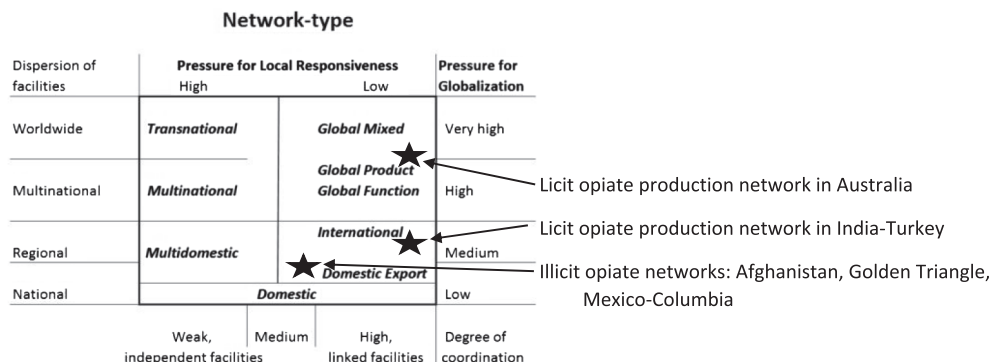
The figure shows that another $4.1 - 1.4 = 2.7\%$ is paid to Afghan heroin processors. $59.3 - 4.1 = 55.2\%$ is paid to wholesalers who move the heroin from Afghanistan to markets in Europe. The remaining $100 - 59.3 = 40.7\%$ is paid to European distributors and retailers. This analysis is rough; others report that about 10% of global revenue is generated at cultivation and heroin processing, another 40% is generated at the wholesale stage, and the final 50% is generated at the distribution and retail stages.

7. Discussion

- (1) Creating product value consists of: (i) cultivating opium poppy plants and harvesting opium, (ii) processing opium into morphine base in an opium lab, (iii) processing morphine base into No. 4 heroin in a heroin lab, (iv) wholesalers moving heroin from sources of supply to global markets, (v) wholesalers selling to distributors selling to retailers, (vi) distributors and retailers cutting the heroin with additives such as fentanyl, and (viii) retailers selling to users. These activities are complex, labor-intensive, and costly. Activity (i) requires 350 person-days of labor per hectare of land or, equivalently, per two kg of heroin. Activities (ii) and (iii) require labor and special chemicals. Activities (iv) and (v) require transportation systems. All activities require security.
- (2) Suitable land, climate, and political conditions are needed to cultivate and process opium and heroin. Afghanistan, the Golden Triangle, and Mexico-Columbia have these conditions and, therefore, cultivation and processing have been embedded there or in nearby regions for at least 300 years. Small-scale farmers cultivate about one-seventh of their farmland with opium poppy plants but earn about one-third of their (low) annual income from the crop. There are almost no alternatives for replacing this crop and income. Legalizing opium and heroin would not help these farmers because they would not be able to compete with large-scale producers who use modern farming practices.
- (3) The demand for heroin is high and steady. A little less than 0.40% of the adult population use opiates and this has not changed significantly over the last 15 years. The average user uses about 28 grams of heroin per year. The average global demand between 1999 and 2016 was 457 tonnes per year. The coefficient of variation of this demand was 0.076.
- (4) The supply of heroin is not steady. Political events and weather conditions greatly affect annual production. The large quantities of heroin seized by government agencies also affect the supply of heroin. Between 1999 and 2016, the average production quantity was 549 tonnes per year and the coefficient of variation of this supply was 0.274. The average seizure was 128 tonnes per year. This leaves an average of $549 - 128 = 421$ tonnes of supply to satisfy the average demand of 457 tonnes.
- (5) There have been two responses to the problem of insufficient supply. First, the global inventory of heroin has been depleted. A total inventory equal to about two years of production is needed by the production networks. Total inventory today appears to be less than one year of production. This is not enough inventory for the pipeline from grower to user, cycle inventory, and safety stock. This causes shortages. The second response is to mix additives with the heroin to increase the supply. Fentanyl is the most popular additive. It is a synthetic (i.e. man-made) opioid. Up until recently (March 2017), it was a legal product in China and, therefore, relatively easy to obtain. Because it is 15–25 times stronger than heroin, it is inexpensive. Mixing or cutting one kg of heroin with fentanyl produces about 10 kg of cut heroin that retailers can then sell to users.
- (6) The retail price of heroin has been relatively constant. Between 2003 and 2010 in Europe, the average retail price was approximately \$70 per gram. In the United States, it was approximately \$100 per gram. This is surprising given all the variability in the production process. Drug users appear to be limited in what they can pay and there are many other drugs available to them. These factors help to keep the price relatively constant (Chalmers, Bradford, & Jones, 2010).

Figure 6. Production network types.

Source: Adapted from Miltenburg (2015, Figure 2).



- (7) Seizures are ruinous for the opiate production networks. Each seizure wipes out hundreds of days of work and thousands of dollars of revenue needed to pay costs already incurred. Heroin that is seized cannot be replaced. There is no safety stock inventory in the supply chain to mitigate the effects of seizures. Seizures drop the level of supply to below the demand, which results directly in the necessity to use additives such as fentanyl. To minimize seizures organizations in the supply chain need to be very vigilant.
- (8) A third response to the problem of insufficient supply is to bring more farmland under opium poppy cultivation. This is not easy because governments try very hard to prevent this. Recall Table 3. The total global area under opium cultivation actually decreased from 2013 to 2015. Except for Mexico there are no areas of the world when a significant amount of additional land is being cultivated.
- (9) A global production network can have a substantial effect on a local economy (Piazza, 2011). Consider the effect of the Afghanistan production network on the economy of Afghanistan. In 2014, 641 tonnes of heroin (Table 3) were produced in Afghanistan and the retail price of heroin in Europe was about \$60 per gram. An estimate of the revenue from this activity is $641 \text{ tonnes} \times 10^6 \text{ grams per tonne} \times \$60 \text{ per gram} = \$38.46 \text{ billion}$. If 20% of this revenue is generated in Afghanistan, then this $20\% \times \$38.46 \text{ billion} = \7.7 billion . GDP in Afghanistan in 2014 was \$69 billion and (licit) exports were \$571 million. So opium and heroin represent about $7.7 \div 69 = 11\%$ of Afghanistan's economy and far exceed the value of all licit goods and services exported by the country.
- (10) The production network producing licit opiates (Appendix 2) in Australia is a high-capability global product network (see Figure 6). The production network producing licit opiates in India and Turkey is likely a low capability international network. The three networks producing illicit opiates are low capability domestic export production networks. This suggests that as the capabilities of the three illicit networks develop and increase they may become international networks or even global product networks. As they work through the current problem of low supply due to seizures, they will develop new capabilities and will improve their network type. This will have implications for future global supply and production cost.

8. Conclusion and areas for future research

The UNODC reported that in 2014 about 19 million adults used opiates (i.e. opium, heroin). This is 0.4% of the global adult population and 8% of the adults who use drugs. The adults using opiates were supplied by three major opiate supply chains: the Afghanistan network, the Golden Triangle network, and the Mexico-Columbia network. The supply from these networks cannot satisfy the demand; the supply is too low. The research problem in this paper was to analyze the three supply chains: (i) to understand how supply chains for illicit products operate, and (ii) to determine the elements in the supply chains that restrict the supply and what can be done to ease this.

Following the GPN framework, this paper analyzed important elements in the three global opiate supply chains; including how product value is created and captured, markets and demand, networks, distribution routes, supply, inventory, and cost. We found that the biggest problem faced by the supply chains is low supply caused by a high rate of seizures. The current solution is to increase supply by mixing the existing supply of the high-quality opiates with synthetic additives, especially fentanyl, which are available and cost-effective. Unfortunately, when this is done the purity and quality drop significantly. Other solutions will emerge when the networks develop new capabilities and improve their production network type.

There are many areas where more research can be done. A more detailed analysis of the Mexico-Columbia network and the Golden Triangle network would be interesting. The distribution routes in the Afghanistan network can be analyzed and compared; of particular interest would be the newer part of the network's southern route from east to west Africa and then to markets in southern Europe and North America. The effect on the network of market dynamics such as changes in heroin availability, purity, and price can be studied. Chalmers et al. (2010) study the effect of these changes on users. For example, users change the amount they consume, switch to a similar drug (e.g. heroin to oxycodone) or to a different drug (e.g. heroin to cocaine), change the way they take heroin (e.g. switch from inhaling to injecting), enter treatment, and so on. But the effect of market dynamics on the networks themselves is less well understood.

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Appendix 1

Timeline in the opiate production network Table 6

Table 6. Opiate network timeline			
Year	Month	Activity, price (1), profit margin	Agent
Previous year	October	Till and fertilize fields	Farmer or grower
Year 1	April	Plant opium seeds	
		Weed fields while opium plants grow (3 months)	
	July	Opium poppies bloom	
		Opium is harvested (2–3 weeks)	
		Finished product is “dried opium latex”	
		Farmer keeps some dried opium latex for savings	
	August	Farmer sells dried opium latex to broker	
		price: farmer sells dried opium latex for \$140 per kg	
		Broker keeps some dried opium latex for savings and speculation	Broker
		Broker transports dried opium latex to opium processing lab	
	August	Broker sells dried opium latex to opium processor	
		price: broker sells dried opium latex for \$168 per kg	
		profit contribution for agent: $(\$168 - \$140)/\$140 = 20\%$	
		Opium processor converts dried opium latex into “morphine base”	(opium) processor
		Transport morphine base to heroin processing lab	
		Heroin processor converts morphine base into “No. 4 heroin”	(heroin) processor
		Heroin processor keeps some No. 4 heroin for savings and speculation	
	November	Heroin processor sells No. 4 heroin to wholesaler	
		price: heroin processor sells No. 4 heroin for \$3,000 per kg	
		profit margin for agent: $(\$3,000 - \$140 \times 10)/(\$140 \times 10) = 114\% (2)$	
		Wholesaler keeps some No. 4 heroin for savings and speculation	Wholesaler
	December -->	Wholesaler transports No. 4 heroin around the world	
Year 2	April -->	Wholesaler sells to local distributors	
		price: wholesaler sells No. 4 heroin for \$30,000 per kg	
		profit margin for agent: $(\$30,000 - \$3,000 \times 1.2)/(\$3,000 \times 1.2) = 733\% (3)$	
		Distributors keep some heroin for speculation	Distributor
	May -->	Distributors cut heroin to increase supply	
	June -->	Distributors sell to local retailers	
		price: distributor sells cut heroin for \$100,000 per kg	
		profit margin for agent: $(\$100,000 - \$30,000 \times 1.2 \times 0.5)/(\$30,000 \times 1.2 \times 0.5) = 456\% (3,4)$	
	July -->	Retailers cut heroin to increase supply	Retailer
	July -->	Retailers sell to users	
		price: retailer sells cut heroin to users for \$20 per 100 mg or \$200,000 per kg	
		profit margin for agent: $(\$200,000 - \$100,000 \times 1.2 \times 0.5)/(\$100,000 \times 1.2 \times 0.5) = 233\% (3,4)$	

Notes: (1) 2005 North America prices, (2) 10 kg of opium are needed to produce 1 kg of heroin, (3) 20% of product is seized by law enforcement, (4) Heroin is cut by 50%.

Appendix 2

How globalization affects the opiate networks

Opium has a long history of global trade. Between the late eighteenth century and the early twentieth century, opium was a licit (i.e. legal) commodity similar in trade characteristics to tea, tobacco, and coffee. In, for example, the 1820s English merchants managed the production of £22 million of opium and cotton in India, which they traded to China for £20 million of tea, which they traded to England for £24 million of textiles and machinery, which they traded back to India. They made a large profit on each trade, and repeated the cycle of trades every year.

In the twentieth century, world powers moved to prohibit opium and heroin production and use (e.g. in 1906 the British parliament passed a law to end India's opium trade, the 1910 Hague Opium Convention in Europe, the 1914 Harrison Narcotics Act in the United States, and the 1925 Geneva Conference). Almost immediately an illicit industry arose to take over the previously licit activities. In 1972 at the time of the United States first "war on drugs" the most important opiate production network was: cultivation and opium processing in Turkey, heroin processing in Marseille (France), and distribution to Europe and the United States. The second most important production network was: cultivation in South-East Asia, processing in Bangkok (Thailand), and distribution to Europe and the United States. The first war on drugs disrupted the supply in both networks. It also disrupted demand. For example, in New York the price increased 300% while heroin purity decreased by 50%. The high price (and unsatisfied demand) stimulated new producers to begin cultivation in Afghanistan and elsewhere. By the late 1970s, the three production networks discussed in this paper were emerging. Instead of reducing supply and demand, the first war on drugs actually increased global production and initiated new production networks (McCoy, 2000).

A second factor stimulated the development of enhanced capabilities. During the cold war (1947–1991) and before the breakup of the Soviet Union (1991) and the opening up of China (1995), opium and heroin cultivation, production, and distribution were almost impossible inside the tightly controlled regions of the communist Soviet Union and communist China. The end of the cold war, the breakup of the Soviet Union, and the opening up of China, all occurring within a short period of time, created numerous opportunities for the global opiate networks to add capabilities in these regions (e.g. new criminal organizations, new locations for cultivation and processing, new routes for trafficking, new government partners, and new financial institutions). Flexibility was an especially important capability. Hülsmann, Grapp, and Li (2008) observe that (licit) global production networks face "hyper competition" because of their complex and dynamic stakeholders, resources, structures and processes. Global networks respond to hyper competition by building competitive advantage especially flexibility. This behavior is evident in the new opiate production networks.

More recently, globalization has improved and augmented network capabilities. For example, more than 420 million shipping containers cross the world's oceans every year. Some of these contain illicit opioids and the illicit chemicals used to produce them (recall Table 1). Containers are now checked at the entry points to free trade zones, export processing zones, economic areas, and customs unions; not at the entry points to countries. This reduces the opportunities authorities in destination countries have to detect and disrupt illicit trafficking. Globalization eases the movement of people, making it more difficult to detect traffickers. Globalization also makes it easier for criminal organizations in different countries to cooperate and form alliances. Storti and DeGrauwe (2008) found that globalization has actually reduced heroin prices.

In the late 1960s, international agreements were made to restrict licit (i.e. legal) opium cultivation and production to a small number of secure locations, mainly in Turkey and India, where previously illicit opium was grown and produced, and in Australia. At the same time, the United States required US pharmaceutical companies to purchase 80% of their opiate raw material from Turkey and India,

presumably to prevent the resumption of illicit cultivation and production in those countries. About 2,000 tonnes of licit opium are produced each year (compared to about 6,000 tonnes of illicit opium produced by the three illicit networks). Licit opiate cultivation and production is monitored by a United Nations agency called the International Narcotics Control Board. The agency tracks production and security. It also tries to keep global inventory levels equal to about one year of production; this prevents extra production, which could be diverted to illicit markets.

In Australia, licit opium poppies are grown in the secure island location of Tasmania (Bradsher, 2014). The opium is extracted there and shipped to pharmaceutical factories, owned mainly by GlaxoSmithKline and Johnson & Johnson, in the northeastern United States. In 2013, Australian opium provided: (i) 25% of the world's morphine and codeine, which are opiates used to make older pain management drugs, (ii) 85% of the world's thebaine, which is an opiate used to make newer pain management drugs (e.g. OxyContin), and (iii) 100% of the world's oripavine, which is an opiate used to make drugs to treat heroin overdoses. Thebaine and oripavine are not included in the US Government policy of buying 80% of opiate raw material from Turkey and India. This loophole allows US pharmaceutical companies to source the opiate raw materials needed for newer pain management drugs and for addiction treatments from Australia. The global sales boom for OxyContin and more than 40 chemically similar products resulted in a tripling of Tasmania's poppy farmland from about 10,000 hectares in the late 1990s, to nearly 30,000 hectares in 2013. This is half as large as the Golden Triangle area for illicit opium and twice as large as the Mexico area for illicit opium. The varieties of licit opium poppies grown in India and Turkey and the varieties of most illicit opium poppies are simpler than what is grown in Australia. The variety of opium poppy grown in Australia is engineered to produce the highest possible level of thebaine, to be cultivated using modern, large-scale, agricultural practices (e.g. fertilizers, insecticides, machinery, irrigation), and to be harvested using mechanical rather than manual methods.



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