A Game-Theory Analysis of US Efforts to Curb the Colombian Cocaine Trade

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ABSTRACT

In the United States, efforts to disrupt the cocaine trade have centered on coca eradication in nations such as Colombia. In spite of funding increases for eradication initiatives, cocaine production levels in Colombia did not decrease between 2004 and 2009. Current US intervention strategy involves fumigating coca fields with herbicidal spray; the most herbicide is dispensed to the areas with the most coca cultivation. While this approach seems valid from a conventional viewpoint, it does not consider the motivations of individual farmers and thus results in an improper allocation of funding. By approaching the scenario from the level of the farmer as opposed to a nationwide perspective, this problem can be solved using game theory, a branch of mathematics that can be used to determine the optimal choice for rational actors in a given competitive scenario. For this analysis, Colombia was broken down into smaller regions called departments, and regional data on coca production from the UN Office on Drugs and Crime was utilized to determine estimated payoffs to Colombian farmers by region for coca and a licit alternative, coffee. The results of the analysis suggest that coca production levels in Colombia can be significantly decreased with only modest increases to herbicidal spraying: fumigating approximately 4,000 more hectares could eradicate almost 19,000 hectares of coca. More precise figures on coca cultivation and more accessible information on the export value of licit crops could yield a more accurate analysis.

INTRODUCTION

In 2007, the number of Americans twelve years and older addicted to cocaine reached 2.1 million, a little under 1% of the population.[1] Every day, 2,500 Americans use cocaine for the first time.[1] Approximately 42% of 12th graders mentioned in a US survey that they had "fairly easy" to "very easy" access to cocaine.[2] These alarming numbers only begin to reveal the growing cocaine crisis in the United States. The US—which is responsible for approximately 60% of the world's illegal drug consumption[1]—has taken the lead in efforts to curb the cocaine trade, both domestically and abroad. Of the two possible ways to reduce the amount of cocaine consumption—reduction in demand and reduction in supply—the United States has primarily targeted the latter, specifically through intervention in Colombia, the world's largest producer of the coca crop since the 1990s. During the Clinton administration, the United States gave Colombia 860 million dollars worth of aid—three-quarters of which was used by the government for Colombian military development—in a program known as “Plan Colombia” [3][4]. By equipping the Colombian police force and military with drug eradication equipment, the United States hoped to stop coca production at its source by targeting cocaine-selling guerrilla groups and coca-growing communities. Since then, the US has loaned Colombia growing sums of money to combat the cultivation of coca, with a large percentage of funds still devoted to improving Colombia’s security forces.[5] Although the US government has been partially successful in reducing the cultivation of coca in Colombia, production figures from 2001 through 2006 still hovered at 1997 levels, despite increased funding and greater efforts to eliminate the coca crop.[6] As a result, UN Office on Drugs and Crime Executive Director Antonio Maria Costa claims that even greater funding is what is needed to solve the coca problem.[6] Through a game-theory analysis of the Colombian farmer, this paper attempts to explain how the United States can better use its resources in Colombia. With a greater understanding of the Colombian farmer’s choices and relative payoffs, the UN, United States, and Colombia can better allocate their resources to greatly reduce the illegal coca trade.

Currently, the United States allocates its funds in Colombia from a “top-down” perspective: it distributes the most herbicidal spray to the area that grows the most coca. While this may be the best approach by conventional wisdom, this course of action makes one major and invalid assumption: that the only way to stop coca production is by destroying as much of it as possible. Colombian farmers grow the coca crop not because they want to create large amounts of illegal cocaine but rather because it is the most profitable economic decision for their livelihood. If growing licit crops became more lucrative than growing illegal alternatives like coca, then Colombian farmers would gradually defect to the more profitable crops: the licit ones. By understanding that each Colombian farmer is self-interested and not necessarily interested in the success of all Colombian farmers, the scenario can be reduced to a game that pits an individual Colombian coca farmer—representative of the group as a whole—against the US and its drug eradication efforts. Thus, a game-theory approach lends itself well to this situation, as it is a strategic interaction between two or more parties that want to maximize their own gains, sometimes at the expense of other players. Because both the Colombian farmer and the Colombian government want to maximize payoffs, game theory is applicable to the analysis of the Colombian coca scenario.

BACKGROUND

Coca cultivation in the Andes is rooted in tradition. Primarily in the region around Bolivia, the coca leaf is an integral part of the Andean life, whether chewed for cultural, religious or simply recreational purposes.[7] [8] [9] [10] [11] In Colombia, however, the growth of the coca bush is a rather novel occurrence that has its origins in the rise of the illegal cocaine trade.[12] After it is harvested, coca leaf can be transformed into coca paste with the addition of sulfuric acid and certain combustibles. Following a variety of chemical reactions—including acidification, oxidation, and neutralization with a base—the coca paste becomes cocaine base. The illegal drug known as powder cocaine is actually cocaine hydrochloride, a compound that can be easily synthesized from cocaine base.[6] [13] By the end of this transformation process, the value of the cocaine has risen from one dollar per kilogram of raw coca leaf to 1,762 dollars per kilogram of wholesale powder cocaine.[6] The source of this highly addictive drug is the plant *Erythroxylum coca*, which is generally grown in the lower altitudes of the Andes and matures within 18 months of planting. [7] [14][13] After this growth period, the coca bush averages about three to six harvests a year and produces approximately 1,446 kilograms of coca leaf per harvest.[6] Compared to other lucrative alternatives, such as coffee, coca is a rather high-yielding and fast-growing crop. This further complicates US intervention efforts, as only a few bushes are needed to produce a substantial amount of cocaine.[15]

The Colombian police and armed forces have reduced the coca supply primarily through two direct methods of involvement: aerial fumigation and manual eradication. Manual eradication involves the deployment of troops into coca-rich regions and the uprooting of all coca bushes in the area. This process is only efficient on a small-scale, can be used only in easily-accessible locations, and puts the troops in danger; for these reasons, manual eradication is limited to a small scope.[6] However, manual eradication is very effective: after coca bushes are removed by manual eradication, it takes approximately eighteen months until another set of illicit crops can fully mature.[16] In addition, manual eradication specifically removes drug-producing crops, not legal crops.[6] Aerial fumigation, also known as aerial spraying, involves the dispensing of an herbicide—usually a variant of the Monsanto product Roundup—in a targeted region to kill any coca crops growing in a particular area. Aerial fumigation is useful as it inexpensively destroys large swaths of coca with little effort, but the process often acts as a sword in places where a scalpel is needed: aerial fumigation removes both illicit and licit crops in an area, and it simply destroys one harvest of the coca plant instead of the entire bush.[6] Because it is inexpensive and relatively simple to apply, aerial spraying is the premier method used by the United Nations, the United States, and Colombia to curb coca cultivation in Colombia.

In this model, we have assumed that every farmer is faced with the decision to grow either the illicit coca crop or the common licit alternative coffee. In Colombia, growing illicit crops can be nine to ten times as lucrative as growing legal alternatives such as coffee. However, because coca is such a labor-intensive crop, coca cultivation requires about three times as much labor as coffee cultivation.[17] Thus, the decision to grow coca over other licit alternatives is ultimately a financial decision and not one based off of lack of expertise or convenience of labor.

INTRODUCTION TO GAME-THEORETIC ANALYSIS

Game theory allows a mathematical analysis of interactions between two ideally rational groups with distinct interests, whether cooperative or diametrically opposed. Put simply, game theory is a branch of mathematics that allows two agents to optimally obtain resources in a given competition or scenario. Whenever two parties are concerned with maximizing their gains and minimizing their losses, a general branch of game theory known as minimax game theory is often applied. The major stipulation of this theory is fulfilled in this simulation: that the payoffs used must have constant values and be independent of any particular strategy. While the created game has overarching similarities to a minimax game, some of the underlying assumptions for minimax game theory do not apply to this model, rendering some of the tools of this subfield of game theory inapplicable.[18]

Mathematics has previously been used to analyze the Colombian cocaine trade. Research—in particular much work by Daniel Mejia—focuses on all stages of the problem, from coca cultivation through interdiction, trafficking, and ultimately consumption.[19][20] One paper by Mejia et. al in particular utilized game theory to analyze drug production and trafficking—a separate phase of the cocaine trade—through an advanced game with multiple stages and rational actors.[21] Much of the current research involves using mathematics to analyze the economic effects of certain policies: for example, how crop subsidies would affect supply and demand. Our research is distinct in that it proposes a new outlook on the situation, a reassessment of the roles of individual Colombian farmers.

As a preliminary approach to the problem, a two-player, two-strategy game was created in which a single Colombian farmer is interacting with a coalition of the UN, the United States government, and the Colombian government. The Colombian farmer has two choices: either to grow the coca crop on his plot of land or to grow a licit alternative, simulated here as coffee, Colombia's largest licit agricultural export.[15] The farmer is limited to playing only these two pure strategies. The government coalition is also limited to two pure strategies: to either aerially fumigate only coca crops or do nothing. The payoff for the farmer is crop revenue, evaluated as US dollars per hectare for the sake of universality. The payoff for the government, however, is the number of coca plants, evaluated as coca leaf revenue per hectare. By minimizing the amount of coca grown, the United States is limiting the supply of cocaine which is its ultimate goal in giving foreign aid to Colombia. In this model, the game is played under idealized conditions, as both the farmer and the government coalition have more strategies and the opportunity to use mixed strategies in real life. Minimax game theory cannot be applied here because one player is aware of the other's moves and payoffs. In the game, the government coalition is aware of the farmer's actions, as the government can aerially survey the farmer's lands, and it acts after the farmer does. Since one player is aware of the other's actions, certain techniques from minimax game theory cannot be used, as that player could take advantage of the greater information he has to improve his payoff.[18] If the coalition of governments knows that the farmer is going to grow coca—perhaps from conducting an aerial survey—then it will aerially fumigate his crops, but otherwise it won't bother. This preliminary game uses data that are too nonspecific to provide specialized and actionable results, but nonetheless it is useful as an introduction to this game-theory analysis and as a generalized simulation of the scenario.

The values payoffs used in the normal form of the game are as follows.

$$Revenue_{Coca} = \left(Average\ Yield\ in \frac{kg}{hectare * year}\right)\left(Average\ Colombian\ Price\ in \frac{US\ Dollars}{kg}\right)$$

$$Revenue_{Coffee} = \left(Average\ Yield\ in \frac{kg}{hectare * year}\right)\left(Average\ Colombian\ Price\ in \frac{US\ Dollars}{kg}\right)$$

$$Expenses_{Coffee} = \left(Average\ Yield\ in \frac{kg\ Coffee}{hectare * year}\right)\left(\frac{lb\ Coffee}{kg\ Coffee}\right)\left(Production\ Cost\ in\ \frac{US\ Dollars}{lb\ Coffee}\right)$$

$$Expenses_{Coca} = \left(Average\ Yield\ in\ \frac{kg\ Coca}{hectare * year}\right)\left(Production\ Cost\ in\ \frac{US\ Dollars}{kg\ Coca}\right)$$

Other mentioned values include $Effectivness_{AF}$, the average effectiveness of aerial fumigation in destroying coca fields. When fields are aerially fumigated, farmers only profit and incur cost from the crops that survive, so $Revenue_{Coca}$ and $Expenses_{Coca}$ become the following.

$$Revenue_{Coca} = (1 - Effectiveness_{AF})(Average\ Yield)(Average\ Colombian\ Price\ )$$

$$Expenses_{Coca} = (1 - Effectiveness_{AF})(Average\ Yield\ )(Production\ Cost\ )$$

(See FIGURE 1 in Appendix)

With proper data, the game can be evaluated to provide a meaningful solution. In 2006, coca leaf was sold for an average of one dollar per kilogram, and the average annual yield was 6300 kilograms per hectare per year.[6] The coffee crop's price was set at $199.22 for 125 kilogram bags, and the average yield in Colombia was 450 kilograms per hectare per year.[22] [23] The values marked as expenses in the matrix are the cost of production of these crops, which includes cost of seeds, herbicides, pesticides, fertilizers and wages.[6] Literature values place the average production cost per pound of coffee at $0.80.[24] Not enough information was available to generate a specific dollar value for coca leaf production expenses, but data from Bolivia suggest that, on average, production costs expend 30% to 35% of coca leaf revenue.[17] For this analysis, we use 30% as our benchmark.

$$Revenue_{Coca} = \left(6{,}300\frac{kg}{hectare * year}\right)\left(1.0\ \frac{US\ Dollars}{kg}\right) = 6{,}300\frac{US\ Dollars}{hectare * year}$$

$$\boldsymbol{Revenue_{Coffee} = \left(450\frac{kg}{hectare * year}\right)\left(\frac{199.22}{125}\ \frac{US\ Dollars}{kg}\right) = 717.192\frac{US\ Dollars}{hectare * year}}$$

$$\boldsymbol{Expenses_{Coca} = \ 0.30 * Revenue_{Coca}\ \frac{US\ Dollars}{hectare * year}}$$

$$\boldsymbol{Expenses_{Coffee} = \left(450\frac{kg\ Coffee}{hectare * year}\right)\left(0.45359237\frac{lb\ Coffee}{kg\ Coffee}\right)\left(0.80\ \frac{US\ Dollars}{lb\ Coffee}\right) = 163.293\frac{US\ Dollars}{hectare * year}}$$

(See FIGURE 2 in Appendix)

(See FIGURE 3 in Appendix)

The government coalition's strategy of not aerially fumigating is iteratively dominated by the aerial fumigation strategy, leaving a 1x2 matrix. When we eliminate the lower payoff for the farmer, there remains only one solution: aerially fumigate and grow coffee. This value from the model is counter to what actually occurs in Colombia, as the results suggest that coffee is slightly more lucrative than coca. If this were true across the board in Colombia, this would mean that it does not make rational sense for farmers to grow coca in Colombia. If we suppose the model is valid, the question is then raised of why some Colombian farmers do indeed cultivate coca. We propose a simple explanation. To simulate this game over time, it is simply played for every year in the simulation. Using the solution we found earlier, the result is a payoff of 553.899*t to the farmer, where t is equal to the number of years. However, if the government coalition does not always choose the optimum payoff—if it makes a mistake one year—the resulting total payoff for the farmer would be different. If the government does not aerially fumigate the crops one time in 100 years, then the average expected payoff for growing coca is 568.008, a value higher than 553.899.

(See FIGURE 4 in Appendix)

While it is unlikely that the government coalition would make a mistake if it monitored only one farmer, the likelihood of this error becomes more pronounced as the analysis is extended to a greater and greater number of farmers. In addition, the analysis becomes more relevant: the actual scenario in Colombia involves the monitoring of thousands and thousands of farms, not just a single plot of land. The analysis becomes even more useful when the values used are more specialized. The values used thus far have been Colombian national averages. By centering games around specific regions, this analysis can take advantage of more precise values that take the geographic and economic differences between each region into account.

REGION-BY-REGION ANALYSIS

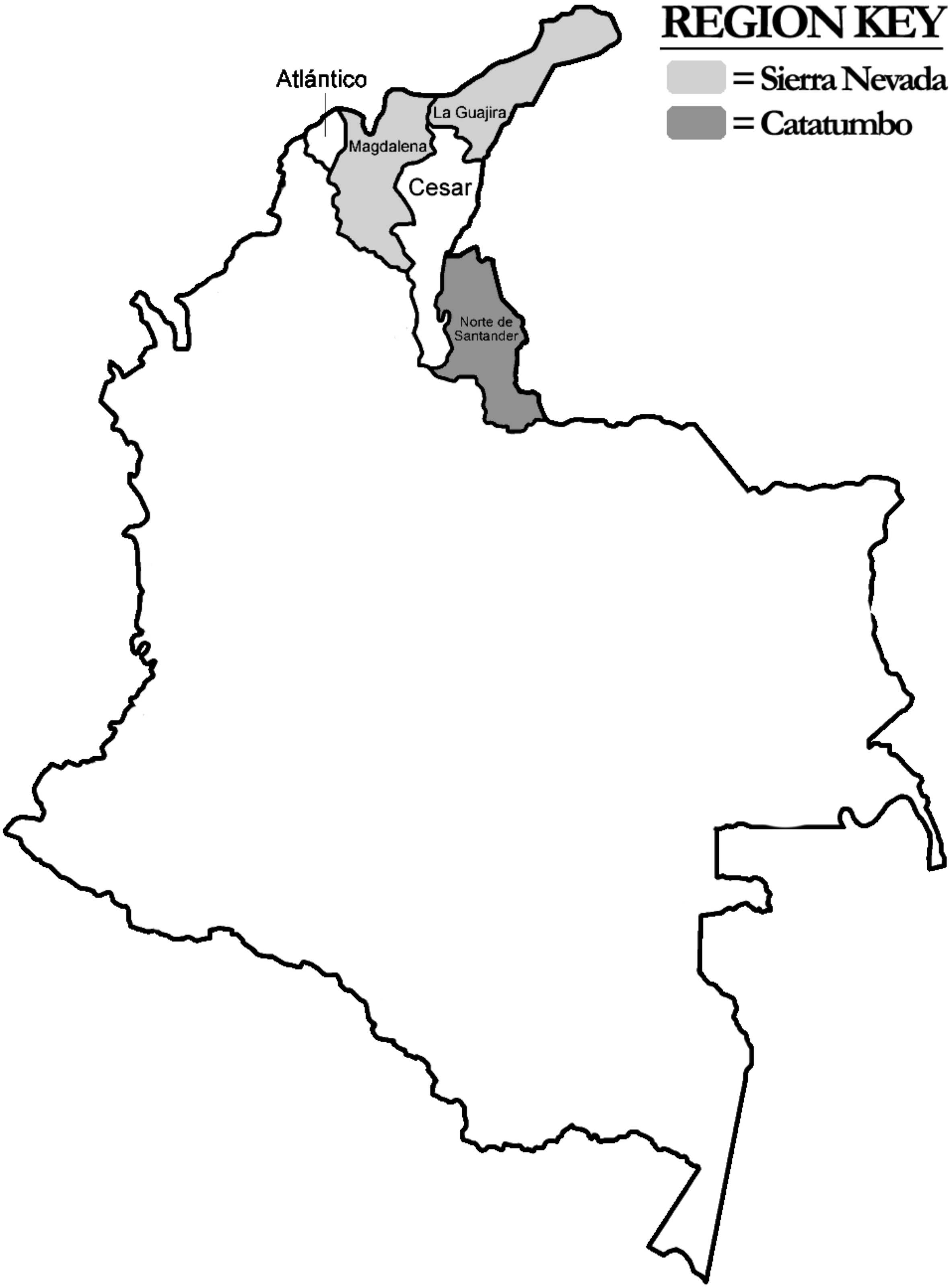
As the simulation is limited to regions of Colombia, however, the information states of each player change. In larger regions, the coalition becomes less informed about what crops are planted where, and limited resources prevent the conducting of unlimited aerial surveys. In larger regions, the single Colombian farmer from the initial simulation is replaced with a group of Colombian farmers. While each farmer may be aware of what the government is doing to his particular plot, each farmer makes a decision independent of what is happening to other farmers and their respective plots. As a result, each player is unaware of the specific actions of the other, although knowledge of the other players' motivations remains. Once the game is extended to this level, it is necessary to allow players to employ a mixed strategy. It is unlikely that the farmers would collectively decide to grow either coca or coffee: crop cultivation will be divided among the farmers in percentages. In addition, limiting the coalition of governments to two moves—aerially fumigating all coca or none of it—is a simplification of its capacity to act. By allowing mixed strategies, the game allows the farmers to make independent decisions and grants the government coalition a greater capacity to act. In expanding the game, an additional assumption is made that the farmers will want to maximize their collective payoffs rather than their individual ones. However, because the game is expanded and not entirely revamped, the collective payoff is analogous to the payoffs of the individual farmer in the initial analysis.

The regions used in this study merged twenty-three of Colombia's thirty-three departments into seven regions: these departments were selected if there was any evidence of coca cultivation. Because of the large amount of data available from the United Nations' Office on Drugs and Crime's 2006 Colombia Coca Cultivation Survey, the regions were combined in the same manner as in that report. The regions are demonstrated below on the maps of Colombia in Figure 5.[1]

[1] Please note that, for parts of the paper, the Central region is mentioned, which is a combination of Sur de Bolivar and Catatumbo


Atlántico
La Guajira
Magdalena
Cesar
Sucre
Córdoba
Bolívar
Norte de Santander
Antioquia
Santander
Arauca
Chocó
Boyacá
Caldas
Casanare
Risaralda
Cundinamarca
Vichada
Quindío
Tolima
Valle del Cauca
Distrito Capital
Meta
Huila
Guainía
Cauca
Guaviare
Nariño
Vaupés
Caquetá
Putumayo
Amazonas

(Figure 5A)


REGION KEY
= Sierra Nevada
= Catatumbo
Atlántico
La Guajira
Magdalena
Cesar
Norte de
Santander

(Figure 5B)


REGION KEY
= Meta-Guaviare
= Amazonia
= Orinoco
Arauca
Casanare
Vichada
Distrito
Capital
Meta
Guainía
Guaviare
Vaupés
Amazonas

(Figure 5C)


REGION KEY
= Sur de Bolivar
= Pacific
= Putumayo-Caqueta
Sucre
Córdoba
Bolívar
Antioquia
Santander
Chocó
Boyacá
Caldas
Risaralda
Cundinamarca
Quindio
Tolima
Valle del Cauca
Huila
Cauca
Nariño
Putumayo
Caquetá

(Figure 5D)

The values used in the simulation for coca are depicted below in the table in Figure 6.[6] The nationally regulated price of Colombian coffee was used, $199.22 for 125 kilograms of coffee.[22] Information on the annual yield of coffee by department or region was not available, so the national average value was used.

Region	**Average annual yield (Kg/Ha/year)**
Meta - Guaviare	9,900
Orinoco	8,552
Sur de Bolivar	6,288
Putumayo – Caqueta	5,559
Catatumbo	5,510
Sierra Nevada	4,840
Pacific	2,705
All regions	**6,343**

(Figure 6)

(See FIGURE 7 in Appendix)

In five of the seven games in Figure 7, the payoff to the farmer of coca cultivation under aerial fumigation was less than the payoff for growing coffee. This means that, in most regions, farmers would generally choose to grow coffee instead of coca if the United States was aerially fumigating all fields. However, this is clearly not the case, as the region with the lowest average payoff for growing coca actually produces the second most coca in Colombia.[6] To find out exactly why payoffs differed so markedly from actual conditions in Colombia, the probability *P* of how much the government coalition aerial fumigates has been derived.[6]

$$P = \frac{Sum\ of Hectares\ of\ Coca\ Aerially\ Fumigated\ (by\ Department)}{Total\ Hectares\ of\ Coca\ Grown}$$

$$P = \frac{Sum\ of\ Hectares\ of\ Coca\ Aerially\ Fumigated\ (by\ Department)}{Sum\ of\ Hectares\ of\ Coca\ Aerially\ Fumigated\ (by\ Department) + Hectares\ of\ Coca\ Cultivated}$$

Meta-Guaviare: $P = \frac{14714+25915}{14714+25915+20540} = 0.6642$

Orinoco: $P = \frac{5485+1400}{5485+1400+6829} = 0.5020$

Sur de Bolivar: $P = \frac{18022+2662+5588+2146+831+1068+41}{18022+2662+5588+2146+831+1068+41+11643} = 0.7228$

Putumayo-Caqueta: $P = \frac{4575+26491}{4575+26491+17221} = 0.6434$

Catatumbo: $P = \frac{1687}{1687+488} = 0.7756$

Sierra Nevada: $P = \frac{0+0+0}{0+0+0+437} = 0$

Pacific: $P = \frac{59865+1536+0+0}{59865+1536+0+0+18807} = 0.7655$

By inserting these payoffs into the regional matrices, the average payoffs for growing coca and growing coffee for every farmer can be determined. These values are available in Figure 7 which is located in the appendix.

$$Payoff_{Coffee} = P * Payoff_{Aerial\ Fumigation} + (1 - P) * Payoff_{Do\ Nothing}$$

$$Payoff_{Coca} = P * Payoff_{Aerial\ Fumigation} + (1 - P) * Payoff_{Do\ Nothing}$$

As the values above show for every region, it is (on average) in the farmer's interest to grow coca, as the payoff over multiple years from growing coca would be higher than that from growing coffee. The margin is smallest in the Pacific region, the department second in total coca cultivation. Therefore, in order to find out how much more the government coalition needs to aerially fumigate to make it more lucrative on average to grow coffee, the probability P of aerial fumigation was derived in each regional matrix. This value of P reveals what percentage of coca fields the government coalition needs to aerially fumigate in order to make the average payoff for growing coca lower than that for growing coffee. By inputting this derived P, the simulation reveals how the economic situation in Colombia needs to change for coca production to be unprofitable.

$$Payoff_{Coca} < Payoff_{Coffee} = 553.899$$

$$553.899 > P * Payoff_{Aerial\ Fumigation} + (1 - P) * Payoff_{Do\ Nothing}$$

Meta-Guaviare: $P > 1 \quad (Not\ Possible)$

Orinoco: $P > 1 \quad (Not\ Possible)$

Sur de Bolivar: $P > 0.9934$

Putumayo-Caqueta: $P > 0.9746$

Catatumbo: $P > 0.9732$

Sierra Nevada: $P > 0.9506$

Pacific: $P > 0.8039$

The values above reveal that, on average, the government coalition needs to fumigate about 97% of fields in order to make coffee cultivation the more lucrative of the two options. There are exceptions however: in Meta-Guaviare and Orinoco, no P value will make coffee cultivation more lucrative, and in the Pacific region, only about 80% of fields need to be aerially fumigated. The figures for Orinoco and Meta-Guaviare are somewhat misleading, as this analysis assumes that fields can be sprayed only once per harvest. If we allow fields to be sprayed twice per season, the equations and payoffs change.

$$Revenue_{Coffee} = (1 - Effectiveness_{AF})^N * (Average\ Yield)(Average\ Colombian\ Price)$$

$$Expenses_{Coca} = 0.3 * Revenue_{Coffee}$$

$$where\ N\ is\ equal\ to\ the\ number\ of\ times\ a\ field\ is\ aerially\ fumigated\ per\ harvest.$$

By plugging in N = 2, the average yields, and the average Colombian price for Meta-Guaviare and Orinoco, the following results appear:

Meta-Guaviare: $Revenue_{Coca} = (1 - 0.88)^2 * (9900) = 142.56$

$$Expenses_{Coca} = 0.3 * Revenue_{Coffee} = 42.768$$

$$Revenue_{Coca} - Expenses_{Coca} = 99.792 = Profit_{Coca}$$

Orinoco: $Revenue_{Coca} = (1 - 0.88)^2 * (8552) = 123.149$

$$Expenses_{Coca} = 0.3 * Revenue_{Coffee} = 36.945$$

$$Revenue_{Coca} - Expenses_{Coca} = 86.204 = Profit_{Coca}$$

Inputting the profit values as the payoffs in the equations used for solving for P, the following P values are revealed:

$$Payoff_{Coca} < Payoff_{Coffee} = 553.899$$

$$553.899 > P * Payoff_{Aerial\ Fumigation} + (1 - P) * Payoff_{Do\ Nothing}$$

Meta-Guaviare: $553.899 > P * 99.792 + (1 - P) * 9900$

$$P > 0.9537$$

Orinoco: $553.899 > P * 86.204 + (1 - P) * 8552$

$$P > 0.9448$$

This data suggest that if the government coalition sprays about 95% of fields in Meta-Guaviare and 95% of fields in Orinoco two times per season, the coffee cultivation will be more profitable than coca cultivation there.

While the data for Orinoco and Meta-Guaviare are intriguing, the data from the Pacific region reveal insight into more efficient eradication methods. For coca cultivation to be less lucrative than coffee on average in the Pacific region, P needs to be in the $P_{CALCULATED}$ range.

$$P = \frac{59865+1536+0+0}{59865+1536+0+0+18807} = 0.7655 \qquad P_{CALCULATED} > 0.8039$$

$$\Delta P > 0.0384$$

Base Coca Production = 18,807 hectares of coca annually in the Pacific region

$$\frac{(59865 + 1536)}{0.7655} * \ 0.8039 = \ 76378.9 \ Hectares \ (Theoretical)$$

$$59865 + 1536 + 18807 = 80208 \ Hectares \ (Current)$$

$$Needed \ Reduction = Current - Theoretical = 3829 \ Hectares \ of \ Coca \ annually$$

P is a percentage calculation. Thus, if aerial fumigation is increased by 3.84% or more in the Pacific region, then policymakers should see Colombian farmers in that region gradually defect to other, licit crops. Defections could reduce coca production by up to 18,807 hectares annually with as little as 3,829 Hectares of increased fumigation. In contrast, if the United States maintains its current approach, it would require the full 18,807 hectares to be fumigated.

DISCUSSION OF RESULTS

The framework reveals ways that the government coalition can discourage farmers from growing coca. The solution appears to be—as UNODC Executive Director Costa mentioned—greater funding for aerial fumigation efforts. Although the pure strategy payoffs for coca cultivation are lower than coffee cultivation under the right conditions, not enough aerial fumigation is occurring to yield this result. For the UNODC to have increased success combating coca cultivation, the amount of aerial fumigation will have to increase. To allocate this extra funding most efficiently, this study suggests that aerial fumigation increases need to be restricted to one region at a time, as reducing the payoff of coca cultivation is only worthwhile if the payoff is lowered to a level below that of coffee cultivation. Another way to decrease coca cultivation would be to increase the efficiency of aerial fumigation. While using a more effective herbicide is one solution, another would be to spray all regions twice per harvest: this would change the effectiveness of aerial fumigation from 88% to over 98.5%, reducing the percentage of coca fields that need to be sprayed. However, this statistic is somewhat misleading, as it means that the United States would have to spray around 90% of fields twice instead of about 100% of fields once, thereby leading to a tremendous increase in aerial fumigation. Such a large increase in spraying herbicides poses environmental and ethical concerns. Another purported option—subsidizing farmers to encourage licit crop growth—is shown by this model to be a very expensive solution. Without greater aerial fumigation efforts, the government coalition would have to subsidize farmers multiple times the market selling price of the licit alternatives they grow. Therefore, the model suggests that aerial fumigation is considerably less expensive—provides “more bang for the buck” so to speak—than crop subsidies, which explains why the use of aerial spraying by intervening bodies is currently so prevalent in Colombia.

This analysis not only advises the Colombian government to fund more aerial fumigation, but it also reveals the best regions to increase aerial fumigation in. If the government coalition aerially fumigated about 4% more land in the Pacific region—the region with the second most coca cultivation— then the average coca payoff would be less than the average coffee payoff, which should result in widespread abandonment of the coca crop. The government coalition should target its efforts in that particular region, as large gains are possible there with only a modest increase in activity. The eradication of approximately 3,829 hectares of coca in the Pacific region should result in the eradication of approximately 18,807 total hectares of coca. To put this potential change in perspective, the government coalition would have to triple the current amount of aerial fumigation in the Meta-Guaviare region, the region with the highest amount of coca cultivation, in order to achieve comparable results with the Pacific region.

Before the United Nations, United States, and Colombia decide to pursue greater aerial fumigation efforts, the ramifications of current coca eradication methods need to be mentioned. Although game theory allows researchers to follow the rational decision-making process of two players, it does not reveal other non-quantitative motivations and consequences. In this particular scenario, there are two sets of implications—moral and environmental—that are not considered in this analysis. The first to be considered, moral, involves the livelihood of Colombian farmers. Those farmers who decide to grow coca do not always do so for selfish reasons; it can be impossible to make enough money growing other, less lucrative crops, and although the coalition of governments does want to eradicate the coca trade, doing so might destroy a way of life and force thousands of farmers to seek a new way to make a living. In addition, greater aerial fumigation could have an untold environmental impact. Information is available that indicates that current levels of aerial fumigation are having a detrimental impact on the environment, and increasing the amount of herbicide dispensed in Colombia will only lead to greater environmental damage.[25] While the government coalition could potentially eradicate coca cultivation in Colombia by increasing the aerial fumigation levels, a decision needs to be made about whether or not it is environmentally worthwhile to move in this direction; if the UN, USA, and Colombia decide they do not want to pursue this action, perhaps they should decide whether or not aerial fumigation and foreign intervention is the proper response to the cocaine trade at all.

LIMITATIONS

It is necessary to briefly mention the limitation of this model. With any game-theory model, one of the underlying assumptions is that all parties must act rationally and always choose greater payoffs, which is not always the case in the real world. In addition, while this model takes many of the economic incentives for growing coca into consideration, other non-financial (and often non-quantifiable) motivations do exist. In some cases, farmers grow coca not necessarily because it is more financially lucrative but rather because of the pressure and threats from narco-terrorist or guerrilla organizations, such as the Revolutionary Armed Forces of Colombia (FARC). However, we posit that this kind of scenario should be considered an exception rather than the norm. Because the major reason is essentially economic in nature, economic frameworks are directly applicable to model this scenario.

CONCLUSION

This study involves the analysis of coca cultivation in Colombia for the purpose of developing strategies that can improve the efficiency of aerial fumigation efforts in Colombia. The game theory framework reveals that, with enough aerial fumigation, the government coalition can make licit crop growing more profitable than coca cultivation, thereby reducing the amount of coca cultivation in Colombia. However, the government’s current levels of aerial fumigation are insufficient to make coca cultivation uneconomical on a widespread level. Most of the viable solutions to the problem of coca cultivation in Colombia involve aerial fumigating the coca crop to a greater degree, by either spraying fields twice or spraying more coca fields. This report discusses an approach to reducing the coca trade in Colombia by assessing coca cultivation from a behavioral standpoint. By specifically targeting modest increases in eradication, large decreases in coca cultivation can be attained. Ultimately, the government coalition can make more educated decisions about where coca eradication efforts should be increased by considering the economic perspective of individual farmers.

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