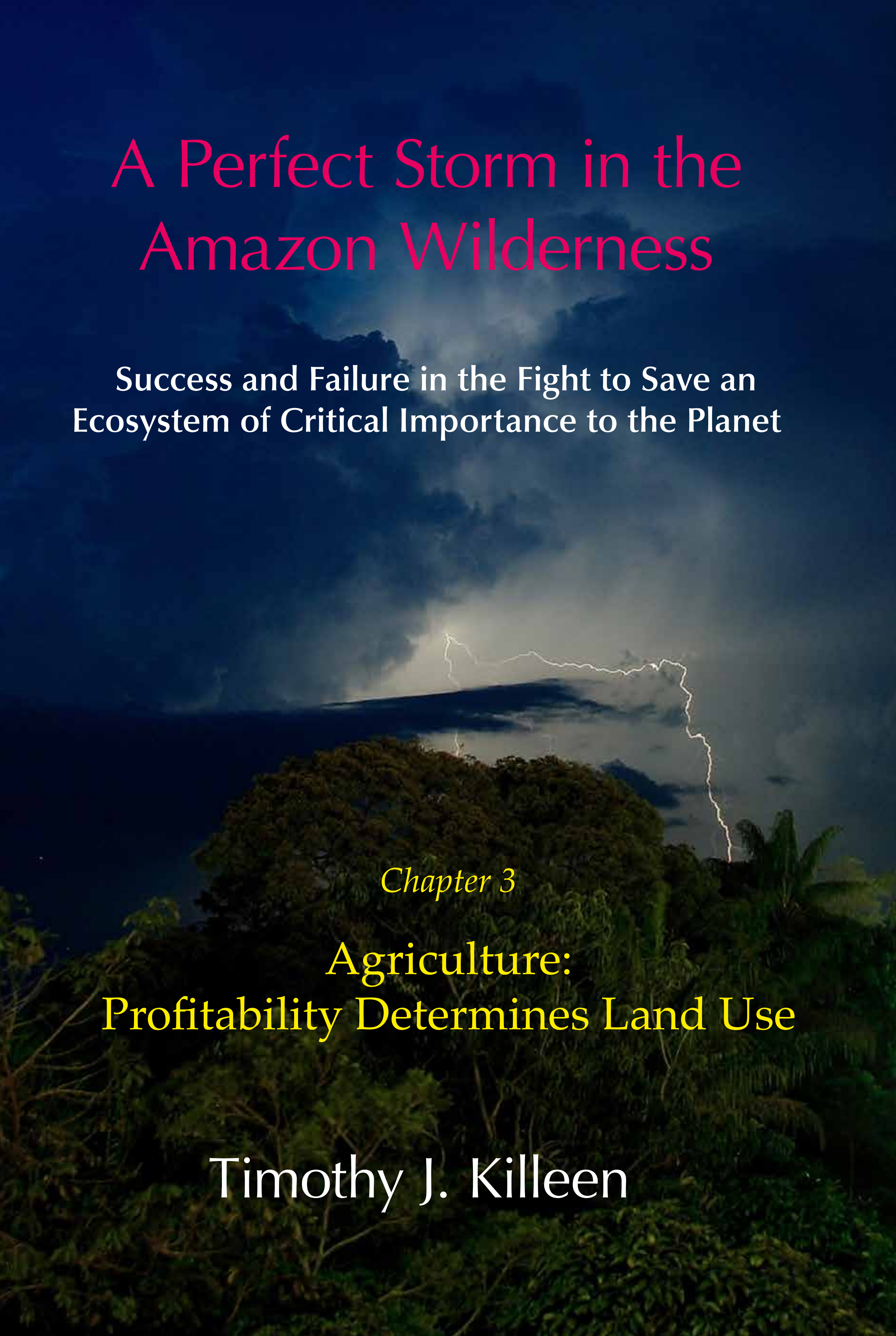

A Perfect Storm in the Amazon Wilderness

Success and Failure in the Fight to Save an Ecosystem of Critical Importance to the Planet

Chapter 3

Agriculture: Profitability Determines Land Use

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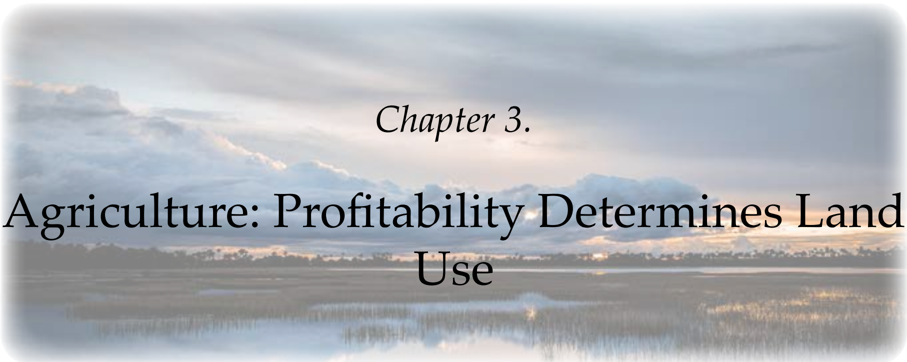
A Perfect Storm in the Amazon Wilderness
Chapter 3: Agriculture

Contents

Figures, Tables and Text Boxes



Chapter 3.

Agriculture: Profitability Determines Land Use

Highway infrastructure initiates the deforestation process, but it is almost always accompanied by some sort of agricultural activity. Depending upon circumstances, deforestation can proceed rapidly or slowly, lead to large or small forest clearings, and create forest remnants of different sizes and configurations. Agricultural production models vary from huge ranches and plantations spanning tens of thousands of hectares to small plots consisting of less than a single hectare. These differences are rooted in cultural traditions and business models as well as incentive systems and land tenure regimes imposed by the state. The Pan Amazon covers a vast geographic area with a diversity of landforms, soil types and climates that support a wide range of production systems supplying food, fibre and biomass energy to local, national and global markets.

The diversity of landholdings, production systems and business models leads to a similarly wide range of social and environmental impacts. Agriculture supports the livelihoods of millions of families across the Pan Amazon. For many migrant families, it provides a pathway out of poverty. For the middle class, it is a way to accumulate wealth and ensure prosperity for future generations. For entrepreneurs, it represents a business opportunity with a proven technology and manageable levels of risk. As long-term investments, agricultural production systems can assume a role as key elements of a sustainable economy. When practised as a speculative enterprise, however, extractive practices that yield cashflow tend to degrade productive potential over the medium term. Under-investment in smallholder communities forces the adoption of non-sustainable options that function as a poverty trap and rob the regional economy of an important driver of growth.

A great deal of emphasis is placed on the first phase of deforestation, which follows soon after the construction of a highway through a remote area. The amount of deforestation that occurs in later years depends large-

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ly on the ability of producers to move their production to market. Some landscapes remain remote due to distance or a physical barrier, such as a river without a bridge or mountain range subject to landslides. These forest frontiers may experience relatively low deforestation rates over many years. Those that enjoy more direct market access usually have a higher rate of deforestation, which creates a larger agricultural landscape but also one with fewer forest remnants. Over time, agricultural frontiers evolve into consolidated frontiers as they become incorporated into the global economy as producers of basic food commodities.*

The role of the private sector becomes increasingly important in landscapes with viable transportation networks and expanding agricultural production. Landholders are the primary actors in determining land use, but commercial agents play an essential role by supplying inputs, such as seeds, fertiliser and pesticides, as well as by acting as intermediaries between the producers of basic food commodities and consumer markets. Commodity traders invest in logistical facilities and bulk transport systems that are key components in global supply chains. Industrial infrastructure, such as crushing mills and slaughterhouses, adds value to primary production that increases demand for basic commodities. As the rural economy grows and becomes more diversified, incomes increase for farmers and ranchers, which acts as a catalyst to accelerate deforestation.

Agricultural production systems can be classified as a proximate cause of deforestation, but the demand for commodities is the ultimate driver that motivates producers to expand production.[1] The markets that influence agricultural production are as varied as the commodities produced by the farmers of the Pan Amazon. Global markets dominate the supply chains of soy, coffee and cacao, while maize, rice, manioc and perishable fruits are largely commercialised in national markets. Beef and palm oil are global commodities and are influenced by international markets, but most of the production in the Pan Amazon is commercialised domestically to meet the needs of national consumers. Understanding the market dynamics of each commodity is essential to devise strategies that promote sustainability and to eliminate deforestation.

The global market for food commodities has been greatly influenced by demand from China. Policies designed to improve the standard of living of its citizens combined with phenomenal economic growth created positive synergies that led China to import large quantities of basic food commodities.

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* A commodity is a basic good used in commerce that is interchangeable with other materials of the same type; they are used as inputs in the production of other goods. Commodities are uniform and interchangeable in the production of goods and services. 'Hard' commodities refers to minerals, including petroleum and natural gas. 'Soft' commodities refers to basic foodstuffs and fibre produced by the agriculture and forest product sectors.

Forest is cleared to establish some type of agricultural activity, like this cattle ranch near Riberalta, Bolivia.

Unlike mineral commodities, which experienced a unique super-cycle linked to a one-time buildout of that nation's basic infrastructure, the demand for food commodities will continue to grow for the foreseeable future. China is transitioning from a dependence on manufacturing and infrastructure investment to a more diversified economy with an emphasis on consumer spending. Food commodities will continue to be subject to short-term volatility but, over the medium to long term, demand for food will grow. The impact of China is most noticeable in Brazil, but producers in the Andean republics all aspire to sell their production to China, be it beef (Bolivia and Colombia) or coffee and cacao (Ecuador and Peru).

Many conservation advocates focus their attention on forest communities and promote policies that will foster a more robust forest economy. This is well and good. A coherent conservation strategy, however, must also address the proverbial 800-pound gorilla that dominates the domestic policies governing land use on frontier landscapes. The commodities that flow from the region's farms, ranches and plantations are essential to the financial wellbeing of all the Pan Amazonian nations. Consequently, there is an enormously powerful group of stakeholders who are not likely to abandon the policies and practices that underpin their business models. Like most economic interest groups, they are not satisfied with the status quo; much to the contrary, they hope to expand their financial wellbeing and their economic power. This is true of the corporate sector, typically represented by groups like the chamber of commerce, as well as the smallholders' associations and syndicates who represent the rural poor, particularly the migrant populations on forest and agricultural frontiers.

Some environmental and social activists, particularly those who hold progressive (socialist) views, advocate for a regulatory approach to constrain the negative forces emanating from an expanding agricultural production. That approach, however, must overcome the real political and economic power of these vested interest groups, many of whom righteously believe their systems are in the national interest. A more realistic option is to convince these groups there are growth-positive options that do not include an expansion of the forest frontier, which will outperform the conventional options they seek to protect.

With that goal in mind, this chapter seeks to describe and understand the predominant agricultural production systems that dominate the conventional economy of the Pan Amazon in the second decade of the twenty-first century.

Beef Production Models

The single largest cause of deforestation in the Pan Amazon is the clearing of forest to establish cultivated pasture to produce beef cattle. By some estimates, as much as eighty per cent of previously deforested landscapes are covered by non-native forage grasses (Figure 3.1). In most cases, grasses have been seeded directly into the recently deforested soil in newly established cattle ranches, but smallholders also use pastures as a rotational fallow as part of a production system based on food crops.

The use of technology among livestock producers ranges from extremely rudimentary to highly sophisticated; not surprisingly, technology improves productivity and economic return but requires 'know-how' and financial capital. Brazil has the most sophisticated beef production system, which includes three overlapping phases that correspond to the life stages of a typical bull or cow:

A. Cow-calf operations span gestation (9.5 months), birth and early growth until calves are weaned from their mothers (8–12 months);*

B. Grow-out operations start when yearlings are sold or moved to separate pastures until they are full-sized in stature but not weight (~12 months); these animals are known as *gado magro* (skinny cattle).

C. Fat-cattle operations describe the finishing stage, which varies depending upon feed ration and breed (6–12 months) until they reach optimum slaughter weight (375–425 kilograms).

* Breed cows typically live four to six years before being sent to slaughter.

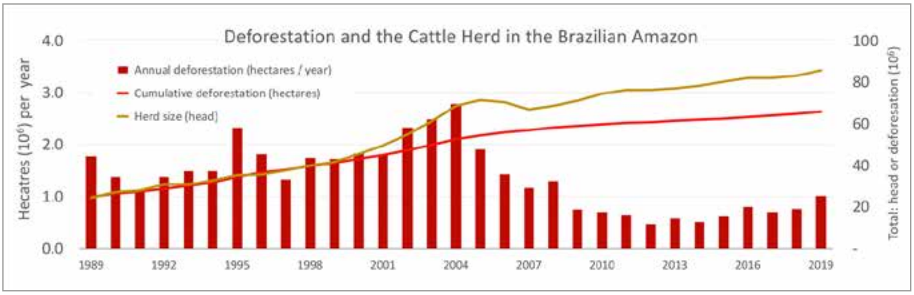

Figure 3.1: A comparison of the size of the cattle herd with the total accumulated deforestation in the Legal Amazon of Brazil.
Data sources: IBGE/SIDRA and PRODES.

Ranchers can specialise in a single phase, but more often they combine two or more production phases into a business model appropriate to their geographic location and predilection to technology. For example, ranchers in remote areas with poor infrastructure are almost uniformly dedicated to running cow-calf operations combined with grow-out operations (A+B). For them, the only realistic option is to drive cattle to a market on foot because poor roads make moving live animals by truck uneconomic and risky. Animals lose weight if they are confined in a truck over several days and can die if the truck becomes stuck on a poorly maintained road. Calves are too fragile for long drives, while fat cattle lose weight if they are forced to walk. Cattle drives are still common on forest frontiers, and many landholders maintain pastures explicitly for rental to drovers, who move their herds to market at a relaxed pace to avoid subjecting animals to undue stress. Drovers will move a herd to a town or small city, typically located on a trunk highway or improved secondary road highway, where they will be sold to a cattle trader or another producer via auction.

Producers who wish to avoid the risk of birthing calves purchase yearlings and keep them on pasture until they reach slaughter weight (B+C). Some ranchers integrate them all on the same property (A+B+C), which allows them to avoid middlemen and maximise the return on a per-animal basis. Others specialise in producing calves of known genetic background (A), which are sold at a premium for qualities linked to productivity, meat yield or disease tolerance.* Although the practice is still rare in the Amazon,

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* There are various Brazilian breeds, but all are Zebu types derived from South Asian stock. The most popular breed is the *Nelore*, which was developed in Brazil in the first decades of the 19th century from *Ongole* breed stock imported from the state of Andhra Pradesh in India. Source: *Associação dos Criadores de Nelore do Brasil – ACNB*; http://www.nelore.org.br/Raca/Historico

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The beef supply chain extends from remote ranches dedicated to producing calves (top) to feedlots where cattle are fattened prior to slaughter (bottom).

feedlot operators specialise in fattening cattle using balanced rations (C), a practice more common in consolidated frontiers with an ever-increasing supply of feed grains (see below).

The economics of cattle ranching is calculated on a per animal basis. The sale price for a calf ranges from $US 180–250 per animal and from $US 1,000–1,200 for a full-grown breeding bull; most steers are slaughtered at about 400 kilos, with a value of between $US 600 and 800. A smallholder in Ariquemes (Rondônia) with fifty hectares of pasture specialising in the production of calves would have gross income of between $US 8,000 and 12,000 annually. A middle-class rancher with 3,000 hectares in Alta Floresta (Mato Grosso) with a similar cow-calf production model would gross between $US 375,000 and 425,000 per year.* For an integrated ranch (A+B+C) where cattle are held for the entire 36 months, revenues should be about ten to twenty per cent greater.

The net worth of a producer would depend upon land values and capital improvements, but at $US 2,000 per hectare, the small farm would be worth about $US 200,000, while the larger ranch would bring approximately $US 3 million.† Although these numbers look plausible, the viability of smallholder production is dependent upon family labour, and if those producers had to pay market value for their labour, they would barely break even. Similarly, many medium- to large-scale cattle ranching operations enjoy the legacy of past decades, when land was obtained at a large discount and would be hard-pressed to establish a ranch if they had to purchase land at its current market value. The difference in the value of land between the forest frontier and agricultural frontiers is the primary driver of rural real estate markets and, arguably, the greatest single driver of deforestation (see Chapter 4).[2]

The cattle herd in the Legal Amazon grew from fourteen million head in 1980 to more than 85 million in 2019; along the way, its growth caused the deforestation of more than seventy million hectares (Figure 3.1). Between 1980 and 2000, approximately one hectare of forest was sacrificed for the possibility of maintaining one live animal; however, tropical grass-fed cattle require three years to reach slaughter weight. Consequently, it requires about two hectares of pasture to produce 100 kilograms of live animal per year, which actually represents only fifty kilograms of [bone-in] dressed beef.[3]

These numbers are phenomenally unimpressive in terms of productivity when considered based on a kilogram of protein per hectare. By way of comparison, soy yields about four tonnes of beans per hectare, which

* Calculations are based on exchange rates of approximately R$ 5 per $US.

† These valuations assume 50% of the land is planted to pasture and include the value of the land, cattle and on-farm infrastructure; apparently, land values are higher in densely populated Rondônia compared to Alta Floresta. (Values taken from online rural real estate markets).

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Amazonian pastures are notorious for their low productivity and frequently show signs of overgrazing and soil degradation (top). The cattle herd in the Brazilian Amazon are derived from South Asian breeds, particularly Nelore, Gir, Zebu and Brahma; those pictured are nearing slaughter weight of approximately 400 kilograms (bottom).

upon refining produces approximately one tonne of vegetable oil and three tonnes of soymeal, of which the latter is about fifty per cent protein. In other words, soy produces about fifty times the amount of protein per hectare as grass-fed beef raised in the Amazon. Aquaculture is even more productive when calculated on a per hectare basis, producing between two to three times as much as soy (see Chapter 8).

As disappointing as beef productivity numbers are, there was a noticeable improvement in overall stocking rates after 2000.[4] The surge in productivity was the result of several factors, one of which was a surplus of available pasture caused by land speculation, which allowed ranchers to rapidly expand herd size in response to booming demand. There was a short-term reduction in the herd following the economic crisis of 2008, but the ratio between the total herd size and the pasture area has been continuously improving over the last decade.*

Increased stocking rates are only one aspect of the improved productivity of the Brazilian beef industry. At the national level, between 2000 and 2019, the cattle herd increased by about 26%, while total spatial extent of its pastures declined by 12%, a gain in efficiency of more than 44%. The use of technology and management practices is most notable in South and Southeast Brazil, where stocking rates surpass three head per hectare.† There have been similar improvements by Amazonian producers, who increased stocking rates by 62%; however, they started from a much lower baseline and still lag their counterparts in Southern Brazil by ~50%. Surprisingly, the highest stocking rates in the Legal Amazon have been obtained by smallholder cattle producers in Rondônia and Acre, who have also made impressive gains in overall efficiency (Table 3.1).[5]

Improving the productivity of cattle ranchers is a major component of initiatives designed to improve the image of the Brazilian beef industry and, allegedly, reduce deforestation. The goal is to channel future growth into technological improvements that allow producers to expand production without increasing the spatial extent of pasture area. There are essentially six technologies that can be deployed to increase the efficiency of beef production systems:

- *Pasture management*: stocking rates can be improved via rotational grazing, agroforestry and rotating pasture with crops. Stocking rates of up to four head per hectare have been achieved by experiment stations.

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* The use of deforestation data is a crude measure of grazing intensity because it ignores deforestation linked to other crops, such as oil palm (Pará) and soy (Mato Grosso), as well as Cerrado lands that were converted to pasture (Maranhão, Mato Grosso and the Tocantins).

† Santa Catarina, Rio Grande do Sul, Paraná, São Paulo

Table 3.1: Cattle stocking rates in the Legal Amazon.

State	Total Area (km²)	Forest Area (km²)†	Accumulated Deforestation†	Reported Pasture††	Pasture as % of Deforestation†††	Cattle Populations	Cattle Density head / ha
Acre	170,895	148,700	21,611	18,387	85%	3,509,682	1.91
Amapá	142,926	110,266	2,283	3,081	135%	54,296	0.18
Amazonas	1,589,691	1,452,267	43,718	16,099	37%	1,455,842	0.90
Maranhão	264,714	40,127	50,455	63,291	125%	8,008,643	1.27
Mato Grosso	904,865	312,691	224,736	209,192	93%	31,973,856	1.53
Pará	1,249,718	876,635	228,414	175,004	77%	20,881,204	1.19
Rondônia	240,398	125,926	98,573	78,966	80%	14,349,219	1.82
Roraima	226,224	152,469	11,474	6,610	58%	879,007	1.33
Tocantins	278,998	9,803	25,296	75,246	297%	8,480,724	1.13

† Forest cover and accumulated deforestation date from PRODES.

†† From *Laboratório de Processamento de Imagens e Geoprocessamento* (Lapig) or IBGE (AP, MA).

††† States with positive values where pasture / deforestation > 100% occur because they contain areas of Cerrado savanna that have been converted to pasture.

- *Health and reproductive success*: Cows sometimes fail to be impregnated, or suffer a miscarriage, or lose their calves to illness or predation. Reproductive success on modern commercial ranches ranges from 60% to 80% but can reach levels as high as 95% under ideal conditions.
- *Nutrition management*: Cattle are ruminants and have the capacity to metabolise cellulose, but they need vitamins to thrive; combining soil analysis with vitamin supplements will improve the daily weight gain, a key metric used to monitor productivity.
- *Supplemental feed:* Cattle will increase their daily weight gain when their ration of cellulose is complemented with starch (maize) and protein (soy). Providing cattle on pastures with feed rations will increase daily weight gain, but greater gains are obtained when they are finished in feedlots.
- *Genetics*: Cattle breeders have multiple avenues for enhancing productivity by improving resistance to disease and boosting physiological efficiency as well as by increasing meat yield per animal, which is measured by the ratio of carcass weight to live weight, currently about 50–55%.
- *Reducing time to slaughter*: This is a function of growth measured by daily weight gain, which is dependent upon genetics and

nutrition; shortening the lives of animals increases the proportion of the total herd harvested each year.

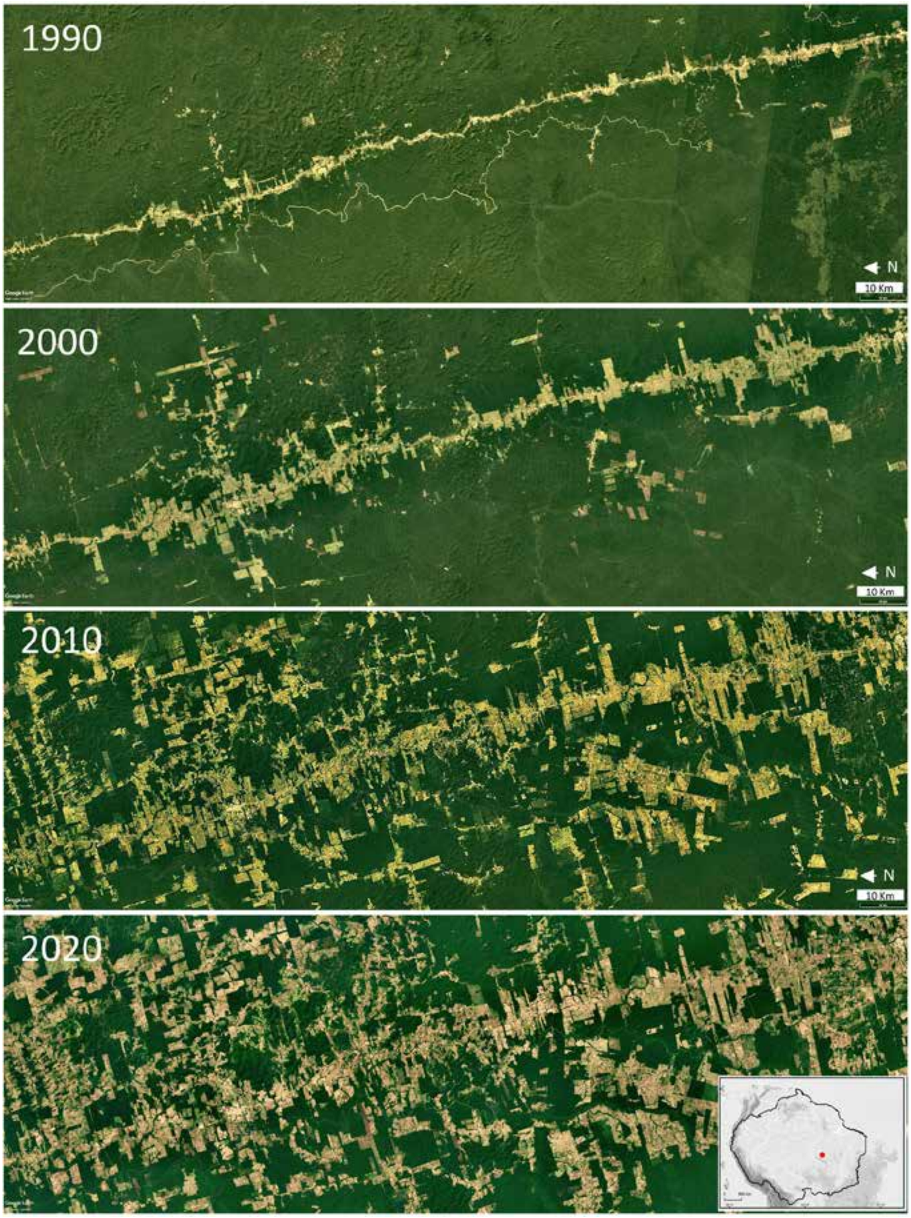
Industrial infrastructure

Packing plants are also important to producers because the construction of a modern facility will stimulate the growth and diversification of the livestock sector. Modern packing plants must be located on a good (preferably paved) road to avoid wear-and-tear on refrigeration trucks that transport the meat to urban markets. The number of modern industrial-scale packing plants is a good measure of the productivity and sophistication of the beef sector: Mato Grosso has forty packing plants that slaughter about 100,000 head per week, followed by Rondônia with 22 packing plants processing 50,000 head per week. In contrast, Pará has only thirteen modern industrial-scale plants but still manages to harvest 45,000 head per week, mainly in smaller-scale packing plants. Acre, far removed from urban markets, has only three industrial plants that slaughter about 5,000 animals per week.[6] Packing plants must be operated at or near capacity to be profitable, and their construction will change the cattle market in the surrounding landscapes. Having a slaughterhouse nearby increases the production options for ranchers. They can pursue a fully integrated production model (A+B+C), but many opt to specialise in fat-cattle operations (C), which are less risky and more profitable. Increased profitability will motivate most cattlemen to increase production, either by increasing herd productivity using technology or by expanding pasture area or both.

As of 2021, there were no industrial slaughterhouses along the entire length of the Transamazônica (HML #10 and #19) or in the municipalities of São Felix de Xingu (HML #9) or Novo Progresso (HML #17),[*] where cattle ranchers only have the option of pursuing the A+B production paradigm (Figure 3.2). Still, these remote communities play an essential role in the beef supply chain because they export their *gado magro* to producers near slaughterhouses specialising in the production of fat cattle. The municipality of São Felix de Xingu is home to the largest herd of cattle in Brazil, with more than two million head grazing on approximately 1.8 million hectares of pasture. Coincidentally, this municipality has suffered the highest annual deforestation rate in Amazonian Brazil since 2001.[7]

Another type of industrial infrastructure is the feedlot, known as *confinamentos* in Brazil. These industrial facilities increase daily weight gain and shorten the time-to-slaughter, two key metrics that track improvement in beef productivity. The use of feedlots has increased in Brazil from 500,000 head in 2003 to 4.5 million in 2016 and 6.2 million by 2020.[8] In 2019, Mato Grosso led the nation in feedlot development with more than 175 facilities

* HML: human modified landscape (see Chapter 1, Figure 1.2).



Source: Google Earth

Figure 3.2: Deforestation adjacent to BR-163 over three decades. There was no respite after 2000, following the implementation of the Plano BR-163 Sustentável, a high-profile project managed by the Casa Civil da Presidência da República; or the Cattle Agreement in 2010.

and an installed capacity for 800,000 head. Since feedlots shorten time-to-slaughter, the total number of animals fed in *confinamentos* exceeded 1.2 million.[9]

The impact of feedlots on land use is complex. Their growing popularity has contributed to the improvement in land-use intensity of the beef supply chain; however, the expansion of the feedlot model is dependent on the soy-maize production paradigm, which also has an expanding spatial footprint (see below). Simultaneously, feedlots increase the demand for *gado magro* supplied by ranchers from the forest frontier. Feedlots are also a source of pollution, due to the concentration of nitrogen-rich runoff from manure, which contributes to the hydrological degradation of the Tapajós, Xingu, Araguaia and Tocantins rivers.

National versus global markets

Brazil is both a massive producer and consumer of beef. Domestic consumption has expanded steadily year on year with slight variations linked to periodic recessions, but most of the recent growth is caused by Brazil's increasing dominance in global export markets. Most of that growth has occurred within the Legal Amazon (Figure 3.3). Prior to 2000, exports largely consisted of processed meat[*] and fluctuated between five and six per cent of total production; after 2000, beef packing companies started exporting fresh and frozen beef to Europe, the Middle East and East Asian markets.[†] Within five years, exports represented about twenty per cent of total national production. Exports fell by 25 per cent during the global economic crisis of 2008 and 2009. Domestic consumption buffered the market shock, but the drop in demand reverberated through the supply chain. The contraction coincided with an international boycott of Brazilian beef that motivated the three largest meat packing companies in Brazil to embrace the 'Cattle Agreement' and to eliminate deforestation from their supply chains (see Text Box 3.1).

The growth in exports resumed after 2012, growing at a mean annual rate of ~7 per cent and now represent about 25 per cent of national production. The Peoples Republic of China began to import Brazilian beef in 2016 and rapidly scaled-up its purchases to almost 900,000 tonnes in 2020.[10] China is now the largest international market for Brazilian beef and approximately half of those sales orginate in Mato Grosso. Exports to China from Amazonian Brazil will increase in 2021 as packing plants in

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* Corned beef, salted beef and canned beef.

† This coincided with the eradication of foot and mouth disease (aftosa), which was accomplished by the mass vaccination of cattle in Mato Grosso (2001), Rondônia (2003), Acre (2005) and Pará (2007). Source: Marques et al. (2016).

Pará have been authorised to sell to the the world's largest growing market for dressed beef.

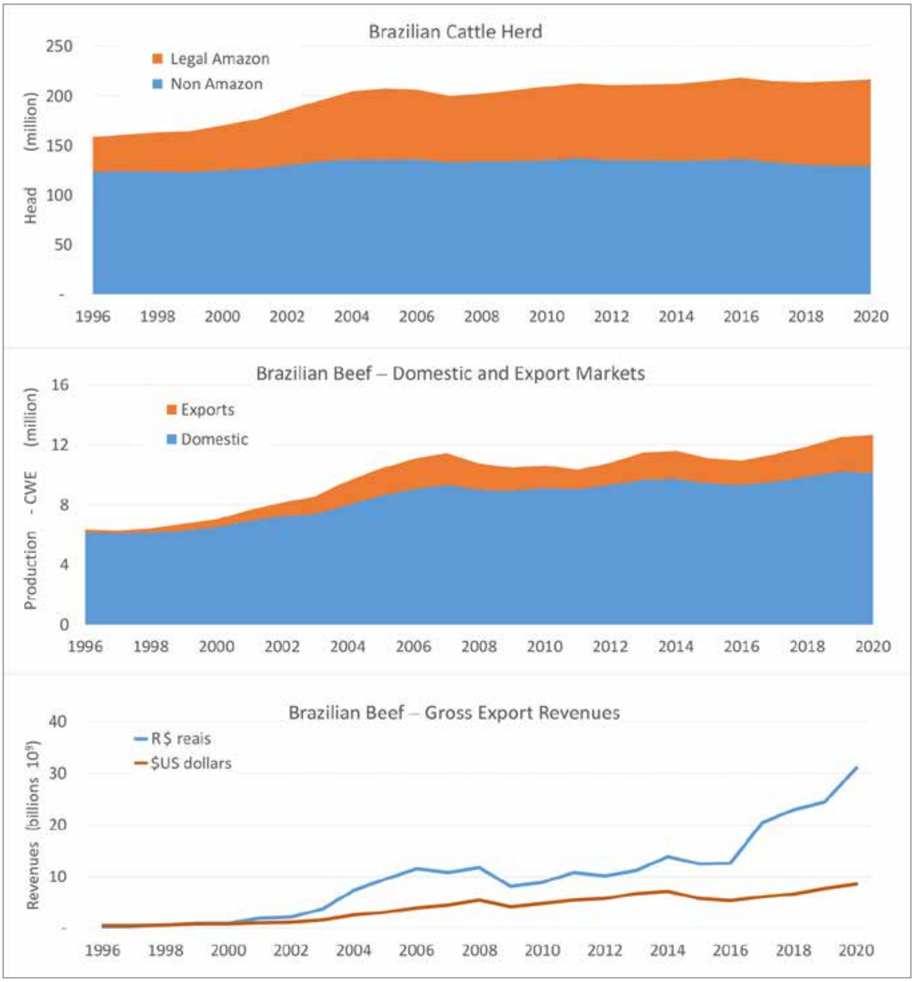

Figure 3.3: Brazilian beef production: (a) The evolution of the national herd; (b) demand from domestic and export markets at national scale; (c) Gross revenues expressed in R$ and $US at national scale.

Data sources: IBGE/SIDRA and ABIEC.

Text Box 3.1: The Cattle Agreement

Greenpeace declared a boycott of Brazilian beef in 2009 as part of its campaign to halt deforestation in the Amazon. It ended the boycott when Brazil's four largest beef-packing companies (JBS, Marfrig, Minerva and Mercurio) agreed to adopt measures to exclude from their supply chains cattle that were raised on landholdings that were not in compliance with the environmental laws of Brazil. Among its provisions were three commitments on the part of beef-packing companies:

- Obligate suppliers (direct and indirect) to provide geographically precise data identifying their rural properties.
- Accept only suppliers who can prove they are in possession of properly registered land tenure documents.
- Validate the origin of all cattle by a tracking system that demonstrates suppliers do not engage in illegal deforestation or unfair labor practices or encroach on indigenous lands and protected areas.

The agreement contributed to the dramatic eighty per cent reduction in deforestation in the Brazilian Amazon between 2006 and 2012. It did not succeed, however, in eliminating illegal deforestation from the beef supply chain. There are several sources of non-compliance, including the approximately thirty per cent of animals that are slaughtered by smaller companies who commercialise their beef entirely within the domestic market. There is also evidence that some ranchers game the certification system by the sale of immature cattle (*gado magro*) from non-compliant ranches to long-established operations that adhere to the law. Producers from the frontier landscapes presumably sell their animals at a discount, while the compliant ranches closer to packing plants mix the illegal animals with their own herds to avoid detection – and increase their bottom line.

The failure of the Cattle Agreement motivated Greenpeace to withdraw as an active participant in 2017 and to renew its campaign to boycott Brazilian beef. Meanwhile, an upsurge in deforestation in 2018 and the election of Jair Bolsonaro in 2019 increased consumer attention on the Brazilian beef industry. This motivated the three largest of the packing companies to move their self-imposed deadline for eliminating illegal deforestation forward from 2035 to 2025. They have adopted a system that will unite vaccination certificates and blockchain technology to identify properties where calves are born and, presumably, eliminate rogue cattle from their supply chains.

Sources: Zero Deforestation Working Group 2017; Klingler et al. 2018; Alves 2021; Conecta – Parcerias de Agropecuária Responável 2021.

The Andean Amazon and the Guianas

Beef production technology in all other Amazonian regions lags Brazil except for Bolivia, which has largely adopted the Brazilian approach to beef production (Figure 3.4).[11] Bolivian producers can be classified into two

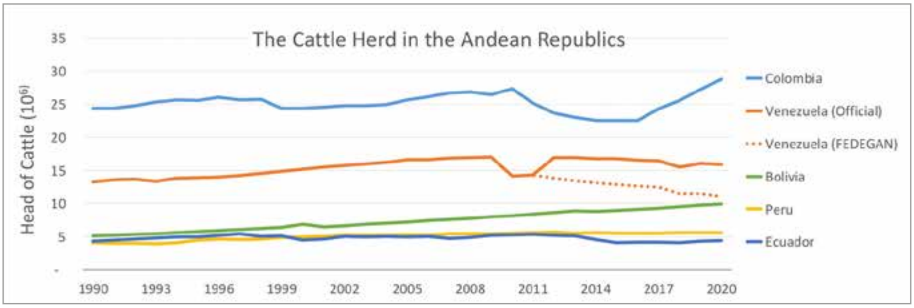

Figure 3.4: Cattle herds have declined in Venezuela, while expanding in Bolivia and in Colombia after 2016; in both nations, beef production is a major driver of deforestation. Cattle herds are small and stable in Ecuador and Peru; in neither country is beef production a major driver of deforestation.

Data sources: FAOSTAT and USDA/FAS

major types, each of which is in a different region: (1) extensive ranches on seasonally flooded natural grasslands in the Beni;* and (2) intensive ranches on cultivated pastures in Santa Cruz. Both groups include large and medium-sized producers, and both have adopted Brazilian breeds and veterinary technology. The ranches in the Beni have very low stocking rates due to the poor forage quality of the native grasses. Consequently, they largely produce calves and immature males (A+B), which are sold to *Cruceño* producers located closer to population centres and packing plants.

Cruceño producers have embraced the Brazilian production model in its entirety, including the practice of seeding cultivated pasture grasses directly into recently deforested soils. The sector is responsible for about 35 per cent of the total historical deforestation in Bolivia,[12] which amounts to about four million hectares (HML # 29, #30 and #31). In 2016, the government ended its decade-long ban on beef exports as part of a strategy to diversify the national economy.[13] China initiated imports from Bolivia in 2019 with an initial purchase of about a thousand tonnes of dressed beef, a volume that increased to 7,900 tonnes in 2020, eighty per cent of total beef exports.[14] The value of those exports in 2020 was $US 42 million, a small but significant number in the rural economy of Santa Cruz.† Looking forward,

* These seasonally inundated wetlands, also known as the Llanos de Moxos, cover about 100 km2 and are the third largest wetland complex in South America after the flood plain of the Amazon river (250,000 km^2) and the inundated sections of the Llanos del Orinoco (3,200 km^2).

† The GDP attributed to the livestock sector in 2017 was $US 250 million.

the government hopes to expand that number by a factor of five by 2025;[15] this and other policies have stimulated deforestation,[16] which reached a historical high of 240,000 hectares in 2020.[17]

In Peru and Ecuador, cattle raising is more accurately described as an artisanal activity than a modern production model. Herds are typically a genetic mixture of traditional stock, dairy cows and Brazilian breeds; reproductive rates are low, and mortality is high. Stocking rates are usually below 0.5 head per hectare; forage is of very poor quality and weed infestation is a universal problem. Most pastures are fallow, part of a production system where pastures and second-growth forest occupy a temporal stage in a rotation cycle centred on annual crops. The economic return on these low-tech cattle production practices is notoriously poor, with a net cash flow of only about $50 per hectare, compared to about $US 300 for maize and $US 850 for cacao.[18]

Small farmers in Peru and Ecuador raise cattle on land that has essentially no other economic activity. Cattle are viewed as a liquid asset that accrues value over the short-term and can be monetised easily for medical emergencies or milestone events. Essentially, a savings account with hooves. Both countries have programmes designed to improve productivity, but neither country exports beef, nor are they likely to do so in the near future.

Pastures occupy about seventy per cent of previously deforested land in the Amazon in both countries, but cattle production is not a cause of deforestation; rather, it is a by-product of land clearing by small farmers who grow food crops for national markets or cultivate a perennial cash crop for international markets (see below). There are some exceptions. In Morona-Santiago Province in Southeastern Ecuador, Schuar and Achuar families adopted cattle farming in the 1970s as a tactic to formalise land tenure (see Chapter 11). The motivation for clearing the forest was not to pursue cattle ranching as a livelihood but to protect their lands from encroachment by immigrants.[19] They are, nonetheless, an important source of high-quality beef in Ecuador.

In Colombia, the beef supply chain is more sophisticated than in Ecuador and Peru but still lags the productivity of cattle ranchers in Bolivia and Brazil. In part, this represents the diversity of its rural communities and producers, but it also reflects a lack of investment caused by its decades-long civil conflict. The cattle sector is undergoing profound changes, stimulated in part by the peace process that began in 2016, but also by the free trade agreement with United States that is obligating producers to increase efficiency or lose market share. [*]

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* Between 2012 and 2019, beef imports from the USA increased from $US 3.5 to $US 25 million; tariff barriers are being phased out and will end in 2022. Source: USDA/FAS, https://www.fas.usda.gov/colombia-2019-export-highlights

Prior to 2010, the Colombian cattle herd comprised about 25 million head, a population that was stable for approximately thirty years. About 55 per cent of the herd was destined for beef and four per cent for dairy operations, with the remainder raised for both milk and meat, a characteristic typical of traditional artisanal systems.[20] The most sophisticated producers were the large-scale ranchers on the natural savannas of the *Llanos del Orinoco*[*] where native grasses imposed low stocking rates. In the Andes and on the Caribbean Coast, tens of thousands of small, medium and large-scale producers raised cattle on poor pasturage cultivated on degraded soils. In the Colombian Amazon, three departments have a legacy of deforestation linked to the cattle industry: Putumayo (HML #51), Caquetá (HML #52) and Guaviare (HML #54). The most important, Caquetá, was settled by migrants starting in about 1960 and is now characterised by medium to large-scale cattle ranchers on approximately 1.3 million hectares.

The government and *Federación Colombiana de Ganaderos* (FEDEGAN) have embarked on an ambitious programme to expand and modernise the cattle sector. The sector is essentially adopting the Brazilian technology and production model, which has led to a sustained increase in the national herd over the last several years (Figure 3.4).[21] This effort has revitalised the cattle industry in Caquetá, where the cattle herd grew from 1.3 million in 2016 to more than 2.3 million in 2019.[22] The initiative is notable for its intent to create a zero-deforestation production model and most of the expanded production has been obtained by improving animal husbandry and pasture management.[23] Nonetheless, the Colombian Amazon has experienced an upsurge in deforestation that reached record levels in 2017 (130,000 ha), 2018 (155,000 ha) and 2020 (145,000).[24] The spike in deforestation is often linked to the production of illicit coca, but pastures are being simultaneously established on landscapes where law enforcement is poor and land tenure is characterised by chaos (see Chapter 4).[25]

Venezuela has a relatively large cattle sector located in the Llanos del Orinoco (Figure 3.4), but the country still imports about forty per cent of its national consumption – or did prior to the economic crisis that became particularly acute after 2016. Government-generated statistics show a stable herd, but unofficial sources report a drop of about 45 per cent.[26] Regardless, the Amazonian region has never developed an economically significant cattle industry. Similarly, Guyana and Suriname have minuscule cattle sectors and no history of deforestation linked to the cattle industry. Roraima in Brazil has a moderate-sized cattle industry based on its native savanna with about 880,000 head; nonetheless, the municipality with the largest population of

* The Llanos del Orinoco is one of three savanna ecoregions located within the Greater Amazon: the others include the Cerrado (Brazil), Llanos de Moxos (Bolivia) and Gran Sabana (Venezuela). There are also scattered white-sand savannas across the Northern Amazon.

cattle is Mucajaí (100,000 head), a heavily deforested smallholder landscape located south of the state capital of Boa Vista (HML #51).[27]

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In Mato Grosso, farmers can plant two crops per year, and many are choosing to rotate soybeans (top) with maize (bottom) as part of an integrated strategy to manage plant pathogens; this approach also maximises profits.

Intensive Cultivation: Soy, Maize and Other Field Crops

The most important production system in the Pan Amazon when measured by GDP is the cultivation of annual crops: particularly soy, but also maize, rice, sorghum, wheat and cotton. In Brazil and Bolivia, annual cropping is organised around soy, because export markets provide the potential for a very substantial return on investment. Industrial-scale farming is much riskier than cattle ranching because it requires a considerable capital outlay to sow and harvest a crop. A successful harvest depends upon weather, which is unpredictable, and price, which is determined by commodity markets that are notoriously volatile. A poor harvest during the bottom of the commodity price cycle can bankrupt a farmer, especially those that are overly reliant on short-term credit to finance operations. The increase in risk is offset, however, by the potential return.

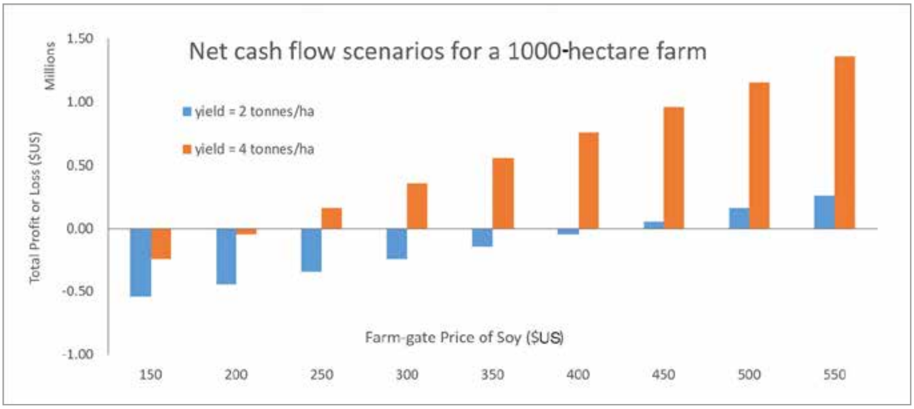

Figure 3.5: Risk profile of a 1000-hectare farm in Mato Grosso showing different potential outcomes depending on yield (tonnes/hectare) and price of soy ($US/tonne) at the farm gate.

Source of cost estimates: Instituto Mato-Grossense de Economia Agropecuária (IMEA).

The cost of production in 2020, including fuel, fertilisers, pesticides, labour and on-farm operations was approximately $US 700 per hectare in Mato Grosso.[28] Yields range between two to four tonnes per hectare, while the international price of soybean has fluctuated between $US 200 and $US 600 per tonne since 2000.* Farmers in the hinterlands of South America

* Between March 2020 and March 2021, the price surged from $US 375 to $US 575 per ton; the previous year the value of the real fell by 30% – these types of fluctuations are out of the control of producers. Source: https://www.indexmundi.com/commodities/

are paid a discounted price that reflects the cost of transport to the export terminal, where it is loaded onto ocean-going grain ships (see Chapter 2). In a good year, soybean farmers can double their money, but in a bad year, some will go bankrupt (Figure 3.5). Although these back-of-the-envelope calculations do not include capital investments in farm equipment or land, they do reveal the risk-reward potential of the industry.

Although the cultivation of soy is lucrative, it can be grown only in rotation with other crops, due to the proliferation of plant pathogens in monoculture production systems. Farmers in both Bolivia and Brazil sow two crops per year, which also allows them to spread climate risk between a summer (wet season) and winter (dry season) harvest. Many opt to plant a cover crop for one of the two cropping seasons; this allows them to improve the organic matter in the soil as well as reduce the risk from pest outbreaks. Farmers increasingly are choosing to cultivate a feed grain as a rotational crop because it can improve their bottom line and diversify their market opportunities. Maize is the most common rotational crop in Brazil, while drought-tolerant sorghum is preferred in Bolivia. The rotation of soy with feed grains has brought substantial benefits to the farm economy because it has increased the supply and affordability of feed rations for poultry and swine (see below).

The expansion of the soy / maize production model continues apace in the Brazilian Amazon (HML #4, #5, #6, #7, #11, #12, #13, #14, #15 #16 and #23) and Bolivia (HML #30 and #31). There have been dips in production, but overall, the sector has expanded its spatial footprint year after year for more than forty years. In Mato Grosso, mean yields have increased from around 3.1 in 2000 to 3.5 tonnes per hectare in 2019; producers in Bolivia tend to use less fertiliser and other inputs and average between 1.8 to 2.2 tonnes per hectare. Mato Grosso produces about 27 per cent of Brazil's total soy crop, a proportion that has remained stable over the last decade, although total production has increased by fifty per cent since 2010 (Figure 3.6).

The municipalities that produce the most are Sorriso, Nova Mutum and Nova Ubiratã, which are situated along BR-163, or Diamantino, Sapezal, and Campo Novo do Parecis, which are located further west along BR-364 (HML#15). Farmers in each of these municipalities harvested between one and two million tonnes of soy in 2019. Expansion has been most pronounced in the municipalities associated with BR-158, where soy plantings expanded by 500,000 hectares between 2016 and 2019 (HML #11 and #12).[*] A similar phenomenon is underway in Tocantins, northeast Pará and Maranhão to take advantage of the lower transportation costs

* Mato Grosso: São Felix deo Araguaia, São Jose do Norte; Pará: Santana de Araguaia, Conceição do Aaragaia, Santa Maria das Barreiras.

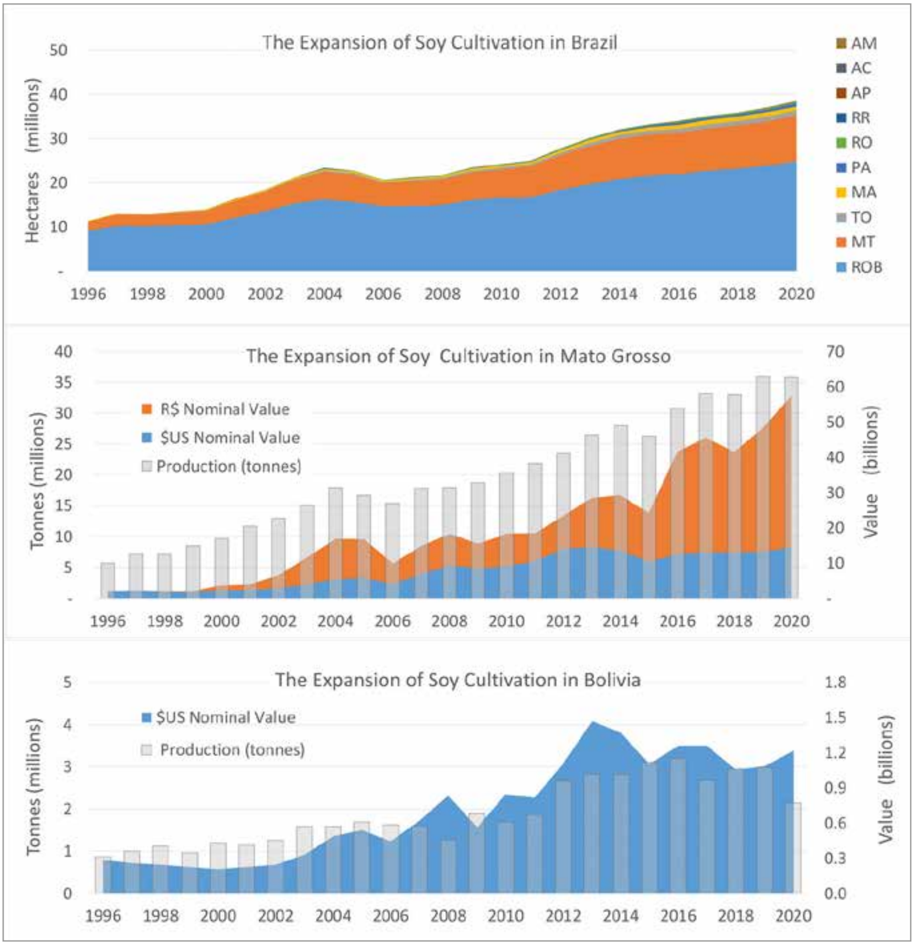

Figure 3.6: The evolution of the cultivation of soybeans in (a) Brazil, (b) Mato Grosso and (c) Bolivia. Mato Grosso is the largest producer of soy within the federal union, producing about 27% of national production. The cultivation of soy has expanded to all nine states in the Legal Amazon; abbreviations in (a) are postal codes (except ROB which stands for 'rest of Brazil'). Nominal value is based on total production and the mean annual value of soybeans in international markets; producers are paid that value minus the cost of transportation.

Data sources: CONAB and IBGE/SIDRA (Brazil); FAOSTAT and IBCE (Bolivia).

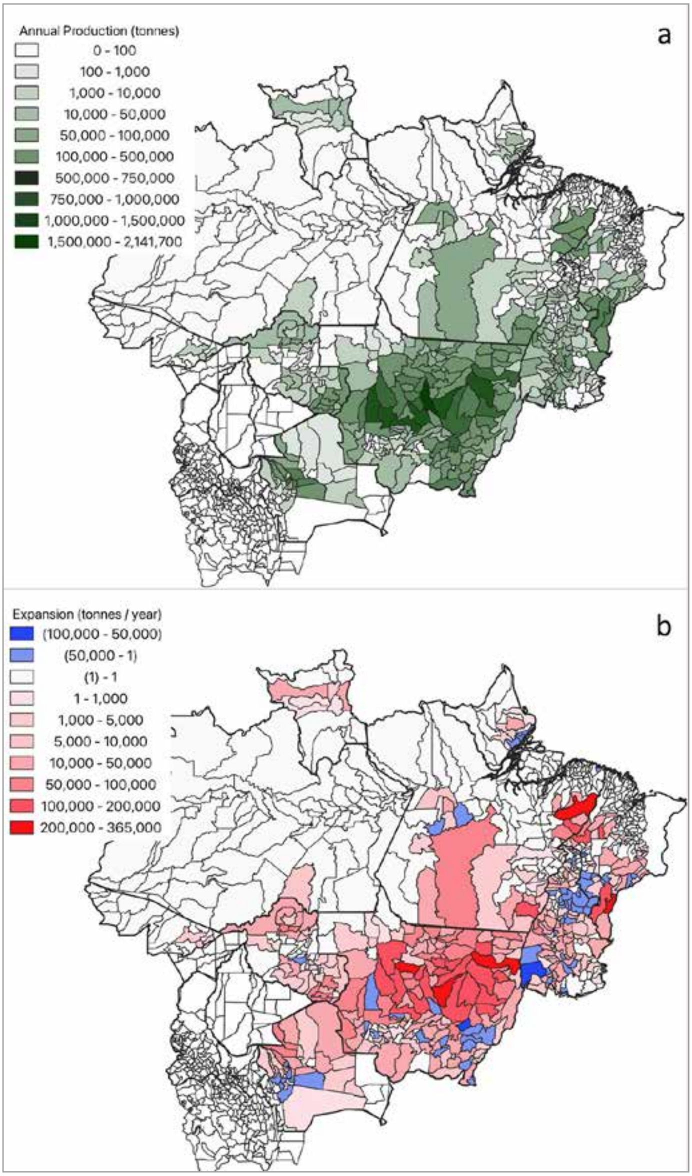

Figure 3.7: The dimensions and expansion of soybean production are reflected in municipal harvest data. The municipalities of Central Mato Grosso continue to expand production via both intensification and extensification, while bulk transport systems facilitate expansion in Northeast Pará and Western Rondônia. The relatively modest production statistics in Santa Cruz, Bolivia reflect lower yields and highlight the potential to expand via intensification.

Data sources: CONAB and IBCE.

provided by the *Ferrocarril Norte-Sul* (see Chapter 2).* Landscapes with the highest rate of conversion to soy include several located in north-central Mato Grosso, where farming became more attractive following the paving of BR-163.† Similarly, the proliferation of soy cultivation in municipalities adjacent to the river ports on the Madeira, Tocantins, Tapajós, Xingu and Amazon rivers reflects investors' desires to improve returns by lowering transportation costs;‡ more surprising, and worrisome, is the installation of soy fields in remote municipalities of the northern Amazon (Figure 3.7).

The cultivation of soybeans in the Brazilian Amazon was linked by academics and journalists to deforestation in the early 2000s when annual deforestation in the Brazilian Amazon surpassed 2.5 million hectares per year. The revelation of soy-related deforestation happened to coincide with a period when European imports of soy from Brazil reached an all-time high of fifty million tonnes per year.[29] The public linkage between soy and Amazonian deforestation led to a high-profile campaign by Greenpeace and other NGOs, which led to the Soy Moratorium (see Text Box 3.2).

The Soy Moratorium contributed to and coincided with a multi-faceted policy, referred to as the PPCDAm,§ which was organised by the administration of Lula da Silva to reduce deforestation in the Brazilian Amazon (See Chapter 7). The declines were particularly impressive in Mato Grosso, where forest clearing by farmers fell to near zero, a success story essential for the future of one of Brazil's most important export industries. Nonetheless, the actual land-use change associated with the expansion of soy/maize production model is a more nuanced story.[30] Of the approximately ten million hectares of soy planted in Mato Grosso in 2020, about thirty per cent was cultivated on land originally covered by forest vegetation, while the other seventy per cent was established on landscapes within the Cerrado savanna biome (Figure 3.8).[31] In neither case, however, was conversion always a direct operation that cleared native vegetation to establish a working soybean farm; approximately 75 per cent of the land involved was first cleared to plant pasture grasses as part of a beef production operation that was subsequently converted to the cultivation of annual crops. Farmers expand via the conversion of pasture rather than forest because it is more cost-effective. Forest properties tend to be more remote, which

* Pará: Paragominas, Dom Elise, Ulianópolis, Rondon do Pará, Dom Eliseu; Tocantins: Campos Lindos, Porto Nacional, Mateiros, Monte do Carmo, Caseara; Maranhão: Açailândia.

† Novo Horizonte do Norte (122% annually), Paranaíta (76%), Alta Floresta (43%), Peixoto de Azevedo (32%).

‡ Porto Velho (10,000 ha), Santarem (19,000 ha) and Mojuí dos Campos (64,500 ha), Macapá (8,000 ha).

§ PPCDAm: Plano de Ação para Prevenção e Controle do Desmatamento na Amazônia Legal. See http://www.mma.gov.br/component/k2/item/616?Itemid=1155

Text Box 3.2: The Soy Moratorium

In 2006, Greenpeace released a report exposing the links between deforestation in the Amazon and the expansion of the cultivation of soy. The report highlighted how soy was used as a feedstock to produce meat and other consumer goods and called for a boycott of the brands and enterprises whose supply chains extended into the Brazilian Amazon. The boycott focused the attention of major corporations (MacDonald's, Walmart, Carrefour and many others), which exerted pressure on the five major commodity traders (ADM, Bunge, Cargill, Louis Dreyfus and Amaggi Group) to devise a system that would exclude producers who were clearing forest to establish industrial farms dedicated to the cultivation of soy.

The ban was originally organised as a ten-year moratorium that committed the traders to organise a system that would eliminate any farmer guilty of clearing forest, using slave labour or encroaching on indigenous lands or other protected areas. The moratorium participants succeeded in developing a robust and transparent monitoring system that essentially eliminated the practice of clearing forest to establish industrial-scale farms. The ten-year moratorium was made permanent in 2017, and its success has been used to inform similar efforts to reform the supply chains of other commodities, notably beef and palm oil.

Source: Greenpeace: https://www.greenpeace.org/usa/victories/amazon-rainforest-deforestation-soy-moratorium-success/

increases transportation costs, and clearing them requires contracting heavy machinery. The business preference of farmers coincides with the interest of cattle ranchers who decide to monetise the capital appreciation they had obtained by being early-stage pioneers. Some ranchers relocate to forest frontiers where land is cheap.

In 2016, the amount of pasture in Mato Grosso was estimated at approximately twenty million hectares, while total cropland was reported to be ten million hectares. Most analysts project that the soy/maize production model will continue to expand and pasture area will decrease over the short term. Within Mato Grosso, that expansion is most likely to occur in the northern tier of municipalities (HML #16) where (1) landscapes are well-suited for mechanised agriculture because they have flat topography and deep, well-drained soils,* and (2) land is privately-owned and farmers can expand into the region without violating the criteria of the Soy Moratorium (Figure 3.8). The construction of the *Ferrograu* will likewise catalyse the

* With very few exceptions, tropical soils are acidic and require large inputs of agricultural lime ($CaCO_3$) to make them suitable for intensive cropping; after deforestation, this is the largest component of the GHG emission profiles of industrial agriculture in Brazil (see Ch. 4).

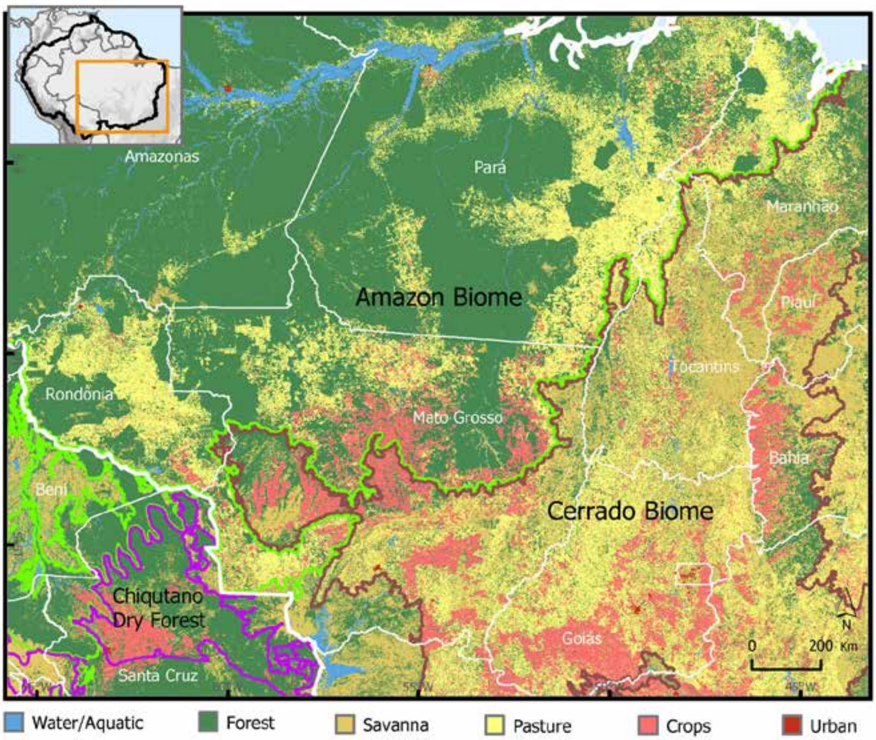

Figure 3.8: Across the Southern Amazon, intensive agriculture predominates on landscapes with flat topography and arable soils, particularly the tablelands of Central Mato Grosso, Bahia, Piaui and Maranhão. Current sustainability protocols allow for the cultivation of soybeans on pastureland within the Amazon biome, a process underway in Northern Mato Grosso, Rondônia, Eastern Pará and on the landscapes near Santarem. Within the Cerrado Biome, the Forest Code allows landholders to clear between 65% to 80% of the native vegetation; currently, about 50% of its original savanna habitat has been converted to pastures or cropland. In Bolivia, intensive agriculture has transformed the alluvial plain of Santa Cruz, largely at the expense of the Chiquitano Dry Forest, a transitional ecoregion distinct from both the Amazon and Cerrado biomes.

expansion of intensive agriculture into these previously remote landscapes that will have an advantage due to lower transportation costs. Similarly, if the *Ferrovia Paraensis* is extended south to the border between Mato Grosso and Pará, the cattle ranching landscapes along BR-158 will most likely be converted into farmland (see Chapter 2)

Land-use change also impacts the watersheds that drain these landscapes. Both deforestation and Cerrado conversion degrade the physical properties of topsoils, which makes croplands susceptible to surface erosion and increases lateral transport of nutrients to the stream network. This increases the potential for eutropication in aquatic habitats due to nitrogen enrichment from the use of fertiliser or nitrogen-fixing crops such as soy. Pesticides are present throughout the entire aquatic system, sometimes at levels that may pose serious health risks.[32] The growing adoption of centre-pivot irrigation systems threatens to seriously diminish water flows, particularly in the Tapajos basin (See Chapter 4).

In Bolivia, the expansion of soy is largely the consequence of direct deforestation, which includes not only humid forests forest near the Andean foothills but also the seasonal and dry forests of Chiquitania and the Gran Chaco (Figure 3.8). Unlike Mato Grosso, where the conversion of pasture to cropland predominates, the expansion of soy cultivation can be directly linked to new deforestation.[33] The expansion of the farm sector has been a top priority of successive governments, including that of Evo Morales, who adopted a policy to double the area under cultivation by 2025.[34] In spite of the favourable policies, expansion is constrained by the realities of farming in Bolivia. Producers face significant risk linked to weather, as well as challenges linked to poor secondary road infrastructure, inadequate storage facilities and contradictory government policies that limit the use of genetically modified organisms. Bolivian producers can compete in export markets due to fertile soils and inexpensive land, both of which are the consequence of the expanding agricultural frontier. They also benefit from a multi-modal bulk transport system (rail and waterway), which mitigates the high cost of transport that is a consequence of their geography (see Chapter 2)

Industrial infrastucture

The soy/maize supply chain is dependent on the existence of privately owned logistical facilities that are essential for receiving, drying and storing soy and feed grains post-harvest. Without silos, the entire harvest would have to be transported immediately to distant processing plants or export terminals. This would cause inefficiencies in the supply chain and lead to traffic jams on the limited number of highways that connect producing landscapes with export terminals.* Silos absorb production during harvest and then permit grains to be dispatched to markets over the following weeks and months. Soy will ferment and spoil when access to storage is restricted due to hauling distance or long lines at logistical facilities, particularly if

* Traffic jams are a common occurrence due to the shortage of bulk transport systems, particularly on BR-163 and BNR-364. Source: Reuters Commodities, 1 Mar. 2017, http://www.reuters.com/article/us-brazil-soybeans-road-idUSKBN1685AN

the beans have a high water content. Estimates of the loss due to spoilage range from five to six per cent per year, which in terms of monetary value ranges from $US 200 to 500 million annually for the state of Mato Grosso.[35]

According to *Companhia Nacional de Abastecimento* (CONAB), Mato Grosso had a total storage capacity of 38.6 million tonnes in 2016, approximately 53 per cent of the combined harvest of soy and maize in 2020. Much of this capacity is owned and operated by one of the four global trading companies: ADM, Cargill, Luis Dreyfus and Bunge. However, the largest operator is the Amaggi Group, a family-held Brazilian company, which has an integrated supply chain that spans production (280,000 hectares), silos (25 facilities), crushing mills (3) and transportation assets (barges and trucks). Other Brazilian companies that focus on the domestic market compete with these larger companies, as does a Chinese company, COFCO, with silos in Sorriso and San Lucas do Rio Verde, as well as a crushing mill in Rondonópolis.[*] In addition, the corporations that operate key railroads (Rumo and VLS) have silos at their logistical facilities both in the field and at the port terminals they operate in Santos (SP) and São Luis de Maranhão (MA).

There is currently an initiative organised by the Brazilian soybean association *(Aprosoja Brasil)* to promote investment in on-farm silos, which would reduce wastage and provide farmers with the option to hold their beans for later sale; this would benefit their bottom line because farm-gate prices are lowest during the harvest season.[36] In Bolivia, which is the world's tenth largest producer of soybeans and sixth largest exporter of soybeans, producers likewise depend on the presence of the four global traders, but about half of its production is processed and traded by companies based in Bolivia, Venezuela or Peru.

Crushing mills are the other major soybean industrial asset. As the name implies, these facilities process the beans by crushing them to extract vegetable oil and separate it from soybean meal (also referred to as soy cake). Soy oil is consumed as food or as an ingredient in food products or other consumer goods; in Brazil, it is used as a feedstock for the production of biodiesel (see below). Soy cake, which is high in protein, is used as an ingredient in animal feeds. Soy is exported as a seed (soybean), as vegetable oil and as soy cake. When exported as a seed, it is processed at its destination, where its two major products are consumed, but when it is processed near the farm, it provides the traders with the opportunity to export the sub-products to different markets. More importantly, crushing mills create a strategically important opportunity to add value to soy production by transforming it into a product with a higher market value. This

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* China National Cereals, Oils and Foodstuffs Corporation (COFCO) is China's state-owned food processing holding company and is China's largest food processing, manufacturer and trader.

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On-farm silos reduce wastage and allow farmers to commercialise production later in the year, rather than during the harvest period when prices tend to be low.

is the basis of the poultry and swine industries in both Mato Grosso and Bolivia (see below).

Global markets

Because soybeans are annuals, soybean prices can vary sharply over relatively short periods of time. Farmers can choose to expand soy cultivation when prices are 'good', which eventually leads to oversupply and a drop in prices; this motivates farmers to switch crops or leave land idle. For this reason, soybean farmers are more attuned to global markets when compared to beef producers (see above) and more agile when compared to palm oil producers (see below).

Brazil exports between seventy and eighty per cent of its national harvest of soybeans, while Bolivia exports as much as 85 per cent of its production. Consequently, the global market has an overriding impact on the farm economy in both countries. The global demand for soy is driven by the combined consumption of vegetable oil and vegetable protein. Soy

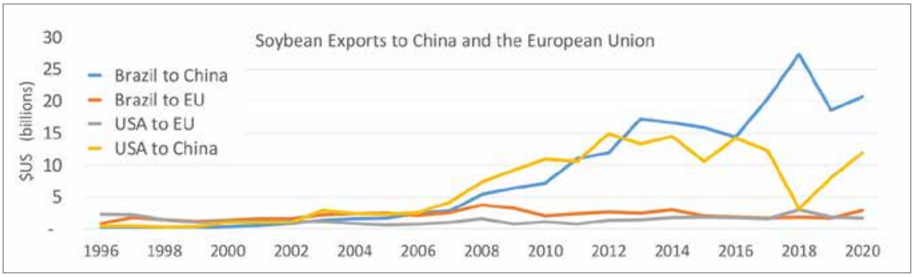

Figure 3.9: China is the world's largest importer of soybeans and Brazil is the world's largest exporter. Tensions between the United States and China have led to an increase in exports from Brazil. Approximately 35% of Brazil's production comes from the Legal Amazon, where harvests are growing at approximately double the rate as that seen for extra-Amazonian producers.

Data sources: FAOSTAT and the USDA/FAS.

oil competes with palm oil, which is more competitive based on price, but the revenue producers enjoy from soy cake ensures that it will continue to be widely cultivated for the foreseeable future.

Geopolitics also plays a role. The trade war between the United States and China initiated by the Trump administration in 2017 led to a dramatic increase in the export of soybeans from Brazil to China. Subsequent agreements led to a return of exports from the United States to China, but Brazil has consolidated its position as the world's largest exporter of soybeans (since 2013) and displaced the United States as the largest producer in 2019 (Figure 3.9).

Demand for soy is expected to double by 2050.[37] In 2020, Brazil exported approximately fifty per cent of total production to China;[*] however, increased growth in future exports is more likely to come from South Asia as this region becomes wealthier and increases its consumption of animal protein dependent upon soy cake. Similarly, population growth and increased per capita income in Sub-Saharan Africa are projected to increase consumption of chicken and pork. If future supply chains remain tied to current production landscapes, South American producers will provide most of the increase in future production. There are other options, but if the projected increase in global demand for soy is met only by production in South America, this would almost inevitably lead to new deforestation in

* Leading Chinese soy importing companies include the Jiusan Group, Hopefull Group, Sinograin, COFCO, CP Group and Chongqing Grains, but the four major trading companies (ADM, Bunge, Cargill, Dreyefus) are intermediaries for most of the transactions.

the Amazon or, more probably, large-scale conversion of natural grasslands in the Cerrado, Campos and Pampa biomes.*

Over the short term, Brazilian producers will continue to expand production because their technological know-how, abundant land resources and post-harvest infrastructure makes expansion an attractive investment. The improvement of bulk transport systems will facilitate the expansion of production in Northern Mato Grosso and increase that region's competitive position in global markets. Increases in cultivation area will most likely occur on non-forest landscapes, including both cultivated pasture within the Amazon biome , as well as by the conversion of Cerrado landscapes, especially in the northeast sector of the Pan Amazon (Figure 3.8).

Over the medium term, pressure on the Amazon from soy and feed grains will depend on the evolution of the global market. Future supply chains could be radically different than those that dominate today. For example, the increase in demand from Sub-Saharan Africa could be met by policies designed to ensure that region remains self-sufficient in food production. Similarly, the EU may choose to embrace an emerging trend to source non-GMO and organic soy from producers in the Ukraine.[38]

Swine and Poultry: Adding Value to Farm Production

The cultivation of soy and maize has brought additional benefits to the farm economy in Mato Grosso because it has increased the supply and affordability of feed rations for livestock producers. Although there is a robust international market for both commodities, the potential return for farmers in Mato Grosso is not as lucrative for maize when compared to soy. This is due mainly to the very substantial gap between maize yields obtained by farmers in the United States when compared to producers in Brazil,† but also to the steep transportation costs that limit the profitability of producers in Mato Grosso. Consequently, the agricultural industry has a strong incentive to create livestock production systems that convert crop commodities into a product with greater market value. The poultry and swine industries have expanded at about the same rate as the soy/maize complex in Mato Grosso (Figure 3.10). In contrast, poultry production in Rondônia and Pará, which do not (yet) cultivate significant areas of soy, declined over the same period in both states.

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* In Argentina, soy is encroaching on the Pampas biome at the expense of cattle ranching, while the largest growth in soy cultivation in Brazil is occurring via the conversion of Cerrado savannas in the states of Maranhão, Piauí and Bahia, which are collectively known as MATOPIBA (Modernel et al. 2016; Spera et al. 2016).

† Yields in Iowa average about 15 tons per hectare, compared to between 9–7 tons per hectare in Mato Grosso.

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Industrial-scale production of pork and chickens has expanded by about 400% over the last thirty years due, in part, to the affordability of feed grains in Mato Grosso (soy + maize) and Santa Cruz Bolivia (soy + sorghum).

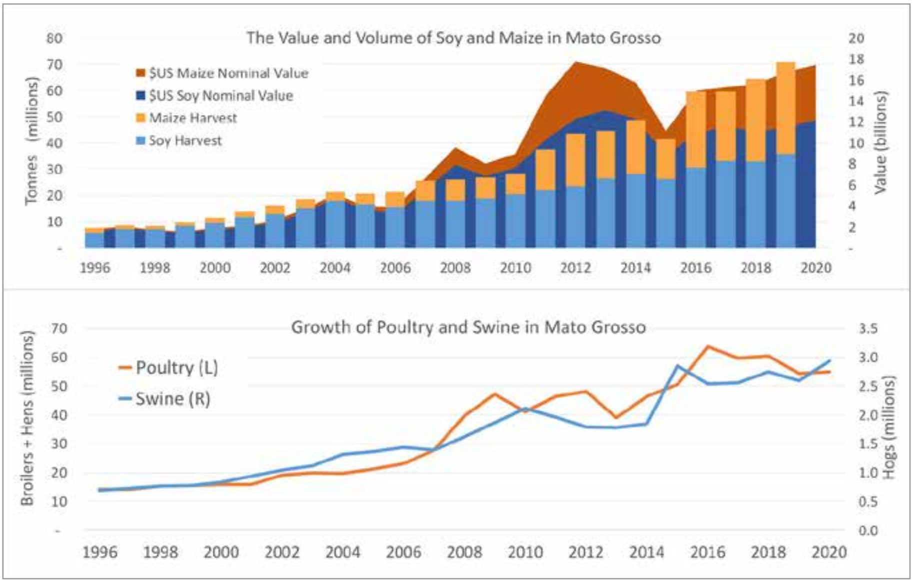

Figure 3.10: The soy boom in Mato Grosso has been accompanied by an increase in the cultivation of maize, which has catalysed the development of the livestock sector, particularly swine and poultry, both of which have grown ~7% annually for more than two decades.

Data source: IBGE/SIDRA.

Brazil is the second-largest producer of poultry in the world and the largest exporter of processed chicken meat. The largest producing states are Paraná, São Paulo, Santa Catarina and Rio Grande do Sul, which are closer to urban markets and ports. Nonetheless, Mato Grosso enjoys the fastest growth rate of poultry production in Brazil: Between 2000 and 2020, the total chicken population in Mato Gross grew an average of seven per cent per year, from ten million to sixty million birds.[39] About 75 per cent of these are broilers (chicken raised for meat) that have a life span of between six and seven weeks, which means that Mato Grosso produced about 330 million chickens for slaughter in 2020. This translates into approximately 700,000 tonnes of meat, about five per cent of Brazil's annual poultry production.[40]

The amount of maize and soy consumed by the production of broilers is dependent upon two factors: the composition of chicken feed and the feed conversion ratio (FCO), which is the metric animal scientists use to calculate the quantity of feed required to produce one kilogram of meat. Chicken feed is about sixty per cent grain and twenty per cent soy cake: the FCO for broilers is about 1.67, while hens have an FCO of 2.0 per kilogram

Source: Google Earth

Figure 3.11: Industrial livestock production facilities near Sorriso in Mato Grosso: (a) Swine barns are accompanied by wastewater treatment ponds; (b) poultry sheds are separated by eucalyptus plantations and a patch of remnant forest.

of egg. This suggests that Mato Grosso's poultry industry was consuming about 0.8 per cent of the state's production of soy and about 1.9 per cent of its maize harvest in 2015.* The situation for the swine industry is similar, except feeder pigs live between six to eight months and have an FCO of about 2.5.† Taking into account the feed intake of sows, a swine herd of about three million pigs would consume about one million tonnes of feed, constituting about one per cent of soy and 1.7 per cent of Mato Grosso's maize production annually.

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* This calculation assumes that broilers live about 7 weeks and yield 2.2 kilograms of meat at slaughter.

† The take-off rate is the number of heads slaughtered each year compared to the total herd size. In Brazil that value is 0.98; the take-off rate is 1.68 in the U.S., because pigs have shorter lifespans and higher reproductive success.

Although local consumption of soy and maize by the livestock sector is not enormous, it is significant when viewed from an economic perspective. The swine and poultry industries generated about $US 1 billion dollars in gross sales in 2020, a value about three times greater than the unprocessed maize and soybeans fed to those animals. This is why the livestock sector can be viewed as a value-added component of the soy/maize production system. The livestock sector injects significant capital into the rural economy, most of which will be reinvested to expand production.

The growth of the livestock sector has been accompanied by the creation of the industrial infrastructure linked to these industries, specifically facilities dedicated to different stages of the livestock life cycle: breeding, brooding, grow-out, packing plants and associated logistics (Figure 3.11). The growth of these industries increases the demand for soy and maize, which will be met either by expansion through extensification or intensification (see Chapter 4). In the first case, this will lead to new deforestation or, more likely, the conversion of remnant Cerrado habitat. Intensification also comes with the risk of environmental degradation, through either the conversion of forest remnants within agricultural frontiers or the displacement of beef ranching operations to the forest frontier. The poultry and pork industries can be viewed as indirect drivers of deforestation because they contribute to the expansion of both the farm and beef sector.

Palm Oil

Oil palm is highly suited to cultivation in the ecological and climatic conditions of the tropics and its cultivation in South America has expanded steadily over the last three decades. The area under cultivation has shown a marked increase in its rate of growth during the last decade (Figure 3.12). Palm oil has been the second-largest global driver of deforestation in the tropics, and its expansion in the Amazon has been accompanied by widespread concern that land-use practices that characterise the industry globally will be replicated there. The concern is based on the predominant business model within the industry, which combines ownership of large-scale plantations with the operation of industrial processing mills. The modern palm oil corporation is a classic example of the benefits of vertical integration and the economies of scale. Some companies also invest in transportation systems, refineries and manufacturing enterprises that transform crude palm oil into consumer goods. The industry brings multiple social and economic benefits to its host nations by improving food security, balance of trade, tax revenues, job creation and economic growth in rural landscapes.

The industrial-scale business model depends upon the acquisition of large landholding – minimally 5,000 hectares but often as large as 50,000

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Large-scale oil palm plantations require a work force of unskilled, semi-skilled and professional employees. Smallholders like them because the trees produce fruit and revenue throughout the year. They are replanted after about 25 years because they are too tall to harvest efficiently; smallholders tend not to replant, however, because they cannot afford to lose five years of production between planting and the initiation of fruit production.

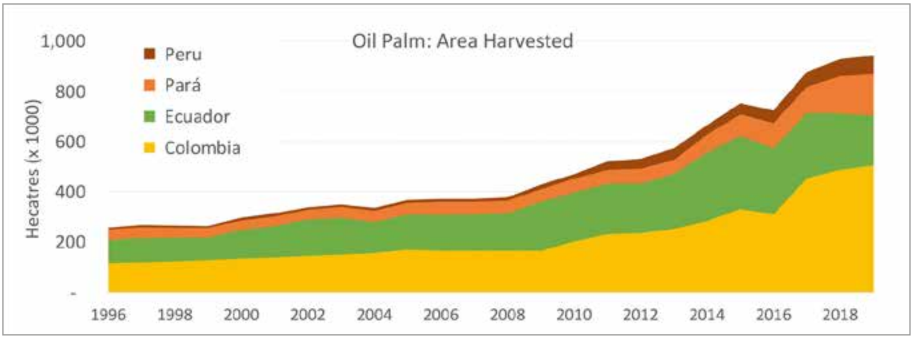

Figure 3.12: Oil palm plantations harvested each year; excludes new plantings that are not yet producing fruit, while the data for Colombia and Ecuador include non-Amazonian landscapes.

Data source: FAOSTAT.

hectares. These are difficult to acquire on landscapes that have already been deforested, especially in those developing countries where past migratory phenomena and weak administrative systems have made land tenure systems chaotic and insecure (see Chapter 4). Palm oil corporations have used their political influence to gain access to public lands in the forest estate to avoid the extra cost of acquiring land on previously deforested land.* Historically, this was the predominant business model for palm oil companies in the Pan Amazon, but the countries have diverged in their practices since about 2000 (see below).

Palm oil corporations act as a proximate (direct) cause of deforestation when they acquire forest land and establish new plantations; however, large vertically integrated corporations also function as an ultimate (indirect) driver of deforestation because they manage the supply chains that commercialise palm oil in consumer markets. The obvious linkages between the cultivation of oil palm and deforestation have motivated multiple environmental organisations to forcefully criticise the industry, which has been the focus of numerous campaigns and boycotts over the last two decades.

Although large corporations dominate most oil palm landscapes, particularly in Southeast Asia, they usually coexist with smallholders and independent producers who are also seeking to benefit from a highly profitable production system (see Text Box 3.3). In most cases, smaller producers

* In many cases, this would require resolving conflicting land-titling claims for dozens or hundreds of small individual properties, as well as purchasing the properties at prices that would increase once residents learned of the investment plans of the company.

rely on the corporate mill to commercialise their production. Sometimes this coexistence can evolve into a stronger partnership where the company provides technical support or commits to long-term purchase agreements.

Text Box 3.3: Oil palm growers can be classified into three groups:

Smallholders are growers with less than 20 hectares and, typically, incompletely documented legal tenure. They depend upon family labour and manage groves with limited technology and yields between 50% to 60% of industrial plantations. They are dependent upon public programmes for technical assistance, tend not to renovate plantings and have limited access to financial credit. Annual cash flow varies from $5,000 to $10,000.

Independent producers are family-owned enterprises with between 20 and 1,000 hectares; most have secure land tenure and contract both permanent and temporary employees. Fresh fruit yields tend to be between 70% and 90% of industrial plantations due to technical assistance contracted from specialised service providers. Growers are more risk tolerant when compared to smallholders and are more willing to take on credit to expand or replace senile palm trees. Annual cash flow varies from $50,000 to $500,000.

Industrial-scale plantation and mill complex are corporate entities, usually subsidiaries of family-held holding companies with landholding of 5,000 hectares or larger. Land tenure is secure in all but a few cases; plantations and mills are managed by professionals with university education who oversee hundreds of permanent employees with benefits and low turnover; day labor is contracted as needed and paid minimum wage. Companies have almost unrestricted access to credit and new capital; annual cash flow can vary between $50 and $100 million.

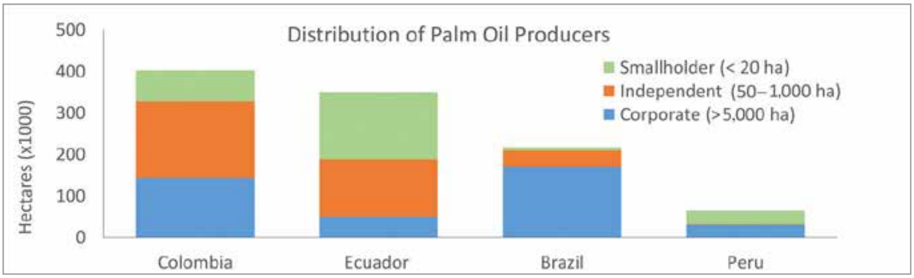

Figure 3.13: The distribution of oil palm plantations stratified by size and social group; data based on a 2016 study by the author, from multiple sources.

Mixed production landscapes exist in all South American countries, where the relative abundance of the different types of producers is the consequence of market forces, social phenomena and public policies that are unique to each country (Figure 3.13).

The presence of a diverse population of producer types opens the door for alternative business models that delink deforestation from the establishment of new oil palm plantations. Unlike industrial-scale operators, smallholders and independent producers are more likely to establish plantations on previously deforested landscapes. In the case of smallholders, many own properties that were homesteaded in previous decades and are now adopting oil palm cultivation because it is more lucrative than cultivating food crops. Independents are a diverse group: some are urban businessmen investing in a production with future growth potential, while others are successful smallholders who are purchasing and consolidating properties to benefit from the economies of scale. They are more likely than smallholders to deforest land, but they are also more likely to own properties that have been previously deforested, particularly cattle ranches.

The era of industrial-scale expansion of oil palm plantations at the expense of forest habitat may have come to an end in the Pan Amazon. There are multiple reasons that this is occurring, and they differ in each country, but the motivation is the same: producers are seeking to penetrate export markets, and the global demand for deforestation-free palm oil has created an opportunity they seek to exploit. The most astute companies have recognised that the best opportunities for growth are via partnerships with smallholders and independents who own or occupy most of the previously deforested land that can be converted to oil palm plantations.

Colombia

Colombia is Latin America's largest producer of palm oil, with nearly 450,000 hectares of oil palm plantations in 2020, with another 100,000 immature plantings that will expand production by ~ 20 per cent over the next few years. The sector generated approximately $US five billion in gross revenues in 2019* and contributes about 150,000 jobs to the national economy.[41] Colombia has a relatively diversified producer sector, and most of the industrial producers actively support independent and smallholder producers (Figure 3.13). The sector is self-organised via the *Federación Nacional de Cultivadores de Palma de Aceite* (FEDEPALMA) and its highly competent research and extension service, *Corporación Centro de Investigación en Palma de Aceite* (CENIPALMA).

* Nominal value based on the mean price of one ton of refined palm oil in international markets; smallholders and independent growers only receive a fraction of this amount.

Smallholders represented a small minority of plantation area in Colombia until 2000, when the government initiated the *Alianzas Productivas*, an initiative that supports collaboration between smallholder associations and industrial-scale producers. When the programme started in 1999, there were an estimated 390 farmers with oil palm groves smaller than twenty hectares; by 2015, almost 55,000 smallholder families were participating in the initiative.[42] This programme is expected to expand over the short term as part of Colombia's efforts to provide economic opportunity to displaced people who reside, or once resided, in conflict areas.

There are four major oil palm regions in Colombia, and none of them are in the Amazon.[*] Approximately fifty per cent of the nation's plantations have been established on landscapes that were transformed by human activity long ago. Deforestation did lead directly to the establishment of about five per cent of the nation's plantations on the Pacific Coast, while the conversion of natural savanna vegetation has preceded most plantations established on the *Llanos de Orinoco*. The Llanos region is immediately adjacent to the Amazon watershed, and the savanna habitat located in that ecoregion is broadly comparable to the Cerrado biome of Central Brazil. Colombia's palm oil sector promotes itself as 'deforestation-free'; however, this claim ignores the land-use change and environmental degradation that accompanies expansion into the *Llanos del Orinoco,* which now accounts for about forty per cent of palm oil produced in Colombia.

Only one industrial-scale oil plantation is located within the Colombian Amazon; a single plantation in Caquetá (HML #52) has struggled to survive in a region better known for cattle and as a centre of armed conflict and illicit drug production. Nonetheless, Caquetá and nearby landscapes in Putumayo (HML #51) and Guaviare (HML #54) have climates and landscapes appropriate for oil palm. In Caquetá alone, more than 1.2 million hectares of degraded pasture provide a unique opportunity to expand palm oil production with net positive environmental and social outcomes. Palm oil plantations established on degraded pastures sequester carbon and restore evapotranspiration functionality; they are also economically much more productive than cattle operations. Because relatively large landholdings exist in the region, they provide an opportunity for corporations seeking to establish new plantations. Investment in Caquetá has long been suppressed due to civil conflict, although the peace and reconciliation process provides an opening for expansion of the industry into the region.

Producers in high rainfall regions must deal with the constant threat from a serious plant disease, which affects plantations throughout South America (see Text Box 3.4). The disease has led to mass die-offs on large-scale

* Zona Norte (Caribbean Coast), Zona Central (Río Magdalena Valley), Zona Sur (Pacific Coast) and Zona Oriental (Llanos de Orinoco)

Text Box 3.4: Integrated pest management in oil palm plantations

Pudrición del Cogollo (Bud Rot) is a complex plant disease caused by an initial infection by a fungal pathogen (*Phytopthora palmivora*), which facilitates secondary infections by other fungi and bacteria that eventually overwhelm plant defence mechanisms. The disease is spread by the palm weevil (*Rhynchophorus palmarum*), which feeds on tender young palm leaves and acts as a vector for the initial fungus infection.

Prevention requires the use of pheromone-baited traps to control weevil populations, culling infected trees and adhering to best management practices, particularly soil nutrition, to ensure robust growth. Where infestations are severe and recurring, crop scientists recommend planting a resistant hybrid cultivar derived from a cross between the African oil palm (*Elaeis guineensi)* and its Amazonian cousin *(Elaeis oleifera).* Hybrids must be pollinated manually because the plants' male flowers are sterile.

Corporate growers prefer to pursue prevention because best management practices bring collateral benefits in yield while manual pollination is labour-intensive and costly. In contrast, smallholders prefer to plant the hybrid, because it reduces risk and they can absorb the extra cost of pollination by using family labour. In addition, the dwarf stature of the hybrids facilitates harvesting and will prolong the lifespan of a plantations from twenty to thirty years, which will benefit smallholders in the future by lowering the need to replant at regular intervals to maintain peak production.

oil palm plantations on the Pacific Coast in both Colombia and Ecuador, which demonstrates the very real risk of catastrophic failure inherent in any monoculture production system where the plants under cultivation are genetically identical.

Ecuador

Ecuador has one of the most egalitarian palm oil sectors in the world, with more than 85 per cent of all oil palm plantations owned by independent and smallholder producers (Figure 3.13). This trend will become even more accentuated in the future because smallholders have increased the area under cultivation over the past decade, while the area managed by corporate producers has shrunk due to disease infestations (Figure 3.12). In 2020, there were about 6,800 oil palm farmers and about 50,000 jobs directly connected to the sector; an additional 100,000 indirectly benefit from palm oil production.[43] One of the most unusual aspects of Ecuador's palm oil sector is the diversity of its milling sector. Thirty independent mills are owned and operated by individuals who started as independent growers but have diversified their businesses by investing in medium-scale palm oil mills. Their combined milling capacity approximately equals that of the large corporations. Independent millers are, essentially, service providers to the independent growers and smallholder producers who dominate the sector in Ecuador.

Most of Ecuador's 410,000 hectares are located on the Pacific coastal lowlands, where transportation costs make producers more competitive in export markets and where banana growers have been diversifying their production systems. The Amazonian provinces of Sucumbíos and Orellana (HML #49) are important areas for palm oil production and plans for future expansion figure prominently in national development strategy documents. There are currently about 18,500 hectares of corporate plantations operated by two companies that were established via the standard model of deforestation in the 1980s. In 2018, there was one independent palm oil mill that was building partnerships with smallholders.* There are approximately 58,000 hectares of smallholder producers in Amazonian Ecuador; each farmer typically owns about forty hectares and pursues a diversified production model that includes coffee, cacao, livestock and subsistence crops, as well as forest remnants and fallow lands. These producers are increasingly adopting oil palm due to its overall profitability but also because of the economic stability it offers by producing throughout the year. In practical terms, this means farmers receive a cheque from the mill about every two weeks, which is a powerful incentive for a low-income family.

Peru

The first oil palm plantations in Peru were established in the 1970s by a state-owned palm oil company near the village of Tocache in the Upper Huallaga Valley in the Department of San Martin (HML #42); similar facilities were soon established near Pucallpa in Ucayali Province (HML #41) and between Tarapoto and Yurimaguas in the Lower Huallaga Valley (HML #43). Economic mismanagement combined with civil unrest eventually pushed these enterprises into bankruptcy; nonetheless, they left a legacy of oil palm plantations and mill infrastructure that are important parts of Peru's current palm oil supply chain. Each of these production landscapes is now home to farmer-owned companies whose shareholders received their equity stake as severance pay when the state-owned company declared bankruptcy in the mid-1980s.† Growth in the smallholder sector stagnated

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* Most independent processing mills, known as extractors, compete on price to attract feedstock, but one company (Oleana) seeks to establish long-term partnerships with small farmers by providing technical expertise to generate loyalty (see https://www.oleana.ec/es/nosotros)

† In the Upper Huallaga Valley, workers organised as the Asociación Central de Palmiculltores de Tocache – (ACEPAT), while the industrial facilities were reconstituted as Oleaginosas del Perú S.A (OLPESA); the members of ACEPAT are the majority shareholders of OLPESA. This business model has been replicated

between 1990 and 2010, despite investments by international development agencies who viewed it as a viable alternative to illicit crops.[44]

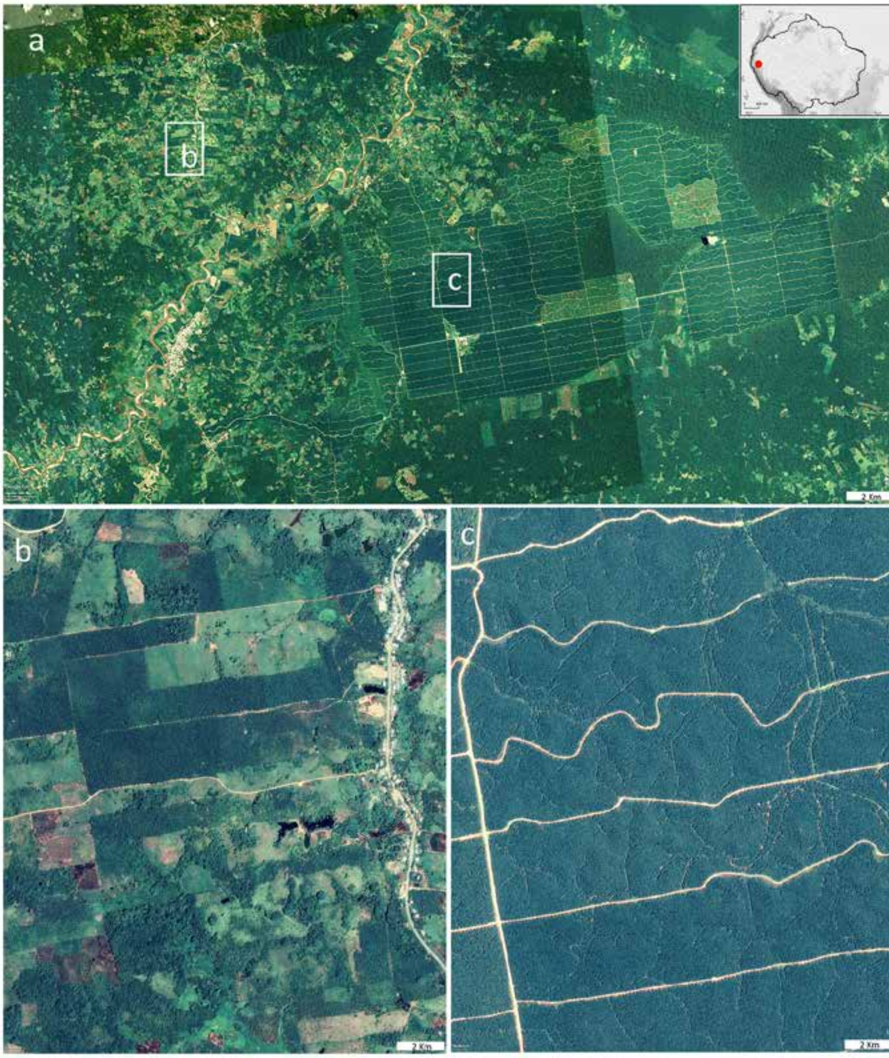
A biofuel policy promulgated by the government in 2008 instigated a new phase in the palm oil sector in Peru. The policy motivated growers to expand production, as well as attract new farmers and investors to adopt the palm oil production system. Medium-scale independent growers, previously nonexistent, have established a presence on landscapes dominated by smallholders. As in Ecuador and Colombia, some of these middle-class producers are successful smallholders who have scaled-up production by purchasing more land; others are urban investors seeking a profitable long-term investment. In 2017, the members of grower associations linked to grower-owned companies operated about 33,000 hectares and provided about forty per cent of the country's palm oil supply.

At approximately the same time the state was introducing oil palm in Tocache, one of the country's largest private corporations, *Grupo Romero*, established a plantation and mill complex in Tocache. That enterprise also suffered from the economic and civil unrest of the 1980s and 1990s, but its owners persevered and are now Peru's largest producer of palm oil via its subsidiary corporation *Grupo Palmas.* This family-owned enterprise operates two industrial-scale oil palm plantations and associated industrial-scale processing facilities: *Palmas de Espino* in Tocache with about 12,000 hectares and *Palmas de Shanusi*, which has approximately 10,000 hectares located between Tarapoto and the Amazonian port city of Yurimaguas (HML #44).

Almost one hundred per cent of the original smallholder plantations were established via the direct clearing of primary forest during the 1980s and 90s; subsequently, they expanded via the conversion of pasture, idle cropland and secondary forest, as well as by clearing remnant natural forest patches.[45] The vast majority of the *Grupo Palmas*' 23,000 hectares of plantations have been established via the direct clearing of primary natural forest. Approximately 9,000 hectares were established in the 1980s and 1990s at Tocache; more recently, direct forest clearing also preceded the establishment *Palmas de Shanusi* between 2005 and 2013 (Figure 3.14). This last expansion generated considerable controversy and was challenged in court by environmental advocates. The company prevailed through the regulatory process, however, because they processed their permits via the Ministry of Agriculture and its land-use planning law, which the court determined had precedence over the guidelines established by the Ministry of the Environment (see Chapter 4).[46]

There is a fourth major player in Peru's palm oil industry, known as the *Grupo Melka*, a corporate entity that represents (or represented) a group

in Ucayali, which is home to three farmer-owned mills (OLAMSA-1, OLAMSA-2 and OLPASA) and in the Lower Huallaga Valley near the town of Tarapoto (INDUPALMA).



Source: Google Earth

Figure 3.14: Satellite images of the oil palm plantations on the border between San Martín and Loreto, Peru: (a) Regional perspective showing the Shanusi plantation (Grupo Palmas) and adjacent smallholder communities; (b) close-up of a heterogenous smallholder landscape with palm groves from 5 to 50 hectares; and (c) close-up within the homogeneous industrial plantation. The industrial plantation was established between 2005 and 2015 by the direct conversion of natural forest habitat; smallholder groves were planted on land adjacent to a trunk highway (PE-5NB) that was deforested in the late 1960s.

of investors with connections to Southeast Asia. This company attempted to establish two oil palm plantations in Coronel Portillo Province of Ucayali Region in 2013. In contrast to the *Grupo Romero*, these investors have had less success using the legal and regulatory processes in Peru to legitimise their plantations and in 2017 abandoned their investment.[47] The failure of the *Grupo Melka* represents a significant financial loss to its investors and may signal the end of attempts to create industrial-scale oil palm plantations at the expense of the forest estate in Amazonian Peru. The *Grupo Palmas* essentially ratified this new reality when it publicly embraced a no-deforestation policy in April of 2017. Presumably, the company adopted the zero-deforestation policy based on its evaluation of the business risk associated with deforestation and a desire to increase exports to North American and European markets.[48]

Brazil

The first cultivation of oil palm outside of Africa occurred in Bahía, where it was introduced as a food crop more than 400 years ago. Currently, there are about 54,000 hectares of oil palm groves scattered across the coastal municipalities of Bahía where they are cultivated on plots that are seldom larger than ten hectares. These producers supply most of the national consumption of *dendé*, which is the name for the crude red palm oil that is an ingredient in many traditional Brazilian recipes. Industrial-scale palm oil is concentrated in the Amazonian state of Pará, where a modern palm oil industry was created in the 1970s in response to Brazil's geopolitical strategy to populate and develop the Amazon (see Chapter 6). Production in Pará grew steadily over the next three decades, averaging about three per cent growth per year until 2007. Over the last ten years, however, the area under cultivation grew rapidly rising from about 55,000 hectares in 2010 to more than 165,000 hectares in 2019 (Figure 3.12)

Like other oil palm landscapes in South America, Pará has a combination of large, medium and small-scale farmers (Figure 3.13); however, large-scale producers dominate the sector and can be stratified into three subcategories: large (2,000–4,000 ha), very large (5,000–10,000 ha) and massive (> 35,000 ha).[49] Of the three massive producers, Agropalma is a long-established company that has grown organically since its founding in the 1980s. The other two, Belem Bioenergía Brasil and Biopalma da Amazônia were established in 2011 by two of Brazil's largest corporations (Petrobras and Vale) when the government was promoting biofuel as a component in its national energy and rural development strategies.

Agronomics and logistics plagued both operations and neither company started to produce significant volumes of palm until 2018; moreover, the economics of biofuels were undermined by price declines in the fossil-fuel market after 2015. Both parent companies divested their interests in 2019 and 2020 at a loss estimated at more than R$ 1 billion each.[50] Both plantations were acquired by Brasil Biofuels, a start-up company cultivating oil palm as a biodiesel supplement for thermal generation plants in Roraima, Acre and Rondônia and Amazonas. They are currently the largest oil palm producer in Latin America, with more than 63,000 hectares that supply vegetable oil to power plants in municipalities that are physically isolated from Brazil's integrated energy grid.[51]

Brazil's palm oil corporations have pursued a strategy of sourcing oil palm fruits from smallholders and independent producers, an effort that has been proactively supported by the Brazilian government via two programmes: *Programa Nacional de Fortalecimento da Agricultura Familiar* (PRONAF) a nationwide programme that provides technical assistance and concessionary loans to small farmers, and the *Produção Sustentável de Óleo de Palma* (PSOP), which has provided tax incentives to companies and concessionary loans to small and medium-scale farmers since 2010.[52] In spite of these programmes, efforts to expand smallholder production have faced many challenges; most are related to a general lack of technical capacity and the multiple problems linked to making credit available to small farmers.

Prior to 2000, almost all expansion occurred via forest clearing; however, all the producers in Pará have halted these practices and embraced a zero-deforestation policy.[53] *Agropalma* has reported that 45 per cent of its total plantation area was established via forest clearing. The change in practices stems, in part, from regulatory rules to ensure that palm oil production for biofuel avoids deforestation, but also because Brazilian producers seek to compete in overseas markets by providing certified, identity-preserved, deforestation-free palm oil.

Industrial infrastructure

Palm oil is different from most agricultural commodities because the raw harvested product, fresh fruit bunches, must be processed within 48 hours or it will spoil. This fact dictates that plantations and mills must be in close juxtaposition. In the case of soy and beef, the decision on where to locate a crushing mill or slaughterhouse is an option with considerable leeway, and its existence is not a prerequisite to the installation of a production system. In contrast, palm oil is a hundred per cent dependent upon the simultaneous creation of a mill and a plantation at the initiation of the development process. Palm oil mills require a significant capital investment and a large-scale facility capable of competing in the global market requires an investment of about $US 40 million.* To justify this capital outlay, insti-

* A plantation with 5,000 hectares of production oil palms would require a mill capable of processing 20 tonnes of fresh-fruit bunches per hour.

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Large-scale oil palm plantations require a sophisticated logistical operation and an industrial mill, which needs a large capital investment, typically in excess of $US 50 million.

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The orange flesh (mesocarp) of oil palm fruits is the source of palm oil (left vial), while seeds (white) are the source of palm kernel oil (right vial). Palm oil is widely used for food, consumer products and as a biofuel feedstock; palm kernel oil is used in cosmetics and for other specialty purposes.

tutional investors require that the mill be accompanied by a plantation of at least 5,000 hectares to ensure the supply of sufficient feedstock to safeguard the viability of the mill. At about $US 10,000 per hectare, a 5,000-hectare plantation would require another $US 50 millions of investment capital.

Global versus national markets

Oil palm is cultivated for two basic products: palm oil, which is extracted from the fruit, and palm kernel oil, which is extracted from the seeds.[*] Palm oil is used in products ranging from cooking oil and ice cream to soap and toothpaste and is a feedstock for the biofuel and chemical industries. Palm kernel oil is similar to coconut oil and enjoys a market niche linked to cosmetics and personal care products. Thirty years ago, palm oil represented less than two per cent of global consumption of fats and oils; today that figure stands at 41 per cent. In 2020, the cultivated extent of oil palm reached 28 million hectares globally, with an annual growth rate of 5.5 per cent between 2000 and 2020, more than double the annual growth rate of soybeans (2.6 per cent). Palm oil displaced soy as the world's most important vegetable oil in 2006.[54] Its dominance as a feedstock for the consumer goods industry is due to its lower cost of production versus soy oil and the chemical characteristics of its constituent fatty acids, which make it a more attractive ingredient for many recipes and formulas.

Global supply chains for palm oil are dominated by producers from Southeast Asia because they have created a hyper-efficient production system based on access to state lands, low labour costs and strategic investments in technology and management systems. Producers in Latin America have missed out on this spectacular growth because their costs of production are significantly higher than their competitors in Indonesia and Malaysia. According to a recent study, the total cost per tonne of crude palm oil produced by an integrated Colombian or Brazilian producer was approximately double that incurred by similar companies in Southeast Asia.[55†] The difference was due largely to higher labour costs, but efficiency and superior yields also favour Southeast Asian producers. The cost differential makes it difficult for South American producers to compete in international markets and forces them to accept lower profit margins. This has caused them to focus on domestic markets, at least in the early stages of their development, but most companies are now focusing on export markets as a growth strategy. Each country has pursued different development strategies, which has

* In addition, two valuable byproducts are generated by the palm oil processing mill: palm kernel cake, an ingredient in animal feed, and biomass that is used to generate thermal energy to power the palm oil mill.

† Mean costs over several years calculated for Colombia ($US 477/ton), $US Brazil ($US 509/ton), Malaysia ($US 266) and Indonesia ($US 233) include plantation establishment and operations, harvest and transport and mill operations.

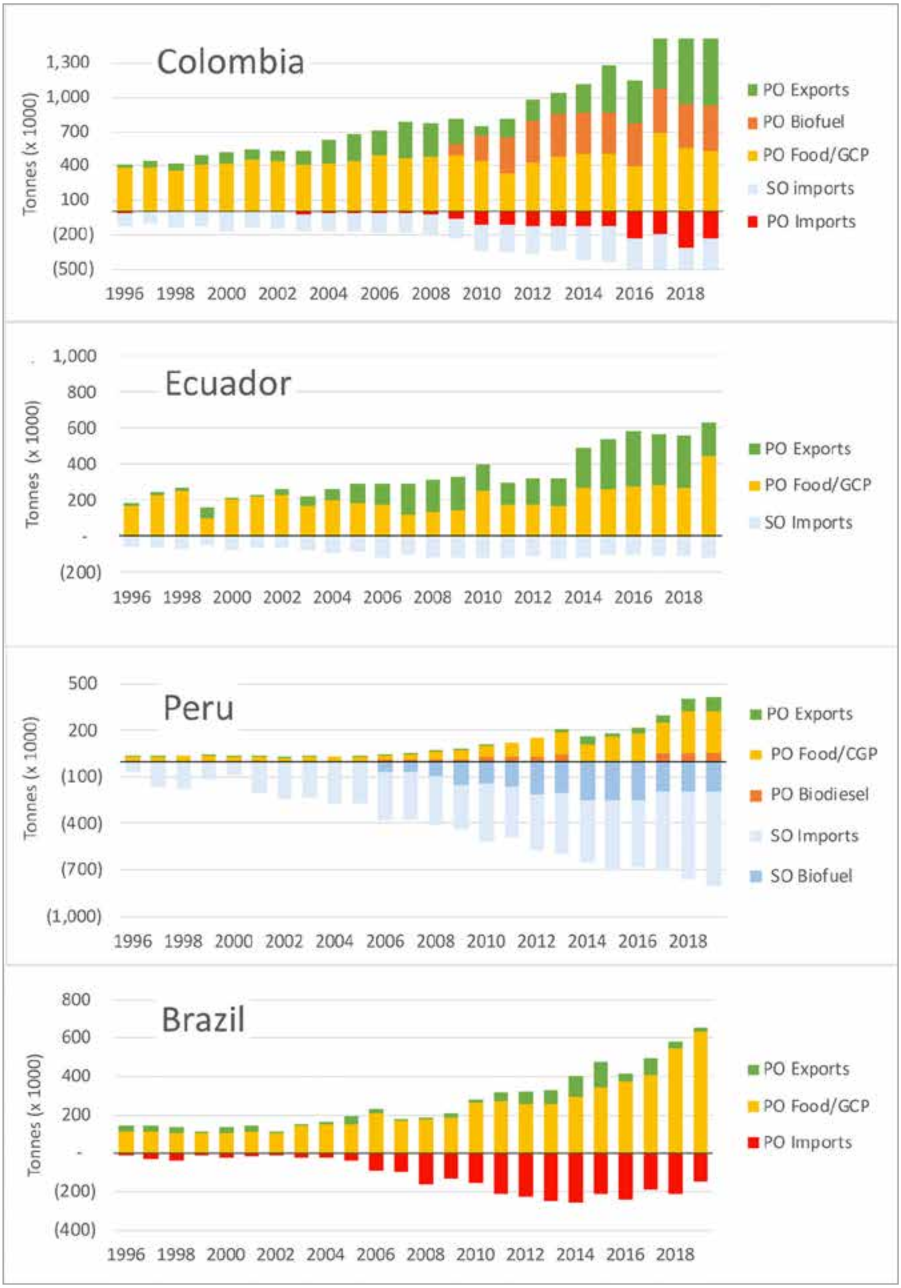

Figure 3.15: Trade flows of palm oil in four South American counties. Soy oil (SO) is shown for the Andean countries, where it is mixed with palm oil (PO) to ensure cooking oils remain liquid at the low temperatures common at high altitudes.

Data source: FAOSTAT

influenced how rapidly they have expanded and their ability to compete in national and global markets (Figure 3.15).

Colombian producers were making progress in penetrating overseas markets, but a disease outbreak in 2010 combined with drought conditions limited gains at a time when the sector was increasing plantation area in response to a national biofuel policy (Figure 3.14). The biofuel policy did promote the expansion of the industry and enabled the sector to export greater quantities overseas. Ecuador has a similar history, including periodic bouts with plant pathogens but, unlike Colombia, Ecuador's government did not embrace a biodiesel policy. Consequently, the palm oil sector has expanded by focusing exclusively on exports. Domestic consumption in both Colombia and Ecuador is flat; major export markets include Venezuela, the EU, Mexico, Chile and Brazil. Ecuador actually exports about thirty per cent of its production to Colombia.

Peruvian producers have not only failed to garner a significant export market but have also failed to reduce the country's dependence on imported soy oil. The macroeconomic incentives for expanding palm oil production in Peru would seem obvious to a casual observer since it would replace imported soy oil. The expansion of oil palm plantations in Peru is increasing and will be a significant driver of land-use change in Amazonian Peru over the medium term.

Brazil has enjoyed consistent growth of its palm oil sector, but domestic demand has far outpaced the ability of producers to meet supply (Figure 3.15). Brazil is the world's second-largest producer of soybeans, so palm oil must compete with soy oil for market share. For example, Brazil has a long-established policy of using biofuels as alternative energy sources, but very little palm oil has been allocated to the biodiesel market (see below).*

Brazil has a massive market for consumer goods, and many global brands manufacture their products in Brazil using derivatives from palm oil or palm kernel oil.† Apparently, the lack of domestic production combined with cheaper imports has motivated companies to source between twenty and forty per cent of Brazilian demand from overseas suppliers. Colombian and Ecuadorian imports represent about ten per cent of total imports, so the remainder must be coming from Southeast Asia.

The future Brazilian market for palm oil may be at a crossroads. The 100,000 hectares of new plantations established in Pará between 2010 and 2016 were intended originally to be used as feedstocks in an expanding biofuel industry, either for export to the EU (Belem Bioenergia Brasil) or to

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* According to the Agência Nacional do Petróleo, Gás Natural e Biocombustíveis (ANP), Brazil consumed about 3.9 billion litres (3.5 million tons) of biodiesel in 2015, of which 80% was manufactured using soy oil. National production of soy oil in 2015 was approximately 7.5 million tons (FAOstat).

† Unilever, Procter & Gamble, Mars, Mondelez, Kraft-Heinz

defray the cost of diesel consumed by Vale's heavy machinery and railroad operations (Biopalma da Amazônia). However, the decline in demand for biodiesel may change this calculus, and this new production – which has yet to come fully online – might be targeted at Brazil's expanding consumption of traditional uses of palm oil.

Over the short term, there is considerable uncertainty regarding the future of the palm oil sector in the Pan Amazon. Production in Ecuador and Peru will probably continue to expand, but almost all this expansion will occur via smallholders and independent producers. In Colombia, the current government has changed the biofuel policies that contributed to the expansion of the sector over the last decade,[56] but a decline in domestic demand may be offset by increasing exports. Brazil has almost unlimited capacity for expansion, and government policy in the recent past has favoured the sector; however, recent expansion may have saturated domestic demand for the next several years. In all four countries, expansion will occur without deforestation by large-scale producers due to market pressure. Some small-scale deforestation will occur in Ecuador and Peru because smallholders are not subject to the same level of monitoring. That forest loss will occur via the loss of forest remnants or the gradual expansion of the agricultural frontier.

Biofuels

The spikes in commodity prices in the first decade of the twenty-first century coincided with a global boom in biofuels. The interest in biofuels was motivated allegedly by a concern for global warming but other, more mundane, reasons played a vital role. In advanced economies, this included a geopolitical urgency to lessen dependence on fossil-fuel imports from countries suffering political instability, combined with the political expediency of supporting domestic production of agricultural commodities. Well-known examples include the corn lobby in the United States and the rapeseed constituency in the European Union. Biofuel policies in both jurisdictions are now under pressure. Low oil prices have reduced demand for biofuels, while the unexpectedly rapid development of electric vehicles and renewable energy provide more attractive pathways for lowering greenhouse gases (GHG). The long-delayed operation of advanced biofuel production has caused several companies to declare bankruptcy and dampened investment in these once-promising technologies. Finally, concern about indirect land-use change and food security issues has motivated the EU to roll back subsidies and end policies that once favoured the biofuel industry.[57] The US is a net exporter of ethanol but imports about twenty per cent of its biodiesel consumption, which is largely based on soy.[58]

In South America, several countries have adopted biofuel policies. The motivation in these countries has little to do with climate change, being more obviously meant to advance rural development and boost export industries. Brazil, Colombia, Peru and Ecuador all have biofuel mandates that require distributors and retailers to blend a specified amount of biofuel with traditional fossil fuels. Gasoline is mixed with ethanol produced from sugar cane and maize, while biodiesel is a blend using derivatives of soy or palm oil or waste oil and fats collected from the food chain.

Brazil has a long history of promoting bioenergy, particularly ethanol from sugar cane, and the Brazilian sugar industry is renowned for its efficiency and low GHG footprint. Brazilian companies also lead efforts to produce cellulosic ethanol and most use waste biomass as a source of thermal energy to generate electrical energy that is monetised in domestic electricity markets.[59] Brazil is the world's largest producer and exporter of ethanol and has recently started to export biomass pellets from agricultural waste to North American and European utilities seeking to reduce emissions from coal-fired power plants.[60] An increasing number of corporations with landholdings in Mato Grosso are building thermal biomass plants with plans to install carbon-capture and sequestration technologies over the medium-term.[61]

The expansion in maize cultivation in Mato Grosso has catalysed its use as a feedstock for the production of ethanol. Manufactured in Brazil for the first time in 2012, maize-based ethanol has exploded as a business model with 1.4 billion litres produced in 2019/2020 and 3.2 billion litres projected for 2021/2022. Current production represents about four per cent of total national ethanol consumption, but is expected to reach twenty per cent by the end of the decade (8.0 billion litres).[62]

As of 2019, there were seven maize-based distilleries operating in Mato Grosso, three under construction and seven in different stages of planning.[*] A large plant, capable of manufacturing 500 million litres annually, requires a $US 100 million investment; it will generate gross revenues of ~ $US 200 million and create as many as 8,000 direct and indirect jobs.[63] The nominal value of maize-based ethanol production was approximately $US 1.3 billion in 2020/2021; about half can be attributed to Mato Grosso.

The economic impact of maize-based ethanol is maginified by fermentation byproducts with their own commercial value: corn oil and a solid residue known as DDGS (distiller's dried grains and solvents). Corn oil has chemical characteristics similar to soy and can be sold into vegetable oil markets; DDGS is even more lucrative because it is rich in protein

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* As of 2020, there were four corporations operating in Mato Grosso: FS Fueling Sustinability (6 plants); USIMAT (2), INPASA (2) and ALD Bioenergia (1); source: União Nacional do Etanol de Milho, http://etanoldemilho.com.br/quem-somos/

and vitamins that makes it an excellent feed supplement for the livestock industry (see above). The development of a maize-based ethanol industry has resolved a crucial challenge for the industrial farm sector: surplus maize stocks. Unprocessed grain is non competitive in global markets due to high transportation costs, but as a biofuel feedstock it can be commerecialised in domestic energy markets, while corn oil and DDGS add value to meat products destined for overseas markets (see above).

The Brazilian government supports biodiesel production with a blend mandate of ten per cent. Most of the feedstock is soy oil, which in 2019 totalled 4.8 million cubic metres. This volume is equivalent to the oil content of ~18 per cent of the total national production and fifty per cent of the soy oil processed domestically within Brazil. Mato Grosso produced 26 per cent of that total. In contrast, < 2 per cent of the biodiesel mandate was supplied by palm oil, which represented less than six per cent of the total national harvest in 2019.[64] Most of that was produced by Brasil Biofuels, which blends it with conventional diesel to fuel its eighteen power plants located in Acre, Roraima, Rondônia and Amazonas.[65]

The decision to promote soy rather than palm oil as a biodiesel feedstock is noteworthy because the GHG footprint of Brazilian palm oil is significantly smaller than soy. The carbon emissions of palm oil are approximately fifty per cent less than soy when land-use change is excluded from the calculation; however, if palm oil is assumed to be deforestation-free and soy expansion occurs via the conversion of Cerrado landscapes, then the GHG footprint is about 140 per cent less for palm oil when compared to soy.[*] Palm oil produced on degraded pastures is carbon negative because both above and below ground biomass increases over time until it reaches an equilibrium after a couple of decades.

Presumably, the decision to give priority to soy over palm oil was driven by the pre-existing logistical infrastructure near the urban centres in Southeast Brazil and the limited capacity of palm oil companies to produce the volume of feedstock required by regulatory mandates.[†] Political

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* The GHG footprint for palm oil versus soy, excluding land-use is 15 to 20 g CO2/MJ versus 27 to 59 g CO2/MJ. The GHG footprint for palm oil versus soy, assuming palm is cultivated in pastures and soy in converted Cerrado, is -35 to -60 g CO2/MJ versus 82 to 142 g CO2/MJ. Derived from emission factors in Stratton et al. 2010.

† Total Brazilian production of crude palm oil in Pará in 2014 was ~300,000 tons, while the total biodiesel demand was 3.4 million tons. Source: IBGE –Instituto Brasileiro de Geografia e Estatistica (2019) Sistema IBGE de Recuperação Automática – SIDRA, Produção Agrícola Municipal: https://sidra.ibge.gov.br/pesquisa/pam/tabelas and USDA-FAS / GAIN Report, Brazil Biofuel report (2016): https://apps.fas.usda.gov/newgainapi/api/report/downloadreportbyfilename?filename=Biofuels%20Annual_Sao%20Paulo%20ATO_Brazil_8-12-2016.pdf

influence may also have contributed to favouring the soy sector, which had gross revenues of about $US 40 billion in 2015 compared to about $350 million for palm oil.

Colombia designed its biofuel programme to support the domestic sugar cane and palm oil industries, two business sectors with influential constituencies that also generate tens of thousands of jobs in the rural economy. Biodiesel mandates increased production and now represents about a third of total production, which helped palm oil companies manage supplies impacted by disease outbreak and fluctuating export markets (see Figure 3.15). Producers hope to penetrate overseas biodiesel markets in the future by creating deforestation-free supply chains.

In Peru, the decision to adopt biofuel mandates was meant to fortify its rural economy and, simultaneously, reduce imports of vegetable oil, valued at about $US 500 million per year (see Figure 3.15). This did not have the desired effect, however. Instead, fossil-fuel companies imported soy oil from Argentina by ocean transport, which enjoyed a price advantage when compared to palm oil hauled over the Andes by truck. The price differential was so large that Grupo Palmas shuttered its biofuel refinery in Tocache in 2014 – only two years after its inauguration.

In Ecuador, the government elected to impose ethanol mandates, but declined to do the same for biodiesel. Apparently, the subsidised price for fossil-fuel diesel makes the implementation of a biodiesel mandate problematic because it would lead to an increase in the cost of diesel fuel at the pump. Producer groups have called for a policy that promotes biodiesel, but the enthusiasm for a biodiesel mandate varies among stakeholders: larger companies are active proponents, while the representatives of the smaller producers are less enthusiastic. The conventional logic for opposition to a biodiesel mandate is hard to understand given the obvious macro-economic benefits of a domestic biodiesel market and the example of Colombia, which has used the domestic biodiesel market as a mechanism to expand both production and exports.[66]

In Bolivia, the government of Evo Morales rejected all biofuel policies that would have diverted revenues from the state-controlled oil company to the agricultural sector, which is dominated by private companies linked to the political opposition. This may be about to change, however; in 2021, the newly elected government of Arce Catacora announced a plan to develop a biodiesel refinery. The proposed $US 250 million investment would alleviate the country's reliance on imported diesel.[*] Unlike the biofuel mandates in Colombia, Peru and Brazil, which are based on blends of fatty acid me-

* Bolivia imported approximately $US 500 million in conventional diesel in 2020 during a time of record low oil prices. Government subsidies of about 50% have been maintained in order to ensure civil peace among its conflictive transportation sector and to support its agrobusiness sector. See Laserna 2018.

thyl-ester (B5, B10, B20), the proposed refinery would convert vegetable oil to pure biodiesel (B100).[67] The project would require an additional 250,000 hectares of soybean plantations, which historically have been created by deforestation. The government expressed a commitment to use other feedstocks, such as waste animal fat, or to invest in the industrial production of a Macauba palm, a native species with commercial potential (see Chapter 7).

Coffee and Cacao*

Coffee and Cacao have much in common. Both are descended from understorey trees adapted to the low-light conditions of the forest floor. Each have multiple cultivated varieties that differ with respect to quality, as defined by the aromas and other phytochemicals that act as flavour enhancers and stimulants. Both are perennial cash crops that require unskilled labour at harvest and a certain amount of technical proficiency for post-harvest processing. The basic commodity of commerce is a seed, referred to as a bean, while the fruits are subject to fermentation to facilitate the collection of beans, which are washed, dried and bagged for transport and sale.

Unlike oil palm, the post-harvest processing of coffee and cacao do not require a large capital-intensive industrial facility. This is important because it allows small farmers who reside in remote villages to process their own production and transport it to the nearest logistical centre. Like all artisanal systems, there are cultivation practices and processing procedures that influence the quality of the product. A combination of these factors leads to the production of elite coffees and fine cacaos, which have niche markets that impact the prices paid to farmers.

Both cacao and coffee have been implicated in the loss of natural forest habitat, most of which is associated with smallholder production systems.[68] The proximate cause of this deforestation is a desire to expand production or a need to replace existing plantations that have become infested with pests, or have lost vigour due to age. These are crops common to the agricultural frontier, where farmers' *modus operandi* is to occupy and clear forest to establish new plantings. Several of the most popular varieties of both coffee and cacao are adapted to full sunlight; in these cases, the plot is completely deforested prior to planting. Some varieties of both crops grow better under shade, which motivates landholders to expand production into forest habitat to take advantage of the canopy trees. Although this is less damaging than clearing the forest of all its biomass, it is still a form

* The term cocoa is often used as a synonym for cacao, but cocoa actually refers to a processed product (cocoa powder) that is derived from the cacao bean. Using the term cacao also avoids confusion with coca, the plant whose leaves are used to make cocaine.

Both coffee and cacao are small trees adapted to the conditions of the forest understory. Coffee cherries (drupes, in botanical terminology) are harvested once a year by hand when ripe (top). Cacao pods (fleshy capsules) develop in an unusual manner, being born on the stems rather than on the branches, and maturing gradually over several months (bottom).

of cryptic deforestation and contributes to the loss of biodiversity and ecosystem services.[69] As trees mature and production declines, farmers tend to remove shade trees in order to maintain yields over the short term; eventually, the land is converted into some other land use, typically pasture for cattle and dairy

Cacao is a labour-intensive crop that requires an artisanal, post-harvest fermentation process that makes it a good option for small farmers. Both coffee and cacao are often promoted as alternatives to the cultivation of illicit coca, in part because they fetch a decent price, but also because their smallholder production system is similar to coca leaf. Numerous initiatives have sought to promote coffee and cacao as development options on conflictive landscapes, and most of these initiatives have also sought to avoid new deforestation by offering technical assistance. Unfortunately, these efforts have not been particularly successful, either in eradicating illicit coca or in avoiding deforestation.[70]

The cultivation of cacao and coffee has expanded on some, but not all, of their traditional landscapes in the Amazon; in some instances, production has declined (Figure 3.16 and Figure 3.17). Changes in crop area occur largely in response to market demand that is determined by conditions in other parts of the world, either by weather events or structural challenges that are motivating commodity traders to diversify their supply chains. In the case of declining coffee production in Ecuador, overseas competition has caused producers to abandon a long-established cultivation system in favour of other crops. The increase in supplies from South America has been accompanied by renewed attempts to delink the expansion of coffee and cacao from new deforestation;[71] these initiatives are taking advantage of new subsidies linked to climate-change programmes or improved pricing mechanisms linked to certification systems that support farmers who embrace the concepts of sustainability.[72]

Coffee

There are two major cultivated species of coffee: arabica (*Coffea arabica*) and robusta (*Coffea canephora*), each with a multitude of varieties adapted to a broad range of ecological conditions. Arabica represents seventy per cent of global production, while robusta represents about thirty per cent. Traditionally, arabica has been cultivated as 'shade coffee' grown at higher elevations, while robusta is 'sun coffee' cultivated at lower elevations. There are exceptions, including arabica varieties grown without shade at higher elevations and with shade at lower elevations. Both species of coffee are cultivated in the Amazon. Elite coffee varieties tend to come from arabica trees grown under shade at optimum altitudes, which vary by latitude but range between 750 and 1,500 metres above sea level. Harvesting and post-harvest processing practices are also important for maintaining quality in elite coffees.*

In the Andes, arabica is the predominant coffee cultivar. Colombia is third largest producer of coffee and is well known for its high-quality elite arabicas. However, most Colombian coffee is grown in the Magdalena watershed, while production in Venezuela is concentrated in the mountains overlooking the Caribbean coast. The largest producer of arabica in the Amazon is Peru (HML #37, #38, #42, #43, #45), followed by Bolivia (HML #33) and Ecuador (HML #48). Robusta was once widely cultivated in Amazonian Ecuador (HML #49 and #$50), but after about 2000, Ecuadorian smallholders began shifting production to oil palm or cacao.† Robusta is cultivated sporadically in lowland Peru (HML #40, #41, #44, #46) and Chiquitania Bolivia (HML #29).

In Peru, coffee is commonly cultivated on small farms that also produce food crops and livestock; more than 85 per cent of production originates on 150,000 family farms with coffee groves smaller than five hectares. Coffee is a cash crop harvested once a year over several weeks. Family labour is key to its success because it allows small farmers to absorb the fluctuations of price volatility; however, it also limits their ability to expand production. Commercial farms cultivating larger extensions obtain better yields, but since they rely on contract labour, they are also exposed to greater price risk from international markets. Net income varies depending upon production strategy but gross annual revenues between $US 1,000 and $US 1,500 are possible with yields of about 700 and 900 kilograms per hectare. The coffee sector exported about $US 670 million in 2016, roughly two per cent of total Peruvian exports.[73] According to the United States Department of Agriculture, coffee generates some 855,000 jobs in Peru, the vast majority of which are on-farm jobs performed by family members.[74]

The arabica coffee plant grows in a climate zone subject to weather fluctuations that can greatly impact yield and, in some cases, lead to large-scale die-off of plantations. When this type of event hits one of the major producing countries, particularly Brazil, price hikes can dramatically im-

* Management of the roasting and blending processes is essential to ensure consistent quality and these are done at the end of the supply chain, because roasted and ground coffee loses aroma and flavour over time. Consequently, the supply chain in producing countries tends to end with the commercialisation and export of green coffee beans.

† This collapse of the robusta coffee sector in Ecuador coincided with phenomenal growth of the Vietnamese coffee industry, which expanded by an order of magnitude (10 x) between 1990 and 2000; yields in Vietnam average about 1.5 tons per hectare versus about 300 kg per hectare in Amazonian Ecuador.

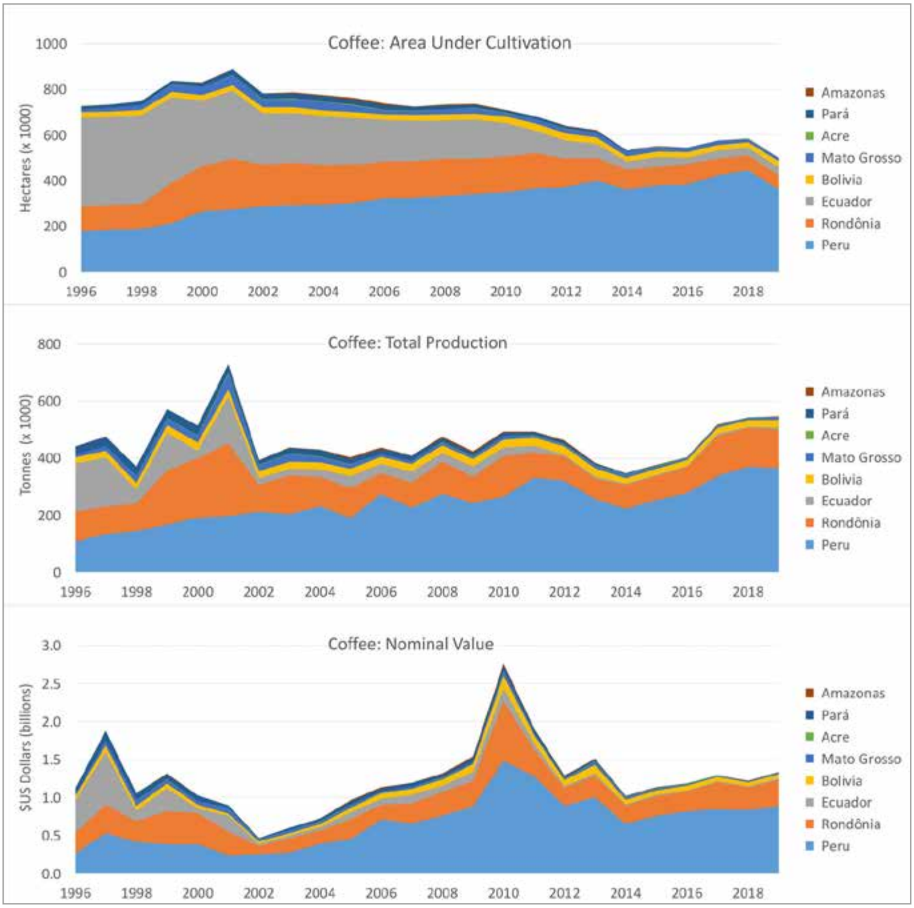

Figure 3.16: Coffee production trends in Amazonian territories of four countries. Cultivated area is decreasing in Rondônia, Brazil, but yield increases have kept production relatively stable. Ecuadorian producers have abandoned the cultivation of [robusta] coffee in Ecuador's Amazonian provinces, where growers are switching to cacao and oil palm. Price volatility linked to weather events in other regions (mainly Southern Brazil) causes periodic windfalls for Amazonian and Andean producers.

Data sources: FAOSTAT and IBGE/SIDRA.

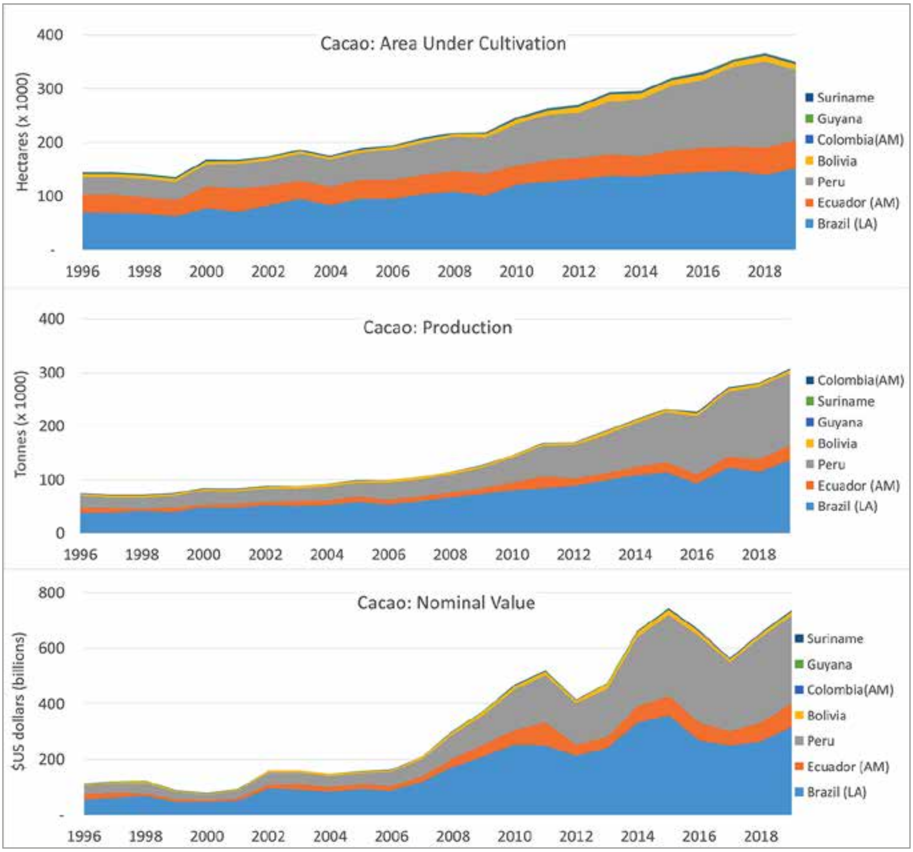

Figure 3.17: Cacao cultivation has been increasing in all jurisdictions; the lower production in Ecuador reflects Amazonian growers' predilection for low-yielding but high quality varieties. Variation in international commodity markets impacts annual revenues. The graphic excludes coastal producers in Ecuador (~90% of national production) and Bahia, Brazil (~75% of national production).

Data sources: FAOSTAT and IBGE/SIDRA.

prove incomes.* Many Peruvian coffee farmers go years with only marginal rates of return, but a price spike will provide a windfall that justifies what is essentially a long-term investment (Figure 3.16). Producers may lose their investment due to local weather events, such as drought or exceptionally humid years, or a disease outbreak. Coffee plantations across the Americas suffer from a coffee rust known as *la roya*, a fungal pathogen that can quickly devastate a plantation. Peru suffered from an outbreak of coffee rust in 2012/2013, which reduced the harvest and forced growers to replant infected groves with resistant varieties.†

Conventional and traditional producers in Peru represent about seventy per cent of total production and typically do not participate in certification programmes, choosing instead to emphasise yield, maximise income over the short term and reduce risk from plant pathogens. Entrepreneurial growers who adopt shade or organic practices tend to participate in growers' associations in order to improve market access via a certification programme. Shaded, organic, certified beans pay a premium of about ten per cent when compared to traditional coffee beans. These growers often obtain assistance from NGOs or alternative development programmes.[75]

The Brazilian coffee industry generates about 25 per cent of global coffee production. Arabica is the main coffee crop, with production in the states of Paraná, São Paolo and Minas Gerais contributing about eighty per cent of national production, all of which is outside the Amazon. In Amazonian Brazil, production is concentrated in Rondônia, where robusta varieties are cultivated by about 22,000 smallholders, each with plots between four and ten hectares in size. It is also cultivated in Acre and in the smallholder communities of Northern Mato Grosso. Referred to by Brazilians as *conilon*, this non-elite coffee is an important part of the smallholder production model in Rondônia, contributing about $US 150 million annually in gross revenues. The total area under cultivation has declined over the last couple of decades from more than 200,000 hectares in 2005 to less than 95,000 hectares in 2016; however, yields climbed from 550 kg/ha to 1.2 tonnes/ha over the same period (Figure 3.16).

According to agronomists with the Brazilian extension service, *Empresa Brasileira de Pesquisa Agropecuária* (EMBRAPA), the potential yield for robusta varieties in Rondônia is ~4 tonnes/ha when grown with irrigation and optimum nutrient management.[76] Depending upon the price, which

* Large scale frosts or extended drought have decimated coffee plantations in Southern Brazil on 10 different occasions between 1900 and 2000; the 2016 harvest was also impacted by an extended drought. Source: http://www.coffeeresearch.org/market/frosthistory.htm

† According to the Peruvian ministry of agriculture, replanting coffee plantations decimated by coffee rust has reduced infestation by 50% of all trees to only 17% between 2013 and 2016.

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Processing coffee is an artisanal activity that is performed on the farm and requires only a moderate amount of infrastructure and know-how. Coffee beans are separated from the fruit (top) and then dried in ovens or in the sun (bottom).

varies greatly from year to year, a small farmer in Rondônia can generate revenues of between $US 1,100 per hectare to more than $US 6,300.* The feasibility of this production system depends partially on family labour, though less so than in the Andes.

The global coffee market has experienced significant changes over the last decade. Global demand for mass-market coffees has increased by an order of magnitude (x 10) due to changes in consumer preferences in traditionally tea-drinking nations such as China. Simultaneously, coffee-drinking counties, like the US, have increased consumption of elite coffees. Peru and the other Andean countries are focusing on the elite coffee market, and many producers are adding value to their production by embracing certification and organic production paradigms. These countries have large areas of idle land located on landscapes with current growing conditions capable of producing premium coffee beans that are highly competitive in global markets. Nonetheless, climate change threatens the long-term viability of existing plantation landscapes, and growers may be forced to 'migrate upward' into intact montane and cloud forest habitat.[77] If so, that would provoke widespread deforestation, the main driver of which would be climate change in combination with the ongoing demand for elite coffees from arabica varieties grown under ideal climate conditions.

Cacao

Cacao (*Theobroma cacao*) is native to the Amazon rainforest and has been cultivated and consumed throughout the Americas since before Columbus. Cacao can be broadly segregated into two contrasting types based on quality: bulk cacao is used for most candy and food products, and fine cacao is preferred for speciality chocolates. There are dozens of varieties, strains and hybrids, but these two major types have dominated production and trade for centuries. The supply of bulk cacao was largely diverted from Latin America to West Africa and Southeast Asia during the colonial period of the late nineteenth century. Fine cacao represents only about five per cent of global cacao consumption, but almost all of that originates in Latin America where the genetic diversity of the wild species has been used to improve the concentration of aromatic compounds in the cacao bean. A combination of events has stimulated a revitalisation of cacao production in South America, and the production of both bulk and fine coca has been increasing at about ten per cent annually over the last decade (Figure 3.17).

The traditional method for establishing a plantation is to clear the understorey of a natural forest and plant cacao seedlings that were germinated in a nursery or directly under an intact canopy. It takes about four years for young trees to flower and fruit, after which light management

* Yield = 0.5 t/ha @ $US 2/kg versus yield = 1.2 t/ha @ $US 2.6/kg.

is important for maximising production and quality: too much light and plants will suffer stress; too little and yields decline. An individual tree can live decades, but most commercial plantings are programmed to last about twenty years due to declining yields. One of the practices used to improve or prolong productivity is to open the canopy to increase light and stimulate photosynthesis, which will increase yields over the short term. Eventually, productivity will decline, however, and groves are converted to pasture or allowed to lapse into a forest fallow. Cacao farming as traditionally practised is a form of slow-motion deforestation.

Traditional cacao farming has contributed to the devastation of the tropical forests of West Africa, which provided about sixty per cent of global demand throughout the twentieth century. As forest habitat has become increasingly scarce in West Africa, cacao growers have adopted full-sun production systems to maintain yields. Many analysts predict that these practices will lead to a permanent decline in West African cacao production.[78] Not surprisingly, global commodity traders and food companies have been seeking alternative sources of cacao, and that is one reason production in the Amazon has been on the increase (Figure 3.17).

Brazil produced more than 275,000 tonnes of cacao in 2014, mainly from Bahía (58%) and Pará (42%), particularly in the municipalities located on the north bank of the Amazon River (HML # 1) and the Transamazônica highway (HML #10), where yields are almost double those of traditional cacao growers in Bahía. The popularity of cacao in smallholder landscapes is expected to grow over the short-term, and the *Associação Nacional das Indústrias Processadoras de Cacau* (AIPC) has pledged to double production over the next ten years.[79]

Ecuador produced approximately 160,00 tonnes in 2016 with about 85 per cent cultivated in the provinces of the coastal Pacific and the remainder originating in the Amazon (HML #49 and HML #50). Most of Colombia's production occurs in non-Amazonian watersheds, but its Amazonian provinces have the required climatic and edaphic characteristics. Caquetá has about 400 growers with about 1000 hectares (HML #52), which is less than two per cent of national production; efforts to increase production are linked to efforts to displace illicit coca. Venezuela produces cacao but not in the Amazon, while Bolivia's limited production is largely targeted at domestic consumption, except for an association of growers in the Yungas of La Paz (HML #33)

Ecuador has a special market niche because its growers supply about seventy per cent of the fine cacao commercialised in global markets. The source is a local variety known as *Nacional,* which has been cultivated on Ecuadorian farms for decades. It was recently christened *Sabor Arriba* by the Ecuadorian association of cacao exporters. Ecuador's position as a provider of fine cacao is being challenged, or at least modified, by the increasing popularity of a hybrid cacao variety known as CCN-51, which has gained market share because of its robust growth and high yields (see Text Box 3.5).

There is concern among chocolate connoisseurs and export companies that CCN-51 may displace *Nacional* and compromise Ecuador's dominance of the specialty cacao market. It is preferred by farmers because *Nacional* trees yield only about 300–400 kg/ha compared to 700–1,100 kg/ha for CCN-51, which can yield three tonnes per hectare when cultivated in experimental stations under ideal conditions. The increased productivity of CCN-51 is the result of its genetic makeup, which controls the size and number of the fruits per tree and seeds per pod. It can be cultivated in full sun, has a lower rate of disease infestation, and responds better to agrochemicals. These attributes cause concern among environmental advocates who criticise its genetic narrowness as a clone and cite its potential to become another monoculture production system.

Like all commodities, price varies enormously but, on a per hectare basis, cacao producers' revenues will vary from as low as $US 500 to as much as $3,000.* Smallholders in Amazonian Ecuador typically cultivate only between one and five hectares of cacao, while commercial producers on the Pacific Coast might have as much as fifty hectares. Certified production of fine cacao delivers a price premium to the farmer of about twenty per cent, but this is not sufficient to offset the lower yields of *Nacional* trees. Currently, CCN-51 contributes about 36 per cent to Ecuadorian national production compared to 37 per cent from *Nacional.* Amazonian producers largely produce a third type, known as *Cururay*, which is similar to *Nacional* in both yield and cocoa characteristics.[80] Production in Amazonian Ecuador is static (see Figure 3.17), but efforts to expand production are underway as part of initiatives to promote alternatives to deforestation-based agriculture.[81]

In Peru, a similar phenomenon is occurring with respect to CCN-51, which is making inroads among both established and new producers. The area under cultivation has approximately doubled between 2005 and 2015, with particularly strong growth on landscapes that are the focus of 'alternative development' programmes linked to the war on drugs. Apparently, these programmes have been proponents of the cultivation of CCN-51 due to its superior yield and the need to compete with coca cultivation (see below). In 2015, more than 53 per cent of all cacao groves were planted in CCN-51 with only about 44 per cent dedicated to fine cacao, which apparently includes a mixture of introduced *criollo* cultivars and native varieties derived from Amazonian wild populations.[82]

Production has grown annually by about eight per cent, reaching more than 85,000 tonnes in 2016 produced on about 110,00 hectares. The major production area is San Martin (HML #42 and HML #43) with 31 tonnes,

* Estimates based on 350 kg/ha @ $500/ton and 1000 kg/ha @ $300/ton.

Ecuador is renowned for its fine cacao, most of which is harvested from the variety known as Nacional (top). It has lost some market share, however, to CCN-51 (bottom), a hybrid developed by a plant breeder in the 1990s, which is inferior in quality but has better yield.

Text Box 3.5: The origin of CCN-51

CCN-51 was developed by an Ecuadorian horticulturist, Homer Castro, in the 1960s, when he was leading a plant-breeding programme to develop genetic resistance to a common plant pathogen, *mal de machete*, which causes plants to wilt when their vascular system becomes infested with fungal tissue.

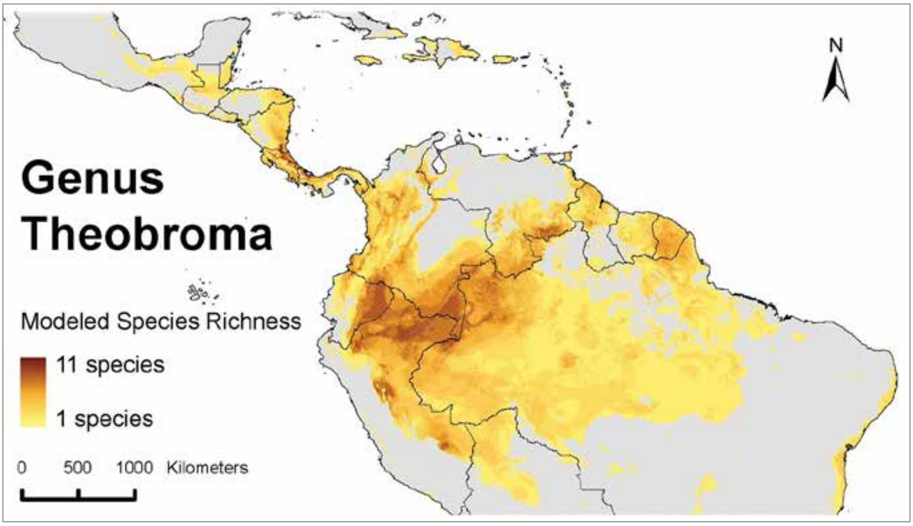
Genomic studies of more than 900 accessions of cacao held by plant breeders revealed that the CCN-51 hybrid is a descendent of wild Amazonian seed collected near Iquitos (45% of the genome) and two common cultivars: Criollo (22% of the genome), which is the leading type of fine cacao in Central America, and Amelonado (21.5% of the genome), which is similar to Forastero and the source of about 80% of global bulk cacao. The remainder of CCN-15 genome is composed of other genotypes collected from wild populations in the upper Amazon, including Contamana (~4%), Purús (2.5%) and Marañon (~2%).

In other words, CCN-51 is a hybrid that combines the genetic attributes of both bulk and fine cacao; however, it is not considered to be a fine cacao due to the chemical properties of the beans. Many chocolate gourmets consider CCN-51 to be of extremely low quality and its flavor has been described as: 'weak basal cacao with thin fruit overlay; lead and wood shavings; astringent and acidic pulp; quite bitter'.

Source: Motamayor et al. 2008

which represents 44 per cent of total national volume; these tend to be new producers, and they are overwhelmingly adopting CCN-51. Other regions include landscapes near Pucallpa (HML #41), Huanuco and Junín (HML #40) and La Convención (HML #35). *Criollo* and native varieties predominate on these landscapes, but CCN-51 contributes between twenty and 35 per cent of the harvest.[83] Prior to 2000, most cacao production was dedicated to meeting domestic demand; subsequent growth can be attributed to exports, which accounted for more than two-thirds of total production in 2016 with a value of approximately $US 200 million. These proceeds are distributed among 26 growers' associations representing approximately 30,000 families, with mean gross revenues of between $1,000 and $1,500 per hectare, depending upon price.

An experiment in corporate cacao production may be underway courtesy of a controversial development located near Tamshiyacu, a village located about forty kilometres upriver from Iquitos, the capital city of Loreto Department in Amazonian Peru. This industrial-scale plantation was established by an entity knows as United Plantations, a subsidiary of the *Grupo Melka*, the same corporation that attempted to establish large-scale oil palm plantations in Ucayali Department (see above). The more than 2,400 hectares of primary forest that were cleared were intended, apparently, to



Source: Thomas et al. (2012) CC BY 4.0

Figure 3.18: The upper Amazon is a centre of diversity for the genus Theobroma. This genetic diversity is the source of the region's fine cacao, which is highly prized by chocolatiers.

establish what would be the first industrial-scale cacao plantation in the world.* Fortunately, the legality of this deforestation has been challenged in court and activities have been paralysed. The *Grupo Melka* has sold its assets and abandoned its investments in Peru.

Despite the predominance of CCN-51, the association of Peruvian cacao exporters is seeking to improve its market position by emphasising the quality of its fine cacao offerings. The motivation is driven in part by a commercial logic to provide a niche product with a price premium, but it is also influenced by a long-held desire to monetise the value of a biodiversity asset of the Amazonian biome. The Western Amazonian is a centre of genetic diversity of cacao and the evolutionary origin of the genus (Figure 3.18).[84] Ecuador and Peru hope to capitalise on the genetic diversity of their wild populations to develop new cultivars that combine both the improved aroma characteristics of fine cacao and the disease resistance and superior yield attributes that make CCN-51 popular with growers.

* This may not be an isolated case, however, as palm oil companies in Indonesia, which is the world's third largest producer of bulk cacao, are allegedly seeking to diversify their income stream by establishing cacao plantations. Key to the success of these initiatives is the prospect of using the CCN-51 cultivar, which under ideal conditions can produce up to 3 tons of cacao seed per hectare.

Local and National Food Crops

Many of our staple food products are highly dependent on industrial agriculture and global supply chains, but small farmers in the Amazon continue to produce foodstuffs for their families, local communities and national markets. This is particularly true in the Andean nations where poverty and a strong cultural tradition of subsistence farming influence both land use and food production. Most of the small farmers in the Andean Amazon are migrants from the Andean highlands where landholdings are often extremely small (see Chapter 6).

An economic production system based on small farms accompanied these migrant communities to the Amazon lowlands; although holdings are small, typically between ten and fifty hectares, they are an order of magnitude larger than what migrants were accustomed to in the villages of the High Andes. The opportunity to acquire land and grow food is the primary driver of deforestation in Andean countries; in all these countries, legal systems exist that allow individuals to homestead public lands and acquire tenure if they occupy and work the land. For many families, this is one of few viable pathways out of poverty.

Small farmers in the Andean Amazon grow a diversity of crops for household consumption and for sale to local, national and global markets. The use of technology varies but, like small farmers across the globe, they depend on family labour. This includes clearing the land, preparing the soil, sowing seeds or transplanting individual plants, weeding and pest control, as well as harvest and post-harvest activities. Some crops have labour-intensive stages when the family may contract outside labour, especially successful small farmers who have consolidated multiple small plots into a larger family landholding.[85]

Many food crops are annual species planted immediately after forest clearing, which may be natural forest on forest frontiers or second-growth forest in areas with a longer history of settlement. Common annual species are rice, cassava, maize, yams, beans and peanuts; farmers also plant fast-growing perennial crops such as sugar cane, plantains, bananas and papaya, while investing in longer-lived tree species such as mangoes, avocados and citrus. Sometimes these are planted simultaneously with perennial cash crops targeted at overseas markets, such as cacao, coffee and oil palm (see above). Over the short term, food crops produce essential resources that families need to survive, but it requires a constant effort to maintain production using the slash-and-burn/forest-fallow system. In contrast, perennial plantations produce for ten to twenty years, or longer, although they require up to five years to start producing revenue. Importantly, neither the perennial nor annual production models are profitable without the benefit of family labour.[86]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Small farmers tend to grow foodstuffs for domestic markets, including manihot (top left), plantains (top right), rice (bottom left) and tropical fruits (bottom right).

For a recent arrival to the frontier, land clearing provides a positive cash flow from the production of food crops that can be consumed and/or sold into national or local markets. Maize production may be used to raise swine and poultry, which adds value to the farmer's primary production while contributing protein to the family diet. The effort to create a long-term cash flow from cacao, coffee or palm oil is cost-effective, but these will not turn cash-flow positive until the fourth or fifth year. More importantly, perennial plantations generate a windfall if they are producing during a periodic price spike, which tends to occur in decade-scale intervals (Figure 3.16 and Figure 3.17).

Established farmers have greater flexibility than migrants because they can discount the capital costs of land acquisition and deforestation as 'sunk costs', which makes the perennial production models more attractive on long-established landholdings. Moreover, an established farmer can use contract labour to expand his or her landholdings, since the return from an annual food crop will largely offset the cost of expansion. The most logical option is to pursue both strategies: invest in existing properties via perennial cash crops while growing food crops by expanding into unoccupied or inexpensive land (see Chapter 4). Combining family labour with contract labour can maintain a positive cash flow over the short term while acquiring a real estate asset that will accrue value over time. This includes more land, cleared land and land with a perennial production system.

For both the recent arrivals and the long-established small farmer, speculation in land represents the primary means for generating wealth. More wealth is created via perennial production systems when compared to annual crops, but annual crops initiate the cycle by allowing new immigrants the opportunity to acquire land, while providing established farmers the opportunity to expand their holdings. This logic and cycle hold true in most of the major smallholding landscapes in the Andean Amazon, although the relative mix of annual and perennial crops varies among geographies.

Coca – The Anti-Development Crop

The most lucrative agricultural system in the Amazon is neither soy nor palm oil, but coca leaf, which is cultivated for both legal and illegal markets. There are two species, *Erythroxylum coca*, which is grown at higher elevations and is preferred for the legal market, and *Erythroxylum novogratenensis*, which is cultivated at lower elevations and is the primary feedstock for the manufacture of illicit cocaine. Historically, coca was cultivated in the montane forests of the Eastern Andes in Bolivia and Peru, where the leaf is consumed as a mild stimulant via infusions or mastication. The consumption of legal coca leaf has grown steadily over the past several decades, as it has

Coca leaf (top) is cultivated to produce a variety of consumer products as well as illicit cocaine. It is cultivated legally in the Coroico municipality of Bolivia (bottom).

become a habit adopted by consumers inside and outside of the Andes. The consumption of illegal cocaine has boomed since the 1970s when it became a popular drug among the urban elite in North America and Europe, a habit which become democratised and globalised as cocaine consumption spread to populations in other economic strata and social groups across the world.

Coca farmers are the smallest of the commercial farmers in the Amazon; a legal coca plantation in Bolivia is a 40 x 40 metre plot of land referred to as a *cato de coca*. Individual plantings can produce for years, if not decades but, since the overwhelming majority of plantations are illegal and subject to eradication efforts, most coca plantations are probably younger than five years old. A well-managed coca plantation can produce up to two tonnes of dried coca leaf per year; as with any crop, harvesting a significant amount of biomass will deplete the nutrient content of the soils, which is another incentive to constantly move and renew coca plantations.

Starting in the mid 1990s, Colombia surpassed Peru and Bolivia as the primary source of coca leaf, a transition that coincided with an increase in the civil unrest in Colombia and the initiation of interdiction efforts in Peru and Bolivia that were financed by the United States and the European Community (Figure 3.19).[87] Subsequently, Colombia increased its efforts to combat cocaine trafficking; according to recent reports, the sum total of coca was reduced to about 50,000 hectares by 2014, of which about 25,000 hectares were located in the four departments located with the Amazon (Table 3.2).

Cultivating coca is legal in both Bolivia and Peru due to the traditional market for coca leaf; however, its conversion to cocaine or its precursors is widespread. Efforts to promote alternative production schemes have met with only limited success, mainly because of the economic advantages of cultivating coca. One hectare of coca leaf will produce about $US 5,000 to $US 7,000 of income based on the mean yield and market value of the leaf as paid to the farmer; a similar area of any of the other cash crops generates revenues of about $US 1,000 to $US 1,500. The economics of coca production reflect market demand, which ensures that somewhere, somebody will grow coca leaf for conversion to illicit cocaine.

If the reported area under cultivation is accurate, this translates into between $US 300 to $US 500 million in Peru, with slightly lower values in Bolivia and slightly higher values in Amazonian Colombia. However, these are only the farm-gate proceeds that flow directly to the farmer, and the total value to the national economy is many times greater when the post-harvest processing and commerce are considered. According to the UNODC,* the full

* United Nations Office on Drugs and Crime.

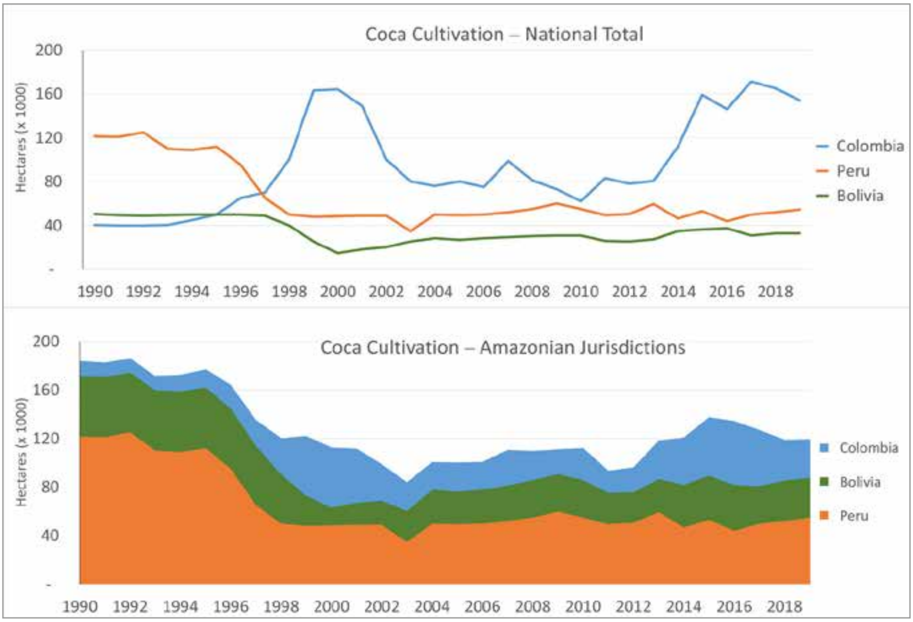


Figure 3.19: Coca cultivation between 1990 and 2019. There was a large displacement of coca cultivation in the 1990s, following the defeat of the Marxist guerillas in Peru and the decision by Colombia's armed militias to embrace illicit drugs as a source of revenue. The spike in coca cultivation after the beginning of the peace process in 2015 was more pronounced in the extra-Amazonian provinces of Colombia than within the Colombian Amazon.

Data source: United Nations Office on Drugs and Crime (UNODC).

coca-cocaine supply chain contributes about 0.9 per cent to Bolivia's GDP, which would place the total value of the supply chain in Bolivia at about $US 4 billion in 2019, with estimates for Colombia and Peru at around $US 8 billion each. Presumably, this does not include the proceeds from 'money laundering', which acts as a subsidy to other sectors of the economy. For example, in Bolivia the construction sector is used to turn illicit proceeds into real estate assets, because buildings can be constructed with cash and sold through banks via mortgages. In Bolivia and Colombia, unusually large investments in cattle ranches and industrial farms are commonly assumed to be financed in part by financial resources of dubious provenance.

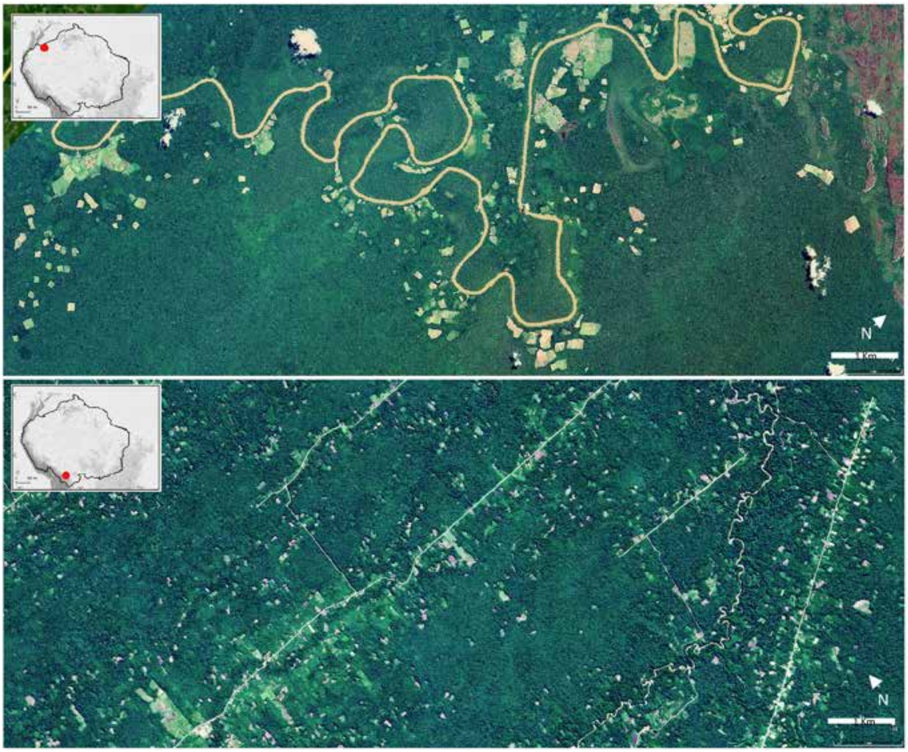
Table 3.2: The major coca producing regions in the Andean countries.

HML #*	UNODC hotspot	Annual deforestation (ha)	Total anthropic area (ha)	Coca fields (ha)	% Coca/ anthropic	% Coca/ deforestation	Revenues ($US million)	
							@ $6k/ha	@ $10k/ha
32	Chapare	15,000	392,100	8,720	2.2%	93%	52.3	87.2
33	La Paz Yungas†	7,007	276,900	17,390	6.3%	248%	104.3	173.9
35	Interoceanic Corridor	16,786	691,900	5,514	0.8%	33%	33.1	55.1
35	La Convención-Lares*	--	--	13,090	--	--	62.7	104.5
35	VRAEM	1,757	45,500	19,247	42.3%	1095%	115.5	192.5
40	Selva Central	23,514	970,300	3,235	0.3%	14%	19.4	32.4
44	San Martin & Yurimaguas	23,993	1,583,300	5,777	0.4%	24%	34.7	57.8
45	Marañon	3,457	596,300	3,250	0.5%	94%	19.5	32.5
51	Putumayo	3,400	330,800	8,432	2.5%	248%	50.6	84.3
51	Caquetá	20,486	1,726,400	4,093	0.2%	20%	24.6	40.9
54	La Macarena	9,779	639,400	3,339	0.5%	34%	20.0	33.4
54	Guaviare	8,621	364,700	5,355	1.5%	62%	32.1	53.5

* HML: human modified landscape (see Chapter 1, Figure 1.2)
† Coca plantings are legal in these regions.

Source: UNODC (Bolivia, 2019; Colombia, 2019; Peru, 2017) [88]

Comparing the deforestation data with the coca monitoring data compiled by the United Nations reveals multiple patterns of coca production. In some, coca plantations are located in areas with a centuries-long tradition of coca cultivation; these include the La Paz Yungas (HML #33) of Bolivia and the La Convención-Lares region near Cuzco, Peru (HML #35). Coca farming in these regions seems to be stable and practised openly on landscapes that have been settled for decades or centuries. They are legal because they are assumed to be producing coca leaf for domestic consumption; nonetheless, the vast majority of coca leaf is channeled into the illegal production of cocaine. In other areas, such as the Chapare of Bolivia (HML #32), the VRAEM (HML #35b) and all the regions in Colombia (HML #51 and #54), the cultivation of coca is a more recent phenomenon and is entirely illegal. In all localities, however, new deforestation patches can be observed in the remote areas and, typically, are less than one hectare in size and are isolated from villages and roads (Figure 3.20).



Source: Google Earth

Figure 3.20: Deforestation pattern typical of coca-producing landscapes: (a) Guaviare, Colombia, where rivers are the primary source of transit; and (b) the Chapare region of Bolivia where successive governments have supported or tolerated coca cultivation.

Recent press reports indicate that coca cultivation in Colombia has skyrocketed since 2016 from a historic low of about 48,000 hectares to more than 170,000 hectares because of the peace process and the policy of tolerance that was implemented during the negotiations. In the Caquetá- Putumayo region (HML #51) the coca cultivation area increased by an average of forty per cent per year between 2014 and 2017. Ironically, this would make the peace process a driver of deforestation.

Roundtables and Certification Schemes

Sustainability initiatives have been organised for most of the agricultural commodities of the Pan Amazon, including palm oil, soy and beef, but also for coffee and cacao. Several of these initiatives have adopted the term 'roundtable' in their names because it conveys the notion of inclusiveness that is a core concept in these multi-stakeholder initiatives. Typically, the stakeholders include all the participants in a supply chain, from the farmer to the retailer, but also commodity traders, consumer goods manufacturers, banks and service supplies, as well as civil society groups. Their shared goal is to identify effective solutions to the social and environmental challenges associated with conventional production systems. The mechanism used to reform supply chains is typically a voluntary certification system that verifies that the production, trade and transformation of a commodity has complied with a set of best practices that have been agreed to by all the parties.* The search for consensus is important, because it means all of the stakeholders have agreed to accept this package of solutions and commit to supporting the commercialisation of the goods that have been certified as 'sustainable'.

Some environmental activists view these initiatives as a form of green-wash and have questioned their efficacy. Participating companies certify the production within their own supply chain, but roundtable initiatives have not succeeded in transforming their respective sectors.[89] Demand for certified commodities has failed to attract a critical mass of producers that would actually transform the market and change the economic drivers of deforestation. Adoption is highest for coffee (40%) and cocoa (22%), while commodities linked to industrial plantations tend to be lower: palm oil (20%), sugar (3%) soy (2%) and beef (<1%). Part of the explanation for the slow uptake of the voluntary standards is the lack of demand; typically, only about fifty per cent of certified production is actually sold as a certified commodity.[90]

The lack of uptake is yet another manifestation of the dilemma of allocating the cost of environmental protection and social justice. Sustainability protocols cost money, which either adds to the price of a consumer good or reduces the profit margin of commodity producers. Although North American and European consumers are concerned about deforestation, most still choose a lower-cost product, while those in Asia, Latin America and the Middle East are overwhelmingly focused on price.† Moreover, global commodity markets are dominated by producers on landscapes that were transformed by agriculture decades or centuries in the past, and these

* The proliferation of voluntary standards and certification protocols led to the creation of an initiative known as the Committee on Sustainability Assessment (COSA) that seeks to standardise evaluation criteria across platforms and demonstrate that these initiatives lower production costs, increase yields and improve profit margins, as well as work to ensure that these positive benefits are reaching small farmers.

† The emphasis on price is superseded only by health concerns. In advanced economies, consumers seek 'healthy' products, while in developing countries there is a greater focus on quality and, in the case of China, an ingrained fear of contaminated products.

farmers operate without fear of being accused of environmental crimes. Consequently, traders are not motivated to pay a premium to farmers on the agricultural frontier.*

A few producers seek to differentiate their products as organic, deforestation-free, fair-trade or antibiotic-free because they are selling their products into a differentiated market and receive a premium for their production in compensation for the extra cost and reduced yields that these systems [allegedly] entail. Others participate because it guarantees them market access. Most producers opt to circumvent the voluntary guidelines or sell to traders unconcerned about sustainability or just ignore the whole process entirely.

Social advocates have questioned the economic benefits of certification because they tend to discriminate against small-scale producers who cannot meet the record-keeping and logistical demands of a certification process. These protocols are negotiated by large-scale producers that dominate the roundtable initiatives and tailor the certification criteria to their supply chains.† As formalisation spreads throughout national and international markets, smallholders could be increasingly marginalised within regional and even local markets in contradiction with the stated social objectives of these certification schemes.[91]

Rural Finance

The agricultural producers of the Amazon have access to radically different levels of credit depending upon national policies, the willingness of each country's financial services industry to engage rural populations and, most importantly, the scale of their production system. Brazil has the most sophisticated agricultural sector and, not surprisingly, the most generous and far-reaching system to support its producers. Industrial-scale farmers have access to multiple forms of credit, which they access to pay operational costs, acquire technology and invest in on-farm infrastructure. If they are entrepreneurial, and many are, they borrow money to acquire land and expand production. Small family farms have fewer options, but the federal government has programmes to provide them with affordable short-term credit. Regardless, the cash economy predominates on forest frontiers and within smallholder landscapes where producers must overcome barriers imposed by physical isolation and subsistence livelihoods. Financial cred-

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* Rainforest Alliance, UTZ-Certified, Fair Trade are the best-known organisations offering certification protocols that cover multiple commodities.

† Roundtable for Sustainable Palm Oil (RSPO), Round Table Responsible Soy (RTRS), Global Roundtable for Sustainable Beef (GRSB), BONSUCRO (the global sugarcane platform for sustainability), 4C-Association for a better coffee world.

it to support production is largely absent in the Andean Amazon, where small farmers operate within an informal economy with limited access to financial services.

Brazil's financial system operates on two tracks: the *Sistema Nacional de Crédito Rural* (SNCR), which is managed by the financial industry according to rules established by the federal government; and an independent system managed by multinational trading companies designed to capture commodities for their competing supply chains. The latter includes the four well-known western giants: ADM, Cargill, Bunge and Louis Dreyfus, as well as second-tier companies based in Brazil (Amaggi), Japan (Gavilon), Europe (Sodrugestvo) and China (COFCO). Within the Amazon, the SNCR provides most of the credit used by the livestock sector, while the region's grain farmers depend upon credit obtained from the SNCR, loans from commercial banks and, most importantly, short-term credit provided by commodity traders.

The SNCR was established in 1965 in conjunction with government policies to promote settlement and investment in the agricultural frontiers of the Southern Amazon. Its main objective is to provide producers with working capital at below-market interest rates so they can plant and harvest a crop or raise a herd of cattle for slaughter. The national rural finance plan (*Plano Safra*) of 2020/2021 provided $R 236 billion (~$US 45 billion) in loans to the livestock, farm and plantation sectors; 75% was used for short-term credit, and 25% was allocated for medium to long-term investments. Small producers had access to R$ 33 billion with interest between 2.75% and 4%, while medium-sized producers received a similar sum at 5%. Large-scale producers, who receive the bulk of the finance, were charged between 6 and 7% annual interest.[92]

The SNCR programme has been, and remains, an important element in national development strategies and has catalysed the impressive growth of Brazilian agriculture. The success of the SNCR rests on its ability to leverage the domestic savings of the Brazilian people with the technical capacity of Brazil's commercial banking sector. Its genius was to provide low-cost credit to strategically important producers in an economy characterised by high interest rates. The lion's share of the SNCR's financial resources is generated by a regulatory requirement that obligates commercial and savings banks to either: (a) transfer 34 per cent of their deposits to the *Banco Central do Brasil* or (b) use those resources to fund loan portfolios in agriculture and forestry.[93] Attractive interest rates are a magnet for investors, especially when combined with an easily understood business model based on conventional economics. Brazil's abundant soil and water resources are the foundation of its rural economy, but the SNCR shares much of the credit for creating an agricultural powerhouse. It also shares responsibility for the conversion of approximately eighty million hectares of Amazonian rainforest and an approximately equivalent area of Cerrado savannas.[94]

The SNCR channeled hundreds of millions of dollars into the Southern Amazon during the 1970s to establish a cattle industry on land being distributed to influential families and corporations.[95] In the 1980s, the programme loaned money during a period of hyperinflation at interest rates well below the rate of inflation, an untenable situation that led to its near-collapse in the early 1990s. The SNCR was revitalised following the stabilisation of the Brazilian economy in the administration Fernando Henrique Cardoso, who introduced two additional programmes managed by the national development bank: PRONAF, which is targeted at smallholders, and PRONAMP, which provides finance to medium-scale producers.[*] Regional development banks, known as *Fundos Constitucionais de Financiamento*, also have credit programmes targeted at their rural constituents.[96]

A recent review revealed that between $US 9 and 12 billion dollars were loaned annually via the SNCR to Amazonian producers during the last decade. Of this amount, approximately 44% went to Mato Grosso, followed by Tocantins (18%), Pará (13%), Maranhão (13%), and Rondônia (9%).[97] This study looked only at four commodities considered to be the main drivers of deforestation and reported that 64% of the loans went to cattle ranchers and 35% to soy farmers, with smaller amounts to timber (0.5%) and oil palm plantations (0.7%). Data for PRONAF were reported only at the national level, but small farmers cultivating soy, beef and palm oil received only two percent of the resources channeled via the SNCR.[†]

The contribution of the trading companies is difficult to know because they do not break out those numbers in their annual reports. They can be estimated, however, using bottom-up methods and government reported statistics. In the 2019/2020 crop-year, soy and maize were cultivated on approximately eighteen million hectares in the states of the Legal Amazon, where the leading extension agency reported the cost of seed, fuel, agrochemicals and labour at $US 650 per hectare.[98] Assuming that a hundred per cent of crop is planted and harvested using short-term credit, then agribusiness would need approximately $US 13 billion to plant and harvest a crop. Since only $US 1.6 billion was obtained via the SNCR,[99] the remaining $US 11.4 billion was probably supplied by the commodity trading companies. That may be an overestimate, however, because large-scale

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* *Banco Nacional de Desenvolvimento Econômico e Social* (BNDES); *Programa Nacional de Agricultura Familiar* (PRONAF); *Programa Nacional de Apoio ao Médio Produtor Rural* (PRONAMP); in total, there are 19 separate financial programmes that fall within the confines of the SNRC. Source: Souza et al. 2020.

† According to the *Banco Central*, those two programmes receive about 10% each of total rural credit, but most is lent to small farmers in the South and Southwest. Source: Capellesso et al. 2018.

producers, who control approximately 46 per cent of the agricultural land in Brazil, are often subsidiaries of diversified corporations. As such, they have access to multiple forms of credit, including domestic bond markets and overseas private equity.[100]

Bond markets include corporate bonds, which are 'debentures' backed by the reputation of the company and *Certificados de Recebíveis do Agronegócio* (CRA), which are securities that place a lien on a physical or contractual asset. Both are used by agribusinesses and banks to finance medium to long-term investments (two to twelve years). If the CRA is issued by a bank, it is likely to be a basket of loans to family farmers, while corporations use them to fund individual projects or activities. The Brazilian bond market has attracted international attention over the last several years (post-2015) because it is viewed as a venue for sustainable finance that seeks to minimise risk from 'environmental, social and governance' (ESG) factors that harm society and, presumably, increase the risk of losing money.

The most common types, and the largest by volume ($US 10 billion) have been 'green bonds' issued by corporations accessing capital markets without the intermediation of banks.* In the Amazon, companies are committing to consume (self-generated) renewable energy, increase productivity, sequester soil carbon and, allegedly, conserve biodiversity and water resources. One of the largest offerings is FS Bioenergia ($US 639 million) a maize-based ethanol producer that is a joint venture between the Iowa-based Summit Holdings and a Tapajos Participaes S/A, a Brazilian subsidiary of a Chinese holding company (Hunan Dakang). Brazilian agribusiness giants are likewise accessing the green bond market, including SLC Agrícola ($US 480 million) that farms 150,000 hectares in Mato Grosso and Maranhão; and Amaggi S/A ($US 750 million), which operates an integrated supply chain spanning 259,000 hectares in Mato Grosso and includes logistics and processing facilities in Rondônia, Amazonas and Pará.[101]

One of the most controversial offerings, is a 'transitional loan' to Marfrig Alimentos S/A ($430 billion), a beef packing company committed to eliminating illegal deforestation and unfair labour practices from its supply chain. The tender is classified as a loan rather than a bond due to the contractual terms of the offering; it is controversial because most of the resources will be used to support their dedicated supply chain (Marfrig Club) without adequate guarantees to reform or exclude calves originating from independent producers who are not in compliance with the Forest Code.[102] The criteria for evaluating the ESG performance will rely on Key

* The forest products sector has issued the most green debt, but none operate within the Legal Amazon; they inlcude Suzano ($US 5.1 billion), Klabar ($US 1.7 billion) and Irani Cellulose ($US 131 million). Source: Climate Bond Initiatives (2021) https://www.climatebonds.net/files/reports/cbi-brazil-agri-sotm-eng.pdf

Performance Indicators (KPIs), metrics that are specified in the prospectus of individual bond tenders that must be validated by independent third party review.*

There is only limited potential for finance to change agricultural practices in the Andean Amazon, because landscapes are largely populated by smallholders who are notoriously risk-adverse in how they manage their finances and cropping systems. They are cautious because the consequences of a crop failure are catastrophic for their families; consequently, they are less likely to adopt novel production systems that require a capital investment that would have to be financed by debt. Nearly all understand the value of credit and its potential to transform their lives; however, the options available to them are neither friendly nor fair.[103]

Andean governments have launched multiple efforts over several decades trying to create mechanisms and institutions to provide financial credit for rural communities, but they have failed to change the calculus that impedes investment on smallholder landscapes. One manifestation of the challenge is the high proportion of families that are unbanked, a term economists use to describe individuals who, by choice or circumstance, do not use financial services. Another is the role of microfinance institutions that provide credit to individuals who do not qualify for loans from conventional banks; instead, they borrow money based on 'good faith' and reputational integrity.† Their presence has materially benefitted the lives of tens of thousands of individuals, many of them female, by allowing them to participate in the informal market economy that characterises commerce in these nations. In addition, they offer savings accounts and provide families with a digital identity for interacting with government agencies and utility companies. Unfortunately, these institutions lend money at interest rates that are out of reach for small farmers.

The microfinance business model was born in the marginalised neighbourhoods of major cities, but these institutions are now present in most mid-sized cities where they also cater to the needs of surrounding rural communities. Interest rates, which range from twenty to eighty per cent, reflect the risk of default associated with their clientele and the high transaction costs associated with administering tens of thousands of small loans.[104] Most microfinance entities operate with capital obtained from conventional banks and investment funds and pay those institutions

* External reviews known as Second Party Opinions (SPO) and Certification under the Climate Bonds Standard are two methodologies recognized by the Climate Bond Intiatitive

† Loans are given to anybody with valid ID and an explicit promise to lend more money in the future if the current loan is serviced and amortised. Many impoverished individuals cherish their personal reputation because it is the only thing of value they own.

standard commercial interest rates (five to eight per cent). Microfinance, which is marketed as a pro-poor public service, is also a highly lucrative business model.[105]

Presumably, a farmer would be a low-risk debtor when compared to an individual engaged in speculative commerce, but the financial sector considers small family farms as high-risk creditors due to weather and pests. In Peru, inflation-adjusted interest rates for small farmers are between twenty and thirty per cent, a value that is out of reach for all agricultural production systems, much less smallholders living on the edge of poverty. Large- and medium-scale producers have access to conventional forms of credit because they can meet the conditions required by lending agencies, particularly legal title to their land and a documented history of production and sales. Even these numbers are disappointing, however. In 2019, government agencies reported that $US 33 million were loaned to 4,199 beneficiaries in a country with an estimated 2.2 million farmers.[106]

Peru has attempted various models to channel funds via savings and loan cooperatives (COOPACS), privately-owned rural savings banks (Caja Rurales), mixed associations of private capital and local government (Caja Munciaples) and a specialised state-owned development bank (Agrobank). None have succeeded in providing affordable credit to small farmers. The most recent attempt, a special fund (FAE-Agro) that is capitalised by the national development bank (COFIDES)[*] is doomed to failure because recipients are required to show legal title for their properties, a condition enjoyed by only fifteen per cent of the farmers of Peru (see Chapter 4).[107]

Civil society has had better success working with grower's associations that simultaneously provide technical support in agronomics, pest management and business administration for individual growers and their umbrella organisations. Successful initiatives are characterised by a long-term commitment on the part of civil society organisations and specialty buyers willing to invest in programs that guarantee a supply of coffee and cacao that is certified as deforestation-free, organic, indigenous and/or gender positive.[†]

Bolivia's agricultural sector is similar to Brazil's but also quite different. There is a limited number of large-scale producers, quite a few (upper)

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* FAE-Agro: *Financiamiento Agrario Empresarial*; COFIDE: *Corporacion Financiera de Desarrollo S.A*

† Root Capital works with the APROCAM coffee and cacao cooperative of Awajún communities in Amazonas Region; APROCASSI, a woman's coffee cooperative in Cajamarca region; CAC Pangoa, a coffee cooperative of Asheninka growers in the Selva Central in Junin region. Solidaridad supports 1,200 coffee producers in San Martin region; Rabobank works with the Norandoino, a consortium of three coffee cooperatives with 8,250 members and 9 regional offices in Northern Peru. Sources: https://rootcapital.org; https://www.rabobank.nl/over-ons/rabofoundation; https://www.solidaridadsouthamerica.org/es.

middle-class landowners and a large, dynamic small-farm constituency. It lacks, however, a state sponsored rural credit programme that obligates the financial industry to channel money to its producers. Large and mid-scale farmers access capital via the commodity trading companies, as well as from an informal credit market best described as a normalised system of loan sharks.* Ranchers rely on family capital, personal savings or cash flow generated by urban business ventures (medical services, real estate, commerce).

The smallholders of Bolivia are also active participants in the national foodstuffs market, and quite a few have evolved into successful soybean farmers. Many are descendants of Andean indigenous migrants with a strong cultural tradition of savings and investment, traits shared by a large Mennonite community. These groups also have an informal credit market they use for short-term finance. Microfinance institutions are present and, as in Peru, have opened offices in regional cities. Government policies to distribute cash income to elderly and school-age children have motivated tens (hundreds) of thousands of rural families to open savings accounts. High interest rates, however, preclude their ability to borrow money to invest in agricultural technology.

Ecuador's microfinance industry is dominated by savings and loan associations that serve both urban and rural populations; interest rates range between 25 and 28 per cent. The traditional banking system treats agricultural credit as one of several types of 'productive enterprise', all of which have annual interest rates between eight and twelve per cent.[108] The government hopes to support its agricultural sector via a newly constituted public bank, *BanEcuador*, which offers loans specifically designed for, and marketed to, producers of coffee, cacao and oil palm.† Producers can borrow up to $US 150,000 for both short-term credit and to improve productive capacity (plantations); for the latter, terms of up to fifteen years are available, with a grace period of between three to five years.[109] Loans greater than $US 20,000 require a mortgage guarantee.

The *BanEcuador* programmes show an understanding of the needs of their potential clientele, including payment schedules based on the cash flow of individual production strategies (monthly, quarterly, or annually).

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* Individuals with a reputation for probity collect capital from individuals seeking investment opportunities with a good rate of return. They lend money to established farmers, who pay off the loan after each harvest cycle, which is typically four to six months. This system thrives because the financial system pays extraordinarily low interest rates on savings accounts and depositary certificates (<1%); Bolivia's bond and equity markets are closed to retail investors.

† The administration of Rafael Correa created *BanEcaudor* in 2015; it inherited the assets and liabilities of the *Banco de Fomento de Ecuador*. Its board of directors comprises five cabinet ministers. Source: https://www.banecuador.fin.ec/historia-banecuador/

Annual interest rates range between 9.75 and 16.5 per cent, in line with business loans from private banks and significantly lower than those available from microfinance institutions. Regardless, interest rates at this level are not likely to catalyse a wave of much-needed investment in agricultural production. In 2019, BanEcuador loaned $US 3 million to 700 producers, a relatively small amount that would translate into only about 500 hectares of new oil palm plantations.

Colombia has a programme similar to the SNCR of Brazil. It is administered by FINAGRO (*Fondo Para el Financiamiento del Sector Agropecuario*), a public agency that operates as a second-tier lender to private institutions and a guarantor for a variety of financial products, including short and long-term credit and crop insurance. The FINAGRO system establishes standard terms and rates for a diversified portfolio of credit products specifically designed for the needs of producers in agriculture, livestock and plantation forestry. Programmes span the landholder spectrum and include special initiatives for producer associations. Interest rates range from three to ten per cent above a base rate set by the central bank, which has fluctuated between three and five per cent since 2010. FINAGRO also offers discounts to the intermediary institution to make the loan more accessible to the retail client.[110] For a commission, FINAGRO will guarantee the loan for the producer, which is essentially a form of crop insurance; it also offers conventional crop insurance to protect the producer and the lending agency from climate risk and pests.

At the national scale, FINAGRO facilitated financial credit worth approximately $US 7.1 billion in 2020, up from $US 2.9 billion in 2011, increasing by an impressive twenty per cent annually over the same period. Although the Colombian programme is well designed and considers both market reality and the special needs of producers, it operates only on landscapes where the state has imposed the rule of law.[*] Unfortunately, Amazonian landscapes are characterised by the absence of the state, either because they are remote or because they are under the control of armed criminals. In Amazonian departments, FINAGRO facilitated only about $US 80 million in 2020, a number that has remained essentially flat since 2010.[111] Approximately half of that was in Caquetá and, presumably, was lent to the cattle sector, which is also the largest single recipient of agricultural credit within the FINAGRO system.

Harnessing finance to change behaviour

Rural finance has enormous potential to reform conventional agricultural production systems. Consequently, it is a common component of policy

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* Approximately, 60% of FINAGRO credits are issued in Bogota (D.C.), Cundinamarca, Antioquía and Valle de Cauca.

proposals to combat deforestation where it is viewed as a 'carrot' to accompany the 'sticks' that seek to coerce landholders to reform land use practices (see Chapter 7).

The experience of the Cattle Agreement and the Soy Moratorium show the potential when commercial intermediaries are used as pressure points to eliminate illegal deforestation. These initiatives, which focus on excluding transgressors from supply chains, could be expanded by conditioning access to the billions of dollars of short-term loans provided annually by international commodity traders and meat packing companies. As a driver of sustainability, credit might be even more effective if these same companies offered long-term loans with concessionary rates that motivated their suppliers to restore forest that had been converted illegally in the recent past.

Similar changes to the *Sistem Nacional de Credito Rural* (SNRC) could likewise catalyse widespread change, particularly within the Brazilian cattle industry where decades of overgrazing have degraded millions of hectares of pasture. Pasture restoration begins and ends with soil conservation, which relies on management practices to increase soil organic matter and, in the process, create a long-term carbon sink (see Chapter 4). This is essentially the goal of Brazil's *Agricultura de Baixo Carbono* (ABC) programme, a subcomponent of the SNCR with attractive interest rates and an extended pay-back period.[112] Supported technologies include reduced tillage, pasture renovation, integrated crop and livestock management, and the restoration of riparian habitat (see Chapter 4 and Chapter 7). The ABC programme has enjoyed modest success – in 2020, the programme lent approximately $R 2 billion ($US 400 million) – nonetheless, that is less than one per cent of the total channelled through the SNCR in 2020. The potential, given Brazil's history of using the SNCR to subsidise its agricultural producers, is massive and eminently practical.

Green bonds and similar types of ESG finance are the fastest growing component of Brazil's financial sector. International capital markets are frenetically seeking viable projects to satisfy massive global demand for ESG investment. Brazil's potential to satisfy this demand by reducing GHG emissions caused by deforestation can be leveraged by an equally massive capacity to sequester carbon via economically advantageous technologies to make conventional agriculture more sustainable. This type of risk-limited green investment will be a magnet for global investors. The country's attractiveness is reinforced by the nation's cultural commitment to a market economy, its openness to international capital and the abundant natural resources that are the foundation of its rural economy.

The performance of green bonds in Brazil is being closely watched by policy analysts, because of their potential to drive climate change action 'at scale'. Nonetheless, these instruments, and others like them, risk being labled as 'greenwash' if they succeed in improving the performance of participating companies but fail to resolve the deforestation crisis. That outcome will depend, in large part, on the ability of the Brazilian state – and its private sector partners – to incorporate smallholders in a revitalised and reformed rural economy. Brazil has created the institutional mechanisms for pursuing that goal (INCRA, EMBRAPA, PRONAF, SNCR), but its track record for dealing equitably with its own citizens is not particularly encouraging (see Chapter 6)

In the Andean Amazon, the potential to link finance, including short and long-term credit, with effective policies to transform their agricultural sector is even more challenging. No nation has succeeded in delivering affordable credit to their Amazonian populations, nor developing an extension system capable of ensuring those resources are invested in productive enterprises that are globally competitive and environmentally sustainable. If they have any advantage, compared to Brazil, it is the preponderance of smallholder systems that creates a precondition that favours social equity. That advantage, however, is a double-edged sword. It may ensure that a reformed system will be socially sustainable, but it also makes it enormously more difficult to implement.

If the Amazon Forest is to be saved, deforestation must end. Full stop. Global and national markets, however, will continue to demand more commodities from the farmers and ranchers of the Southern Amazon and Andean Piedmont. They will respond by increasing production. Full stop.

Producers can expand by investing in technology to intensify land use, or they can purchase more land to enlarge the area under cultivation. Left to their own devices, they will pursue both options because that is the logical pathway to maximise the return on their investments. Producers do not operate in a vacuum, however. Farmers and ranchers, large and small, allocate their resources in response to regulatory and market forces that govern the agricultural economy. Among the most important are the constraints and incentives in rural real estate markets (see Chapter 4). When the forest frontier ceases to be a source of inexpensive land, the agricultural sector will be forced to invest in the land under production – and only the land under production. Making that happen sooner, rather than later, is essential for saving the Amazon.

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