The Origins of Cocaine

Colonization and Failed Development in the Amazon Andes

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2 The ghosts of development past

Deforestation and coca in western Amazonia

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Introduction

Coca growers and their illicit crops have been described as a critical factor in understanding the extent and location of deforestation in the Andean fringe of the Amazon for decades (e.g., Dávalos *et al.* (2011); Young and León (1999). From a purely economic perspective, however, disproportionate deforestation by coca growers is puzzling. Quite the opposite, growing a highly lucrative crop should lead to decreases in both the cultivated area and the rate at which growers have to bring forested land into production (Kaimowitz 1997). As most coca since the 1970s has been produced for the illegal cocaine market, at least two other explanations have been proposed for coca deforestation. First, coca cultivation and harvesting might attract growers who would otherwise intensify production of other crops at already developed sites to new, forested sites. Second, aggressive efforts to suppress the crops force growers into remote sites that would otherwise remain untouched. In both cases, the resulting deforestation increases because of the illegal nature of coca. Hence, deforestation and environmental damages in western Amazonia would arise from coca prohibition and not expansion of agriculture, or not primarily because of this expansion.

There are high stakes for discovering and addressing the dominant factors driving growers to both adopt coca and contribute to deforestation in the western Amazon. Just the last twenty years, as the decades-long war against coca in the region has intensified, have seen most coca cultivation shift from the edges of the Amazon of Bolivia, Peru, and Colombia, first to every ecosystem of Colombia, then to Peru (Dávalos *et al.* 2009), then back to forest frontiers of Colombia again. All the while, foci of production in the Amazon persisted even as eradication investments boomed, and alternative development programs to persuade growers to switch away from coca to other crops multiplied. But even as the dynamics of coca cultivation shifted across the Andes, deforestation in the western Amazon continued apace, sometimes worsening in parallel with programs for eradication and alternative development (Bradley and Millington 2008b).

Here, I review current research on the quantity and location of both deforestation and coca cultivation in western Amazonia, finding illegal crops explain little deforestation. Instead, the wedges of deforestation into the Amazon lowlands have tracked roads and sites targeted for colonization and development decades ago. While this approach cannot address the history and idiosyncratic trajectory of particular sites, it outlines features common to the process of agricultural expansion into the Amazon across the northern Andean countries. Grounded on analyses of land use change, the synthesis presented here focuses on the forests, their fragmentation and loss across the region, complementing the localized case studies of the rest of the book.

Background: tropical deforestation, the problem and models

Since the 1980s, international attention has focused on tropical forests as rapidly disappearing ecosystems harboring the greatest biological diversity on Earth (Myers *et al.* 2000). While the task of finding optimal areas for conservation has produced a large literature on the ecology of these complex systems (Brienen *et al.* 2015), a parallel quest for solutions has emerged, strongly linked to the history, economics, and human geography of the Amazon and similar regions (Barber *et al.* 2014; Dávalos *et al.* 2014; Fearnside 1993). Clearly, the accelerated change from vast, continuous, old-growth tropical forests to agricultural uses since the 1950s is one of the main current threats to global biodiversity (Laurance 1999; Laurance *et al.* 2012). As tropical forests provide critical ecosystem functions through carbon sequestration, regulation of water and sediment flows, and soil nutrient cycling (Asner *et al.* 2009; Hedin *et al.* 2003), the prospect of an Amazonia dominated by agriculture raises concern about the stability of both global climate and the water cycle. Currently, tropical deforestation and tropical fires contribute substantial and increasing proportions of global carbon emissions (DeFries *et al.* 2002; Harris *et al.* 2012), but a substantially denuded and drier Amazon could even switch from a carbon sink that absorbs emissions to a net source that accelerates climate change (Brienen *et al.* 2015; Nepstad *et al.* 2008). If the goal is to maintain productive agricultural systems based on a stable climate into the future, the continued stability of Amazonian forests is a global priority.

As remote sensing data and computing power have become increasingly available, analyses of satellite imagery have confirmed agriculture—and not logging or similar extractive activities—as the main direct cause of Amazon deforestation over the last fifteen years (Graesser *et al.* 2015; Gutiérrez-Vélez *et al.* 2011). Still, identifying agriculture, and in particular the expansion of pastures (e.g., (Chadid *et al.* 2015; McAlpine *et al.* 2009)), as the main contributor to forest loss is unhelpful when designing long-term policies to address deforestation, as both factors enabling change and structural drivers of change remain intact. Instead it is more helpful to distinguish between proximate causes and underlying drivers when considering the human activities influencing tropical deforestation (Geist and Lambin 2002). Proximate causes directly change land use from forest to human uses, including mining, logging, roads, and particular forms of agriculture (Fearnside 2005; Laurance *et al*. 2002).

In contrast to the clear and large role of agriculture and agriculturalists as proximate causes of deforestation, the underlying drivers of deforestation are subject to much debate (Lambin *et al.* 2001). Identifying and understanding these drivers is vital, as national and global development policies aim to reduce or at least not unduly increase deforestation (Angelsen and Kaimowitz 1999). The debate on the underlying or ultimate causes of deforestation pits proponents of population growth as the ultimate driver of all environmental degradation (e.g., Ehrlich and Ehrlich (2002)), against social scientists who argue human ingenuity and adaptation tend to avert environmental catastrophe as populations grow (e.g., Bhattarai and Hammig (2001); Boserup (1965)). The Malthusian view of population invariably expanding to match productivity thereby undermining any gains in wellbeing (Malthus 1798), is the basis of demography and poverty as explanations for tropical deforestation (Geist and Lambin 2001; Rudel and Roper 1997). The evidence, however, suggests population and poverty result in tropical deforestation only when accompanied by specific economic development policies, social arrangements, cultural practices, and even beliefs (Geist and Lambin 2001).

The evidence for a strong institutional influence—and against a strictly Malthusian view—on how people respond to economic opportunities and the consequences for land use and deforestation has accumulated only recently (Geist and Lambin 2001; Lambin *et al.* 2001; Rudel and Roper 1997). For example, even in the pre-industrial era, the rate of conversion of natural habitats to human use was lower than expected given population growth, according to historical reconstructions of land use (Ellis *et al*. 2013). These findings are replicated with data from tropical countries, collected recently using remote sensing and comprising four decades of surveillance. Those studies confirm a decoupling of agricultural productivity and habitat change. While developing countries have increased agricultural production ~3.3–3.4 percent annually, deforestation has increased agricultural area by only 0.3 percent each year, suggesting forest conversion plays a minor role in productivity gains (Angelsen 2010). At the same time, if deforestation has expanded agricultural area by only ~0.3 percent annually, higher deforestation rates such as those recorded for the Amazon require additional explanations (Table 2.1).

Divergent conceptual models of deforestation can help explain the apparent contradiction between high rates of land use change to agriculture in the short term, and lower rates of long-term growth in agricultural extent. While the models elide much variation from one country to the next (e.g., the oil-centered economies of Ecuador and Venezuela, or the history of armed conflict and its relationship with urbanization for Colombia and Peru), they provide a framework for relating the geography of deforestation

Table 2.1 Deforestation rates in countries with coca cultivation recorded since 2000 and neighbors without records over same period

Country	*Annual loss km²*	*Deforestation rate (percent)*	*Coca cultivation*
Bolivia	2339	0.407	Yes
Brazil	25480	0.536	–
Colombia	2022	0.258	Yes
Ecuador[1]	422	0.235	–
Peru	1259	0.164	Yes
Venezuela	939	0.175	–

Source: Deforestation data from Hansen *et al.* (2013), coca production data from UNODC (2015). Only areas with >50 percent tree cover were included in calculating the rate. Deforestation rates were calculated following the compound interest formula of Fearnside (1993). Positive rates indicate forest loss.

Note:

[1]Although both opium poppy and coca cultivation have been detected in Ecuador (UNODC and Gobierno Nacional de la República del Ecuador 2015), the area detected during the study period is negligible compared to its Andean neighbors.

to the history of economic development. These models, first outlined in reference to global tropical deforestation (Rudel and Roper 1997), relate forest loss to economic development and poverty in distinct ways.

The immiserization model of deforestation

The engine of deforestation in the immizerization model is a growing population of small farmers with limited access to the means of intensification, who then expand agriculture into marginal lands at the expense of forests (Rudel and Roper 1997). Although sometimes linked to slash-and-burn agriculture (Myers 1993), slash and burn can be sustainable when tropical forests are used in an impermanent manner for fewer years than the land is fallowed (Harris 1971). Instead, the immiserization model requires poverty both among agriculturalists and more broadly in the national economy which fails to absorb workers (Walker 1993). For this model to explain the gap between growth in agricultural land and deforestation requires the ultimate collapse of marginal lands brought into production and their failure to lead to long-term permanent agriculture. In contrast to traditional slash-and-burn agriculture, which requires abundant forests to be sustainable, the long-term footprint of deforestation from immiserization is degraded and unproductive land where forests used to be. No capital or investment is necessary for deforestation to take place, just an abundance of poor growers.

The frontier model of deforestation

When forested land is abundant (e.g., Figure 2.1), entrepreneurs, small farmers, and companies work together or separately to develop a region

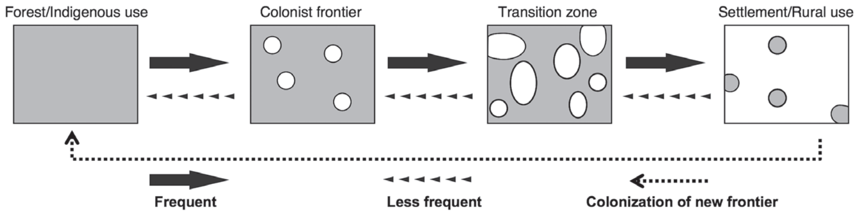

Figure 2.1 Stylized trajectory of forest fragmentation at agricultural frontiers, from old-growth forests to rural fields

and open a frontier (Rudel and Roper 1997). Although population growth and poverty do contribute to deforesting the frontier, insofar as landless rural laborers and smallholders help exploit and settle the newly opened lands (Rudel and Roper 1997), poor growers are not the driving factors of forest loss (Fearnside 1993; Lambin *et al*. 2001). Instead, both state assistance (e.g., through road construction) and private capital are necessary to open predominantly forested lands to exploitation (Hecht 1985). Lacking infrastructure to adequately enforce property rights (Angelsen 1999), the leading edge of the frontier invites conflict over the land and its resources. Often, the forests are quickly cleared to establish ownership, extract as much of its natural resources as possible, or both (Fearnside 2005; Southgate 1990). In contrast with the framework of immiserization, which would predict a decrease in forest loss with investment (e.g., for intensification), public or private investment at the frontier increases deforestation (Rudel and Roper 1997).

If immiserization were the better explanation for western Amazon deforestation, then investment into the frontier would not be a necessary condition for deforestation and only the presence of large *campesino* populations would be enough. In contrast, if deforestation in the region arose through the opening of the frontier, then development plans and in particular road construction would be indispensable for deforestation. In both cases, coca deforestation would concentrate among poor growers and regions. Here, I review the different studies on deforestation to systematically evaluate these models in light of deforestation data.

Coca in the deforestation literature: coca cultivation as a special force for deforestation

Without the advantage of detailed remote sensing analyses, early studies on coca and deforestation highlighted its uniquely destructive potential. For example Álvarez (2002) used back-of-the envelope calculations to estimate roughly 50 percent of 1990s deforestation in Colombia could be attributed to coca growers and their crops. In another example, an estimate of "several million hectares of tropical forest" cleared by coca growers in the Andean countries (Young 2004b) was accompanied by an urgent call for collecting systematic data on deforestation in Peru (Young 2004a). Today, the data needed to assess the extent of forest transformed into coca cultivation have become available both through analyses conducted by the UNODC (UNODC 2008; UNODC and Peru *Ministerio del Medio Ambiente* 2011), and through studies undertaken by independent research groups including illicit crop cultivation as one of multiple human land uses (Armenteras *et al*. 2013b; Chadid *et al*. 2015; Dávalos *et al*. 2011). These studies have focused on direct and indirect deforestation from coca.

Direct deforestation

The surface area devoted to coca is small compared to other land uses (Dourojeanni 1992), but this small area is viewed as an underestimate of the deforestation resulting from cultivation (Young 1996). This is because coca is seen as the cash crop of pioneering transformation, taking agriculture to remote locales where cultivation would not occur otherwise (Álvarez 2001; Young 2004b; Young and León 2000). This encroachment into old-growth forests is believed to then lead to further forest loss, as other forms of agriculture expand next to the illicit crops. Ancillary uses leading to deforestation include other (subsistence) crops, pastures, airstrips, roads and dwellings (Álvarez 2002).

A systematic search for remote sensing analyses providing sufficient information to estimate deforestation rates in coca-growing areas is summarized in Figure 2.2, and reviewed chronologically. The study reaching the longest

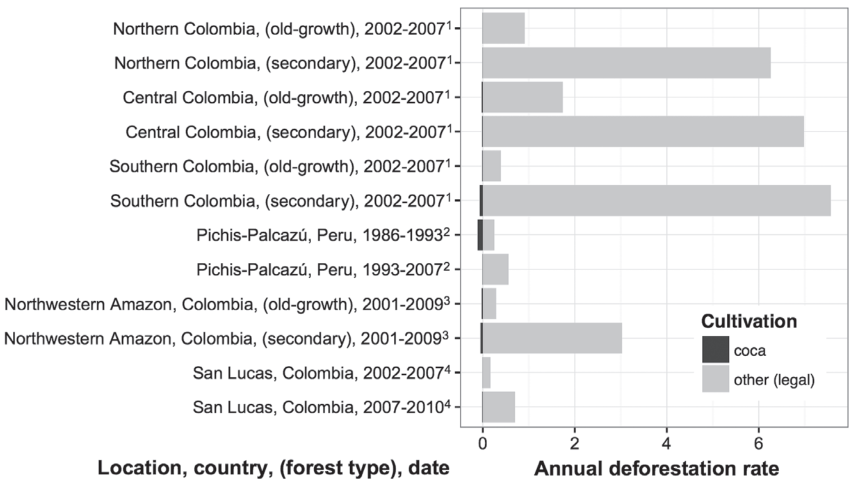

Figure 2.2 Annual deforestation rates from legal crops or from coca cultivation

Sources: 1 Dávalos *et al*. (2011), 2 UNODC and Peru Ministerio del Medio Ambiente (2011), 3 Armenteras *et al*. (2013b), and 4 Chadid *et al*. (2015). All analyses correspond to the Amazon frontier except 4 into the past was the analysis of Landsat5 coverage for 1986, 1993, and 2007 for Pichis-Palcazú in the Amazonia of Peru (UNODC and Peru *Ministerio del Medio Ambiente* 2011). The express purpose of the study was not only to quantify deforestation, but to determine the economic contribution of different activities and their opportunity costs. Therefore, estimates of the value of frontier agriculture included both coca cultivation and raising cattle in pastures cleared from the forest. Additionally, illegal logging was also mentioned as contributing to the deforestation by enabling traffickers to launder illegal revenue. Compared to pastures, which made up 57 percent of the area cleared of forest for human uses, coca cultivation was a minor use at 0.39 percent of total. The estimated net value from coca cultivation and cattle ranching were estimated to sum about US $4.6 million, while the partial value of the standing value of woods from the deforested area was estimated at over US $19 million. Hence the opportunity costs of alternative exploitation were roughly four times the revenue generated from frontier agriculture, making frontier exploitation both economically wasteful and environmentally unsustainable. Although the study does not directly address it, the contradiction between great economic potential from carbon sequestration or careful logging and the reality of encroaching agriculture highlights the tension between the formal value of the forest and clearing dynamics in the western Amazon frontier.

The second study compared Landsat5 from 2001 and 2009 to quantify land use change for Guaviare in Colombia, and relate changes to the fires (Armenteras *et al*. 2013b). Although deforestation associated with coca cultivation in Guaviare has been documented since 1990, it is at least a decade older (Arcila *et al*. 1999; UNODC 2010). Coca cultivation declined steadily throughout the period of analysis, but mosaics with illicit crops had significantly lower probability of reverting to forest (6.8 percent) than mosaics dominated by pastures (13.5 percent). This was further corroborated by the finding that coca-dominated mosaics had the lowest probability of illicit crop plots reverting to forest at 14.3 percent, compared to 26.4 percent probability for coca plots in forest-dominated mosaics. In short, coca does not need to occupy much area to signal a transformation of the landscape toward forest loss. Subsequent analyses of these data confirmed both the decline of coca and the contribution of other land uses, particularly pastures, to high deforestation rates in the most rapidly developing section of Guaviare (Dávalos *et al*. 2014), as discussed on pp. 35–36.

The third study relied on land use data for Colombia generated by the UNODC from 2002 to 2007 to estimate the influence of coca cultivation as a catalyst of deforestation beyond its immediate surface area (Dávalos *et al*. 2011), discussed on pp. 28–30. Three regions of the country were analyzed, none of which correspond to a single biogeographic region. The northern region comprised primarily Andean forest remnants of the Sierra Nevada of Santa Marta and the Serranía del Perijá (Álvarez 2002). The central region included Andean forests of the three Colombian cordilleras, and in particular the Cordillera Central in San Lucas (Dávalos 2001), as well as remnant lowland forests of the corresponding inter-Andean valleys and the Chocó biogeographic region (moist tropical forests of the western slopes of the Cordillera Occidental and lowlands abutting the Pacific Ocean from southern Panama to northern Ecuador). The southern region included remnants of Chocó and Andean forests and overwhelmingly comprised Amazonian forests, especially at the colonization frontier. Along with the common pattern of much higher deforestation rates from uses other than coca cultivation, this study showed 4- to 20-fold higher deforestation rates in secondary forests than in old-growth stands. This is roughly consistent with the 10-fold increase in deforestation rate for secondary forests compared to old-growth stands found in the Guaviare study (Armenteras *et al*. 2013b).

The final study also used the UNODC layers for Colombia with a much narrower focus on modeling forest loss in the Andean and sub-Andean forests of San Lucas (Chadid *et al*. 2015). Beyond the 2002–2007 period, analyses expanded to 2007–2010. Coca cultivation tended to expand in San Lucas from 941 hectares recorded in 2002 to 6,013 hectares in 2010, and this makes the region unlike other locations analyzed. Despite this difference, coca cultivation was still a minor land use, with 0.3 percent of land use even at its maximum in 2010. This contrasts sharply to pastures going from 9 percent of land use to almost 24 percent of land use in less than one decade. For comparison, the Guaviare study also found "considerable" pasture, from 8 percent to 10.3 percent in the 2001–2009 period (Armenteras *et al*. 2013b). The deforestation models generated for San Lucas also provide some insights on key differences between coca cultivation and pastures, including optimal intermediate distance to other crops, high distance to settlements, cultivation on slopes, and proximity to rivers (Chadid *et al*. 2015). This is the first quantitative confirmation of the observation of coca cultivation taking place in slopes growers would not use for other agriculture (López Rodríguez and Blanco-Libreros 2008; Young 2004a, 2004b; Young and León 1999), and to systematically compare coca and pasture deforestation.

Comparisons of deforestation rates across studies show two clear patterns. First, deforestation rates for agricultural uses other than illicit crops are higher by one order of magnitude or more (Figure 2.2). The small direct footprint of coca is highlighted in all source studies (Armenteras *et al*. 2013b; Chadid *et al*. 2015; Dávalos *et al*. 2011; UNODC and Peru *Ministerio del Medio Ambiente* 2011). This is also expected because during the period of analyses, illicit crops have been monitored through remote sensing, resulting in smaller coca plots (UNODC 2008; UNODC and Gobierno de Colombia 2013). Labor availability for harvesting leaves is thought to constrain plot size on these productive systems (Kaimowitz 1997). The data reviewed here are insufficient to test this potential explanation, although a study purporting to test this effect found mixed results in Chapare, Bolivia (Bradley and Millington 2008b). Regardless of the mechanism, coca replaces only a small fraction of the forest. The conversion of forests for other land uses is what produces high deforestation rates in each of these agricultural frontiers. These uses are thought to be associated with coca cultivation through the activities of coca growers as agents of deforestation (contrasting with commercial logging, for example).

Second, deforestation rates are higher for secondary forests than for old-growth forests (Figure 2.2). Overall deforestation rates up to 6 percent have been observed at sites in Santa Cruz, Bolivia (Steininger *et al.* 2001), with rates from 1.2–4.5 percent historically more common at now-denuded lowlands of Colombia, and peaking at 7.8 percent when secondary forests are included (Etter *et al.* 2006b). By separating rates for old-growth and secondary forests, a pattern of high turnover for fallowed regeneration plots becomes evident (Figure 2.2). In the agricultural frontier, secondary forests are the result of previous human intervention, and their presence implies an earlier process of land use change (Guariguata and Ostertag 2001). This process of regrowth is therefore concentrated at the forest frontier, as almost all the analyses highlight (Armenteras *et al.* 2013b; UNODC and Peru *Ministerio del Medio Ambiente* 2011), including by estimating the probability of regrowth to be highest at the forest frontier (Dávalos *et al.* 2011). Even when a secondary forest has regrown for several years, its physical characteristics differ from old-growth forests. These differences include lower canopy heights, lower biomass, and lower biodiversity (Guariguata *et al.* 1997; Laurance 2015). The process of forest fragmentation in the agricultural frontier proceeds more frequently toward greater fragmentation and physical separation between patches of forest than toward regeneration (Figure 2.1). It is also easier to access, light fires, and further fragment these fragmented landscapes than large, unbroken stands of old-growth forests (Armenteras *et al.* 2013b; Dávalos *et al.* 2014; Etter *et al.* 2006b; Fahrig 2003). In line with these historical and physical considerations, deforestation rates from coca cultivation were higher for secondary forests as well, with the single exception of the Central Colombia region analyzed by Dávalos *et al.* (2011) (Figure 2.2).

In conclusion, and contrary to some news headlines, coca causes little direct deforestation. Measurements reveal coca replaces a minimum of forest along the agricultural frontier, amounting to one-tenth or more often much less of the total transformation. These areas are not losing forest only or mainly because they have coca. Instead, the high rates of loss of secondary forests suggest these sites correspond to the agricultural frontier where colonization and migration only began over the last few decades (Dávalos *et al.* 2011; Etter *et al.* 2006b, 2008; Young and León 1999). The use of higher-slope terrain for coca cultivation where other crops are not grown (Chadid *et al.* 2015), confirms decades-old claims using statistical analyses (López Rodríguez and Blanco-Libreros 2008; Young 2004a, 2004b; Young and León 1999), and indicates one uniquely unsustainable characteristic of coca. Coca is grown on slopes where growers choose to plant nothing else.

The hypothesis that coca itself attracts growers to these sites and drives otherwise nonexistent deforestation is discussed below.

Indirect deforestation

Analyses of direct deforestation from coca cultivation show this crop leads to relatively small clearings. Besides the high economic return per hectare (Bradley 2005; Kaimowitz 1997), the multi-year productive cycle of coca and its productivity despite replanting at the same site can reduce the fragmentation and deforestation effects of this crop (Salisbury and Fagan 2011; Salisbury 2007). This last finding does not address the hypothesis of coca as particularly destructive because of its unique tendency to promote land use change in remote areas, or to attract colonists (Álvarez 2001, 2003; Young 2004b; Young and León 2000). There are two ways to evaluate this argument. The first is by demonstrating deforestation observed in with areas influenced by coca is somehow related to coca, and not just the result of pioneering or colonist agriculture in general. This is difficult to document because coca cultivation concentrates along existing colonization fronts in all three Andean countries (Andrade 2004; Etter *et al*. 2005, 2006a; Fajardo 2004; UNODC 2010, 2014; UNODC and Peru *Ministerio del Medio Ambiente* 2011). The second way of evaluating this claim requires comparing deforestation rates from sites influenced by coca to those where coca is minimal or absent. If coca cultivation is uniquely damaging, then deforestation rates in affected regions should exceed those of unaffected regions (other things being equal, meaning along agricultural frontiers).

There was a single study attempting to isolate the unique effect of illicit crops as catalysts of forest loss throughout the landscape (Dávalos *et al*. 2011). The effect of coca cultivation was measured in two ways: as the distance to the nearest coca plot, and as coca cultivation present per kilometer square. If coca cultivation were a unique catalyst of land use change, then the probability of a forest pixel converting to any human use should decrease with distance to coca and increase with the quantity of cultivation in the larger area. A series of landscape variables usually associated with the probability of deforestation were also included: the proportion of forest remaining (Ewers 2006), distances to roads and rivers (Laurance *et al*. 2009; Mahecha *et al*. 2002; Viña *et al*. 2004), biophysical characteristics related to agriculture in general such as climate, slope, and aspect (Etter *et al*. 2006c), and the protection status of the land (Barber *et al*. 2014). The results of models accounting for spatial autocorrelation inherent to the landscape data showed the expected effect of coca cultivation in southern Colombia, but not in the northern or central region (Dávalos *et al*. 2011). Those results show for every two pixels of forest of any type converting to human use in southern—mostly Amazonian—Colombia, 98 stay the same during the 2002–2007 period. But when the quantity of coca in the surrounding kilometer square increased by 2 hectares, only 84 stayed the same. In contrast, when the distance to the nearest coca plot increased by 15 kilometers, 222 pixels stayed the same. The change in probability of losing a forest pixel behaved as expected if coca was indeed a unique catalyst of forest loss in the landscape.

Two additional results of Dávalos *et al.* (2011) merit discussion. First, no similar landscape effect was demonstrated for northern and central Colombia, despite the extent of coca cultivation and presumed association with deforestation in both regions (Figure 2.3) (Chadid *et al.* 2015; Dávalos 2001; UNODC 2008). The large number of pixels sampled ensures this result was not caused by low statistical power. Instead, this implies coca did not behave as a special catalyst and instead was just one more crop in agricultural colonization fronts. Second, analyses of deforestation rates using municipalities found no evidence that the quantity of new coca cultivation in 2002–2007 resulted in higher deforestation rates. This result shows effects detectable across the landscape do not scale up to political units for which socioeconomic data become available, and this will become important when discussing analyses modeling deforestation at the subnational scale.

Instead of finding coca cultivation (or eradication) as a factor explaining deforestation rates, Dávalos *et al.* (2011) found gaining population density increased rates in municipalities with new coca during the period. The 267 remaining municipalities in the sample showed no such pattern. This effect could not be explained by coca attracting colonists: new coca cultivation was unrelated to changes in population density. The authors interpreted

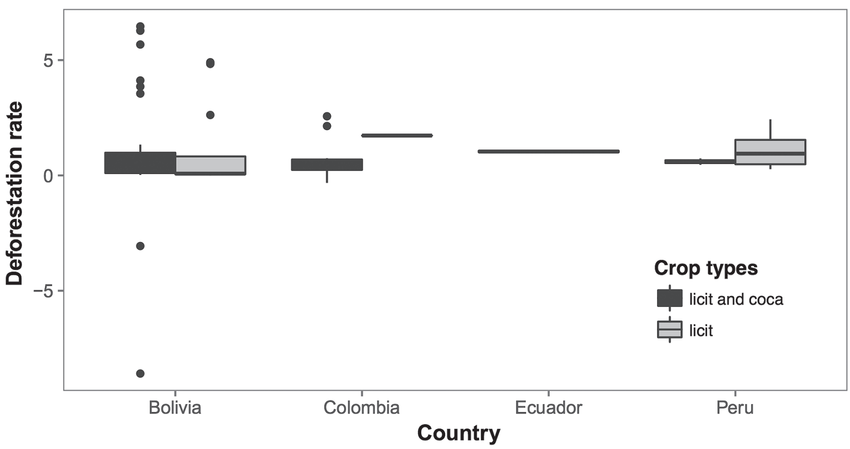

Figure 2.3 Summary of deforestation rates in areas or at times without illicit crops, or when coca cultivation was present

Source: See Table 2

these results as evidence that coca cultivation was a symptom, and not the ultimate cause of deforestation (p. 1225):

> [W]e hypothesize that what sets coca-growing municipalities apart is poor rural development. Gains in rural population density relate to higher deforestation rates because most or all economic activities that absorb immigrants, or used to occupy emigrants, require forest clearing. Municipalities without new coca would have a diverse suite of economic activities to accommodate population growth, so that the relationship between population and deforestation breaks down. […] The expansion of coca itself is an indication that these municipalities constitute the agricultural frontier, where settled land ends and new inroads begin. […] Coca is expanding in these municipalities because they are underdeveloped, rather than the converse. Coca is therefore a symptom rather than the ultimate cause of deforestation, and structural features such as socioeconomic inequality, failed agricultural development policies, and armed conflict are the large-scale drivers of deforestation.

Subsequent analyses of MODIS imagery from 2001 to 2010 support this last interpretation (Sánchez-Cuervo *et al*. 2013). Those analyses modeled land use change as a function of a suite of biophysical and socioeconomic variables, including climate, accessibility by road or river, changes in human population density, poverty, changes in coca cultivation, displacement, and the activities of armed groups. While the activities of armed groups explained forest loss in particular ecoregions, changes in coca cultivation did not explain changes in land use change at any spatial scale (Sánchez-Cuervo *et al*. 2013).

Another study from Colombia focused exclusively on deforestation rates at different stages of colonization in the Meta/Guaviare colonization front (Table 2.2, (Rodríguez *et al*. 2012)). Satellite imagery data from early periods are difficult to parse, but coca has influenced land use change in the region since the 2000s, may date back to the 1980s (Molano 1989), and was definitely present by 1990 (UNODC 2010). The key finding was deforestation rates increase along the gradient of human influence, from lowest to highest for indigenous settlements, colonist frontier, transition zones and settlement zones (as proposed in Figure 2.1). Settlement zones have deforestation rates 100-fold greater than indigenous settlement areas, and transition zones have 10-fold greater rates of deforestation than colonist frontiers (Table 2.2). Despite lacking a quantitative assessment of the influence of coca cultivation, coca agriculture was proposed as influencing both stages with the highest rates of land use change: transition zones and settlement zones (Rodríguez *et al*. 2012).

A series on Colombian deforestation from Landsat imagery in 1985 and 2005 (Armenteras *et al*. 2011, 2013a) further evaluated the relationship between coca cultivation and deforestation rates. The relevant analyses encompassed all ecoregions but the Andes, including Amazonia (Armenteras *et al*. 2013a). While the goal in each case was to identify the drivers

Table 2.2 Local and regional rates of forest loss with and without coca in Andean countries, in chronological order

Coca presence	*Annual loss (ha)*	*Deforestation rate (percent)*	*Period*	*Country*	*Source*
No	1,877	1.727	1973–1985	Colombia	(Viña *et al*. 2004)
No	1,764	1.099	1973–1985	Ecuador	(Viña *et al*. 2004)
No	7	0.224	1975–1983	Bolivia	(Bradley 2005)
Yes	39	3.854	1975–1986	Bolivia	(Bradley 2005)
Yes	2,500	0.026	1976–1986	Bolivia	(Killeen *et al*. 2007)
No	0	0.000	1976–1986	Bolivia	(Killeen *et al*. 2007)
Yes	5,000	0.250	1976–1986	Bolivia	(Killeen *et al*. 2007)
No	6,700	0.110	1976–1986	Bolivia	(Killeen *et al*. 2007)
Yes	1,200	0.021	1976–1986	Bolivia	(Killeen *et al*. 2007)
Yes	32,900	0.175	1976–1986	Bolivia	(Killeen *et al*. 2007)
Yes	2,800	0.213	1976–1986	Bolivia	(Killeen *et al*. 2007)
No	59	4.836	1983–1986	Bolivia	(Bradley 2005)
No	151	4.907	1983–1986	Bolivia	(Bradley 2005)
Yes	2212	2.566	1985–1996	Colombia	(Viña *et al*. 2004)
No	1,356	0.974	1985–1996	Ecuador	(Viña *et al*. 2004)
Yes		0.04[1]	1985–2002	Colombia	(Rodríguez *et al*. 2012)
Yes		0.17[2]	1985–2002	Colombia	(Rodríguez *et al*. 2012)
Yes		1.99[3]	1985–2002	Colombia	(Rodríguez *et al*. 2012)
Yes		3.68[4]	1985–2002	Colombia	(Rodríguez *et al*. 2012)
Yes	27,420	0.747	1985–2005	Colombia	(Armenteras *et al*. 2011)
Yes	46,477	0.634	1985–2005	Colombia	(Armenteras et al. 2011)
Yes	108	4.117	1986–1992	Bolivia	(Viña *et al*. 2004)
Yes	−18	−3.061	1986–1993	Bolivia	(Viña *et al*. 2004)
Yes	8	0.766	1986–1993	Bolivia	(Viña *et al*. 2004)
Yes	13,400	0.137	1987–1991	Bolivia	(Killeen *et al*. 2007)
No	0	0.000	1987–1991	Bolivia	(Killeen *et al*. 2007)
Yes	21,800	1.118	1987–1991	Bolivia	(Killeen *et al*. 2007)
No	3,800	0.063	1987–1991	Bolivia	(Killeen *et al*. 2007)
Yes	9,600	0.166	1987–1991	Bolivia	(Killeen *et al*. 2007)
Yes	87,000	0.472	1987–1991	Bolivia	(Killeen *et al*. 2007)
Yes	2,300	0.179	1987–1991	Bolivia	(Killeen *et al*. 2007)
Yes	46,346	0.608	1990–2002	Colombia	(UNODC 2010)
Yes	31,524	0.421	1990–2005	Colombia	(Armenteras, *et al*. 2013a)
Yes	33,822	0.216	1990–2005	Colombia	(Armenteras *et al*. 2013a)
Yes	50,260	0.333	1990–2005	Colombia	(Armenteras *et al*. 2013a)
Yes	125,785	0.260	1990–2005	Colombia	(Armenteras *et al*. 2013a)
Yes	112	5.677	1992–1996	Bolivia	(Bradley 2005)
Yes	8,000	0.083	1992–2000	Bolivia	(Killeen *et al*. 2007)
No	900	0.059	1992–2000	Bolivia	(Killeen *et al*. 2007)
Yes	10,100	0.542	1992–2000	Bolivia	(Killeen *et al*. 2007)
No	5,100	0.085	1992–2000	Bolivia	(Killeen *et al*. 2007)
Yes	3,000	0.052	1992–2000	Bolivia	(Killeen *et al*. 2007)
Yes	122,900	0.680	1992–2000	Bolivia	(Killeen *et al*. 2007)
Yes	700	0.055	1992–2000	Bolivia	(Killeen *et al*. 2007)
Yes	84,250	0.211	1992–2004	Bolivia	(Müller *et al*. 2012)
Yes	29,667	0.074	1992–2004	Bolivia	(Müller *et al*. 2012)
Yes	43,083	0.108	1992–2004	Bolivia	(Müller *et al*. 2012)

(*Continued*)

Table 2.2 (Continued)

Coca presence	*Annual loss (ha)*	*Deforestation rate (percent)*	*Period*	*Country*	*Source*
Yes	35	3.55	1993–1996	Bolivia	(Bradley 2005)
Yes	45	6.276	1993–1996	Bolivia	(Bradley 2005)
Yes	40,000	4.1	1996–1999	Colombia	(Etter *et al*. 2006a)
Yes	−50	−8.591	1996–2000	Bolivia	(Bradley 2005)
No	40	2.621	1996–2000	Bolivia	(Bradley 2005)
Yes	57	6.463	1996–2000	Bolivia	(Bradley 2005)
No	1,071	2.032	2000–2005	Peru	(UNODC 2014)
No	1,382	0.308	2000–2005	Peru	(UNODC 2014)
No	1,517	0.273	2000–2005	Peru	(UNODC 2014)
No	1,554	1.250	2000–2005	Peru	(UNODC 2014)
Yes	1,771	0.514	2000–2005	Peru	(UNODC 2014)
No	2,167	0.687	2000–2005	Peru	(UNODC 2014)
No	2,246	0.892	2000–2005	Peru	(UNODC 2014)
No	2,813	2.430	2000–2005	Peru	(UNODC 2014)
Yes	4,014	0.607	2000–2005	Peru	(UNODC 2014)
Yes	4,464	0.673	2000–2005	Peru	(UNODC 2014)
Yes	20,800	0.216	2001–2004	Bolivia	(Killeen *et al*. 2007)
No	400	0.027	2001–2004	Bolivia	(Killeen *et al*. 2007)
Yes	23,800	1.335	2001–2004	Bolivia	(Killeen *et al*. 2007)
No	4,100	0.069	2001–2004	Bolivia	(Killeen *et al*. 2007)
Yes	8,800	0.153	2001–2004	Bolivia	(Killeen, *et al*. 2007)
Yes	160,800	0.940	2001–2004	Bolivia	(Killeen, *et al*. 2007)
Yes	5,900	0.464	2001–2004	Bolivia	(Killeen *et al*. 2007)
Yes	10,867	0.154	2002–2009	Colombia	(UNODC 2010)
No	863	1.637	2005–2010	Peru	(UNODC 2014)
No	1,236	0.994	2005–2010	Peru	(UNODC 2014)
Yes	1,587	0.460	2005–2010	Peru	(UNODC 2014)
No	1,944	0.617	2005–2010	Peru	(UNODC 2014)
No	1,977	0.356	2005–2010	Peru	(UNODC 2014)
No	1,977	0.440	2005–2010	Peru	(UNODC 2014)
No	2,064	1.783	2005–2010	Peru	(UNODC 2014)
No	3,042	1.208	2005–2010	Peru	(UNODC 2014)
Yes	3,979	0.601	2005–2010	Peru	(UNODC 2014)
Yes	4,878	0.736	2005–2010	Peru	(UNODC 2014)
Yes	−18,8478	−0.325[5]	2011–2010	Colombia	(Sánchez-Cuervo *et al*. 2012)
Yes	325,356	2.141[6]	2011–2010	Colombia	(Sánchez-Cuervo *et al*. 2012)

Note: Deforestation rates were calculated following the formula of Fearnside (1993). Positive rates indicate forest loss.

[1]Rate for indigenous settlement zones (Rodríguez *et al*. 2012).
[2]Rate for colonist frontier zones (Rodríguez *et al*. 2012).
[3]Rate for transition zones (Rodríguez *et al*. 2012).
[4]Rate for settlement zones (Rodríguez *et al*. 2012).
[5]This is the rate for the woody vegetation category (Sánchez-Cuervo *et al*. 2012).
[6]This is the rate for the mixed woody/non woody vegetation category, probably comprising secondary growth (Sánchez-Cuervo *et al*. 2012).

of deforestation, the quantity of coca cultivation and its variation between regions was a special focus of the discussion. Additionally, those analyses controlled for multiple factors known to influence deforestation such as the extent of pastures and legal crops, temperature and precipitation, road density, and rural and urban population. Surprisingly, the amount of coca cultivation was a positive covariate of deforestation in the Caribbean and Orinoco regions, but not in Amazonia (Armenteras *et al*. 2013a). To explain the finding that coca cultivation was not a covariate of deforestation rates in Amazonia, the authors discuss two alternatives (p. 1191):

> One possible explanation is that the effect of illicit crops in Amazonia was not captured by our model or either they have smaller impact on total deforestation than previously expected [...]. Alternatively, there might be a link between rural population density, deforestation, and an illegal economy such that, as Dávalos et al. (2011) suggest coca growing might be a consequence (attractor) of poverty and not a cause of deforestation.

Two important conclusions follow from these subnational analyses. First, and in line with the municipality analyses of Dávalos *et al*. (2011) and Sánchez-Cuervo *et al*. (2013), the effect of coca on the landscape in Amazonia does not scale up to the levels of political units or disappear when demographic and socioeconomic factors are included. Second, coca cultivation was a covariate of deforestation in two regions: the Caribbean and Orinoco. Importantly, the Orinoco region excluded the vast frontier along the east Andes surrounding the Picachos, Macarena, and Tinigua parks—which corresponds roughly to the Ariari colonization front studied in Chapter 5—which are analyzed instead as part of Amazonia (Armenteras *et al*. 2013a). In other words, coca cultivation was not correlated to deforestation rates in the regions with the most coca.

Another way of demonstrating the unique properties of coca in causing deforestation would be to show that deforestation rates influenced by coca are higher than what they would be without coca cultivation. Studies of deforestation from Andean countries with sufficient data to determine whether or not coca influences deforestation rates are summarized in Table 2.2. Data were available for Bolivia, Colombia, Ecuador, and Peru.

The earliest study was the analysis of Landsat coverage for 1973, 1985, and 1996 along the Colombia–Ecuador border, or the Putumayo colonization wedge (Viña *et al*. 2004). Although the deforestation rate in Colombia almost doubled the rate of Ecuador for the first period and almost trebled it during the later period (Table 2.2), the causes of these differences are unclear. For the first period, the higher Colombian rates were attributed to higher colonization pressures from oil exploitation (Wesche 1968), and coca cultivation during the second period. But there was no quantitative evidence to support this last explanation. The patterns of deforestation, however, are indicative. In Ecuador deforestation followed roads, forming a clear "herring-bone" spatial pattern, while in Colombia a wedge formed at the road's terminus early on, resulting in concentric and outwardly expanding agricultural plots. For the purpose of comparing results to other studies (Figure 2.3), the data from Ecuador were coded as having no influence from coca although the region is tightly interconnected.

The second earliest study analyzed land use change using Landsat images from 1975, 1985, 1992 or 1993 and 2000 at three sites in Chapare, Bolivia (Bradley 2005). Uniquely among all studies analyzed, Bradley (2005) conducted interviews to ascertain the decision-making process of colonists regarding land use. As a result, published sections of this dissertation are among the few comparisons of deforestation rates during different anti-coca regimes (Bradley and Millington 2008a, 2008b). At each of the three sites, three periods were demarcated: pre-coca, coca-dominant, and post-coca dominant. The last two periods are designated as influenced by coca in Table 2.2 and Figure 2.3. The interviews also helped determine the immediate factors motivating deforestation agents, including sale prices of local agricultural commodities (cattle and milk, coca, bananas, pineapple, oranges, and heart of palm), and government enforcement of anti-coca policies. Although the general conclusion is that *laissez-faire* approaches to coca cultivation generated less deforestation than alternative development projects, there was high variance in deforestation rates, as illustrated in Figure 2.3.

In contrast with this result, another study from Bolivia found coca permissiveness increased deforestation rates. Killeen *et al.* (2007) examined deforestation for 7 *departamentos* (departments) using Landsat imagery from 1975/1976, 1986/1987, 1991/1992, 2000/2001 and 2004/2005. Additionally, subsequent analysis disaggregated potential agents of land use change by agricultural sector (Killeen *et al.* 2008). During the entire period mechanized agriculture and cattle ranching were identified as key drivers of rapid rise in deforestation rates in Santa Cruz (Killeen *et al.* 2007). By cross-referencing coca cultivation reports, all *departamentos* except Pando and Chuquisaca were influenced by the illicit crops category in Table 2.2 and Figure 2.3 (UNODC and Estado Plurinacional de Bolivia 2011). The relationship between rates and agriculture in general is analyzed in detail below.

One additional analysis from eastern Bolivia between 1992 and 2004 discriminated between direct causes of deforestation by mechanized agriculture, smallholder production, or pastures for cattle (Müller *et al.* 2012). The study noted the regional importance of coca cultivation, particularly among local smallholders in the Chapare (Tejada *et al.* 2016). Based on the timing and spatial location of those analyses, all estimates were assigned to the influenced by coca category of Table 2.2 and Figure 2.3.

A few additional studies provided sufficient information to estimate deforestation rates in Colombia when coca might influence these measurements (Etter *et al.* 2006a; Sánchez-Cuervo *et al.* 2012). The earliest of these estimates examined waves of unplanned deforestation in Caquetá for the

1982–2002 period, with the peak deforestation rate of 4.1 percent (Table 2.2) reported for the 1996–1999 period (Etter *et al*. 2006a). This peak deforestation rate was attributed in part to coca cultivation, although without quantitative evidence. Finally, Sánchez-Cuervo *et al*. (2012) analyzed MODIS imagery for the 2001–2010 period, finding overall gain in woody vegetation (or forest-rich landscapes) and loss of mixed woody and non-woody vegetation, which would be roughly equivalent to secondary growth. Eight of the 10 municipalities recording the greatest loss of wood vegetation correspond to areas in the Orinoco basin, and oil exploration and exploitation is one of the explanations proposed for these deforestation outliers (Sánchez-Cuervo *et al*. 2012).

Two analyses conducted by the UNODC, one in Colombia (UNODC 2010), and another in Peru (UNODC 2014), provided extensive information on deforestation along coca-producing colonization fronts. The goal of the first study was to give policymakers better information on the biophysical, socioeconomic, and security aspects in regions affected by coca cultivation. Those analyses focused on the ecological transition between the Orinoco basin and Amazonian forests in the departments of Meta/Guaviare, a region experiencing the rapid conversion of forests to pastures and, to a much lesser extent, coca cultivation (Table 2.2) (Armenteras *et al*. 2013b; Dávalos *et al*. 2014). The UNODC analyses found a 4-fold higher deforestation rate for 1990–2002 than for 2002–2009 (Table 2.2). Coca was initially concentrated along the Andean slopes at the western end of the region, and by the end of the study period, cultivation had shifted to the more isolated moist savannas in the easternmost flank of Meta. The study highlights two parallel and seemingly contradictory dynamics:

> [C]oca cultivation presents two simultaneous and antagonistic processes. At one end, rural consolidation spreading from population centers occupying a zone of 1,045,000 ha; at the other, a colonizing front progressively taking over the Amazonian that currently ecosystem occupies 1,500,000 ha. That zone requires action to limit effects on strategic ecosystems.

The first dynamic corresponds to the integration of former forests (and former coca cultivation) into the urban land markets of emergent, regionally important cities (Dávalos *et al.* 2014). These areas were identified by the UNODC as low risk for coca cultivation (UNODC 2010), despite corresponding to centers fringed by large clusters of cultivation in the 1990s (Lee and Clawson 1993). The declining trends in coca cultivation in those zones strongly relate to the growing fraction of the local population living in the core cities, signaling intensifying urbanization and greater importance to the regional economy (Dávalos *et al.* 2014). These changes signal a complete rearrangement of the landscape from one almost 50 percent forested in 2000, to one comprising vast open areas of low-productivity pastures in 2010 (Dávalos *et al.* 2014). These would also constitute settlement zones with the greatest rates of deforestation of Rodríguez *et al.* (2012). Although Rodríguez *et al.* (2012) mentioned coca cultivation—without quantification—as an important component of the landscape in settlement zones, the decade-long trend in the San José-Calamar axis of Guaviare instead suggests coca cultivation is declining (Dávalos *et al.* 2014). There is no contradiction between Rodríguez *et al.* (2012) and Dávalos *et al.* (2014), as coca cultivation is indeed present but declining. At the forested edges of the newly consolidated rural spaces lies the forest frontier, from which new waves of frontier agriculture depart along the large and navigable rivers. These zones correspond to the second dynamics, harboring more than 70 percent of the total coca cultivation (UNODC 2010). Using the classification of Rodríguez *et al.* (2012), these are transition zones between new or early colonist territories and settlement areas.

The UNODC study of San Martín, Peru, aimed to analyze economic effects from alternative development programs and other productive initiatives relative to deforestation and coca cultivation (UNODC 2014). In contrast with the Meta/Guaviare study, a key feature of San Martín is the decline in coca production since its peak in the 1980s, despite sudden jumps in production recorded in 2004 and 2010. San Martin comprises the middle of the Huallaga River Valley, abutting the Andes to the west and extending into Amazonian lowlands to the east. The natural vegetation encompasses a gradient from subtropical montane forests along the eastern flank of the Andes to Amazonian lowland forests to the east and south. Based on preliminary analyses conducted by Conservation International, the report included forest cover for each of the provinces of the region for the 2000–2005 and 2005–2010 periods. By revenue, the top licit products were rice, concentrated in the central Huallaga Valley, coffee in the mid elevations of the valley to the north, and plantain, presumably in the lowlands. Coca cultivation and deforestation were tallied as losses in economic analyses. The net balance was negative, with losses exceeding revenue between 2002 and 2011 by almost a factor of 2 (total revenue of US $2,900 million, losses of US $5,300). There were no quantitative analyses on the relationships between agricultural uses (including coca cultivation) and deforestation. Nevertheless, low-productivity cattle ranching (1 head per hectare) was deemed a key driver of deforestation during the last decade. Two large deforestation fronts were evident based on the data: an inter-Andean valley front predominantly associated with licit agriculture and the road network in northern San Martin, and another pushing northward from the south along the upper Huallaga River. This last front overlaps with areas of varying density of coca cultivation.

Plotting the different deforestation rates highlights three patterns (Table 2.2, Figure 2.3). First, the greatest variance in deforestation rates as well as highest rates of forest loss were recorded for smaller areas in Bolivia (Bradley 2005). This is likely related to the history of fragmentation of Chapare generating small forest patches from deforestation spreading outward along the Cochabamba–Santa Cruz road (Millington *et al*. 2003). This landscape configuration makes further land cover change easier and faster than larger contiguous forest blocs. As discussed before, such a dynamic landscape will also experience regrowth in abandoned coca plots and fallows (Dávalos *et al*. 2011). The highly dynamic landscape then explains the variance corresponding to forest gains in places and at times in Bolivia. Another pattern is the great majority of records corresponding to deforestation instead of regrowth. Only a few records from Chapare in Bolivia, and the MODIS analysis of woody vegetation in Colombia show regrowth (Table 2.2). The final pattern is lower deforestation rates during periods influenced by coca in Colombia and Peru, but not Bolivia (Figure 2.3). If coca were a unique catalyst of deforestation, then coca-influenced records should correspond to high deforestation rates, but the opposite trend is evident in Colombia and Peru. This is consistent with models by several authors who proposed coca generates less deforestation than expected from other crops (Kaimowitz 1997). The only country fitting the prediction of higher deforestation rates when coca is part of the agricultural frontier is Bolivia (Figure 2.3).

To summarize: claims of coca as a promoter of deforestation beyond that expected at the forest frontier in western Amazonia region are at odds with almost all the data. A single study detected the effect of coca, only in southern Colombia, and likely because relevant socioeconomic variables such as changes in population density were unavailable at the relevant spatial scale (Dávalos *et al*. 2011). Once socioeconomic characteristics—including variables related to economic development, roads, and armed conflict—are included, analyses of independently collected data show coca cultivation fails to explain variation in deforestation rates in the Amazonian region most affected by this type of agriculture (Armenteras *et al*. 2011, 2013a; Dávalos *et al*. 2011; Sánchez-Cuervo *et al*. 2013). Instead, most analyses bolster the interpretation of Dávalos *et al*. (2011): the presence of coca is an indicator or symptom of the conditions of the agricultural frontier. These conditions, and the model of extractive development they embody, both drive deforestation rates associated with immigration and provide the medium for coca cultivation.

Analyses showing that Bolivian *departamentos* without coca cultivation have lower deforestation rates are also potentially consistent with this hypothesis (Killeen *et al*. 2007, 2008). Both Bolivian studies lacked demographic and economic covariates, or the amount of coca cultivation as a factor on deforestation rates: the pattern of Figure 2.3 may correspond to the forest frontier actively attracting migration for extractive activities at times when coca and/or another factor fuels the regional economy.

Discussion: frontier deforestation dynamics in the Andean region

Although impoverished farmers are often cited as a key factor in Amazon deforestation (Myers 1993), deforestation and coca cultivation in the

Andean region cannot be explained without reference to the agricultural frontier, and its ecological and socioeconomic conditions. The resource frontier model helps explain several vexing features of Amazonian deforestation in the Andean region, and its coca-related manifestation. First, it provides a geographic focus. Even in Colombia, the country with the most ecologically diverse distribution of coca, cultivation is mostly restricted to the last remnants of mostly forested natural habitats at the agricultural frontiers. The exceptions (e.g., in remote outposts in Guaínia; small concentration of coca in Pando; Bolivia in the 2000s (UNODC and Estado Plurinacional de Bolivia 2011)) are, without migration, short-lived and easy to eradicate compared to the large clusters at the ecotone of the Andes and the Amazonian lowlands. The coca clusters at this transition in the Ariari of Colombia, Huallaga and Apurimac in Peru, and Yungas de la Paz and Chapare in Bolivia persist to this day.

Second, it helps explain why, though surrounded by a seemingly extraordinary bounty of forest products with the potential to yield great benefits if managed sustainably (e.g., UNODC and Peru *Ministerio del Medio Ambiente* (2011)), the final land use tends to be pastures for extensive cattle ranching (Hecht 1993). Opening the frontier to agriculture requires investment (often public, as outlined above), and always involves personal risks for smallholders. Once at the frontier, and as long as territorial control is weak, managing the productivity of agricultural lands is more expensive than opening a new frontier. This creates progressive encroachment into Amazonian lowlands, sometimes perceived as the result of illegal drug prohibition (McSweeney 2015). The advancement of the frontier, however, continues to take place in countries entirely lacking coca cultivation, as in Ecuador or Brazil (Graesser *et al.* 2015; Rodrigues *et al.* 2009; Rudel *et al.* 2002). In short: the frontier continues to advance as the older deforested areas either become commercial and population centers in their own right—as in San José del Guaviare and El Retorno in Colombia and Santa Cruz in Bolivia—or decline as their population migrates to cities or further afield (Carr 2009; Hecht *et al.* 2015).

Finally, the frontier model helps explain why the closing of the forest frontier, when the near-complete transformation of the landscape has played out in a region, also signals the decline of coca cultivation. This is sometimes incorrectly interpreted as the result of anti-coca policies (Dávalos *et al.* 2014). Instead, it relates to smallholders dependent on coca migrating (to cities or other frontiers), while formerly forested lands become properties for investment in an emergent, now better-connected region (Dávalos *et al.* 2014; Rudel *et al.* 2002). This process may involve land grabs and a great deal of violence (Fergusson *et al.* 2014; Salisbury and Fagan 2011). Newly settled agricultural lands where state control and property rights remain fluid provide opportunities to forcibly take the land, a scarce and increasingly valuable resource (Borras *et al.* 2012; Lambin and Meyfroidt 2011).

These are generalizations and many objections can be raised, but the frontier model has distinct advantages over its alternative for understanding deforestation in western Amazonia. To understand these advantages requires first reviewing the role of coca in discussions on deforestation in the Andean countries, and examining the evidence on this purported role. These discussions on coca and its role in deforestation provide the background to the central thesis of this chapter: that government investment in opening the western frontier of Amazonia played a decisive role in the subsequent onslaught of the deforestation as well as the establishment of coca.

The human geography of the Amazonian frontier of the Andes

If not coca, then what factors explain the location and rates of deforestation in western Amazonia? At the center of this book is the history of Andean colonists at the Amazonian forest frontier, a topic of longstanding interest in the social sciences (e.g., Crist and Nissly (1973). This crucial history, however, tends to be overlooked by studies of land use change (e.g., Etter *et al*. (2008), but see Young and León (1999)) even though it is indispensable to understand both the location and extent of transformation of western Amazonia.

To summarize a vast literature: the Andean nations of Colombia, Ecuador, Peru and Bolivia coordinated efforts to develop road infrastructure into their Amazonian lowlands with the ultimate—and still unachieved—goal of interconnecting the Andean section of the Amazon basin from Venezuela to Bolivia (Denevan 1966). The hemispheric Declaration of the Presidents of America in Punta del Este in 1967 crystalized the scope and ambition of this massive development plan (Meeting of American Chiefs of State 1967). The goals of laying the foundation for economic integration by completing the *Carretera Marginal de la Selva* and modernizing agricultural food production through development, agrarian reform, and land settlement are the most relevant to land use change in the declaration (Meeting of American Chiefs of State 1967). These goals were soon bolstered by international support and, indeed, development funds and multilateral loans became conditioned on reforms to achieve a solution to the political challenge of landless campesinos (INCORA 1974a). The goal of developing and settling Amazonia, however, did not begin with this declaration. Instead, the vision embodied by the Carretera Marginal de la Selva was in itself a culmination of processes begun decades earlier within Andean nations.

The Carretera Marginal de la Selva was a long-held goal of presidential candidate Fernando Belaúnde Terry of Peru, an important factor in his 1963 election (Denevan 1966). By October 1963 the government of Peru started spearheading the *Marginal de la Selva* as an Andean initiative in meetings with ministers from Colombia, Ecuador, and Bolivia. Construction of Peru's Marginal de la Selva started in 1966, and was supposed to complement a network of 28 planned access roads from the Andes into the lowlands. The top priority for construction was the Tarapoto highway linking Tarapoto up the Huallaga River Valley to Juanjui and connecting to the road branching south from Tingo María, thereby opening the entire Huallaga Valley to agriculture with the expectation of allocating up to 7 million hectares of land and accommodating no fewer than 1.5 million settlers (Denevan 1966; Young and León 1999). At the time, this road was seen as the Peruvian answer to Bolivia's success in building the first Cochabamba–Santa Cruz road in the 1950s, which ushered migration and a series of agricultural booms—very much including illegal coca—that persist even today (Gallup *et al*. 2003).

In contrast with these projects led by the central government, efforts to improve access into the Amazon frontier in Colombia and Ecuador were, at least at first, private or undertaken by local governments. As early as the 1940s, rubber companies and local governments developed often-failing roads along the Ariari River from Villavicencio to Calamar through San José, Guaviare (Molano 1989). In southern Colombia, oil companies helped improve the trail from Nariño to the upper Caquetá and upper Putumayo rivers (Wesche 1968). It was only until the 1960s, and directly connected to settlement programs, that national resources were deployed to improve the roads (INCORA 1974a). As in southern Colombia, Ecuador's road into the Amazon was built with support from oil companies, but in contrast with the Colombian example, Ecuador's colonization projects focused on the Pacific and north of the Andes, not the east (Schuurman 1979). In sum, by the time the Carretera Marginal de la Selva was proposed as a hemispheric project, all Andean countries had already built some infrastructure to reach their Amazonian foothills and to eventually reach the lowlands, even as the scope of the infrastructure and its economic targets varied (Figure 2.4).

Both Peru's Marginal de la Selva and Bolivia's Cochabamba-Santa Cruz roads transformed local landscapes by attracting settlers who fragmented the forest for agriculture and whose products were now more accessible to the Andean core (Denevan 1966; Young and León 1999). Even the less ambitious Colombian access roads had similar effects, accelerating the formerly slow process of clearing and colonization (Brücher 1968; Etter *et al*. 2006b, 2008). Transforming the entire region into a wedge of colonization, however, required the hemispheric goal of building the Marginal de la Selva, which released hitherto unavailable international financing, and provided a focus for agrarian reform programs just as actions to expand the agricultural land base became urgent (Crist and Nissly 1973). Despite the then known shortcomings of Amazonian soils for continued cultivation (Denevan 1966), opening the vast Amazonian forests to campesino cultivation was seen as one of the keys to meeting the political clamor for land reform, increasing agricultural productivity, and relieving pressure from mass migration into cities. Agricultural development based not on intensification but on extensive clearing followed by steady production promised to also secure domestic food supplies for each expanding nation (Schuurman 1979; Wesche 1968).

The access roads facilitated migration into the already existing towns at the foothills of the Andes, where most of the agricultural development was expected to concentrate (Denevan 1966). But the same forces that made

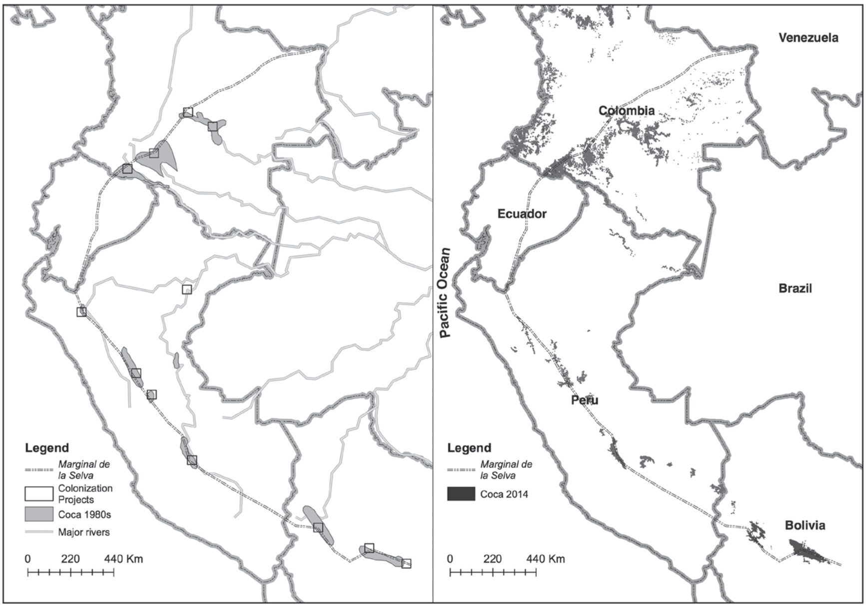

Figure 2.4 Left: planned Carretera Marginal de La Selva connecting the Colombia–Venezuela border to Santa Cruz. Major centers of illegal coca production. Right: illegal coca cultivation in the Andean countries for 2014

Sources: Brücher (1977), Lee and Clawson (1993), UNODC (2015)

campesinos migrate from the Andes—demographic growth, vastly inequitable land distribution in the Andes, and pervasive lack of capital and credit—pushed farmers farther into the Amazonian frontier. As early as the beginning of the 1970s, land grabs for the most fertile plots, along with soil erosion following deforestation had emerged as crucial challenges (INCORA 1974b). Colonization projects to complement the roads had been planned from the beginning, but with the massive influx of colonists and aided by state-sponsored calls for migration into the internal frontier, setting up the projects gained new urgency. Although originally the projects aimed to direct colonization, most often they followed the migration flows of Andean farmers seeking land, a new start, or fleeing violence (Brücher 1968; Jülich 1975; Maass 1969; Schoop 1970; Wesche 1968). Table 2.3 summarizes the major colonization projects in the Amazon frontier of the Andean countries, including the smaller projects undertaken in Ecuador (Schuurman 1979). The major projects were concentrated in Colombia, Peru, and Bolivia. Colombia opened projects in Meta along the Ariari, at El Retorno in Guaviare, near Florencia Caquetá, and Puerto Asís, Putumayo (Brücher 1968, 1977; Schuurman 1978, 1979). Peru opened projects in Alto Marañon, Tingo María-Tocache in the Huallaga Valley, and Apurimac, in 1978 at Pichis-Palcazú, as well as smaller research-oriented projects in Jenaro Herrera and Caballococha

Table 2.3 Government-sponsored colonization projects in western Amazonia, 1960s–1970s

Project	*Country*	*Location*	*Name Brücher (1977)*	*Name Schuurman (1978)*
Ariari-Güéjar	Colombia	Ariari, Meta	—	Meta
Guaviare	Colombia	San José, Guaviare	S. José	El Retorno
Caquetá	Colombia	Florencia, Caquetá	Caquetá	Caquetá
Putumayo	Colombia	Puerto Asís, Putumayo	Puerto Leguízamo	—
Lago Agrio	Ecuador	not mapped	—	Shushufindi
Payamino	Ecuador	not mapped	—	Payamino
Palora-Pastaza	Ecuador	not mapped	—	Palora Pastaza
Upano	Ecuador	not mapped	—	Upano vallei
Morona	Ecuador	not mapped	—	San José de Morona
Alto Marañón	Peru	Alto Marañón, Marañón	Alto Marañón	Alto Marañon
Jenaro Herrera	Peru	Jenaro Herrera, Loreto	Genaro Herrera	Jenaro Herrera
Middle Huallaga	Peru	South of Tingo María, Leoncio Prado	Mittl. Huallaga	Tingo María-Tocache
Pichis-Palcazú	Peru	Puerto Bermudez, Oxapampa	—	—
Apurímac river	Peru	San Francisco, Ayacucho	Apurímac	Apurímac
Alto Beni	Bolivia	Yungas de la Paz	Alto Beni	Alto Beni
Chapare	Bolivia	Chapare, Cochabamba	Chapare	Chimoré
Santa Cruz	Bolivia	West of Santa Cruz de la Sierra	Sta. Cruz	Yapacaní

(Reategui and Taminche 1980; Schuurman 1978, 1979; UNODC and Peru *Ministerio del Medio Ambiente* 2011). Bolivia opened projects in Santa Cruz, Chapare, and Alto Beni (Schoop 1970).

Based on contemporary accounts of the colonization projects most directly associated with the Marginal de la Selva road (locations mapped in Table 2.3), Dávalos *et al.* (2016) tested the spatial relationship between coca cultivation in 2014 and the projects of the 1970s (Figure 2.4). Despite more than four decades separating the projects from the contemporary distribution of illegal coca in the Amazon, spatial models using only the distance from the projects can accurately predict the location of coca cultivation. This demonstrates persistent spatial clustering in spite of many multi-lateral efforts to eradicate coca. Coca cultivation to date still clusters around the colonization projects, which can be traced to at least the 1980s (Figure 2.4). The association between the colonization centers and coca can help explain why this crop is invariably part of the western Amazon deforestation frontier: both large-scale deforestation and coca share a common origin with the mass immigration from the Andes facilitated by the roads and at least partially supported by the projects.

The migrant waves of Andean campesinos associated with the colonization projects encountered poor and incomplete roads, sparse—if any—infrastructure, and greater challenges to agriculture than in the Andes (Clawson 1982; Schuurman 1979). Although some colonization projects succeeded in directing colonization and legitimating land claims, agricultural credit was scarce and in any case most farmers were unfamiliar with it, or with lowland tropical agriculture. In the face of these challenges, colonists traded labor for access to cleared land, and moved on as fertility declined thus establishing a cycle of frontier clearing that continues to this day. Even very early on, it became clear colonization projects were not delivering on the promises of more equitable land distribution or even food security (INCORA 1974a). With high transport costs, few products of the Amazon frontier could compete with the yields from Andean farms. Not coincidentally, these beachheads of Amazonian colonization from the Andes in Colombia, Peru and Bolivia, also became centers of coca cultivation (Figure 2.4).

Perhaps it could not have been any other way and the coca/deforestation frontier would have emerged with or without the development vision that built the roads and the colonization projects. After all, the coca leaf to supply the cocaine that became a consumption trend in the 1970s and 1980s had to be grown somewhere. There is, however, and important counterfactual in the trajectory of colonization, deforestation, and agriculture of the region: Ecuador. Both Brücher (1977) and Schuurman (1979) discounted the Ecuadorian projects east of the Andes—as opposed to those along the Pacific—as being too small and disconnected from Andean markets to accomplish their goal of attracting settlers. In the Ecuadorian Oriente, only the Upano Valley project was linked to the Marginal de la Selva, and it was hindered by the poor state of the road from Cuenca to Limón (Schuurman 1979). Other projects in the Oriente, such as the Lago Agrio, focused on providing support for colonists along the single and oil extraction road (Schuurman 1978, 1979). The road itself was completed fairly late, by 1971, in contrast with the earlier completion of state-sponsored access roads in both Bolivia and Peru. Deforestation radiates out of this road and its later tributaries, and contrasts with the wedge pattern of nearby Putumayo in Colombia (Viña *et al*. 2004; Wesche 1968). The colonization projects in eastern Ecuador had neither the scope nor the agricultural focus of those in the other Andean countries linked through the *Marginal del la Selva*, and the resulting deforestation also differs in pattern and extent. This example suggests the massive influx of Andean campesinos enabled by the roads and colonization projects was a necessary condition for the creation of the coca frontier.

Conclusion

The forest frontier of western Amazonia opened through the development of access roads allowing mass migration into the foothills of the northern Andes. Although local and private efforts to build roads into the Amazon had been underway for decades, the Carretera Marginal de la Selva unleashed international financing specifically for projects to direct and aid colonists, further boosting the attraction of the region to upland Andean campesinos. In time, neither the social benefits of more equitable access to land and credit, nor the steady production for Andean markets were realized on the scale needed for the frontier to become prosperous or self-sustaining. Instead, new waves of frontier colonization launched from the foothills deeper into the Amazon, as land tenure concentrated near towns swelled from migration. The combination of high transport costs and low productivity in the challenging tropical environment led to uncompetitive agriculture. By this time, investment in both the roads and support for the colonists dwindled, while campesinos adopted coca cultivation for the burgeoning illegal market. Hence the apparently puzzling finding that coca cultivation is a poor predictor of deforestation rates and yet seems to be present at almost every forest frontier in the western Amazon has a simple explanation. Both coca and deforestation are the result of a grand twentieth-century modernizing effort to develop this vast region whose consequences are visible today, even from space.

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