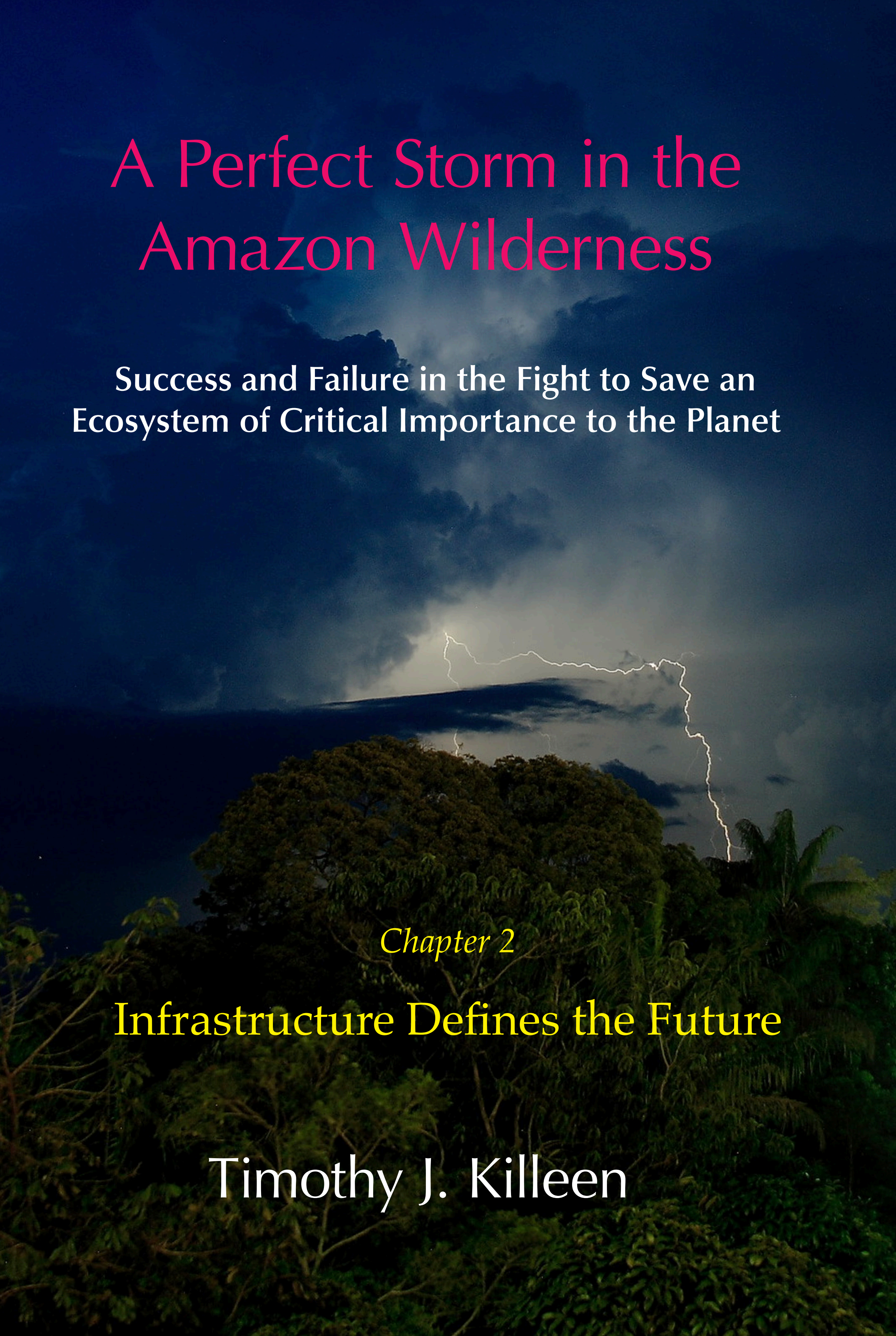

A Perfect Storm in the Amazon Wilderness

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

Chapter 2

Infrastructure Defines the Future

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Chapter 2: Infrastructure Defines the Future

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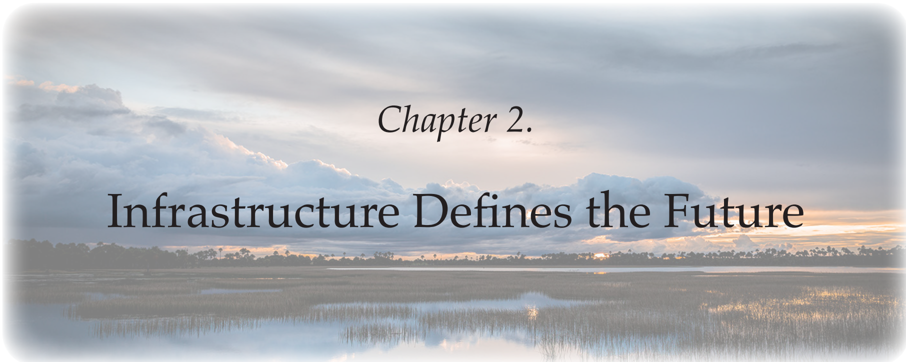

Chapter 2.

Infrastructure Defines the Future

The Merriam-Webster dictionary defines infrastructure as the 'underlying structure' of a country – specifically, the physical installations needed to ensure that its economy functions for the benefit of society. Modern infrastructure is made of steel and concrete and is ubiquitous in an advanced economy; typically, it is taken for granted by the people who depend upon it for their livelihoods. People living in emerging economies and developing countries do not suffer from this underappreciation of the value of infrastructure and, typically, are strong proponents of investing in it.

Conspicuous infrastructure assets include roads, bridges, railways, airports, ports, dams, power plants, energy grids, information networks, and water and sewer systems. Equally important are the physical assets that support key social services, such as schools, clinics, hospitals and recreational facilities. Most are built by the state, although some may be operated by private companies granted concessions by governments; quite a few are privately owned. Infrastructure assets are a perfect example of a long-term investment: they require a large initial investment in financial capital and pay dividends in the form of revenues and increased economic activity over decades or even centuries.[*]

Most infrastructure assets in the Pan Amazon are the product of long-term investment strategies formulated by governments at five-to-ten-year intervals. Regardless of the periodic shifts reflecting societal consensus and electoral cycles that have occurred over the last several decades, two themes have featured prominently in all the plans, programmes and projects: economic development and regional integration.

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* Modern examples of infrastructure assets that have operated for more than a century include the Suez and Panama canals, the rail networks of North America and Europe; historical examples include the roads of the Roman Empire, the irrigation systems of Mesopotamia and the flood control levees of the Yellow River in China.

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Highway E-20 adjacent to the Río Napo in Amazonian Ecuador.

In Brazil, the modern era of infrastructure investment began in the 1970s with the *Programa de Integração Nacional* (PIN) that kicked off the construction of the highway network that has transformed the Southern Amazon. This was followed in the 1990s by the federal government diversifying its investment portfolio to include hydropower, waterways and railroads within priority geographies known as *Eixos Nacionais de Integração e Desenvolvimento* (ENID).* In the 2000s, infrastructure investments were at the core of the *Programa de Aceleração do Crescimento* (Growth Acceleration Program; PAC), which focused on the energy sector and included several mega-scale hydropower projects in the Amazon (see below).[1]

All of the Andean republics organised similar programmes that made highway systems a national priority, but some of their most important investments were in pipelines essential for the exploitation of hydrocarbon reserves that had been discovered in their Amazonian provinces. Historical aspirations and a shared cultural heritage motivated these nations' governments to create the *Comunidad Andina de Naciones* (CAN), a trading block that included within its founding principles investment in trans-frontier infrastructure assets. One of the ambitious early proposals was the Carretera Marginal de la Selva, a highway similar to the Pan Amazonian highway that would integrate their Amazonian provinces.[2] This concept was operationalised and expanded in the early 2000s when all the nations of South America came together to create the *Iniciativa para la Integración de la Infraestructura Regional Suramericana* (IIRSA)† (Figure 2.1).

* There were nine *Eixo de Integração* (Axes of Integration), of which four were located within the Brazilian Amazon: (1) Madeira – Amazonas, (2) Oeste, (3) Araguaia – Tocantins, (4) Arco Norte. The investment framework was part of Avança Brasil, which was the centre piece of the administration of Fernando Henrique Cardoso.

† IIRSA (Initiative for the Integration of the Regional Infrastructure of South America) was originally coordinated by the Interamerican Development Bank

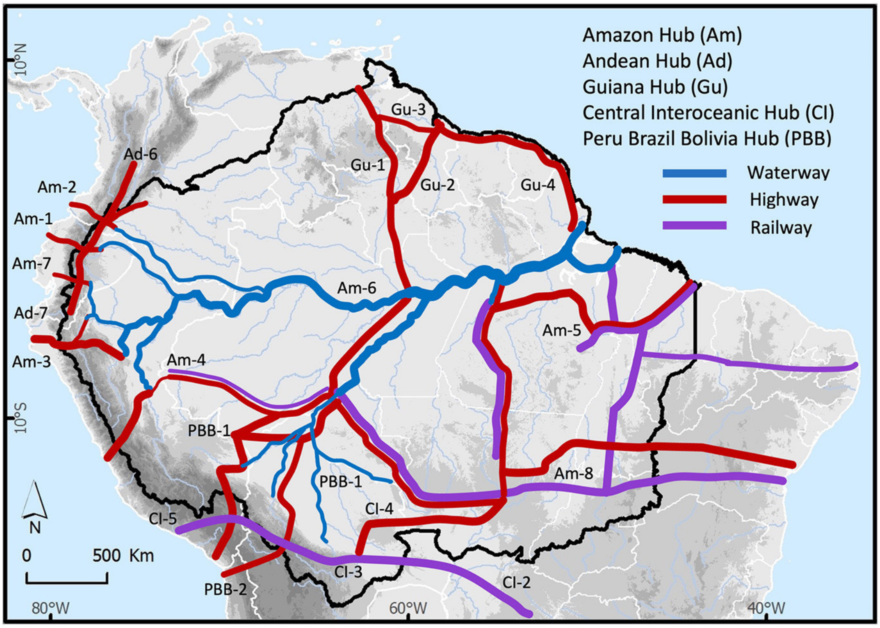

Figure 2.1: The Integration of the Regional Infrastructure of South America (IIRSA) initiative is a master plan for priority investments that are organised into hubs (4), groups (22) and projects (187). A major goal is to create multi-modal transportation corridors based on waterways, highways and railroads. The total projected IIRSA-sponsored investment in the Pan Amazon sums to $US 84.4 billion. See Annex 2.1.

Multilateral financial institutions, such as the World Bank, IDB and CAF* have played an essential role in financing the infrastructure that has transformed the human-modified landscapes of the Amazon (see Chapter 1). Although the resources they have deployed are limited by their pool of available capital, their participation has motivated governments to allocate greater capital to infrastructure and, more importantly, established a framework to leverage public resources with private capital. In addition,

(IDB), but after 2010 that responsibility was passed to the newly created *Unión de Naciones Suramericanas* (UNASUR), which governs the initiative via the *Consejo Suramericano de Infraestructura y Planeamiento* (South American Council for Infrastructure and Planning; COSIPLAN). The two acronyms (IIRSA and COSIPLAN) are synonyms: http://www.iirsa.org/Page/Detail?menuItemId=45

* IDB is the Interamerican Development Bank; the CAF is the Development Bank of Latin America, but retains its acronym from its previous name, *the Corporación Andina de Fomento*.

multilateral agencies finance – and influence the content of – strategy documents that guide long-term infrastructure investment; consequently, they share responsibility for both positive and negative outcomes associated with the infrastructure systems that have transformed the Pan Amazon.

Starting in about 2005, financial institutions from China began to play an important role in infrastructure development, typically by subsidising Chinese companies in the construction sector and, more recently, as underwriters for the acquisition of assets auctioned off by governments and corporations following the corruption scandals of the mid-2010s (see Chapter 6). Financial support is now organised under the banner of China's global policy initiative known as the Road and Belt Initiative.

The other major players in the field of infrastructure finance were the national development banks, semi-autonomous entities that leverage state resources with private capital to promote the participation of corporate actors and facilitate investment by sub-national jurisdictions. The most prominent of these is the *Banco de Desarrollo de Brazil* (BNDES), which has a long history of financing domestic infrastructure investments but expanded its activities to subsidise the operations of Brazilian construction companies competing for contracts tendered by the Andean republics. Investment in infrastructure reached a historical peak during the commodity export boom between 2005 and 2015, a period that provided the Pan American nations with unprecedented financial resources.

Infrastructure in the Pan Amazon has a bad reputation.[3] The largest projects have led to massive deforestation and hydrological degradation; many – if not most – have been beset by accusations of corruption. Nonetheless, investment in infrastructure has benefited millions of Amazonian citizens, particularly in urban areas that now house more than fifty per cent of the region's population. The region is set to begin another cycle of investment and development, in part because governments are once again seeking to expand the reach of conventional economic activities into the region but also because external events, particularly the COVID pandemic, are creating momentum within financial agencies to stimulate infrastructure investments as a means of restoring economic growth following the recession of 2020.[4]

Roads: Primary Vectors of Deforestation

It all starts with a road. In Brazil, the federal government commissioned the construction of mule trails and telegraph lines to link their coastal cities with long-established settlements on remote Amazonian tributaries.* In

* The most famous Amazonian explorer of the 20th century was Candido Rondon who established telegraph lines to Cuiabá and Porto Velho between 1900 and

the Andes, communication between the highlands and the lowlands has occurred over millennia via trails that traverse the foothills using routes dictated by topography. Most of these early roads had little impact on settlement and were associated with only a limited amount of deforestation, but most modern highways trace these routes into the wilderness.

Deforestation occurs when a government sends a clear signal that it is investing in a major trunk highway; objectives vary, but have included strategies to integrate an isolated population centre, open a region to settlement and create access to a valuable mineral asset. Settlers move into a region only when there is a commitment to keeping the road accessible on a permanent basis. There have been exceptions, particularly in Brazil in the 1980s, when the promise of future pavement did not materialise, but in general people will invest time and money in clearing the forest only when they believe they can transport their production to market. The examples are abundant and self-evident. All but six of the sixty human-modified landscapes defined in Chapter 1 are organised around a major trunk highway (Figure 2.2 and Annex 2.2).*

The existence and quality of secondary road networks is more important than trunk highways for determining the spatial extent and intensity of land use within a frontier landscape.[5] Access roads change a linear deforestation vector into a two-dimensional front that can trigger a geometric expansion in the deforestation rate. It is not sufficient just to have a secondary road network, however; it too must be open year-round in order to ensure that crops do not rot in the field. A functional secondary road network mandates investment in bridges, culverts and embankments; even more important is a budget to maintain these fragile assets in a region characterised by high seasonal rainfall.

The economic output of deforested lands is very much dependent on the quality of secondary roads because they connect ranches, farms, and plantations with the industrial infrastructure essential to agricultural supply chains, particularly grain silos, rice mills, palm-oil extraction refineries and beef-packing plants (see Chapter 3).[6] An overemphasis on trunk highways at the expense of investment in secondary roads in consolidated frontiers is a misallocation of public investment that results in sub-optimal economic growth.[7]

1915; he was followed by the Villa Boas brothers who cut trails across the Serra de Roncador to establish remote air strips across the Planalto de Mato Grosso during the 1940s (Hemming 2003).

* Those that are not closely linked to a highway use the Amazon River as a transportation corridor (HML #1 & 3) or are coca production landscapes where settlers are deliberately seeking isolation to avoid conflicts with the authorities (HML 35a & 35b).

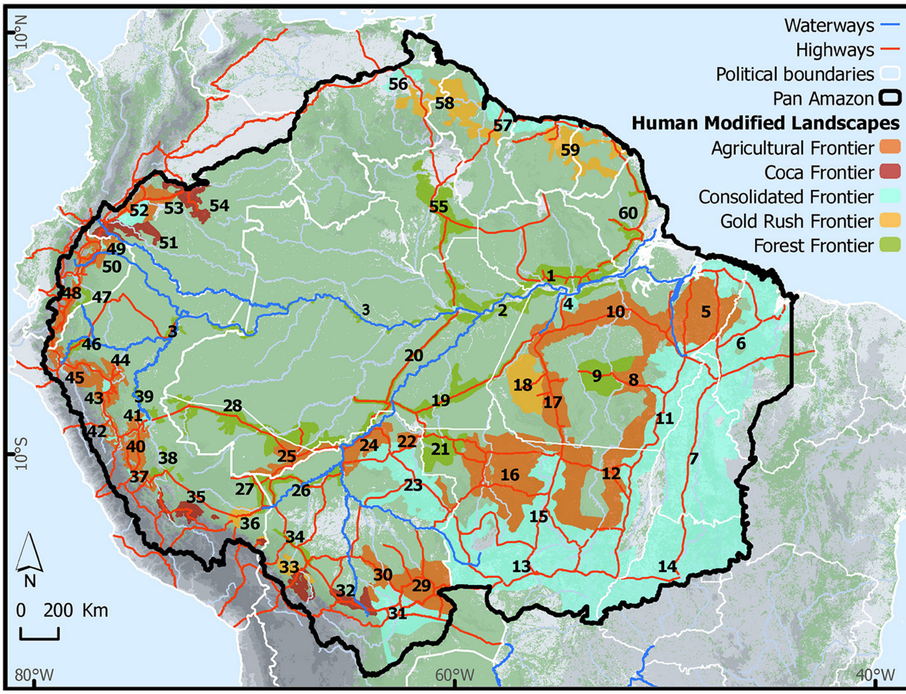

Figure 2.2: Human-modified landscapes are usually associated with one or more highway corridors (see Annex 2.2 for details).

Amazon River Corridor: (1) North Bank Amazon River, (2) South Bank Amazon River, (3) Solimoes, (4) Urban: Macapá, Manaus, Santarem.

Southern Amazon: (5) Belem – Marabá, (6) Carajás – São Luis do Maranhão, (7) Transbrasiliana, (8) São Felix do Xingu East, (9) São Felix do Xingu West, (10) Eastern Tranzamazônica, (11) Vale do Araguaia, (12) Upper Xingu, (13) Cuiabá – Roncador, (14) Alto Araguaia, (15) Sinop – Zapasal, (16) North Mato Grosso, (17) Novo Progresso, (18) Tapajos Crepori, (19) Western Tranzamazônica, (20) Novo Progresso / BR-319, (21) Northwest Mato Grosso, (22) East Rondônia, (23) Rondônia, (24) Interoceanico P Velho, (25) Interoceanico Acre, (26) Interoceanico Pando, (27) Interoceanico Made de Dios, (28) Cruzeiro do Sul, (29) Chiquitania, (30) Guayaros – Beni, (31) Santa Cruz.

Andean Amazon: (32) Chapare, (33) La Paz Yungas, (34) Yucumo – Ixiamas, (35) Peruvian Yungas , (36) Interoceanico Hueyepetu, (37) Selva Central, (38) Gran Pajonal – Atalaya, (39) Ucayali tributaries, (40) Ucayali – Huánuco – Pasco Piedmont, (41) Pucallpa, (42) Upper Huallaga, (43) Lower Huallaga, (44) Yurimaguas piedmont, (45) Marañon – Chachapoyas, (46) Saramiriza Piedmont, (47) Morona – Santiago, (48) Ecuador foothills, (49) Succumbios, (50) Orellana, (51) Putumayo – Caquetá, (52) Central Caquetá, (53) Caquetá – Macarena, (54) Macarena – Guaviare.

Guianan Amazon: (55) Roraima, (56) Arco Minero, (57) Coastal Guiana, (58) Greenstone Venezuela / Guyana, (59) Greenstone Suriname / French Guiana, (60) Amapá.

In aggregate, secondary roads require a greater investment than trunk highway systems, but the responsibility for building and maintaining these key transportation assets is almost always with under-funded local governments. Central governments have access to national budgets and international investment capital, which finance the construction of the trunk highway, but local governments must depend on limited revenues derived from local taxes or revenue transfers from the central government. Not infrequently, secondary roads are built by settlers out of necessity and constructed outside the framework of the environmental review and licensing system.

The Human-Modified Landscapes (HML) and the Brazilian highway network

The Southern Amazon has experienced massive deforestation, coupled with the degradation of soil and water resources.[8] The forest frontiers at the remote corners of the Brazilian highway system have remained isolated and impoverished, but the agricultural frontiers and consolidated landscapes of Maranhão, Mato Grosso, Pará, Rondônia and Tocantins are relatively prosperous. Their rural economies generate approximately $US 125 billion annually, representing about five per cent of the Brazilian economy.[9] That economic output is dependent upon the national and regional highway network and has created a strong constituency for highway development.

The oldest of the trunk highways in the Pan Amazon is the Rodovia Transbrasiliana (BR-010/BR-153), which was initiated in the 1960s simultaneously with establishment of the new federal capital at Brasilia. This north-south transportation corridor transects the upland landscapes between the Araguaía and Tocantins rivers and was the first permanent terrestrial link between Belem and southern Brazil (see Figure 2.3 and Figure 2.4). Its construction facilitated the expansion of the beef cattle industry from Minas Gerais into Goiás and Tocantins* (HML #7, #14) and was linked to northeastern Brazil by a pair of east-west highways (BR-222 and BR-226) that fostered the mass migration of rural poor into eastern Pará (see Chapter 6).

The steady improvement of these highways and their associated secondary and tertiary road networks coincided with the development of the hydropower facilities at Tucuruí on the Tocantins River (see below), the mining complex at Carajás and the metallurgical foundries in Marabá and São Luis do Maranhão (Figure 2.4). Simultaneously, the federal government created SUDAM,† an institution that managed a system of subsidies designed to promote agricultural development and the monetisation of the region's mineral resources (see Chapters 5 and 6). These policies succeeded in cre-

* Tocantins was separated from Goiás in 1988.

† *Superintendência do Desenvolvimento da Amazônia*.

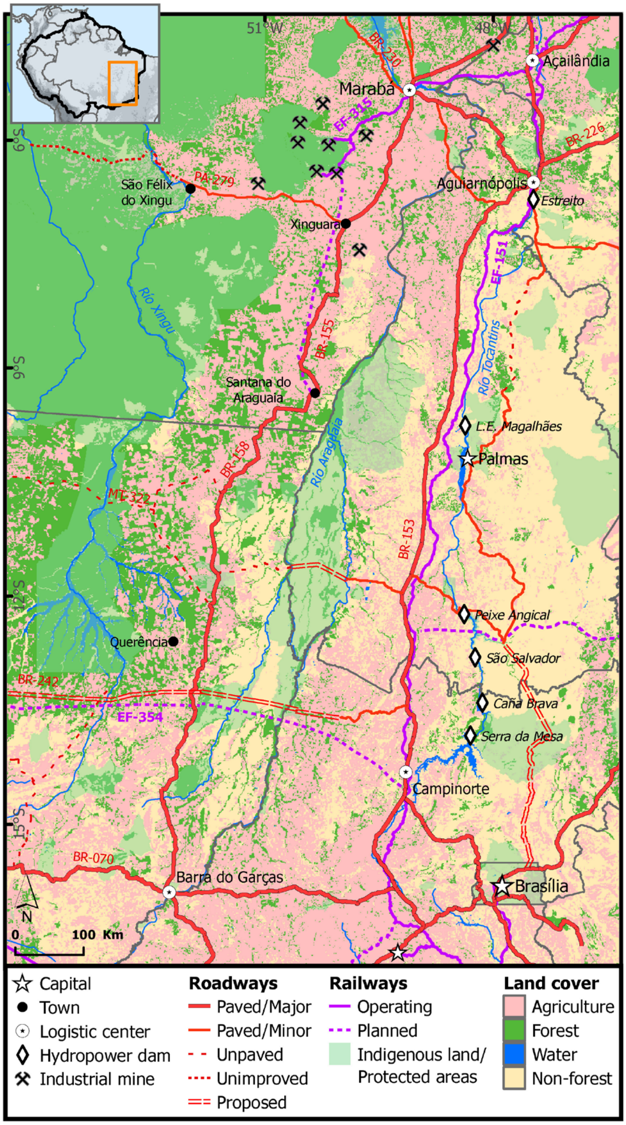

Figure 2.3: Two parallel highways built in the 1960s (BR-153) and 1990s (BR-158/155) opened the southeast Amazon for settlement. This area is now served by a railroad (EF-151) that was completed in 2015. Future planned development includes an extension of rail service into southeast Pará and the extension of the Tocantins Waterway from Marabá to near the border with Goiás.

ating wealth and the transformation of the regional landscape. By 2020, the Carajás -São Luis-Belem corridor had less than eighteen per cent remnant forest cover, the lowest proportional amount in the Pan Amazon (HML #6).[*] The landscape located south of Belem (HML #5) retained a greater forest area but is also home to the country's expanding palm oil industry and a numerous colonisation projects, where smallholder families pursue a combination of subsistence and market agriculture.

In the 1980s and 1990s, another north-south highway corridor (BR-155/BR-158) was constructed ~300 km to the west on the other side of the Araguaía River (Figure 2.3), which eventually connected the municipalities of Northeast Mato Grosso with their counterparts in Southeast Pará (HML: #11, #12). Deforestation has declined significantly since 2010 but remains relatively active on the frontier landscapes adjacent to the indigenous territories along the Río Xingu (see Chapter 11). The cultivation of soy and maize are displacing cattle ranching in Mato Grosso but still predominate in Pará (see Chapter 3).

Settlers moved into the landscapes of Central Pará following the construction of the PA-279, a regional highway that links Xinguara on BR-155 to São Felix do Xingu, once a small village on the river established during the rubber boom of the late nineteenth century (HML #8, #9). The landscapes west of the Rio Xingu are crisscrossed by unpaved roads that service a large area (occupied by large to medium-scale landholdings that have been incorporated into a multiple-use protected area (Área de Proteção Ambiental [APA] Triunfo do Xingu). Most of these properties, established during the land rush of the 1980s, have been characterised by slow but steady deforestation (Figure 2.5). The municipality of São Felix do Xingu has consistently ranked among the five Brazilian municipalities with the highest annual rate of deforestation in the Brazilian Amazon.[10,11]

One of the most economically dynamic regions in the Brazilian Amazon is synonymous with another highway project: The Cuiabá – Santarem Corridor. The social and economic forces that transformed the highway corridors east of the Rio Xingu are being replicated along BR-163, which links the prosperous farming landscapes of central Mato Grosso with the grain terminals and ports on the Tapajós and Amazon rivers (Figure 2.5). This highway was established in the 1970s during the *Programa de Integração Nacional* (PIN), but the northern sector soon fell into a state of disrepair. For approximately 25 years, it was a typical frontier landscape dominated by logging companies that could organise their operations by transporting timber during the dry season when the road was passable (HML #17).

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* The reconstruction of BR-222 was included within the IIRSA highway portfolio: IIRSA, Amazon Hub, Group 5, - Conexión entre la Cuenca Amazónica y el Nordeste Septentrional de Brasil: AMA84 ($180 million): http://www.iirsa.org/proyectos/detalle_proyecto.aspx?h=1387

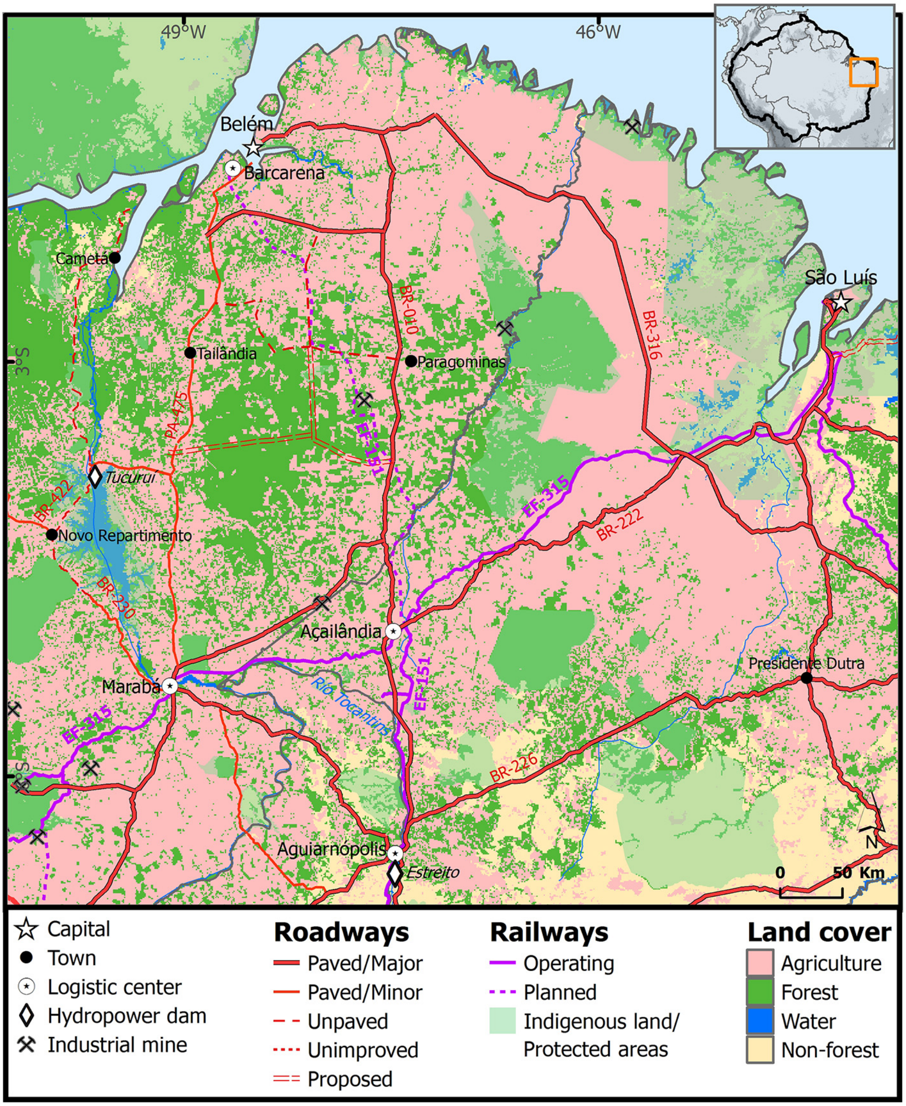


Figure 2.4: The forest remnants between the major highway corridors in eastern Pará and Maranhão are increasingly fragmented; most (but not all) are associated with indigenous territories. The most important infrastructure asset in the region is the rail line constructed between 1980 and 1985 between the mining complex at Carajás and the port of Itaquí near São Luis do Maranhão. In the near future, the North-South rail line (EF-151) will be extended to Barcarena and the Tocantins Waterway will be extended to Marabá.

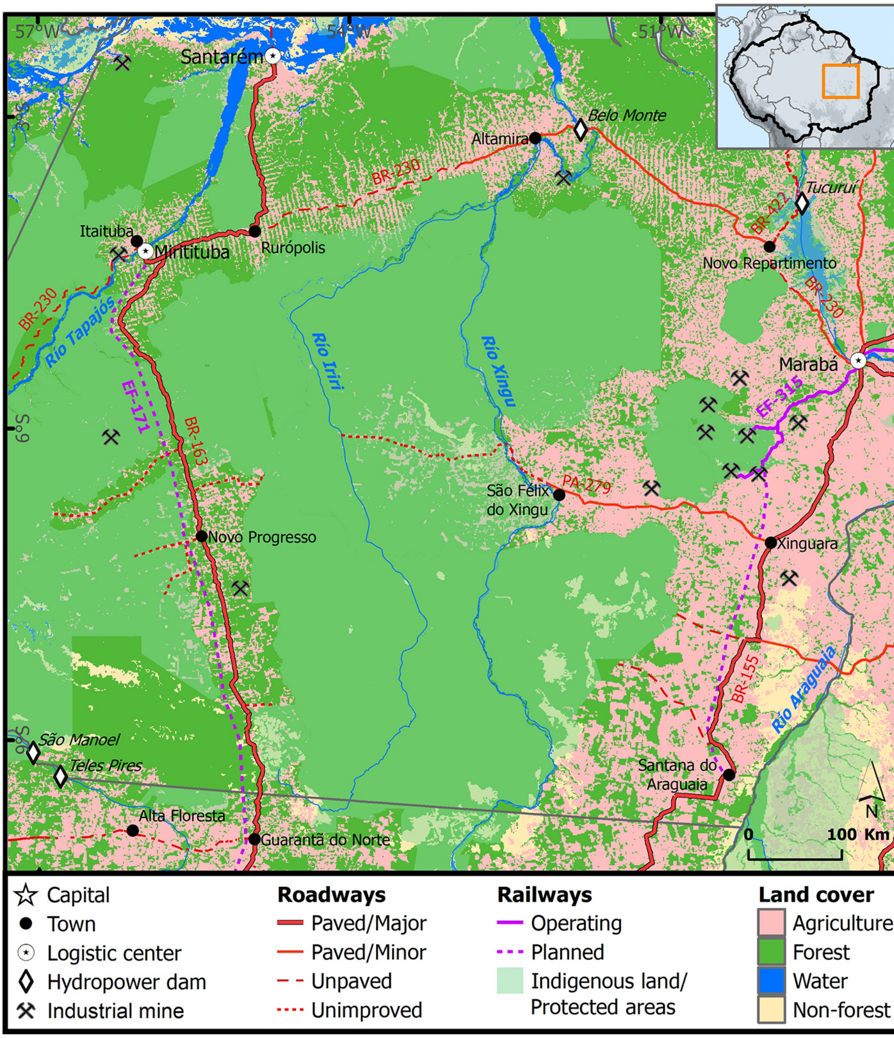


Figure 2.5: The ongoing improvement of the trunk highways in Pará (BR-163, BR-230) will accelerate deforestation on landscapes that are transitioning from forest frontiers to agricultural frontiers. Planned expansion of railroads will connect the farmland of Mato Grosso with grain terminals on the Tapajós river at Miritituba (Ferrogrão/EF-271) and foster the expansion of intensive agriculture into southeast Pará (Ferrovia Paraense).

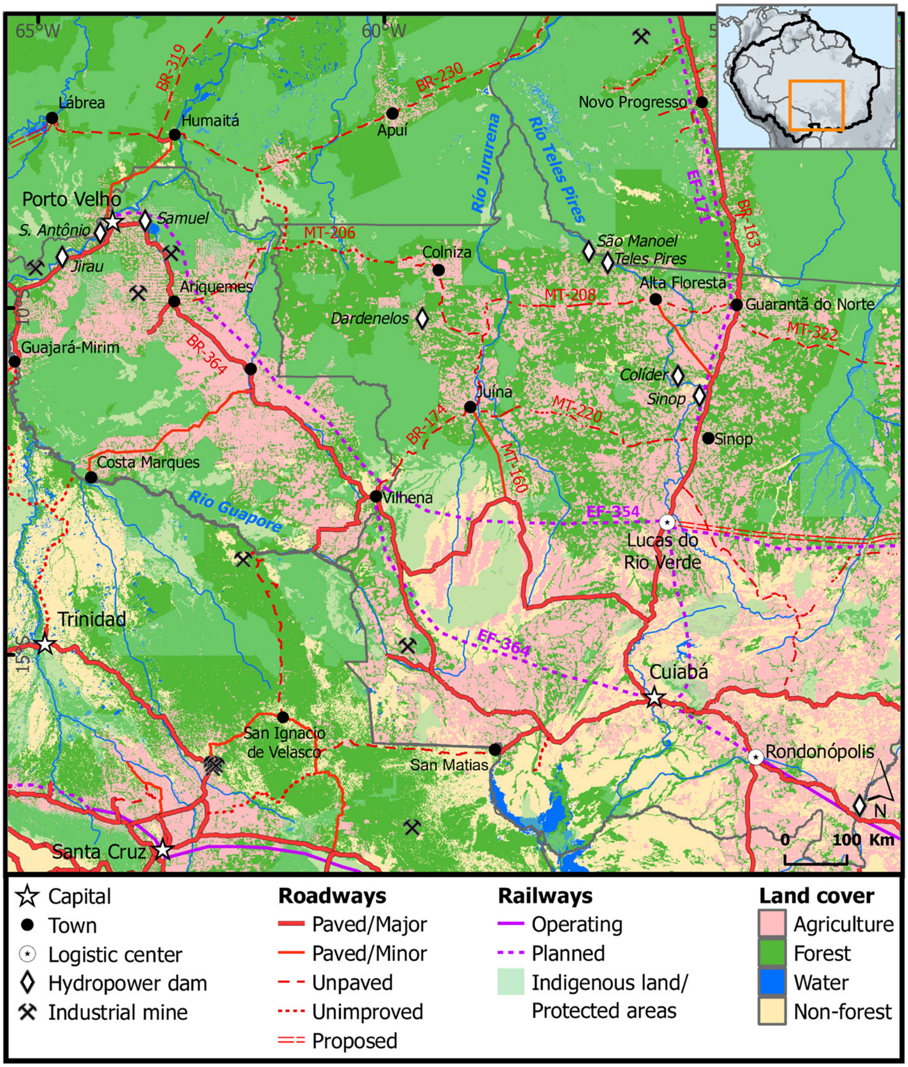


Figure 2.6: The agricultural economy of the Southern Amazon is highly dependent upon a network of paved highways and improved secondary roads. The North-South trunk highways in Brazil (BR-163 and BR-364) are major commercial arteries essential for grain exports. Regional highways in Mato Grosso (MT-208, MT-220, MT-322) are essential to that state's rural economy, as is the dense network of local roads in Rondônia. Rail expansion is planned to connect the region with southern ports via Rondonópolis and to Amazon ports via the BR-163 and BR-364 corridors. The proposed Tapajós waterway will require the construction of multiple dams on the Juruena or Teles Pires rivers.

Migrants from southern Brazil settled the southern sector (see Chapter 6), which was rapidly integrated into the national economy. Industrialised farmers occupied the landscapes with flat topography and well-drained soils ideal for the cultivation of soy (HML #15). Cattle ranchers occupied less fertile land in the hill country of central Mato Grosso (HML #13) and along the border with Pará (HML #16). The agricultural frontier expanded across Mato Gross via a gradually expanding network of state highways (Figure 2.6). Land was deeded to corporations that resold it to families organised into cooperatives or developed industrial-scale operations dedicated to farming or beef production. This is the heartland of Mato Grosso's agro-industrial complex, and it enjoys a well-maintained and extensive network of state and local highways; these support industrial infrastructure built by the private sector, including grain silos, crushing mills and animal production facilities (see Chapter 3). The secondary and tertiary road network has increased the value of rural real estate, while fostering the diversification of the rural economy. Not surprisingly, its inhabitants represent a powerful vested interest that lobbies for the improvement of road infrastructure within their state, but also for the federal highway system, which they view as essential for the growth of their production system. Like all investors, they seek to grow their economic system; as patriots, they view their production systems as a public good and a strategic national asset (see Chapter 6).

The transfer of public lands to the private sector also transferred about fifty million hectares of land that once contained more than 33 million hectares of forest, of which about half has been converted to agricultural production with the remainder distributed across tens of thousands of isolated forest fragments. Continuous forest is restricted largely to indigenous territories arranged as two north-south corridors: one along the Río Xingu and the other along the border with Rondônia. The last bit of public forest in the state is located in the northwest corner of the state (HML #21) where logging companies and land speculators are active along an unimproved road (MT-206/RO-205) between the INCRA* settlement of Colniza (Mato Grosso) and the city of Arequimes (Rondônia).

In the early 2000s, the federal government created an export corridor for the rapidly expanding soy industry of central Mato Grosso by improving the roadbed and bridges of the northern section of BR-163 (Figure 2.5).† The highway project, which would connect the croplands of central Mato

* *Instituto Nacional de Colonização e Reforma Agrária* – INCRAis the federal agency that oversees land reform initiatives and regulates land tenure for all rural properties in Brazil; see Ch. 4.

† The programme was originally conceived as a component within the *Programa de Acceleracião Económico* (PAC) and later included as a component of IIRSA: Amazon Hub, Group 5, Conexión entre la Cuenca Amazónica y el Nordeste Septentrional de Brasil: AMA33 Carretera Cuiabá–Santarém (BR-163/MT/PA)

Grosso with the grain terminals at Santarem, provoked an intense reaction from environmental advocates at a time when the country was experiencing a vigorous debate about the wisdom of Amazonian development.[12] The government responded by organising an ambitious environmental and social review (see Chapter 7), which led to the creation of several new protected areas and the recognition of indigenous land claims (see Chapters 11 and 12). Land speculators had already moved into the region, however, and created secondary roads penetrating landscapes on both sides of the highway, including one that facilitated access to the gold rush frontier in the upper reaches of the Crepori watershed (HML #18). Unlike the regional highways in Mato Grosso, these secondary roads do not appear on official maps, indicating that they were established without the participation of state planning agencies and appropriate environmental review.[13]

In 2016, the administration of Michel Temer[*] attempted to change the status of about half a million hectares in the Jamanxim National Forest,[14] a measure that would have granted *de facto* amnesty to the illegal appropriation of public lands. This led to a backlash from civil society organisations and the environmental prosecutor's office, who questioned the constitutionality of the executive order that authorised the modification of a protected area.[15] The government was forced to withdraw the measure in 2017 by a ruling from the Supreme Court, but neither the Bolsonaro administration nor the state authorities have interceded to combat illegal land grabbing on the landscapes surrounding BR-163 (see Chapter 4).[16]

In spite of R$ 1.5 billion expended on highway improvements between 2005 and 2015, a hundred-kilometre stretch of BR-163 remained impassable during the peak rainy season.[17] Poor road conditions caused massive traffic jams among the 3,000 trucks using BR-163 during the soy harvest. This untenable situation was exacerbated by road blockades organized by settlers seeking legal recognition for their landholdings.[18] In 2018, the federal government allocated an additional R$ 175 million in emergency funding to the Brazilian Army, which finished the paving in 2019.[19] From start to finish, it took twenty years to pave an 800-kilometre stretch of highway considered to be a vitally important strategic asset by the agro-industrial sector.

Commodity traders have responded to the improved road by building five grain terminals at Miritituba (Pará) on the east bank of the Tapajós River at what is essentially its highest navigable port. In 2020, the *Departamento*

($US 6.5 billion) and AMA34 Programa de manejo ambiental ($US 12 million). Source: http://www.iirsa.org/proyectos/Principal.aspx

* Michel Temer acceded to the Presidency following the impeachment of Dilma Rouseff, who was removed from office by a coalition of forces led by the Ruralist block in Congress who are advocates of agricultural expansion into the landscapes adjacent to BR-163 (see Ch. 6) (da Cunha et al. 2017).

The Cuiabá–Santarem corridor (BR-163) is a strategically important export corridor for grains cultivated in central Mato Grosso. It was upgraded from a poorly maintained road to a modern highway. Its construction was preceded by a strategic environmental evaluation and accompanied by a sustainable development programme. Nonetheless, the adjacent landscapes suffer from land grabbing and illegal deforestation, including within newly created protected areas.

Nacional de Infraestrutura de Transportes (DNIT)* initiated a tender process for a concession to administer BR-163 between Sinop (Mato Grosso) and Mirituba. The contract envisions an investment of an additional ~$US 600 million in highway improvements that will be financed by tolls levied on the approximately 6,000 trucks that are projected to use the highway.[20]

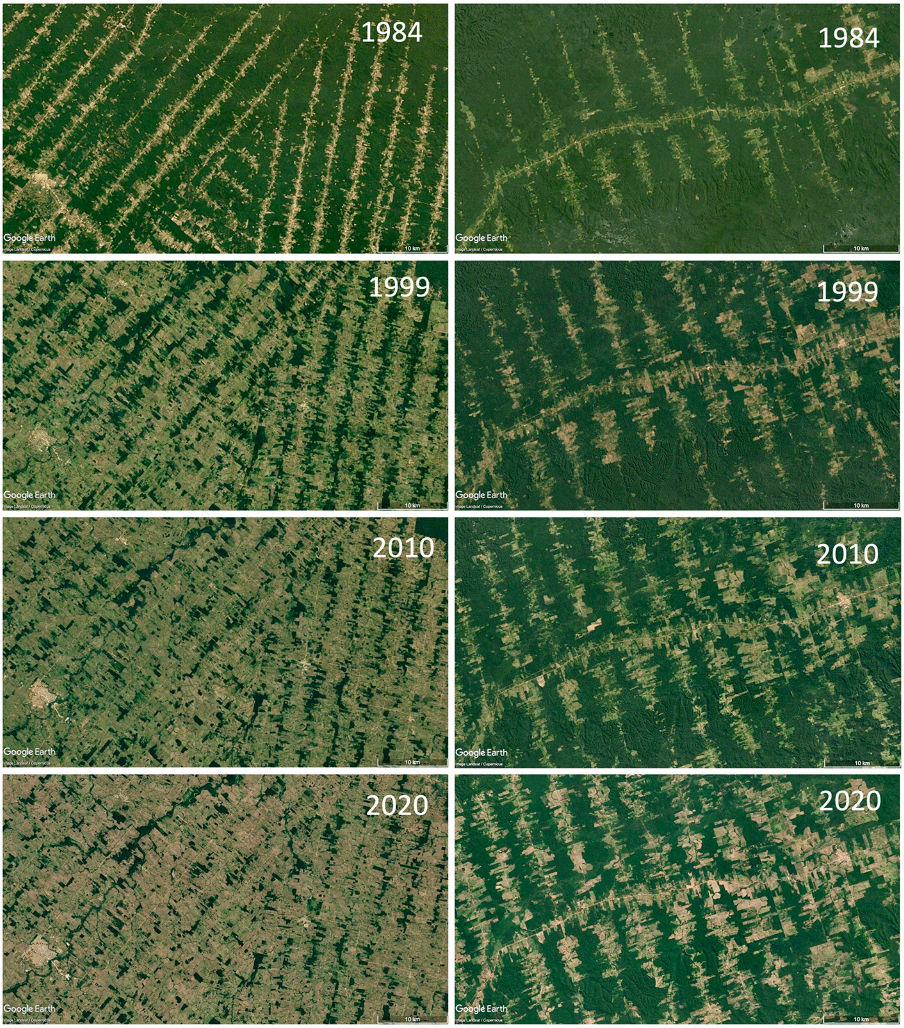
The most infamous highway in the Brazilian Amazon is Rodovia BR-364, which was constructed in Rondônia in the 1970s as part of a state-sponsored resettlement project supported by the World Bank (Figure 2.6).† The project triggered a wave of deforestation that was documented by newly available satellite imagery.[21] An independent review revealed that the environmental damage was compounded by social impacts that threatened indigenous communities and destined most settlers to a life of rural poverty. The resultant controversy catalysed the first serious debate about the conservation of the Amazon and the social impacts of conventional development paradigms (see Chapter 6).

In spite of the rough start, tens of thousands of smallholders eventually mastered the technological challenges of agricultural production in the Amazon. Although Rondônia is widely portrayed as a case study for misguided development policies, it also provides an example of a successful rural economy based on small family farms (HML #23). Key to that success was the creation of an extensive secondary road network that has been improved over several decades. The combination of a dense road grid and small property sizes led to the evolution of a rural landscape with an extremely low proportion of remnant forest (Figure 2.7). In central Rondônia, fifteen adjacent municipalities retain less than twenty per cent of their original forest cover and thirty have less than fifty per cent,[22] which is the approximate minimum amount allowed under the Forest Code of 2012 (see Chapter 7).

The other major highways carved out of the forest in the 1970s and 1980s are even more problematic. These include the eastern section of the Rodovia Transamazônica (BR-230), which starts at Marabá (Pará) on the Tocantins River and extends west for approximately 1,000 kilometres to Miritituba on the Tapajós River (HML #10). From there, the western section continues for an additional 1,000 kilometres through southern Amazonas state to the town of Humaitá on the Rio Madeira (HML #19). This trunk road was originally intended to integrate the three previously described transportation corridors (BR-155/158, BR-163, BR-364), but it was never

* The DNIT is a semi-autonomous agency within the Ministério da Infraestrutura, formerly the Ministério dos Transportes.

† The route largely followed the pre-existing track established by Candido Rondon in the 1900s when he built the telegraph line between Cuiabá and Porto Velho (Rohter 2019).



Source: Google Earth

Figure 2.7: A temporal comparison of deforestation associated with BR-364 in Rondônia (Left) and BR-230 in Pará (Right). Both landscapes were open to colonisation at approximately the same time, but BR-364 was paved, its producers were closer to urban markets, and they enjoyed greater extension support and better government services. When BR-230 is eventually fully paved, the forest remnants will most likely be reduced or lost, as they have been in Rondônia.

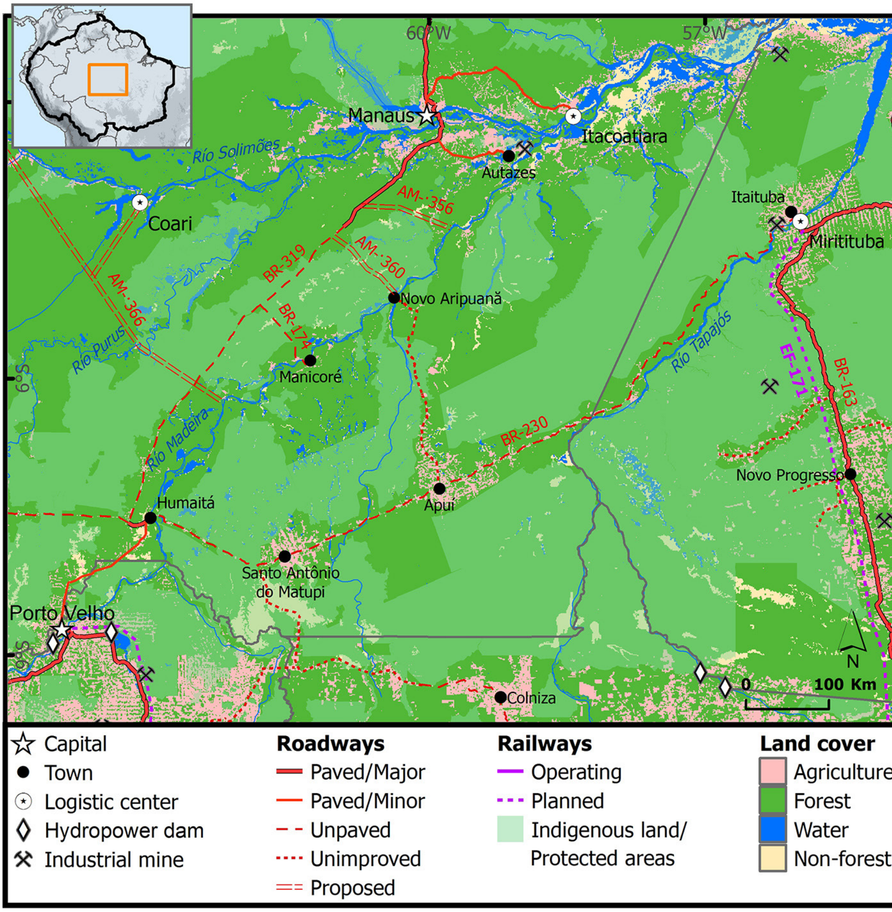


Figure 2.8: The frontier highways (BR-230 and BR-319) roughly parallel the Madeira Waterway. The improvement of existing and proposed secondary roads will accelerate deforestation, expand the footprint of agriculture and accentuate the isolation of a large block of primary forest in southeast Amazonas state.

paved, and its rapid deterioration soon left its settlers isolated and struggling to make a living (Figure 2.5 and Figure 2.8).

Land-use on the landscapes surrounding the Transamazônica in both Pará and Amazonas states is much less intensive when compared to BR-364 in Rondônia, even though all were colonised at approximately the same time and largely dedicated to beef cattle production. The difference, however, is likely to be transitory. Successive state governments have all made commitments to upgrade the highway, which is now paved between Miritituba and Rurópolis, where it overlaps with BR-163, and for another

350 kilometres between Altamira and Marabá (Figure 2.5).[23] Ongoing paving of the Transamazônica is included within the IIRSA portfolio of priority investments;[*] once the entire road is paved, the landscapes adjacent to the Transamazônica will almost certainly come to resemble the smallholder landscapes of Rondônia (Figure 2.7).

Other regions with a trunk highway but relatively low levels of deforestation include BR-174 between Manaus and Boa Vista (HML #4), where the presence of the Waimiri Atoari indigenous community has acted as an effective barrier to land grabbers (See Chapter 11).[24] The landscapes north of those indigenous territories in Roraima have been parcelled out to private landowners (HML #55) but have not transitioned into an agricultural frontier due, presumably, to their inherent isolation. Roraima has large extensions of natural savanna, which could transition into an agricultural frontier if political leaders succeed in their quest to replicate the agro-industrial development model exemplified by Mato Grosso.[25] An important component of their business model is the advantages conferred by the 750-kilometre paved highway (BR-174) between Boa Vista and the port of Manaus, which reduces the transportation cost of exporting soybeans and other grains.[†]

The historical deforestation rate in Acre has been relatively low, particularly along the western section of BR-364 between Rio Branco and Cruzeiro do Sul (HML #28). This 700-kilometre stretch of highway is currently unpaved for about 450 kilometres, but its completion has been a political priority for every state government for the last thirty years. During most of that period, successive administrations have promoted the sustainable use of forest resources, as exemplified by the agro-extractive reserves that both the state colonisation institution (INCRA) and the national protected area system (ICMBio) have sponsored.[‡] Nonetheless, extensive landholdings have been distributed to small and medium-sized producers dedicated to cattle ranching, which contributes almost eight times more to Acre's GDP than the forest sector (see Chapter 1). Eventually, BR-364 will be paved in its entirety, and this will lead to increased deforestation along its margins and on the secondary roads that radiate out from a half-dozen small towns (Figure 2.9).

* IIRSA, Amazon Hub, Group 5; Conexión entre la cuenca amazónica y el nordeste septentrional de Brasil; AMA85, Marabá – Itaituba ($US 1.0 billion): http://www.iirsa.org/proyectos/detalle_proyecto.aspx?h=1388

† IIRSA, Guiana Hub; Group 1, Interconexión Venezuela – Brasil: GUY01, Rehabilitación de la Carretera Caracas – Manaos ($US 405): http://www.iirsa.org/proyectos/detalle_proyecto.aspx?h=175

‡ INCRA: *Instituto Nacional de Colonização e Reforma Agrária* distributes land to landless families via several land-use models, including the sustinabel use of forest resources. ICMBio: *Instituto Chico Mendes de Conservação da Biodiversidade* recognises the territorial rights of traditional people who depend on forest livelihoods (see Chs 4 and 12)

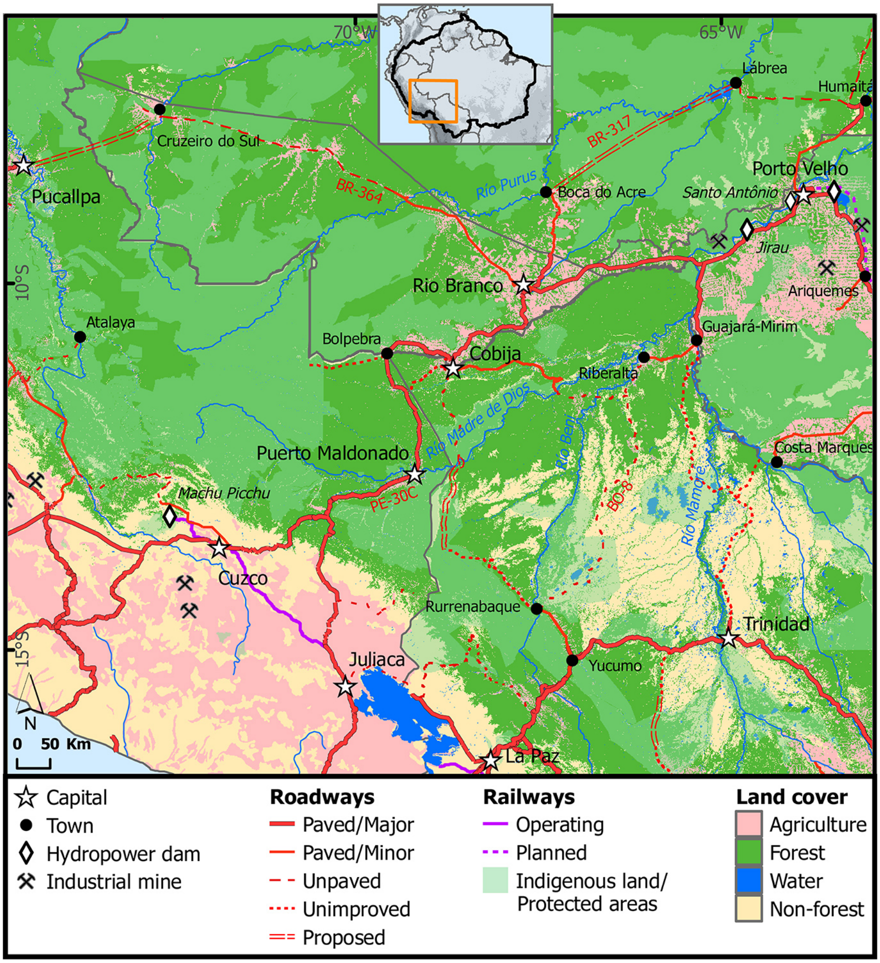


Figure 2.9: The Corridor Interoceanico is the quintessential IIRSA-sponsored initiative, with connections between the Amazonian river port at Porto Velho (Rondônia, Brazil), Cobija (Pando, Bolivia) and Puerto Maldonado (Madre de Dios), as well as to the Pacific coast of Peru and Chile. The proposed connection between Pucallpa and Cruzeiro do Sul would effectively isolate the forest ecosystems of the southwest Amazon from the central and northern Amazon.

Even more problematic is the proposal to extend BR-364 to the Peruvian border, one of two proposals recently incorporated into the IIRSA portfolio. On the Brazilian side, this includes the ongoing effort to complete paving between Rio Branco and Cruzeiro do Sul, a project that was recently included within the subgroup entitled Improving Access to the Ucayali Waterway, revealing the intention to link the Brazilian highway system with Peru via BR-364.* Even more explicit was the designation a 'terrestrial connection' between Cruzeiro do Sul (Acre) and Pucallpa (Ucayali, Peru).† The use of the term 'terrestrial' is purposefully indistinct, because it can refer to a either a highway or a railroad, which has been proposed by advocates of a transcontinental railroad (see below). The construction of the road has the support of Jair Bolsonaro and the governor of Acre, as well as civic leaders in the Peruvian city of Pucallpa.[26]

Acre figures prominently in another high-profile IIRSA initiative, referred to by media outlets as the Corridor Interoceanico, a flagship proposal that includes highway improvements in Brazil, Bolivia, and Peru (Figure 2.9). Efforts to manage the environmental and social impacts of those investments led to the organisation of the MAP‡ initiative, a novel planning process that coordinated actions among sub-national jurisdictions (see Chapter 7). Initiated in the early 2000s, it was at first viewed as a strategic environmental planning process that could identify a pathway to a sustainable forest economy. Efforts to transform the regional economy have had limited success, however, and the MAP region suffers from moderate to high levels of deforestation, a change that is particularly notable in Madre de Dios (Peru) and Pando (Bolivia), which were relatively isolated until the completion of these IIRSA-sponsored highway corridors.

One of the most controversial highway projects in the Brazilian Amazon is the ongoing programme to pave BR-319, the federal highway that links Manaus (Amazonas) with Porto Velho (Rondônia). This 1,000-kilometre corridor (HML #20) has the lowest level of deforestation of all of the trunk highways created in the 1970s (Figure 2.8). Unlike most of the other trunk highways of the epoch, however, it was completely paved in the original construction contract. The work was poorly done, and the roadbed rapidly fell into a state of disrepair. Two stretches have been 'reconstructed' and paved over the last decade: 200 kilometres on the northern sector near Manaus and 165 kilometres near Humaitá. The southern sector is at risk of being the next deforestation hotspot, because of the confluence of three trunk highways (BR-319, BR-230, and BR-364), which will attract settlers and land speculators, particularly from Rondônia, where land is no longer easily accessible.

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* IIRSA: Amazon Hub, Group 4, Acceso a la hidrovía del Ucayali, AMA55 Conexión vial Rio Branco - Cruzeiro do Sul BR-364/AC ($US 573): http://www.iirsa.org/proyectos/detalle_proyecto.aspx?h=920

† IIRSA: Amazon Hub, Group 4, Acceso a la hidrovía del Ucayali, AMA28 Interconexión Terretsre Pucallpa - Cruzeiro do Sul (budget unknown): http://www.iirsa.org/proyectos/detalle_proyecto.aspx?h=29

‡ MAP Refers to the three jurisdictional entities: Madre de Dios (Peru) Acre (Brazil) and Pando (Bolivia).

The road between Manaus and Porto Velho (BR-319) is the most remote national highway in the Brazilian Amazon. It was first paved in the 1970s, but soon became impassable (top). The highway has been rebuilt across about two thirds of its length and is scheduled to be completely upgraded by 2025 (bottom), pending approval of an ongoing environmental review financed from the President's office via the Programa de Parcerias de Investimentos.

Over the last decade, the 'reconstruction' of BR-319 has been promoted by a regional civic organisation, as well as by elected officials and functionaries in the regional government.[27] Proponents of repaving the road contend that the manufacturing sector in Manaus is handicapped by the logistically complex transportation services required to ship consumer goods to southern Brazil. The least costly alternative is the ocean-going route, but it involves the use of trucks, docks and warehouses at both ends of the supply chain. The highway option, though twenty per cent more expensive, would reduce transport time by at least fifty per cent and, perhaps more importantly, provide door-to-door service between the manufacturer and the wholesale distributor.[28]

The planned improvements to BR-319 will require the approval of the federal environmental protection agency (IBAMA), which initiated an environmental impact analysis (EIA) in 2017 and published in June 2020.[29] Among its findings was the predictable forecast that an improved road would increase deforestation along the highway corridor, but the study also identified the road's potential to catalyse societal demand for additional highway development, including pre-existing roads (AM-174, AM-254, AM-354, AM-364) and those planned for the future (AM-360, AM-366, BR-174), as well as illegal roads built by private actors.[30] Particularly problematic would be the construction of AM-366, which would impact at least two indigenous territories and, potentially, open up wilderness sections of the western Amazon to settlement and oil exploration (Figure 2.8).[31]

Not mentioned within the EIA is the long-term impact from the mega-fragmentation of the forests of the Central Amazon. Even a limited amount of deforestation along the highway corridor would create a barrier to wildlife that would isolate approximately 200,000 square kilometres of intact forest located between BR-319 and BR-230 (Figure 2.2). President Bolsonaro has advocated 'repaving' BR-319, and unless judicial action derails the project, its completion seems increasingly likely.[32]

Another controversial highway project the Bolsonaro administration is considering is the extension of BR-163 across the Amazon River to the border with Suriname. The proposed route has been shown on maps since the 1970s but was not one of the projects in the first wave of highway development. The ambitious proposal would require a three-kilometre span over the main channel of the Amazon River at Óbidos (Pará) and more than fifty kilometres of viaduct to cross the floodplain. This would be a completely new highway and open an enormous area to development (Figure 2.10).

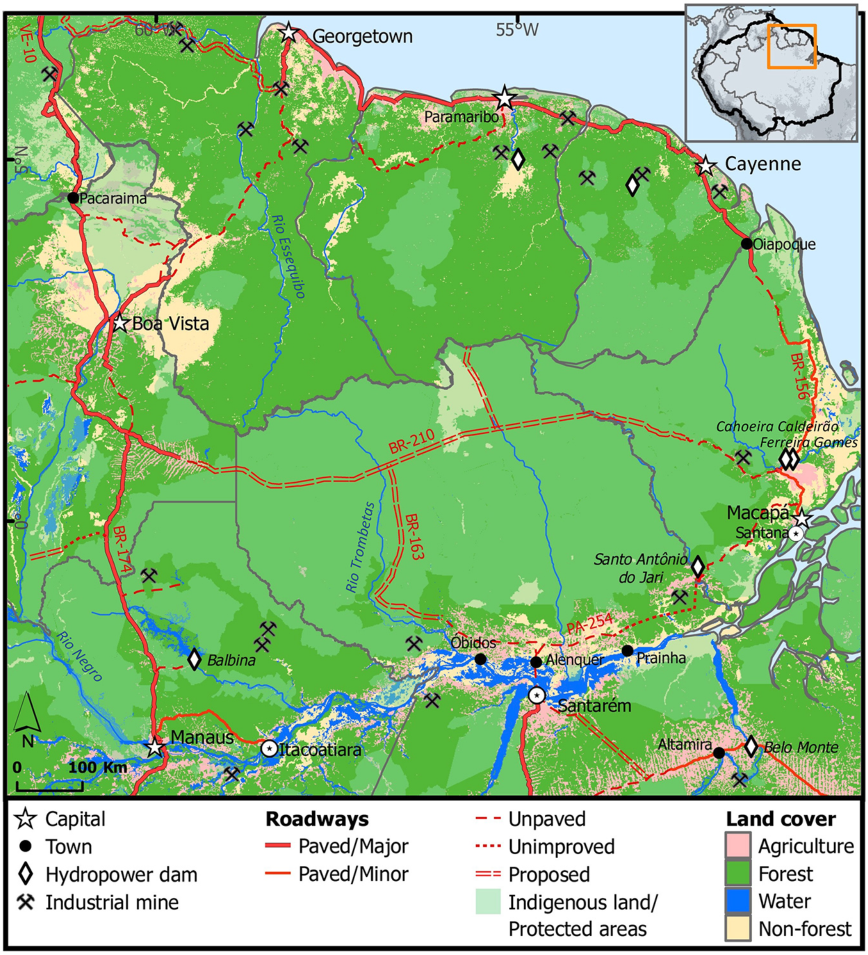

Figure 2.10: The northeast quadrant of the Pan-Amazon is relatively roadless except for BR-174, which extends from Manaus to Boa Vista, from there to the Venezuelan border, and via BR-401 to Guyana. On the coast, BR-156 will soon integrate Macapá with the coastal highway of the Guianas and, eventually, with PA-254 on the north bank of the Amazon river. A recent proposal to extend BR-163 to the border of Suriname would open vast areas to settlement and mineral exploitation.

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(a) Landholders universally support improvements to secondary roads, particularly bridges, because they are essential for moving their production to market. (b) The Ponte Río Negro, built between 2007 and 2012 at a cost of approximately $US 350 million, is one of the longest bridges in South America. It would be surpassed in length and cost by the proposed bridge that would span the Amazon River at Obidos, a key component of President Bolsonaro's project to open the Northern Amazon to development.

The proposal will be fiercely opposed by environmental activists and indigenous groups because it would disrupt a conservation strategy assembled over three decades of planning and coordination. Nonetheless, the highway conforms to a long-held *Calha Norte* strategy espoused by the national security community, based on the objective of 'occupying' the country's northern border (Chapter 6). The concept originated with the military government of the 1970s, but some variant of it has been embraced by all of the democratically elected governments of Brazil, including the Cardoso administration in the 1990s, which included the Arco Norte development pole as part of its *Eixos Nacionais de Integração e Desenvolvimento* (ENID).

One motivation for building the highway is to create momentum to change the status of the RENCA mineral reserve, a globally significant deposit of copper and other industrial minerals.* The proposed northern leg of BR-163 would connect with PA-254, the regional highway that provides access to the settlement zones located between Óbidos and Prainha (Pará). This would almost certainly increase land values and could facilitate the pursuit of industrial agriculture on the arable soils on the upland landscapes located between the Amazon River and the hill country of the Guiana Shield (HML #1). Although it is largely unimproved, the regional road network of northern Pará is already linked to a similarly rustic network of roads in western Amapá (Figure 2.10). The improvement of these existing roads would create an uninterrupted highway from Óbidos (Pará) to Macapá (Amapá) and the coastal provinces of French Guiana, Suriname, and Guyana.† Although this chain of events might seem unlikely, history demonstrates that existing roads attract settlers who lobby for improvements from local and regional governments that can lead to their eventual development into a transportation corridor.

The Andean republics

Bolivia, Peru, Ecuador, and Colombia all invested in major highway building initiatives in the last half of the twentieth century, motivated in part to project sovereignty over their Amazonian provinces. These areas had poorly defined borders and societies remembered the trauma of the rubber boom, when Brazilian agents encroached upon their territories or when they quarrelled among themselves over the disposition of their frontiers.

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* In 1984, the military government created the *Reserva Nacional de Cobre e Associados* (RENCA) as a strategic reserve for future exploitation; President Michel Temer tried to open it up to mining in 2019, but withdrew the initiative due to opposition from environmental and indigenous groups (see Ch. 5).

† IIRSA, G04: G4 - Interconexión Guyana - Suriname - Guaiana Francesa – Brasil, GOY26, Mejoramiento de la Carretera Georgetown - Albina; Carretera de Macapá a Oyapock ($350 million): http://www.iirsa.org/proyectos/Principal.aspx?Basica=1

Unlike the integrated highway network of Brazil, however, these nations built widely separated roads that connected discreet regions of the highlands with adjacent lowland landscapes (Figure 2.2).

Bolivia

Successive governments sought to connect the sparsely populated lowland provinces with the densely populated rural communities of the Altiplano; this policy started in earnest in the 1960s with the construction of all-weather roads to Santa Cruz (HML #31), the Chapare lowlands of Cochabamba (HML #32), and the Yungas of La Paz (HML #33).* Subsequently, the military regimes of the 1970s went on a spending spree that led to a default of Bolivia's sovereign debt in the 1980s, an outcome that limited the country's ability to build infrastructure throughout the 1990s. The most prescient investments occurred on the alluvial plain of Santa Cruz, where public and private resources were leveraged with loans and grants from multilateral agencies to create a secondary road network and industrial infrastructure that triggered a geometric increase in deforestation rates between 1990 and 2010.[33] This landscape now supports the most diversified agricultural production in the Pan Amazon and is a pillar of the Bolivian economy (see Chapter 3); its organic growth is driving the expansion of regional highways north toward the Beni (HML #30) and eastward into Chiquitania (HML #29) (Figure 2.6).

The commodity boom of the 2000s provided the Bolivian state with unprecedented revenues, which the government of Evo Morales used to invest in highway construction across the country. One of the most ambitious projects targeted the northern part of the country, with the objective of linking its administrative capital (La Paz) with communities and landscapes on the border with Brazil and Peru (Figure 2.9). These highways follow transportation routes that have existed for decades, and there is ample support across the region from both settler and indigenous communities. These trunk highways are the Bolivian components of the IIRSA-sponsored Corredor Interoceanico (HML #24, #25, #26, #27), which connects Porto Velho (Rondônia) and Rio Branco (Acre) with the Pacific coast.†

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* Although Bolivia assigns alpha-numerical identities to its roads, nobody uses them; roads are identified by geographical descriptors, such as La Antigua Carretera a La Paz (BO-7), La Carretera al Norte (BO-4), La Carretera a las Yungas (BO-3).

† IIRSA, Peru-Brazil-Bolivia Hub, Group 2, Corredor Rio Branco - Cobija - Riberalta - Yucumo - La Paz; PBB05, Carretera Guayaramerín - Riberalta/Yucumo - La Paz ($US 594 million); PBB06, Carretera Cobija – Riberalta ($US 696 million); PBB07: Yucumo – Trinidad ($US5.5 million); PBB08 Cobija – Extrema ($US 29 million); PBB60 Puente Mamore ($US75 million): http://www.iirsa.org/proyectos/Principal.aspx

Almost all elements of Bolivian society are energetic supporters of highway construction, and national, regional and local governments place road construction near the top of their budget priorities. The stated goal is to link agriculture production with both domestic and export markets, but multiple social actors also seek to open remote landscapes for agricultural development and land speculation. There is one conspicuous exception, however. The Moxeño people have steadfastly opposed the construction of a highway that would dissect their territory: Tierra Indigina y Parque Nacional Isiboro – Securé (TIPNIS). The proposed road was a priority investment of the government of Evo Morales, who sought to open the area to settlement for his constituents in the coca-cocaine frontier of the Chapare (HML #32). The Moxeños have resisted by using non-violent tactics of civil disobedience and, although the government has never formally abandoned the project, it has been removed from the priority list of highway projects.[*]

Other highway projects were specifically designed to open wilderness landscapes to agricultural development. This includes those on the piedmont of the Andes in Irurralde Province of La Paz, whose proponents hope to develop into an industrial sugarcane complex.[†] Even more ambitious are the regional highways being built across the Llanos de Moxos, which will facilitate the conversion of approximately ten million hectares of savanna and forest landscape into soy and rice farms, as detailed in the recently released *Plan de Uso de Suelos del Beni* (see Chapter 4).

Peru

The earliest highway projects penetrated tropical valleys situated between the high Cordillera and the tropical valleys and foothills of the Andean Amazon. In the first half of the twentieth century, roads were built into the cloud forest regions east of Lima in an area known as the Selva Central (HML #37), the lower Huallaga Valley (HML #43), and the Marañon Canyon (HML #45). More rapid change came in the 1970s with the construction of two trunk highways named after a distinguished Peruvian historian (Carretera Federico Basadre [P-18]), and the dominant political figure of the era

* This project was not included within the IIRSA portfolio but was financed by a $332 million loan from BNDES to the Bolivian government; construction was to be executed by a Brazilian construction company (OAS). The conflict eventually motivated the company to abandon the project and BNDES to withdraw its financing in 2012 (see Ch. 11). https://www.americasquarterly.org/blog/brazil-displeased-at-bolivian-decision-to-revoke-highway-contract/

† This highway (BO-16) is also not included within the IIRSA portfolio but was financed by the IDB and the World Bank; a Chinese company (SINPOEC) built a key bridge over the Río Beni, apparently with funds from the national treasury (Molina 2014).

(Carretera Fernando Belaunde [PE-5N]).* Both connect the central highlands with ports on the Amazon River and opened lowlands to settlement and deforestation in the 1970s and 1980s (Figure 2.11).

The Carretera Federico Basadre is part of an IIRSA investment cluster that links the port of Callao (Lima) with Pucallpa on the Rio Ucayali.† The lowland landscapes adjacent to the highway have attracted tens of thousands of settlers over five decades and continue to be among the most active agricultural frontiers in the Peruvian Amazon (HML #40 and HML #41). The port of Pucallpa provides access to the Amazon waterway via the Rio Ucayali and an associated expanding forest frontier that is the source of most of Peru's timber (HML #39).

The Carretera Fernando Belaunde is sometimes referred to as the Carretera Marginal de la Selva (PE-5) because its namesake was the statesman who originally proposed the construction of an international highway integrating the Amazonian regions of the Andes. In Peru, the Carretera Marginal de la Selva is a sinuous route that weaves in and out of the Andean foothills. This road was first constructed in the Upper Huallaga Valley (HML #42) to connect with the previously established agricultural settlements of the Lower Huallaga Valley (HML #43) and was eventually extended eastward to connect with the Port of Yurimaguas on the Rio Huallaga (HML #44).

At the regional city of Tarapoto (San Martín), it merges with an IIRSA investment group collectively referred to as the Corridor Interoceanico del Norte.‡ This has two Amazonian spurs: one originates at Yurimaguas on the Rio Huallaga (PE-5NB). The other starts at Saramiriza on the Rio Marañon (PE-5NC).§ The two segments converge in the Marañon valley (HML #45) before passing over the Cordillera Occidental at the Huancabamba Depression, a geological feature with the lowest elevational point on the continental divide (2,145 metres above sea level). Known as the Paso de Porcullo, this route has been used for centuries as a gateway into the Amazon (see Chapter 6) and provides a significant logistical advantage when

* The Peruvian highway notation system is confusing and named highways often change numerical designation in different regions or sections.

† IIRSA, Amazon Hub, Group 4: Accesso a la Hydrovia de Ucayali; $US 3.6 billion; AMA26 (Tingo María - Pucallpa Road): AMA31 (El Callao Port); AMA55 (Rio Branco Cruzeiro do Sul); AMA63 (La Oroya /Cerro De Pasco/Huancayo); AMA64 (Pasco - Tingo María) and other non-highway projects: http://www.cosiplan.org/proyectos/Principal.aspx

‡ This highway is managed as a concession by *Odebrecht Perú Operaciones y Servicios*; the 25-year contract is based on investment of $US 630 million: https://www.ositran.gob.pe/anterior/carreteras/iirsa-norte/

§ IRSA, Amazon Hub, Group 3: Acceso a la Hidrovía del Huallaga – Marañón; $US 1.3 billion; AMA16 (Tarapoto - Yurimaguas Road); AMA19 (Reposo Saramiriza); AMA25 (Paita - Tarapoto Road) and other non-road projects: http://www.cosiplan.org/proyectos/Principal.aspx

Figure 2.11: The highways of the Peruvian Amazon connect different sectors of the high Andes with disjunct landscapes in the Amazon piedmont. They are partially integrated via the Carretera Marginal de la Selva, which threads its way through the Andean foothills. The Amazon Waterway connects the city of Iquitos with the rest of Peru via the port cities of Pucallpa, Yurimaguas and Saramarisa.

compared to other Andean mountain passes that typically occur between 4,000 and 5,000 metres above sea level (Figure 2.11)

The highway to Saramiriza was originally built in the 1960s during the construction of the Oleoducto del Norte and is a major access point to the northern Peruvian Amazon (HML #46). This relatively remote village plays a prominent role in the Regional Government of Loreto's plan to connect Iquitos with the national road network. The proposed highway includes a 200-kilometre section from Saramiriza that would follow the existing pipeline right-of-way to the oil fields near the Ecuadorian border; here it would connect with another proposed road along the border with Ecuador, as well as a 220-kilometre spur to Nauta, a village on the Rio Marañon with an existing paved road to Iquitos (Figure 2.11).[34] At first glance, the proposed route would seem circuitous, but a more direct one would cross the massive peat swamp of the Pastaza Delta, increasing construction costs and undermining the economic viability of the project.[35]

The construction of any of these roads would open vast areas of primary forest to logging and, almost certainly, settlement by subsistence farmers and land speculators (see Chapter 4). The proposed roads would traverse land deeded to dozens of indigenous communities, while bordering both national (Zona Reservada Santiago – Conaima, Reserva Natural Oucacuro) and regional (Area de Conservación Regional Alto Cona – Pintuyaco Chambira) protected areas. The initiative has been vigorously opposed by environmental advocates and indigenous organisations; nonetheless, elected officials in Iquitos have successfully lobbied the Peruvian Congress to declare the construction of the Saramiriza - Iquitos highway a national priority.[36]

The central section of the Carretera Marginal de la Selva (PE-5) extends south from the Carretera Federico Basadre through the rapidly expanding agricultural frontier of Huanuco and Pasco (HML #40), before ascending the foothills to the coffee-producing landscapes near Oxapampa (HML #37, #38). The southern section (PE-5S) is the main trunk highway of the Selva Central and eventually crosses over the foothills again to connect to the Rio Ucayali at Atalaya (MHL #38), a major logistical centre for the timber industry (Figure 2.11).

The other major trunk highway in the Peruvian Amazon is a component of the IIRSA-sponsored Corridor Interoceanico (Figure 2.9),* which connects the Peruvian coast with the Puerto Maldonado on the Madre de Dios River and the frontier landscapes of Pando (Bolivia), Acre, and Rondônia (Brazil). In Peru, this group of highways is referred to as the

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* This should not be confused with the *IIRSA Eje Interoceanico* (Interoceanic Axis), which extends from São Paulo across Mato Grosso do Sul to Bolivia, Chile and Southern Peru, which incorporates a highway between Santa Cruz and Campo Grande that is sometimes referred to as the *Corridor Bioceanico*.

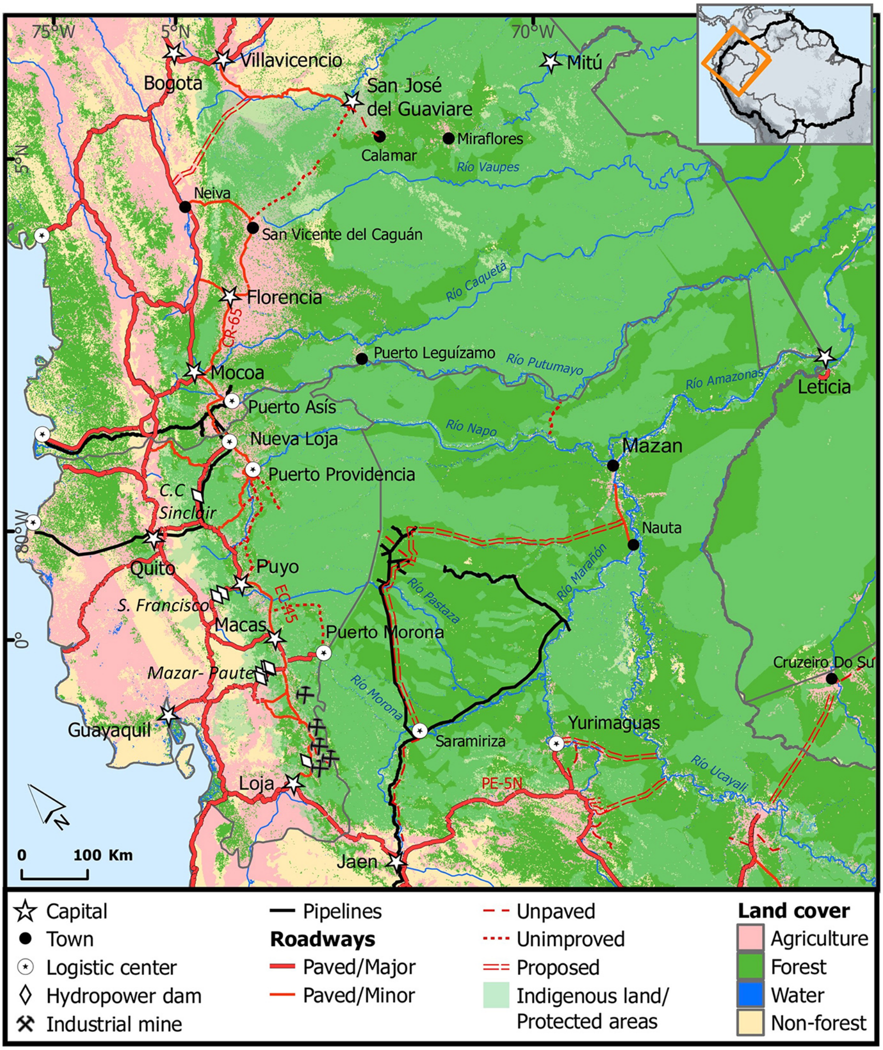

Figure 2.12: The Ecuadorian Amazon has the densest and most improved road network in the Andean Amazon; however, it is more static when compared with Peru and Colombia, where new roads are being carved into wilderness areas. The proposed highway between Saramariza and Iquitos would follow a pipeline right-of-way for about 50% of its route. The Amazon Waterway is connected to two river ports in Ecuador (Puerto Morona and Puerto Providencia) and one in Colombia (Puerto Asis).

Corridor Interoceanico del Sur,* which, like the similarly named highway corridor in northern Peru, is managed by a consortium of Brazilian and Peruvian construction companies that obtained 25-year concessions in exchange for building the project.†

Like most such projects, it spawned a land rush that predated the completion of the highway. The looming impact from deforestation and social displacement motivated regional leaders in Madre de Dios to participate in the MAP initiative with like-minded individuals in Acre (Brazil) and Pando (Bolivia).[37] As in Brazil and Bolivia, the MAP initiative enjoyed success in improving protected-area management and recognising the rights of forest communities but was not successful in changing non-sustainable patterns of land use and natural resource management.[38,39] The new highway contributed to the gold rush then underway on the piedmont of Madre de Dios and, although the gold rush would have occurred regardless, the multilateral financers of the highway failed to take into account the potential for the highway to accelerate illegal mining (HML #36).[40]

The justification for developing the Corridor Interoceanico is an example of 'infrastructure hype', whose proponents exaggerate the economic benefits of a development project. In this case, they overstated the potential for exporting commodities from Rondônia and Mato Grosso via Pacific ports to Asian markets, which ignored (a) the high cost of truck transport and (b) the energy cost of moving bulk commodities over a 5,000-metre pass in the High Andes. The light traffic that has characterised the highway since its completion in 2010 demonstrates that this was never a viable option.[41]

Ecuador

The first road from the highlands to the Amazon lowlands was built by Royal Dutch Shell in 1947, a precursor to a formal policy articulated in the 1960s that linked oil exploration with road construction and colonisation (Chapter 6). Throughout the 1970s and 1980s, the government consolidated the road network in Amazonian Ecuador, which can be divided into two sectors: (1) the Sucumbíos – Orellana polygon, which sits above the major petroleum-producing formation of the country (HML #49 and HML #50) and (2) the Ecuadorian Piedmont (HML #48), which starts in the foothills near

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* IIRSA: Peru-Brazil-Bolivia Hub; Group 1 - Corredor Porto Velho - Rio Branco - Assis - Puerto Maldonado - Cusco/Juliaca - Puertos Del Pacífico; $US 2.9 billion: PBB01 (Carretera Iñapari - Puerto Maldonado - Cuzco ($1.9 billion); PBB03, Puente Rio Acre ($US 12 million): http://www.cosiplan.org/proyectos/Principal.aspx

† The corridor is divided into four sections (*tramos*), each managed by a different consortium; the lowland tramo is operated by IIRSA Sur S/A, a subsidiary of Odebrecht Perú Operaciones y Servicios S.A.C valued at approximately $US 640 million: https://www.ositran.gob.pe/anterior/carreteras/iirsa-sur-t3/

Peru and extends northward to the Colombian border.* This north- south paved highway, known as the Troncal Amazónica (E-45), is the Ecuadorian component of the Carretera Marginal de la Selva (Figure 2.12).

In the south, two roads extend east from the Troncal Amazónica into the lowland plains situated north of the Peruvian border. The most important (E-40) connects to a port on the Rio Morona that was originally built to supply military outposts along a highly contested border (see Chapter 6). Puerto Morona is now the terminus of an IIRSA-sponsored initiative to link the ocean port of Guayaquil with the Amazon waterway† and a large-scale copper mine under development in the Cordillera del Condor (see Chapter 5). The military also built an alternative supply line along the northern stretch of the Rio Morona that passes through the heartland of the Shuar indigenous people (HML #47). The construction of the highway motivated some Shuar families to clear forest as a defensive strategy, legalise land claims and limit incursions by settlers from highland communities (see Chapter 11). The regional government is in the process of paving this road, using credit provided by the *Banco de Desarrollo del Ecuador*.[42]

Two major east-west highways (E-10 and E-20) were built to connect the highlands with the Sucumbíos – Orellana polygon. This region also has the most fertile soils in the Ecuadorian Amazon, which spurred settlement and the development of a secondary road network that parallels the collector pipeline system (Figure 2.12). Annual deforestation continues at relatively constant rates due to the conversion of remnant forest within smallholdings created in the 1980s.[43] The agricultural frontier continues to expand into the landscapes surrounding Yasuní National Park (MHL #50), although the government is imposing stricter controls over settlement along new access roads, and indigenous communities are aggressively seeking to limit the expansion of the petroleum sector (see Chapter 11).

Colombia

Deforestation is less strongly associated with the construction of major highways in the Colombian Amazon because successive governments have embraced a policy that precludes large-scale road-building. Instead, the country has decided that its most remote regional capitals – Leticia (Amazonas), Mitu (Vaupes) and Inírida (Guiania) – can more effectively be integrated into the national economy via air transportation systems. There

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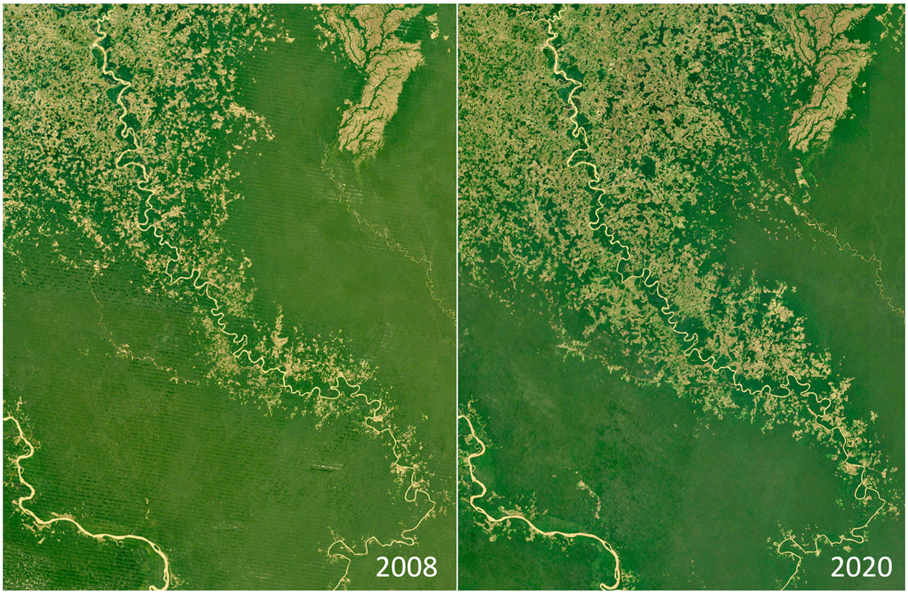
* IIRSA: Andean Hub, Group,6, Conexión Colombia - Ecuador II, AND35, Rehabilitación del Tramo Bella Unión – Gualaquiza, ($US 23 million): http://www.cosiplan.org/proyectos/detalle_proyecto.aspx?h=80

† IIRSA, Amazonas Hub, Group 7 - Acceso a la Hidrovía Amazonas; $US 420 million: AMA 45 (Puerto Morona); (AMA45); AMA 48: (Road Prto Bolívar -Prto Morona); AMA 47 (Road to Prto Bolívar – Méndez); AMA 46 (Guayaquil - Puerto Morona): http://www.cosiplan.org/proyectos/Principal.aspx



Source: Google Earth

Figure 2.13: Rivers also act as deforestation vectors, particularly in Colombia where the lack of roads and the cultivation of coca leaf coincide to create a forest frontier associated with the Rio Caquetá.

is still considerable loss of forest, but it tends to occur along rivers or in roadless landscapes where the state is only marginally present (Figure 2.13).

Although most of the lowlands are roadless, several key highways connect towns on the Andean piedmont with the rest of the country. These include CR-45 between Neiva (Huila) and Puerto Asis (Putumayo) (HML #51), which is being upgraded by the *Agência Nacional de Infraestructura* (ANI), a public-private partnership programme that accelerates investment in infrastructure assets.* Only a few select highways are commercially attractive, and improving access via highway construction to conflict areas is considered to be an essential component of the peace and reconciliation process (see Chapter 6). The *Instituto Nacional de Vias* (INVIAS) oversees the construction and operations of all other national highways, and in Caquetá, this includes two highways (CR-30 and CR-20) that connect Neiva to Caquetá (Figure 2.12), where the potential to expand industrial agriculture is attracting significant new investments (HML #52 & #53).

* A Chinese construction company recently obtained a concession valued at $US 1.0 billion for this section of R45.

Caquetá is otherwise isolated from the national highway network, but its major towns are linked by a trunk highway that runs along the base of the Andes, referred to as the Carretera Marginal de la Selva (CR-65). As the name implies, this is a component of the international highway envisioned in the 1960s. As of 2020, it had been paved for 250 kilometres in Caquetá and 165 kilometres in the adjacent department of Putumayo,[*] but the two segments remain separated by about twenty kilometres of back roads and the 1,000-metre width of the Rio Caquetá. Once a bridge is built, the Carretera Marginal de la Selva will connect all the major towns of Caquetá and Putumayo, as well as link to its counterpart highway in Ecuador.[44] Near the border, it intersects with CR-10, part of an IRSA-sponsored initiative to link Pacific ports with the Amazon waterway.[†]

The northern section of the Carretera Marginal de la Selva extends from San José de Guaviare (Guaviare) to Villavicencio (Meta) and from there along the base of the Andes to the Venezuelan border. There is no connection – yet – to Caquetá. There are, however, two road-building processes underway that will make that link, both of which will isolate Parque Nacional Natural Serranía de Macarena and, in the process, disrupt Colombia's only intact biological corridor connecting the forest ecosystems of the Andes and the Amazon. Along the northern border, INVIAS is financing the construction of the Transversal de la Macarena (R-65A), a regional highway that will facilitate the export of agricultural commodities from the Department of Meta via the Pacific ports of Buenaventura (Valle de Cauca) and Tumaco (Nariño). South of the park, approximately 200 kilometres separate the two sectors of R-65 at San José (Guaviare) and San Vicente de Caguán (Caquetá). INVIAS has no plans to close this gap, but unplanned road-building by local landholders has narrowed it to a mere fifty kilometres (see Figure 2.12).[45]

The eastern terminus of the Transversal de la Macarena will connect with the northern segment of CR-65 about 100 kilometres north of San José de Guaviare. All these landscapes are populated by coca-growing peasants and cattle ranchers, who have created a vast informal network of small roads that are slowly encircling Colombia's oldest national park.[‡] South of San José de Guaviare, a regional highway (CR-75) extends to the

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* IIRSA: Andean Hub, Group 06; Conexión Colombia - Ecuador II (Bogotá – Loja); AMA 090, Tramo San Vicente del Caguán - El Porvenir ($US 240 million) and AND79, Mocoa - Santa Ana - San Miguel Road Section ($US 210 million): http://www.iirsa.org/proyectos/Principal.aspx?Basica=1

† IIRSA: Amazon Hub, Group 01; Acceso a la Hidrovía del Putumayo; AMA01: Corredor Vial Tumaco - Puerto Asís ($US 291 million): http://www.iirsa.org/proyectos/Principal.aspx?Basica=1

‡ PNN Serranía de la Macarena was established as a biological reserve by legislative action in 1948 and was constituted as a national park in 1989. See http://www.parquesnacionales.gov.co/portal/es/

town of Calamar, the gateway to a forest frontier with the highest rate of deforestation in the Colombian Amazon (HML #54).

Carretera Marginal de la Selva

Although never organised as a specific project, the Carretera Marginal de la Selva has emerged from multiple projects that have been established in the Andean foothills from Colombia to Bolivia (Figure 2.14). In addition to the gap across the Serranía de Macarena, there is a small gap between Ecuador and Peru that conserves a biological corridor between Parque Nacional Podocarpus in the Andes to the Reserva biológica Cerro Plateado in the Cordillera del Condor and several Awajún indigenous territories in Peru.*

Within Peru, whose president proposed the idea, the Carretera Marginal de la Selva traces a sinuous route through the foothills of the Andes, the Marañon Valley (HML #45), the Huallaga Valley (HML #42 and #43), the piedmont landscapes of Huanuco and Pasco (HML #40) and the Selva Central (#37). Disjunct from this continuous highway are segments of the Peruvian Yungas (HML #35) and the piedmont of the Madre de Dios (HML #36). Virtually all Peru's lowland tropical agriculture is located within fifty kilometres of this road, which – despite its idiosyncratic route – makes it a strategic asset supporting domestic food security (see Chapter 3).

Official highway maps show a future potential route for the Carretera Marginal de la Selva, (PE-5S), which would extend south from the Selva Central ~800 kilometres toward the Camisea gas fields to the Corridor Interoceanico del Sur near Puerto Maldonado (Madre de Dios).[46]

This 'gap' in the highway network is, perhaps, the world's most important biological corridor, because it facilitates biological interchange between the mega-diverse rainforests of the Southeast Amazon and the montane forests of the Central Andes. The corridor experiences some of the highest annual rainfall on the planet and is considered to be resilient to climate change due to inherently stable, continental-scale patterns of wind flow (See Chapter 10).[47] A highway, either on the piedmont or in the foothills, would interrupt the ability of species to adapt to changes in temperature by migrating up a topographic gradient across the forest-covered slopes of three massive cordilleras (Vilcabamba, Urubamba, Vilcanota).[48]

The importance of the region for biodiversity conservation has been known for decades, and most of the area has been set aside either as a protected area or indigenous reserve. Any attempt to compromise the integrity of these reserves will be met with fierce resistance from academics, civil society and indigenous people. Nonetheless, the Peruvian government, or at least the functionaries within its highway planning agency, continue

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* Comunidad Nativas Naranjos, Supayaco, Alto Tuntus and Tuyankuwas. Source: *Red Amazónica de Información Socioambiental Georreferenciada* (RAISG).

Figure 2.14: The Carretera Marginal de la Selva was first proposed in 1969 by Fernando Belaunde in order to promote the integration of the economies of the Andean Amazon. The concept has influenced the design of national highway systems, but there remain significant gaps among its different components.

to place the proposed highway on official maps and, presumably, in the investment portfolios of its future infrastructure agenda.[49]

The proposed extension of PE-5S to the Bolivian border would likewise intrude on protected areas but would link up with a planned extension of the road currently under construction between Yucumo and Ixiamas (BO-16). Unlike the other Andean nations, Bolivia does not have an explicit plan to construct a highway corridor named 'Carretera Marginal de la Selva'; nonetheless, trunk highways in La Paz (HML #34) and the Chapare (HML #32) essentially conform to the original concept. The 200-kilometre gap between these two sections is, as in Peru, an important biological corridor that has been incorporated into the protected area network and/or indigenous territory.

The Guiana Shield and the Coastal Plain

Roads are scarce in the Northern Amazon, and surprisingly, the few that exist have not triggered widespread deforestation (Figure 2.10). This apparent anomaly is largely the consequence of a development dynamic that has kept these countries from seriously pursuing agricultural development in their Amazonian provinces. Venezuela chose to build an economy based on mineral extraction, mainly oil, and its leaders have viewed its landscapes of the Guiana highlands as a giant national protected area. The colonial history of Guyana, Suriname and French Guiana has caused their residents to look to Europe or North America for economic opportunity, which has suppressed the demand for terrestrial connections to Venezuela and Brazil.

The first truly modern highway in the entire region, the Ruta a la Gran Sabana (VR-10), serves as a transitway for commerce between the Venezuelan Coast and Brazil as well as an entry point for tourists visiting the Gran Sabana and *tepuis*.* Most of Venezuela's tropical timber is extracted using this road, and it is a key infrastructural asset for the mining industry (see Chapter 5). This highway connects with BR-174 in Roraima and is now almost forty years old; its renovation and maintenance are included within the IIRSA portfolio of investments.†

The other major highway corridor is the route between Boa Vista (Roraima) and Georgetown (Guyana). The section in Brazil is paved, but the Guyana component is a gravel road between the mining centre of Linden and the border town of Letham. Although it lacks the attributes of a modern

* A *tepui* is a table-top mountain of the Guiana Highlands of South America. The word is derived from the Pemon indigenous people of the Gran Sabana and translates as the 'house of the gods': http://www.bbc.com/travel/story/20121020-venezuelas-lost-world

† IIRSA; Guianese Shield Hub, Group 1, Interconexión Venezuela – Brasil, GUY01 Rehabilitation of the Caracas - Manaus Road ($US 407 million): http://www.cosiplan.org/proyectos/Principal.aspx

highway, it does include several heavy-load bridges that make industrial transport between Roraima and the Atlantic Coast a viable option. Its completion in 2009 opened up remote landscapes to logging and motivated a limited number of farmers to cultivate rice on the flooded savannas near the Brazilian border. The landscapes surrounding the highway have not yet experienced significant deforestation. This road is considered to be a high priority 'anchor project' in the 2017 IIRSA investment portfolio and will be paved in the near future.* The economic logic for the modernisation of the highway rests, in part, on the assumption that Roraima will become an agricultural exporting region similar to Mato Grosso. Truck transport from the farm landscapes around Boa Vista to the Atlantic Coast (700 kilometres terrestrial) would be more cost-effective than the truck and fluvial transport options via Manaus (850 kilometres terrestrial plus 1,540 kilometres waterway).

Most of the population of Guyana, Suriname and French Guyana live near the coast, where they communicate via a road that has existed for decades (HML #57). Two IIRSA-sponsored highway initiatives seek to improve this terrestrial connection. The Ciudad Guyana – Georgetown – Paramaribo Corridor would create a new highway from Venezuela through the gold-mining landscapes of northeastern Guyana (HML #58).† It is not a priority project, however, because Venezuela does not recognise Guyana's sovereignty over the disputed area. The second initiative is to upgrade the road between Georgetown and Macapá, which would include bridges across the Corentyne River between Guyana and Suriname and the Marwijne River between Suriname and French Guiana; it would connect with BR-156 in Amapá, Brazil.‡

Currently, there are very few settlements along BR-156 (HML #60), although it is used by miners exploiting gold in the greenstone belt near the border with French Guiana. In the near future, settlement could be spurred by the development of offshore oil and gas fields, which presumably will require logistical facilities on the coast. Brazil is in the process of upgrading BR-156 as part of an IIRSA-sponsored corridor on the coasts of the Guianas. Construction began in 2010 and is expected to conclude by 2020 at a cost of

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* IIRSA; Guianese Shield Hub, Group 2, Interconexión Brasil - Guyana; GUY09, Lethem - Linden Road ($US 250 million): http://www.cosiplan.org/proyectos/Principal.aspx

† IIRSA; Guianese Shield Hub, Group 03; GUY18: Routes Interconnecting Venezuela (Ciudad Guayana) - Guyana (Georgetown) - Suriname (Apura - Zanderij - Paramaribo): http://www.iirsa.org/proyectos/detalle_proyecto.aspx?h=200

‡ IIRSA; Guianese Shield Hub, Group: 04 – GUY 28, Routes interconnecting Guyana - Suriname – French Guiana - Brazil, $US 350 million: http://www.iirsa.org/proyectos/detalle_proyecto.aspx?h=200

approximately R$ 1 billion.[50] Once a modern highway exists between Macapá and French Guiana, land speculation and agriculture will likely follow.

Hydropower: A Shift toward Reduced Impact Facilities, But the Controversy Continues

After highways, investments in large-scale hydropower facilities are the most controversial infrastructure investments in the Pan Amazon. Governments pursue hydropower as a sovereign source of renewable energy and driver of economic growth; opponents object due to the environmental and social impacts associated with large-scale projects. There are elements of truth in both of these affirmations, and the debate surrounding hydropower usually focuses on the trade-offs in the costs and benefits that have caused some projects to be approved, others to be modified and a few to be cancelled.

Historically, Brazil has been overly reliant on hydropower. In the late 1990s, it represented a remarkable ninety per cent of installed generating capacity, a situation that provoked the electricity crisis of 2001/2002 when water levels in reservoirs were reduced by a prolonged nationwide drought.[51] The government responded by diversifying its electrical generation capacity in natural gas, biomass, wind and solar (Figure 2.15), as well as by increasing hydropower capacity in Amazonian rivers deemed to be less susceptible to the risk of periodic drought.[52] Brazil is still overly reliant on hydropower, as evidenced by the weather-induced power rationing that rocked the national economy in 2015.[53]

In 2005, the civil engineers within the federal energy agency of Brazil estimated the potential hydropower capacity of Brazil at approximately

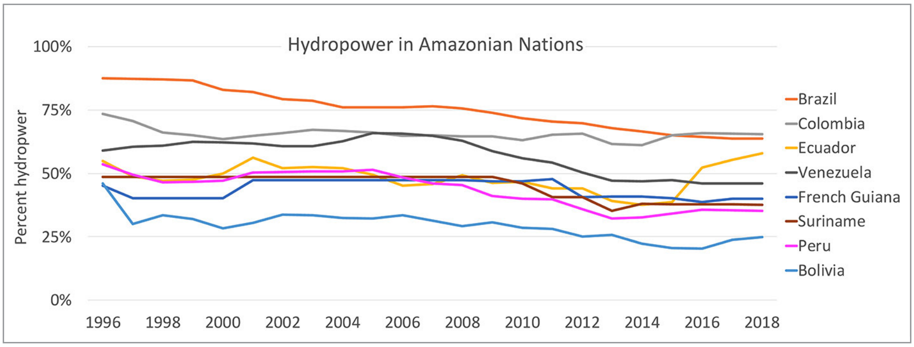


Figure 2.15: The declining dependence on hydropower in Amazonian countries. Data source: The United Nations – Energy Statistics Database (http://data.un.org/Data.aspx?d=EDATA&f=cmID%3AEC).

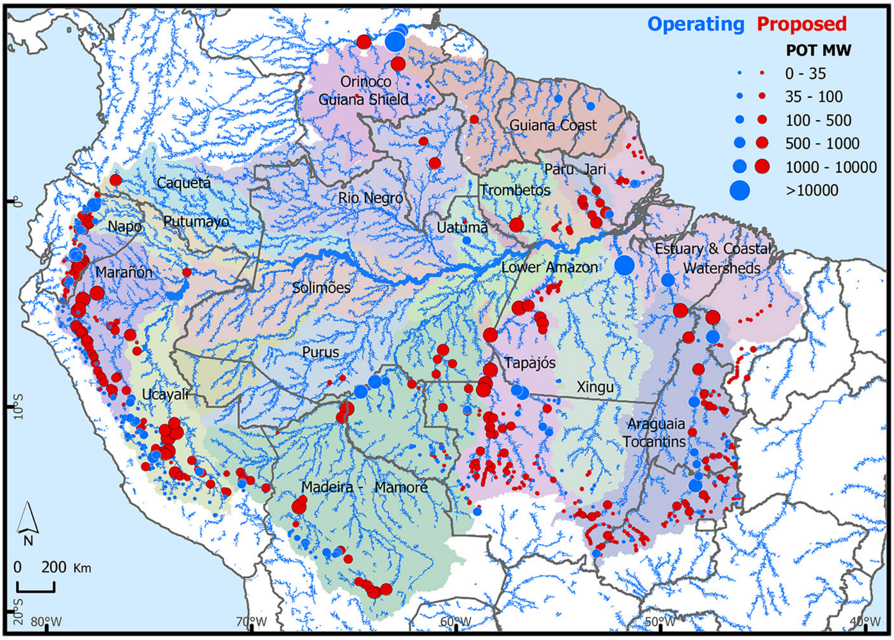


Figure 2.16: The distribution of existing and planned hydropower plants in the Pan Amazon. With the exception of about ten large-scale facilities, most existing power plants are located relatively high in individual watersheds.

Data source: RAISG 2021.

251 GW,* of which about half was located within the Amazon basin.[54] By 2020, however, they had reduced that estimate to 176 GW, while reporting that installed capacity had increased from more than 78 to 108 GW; most of that expansion had occurred within the Amazon, where installed capacity increased from 7 to 43 GW (Figure 2.16).[55] The decrease in estimated potential capacity was due not to a decline in Brazil's hydraulic resources but to a recalculation, after planners eliminated projects that were no longer deemed feasible based on regulatory criteria (See Annex 2.2).

This determination followed a 2018 decision by the government to call a halt to future large-scale development of dams in the Amazon, citing the need to reconcile social and environmental impacts with economic criteria and energy demand.[56] This policy was reversed following the election of

* The capacity of a power system represents the maximum power the system can generate when operating at any point in time; a gigawatt (GW) is a billion watts; for reference, that signifies about 3.1 million state-of-the-art photovoltaic (PV) panels in 2020. Source: Dept. of Energy USA, https://www.energy.gov/eere/articles/how-much-power-1-gigawatt

Jair Bolsonaro, who embraced many of the projects sidelined in 2018 and proposed additional projects that had not been incorporated in the national energy plans.[57] Current plans are in flux, but the database of proposed hydropower facilities under consideration in the Brazilian Amazon totals 112, with a potential installed capacity of 44 GW.[58] In 2021, Brazil once again runs the risk of experiencing an electricity crisis and, once again, the culprit is lower-than-average water levels in reservoirs.[59]

The nations of the Andes are also highly dependent on hydropower and seek to increase that commitment over the next decade. A recent study documented 142 dams in operation or under construction and an additional 160 in various stages of planning (Figure 2.16).[60] This is twice the number reported in 2012[61] and would represent a 500 per cent increase in installed generating capacity.

Peru's National Energy Plan 2014–2025 projects that 54 per cent of its electricity supply will be generated from hydropower; most will come from dams built in the Ucayali and Marañon basins (Figure 2.16).[62] Ecuador hopes to increase the proportion of hydroelectric power from fifty per cent in 2015 to approximately ninety per cent by 2025, at least seventy per cent will come from Amazonian basins.[63] Colombia obtains about sixty five per cent from hydropower, although none of that is obtained from an Amazonian tributary.[64] Bolivia has progessively reduced its reliance on hydropower over the last twenty years as it exploited the natural gas fields discovered in the 1990s; however, future plans rely almost exclusively on hydropower. In 2019, the government announced plans for quadrupling the country's installed capacity, from 1.2 to 5.1 GW, which would increase its reliance on hydropower from thirty to eighty per cent.[65]

In spite of its economic advantages, the physical attributes of the Amazon and its tributaries make hydropower problematic for the conventional dam-and-reservoir (D&R) facilities favoured by civil engineers and energy managers. In the lowlands, broad floodplains limit the potential to create reservoirs in confined areas that store large volumes of water; this impedes operators' ability to regulate reservoir levels for power management. In contrast, the valleys in the Andean foothills provide almost ideal conditions for creating massive reservoirs; however, high sediment loads cause them to lose storage capacity over time, which limits their lifespan as economic assets.*

The retention of sediments also impacts ecosystem function in downstream riparian habitats. This is particularly problematic for dams on 'white-water rivers' that are ecologically defined by high sediment

* The reduction in lifespan does not occur within the temporal framework of financial analysis (50 years) and thus does not impact feasibility studies (Ho et al. 2017).

loads.* These rivers, which originate in the Andes, drain only twelve per cent of the basin's surface, but contribute more than eighty per cent of the sediments that enter the Amazonian floodplain ecosystem (Figure 2.17).[66] The proposed construction of multiple dams within the Marañon, Ucayali, Madre de Dios and Madeira basins would have long-term consequences on biogeochemical processes in floodplain habitats along the entire course of the river and eventually would impact the intertidal zones of the delta and the marine ecosystems located above the continental shelf at the mouth of the Amazon.[67]

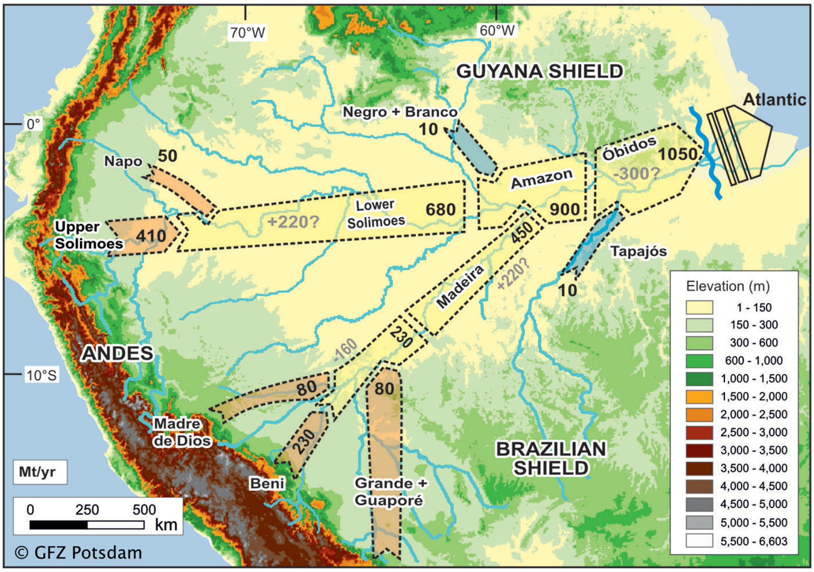
There are other social and environmental impacts associated with large-scale D&R facilities. Large reservoirs displace rural families, forcing them to abandon villages they have inhabited for decades or even centuries. Many dams are built just below a topographic discontinuity to maximise energy production, but these localities are often inhabited by indigenous communities that exploit a natural concentration of fish or occupy an essential portage around non-navigable rapids. Reservoirs not only force these families to move but alter the ecosystem function that sustains the local economy above and below the dam.

The day to day operation of a D&R power plant alters the natural habitats located below the dam because managers manipulate water flows to balance the demand for electricity. These are always substantially different from natural flood regimes that regulate the life cycles of species in floodplain habitats.[68] Amazonian rivers are renowned for the movement of fish and other species between the river channel and the backwater habitats, which are defined by the length and depth of seasonal inundation.[69] Power management disrupts the natural cycles that support wildlife and, consequently, affect the human communities that depend on them. The most obvious impacts occur locally, but alterations to flooding regimes can extend far downstream, while upstream communities suffer impacts when dams block the migration of economically important fish species (Figure 2.17).

Some impacts are global in scale. Amazonian rainforests are characterised by massive quantities of biomass, and if the standing vegetation is not cleared prior to flooding, the reservoir will generate substantial methane emissions via anaerobic decomposition at the bottom of the reservoir. These emissions can last for decades and nullify any potential savings of greenhouse gases (GHG) associated with hydropower as a renewable energy.[70]

One alternative for managing environmental and social impacts is to build dams that employ a run-of-the-river (R-o-R) design that minimises both the size of the reservoir and sediment removal.[71] These configurations still

* There are three broad classes of rivers in the Amazon basin: white water rivers have high sediment loads and neutral pH; black water rivers have low sediment loads and an acidic pH; clear water rivers have low sediment loads and neutral pH; see Chs 8 and 9.



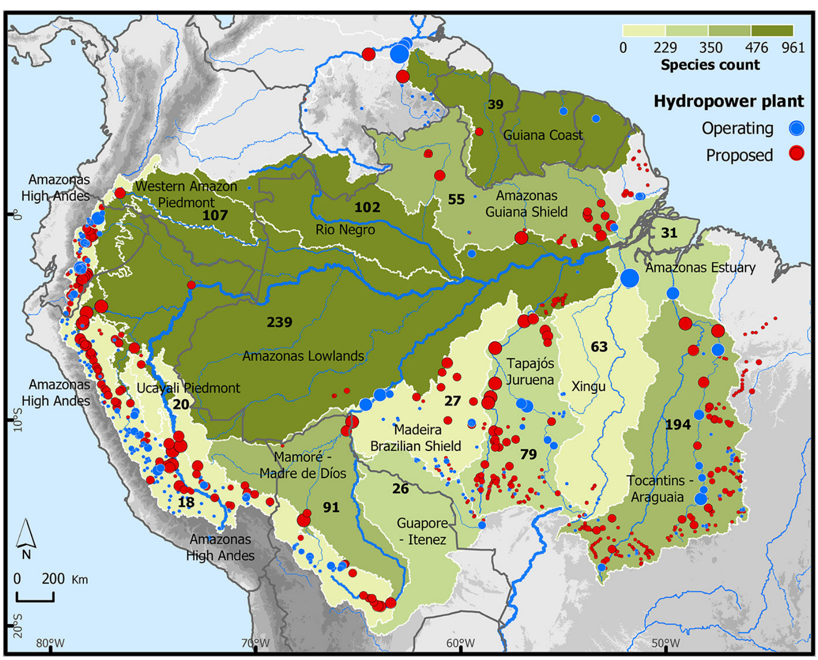


Figure 2.17: Key biophysical attributes of the Amazon Watershed. Top: Source of sediment (see Wittmann et al. 2010). Bottom: Potential fragmentation within freshwater ecoregions; species count refers to species diversity (shade of green), while numbers within polygons are endemic species unique to that ecoregion.

Data sources: Winemiller et al. 2016; RAISG 2021.

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Hydropower facilities that employ dam-and-tube designs avoid most of the impacts associated with dam-and-reservoir and run-of-river designs. They are used in Bolivia at Corani/Santa Isabela (top) and Zongo/Harpa (middle). The concept has been deployed at a few locations in Brazil (Dardanelos, Mato Grosso).

cause impacts linked to biodiversity loss and the disruption of commercial fisheries.[72] From an engineering perspective, R-o-R hydropower facilities are inefficient because they do not store energy in a large reservoir, which limits operators' ability to compensate for seasonal variability in water flows. Moreover, the lack of storage capacity exposes the R-o-R facilities and their linked electrical grids to episodic crises caused by drought, a risk that will be significantly greater in future decades due to climate change.

Dam and tunnel (D&T) designs avoid the pitfalls of both D&R and R-o-R configurations by delivering water to a power plant located several hundred metres below the dam. These configurations are popular in mountainous areas because they generate large amounts of energy per cubic metre of water. Their superior efficiency reduces the need for a large reservoir, particularly in geographies characterised by abundant rainfall. Sediment removal is often close to zero because many D&T combinations are located high in the watershed, where sediment loads are naturally low or because storage times in reservoirs are short. Similarly, their impact on fish populations is minimal because these types of rivers are characterised by waterfalls and rapids that act as natural barriers.

Civil engineers favour large-scale projects because they resolve supply and demand issues over many years and create an infrastructure legacy that appeals to their professional pride. Utility companies prefer them because they conform to their preferred business model of producing energy and commercialising it to urban and industrial centres. Politicians like them because their construction generates tens of thousands of low-skilled jobs. Financial analysts at multilateral institutions approve them because they can allocate significant capital to an industry with guaranteed cash flow that obviates investment risk.

Experience has shown, however, that some projects in the Amazon are just too large or the climatic assumptions that underpin the energy model are inaccurate – or out of date. Unfortunately, corrupt practices have tainted the objectivity of feasibility and environmental studies that are used to evaluate their economic, social and environmental sustainability. Once hydropower was seen as a sign of progress and embraced by a broad sector of society, but that view has changed in recent decades as environmental and human rights advocates have questioned the sustainability of conventional business models.[73] In advanced economies, there is an emerging consensus that some facilities must be dismantled to restore ecosystem function.[74]

The Guri complex and the Caroni Cascade

The largest hydropower complex in Venezuela is the oldest and least sustainable facility in the Pan Amazon. The complex of dams on the Rio Caroni is operated by *Electrificación del Caroni C.A.* (EDELCA), a subsidiary of the state-owned *Corporación Venezolana de Guayana* (CVG) that broke ground on the first D&R power plant at Macagua in 1956 and initiated the construction of the high dam at Guri in 1963.* Energy production began in 1961 at Macagua and at Guri in 1968; both expanded capacity by adding additional turbines over the next two decades to meet demand for electricity during a period of sustained economic growth. Subsequently, EDELCO added an R-o-R facility below Guri at Caruachi that began operations in 2006, and started construction on a fourth power plant at Tocoma in 2009.

When finished, the four facilities combined will have an installed capacity of 18 GW, making the Caroni Cascade the second-largest hydropower complex in the World.† The 162-metre main dam at Guri is almost twice as high as any other dam in the Pan Amazon; it has flooded 425,000 hectares to create the largest man-made lake in South America. The reservoir has a volumetric capacity of 135 cubic kilometres and flow rates that average about 4,850 m^3 s^{-1}, which should be sufficient, theoretically, to maintain maximum water flow for about 320 days per year.

The Caroni hydropower cascade provides almost half of Venezuela's electrical energy, and when rainfall within the watershed falls below normal, waterflow shortages reverberate through the system, immediately plunging the nation into a power crisis. A prolonged drought caused by the *El Niño* phenomenon forced the national power company to impose energy rationing between 2009 and 2013 and again in 2015 and 2016.[75]

The over-reliance on the mega-scale hydropower complex provides three basic lessons: (1) hydropower carries an explicit risk linked to climate variability; (2) diversification of energy sources is essential; and (3) large-scale hydropower suppresses diversification because it outcompetes alternative energy sources during 'normal' years. One positive environmental outcome of the Venezuelan reliance on the Guri complex has been the decision to protect the Caroni watershed with a hundred per cent of the upstream area set aside as a national park or national monument, or zoned as a special watershed reserve with restricted land-use.

The failure to complete the Tocoma dam and power plant is an example of the problems associated with mega-scale hydropower: cost overruns and corruption. The original budget of $US 3.1 billion had increased to $US 9 billion by 2018; an estimated $US 1.5 billion is believed to have been embezzled by governmental functionaries in cahoots with the construction

* This roughly coincides with the construction of Glen Canyon Dam on the Colorado River in Arizona, when building large-scale hydropower was considered to represent 'progress'.

† Itaipú (14 GW) on the border between Brazil and Paraguay is larger than Guri (10.2 GW), but is a stand-alone D&R asset, while the Caroni cascade includes four dams over about 80 km that exploit the same resource.

consortium led by Oderbrecht, the Brazilian firm found guilty of fraud and bribery in the *Lava Jato* scandal.[76]

Tucuruí and the Tocantins Cascade

The oldest hydropower facility in the Brazilian Amazon is the Tucuruí D&R complex (8.4 GW) on the lower Tocantins River, about 200 kilometres south of its confluence with the Amazon River delta.[*] The dam and power plant were built between 1976 and 1984, and its capacity was doubled in 2007; current plans call for capacity to be expanded by another 2.5 GW over the next few years.[77] Tucuruí is owned by Electronorte,[†] a subsidiary of Electrobras,[‡] which supplies most of the electrical energy consumed in the Brazilian Amazon.

Tucuruí was built before the environmental laws that required the completion of an environmental impact study, which allowed its proponents to discount the impacts of a reservoir covering 280,000 hectares and the relocation of an estimated 30,000 citizens, including several indigenous communities.[78] The massive reservoir flooded intact tropical forest and the subsequent methane emissions from rotting vegetation have been estimated at 2.5 million tonnes of carbon annually – a GHG footprint approximately equivalent to a gas-fired power plant.[§] The dam has radically altered the ecology of the river and caused massive disruptions to fish populations. Species richness has fallen by 25 per cent below the dam and by fifty per cent within the reservoir, changes that reflect the composition of fish communities and the decline of migratory species. Total fish catch in the reservoir increased in the years immediately following its impoundment

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* Some geographers do not include this as a sub-basin of the Amazon watershed, but it is similar in biophysical attributes to major Amazonian tributaries, such as the Tapajós or Xingu rivers.

† Electronorte (*Centrais Elétricas do Norte do Brasil S.A*) is composed of 10 subsidiaries and multiple joint ventures that generate or distribute electricity in the different states of the Legal Amazon: http://www.eletronorte.gov.br

‡ Eletrobras (*Centrais Elétricas Brasileiras S.A.*) is the largest electrical utility in Latin America; via its subsidiaries, it owns about 30% of Brazil's generation capacities and controls 43% of the national transmission grid; the Brazilian state owns 42% of the voting shares, which traded on several stock markets; as of January 2021, the administration of Jair Bolsonaro intended to completely privatise the company by the end of 2021. Source: Reuters, July 2020; https://www.reuters.com/article/eletrobras-privatization/brazil-minister-calls-eletrobras-privatization-a-priority-idUSL2N2ET28H

§ Values are for total carbon based on methane emissions expressed as CO_2-equivalents. By comparison, a coal-fired power plant would release about 4 million tons of carbon to produce the same amount of electrical energy, giving Tucuruí a GHG efficiency 2X compared to coal; in contrast, a more efficient hydropower system, such as Itaipú, has a GHG efficiency ratio of about 150X (dos Santos et al. 2006).

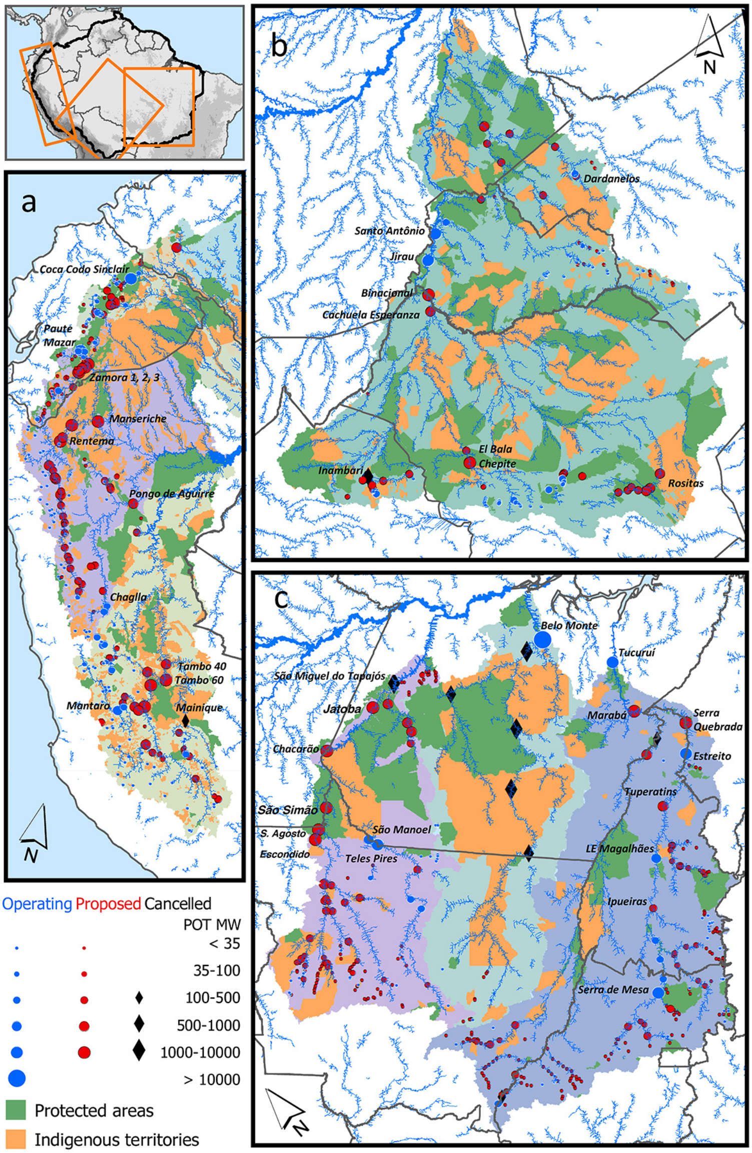

Figure 2.18: The proximity of existing, proposed and cancelled hydropower plants with indigenous lands and protected areas in: (a) the Ucayali, Marañon, Napo, Putumayo and Caquetá watersheds; (b) the Madeira–Mamoré watershed; and (c) Tapajós, Xingu and Tocantins–Araguaia watersheds.

but have declined over time, having stabilised at about eighty per cent of the original value. [79]

The Tocantins is the most heavily exploited watershed in the Brazilian Amazon (Figure 2.18) The Serra da Mesa, a D&R unit, was built in the headwaters near Brasília simultaneously with Tucuruí. These investments were followed by four large-scale D&R projects inaugurated between 2000 and 2010 (Lajeada /Luis Eduardo Magalhães, Cana Brava, Peixe Angical and Sao Salvador)[80] and an R-o-R facility at Esterito in 2014.[81] There are four additional sites on the central sector of the river that are candidates for large-scale dams: Marabá, just below the confluence of the Araguaía and Tocantins, followed by Serra Quebrada, Tuparatins, and Ipueiras (see Annex 2.2; Figure 2.12). The construction of these four dams is required for the development of the Tocantins waterway (see below); none overlap with an indigenous territory or conservation unit. The national energy agency (ANEEL)* has identified 24 additional sites as candidates for medium-scale facilities (<150 MW), all of which are located relatively high in the watershed. If all these proposed dams were completed, the total installed capacity of the Tocantins would increase from about 13.2 GW to 20 GW.[82]

The Araguaía River, the western branch of the Tocantins basin, is free of dams between its mouth at Marabá and central Mato Grosso, although there are several projects planned for the upper watershed. Two controversial projects have been cancelled by the environmental regulatory agency (*Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais* – IBAMA) based on observations made during the environmental impact studies: Santa Isabela, on the lower river near Marabá and at Cachoeira Couto Magalhães, the site of a scenic waterfall on the border between Goiás and Mato Grosso. There are no plans to establish any dams over the mid-section of the river, a broad flat floodplain that includes the Ilha do Bananal, a massive wetland complex that has been set aside as a protected area or indigenous reserve.†

The Madeira hydropower complex

The Rio Madeira was the next Amazonian tributary to attract the attention of Brazil's hydropower developers. The river is free of rapids as it flows along the western edge of the Brazilian Shield for about 1,300 kilometres between Porto Velho (Rondônia) to its junction with the Amazon River near Itacoatiara (Amazonas). Upstream, the watershed is drained by four massive tributaries (Itenez/Guaporé,‡ Mamoré, Beni and Madre de Dios);

* *Agência Nacional de Energia Elétrica* (ANEEL).

† The area is thought to be inhabited by a group of *Avá-Canoeiro* indigenous people who are in voluntary isolation (see Ch. 11).

‡ The river forms the international boundary between Bolivia and Brazil; the Río Itenez is its name in Bolivia and Guaporé is its name in Brazil.

the upper and lower basin are separated by approximately 250 kilometres where four groups of rapids provide a unique opportunity to generate energy from an enormous volume of water collected from a watershed of approximately one million square kilometres.[*]

Between 2005 and 2015, during the administrations of President Lula da Silva and his successor, Dilma Rousseff, the Brazilian state built two mega-scale dams: (1) Santo Antônio, which is located just above Porto Velho; and (2) Jirau, which is located 110 kilometres further upstream near the border with Bolivia. Eventually, the Madeira hydropower complex may include two additional dams: (3) Binacional, which would be located 150 kilometres upstream from Jirau on the border with Bolivia; and (4) Cachuela Esperanza, which would be located another fifty kilometres upstream on the Madre de Dios within the national borders of Bolivia (Figure 2.18). All of these facilities are, or will be, R-o-R facilities because the sites are not well suited to high dams and large reservoirs. Each will be located just below the rock rapids where a low dam will drive a power plant with small reservoirs between 20,000 and 25,000 hectares.[83]

The Brazilian government fast-tracked the design, environmental review and construction of both Santo Antônio and Jirau. Environmental licences were approved in 2008, and the first turbines were operating by 2012; the inauguration of the last fleet of turbines was finalised in 2017. In order to manage the financial and operational risks inherent in two massive projects constructed simultaneously, the government created parallel bidding processes. Each dam was built and is now operated by different consortia: *Energia San Antonio*[†] and *Energia Sustentable do Brasil*.[‡] Financing was spread among multiple domestic banks with BNDES[§] acting as the main source of investment capital; both were included within the IIRSA portfolio due to their potential to facilitate the development of the Madeira waterway (see below).[¶] The original combined cost was projected at R$ 25 billion, but technical challenges caused the budget to balloon to an estimated R$ 43 billion by the end of the project.[84]

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* This stretch of the river became infamous during the first rubber boom as a strategically important bottleneck that provoked a war between Bolivia and Brazil and the construction of misbegotten railroad between Porto Velho and Guayamirim (see Ch. 6).

† Energia San Antonio: Odebrecht, SAAG Investimentos, Furnas Centrais Elétricas, CEMIG and Caixa- FIP,

‡ Energia Sustentable do Brasil; Engie (formerly Suez), Mitsui, Eletrosul Centrais Elétricas and Companhia Hidro Elétrica do São Francisco

§ BNDES: *Banco Nacional de Desenvolvimento Econômico e Social*

¶ IIRSA, - IIRSA, Peru, Bolivia Brazil Hub, Group 3, Corredor Fluvial Madeira - Madre de Dios – Beni. PBB16, Complejo Hidroeléctrico Del Río Madeira (Hidroeléctrica Santo Antonio E Hidroeléctrica Jirau, $US 18.2 billion: http://www.iirsa.org/proyectos/Principal.aspx

The two facilities are considered to be the most expensive hydropower energy on the continent. The cost of energy is exacerbated by the distance from consumer markets, which required an additional investment of $US 3.8 billion for a 2,400-kilometre high-voltage direct-current (HVDC) (600 kV) * transmission line between Porto Velho and Araraquara (São Paulo).[85] Construction of the HVDC† line was completed in 2013; however, a technical audit in 2017 revealed a design flaw that reduced transmission capacity by 25 per cent. Ironically, the power plants had never operated at full capacity and, consequently, the system avoided damage that could have been caused by an imbalance between generation and transmission capacity.[86]

Both the bidding and the construction oversight processes have been called into question by allegations – and eventually proof – of corruption in the *Lava Jato* scandal. Evidence provided in court indicates that (at least) two per cent of the original contracts were paid in bribes by the construction companies to individual politicians and their parties (see Chapter 5). However, this amount does not capture the inflated cost of the actual construction that is reflected in the eighty per cent cost overruns. Theoretically, these losses should be assumed by the concessionaires operating the power stations, but, as regulated utilities, they will probably be allowed to pass on the total (non-penal) cost to the consumer through inflated electricity bills.

Similarly, the costs associated with environmental impacts are not likely to be assumed by the operating companies. For example, the height of the dams was increased after the conclusion of the formal environmental review, which led to a miscalculation in the capacity of the spillway and the size of the water body located between the two dams. This design flaw led to unanticipated flooding in wet years with extreme levels of waterflow. Although funds were allocated to assist families to rebuild or relocate, the companies have managed to avoid legal liability for the irregularities in the environmental review process. [87]

During the planning and construction phase, the Brazilian government essentially ignored the legal issues related to the potential environmental impacts on an international river. The Bolivian government declined to protest or request an international environmental impact study, which would have been amply justified considering the well-known potential impact on migratory fish (Text Box 2.1). Four consecutive Bolivian governments

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* IIRSA, Peru, Bolivia Brazil Hub, Group 3 - Corredor Fluvial Madeira - Madre de Dios – Beni, PBB18: Linea de transmisión entre las dos centrales hidroeléctricas del río madeira y el sistema central, $US 3.8 billion: http://www.iirsa.org/proyectos/detalle_proyecto.aspx?h=336

† HVDC: High Voltage Direct Current is well suited for the bulk transmission of electrical power over long distances, because energy losses average about 3% per 1,000 km, compared to 30 to 40% from AC lines at the same voltage level; source: http://edisontechcenter.org/HVDC.html

Text Box 2.1: 'The dams are blocking the fish' – by Michael Goulding

Dams create impassable obstacles to many, if not most, migratory fish species. Unfortunately, this was recently demonstrated for an iconic Amazonian species: the goliath catfish or dourado (*Brachyplatystoma rousseauxii*), which is remarkable for its size (~2 metres long) and long-distance migration. Adult fish swim upstream from the Amazon Delta to the base of the Andes to spawn while the larvae swim downstream to feed in the rich estuarine waters near the mouth of the river. The Madeira population has the longest migratory route of any freshwater fish.

Tragically, the dams at Jirau and Santo Antônio have ended this ancient evolutionary behavior. The Santo Antônio dam has a fish ladder, which operators hoped would allow individuals to bypass the dam; unfortunately, this strategy has failed. In a recent study, only eleven of 471 tagged individuals were recaptured in the fish passage and only two made it into the reservoir above the dam. Their inability to climb the ladder is probably related to their instinctual navigational talent to track natural features of river morphology. Unless biologists and engineers discover how to trick the fish into climbing the ladder, this species or at least this population, is doomed to extinction.

Michael Goulding, Ph.D. is one of the world's leading experts on Amazonian rivers and their biodiversity and was lead author of the *Smithsonian Atlas of the Amazon*.

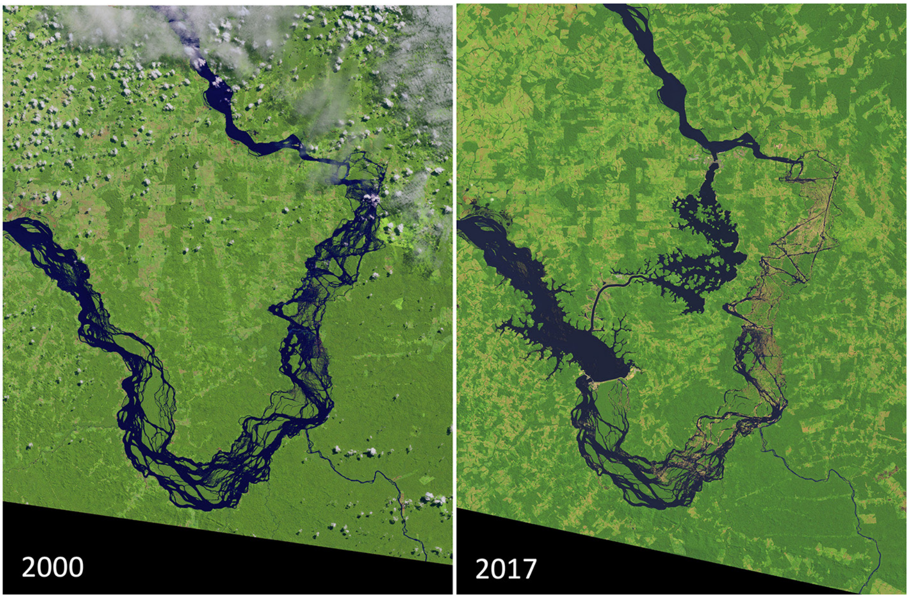
Sources: Barthem et al. 2017 and Cella-Ribeiro et al. 2017.

remained silent during the planning stages, presumably because they all hoped for the eventual completion of the two upstream dams that would include Bolivia as a partner. The collaboration of the Brazilian and Bolivian governments to complete the two remaining hydrodams is an explicit component of the IIRSA portfolio of investments.* The two projects on the Bolivian border remain on hold, in part because the supply of energy in Brazil currently satisfies regional and national consumption, but this will inevitably change as the Brazilian economy grows. The existing HVDC transmission line can be expanded to provide additional capacity, which enhances the feasibility of the Bolivian projects.

Belo Monte and the Río Xingu

The most controversial hydropower project in the Pan Amazon is the complex on the Rio Xingu near the city of Altamira (Pará). The proposal to build a dam on the Rio Xingu dates from 1979 and, as originally conceived,

* IIRSA: Perú-Brasil-Bolivia Hub; G3 - Corredor Fluvial Madeira - Madre de Dios – Beni; PBB12 - Hidroeléctrica Cachuela Esperanza ($US 1.2); PBB17 - Hidroeléctrica Binacional Bolivia – Brasil ($US 5 billion): http://www.iirsa.org/proyectos/Principal.aspx



NASA Earth Observatory

Figure 2.19: The Belo Monte hydropower facility generated enormous civil and legal conflicts. It was redesigned to avoid some of the impacts linked to water impoundment.
Source: NASA Earth Observatory, https://earthobservatory.nasa.gov/images/91083/reshaping-the-xingu-river

consisted of a cascade of multiple dams located at different points along the 2,500-kilometre river. Opposition by indigenous groups, academics and civil society held up the project for decades and caused the government to develop, propose and modify multiple iterations of a constellation of dams, reservoirs and power plants.[88]

In 1987, the government proposed a configuration composed of five D&R units that would have flooded more than 1.7 million hectares of forest and the installation of 24 GW of generating capacity.* This proposal was doomed because it would have flooded hundreds of thousands of hectares of forest within indigenous territories, which were being formally constituted following the constitutional reforms of 1988.† The international

* On the Río Xingu: Kararaõ (11.3 GW/125,000); Babaquara (6.3 GW/627,400 ha); Ipixuana (2.3 GW 327,000 ha), Kokraimoro (1.9 Gw/177,000 ha), Jarina 559 MW/190,000 hectares) and on the Río Iritri (910 MW/4060,000 hectares) (Fainguelernt 2016).

† Eventually, the watershed impacted by the dams would encompass 16 separate indigenous territories; in 1991 the list included TI Kayapo, TI Menkragnoti, TI Arara, TI Capoto/Jarina, TI Paquimba: https://terrasindigenas.org.br

attention caused by the *Encontro das Nações Indígenas do Xingu* in 1989 forced Electronorte to abandon four of the five proposed sites; nonetheless, the company insisted on building the lowest dam on the river, which had the greatest energy potential due to the volume of water and an elevational drop of more than 100 metres (Figure 2.18). Coincidentally, it was located at a spectacular set of rapids, where the Xingu flows off the Brazilian Shield onto the flood plain of the Lower Amazon, known as the rapids of the Volte Grande (Figure 2.19).*

The revised project still provoked fierce opposition from domestic and international groups, as well as technical observations by the environmental protection agency (IBAMA), which were translated into legal petitions filed by the environmental division of the public prosecutor's office (see Chapter 6). The resistance to the dam was organised by the Kayapó, an indigenous nation led by a particularly astute set of tribal leaders. The government planners changed the name of the facility from Kararaõ, the name of a Kayapó tribe, to Belo Monte, the name of the village at the bottom of the Volta Grande. The final version of the Belo Monte hydropower facility is an unusual two-stage D&R facility: an upper dam (Pimental)† that diverts water via a canal to the lower dam and power plants (Belo Monte). The two dams jointly flood 51,600 hectares, of which 38,000 are located on the floodplain above the Pimental dam.[89] An important aspect of the final design was the determination to maintain (reduced) waterflow in the Volte Grande, a measure intended to mitigate the impact on the livelihoods of the indigenous communities residing between the upper and lower dams.

The final scaled-down version of the project was proposed during the administration of Fernando Cardoso and was enthusiastically embraced in 2002 by President Lula da Silva, who, as leader of the workers' party, was attracted by the opportunity to create 50,000 direct and indirect jobs.[90] Construction started in 2011 and the first of eighteen turbines was inaugurated in 2016 during the administration of Dilma Rousseff. Jair Bolsonaro celebrated the completion of the project in 2019.[91]

The Usina Hidrelétrica de Belo Monte became a reality because it had the support of a popular president and his allies in Congress, and the backing of powerful economic interests. It was built by a consortium of construction companies, all of whom would become ensnared in the *Lavo Jato* scandal.‡ The dam and associated infrastructure are operated by *Norte*

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* Volte Grande is Portuguese for Big Bend

† At one stage of the redesign process, this was known as the Altamira dam and before that as *Babaquara* (a demeaning term for a rural inhabitant); the name change occurred when that dam was converted from an energy producing D&R facility to a storage impoundment to support the power plant at Belo Monte.

‡ The shareholders of the Consorcio Construtor Belo Monte are: Andrade Gutierrez (18%), Odebrecht (16%), Camargo Corrêa (16%), Queiroz Galvão (11.5%),

The Belo Monte hydropower complex houses 18 turbines with an installed capacity of 11.2 GW (top). The dam was carved out of primary forest between 2008 and 2012 (bottom).

Energia, a consortium of energy utilities, mining companies and pension funds* Most of the energy generated from the unit will be consumed in Southeastern Brazil via two HVDC transmission lines built by an energy conglomerate from China (see below).

The original estimate for the construction of the entire facility was estimated at R$ 16 billion in 2010, but the final bill is estimated to be about R$ 40 billion in 2020.[92] The total cost is difficult to know due to the complex nature of the contracts and cost overruns that characterise hydropower projects.[93] Converting those numbers into dollars is problematic because the Brazilian Real (R$) lost ~70% of its nominal value when compared to the US dollar over the same period.

In spite of its design to minimise upstream impacts, the dam has drastically curtailed the extent, duration and timing of annual floods in the seasonally inundated forests below the dam, which has changed the ecological functionality of key habitat that supports the river's commercial fisheries.[94] Biologists are particularly concerned about how modified water flows will impact the Tabuleiro do Embauba, a beach located just below the dam where tens of thousands of endangered Giant Amazon River Turtles (*Podocnemis expansa*) congregate annually during the breeding season.[95]

A dramatic example of the biological impact of the dam occurred when operators diverted water to the hydropower facility in 2012. Water flow through the Volte Grande was reduced by eighty per cent and provoked the death of sixteen million tonnes of fish from oxygen starvation when they were stranded in isolated pools in the main channel.[96] A $US 1 billion fund was supposed to compensate the local communities for these impacts, but legal disputes and administrative inefficiencies impeded its disbursement, and the communities were forced to manage what presumably was a foreseen impact without the assistance they had been promised in the environmental action plan.[97]

Unfortunately, the hydraulic models used in the design of the complex two-stage facility failed to take into account the impact of periodic droughts and, in 2019, reduced water flows forced operators to shut down all but one of its eighteen turbines.[98] In late 2020, the environmental protection agency (IBAMA) ordered the company to increase water flows through the Volte Grande, which placed it in danger of defaulting on its energy

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OAS (11,5%), Contern (10%), Galvão (10%), Serveng (3%), J. Malucelli (2%) e Cetenco (2%). Source: Bloomberg, https://www.bloomberg.com/research/stocks/private/snapshot.asp?privcapid=48811102

* The shareholders of *Norte Energia* are: Eletrobras (49.98%) with the remainder distributed among Companhia Energética de Minas Gerais, Light S.A., Vale, Siderúrgica Norte Brasil, J.Malucelli Energia S.A., Fundação Petrobras de Seguridade Social, Fundação dos Economiários Federais (total 50.02%). Source: https://www.norteenergiasa.com.br/pt-br/ri/composicao-acionaria

supply obligations. If this situation recurs or becomes a chronic event, the financial viability of the entire enterprise will be compromised.[99] The loss of electricity from Belo Monte would cause an energy deficit in the national grid that would be particularly serious in the Southeast and Centre West regions of the country.[100]

The Tapajós Basin and the prevalence of indigenous rights

The Tapajós is a clear-water river and the fifth largest tributary of the Amazon; it drops in elevation from about 800 metres above sea level in the highlands of central Mato Grosso[*] to less than seven metres at its confluence with the Amazon River near the city of Santarem. More than 45 sites have been identified as suitable for the installation of hydropower facilities within the basin, which includes the lower river and its two major tributary-branches, Teles Pires and Juruena.[101] As with the Caroni, Xingu, and Tocantins, the largest dam with the greatest potential energy is at the bottom of the watershed, where large volumes of water flow off the Brazilian Shield. Ten sites were selected for development, of which four were under construction by 2015 (São Manoel, Sinop, Colíder, Teles Pires); however, the three largest units (São Luis do Tapajós, Jatoba and Chacarão) were sidelined because they are located within or adjacent to indigenous territories (see Figure 2.18).[102]

The proposed dam at *São Luiz do Tapajós* is located at a set of rapids about 350 kilometres upstream from the mouth of the river; it would have consisted of two dams with a total installed capacity of 8.1 GW.[103] In 2016, the environmental protection agency (IBAMA) rejected the request for a construction permit on the advice of the public prosecutor (MPF) and the federal agency overseeing indigenous affairs (FUNAI).[104] The denial was based on the impacts to indigenous communities and their explicit protection by the Constitution of 1988. The proposed R-o-R dam would have permanently flooded about 72,000 hectares, including 12,500 hectares claimed by a Munduruku community. The decision was noteworthy because the community had yet to gain formal recognition for its territorial claim; the ruling thus extended the concept of protection to include indigenous lands outside of indigenous territories (see Chapter 11).

In 2018, the agency that regulates hydropower facilities (ANEEL) announced that all large-scale projects in the Amazon were being placed on hold because of the challenges of obtaining environmental licences for projects that impacted indigenous communities. The decision to forgo

* Mato Grosso contains the watershed divide between the Amazon and Paraná-Paraguay basins; its most notable geomorphological features are flat-topped plateaus (*planaltos)* and escarpments (*chapadas*) such as the Planalto de Parecis (Northwest), the Chapada de Guimaraes (Central) and the Planalto de Alto Araguaia (Southeast).

development of large-scale projects in the Amazon was influenced by the poor economic returns and the corruption scandals that plagued the Belo Monte complex and two dams on the Rio Madeira.

It is not clear whether the decision to halt the development of São Luis do Tapajós, Jatoba and Chacorão will be reviewed following the election of Jair Bolsonaro, but the construction of all three dams is essential for the proposed Tapajós/Teles Pires waterway (see below).[105] Less important for waterway development, but with greater potential for large-scale hydropower, are sites on the Rio Juruena (São Simão Alto, Salto Augusto Baixo, Escondido), all of which are located within or adjacent to an indigenous territory. Also under consideration are four medium-scale D&R facilities (Jamanxim, Cachoeira do Caí, Cachoeira dos Patos, Jardim de Ouro) located within the confines of Parque Nacional Jamanxim; these sites were presumed to be included within the category of cancelled projects, but a review by the Bolsonaro administration has revived the possibility they will be put back on the list for future development.[*]

The Río Trombetas and the Calha Norte

In 2010, Electronorte initiated the construction of a high-tension (500 kW) transmission line to connect the power plants at Tucuruí and Belo Monte; this line was extended north to the Amazon River with connections to Macapá (Amapá) and Manaus (Amazonas).[†] This ambitious undertaking required the construction of extraordinarily tall tower paillons (300 metres) in order to cross the 2.5-kilometre width of the Lower Amazon.[‡] The line roughly parallels the right-of-way of PA-254, an unimproved regional highway, and supplies electricity to dozens of towns and villages that relied previously on expensive energy from small-scale diesel generators (HML #1).

The transmission line will eventually be extended to Boa Vista (Roraima), following the right-of-way of BR-174; however, its completion has been stalled because it traverses the territories of the Waimiri-Atroari indigenous people who have questioned aspects of the environmental impact

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* These are under development by a consortium of companies that include Eletronorte (Eletrobras), ENGIE, Camargo Corrêa, Cemig, Copel, Électricité de France (EDF) and Neoenergia. Source: Universo Online, https://economia.uol.com.br/noticias/reuters/2020/05/25/estudos-sobre-hidreletricas-no-tapajos-tem-prazo-prorrogado-ate-2021-pela-aneel.htm

† Prior to its connection to the grid, Manaus received about 20% of its energy from the Balbina hydropower dam and 80% from thermoelectric plants powered by natural gas from the Urucú fields located in the Western Amazon (see Ch. 5).

‡ IIRSA, Amazon Hub, Group 05, AMA87, Línea de Transmisión de 500 kV de Tucuruí a Manaos ($US 1.3 billion): http://www.iirsa.org/proyectos/detalle_proyecto.aspx?h=1390

study (See Chapter 11). Ironically, the need for electricity in Roraima has been exacerbated by the termination of a long-standing supply of electricity from the Guri complex in Venezuela.*

Hydropower development has relatively strong support among the inhabitants of both Amapá and Roraima.[106] In Amapá, the D&R unit at Ferreira Gomes (250 MW) and the R-o-R dam at Cachoeira Caldeirão (219 MW) were built between 2008 and 2016 with minimal opposition.† In Roraima, the proposed development of the Bem Querer (650 MW) on the Rio Branco has strong support from the business sector in Boa Vista.[107] The proposed D&R unit would flood approximately 56,000 hectares but is located on a landscape long impacted by smallholder settlements (HML #55) and would not infringe on any existing protected areas or indigenous territories.‡ Environmental advocates oppose the dam because studies show that it will impede the annual migration of the goliath catfish (see Text Box 2.1) and impact the geochemistry of the Rio Negro.[108]

Even more controversial is the recently announced plan to resurrect the development of the Cachoeira Porteira (3 GW) D&R complex on the Rio Trombetas. First proposed in the 1980s, it was included in the national inventory of potential dam sites in 2006 by the Empresa de Pesquisa Energética (EPE), the agency within the *Ministerio de Minas and Energia* responsible for developing the nation's long-term energy strategies.[109] In that report, however, the EPE observed that two of these potential sites were located within a conservation unit, two in indigenous territory, and two in an INCRA-sponsored settlement deeded to Quilombola§ communities. The Cachoeira Porteira project was subject to a preliminary evaluation in 2014, and following consultation with the local communities, the public prosecutor's office recommended that all of the proposed sites in the Trombetas watershed be removed from consideration for future development.[110] The development of Cachoeira Porteira was resurrected in January of 2019 as part of Jair Bolsonaro's plan to extend the BR-163 highway to the border with Suriname and open the Calha Norte to development.[111]

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* In 2020, the Bolsonaro administration was considering declaring an emergency to force the construction of the transmission line. Source: Reuters, https://www.reuters.com/article/energia-linhao-indios-idLTAKBN1ZK2LN

† Both these facilities are 100% privately owned and include investors from Europe and China; financing was provided by BNDES.

‡ The environmental review is being paid for by the *Programa de Parcerias de Investimentos* (PPI), a federal programme that supports the private sector investment. Source: PPI, https://www.ppi.gov.br/uhe-bem-querer-rr

§ The quilombolas are descended from escaped slaves who settled in remote communities across the Brazilian Amazon; they are considered to be a 'traditional community' with special use rights. See Ch. 4.

Bolivia seeks an energy export model

Bolivia's hydropower is based on medium-scale facilities located in a geographical region optimally suited for D&T systems. The oldest of these is in the Zongo Valley, which starts at 4,700 metres above sea level with a small reservoir (~20 hectares) that feeds water into one of eleven power plants, with a total installed capacity of 188 MW. Several similar D&T systems have been built in a region known to geographers as the Elbow of the Andes, where annual rainfall exceeds 6,000 millimetres across an altitudinal drop of 4,000 metres and a horizontal distance of less than forty kilometres (Figure 2.18). Within this area, the state-owned electrical company, *Empresa Nacional de Electricidad Bolivia* (ENDE), has recently undertaken a series of investments that will double the nation's hydropower capacity over the next few years by expanding capacity at Corani (275 MW) and Miguillas (250 MW),[*] as well as adding a new unit at the Ivirizo cascade (290 MW).[†]

Bolivia privatised its electrical energy sector in the 1990s, but Evo Morales renationalised the industry in 2006 as part of a policy to use public investments in energy and infrastructure to drive economic growth and, more importantly, generate revenues for the national treasury. In the first decade of its reincarnation, ENDE focused on building out the national grid while relying on subsidised natural gas to generate power. Eventually, however, ENDE began to focus its investments on hydropower with the explicit goal of creating a surplus of electricity for export to neighbouring countries.[112] Most of these investments were financed from the national treasury and are leveraged with loans from multilateral institutions; however, ENDE has engaged Chinese companies and hopes to entice Brazilian institutions to finance the mega-scale projects on its northern border (see below).

In addition to the D&T facilities under construction in the highlands of the Elbow of the Andes, ENDE plans to build a 600 MW D&R facility on the Rio Grande where it emerges from the Andes. Originally conceived in the 1970s, the dam will have serious environmental impacts, including the displacement of 500 Guaraní families who inhabit the valley, which will be flooded by a 40,000-hectare reservoir. Like all such dams located in the Andean foothills, its reservoir will capture massive amounts of sediment (Figure 2.17) and block the migration of important commercial fish species.[113] Rositas will be a dual-purpose dam and divert water for irrigation that will

* Corani Cascade: Santa Isabel (148 MW) San José (124 MW), Banda Azul (133 MW), Villa Jorka/ Santa rita (44 MW), Ambrosia (85MW), Santa Barbara (85MW); Miguilleas Cascade (440 + 200 MW); Misicuini (120 MW), Oquitos (125 MW) and Molineros (100MW): see http://www.ende.bo/#

† In 2017, Synohydro was awarded a $US 553 million contract to build the Ivirizu D&T facility (290 MW); this is not a loan and is financed with funds from the Bolivian treasury: https://fundacionsolon.org/2020/02/18/china-bolivia-deuda-comercio-inversiones

catalyse the expansion of industrial agriculture across 500,000 hectares of dry forest. Ironically, the diversion of water for irrigation will reduce the replenishment of the aquifers that underlie the alluvial plain of Santa Cruz and limit the irrigation potential on the country's most important agricultural landscape.[114]

The Rositas project enjoys the support of all major political parties and, more importantly, the enthusiastic backing of the business community in Santa Cruz. Potential future hydropower investments on the Rio Grande include five more upstream dams that would add another 2.5 GW to the system.[*] The EIA for the project was executed internally by ENDE with support from the IDB, while the construction contract has been awarded to a consortium led by Synohydro with financing from the ExIm Bank of China.[115] A small but determined group of social and environmental activists has organised a campaign to stop its development by deploying a seldom-used class-action civil procedure that theoretically can halt initiatives that do not comply with health, safety, environmental or social regulations (see Chapter 6). The five upstream D&R units will prolong the economic life of Rositas because they will capture an enormous amount of sediment but, if they are not built, the lifespan of Rositas will be among the shortest in the Amazon – 135 years.[116]

Other investments that are part of Bolivia's strategy to export electrical energy include the development of the two R-o-R dams on the Madeira River[†] (see above) and two large-scale D&R projects on the Rio Beni. The original concept for the Rio Beni, first proposed in 1952, envisioned a 200-metre dam at the Angosto de El Bala, which would have created a massive reservoir covering almost 400,000 hectares. Different iterations of the project were rejected as uneconomic in 1958, 1976 and 1998; meanwhile, the project became even more controversial due to the creation of two high-profile protected areas: Parque Nacional y Tierra Indígena Pilón Lajas (1992) and Parque Nacional Madidi (1995).

The latest configuration is based on a feasibility study contracted by the government in 2015, which calls for a two-stage D&R design with a 168-metre dam and 68,000-hectare reservoir at the Angosto de Chepite, a gorge located about fifty kilometres upstream from an R-o-R facility at Angosto de El Bala. This scaled-down version would limit the total area flooded to 78,000 hectares overall and to 10,000 hectares within the two

* Rositas (600 MW); La Pesca (740 MW); Peña Blanca(520 MW); Ocampo (320 MW); Las Juntas (172 MW); Cañahuecal (500 MW) y Seripona (420 MW). See, Fundación Solon: https://fundacionsolon.org/rositas/

† IIRSA: Perú-Brasil-Bolivia Hub; G3 - Corredor Fluvial Madeira - Madre de Dios – Beni; PBB12 - Hidroeléctrica Cachuela Esperanza ($US 1.2);; PBB17 - Hidroeléctrica Binacional Bolivia – Brasil ($US 5 billion): http://www.iirsa.org/proyectos/Principal.aspx

protected areas; an estimated 4,000 individuals would need to be relocated.[117] Opposition among indigenous communities, the tourist industry and environmental advocates is strong, but the poor economics of the facility are the largest obstacle to its development.[118]

As recently as 2018, the Bolivian government hoped to invest about $US 25 billion by 2025 to quintuple installed capacity from about 1.2 GW to more than 10 GW, approximately five times greater than the estimated domestic demand in 2025.[119] Electricity exports would require significant investment in regional transmission systems, such as those proposed by the IDB in 2017: Bolivia – Brazil (500 kV), Peru – Bolivia (250 kV) and Bolivia – Chile (250 kV).[120] As of 2020, however, Bolivia remains isolated from potential markets, in spite of being a signatory to the *Sistema Andino de Interconexión Eléctrica* (SINEA), an IIRSA-like initiative to integrate the regional energy grids. The ability to pursue these capital-intensive investments is limited by Bolivia's deteriorating financial status,[*] and it is unlikely that financial and technical assistance from China or Brazil will allow the country to implement its ambitious schemes in the short to medium term.[121]

Peru embraces the private energy sector

Peru has enjoyed historic levels of economic growth for more than two decades, mostly due to the expansion of the minerals sector, which is a large consumer of electrical energy. Peru has also made strides in providing affordable electrical energy to its citizens, including to small towns and rural areas via a national grid that now integrates most coastal and highland regions as well as the major colonisation zones in the tropical lowlands.[†] Iquitos remains the only large urban area unconnected to the national grid, and there are plans to make that link over the short-term.[‡]

The consolidation of the Peruvian electrical sector has been accompanied by robust growth in generation, which has increased by about 150 per cent since 2005. Approximately 35% of the country's electricity comes from hydropower, which is sourced approximately equally from the Pacific and Amazon watersheds. Projects on the western slope of the Cordillera Occidental often enjoy subsidies because of their irrigation potential, but

* The balance of payments has fallen from a high of $US 2 billion annually in 2012 to a negative $US 2 billion in 2019; the reversal has caused the country's foreign reserves to fall from of $US 14 billion to less than $US 2 billion in 2020. Source: The World Bank Group, https://data.worldbank.org/country/bolivia

† IIRSA COSPILAN Perú-Brasil-Bolivia Hub, G01: G1 - Corredor Porto Velho - Puertos del Pacífico; PBB59 Línea de Transmisión San Gabán - Puerto Maldonado ($US 23 million).

‡ That connection would require a high tension line through a roadless wilderness area characterised by swamp forest and has generated opposition from environmental advocates.

those resources are inherently limited due to the rain shadow of the Andes. Consequently, most future expansion will take place on the eastern slope of the Andes (Figure 2.18).

In the early 1990s, the state-owned, vertically integrated electricity monopoly was broken into multiple units dedicated to generation, transmission and distribution. The role of the state was limited to developing policy, enforcing regulations and granting concessions.* By 2017, 54 different corporate entities were supplying energy to the Peruvian grid; the largest of them supplies about twenty per cent of the country's electrical energy.[122] The build-out of Peru's electricity sector occurred after the discovery of the Camisea gas field (see Chapter 5), which favoured investment in thermal generation because it is less capital-intensive when compared to hydropower. Moving forward, however, the state intends to decrease its reliance on thermal energy and promote investment in renewable energy. The official plan includes small-scale hydropower but does not consider medium- and large-scale hydropower as a 'renewable' energy.[123]

The exclusion of Peru's traditional hydropower sector is ironic, because it can objectively be characterised as 'sustainable'. Most existing power plants are D&T systems that exploit topographic drops located high in watersheds, which limits their environmental and social impact. Even projects with relatively large reservoirs have a much smaller spatial footprint when compared to D&R facilities located at lower elevations. As in Bolivia, they consist of two to three medium-scale units organised as a cascade, with water recycled from one power plant to another – for example, Mantoro I & II (1,000 MW),† Santa Teresa I & II (500 MW) and San Gabín II & III (313 MW).[124]

The opposition to conventional hydropower is the consequence of failed attempts to develop mega-scale D&R facilities in the foothills of the Andes, where large rivers pass through a narrow gorge (see Annex 2.2).‡ In 2008, the governments of Alan García (Peru) and Lula da Silva (Brazil)

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* The regulatory agency OSINERGMIN (*Organismo Supervisor de la Inversión en Energía y Minería*) oversees the technical, administrative and financial activities of three sectors: mining, hydrocarbons and electrical energy; concessions are managed via the *Dirección de Concesiones Eléctricas*, a separate entity within the ministry.

† Peru's largest hydropower complex, Mantaro I & II, collects water at the 100-ha reservoir behind the Tablachaca dam and diverts it though a 19-km tunnel to the Santiago Antúnez de Mayolo power plant (798 MW), which then recycles that water via the river channel to the Restitución power plant (210 MW) located 10 km downstream.

‡ Madre de Dios Basin: Inambari Gorge (2.2 GW). Ucayali Basin: Urubamba: Pongo de Manique (942 MW); Tambo: Tambo-40 (1.2 GW), Tambo-60 (579 MW), Tambo-P Prado (620 MW); Ene: Sumabeni (1.1 GW), Paquitzapango (1.4 GW); Mantaro: Viscatani (750 MW), Cuquipampa (800 MW). Huallaga Basin: Pongo

signed a memorandum of understanding that sought to integrate the two countries' electricity markets by developing Peruvian hydropower resources using Brazilian technology and capital.* The agreement was signed during the surge in investments in dams on the Tocantins, Xingu, and Madeira and involved the same corporate entities that were designing, financing, and building the hydrodams in Brazil. The initiative focused on localities in southern Peru, where the Corridor Interoceanico offered a right-of-way so transmission lines could connect with the HVDC line that services the dams on the Madeira River.†

The first mega-project to be pursued was a D&R complex on the gorge where the Rio Inambari exits the Andes (Figure 2.18).‡ The project was immediately embroiled in controversy as opponents coordinated actions at local, national and international forums. They successfully demonstrated that the project was seriously flawed and the national environmental agency (OSINERGMIN) declined to approve its EIA in 2011. The impact of that outcome reverberated through the business community, and none of the other proposed mega-scale projects was seriously considered for development. The Peruvian Congress shelved the agreement in 2014 and all of the concessions have subsequently expired.

Although mega-scale projects have proven unviable, several medium- and large-scale investments have been completed successfully. Prior to 2005, the Amazonian watersheds housed eleven power plants with about 1.7 GW of capacity; this was increased by six units and 1.3 GW by 2018 and is projected to grow by another nine plants and 2.7 GW by 2023 (see Annex 2.2). The sector's largest operators are domestic companies, many of which have formed joint ventures with investors from Norway, Italy, Spain, France, Israel, Chile, and the United States. Most of the development has taken place on the Marañon watershed, which has the greatest potential among the three major Amazonian tributaries (Figure 2.20). The large-scale facility at Chaglla on the Rio Huallaga (456 MW), which was inaugurated by Odebrecht of Brazil in 2016, was sold to the China Three Gorges Corporation in 2017 following the *Lava Jato* corruption scandal (see Chapter 6).

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de Aguirre (750 mW). Marañon Basin: Pongo de Manseriche (7.5 GW), Pongo de Escuptebraga (1.8 GW), Pongo de Retama (1.5 GW).

* The proposed scheme required ElectroPeru and Electrobras to sign long-term purchase agreements, while Brazilian construction companies would build and operate the facilities (Odebrecht, OAS, Andrade Gutiérrez, Camargo Correa); key financing would be provided by BNDES.

† The proposed dams included: Inambari (2 GW), Sumabeni (1.1 GW), Paquitzapango (2 GW), Mainique (940 MW), Tambo 40 (1.3 MW) and Tambo 60 (600 MW) (Orcotorio-Figueroa 2020).

‡ The dam would have been located just a few kilometres upstream from the Huepetuhe gold field (see Ch. 4) and the reservoir would have flooded part of the Interoceanic Corridor highway (see above).

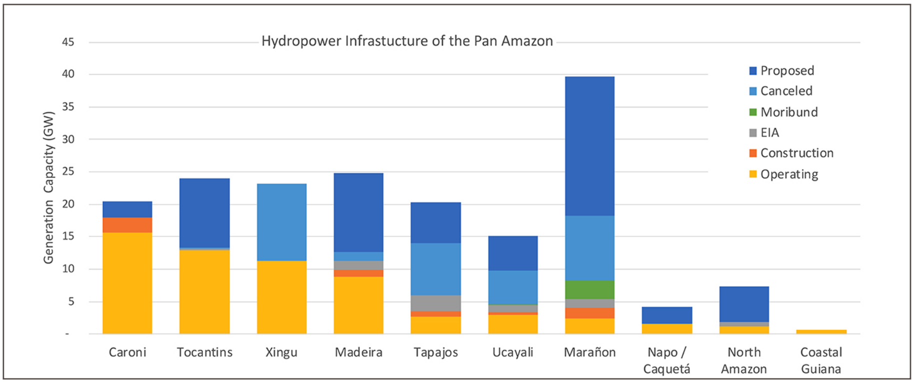

Figure 2.20: The existing, planned and potential hydropower capacity of the major Amazonian river basins.

Data source: modified from RAISG 2021.

Although impacts from hydropower development have been limited to date, that may change if the industry starts exploiting the hydrological resources of the Rio Marañon. Following the demise of the project on the Rio Inambari, President Alan García issued an executive order declaring the development of hydropower and irrigation infrastructure on the Rio Marañon to be in the national interest, a designation that accelerates development by easing environmental reviews and facilitating access to public moneys.[125] The configuration of that river basin makes it particularly attractive for conventional D&R facilities; unfortunately, its geochemistry and biodiversity make it particularly susceptible to environmental impacts (Figure 2.17).

As in southern Peru, the most problematic projects are located in a gorge where the Marañon transects the Andean foothills; this 200-kilometre-long section of the river is the site of three putative mega-scale projects.[*] It is highly unlikely that any of the three D&R projects would ever pass an environmental review, because they would inundate land deeded to Awajún communities who are renowned for their opposition to projects that infringe upon their territorial rights.[†] More likely is the development of the 25 D&R projects on the 500-kilometre section of the river above the regional capital

* The Quechua word for narrow gorge is *pongo* and these sites are known as: Pongo de Manseriche (7 GW), Pongo de Escuprebraga (1.8 GW), Pongo de Rentama (1.5 GW)

† Opposition to hydropower during this period was galvanised by the Baguazo, a peaceful protest that turned violent when the Awajún objected to policies that promote private investment in the Peruvian Amazon (see Ch. 11).

of Jaen into the highlands of Central Peru. This section is attractive to civil engineers because the river collects run-off from the mountains situated to the east and west, while the V-shaped valley provides multiple opportunities for deep reservoirs with significant storage capacity. [126] In 2014, Odebrecht initiated feasibility studies on four potential dam sites;[*] however, none had advanced beyond the EIA stage when the *Lava Jato* corruption scandal effectively ended that company's ability to execute projects in Peru.[†]

Only a single hydropower dam is being promoted for the non-Andean sections of the Peruvian Amazon: The Mazán R-o-R project would be located on a narrow isthmus separating the Napo and Amazon rivers 25 kilometres downstream from Iquitos and forty kilometres upstream from the mouth of the Río Napo. It would include an eleven-metre dam across the Napo that would divert a fraction of that river's current through a canal across the three-kilometre isthmus to the main channel of the Amazon River. The power would satisfy energy demand from Iquitos and, potentially, supply a proposed transmission line between Yurimaguas and Iquitos.[‡] There are numerous reasons to doubt the technical and financial viability of this project,[127] but the governor of Loreto continues to insist it remains viable and important for the development of the region.[128]

Ecuador chooses hydropower with assistance from China

The recent history of hydropower in Ecuador is similar to that described for Bolivia and Peru, particularly with respect to its recent expansion and the predominance of D&T systems that exploit the geographic advantages of the Andean Cordillera. Like Bolivia, the state has assumed a near monopoly on generation and has turned to China for technological assistance and financial capital. In 2013, Ecuador sourced about forty per cent of its electricity from hydropower but increased its contribution to 58 per cent by 2019, while national consumption grew by forty per cent. Approximately, eighty per cent of Ecuador's installed hydropower is generated by power plants on the Napo, Pastaza and Santiago watersheds.[129]

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* Cumba-4 (825 MW), Lorena (634 MEW), Chadin-2 (600 MW); Rio Grande I (600 MW); Río Grande II (150 MW) (Orcotorio-Figueroa 2020).

† Odebrecht maintains only one hydropower asset in Peru: The Olmos Project on the Huancabamba River, a tributary to the Marañon that diverts water through a 19-km tunnel under the Andes to a pair of power plants, prior to supplying water to approximately 40,000 hectares of irrigated farmlands near the Pacific Coast.

‡ Critics observe that the building of both a tension line and a dam is redundant, while the city recently inaugurated a 100 MW thermal power plant powered with fuel produced by the Iquitos Refinery.

Much attention has focused on the recently inaugurated large-scale project with the unusual name of Coca Codo Sinclair.* The design of this new power plant takes advantage of a 650-metre vertical drop that includes a natural waterfall and multiple rapids across about 75 kilometres of river channel. The D&T design diverts water through a 25-kilometre tunnel to turbines at the bottom of the bend with installed capacity of 1.5 GW. It is the largest power plant in Ecuador and supplies about 25 per cent of the national electricity demand. Like most mega-scale projects, it was conceived in the 1950s and underwent multiple iterations before being commissioned by the Ecuadorian government in 2009. It is operated by a subsidiary of the national electrical monopoly *Corporación Eléctrica del Ecuador* (CELEC), but was built by a Chinese construction company, Sinohydro and financed by the Export-Import Bank of China.[130]

The direct environmental impacts appear to be moderate. The reservoir is only 300 hectares and sediments are flushed back into the Coca River periodically; the barrier to fish migration was pre-existing because of the presence of the San Rafael Falls, which are located between the dam and the powerhouse. The facility is located between two national parks, PN Cayambe Coca and the PN Sumaco Galeras, but all of the infrastructure is located on a river valley previously impacted by the right-of-way for an oil pipeline and deforestation along the Troncal Amazónica (see above). The area is sparsely populated, and there is little evidence that local populations have objected to its development.

An unexpected event now threatens the physical integrity of the hydropower complex. In February 2020, the river eroded a channel underneath the lava dyke that created the waterfall and left the once magnificent cascade a mere trickle of water. Once the solid rock of the lava dyke was isolated from the erosional forces of the river, however, the river started to erode through the loosely consolidated sediments of the Coca river floodplain.[131] By December 2020, the top of the waterfall, now a series of rapids, had migrated approximately three kilometres upstream towards the dam and intake tunnel.†

At the current rate of erosion, the top of the cascade could reach the dam in approximately two years, which could force the operators to close

* The facility bears the name for its location at a large river bend (codo = elbow) on the Río Coca, which was first surveyed in the 1920s by the geologist Joseph H. Sinclair (Sinclair and Wasson 1923).

† The erosion caused the failure of an oil pipeline that crossed the river Coca, causing significant oil spill that impacted dozens of indigenous communities downriver and eventually reached the Amazon River. Source: Reuters, 8 Apr. 2020. https://www.reuters.com/article/us-ecuador-oil-spill/ecuador-scrambles-to-contain-oil-spill-in-amazon-region-idUSKCN21R2JU

the tunnel leading to the power plant.* The vertical drop between the dam and the bottom of the falls is similar to equivalent stretches of the river below the falls and above the dam; consequently, civil engineers will probably be able to safeguard the installation. Nonetheless, the incident calls into question the competence of the original feasibility study and the EIA, as well as the wisdom of building a strategically important infrastructure asset at the base of an active volcano (El Revantador).[132]

In spite of its size, the Coca Codo Sinclair is not the largest hydropower complex in Ecuador; that distinction belongs to a cascade of dams and powerplants on the Rio Paute, a tributary of the Santiago River. The Centro Hidroeléctrico Hidropaute began with the inauguration of the Molina D&R unit in 1983 (500 MW) and its expansion in 1991 (600 MW), which was followed by the construction of the D&T units at Mazar in 2010 (170 MW) and Sopladora in 2018 (385 MW). A fourth unit, Cardanillo (596 MW), is under development, and when it is completed, the total combined capacity from the four facilities will exceed 2.1 GW.† The CH Hidropaute is another subsidiary of CELEC, and its newest addition was built by the China-Gezhouba Group with loans from the ExIm Bank of China.

Further expansion is being planned for the Rio Zamora, the southern branch of the Santiago River, with a projected combined capacity of between 5 and 7 GW. The most likely design foresees three D&R units in a cascade though a narrow valley that transects the Cordillera del Condor. Such a design would not be unlike the proposed 'Pongo' dams on the Rio Marañon and the El Bala/Chepite project on the Rio Beni.[133] Ecuador has many options for renewable energy, particularly wind and geothermal, but hydropower is the largest component of its future development plans.[134]

The future of hydropower in the Pan Amazon

The past two decades saw a massive increase in hydropower across the Pan Amazon. The Brazilian government has scaled back investment in mega-scale hydropower projects but continues to pursue development of medium and large-scale projects.[135] Cost overruns at hydropower dams across the world have exposed them as poor investments (Figure 2.21),

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* The dam is located approximately 19 km and 205 vertical metres above the riverbed below the falls, which translates into a vertical drop of 0.0103 m per metre of riverbed, compared to 0.0112 m/m over a similar stretch of the river below the falls and 0.0091 m/m above the dam.

† Mazar is a dam-and-reservoir facility at the top of the cascade (2100 m.a.s.l with a 159-m drop), from which water is fed into dam-and-tunnel systems located at Molina (1,310 m.a.s.l and 6-km tunnels), Sopladora (930 m.a.s.l. and 4.7-km tunnel) and Cardanillo (925 m.s.a.sl. and 4-km tunnel). Source: CELEC, Hidropaute, https://www.celec.gob.ec/hidropaute/

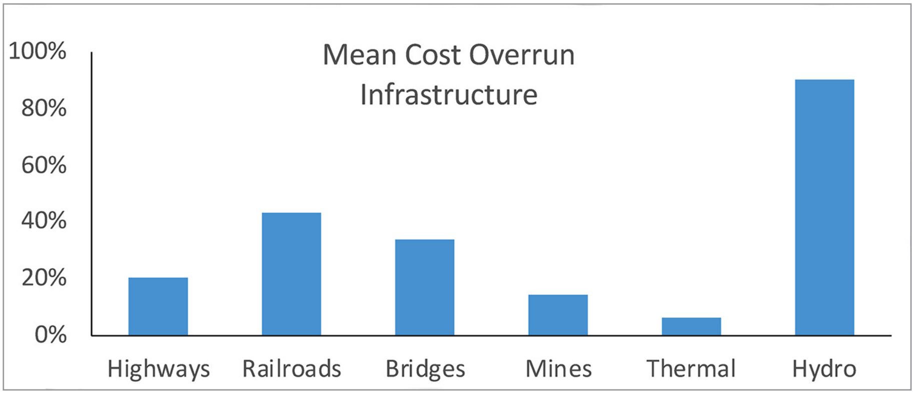

Figure 2.21: Global averages for cost overruns on infrastructure.
Data source: Ansar et al. 2014.

and the national development bank (BNDES) has curtailed investments because it does not have the financial resources for mega-scale projects.

Another factor that may impact future development is the pending privatisation of Electrobras, the state-owned corporation that was the instigator of most hydropower projects. A corporation managed for the profit of its shareholders may be less willing to allocate private capital for large-scale infrastructure investments with dubious economic returns, particularly if the global trend toward solar and wind lessen the need for large-scale hydropower within national development plans. [136]

A policy contingent on economic and political considerations can be reversed using similar criteria, and resistance to the policy to end mega-scale hydropower in the Amazon appeared within days of its announcement.[137] The administration of Jair Bolsonaro has sent clear signals that large-scale hydropower is part of its development agenda, including a prolongation of the window to complete environmental reviews for dams on the Rio Tapajós and reinitiating feasibility studies for a large-scale dam on the Rio Trombetas that had been abandoned in 2014.

Bolivia's strategy to export electricity will face tough competition from corporations investing in state-of-the-art industrial solar parks on the Pacific coast.[*] The government is motivated by the belief that a macro-economic

* Chile's largest solar powered facility (220 MW) is located in the Atacama near the Bolivian border (http://www.acciona-energia.com/areas-of-activity/photovoltaic/major-projects/el-romero-solar-pv-plant/); Peru's largest solar power plant (144 MW) is near Moquegua in Southern Peru: https://www.enelgreenpower.com/where-we-are

policy based on infrastructure investments will drive economic growth, but the proposed model is dependent on foreign investment capital. It is not clear, however, whether Chinese investors will risk their capital on Bolivia's highly uncertain business model. Geopolitical criteria might convince Brazil to purchase the energy from the mega-scale dams on the Rio Madeira where Brazil has compatible energy assets.

In Peru, the metallurgical sector will continue to drive investment in energy infrastructure, a phenomenon that will accelerate as demand for copper from advanced economies increases with their transition to electric vehicles.* The growth of solar and wind energy will limit the demand for high-impact hydropower, but their intermittent nature may motivate investments in hydropower to ensure grid stability. This energy model would favour D&R facilities because they are most adept at managing variations in supply. Ecuador will continue its expansion of hydropower and could experience a step-change in demand if the government follows through on the proposed electric railroad system (see below).

Colombia will continue to develop its hydropower resources, but most of these will focus on non-Amazonian watersheds; Venezuela is unlikely to invest in hydropower over the medium-term due to its current economic crisis. Neither Surinam nor Guyana will need to invest in hydropower because they can generate electricity at very low cost using natural gas that will soon be abundant from offshore platforms (see Chapter 5). Nonetheless, in 2020, the newly elected government of Guyana expressed a desire to resurrect the abandoned Amalia Falls hydropower project that died a natural death in 2013 due to financial considerations.[138]

The role of China adds an element of uncertainty to the trajectory of the hydropower sector across the Pan Amazon. Its engineering companies have a record of building facilities on time and on budget, which could change the economic calculus that currently makes mega-scale hydropower unattractive. Similarly, its state-owned financial institutions have the capacity to mobilise the capital required by large-scale projects and can leverage their status with the Chinese state to mitigate the risk of default. Finally, they have shown the flexibility to operate in multiple regulatory environments: they have acted both as investors purchasing distressed assets in Brazil and Peru and contractors providing turn-key solutions for the design and construction of hydropower assets in Ecuador and Bolivia.

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* The current generation of electrical vehicles use approximately three times as much copper as a standard gasoline powered vehicle

Global Competition Drives Bulk Transport Systems

The modification of the rivers in Brazil has been driven by energy development, but investment in dams has the potential of creating an economically attractive option for shipping Brazil's farm exports to overseas markets. In the 2019/2020 crop year, Mato Grosso produced 35 million tonnes of soybeans, an increase of about forty per cent over 2015/2016.[139] In 2017, nine per cent was consumed within Mato Grosso, six per cent was shipped to other Brazilian states and the remainder was exported directly to overseas markets, mainly China (66 per cent) and Europe (twelve per cent). Soybeans are transported to export terminals by a combination of truck, rail and barge. Producers in Mato Grosso are overly reliant on truck transportation because they operate on frontier landscapes without access to modern rail systems. Until recently, most exported their production via ports in São Paulo and Paraná due to logistical constraints that limited transit to ports on the Amazon River. The need for bulk transport systems has increased over the last decade, not only due to an increase in soy production, but because of a parallel growth in exports of maize, which is increasingly grown in rotation with soybeans (see Chapter 3).

Truck transportation is inherently inefficient, and the cost of moving grain by truck 2,000 kilometres to the Port of Santos in São Paulo has fluctuated between $US 80 and 120 per ton over the last decade.[140] Farmers in Mato Grosso compete in global markets with producers from other counties with significantly lower transportation costs. In Argentina, the distance is typically less than 400 kilometres, and its legacy railroads provide producers with an efficient transport option; for example, the cost between Cordoba and the port of Rosario is only $US 30 per ton.[141] The distance between producing landscapes and export terminals in the United States is longer, but the US has highly efficient bulk transportation systems, including an extensive rail network and the Mississippi waterway, where the shipping costs from Iowa to New Orleans (2,300 kilometres) is only $US 20 per ton.[142]

Opportunities to lower transportation costs are the most obvious intervention point for improving the competitiveness of Brazil's soybean exports. Lower transportation costs will enhance profitability for Mato Grosso's farmers because commodity traders pay producers the international price for their harvest minus the cost of transport and logistics.[*] High transportation costs are essentially a rent that benefits truckers and

* This includes storage fees at regional grain silos, transport, storage and other fees at the export terminal, as well as the cost of marine transport. Depending upon volatile global commodity markets, logistics and transport can represent as much as 40% or as little as 10% of the FOB price paid at the export terminal. The cost of transportation is a powerful incentive for adding value to grain production within Mato Grosso (see Ch. 3).

Investment in bulk transport systems is a priority as inefficient trucking systems are replaced by waterways and railroads: Parking lot of a truck service centre on BR-163 in northern Mato Grosso.

impedes farmers' ability to invest in their productive capacity, which explains why agribusiness has made investments in bulk transport systems a national priority.

As the cultivation of soy exploded across the Southern Amazon, the global commodity traders* and logistical companies† began to invest in transportation systems via the Amazon River. By 2013, approximately thirty per cent of the soy cultivated in central Mato Grosso was exported via Amazonian ports, and by 2017 this proportion had increased to seventy per cent.[143] The shift in transportation patterns has not been due to a reduction in grain shipped via southern ports – that amount has remained relatively constant – but to increased production within the Amazon.

Amazonian options are organised into three logistical corridors with different multimodal combinations of truck, barge and rail (Figure 2.22; Table 2.1). Simultaneously, the cost competitiveness of the southern option has been improved by the extension of a rail line into southern Mato Grosso that has reduced the truck transport component by 1,400 kilometres. Producers

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* Often referred to as the ABCD traders, because of the dominance of **A**DM, **B**unge **C**argill, and Louis **D**reyfus; in Brazil the group also includes Amaggi (Brazil), Glencore (Swiss) and COFCO (China).

† Each commodity trader operates their own logistical supply chain, but they share the market with Brazilian shipping companies: *Companhia Norte de Navegação e Portos* (Cianport); *Hidrovias do Brasil*; *Transportes Bertolin and Chibatão*. Source: ANTAQ - *Agencia Nacional de Transportes Aquaviáriuas*.

Investment in bulk transport systems is a priority as inefficient trucking systems are replaced by waterways and railroads: A barge convoy on the Río Madeira (top); rail cars being loaded at the grain terminal at Rondonópolis, Mato Grosso (bottom).

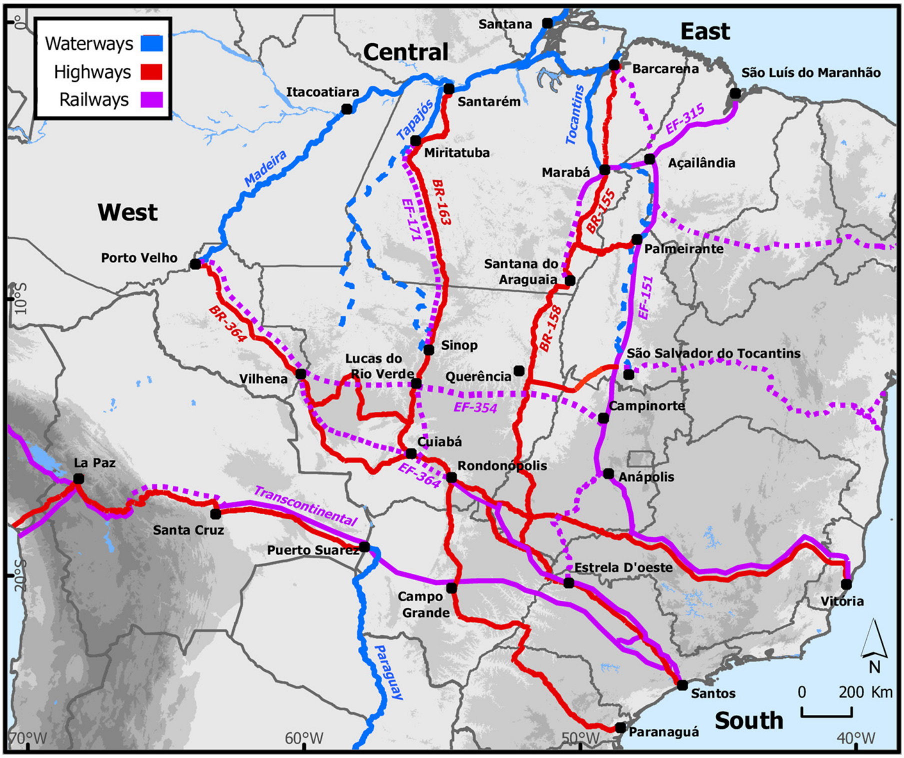

Figure 2.22: Bulk transport systems under evaluation for moving grain production from Mato Grosso to export terminals. These can be organised into four different corridors: West, via BR-364, Porto Velo and the Madeira River to Itacoatiara; Central, via BR-316 to Miritituba on the lower Tapajós or Santarem; East, via BR-158/EF-151/EF-315 to São Luis do Maranhão; and South, via Rondonópolis to Santos via EF-364. Rail and waterways are replacing truck-based systems along all three routes (see text). Data source: Instituto Mato Grossense de Economia Agropecuária (IMEA).

across central Mato Grosso now have four options for commercialising their production:

1). West: Farmers truck their grain via BR-364 to Port Velho, where it is loaded on barges for trans-shipment to Itacoatiara (Amazonas), a port located 75 kilometres east of Manaus, just across the channel from the mouth of Rio Madeira.

2). Central: Farmers truck their grain north via BR-163 to Santarem or Miritituba (Pará) on the Rio Tapajós for loading onto barges for trans-shipment to ocean-going ports on the Amazon River.

3). East: Farmers can use truck transport (BR-158/155) to Marabá (Pará) or the recently completed rail line, Ferrovia Norte – Sur (EF-151), both of which connect with the pre-existing rail line, Estrado Ferro Carajás (EF-315), between Marabá and São Luis do Maranhão.

4). South: Farmers across the region have the option of trucking their grain to a large logistical complex at Rondonópolis (Mato Grosso) where they can transfer their grain to the Ferrovia Norte (EF-364)* for trans-shipment to the grain terminals at Santos (São Paulo). [144]

The expansion of Amazonian ports has improved the profitability of Mato Grosso farmers, but those benefits remain limited by a combination of factors, including a lack of silos and port facilities, poorly maintained roads and, in the case of Porto Velho, an additional 1,000 kilometres of barge transport.[145] The long-awaited completion of BR-163 in 2019 eased some of these constraints and motivated commodity traders and logistic companies to invest in silos and barge-loading facilities at Miritituba,† fleets of high-capacity barges and the expansion of the grain terminals at Barcarena and Santana.‡

Between 2013 and 2017, exports via the three northern corridors represented an annual saving of about $US 100 million when compared to the previous option of trucking production to Santos or Paranaguá (Paraná). The transition from truck to rail for the 1,400 kilometres between Rondonópolis and Santos, however, represented an even greater savings of approximately $US 200 million.§ The transition to rail highlights the potential savings that will accrue as the logistical systems continue a transition away from truck transport and toward rail and barge systems. The estimated savings from future investments in bulk transport systems, perhaps as large as $US 1 billion annually, will lower the logistical cost of producers from central Mato Gross to levels that are cost competitive with their global competitors (Table 2.2). Not surprisingly, farmers are strong advocates for the construction of railways and the modification of rivers so they can function as commercial waterways.

* Sometimes referred to as the Malha Norte (Northern Network)

† Estação de Transbordo de Cargas (ETC) at Miritituba in 2020: ETC-Cargill, ETC-Cianport; ETC-Hidrovias do Brasil; ETC-Unitapajós (Amaggi & Bunge); ETC-LDC (Louis Dreyfus Company); ETC-Bertolini (Transportes Bertolini); ETC-Chibatão. Source: ANTAQ.

‡ Barcarena: Terminais de Uso Privado (TUP) Ponta da Montanha (ADM & Glencore); TUP Unitapajos (Amaggi & Bunge), TUP Villa do Conde (Hidrovias do Brasil,); Santana: Cia Norte de Navegação e Portos. There are also gran terminals at Itacoatiara (TUP Hermasa/Amaagi) and Santarem (TUP Cargill).

§ The potential savings are even greater, because rail transports only about 50% of the grain shipped from Mato Grosso to Santos. Source: *Globorural*, 10 May 2018, Safra de Mato Grosso usa mais ferrovia para chegar ao Porto de Santos: https://revistagloborural.globo.com/

Table 2.1: Estimated transportation options available to producers between 2010 and 2016 for grain shipped from three municipalities in Mato Grosso; cost estimates are derived from the USDA.[218]

Point of Origin *Corridor*	Export terminals (Route options)	Truck (km)	Barge (km)	Rail (km)	Sea (km)	Truck ($/t)	Barge ($/t)	Rail ($/t)	Sea ($/t)	Total ($/t)
Sapazal										
West	Itacoatiara via Porto Velho (BR-364 + R. Madeira)	1,450	1,100		21,760	66.14	19.00		26.67	**112**
South	Santos (various high-ways)	2,260			20,400	100.86			25.00	**126**
	Santos via Rondonópolis (EF-364)	725		1,400	20,400	35.07		24.00	25.00	**84**
Sinop										
Central	Santarem (BR-163)	1,300			21,160	59.71			25.93	**86**
	Santarem via Miritituba (BR-163 + R. Tapajós)	1,000	300		21,160	46.86	8.09		25.93	**81**
South	Santos (various high-ways)	2,250			20,400	100.43			25.00	**125**
	Santos via Rondonópolis (EF-364)	700		1,400	20,400	34.00		24.00	25.00	**83**
Querencia										
East	Itaqui via Marabá (BR-226)	1,989			16,602	89.24			20.35	**110**
	Itaqui via Palmas (EF-151 + EF-315)	718		1,150	21,203	34.77		20.43	25.98	**81**
	Barcarena via Marabá (BR-155)	1,875			20,818	84.36			25.51	**110**
South	Santos (various high-way)	1,789			20,400	80.67			25.00	**106**
	Santos via Rondonópolis (EF-364)	853		1,400	20,400	40.56		24.00	25.00	**90**

Table 2.2: Estimated cost of transportation options for grain shipped from three municipalities in Mato Grosso based on probable future development; cost estimates are derived from the USDA.[219]

Point of Origin *Corridor*	Export terminals (Route options)	Truck (km)	Barge (km)	Rail (km)	Sea (km)	Truck ($/t)	Barge ($/t)	Rail ($/t)	Sea ($/t)	Total ($/t)
Sapazal										
West	Itacoatiara via Porto Velho (EF-364 + R. Madeira)	50	1,100	1,400	21,760	6.14	19.00	23.09	26.67	**75**
	Itacoatiara via Pimenteiras (R. Guaporé + R. Madeira)	250	2,500		21,760	14.71	38.09		26.67	**79**
South	Santos (EF-354 + EF-364)	50		2,400	20,400	6.14		36.73	25.00	**68**
Sinop										
Central	Santarem (EF-171)	50		1,300	21,160	6.14		21.73	25.93	**54**
	Santarem via Miritituba (EF-171)	50	300	1,000	21,160	6.14	8.09	17.64	25.93	**58**
	Santarem (R. Tapajós/ Tele Pires)	50	1,600		21,160	6.14	25.82		25.93	**58**
South	Santos (EF-364)	50		2,250	20,400	6.14		34.68	25.00	**66**
Querencia										
North	Itaqui (EF-360 + EF-151+ EF-315)	100		1,780	21,203	8.29		28.27	25.98	**63**
	Barcarena via Marabá (BR-155 + R. Tocantins)	1,314	550		21,203	60.31	11.50		25.98	**98**
	Barcarena via Palmerirantre (R. Araguaía + R. Tocantins)	872	1,250		20,818	41.37	21.05		25.51	**88**
South	Santos (EF-354 + EF-151 + EF-364)	100		1,800	20,400	8.29		28.85	25.00	**62**

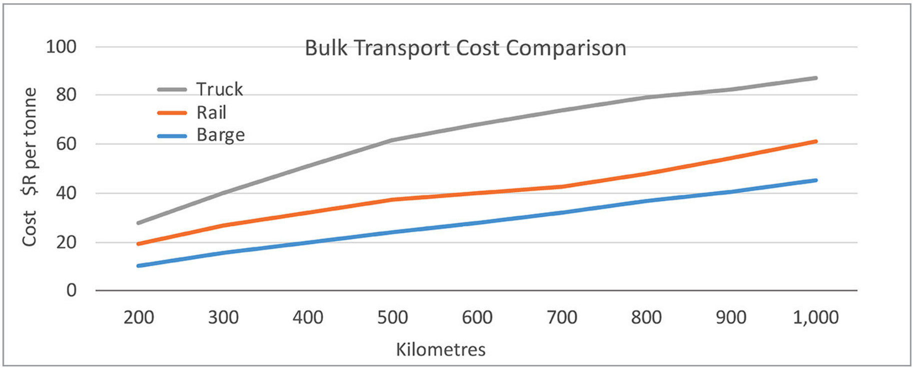

Figure 2.23: The comparative cost of three different bulk transport system as a function of distance for farmers in central Mato Grosso, Brazil.
Data source: ANTAQ 2008.

The Institute of Economic Analysis (IPEA) of Brazil assessed the comparative costs and benefits of waterways when compared to railroads.[146] Based on a standard unit of 1,000 kilometres, a projected lifespan of 25 years, and an average transport of 10 million tonnes of goods per year, fluvial transportation was estimated to be about 35 per cent less expensive when compared to railways (Figure 2.23). This estimate excluded capital investment in dams, however, which are essential components on all Brazilian waterways; for this reason, the construction of hydropower assets constitutes a massive subsidy. The IPEA included neither the cost of the environmental damage that this type of infrastructure would inflict on the Amazon ecosystem, including modifications to the hydrology of its river systems, nor the increased deforestation that might be stimulated by the expansion of agriculture.

Waterway options

The main stem of the Amazon River has provided access to ocean-going cargo ships for centuries, including modern container ships that service the manufacturing sector in Manaus and ore-carriers that haul bauxite from near Oriximiná (Pará) and iron ore and manganese from Santana (Amapá). The first modern grain terminal, built at Itacoatiara in 1998 across from the mouth of the Madeira River (Amazonas), was followed in 2003 by one at Santarem (Pará) at the mouth of the Tapajós, in 2014 at Barcarena near Belem (Pará) at the mouth of the Tocantins, and in 2016 at Santana (Amapá) on the north side of the Amazon delta. These terminals are currently receiving grain from barge loading facilities located at the top of the three major

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The Amazon Waterway is a transportation corridor with a service sector based in Manaus that caters to dozens of communities.

transportation corridors, each of which has developed or hopes to expand an industrial waterway, known as a *hidrovía*.*

Above Manaus, on the section of the river known as the Solimões, river traffic declines by several orders of magnitude because there are no industrial mines or agricultural landscapes producing commodities at scales required to support a bulk transport system. A few ocean-going cargo ships hauling timber are known to operate sporadically from Iquitos (Peru)[147] or deliver heavy machinery required by the oil and gas industry at Coari (Amazonas) and Iquitos. River traffic consists largely of riverboats providing fuel and consumer goods to riparian communities (HML #3), cruise liners catering to tourists on the Rio Negro and timber for the manufacturing sector in Manaus or for export to overseas markets. There is an uptick in activity on the tri-border area around Tabatinga (Brazil), Leticia (Colombia) and Santa Rosa de Yavarí (Peru).

The aspiration of creating an industrial waterway between Brazil and the Andean republics is a major component of the IIRSA investment portfolio (Figure 2.1), which includes eighteen projects organised in four groups with a total budget of $US 530 million.† This basket of proposed

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* The term *hidrovía* is used in both Spanish and Portuguese; Brazil also employs the term *aquivía* as a synonym.

† IIRSA. Amazon Hub: G1 - Acceso a la hidrovía del Putumayo ($Us 3 million); G2 - Acceso a la hidrovía del Napo ($25 million); G3 - Acceso a la hidrovía del

The extractive industries use the Amazon waterway as a bulk transport system and for logistical support for the gas plant at Coari (top); the grain terminal at Santarem is one of several ports that exports soy and maize cultivated in the Southern Amazon (bottom).

and completed projects represents a laudable effort to provide sustainable transportation options that minimise the need for roads. Unfortunately, most river port investments on the Andean piedmont are akin to the *Field of Dreams* approach to infrastructure planning: *If you build it, they will come*.[*] There is no commercially relevant bulk cargo in either direction between Brazil and the Andean nations, while the manufactured goods produced in Manaus are not likely to be competitive with similar products from East Asia.

That does not mean, however, that these are not 'good' investments. They provide essential services to many isolated communities of the region that are being denied road access in the name of forest conservation. As such, their development should not be viewed as an investment that will pay for itself but as a subsidy to support nature-based livelihoods. Ironically, the one example where a waterway might be able to support a self-sufficient commercial transportation system is opposed by environmental and social advocates: the Hidrovía Amazónica between Iquitos, Yurimaguas, Pucallpa and Saramariza in Peru.[148] Resistance is based, in part, on the impacts caused by dredging operations on problematic sections of the river but also from current operators and inhabitants, including indigenous communities, who fear they will be exploited by the concessionaire that has been awarded the contract to upgrade and operate the waterway.[†]

Río Madeira

The largest tributary of the Amazon[‡] has functioned as a fluvial corridor for millennia and was a major commercial artery during the rubber booms of the nineteenth and twentieth centuries. Since 1998, it has experienced a commercial revival due to the transport of soy and maize, and Porto Velho is now one of the busiest ports in the Amazon (Figure 2.22). Historically, navigation between the Madeira and its tributaries of the upper watershed

Huallaga – Marañón ($53 million); G4 - Acceso a la hidrovía del Ucayali ($Us 55 Million); G6 - Red de Hidrovías Amazónicas ($us 305 million): http://www.iirsa.org/proyectos/Principal.aspx?Basica=1

* The film *Field of Dreams* is a 1989 American sports fantasy drama starring Kevin Costner, whose character builds a baseball diamond in a cornfield. The term 'if you build it, they will come' refers to a common error by would-be entrepreneurs who invest time in money based on a passionate belief in a vison rather than rigorous due diligence and feasibility studies.

† The waterway will be operated by *Sociedad Concesionaria Hidrovía Amazónica S.A.* (COHIDRO), a joint venture between the Hidalgo Group of Peru and Sinohydro of China; the consortium signed a 20-year contract in 2017 valued at approximately $100 million. Source: https://www.ositran.gob.pe/anterior/hidrovias/hidrovia-amazonica/

‡ It is the largest by volume of water at 31 m^2/sec, which represents 14% of the total at the mouth of the Amazon (Ziesler and Ardizzone 1979).

(Itenez/Guaporé,* Mamoré, Beni and Madre de Dios) were blocked by multiple rock outcrops distributed along approximately 200 kilometres between Porto Velho and Guajará-Mirim.† About half of these rapids have been flooded by the dams built at Santo Antonia y Jirau, while the rest would be flooded by the two dams that have been proposed for future construction (see above).‡

In 2013, the Brazilian Transportation Ministry evaluated the feasibility of extending the Madeira waterway beyond Porto Velho and confirmed that the construction of the two additional dams would resolve the physical blockages that impede navigation.[149] If all four dams were enhanced by the construction of locks, navigation via the Madeira waterway would extend fluvial transportation to central Mato Grosso (1,200 kilometres via the Guaporé), the agricultural frontiers of the Chapare and the Guayaros (1,000 kilometres via the Mamoré), the Bolivian Yungas (500 kilometres via the Rio Beni), and southern Peru (1,000 kilometres via the Madre de Dios).§

The agency that manages Brazil's commercial waterways, *Agência Nacional de Transportes Aquaviários* (ANTAQ), considers the Guaporé to be an economically important waterway and has, on occasion, supported its extension.[150] However, the 2013 feasibility study identified physical attributes, such as seasonally shallow water and excessive sinuosity, that limit its utility as an industrial waterway while highlighting the presence of indigenous territories in Bolivia and Rondônia that would complicate its development. The agribusiness sector shows no interest in developing the Guaporé as a bulk transport waterway, presumably because it would not be cost competitive with rail (see below).

The most enthusiastic supporters of a greater Madeira–Mamoré waterway have always been Bolivian politicians who dream of converting their lowland provinces into agricultural breadbaskets.[151] This aspiration may be another example of the if-you-build-it-they-will-come syndrome; however, the regional government of Beni has approved a new land-use

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* The river forms the international boundary between Bolivia and Brazil; Río Itenez is its name in Bolivia and Guaporé is its name in Brazil.

† This stretch of the river became infamous during the first rubber boom as a strategically important bottleneck that provoked a war between Bolivia and Brazil and the construction of a misbegotten railroad between Porto Velho and Guayamirim (see Ch. 6).

‡ IIRSA, G3 - Corredor Fluvial Madeira - Madre De Dios – Beni, PBB12: Hidroeléctrica Cachuela Esperanza ($US 1.2 billion; PBB16, Complejo Hidroeléctrico del Río Madeira (Hidroeléctrica Santo Antonio e Hidroeléctrica Jirau), PBB17, Hidrolectica Binacional Bolivia p- Brasil: http://www.iirsa.org/proyectos/

§ IIRSA, G3 - Corredor Fluvial Madeira - Madre De Dios – Beni: PBB13, Hidrovía Ichilo Mamoré; PBB14, Navegabilidad del Río Ben; PBB 15, Hidrovía Madre de Dios y Puerto Fluvial; all are in the 'planning stage' with no projected budgets: http://www.iirsa.org/proyectos/

planning framework that legalises the conversion of one million hectares of savanna habitat for the cultivation of soy, corn and rice, which has the support of both the central government and the agribusiness sector of Santa Cruz (Chapter 4).

Río Tapajós

The Brazilian Transportation Ministry and the agribusiness sector view the Tapajós River as a strategically important waterway located between the most productive farmlands of Mato Grosso and grain terminals on the Amazon River. It is, however, a technically challenging river with multiple rapids that limit its navigability during twelve months of the year. The Tapajós can be used as an industrial waterway only if a series of dams (between three and six) are constructed to create lakes that flood the most problematic rapids and regulate water flows necessary to ensure transit by barge (Figure 2.18).[152]

The waterway was selected for priority development in the late 2010s, and construction was initiated on four dams on the upper the basin: Teles-Pires, São Manual, Sinop and Colíder.[153] The environmental licensing process was initiated for São Miguel do Tapajós, the lowest and largest dam, while development of the two dams located on the mid-section of the river (Chacarão and Jatoba) were placed on the docket for future evaluation. Following the political backlash that accompanied the constriction of the Belo Monte hydropower complex and the corruption scandals that marred the dams on the Rio Madeira, political support for the São Miguel project declined, and the environmental authorities successfully denied approval of its environmental licence (see Chapter 11). This determination has effectively killed the Tapajós–Teles Pires waterway project because the three lower dams are all keystone elements, and if any one of them is eliminated, the waterway is rendered nonfunctional.

Currently, the Tapajós is navigable for 300 kilometres between its mouth and the twin towns of Itaituba and Miritituba, located across from each other at the top of a naturally inundated valley situated at the base of the northern border of the Brazilian Shield.* Itaituba is the larger of the two towns and capital of the municipality, but Miritituba is located near the intersection of BR-163 and BR-230, making it the preferred site for building logistical facilities for loading barges for trans-shipment to grain terminals on the main stem of the Amazon River. Unless the Brazilian Congress acts

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* Sea levels were about 120 m lower at the last glacial maximum during the Pleistocene (~ 20,000 years before present); this caused the Amazon to carve a deep valley that was subsequently refilled with sediments delivered by white-water rivers originating in the Andes. Clear-water rivers, such as the Tapajós and Xingu, lack high sediment loads; consequently, their paleo channels and floodplains became ‘drowned valleys’ that geomorphologists refer to as *ria* lakes (Fricke et al. 2017).

to create a legal mechanism that overrides the 1988 Constitution or the Murunduku indigenous people modify their opposition to dams (Chapter 11), the Tapajós waterway will be limited to the section between Miritituba and the Amazon River.

Tocantins and Araguaia

These two parallel rivers drain the landscapes between the highlands of central Mato Grosso and western Bahía; consequently, they are strategically located to provide a transportation option for two of Brazil's most important agricultural landscapes. Both are candidates for waterway development but differ in their physical characteristics and the complexity of the social and environmental challenges that accompany the development of an industrial waterway (Figure 2.18). The two rivers come together at Marabá, then flow north toward Tucuruí Dam, which was outfitted with locks in 2010, creating the first essential asset on the Araguaía–Tocantins waterway system.*

The Araguaía requires less investment in dams and locks (Santa Isabela and Araguanã) but suffers from seasonally low water levels due to its broad flat floodplain (Figure 2.18). In contrast, the Tocantins has a relatively confined river valley but with numerous rock outcrops that require the construction of several dams and their associated locks. In 2013, the transportation ministry decided to limit its waterway investments to the Tocantins, in part, because of the existence of two dams (Estreito and Lajeado) and the planned construction of three additional hydropower units (Marabá, Serra Quebrada and Tuperintins).[154] The decision not to pursue the Araguaía waterway avoided the inevitable confrontation over the operation of an industrial waterway on the border of a large indigenous territory (TI Araguaía) and two protected areas (PN Araguaía and PE Cantão).†

The inevitable confrontation with environmental advocates began with the difficulty in obtaining an environmental licence to modify the channel of the Rio Tocantins at the Pedral do Lourenço, a massive rock outcrop situated between the Tucuruí Reservoir and the city of Marabá. This stretch of the lower Tocantins is navigable during highwater seasons, but an industrial waterway must be open twelve months of the year to be economically viable. Proposals to dynamite a channel through the Pedral would impact the nesting habitat of two species of aquatic turtles, an endemic species of dolphin and migratory catfish that have already suffered population declines caused by the construction of the Tucuruí Dam.[155] Delay in the approval of the licence has frozen the use of the waterway for

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* The locks were built 30 years after the inauguration of the dam at a cost of R$ 1.6 billion (~$US 300 million; source: G1 Globo.com, 1 July 2017, Demora nas obras do Pedral do Lourenço afeta a economia no Pará: https://g1.globo.com/

† TI: Terra Indigena (indigenous reserve); PN: Parque Nacional; PE: Parque Estadual

The lock at the Tucuruí dam, built between 2007 and 2010, has opened the Tocantins Waterway for future development (top). If the government's plans come to fruition, the run-of-river dam at Estreito will be modified to incorporate a lock that would extend the waterway several hundred kilometres upstream.

almost ten years, in spite of strong support from both national and state authorities * and the demands of private investors who have committed significant financial capital in developing port facilities in Barcarena, Marabá and Imperatriz (Tocantins).

Development of the Tocantins waterway above Marabá is less than certain. To reach the border with the state of Goiás – the goal of the transportation ministry – would require the construction of three more large-scale dams at the cost of between $US 5 and $10 billion, and the installation of locks at all five hydropower facilities at approximately $US 100 million each.[156] Other impediments include the need to build access roads between the farms in Mato Grosso and the waterway, which would entail building a highway across an enormous wetland complex (Ilha de Bananal) that is part of the Araguaía indigenous territory.

Paraná – Paraguay

This non-Amazonian waterway is navigable between Corumbá (Mato Grosso do Sul) and ports in Argentina and Uruguay; it is used by mining companies operating near Corumbá but is not an export corridor for agricultural commodities from Brazil. It is, however, an essential transportation asset for Bolivia's agroindustry, whose producers in Santa Cruz (HML #31) are 2,000 kilometres from the nearest Atlantic port. Pacific ports are closer at 1,500 kilometres but they are also situated on the other side of a 5,000-metre pass via roads that are not designed for high-capacity grain trucks. Bolivia's soybean producers are absolutely dependent upon the Paraguay River and a legacy railroad system (see below), without which they would be unable to compete in global markets.

Railroad Development

The challenges to developing waterways have focused investor's attention on railroads. In 2020, the Amazon Hub of the IIRSA portfolio included eight rail projects, which were either completed (2), under construction (1) or on the drawing boards (5). The estimated total budget ranges between $US 20 and $US 30 billion, but even the larger number is an underestimate because it excludes several of Brazil's most ambitious initiatives.† The Brazilian rail-

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* The EIA was commissioned in 2014 and is financed by the Program de Parcerias de Investimentos, a federal programme that fast-tracks infrastructure investments; the R$ 650 million contract was approved in 2016. The project has the support of Jader Barlbaho, an influential senator from Pará. Source: *Associaçao Brasileira de Operadores Logisticos*, https://abolbrasil.org.br/posts/derrocamento-do-pedral-do-lourenco-deve-ter-inicio-em-2021/

† IIRSA, Amazon Hub, Group 5 G08: G8 - Conexión Ferroviaria Porto Velho - Nordeste Meridional de Brasil (5 Projects @ $US 9 Billion); G05: G5 – Conexión Entre La Cuenca Amazónica y El Nordeste Septentrional De Brasil (5 projects

road sector is an unusual mixture of private and public corporations, and a concessionaire system where public assets are leased to private companies that commit to large capital investments.* Starting in 2008, the federal government launched an initiative to expand the rail network, particularly new lines that would penetrate the agricultural landscapes of the Southern Amazon and the Amazon-adjacent landscapes of Northeast Brazil, which are collectively referred to as MATOPIBA.†

Following is a description of the major rail investments underway in the Brazilian Amazon (Figure 2.22).

Ferrovia Norte (EF-364).

This is probably the most lucrative railroad in Brazil. Built between 1998 and 2012, it has dramatically lowered the cost of commodity transport from the farms of central and southern Mato Grosso to the port of Santos (São Pualo). Operated by Brazil's largest private railroad company (*Rumo Logístico*),‡ the line currently reaches Terminal Ferroviário de Rondonópolis, a massive logistical facility with the capacity to tranship twelve million tonnes per year. The ninety-year concession for EF-340 stipulates the rail line will be extended to Cuiabá and, potentially, to Porto Velho and Santarem.[157] Over the near term, Rumo plans to extend Ferrovia Norte to the town of Lucas do Rio Verde (Mato Grosso), where it will intersect with an East – West railroad under development (see below).[158]

@ $US 10 billion); cost estimates are based on an assumption of $2 million/km: http://www.iirsa.org/proyectos/

* The system is a legacy of state-sponsored corporations that have undergone cycles of nationalization (1950s) and privatization (1990s) and a hybrid model during the administrations of Lula da Silva and Rousseff who used a state-owned corporation (VALEC Engenharia Construcoes e Ferrovias S/A) to undertake the construction of strategic rail lines, including several within the Legal Amazon. VALEC was dissolved in 2019 and its regulatory functions were passed to the *Agencia Nacional de Transporte Terrestres* (ATTN); railroads directly administered by VALEC were leased to private operators via public auction: https://portal.antt.gov.br/en/ferrovias

† The acronym is derived from their postal abbreviations: MA (Maranhão), Tocantins (TO), Piauí (PI), Bahía (BA); agroindustrial farming is expanding on landscapes that are geologically and edaphically similar to the Planalto de Mato Grosso. Source: EMBRAPA, https://www.embrapa.br/en/tema-matopiba/perguntas-e-respostas

‡ Rumo Logistico is a subsidiary of Cosan S/A, a conglomerate with interests in sugar cane, bioenergy and natural gas; it was created in 2008 with the acquisition of América Latina Logística. Rumo operates an integrated rail network consisting of four concessions totaling ~ 12,000 kilometres of rail, 12 transshipment platforms and three terminals in the port of Santos: https://www.cosan.com.br/en/about-cosan/cosan-group/

The extension of the rail network has enhanced the capacity of agroindustry to export soy and maize. The Ferrovia Norte links the port of Santos (São Paulo) with the logistical centre at Rondonópolis in Mato Grosso (top). The recently completed Ferrovia Norte Sur spans Tocantins to connect with the Estrada de Ferro Carajás in Pará (bottom).

Ferrogrão (EF-171).
This is a new initiative that was not included in the strategic transportation plans formulated in 2011, nor is it included within the IIRSA portfolio.[*] It is a direct response to farmers' demands for an economically attractive export option from central Mato Grosso. The Ferrogrão[†] will run parallel to BR-163 for 935 kilometres between Sinop (Mato Grosso) and Miritituba (Pará) (Figure 2.5 and Figure 2.6). Its projected capacity of sixty million tonnes per year approximates the combined soy and maize produced in Mato Grosso in 2019.[159] The $US 1.5 billion investment is being coordinated by a Brazilian engineering firm, *Estação da Luz Participações* (EDLP) with support from the ABCD[‡] commodity traders. The federal government is seeking to fast-track its construction by supporting the environmental review process via the *Programa de Parcerias de Investimentos* (PPI), which is managed from the President's office to facilitate private sector investment in public infrastucture assets.[160] A formal tender process for building and operating a 65-year concession is expected to be convened in 2021. The proposal is unusual in that it would award a monopoly to the concessionaire to operate trains over the railroad, a privilege that would be revoked if the rail line were ever linked to the national rail network.[161]

Not surprisingly, the construction of the Ferrogrão is opposed by environmental advocates and indigenous groups, who maintain that the railroad will promote settlement on the narrow corridor along BR-163 (HML #17). The region suffers from an epidemic of illegal activities, particularly land grabbing and unregulated deforestation, phenomena they contend would be supercharged by the influx of thousands of migrant workers for the railroad's construction.[162] Critics also contend that a reduction in transport costs will increase deforestation across the farm landscapes of northern Mato Grosso, which among other impacts would degrade the water resources of the indigenous territories along the Xingu River.[163]

The most conflictive zone is a 75-kilometre stretch through the heart of Parque Nacional Jamanxim, where the BR-163 right-of-way has a width of only 200 metres. Congress approved a measure that would widen the right-of-way of BR-163 through Jamanxim National Park, a precondition for obtaining an environmental licence from IBAMA.[164] Construction is planned to start in 2021 and be completed by 2025, but like most infrastructure projects in Brazil, it is not proceeding according to the projected timeline.

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* *Sistema Nacional de Viação*, Lei nº 12.379, de 6 de Janeiro de 2011.

† The name *Ferrogrão* is a neologism that translates as the 'grain train'.

‡ ABCD: ADM, Cargill, Bunge, Luis Dreyfus and Amaggi Group.

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The Ferrogrão will parallel BR-163 between Sinop (Mato Grosso) and Miritituba (Pará); the most controversial stretch will cross Jamanxim National Park where the current right-of-way is only 200 metres wide. Construction is contingent on the approval of an environmental evaluation being financed from the President's office by the Programa de Parcerias de Investimentos.

Ferrovia Norte Sul (EF-151).

As the name implies, this rail line will span the country and integrate railroads in the North, Central and, eventually, South of Brazil.* In its current configuration, the line has been split into three sections: The southern component is operated by *Rumo Logístico* for 1,500 km between Porto Nacional (Tocantins) and Estrella de Oriente (São Paulo); at its southern terminus, the line connects with the Rumo network that terminates at their massive port facilities at Santos.

* Amazonas, G 5: AMA73 Ferrovia Nova Transnordestina Fase I ($US 3 b); AMA76; Ferrovia Nova Transnordestina Fase II ($US 1.2 billion); AMA77, Ferrovia Norte-Sur Fase I, Belem - Açailândia ($ 1 billion); AMA78, Ferrovia Norte-Sur Fase II, Açailândia – Palmas, ($US 2 billion): http://www.iirsa.org/proyectos/

The central component between Porto Nacional and Açailândia (Maranhão) is operated by *Valor da Logística Integrada* (VLI),* which also owns the concession for the Estrado Ferro Carajás (EF-315) between the mining complex at the Serra de Carajás and the Port of Itaqui at São Luis de Maranhão. The combination of EF-315 (660 kilometres) and EF-151 (750 kilometres) provides the first fully integrated bulk transport option for farmers from Eastern Mato Grosso, Tocantins, western Bahía, and southern Maranhão. Its capacity was enhanced by the simultaneous construction of fifteen grain-loading platforms located between Anápolis (Goiás) and São Luis de Maranhão. Because it parallels BR-153 through a consolidated frontier (HML #6, #7, #14) inhabited by farmers and ranchers, its construction has been relatively free of social conflict. Its completion has relieved traffic bottlenecks on the regional highway network, while providing a practical alternative to the long-delayed and conflictive Tocantins waterway.

Eventually, a third section of the Ferrovia Norte Sul will be built between Açailândia and Barcarena (Figure 2.4). Its construction was postponed because of the expediency of exporting farm commodities via São Luis do Maranhão, but the state government of Pará has embraced its completion as a regional priority.

Ferrovia Paraense

In 2017, the governor of Pará presented an ambitious plan to expand the nascent rail network to more fully integrate the agricultural landscapes and mineral assets of eastern Pará with an industries park and port facilities at Barcarena. The proposed railway would complete the link between Açailândia and Belem by passing through the oil palm plantations near Tailândia (See Chapter 2) and include spurs to bauxite mines under development at Paragominas and Rondon do Pará (see Chapter 5). At Marabá, the rail line would cross the Tocantins River, proceed south to El Dorado do Carajás and then up the Araguaía valley to the border with Mato Grosso (Figure 2.4 and Figure 2.5).†

* *Valor da Logística Integrada* (VLI) is a subsidiary of the mining conglomerate Vale S/A, Brazil's fourth largest publicly traded company. Vale built the Estrado Ferro Carajás in the 1980s when it was a state owned corporation. The decision to expand its railroad operation was accompanied by a large investment in oil palm plantations with the intention of converting all of their heavy machinery to biodiesel, an initiative that was abandoned in 2018 (see Chapter 3).

† Financing for the $1.5 billion would be provided by China Communications Construction Company (CCCCSA), a state-owned construction company, a quasi-state enterprise that plays a prominent role in China's Belt and Road Initiative. The practices of CCCCSA have been questioned by the World Bank and the US Department of State has placed the company on a list known to participate in human rights violations in Xinjiang province. *Bloomberg Businessweek*, 18 Sept. 2018, A Chinese Company Reshaping the World Leaves a Troubled Trail:

Advocates of conventional development support the construction of the railroad because it would generate about 25,000 jobs over the short-term and facilitate the development of a proposed steel mill in Marabá. Agribusiness supports the initiative because it would sway the choice of production models along the railway corridor. Intensive cropping of soy and maize is already the preferred land-use in Northeast Mato Grosso, and the extension of a low-cost grain transport system would accelerate the expansion of industrial agriculture into the municipalities of southeast Pará.[165] Environmental advocates and indigenous groups oppose the initiative because they contend that the Ferrovia Paraense will catalyse another wave of deforestation in the last block of remnant forest between Marabá and Belem (HML #5), while spurring land grabbing in the indigenous territories on the headwaters of the Rio Xingu. (HML #12).[166]

Ferrovia de Integração Centro Oeste (EF-354)

This is, perhaps, Brazil's most ambitious rail project and, if completed, would extend from Port of Vitoria (Espírito Santos) west to near the western border with Peru.[167] The transportation ministry has stratified its development into three phases: the first phase will connect Capinonorte (Goaías) with Lucas do Rio Verde (Mato Grosso) across 750 kilometres through central Mato Grosso (HML #15). When completed, this railine will reduce trucking costs by linking to both the Ferrovia Norte Sul in the east and [to be extended] Ferrovia Norte in the west (Figure 2.6). The second phase will extend westward to Porto Velho following the approximate route of highway BR-364, which will ensure the Madeira waterway remains a cost-effective option by replacing 1,000 kilometres of truck transport by rail.[*] It will also accelerate the expansion of intensive agriculture into Rondônia (HML #23), where smallholders are restoring degraded soils by rotating pastures with the cultivation of soy and maize (Chapter 3).[168] The third phase will cross the Rio Madeira and extend to Cruzeiro do Sul (Acre) near the border with Peru (HML #28).[†] There is no obvious economic justification for this last segment – except as a link in a transcontinental rail line between the Atlantic and Pacific oceans.

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https://www.bloomberg.com/news/features/2018-09-19/a-chinese-company-reshaping-the-world-leaves-a-troubled-trail

* IIRSA, Amazon Hub, Group 8, AMA90, Ferrovia de Integración Centro-Oeste Fase I, Campinorte - Lucas do Rio Verde ($US 2 billion); AMA91, Ferrovia De Integración Centro-Oeste Fase II, Lucas do Rio Verde - Porto Velho (~$US 2 billion); AMA68: Ferrovía de Integración Centro - Oeste Fase III, Porto Velho - Rio Branco - Cruzeiro Do Sul ($US 2 billion): http://www.iirsa.org/proyectos/

† There is a fourth phase that will connect Capinorte with Vittoria (Espirtu Santos) or via the port of Ilhéus (Bahía), but a more practical route to the Atlantic Ocean is via the Rumo network to the port of Santos.

Ferrovia Transcontinental

In November 2014, the governments of Brazil, China, and Peru signed an agreement to evaluate the feasibility of a transcontinental railroad.[169] The route of EF-364 via Acre was one of several projects under evaluation; its proponents contend that it is the most cost-efficient because it would transit the Andes at the Huancabamba Depression,* where the maximum elevation is only 2,150 metres above sea level, approximately half the elevational incline that exists in competing proposals.[170] A railroad between Cruzeiro do Sul (HML #28) and Pucallpa (HML #41) would cross two national parks and infringe upon indigenous lands; consequently, there is zero possibility that a multilateral agency would finance the project, which is why the participation of entities from China was viewed with alarm by environmental advocates.[171] The rationale for a transcontinental railroad is based on the assumption that the savings in marine transport would offset the increased cost of rail transport. An independent evaluation by the International Union of Railways showed that the energetic cost of crossing the Andes and the capital cost of a new rail line would make the Ferrovia Transcontinental between fifty and a hundred per cent more expensive when compared to routes through southern Brazil or via the Amazon River. †

In 2018, the Brazilian government announced it would support an alternative proposal via Bolivia; known as the Ferroviário Bioceánico Central, this route is both shorter and takes advantage of pre-existing rail lines. Regardless, functionaries within the infrastructure agencies in both Brazil and Peru inserted a nebulous infrastructure component within the IIRSA portfolio, referred to as an 'Interconexión Terrestre', a term that leaves open the option of building either by road or rail line.

Ferroviaria Oriental SA

The pre-existing rail line that made Bolivia's transcontinental proposal 'more attractive' is a legacy rail system built in the 1950s by Brazil in compensation for the [perceived] loss of territories in the first decades of the twentieth century.‡ This rail line may – or may not – be part of a transcontinental railway, but it has played an essential role in the development of

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* The Marañon Depression is also known as the Huancabamba Gap (see Ch. 5 for geological discussion).

† The feasibility study commissioned by a Chinese consulting company used an estimate of $30 per ton in their economic model (1), while the model used by the International Union of Railways revealed a coast of about $160 per ton (2). Sources: (1) ejatlas.com, https://ejatlas.org/print/opposition-against-controversial-amazon-route-of-transatlantic-railway-brazil-peru and (2) https://ecoa.org.br/ferrocarril-bioceanico-entre-peru-y-brasil-seria-inviable-segun-estudio/

‡ IIRSA Amazon Hub; Group 04 Acceso A La Hidrovía Del Ucayali; AMA 28, Interconexión Terrestre Pucallpa - Cruzeiro Do Sul: http://www.iirsa.org/proyectos/detalle_proyecto.aspx?h=29

Bolivia's agroindustry (Chapter 3). Bolivia is a land-locked country and the fertile farmland in Santa Cruz (HML #31) is located 2,000 kilometres from the nearest Atlantic port, while Pacific ports are located on the other side of the Andean Cordillera. Although refined products are exported to Peru by truck, it is not economically viable to move bulk grains. Fortunately for Bolivia's farmers, the Ferroviaria Oriental connects with ports on the Paraguay – Paraná Waterway, which allows them to compete in global markets. Without the pre-existing railroad, which was built for political rather than economic reasons, the agricultural sector in Bolivia would have grown to only a fraction of its current size.*

Tren Electrico de Carga de Ecuador
In 2013, the *Instituto Ecuatoriano de Preinversión* commissioned a pre-feasibility study to evaluate the viability of an electric-powered rail network. According to descriptions in the general press, most of the track would be built on the Pacific coast with the goal of connecting the country's banana and oil palm plantations to port facilities. The idea originated during a time when ambitious plans to reduce carbon emissions were popular among government planners, and the concept caught the attention of then-President Rafael Correa. The scheme included a spur that would cross the Andes to service the copper mines under development at the Cordillera del Condor (See Chapter 5) and, presumably, would have been built with the financial and technical support of China.[172] The rail line's demand for electricity would be very large and, apparently, influenced plans to increase the construction of hydropower dams in the Amazon. The feasibility study was completed in 2017 and in the same year incorporated into the IIRSA portfolio of investments;† however, there is no other evidence the Moreno administration pursued this investment as a priority.

Finance: What is New and What is Not

In spite of the ongoing build-out of infrastructure in Latin America, investment remains well below what most economists think the region needs to spur economic growth and reduce poverty. This includes assets not only within the Pan Amazon, but more importantly, in regions with larger populations and greater economic activity. A brief visit to any major city in these

* The Ferrocarril del Oriente (FCA) was built by Brazil in compensation for the cessation of Acre during the rubber boom at the dawn of the 20th Century. This rail line operated at a loss for decades, but is now an essential component in Bolivia's agricultural economy.

† IIRSA Adean Hub; Group 05. Conexión Colombia (Puerto Tumaco) - Ecuador (Puerto Esmeraldas - Guayaquil) - Perú (Carretera Panamericana); AND95 Tren Eléctrico de Carga del Ecuador; @US17.8 billion: http://www.iirsa.org/proyectos/detalle_proyecto.aspx?h=1437

eight countries will reveal the inadequate infrastructure that plagues the region; not surprisingly, the situation is worse in the countryside.

A well-established tenet of macro-economic theory maintains that poor infrastructure constrains growth because it imposes inefficiencies on domestic production.[173] Investment in infrastructure stimulates growth by creating a short-term demand for labour, machinery and basic materials; more importantly, it increases productivity over the long-term.[174] The absence of basic infrastructure imposes opportunity costs due to lost economic growth that compound over time; in contrast, investment in well-designed projects pays dividends in greater economic growth that likewise compounds over time. It is easy to understand why the region's leaders are focused on making investments in basic infrastructure; it is less easy to understand why there has not been more sustained investment over the past half century.[*]

The infrastructure deficit in Latin America is due to a shortage of investment capital that is a historical legacy of failed economic models, erratic fiscal management, rampant corruption and endemic political instability. The shortage of investment capital exists in both the public and private sector. National economies are characterised by a large informal sector and a culture of tax evasion (see Chapter 6) that obligates governments to operate within budgets that preclude large-scale investment in new infrastructure. Periodic experiments with populist economic philosophies have stunted the development of domestic bond markets, an important source in advanced economies of long-term finance for both national and local governments. Economic mismanagement has created a deeply ingrained fear of inflation, which motivates central banks to pursue monetary policies based on high interest rates.[†] Political risk inhibits the participation of overseas private investors, who are wary of sovereign debt defaults, which also contributes to the persistence of high interest rates. The high cost of capital is the most important constraint on infrastructure investment in Latin America.

Governments have traditionally relied for investment capital to build basic infrastructure on multilateral financial institutions, such as the World Bank Group, the Interamerican Development Bank (IDB), the Development

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* Brazil invests about 2.5% of GDP in infrastructure, well below other emerging economies such as China (8.5%), India (5.2%), South Africa (4.7%), Russia (4.5%) and Turkey (3.6%), and only slightly above developed nations such as the USA (2.4%), the UK (2.2%) and Germany (2%), which enjoy huge legacies from past investments: https://www.statista.com/statistics/566787/average-yearly-expenditure-on-economic-infrastructure-as-percent-of-gdp-worldwide-by-country/

† Base-line interest rates were at historical lows in 2020 (Brazil: 2%; Peru: 0.5%), but they averaged from 20% to 10% between 2005 and 2017 and were as high as 40% in Brazil in 2000; Peru's rates have been less volatile, but still fluctuated between 8% and 2% between 2005 and 2018. Source: https://tradingeconomics.com/

Bank for Latin America (CAF) and bilateral development agencies. The needs of Latin America greatly exceed the lending capacity of these multilateral institutions, however, so loans are usually leveraged with resources from private banks, domestic bond markets and national development funds.

An example of this type of combined operation was an investment by the International Finance Corporation (IFC) to support Brazil's on-again-off-again programme to privatise its electric energy sector. In 2012, the IFC approved a loan to restructure the electrical distribution utility of Pará (CELPA); as part of that agreement, the bankrupt utility was sold to a holding company (*Equatorial Energia S*/A), which was acquiring similarly distressed utilities across Brazil. The IFC's involvement represented a stamp of approval for the new holding company, which bolstered investor confidence for a public offering of *Equatorial Energia* shares in the Brazilian stock market.*

The investment was subject to the standard environmental and social evaluation that accompanies all IFC investments and was ranked category A – the highest level of risk – an unsurprising qualification considering the loan coincided with the construction of the Belo Monte dam. Although CELPA was not a participant, it was an obvious candidate for distributing at least some of the electricity generated by the controversial hydropower project. The loan was approved contingent upon the reform of CELPA's internal procedures to comply with IFC's Social and Environmental Performance Standards.[175] In 2020, the company inaugurated the expansion of its transmission lines across the frontier landscapes of the Transamazon highway (BR-230) between the Xingu substation near the Belo Monte dam and one near Rurópolis (Pará) that supplies energy to both Miritituba and Santarem (Figure 2.5).

The IIRSA initiative relies heavily on this investment strategy, particularly in Colombia, Peru and Brazil, where the state grants concessions to private companies to build and operate infrastructure assets.

Public-Private Partnerships

The concessionaire system in Peru is managed by the *Organismo Supervisor de la Inversión en Infraestructura de Transporte de Uso Público* (OSITRAN), which oversees investments in transportation infrastructure, while the electrical system is administered by the *Organismo Supervisor de la Inversión en Energia y Minería* (OSINERGMIN). Both of these regulatory agencies supervise joint ventures that have been organised by the *Agência de Promoción de la Inversión Privada – Peru* (ProInversión), a government agency

* The IFC invested $US 99 million in a complex operation that included $US 74 million in new equity and matching investments from private funds totaling $US 640 million. Source: IFC 2013.

that conceives projects, attracts investment capital and administers the auctions that launch public-private partnerships (PPP). There have been several high-profile PPP projects in the Peruvian Amazon, most notably the two IIRSA interoceanic highways that are operated by construction companies that allegedly co-financed their construction in partnership with the Peruvian state, the IDB and CAF.* The term 'allegedly' is used because the construction companies didn't actually invest a significant share of the capital upfront but assumed (partial and limited) liability for repaying debt raised in public capital markets.

The northern project (IIRSA Norte) shows the potential to leverage public and private capital for a development project.† It was co-financed by the Peruvian state and the IDB, who together paid for feasibility studies, environmental review and the engineering design required to tender the project via a concessionary system. The construction was financed by infrastructure bonds traded in public markets that are to be repaid (in part) by revenues from highway tolls collected by the concessionaire.[176] The concept has been hailed as an innovative financial product because it expands the pool of financial resources by legally obligating highway revenues to debt repayment.‡ Nonetheless, these bonds are still a form of sovereign debt and, if the business model fails, the state remains responsible for debt repayment. The IIRSA Norte project was completed on time and in relatively good fashion but at more than double the original coast estimate ($US 575 million vs. $US $250). The original budget was unrealistically low and there are multiple reasons to question the quality of the environmental review; nonetheless, the highway is an important transportation asset that

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* IIRSA Norte was built and has been operated by Odebrecht Latinvest Peru SA since its inception in 2005; Oderbrecht also controls IIRSA Sur - Tramos 2 & 3, which was constituted originally with the participation of Peruvian companies (Graña y Montero SA, JJC Contratistas Generales SA, and Ingenieros Civiles y Contratistas Generales SA (ICCGSA)) and IIRSA Sur - Tramo 4 with Andrade Gutiérrez, Camargo Correa y Queiroz Galvão; over time Odebrecht Latinvest Peru S.A has consolidated ownership of IIRSA Sur Tramos 2,3 & 4. Source: OSITRAN, https://www.ositran.gob.pe/

† The Corridor Interoceanico del Norte was financed by a combination of debt (infrastructure bonds) of $US 367 million, a $US 60 million loan from the IDB and expenditures of $US 81 million by the Peruvian state: see http://www.iirsa.org/proyectos/Index.aspx; a similar operation was organised by the CAF for IIRSA Sur: https://www.iirsasur.com.pe/etiqueta/caf/.

‡ Formally referred to as *Certificados de Reconocimiento de Derechos del Pago Anual por Obras* (CRPAOs), they refer to the commitment of future income from the infrastructure asset. The concept was pioneered in Peru and has been used in other countries, including Mexico, Panama and Argentina. See Crédit Agricole Corporate and Investment Bank, 15 Project Bonds To Change Your Preconceptions https://www.ca-cib.com/sites/default/files/2020-03/Project-Bond-Focus-2019-15-Milestone-Transactions.pdf

links economically active areas in the northern part of the country. As of June 2020, the highway was generating significant revenues and OSITRAN listed it as income-generating asset.[177]

In stark contrast, the southern enterprise (IIRSA Sur) is emblematic of the risks associated with a highway through a wilderness area conceived via an inadequate feasibility study with mediocre environmental review, deficiencies that were compounded and expanded by self-dealing and political corruption. This highway is at the heart of the *Lava Jato* scandal in Peru, and its principle contractor, Oderbrecht, has pleaded guilty to various forms of malfeasance (see Chapter 6). The losses incurred by the project are much greater than the bribes paid to officials or the excess billing of avaricious companies* because the final cost of construction ($US 2.5 billion) was vastly underestimated ($US 879 million). Unlike the northern project, the highway has not generated any revenue, which has forced the state to assume full responsibility for debt repayment.[178]

The IIRSA Sur imbroglio has stained the reputation of the concessionaire system in Peru. Nonetheless, it is used to operate sixteen highways, 22 airports (four in the Amazon), three rail systems, and ten ports (four in the Amazon) and the Amazon waterway. The total investments channelled via the OSITRAN concession system add up to more than $US 9 billion, approximately double the amount lent to Peru for infrastructure by the IDB over the same period.[179,180]

Peru also has a national development bank that finances private sector projects, the *Corporación Financiera de Desarrollo SA* (COFIDES) has multiple strategies for raising capital, including by offering sovereign debt in international bond markets.[181] Some of these are part of the IIRSA portfolio, including IIRSA Sur -Tramo 1&5 (the non-Oderbrecht components) and others, such as the Gasoducto Sur Peruano, that fall outside the remit of the regional infrastructure integration portfolio (see Chapter 5). COFIDES is active in the electrical energy sector and coordinates its investments with OSGERMIN and ProInversión. Within the Amazon watershed, hydropower investments are valued at approximately $US 300 million.† This amount, however, is only a fraction of the OSGERMIN's projected investments, which in 2020 showed the construction of sixteen hydropower plants with a total capacity of 2.7 GW at an estimated cost of $US 5.7 billion.[182]

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* The construction consortium is accused of over-billing the state by $US 182 million, which included a $31 million dollar bribe to then-President Alejando Toledo. Source: *Carreteras Pan Americanas*, 6 June 2019, Ex socias Odebrecht incluidas en caso de sobornos en IIRSA Sur: https://www.carreteras-pa.com/noticias/exsocias-odebrecht-incluidas-en-caso-de-sobornos-en-iirsa-sur/

† Cerro del Aguila ($US 75 million), Chaglla $US 100 million), La Virgin ($US 100 million), H-1 ($33 million), El Angel ($US 47 million); see http://www.minem.gob.pe/

In Brazil, highway and rail concessions are managed by the *Agência Nacional dos Transportes Terrestres* (ANTT), the electrical energy sector by the *Agência Nacional de Energia Elétrica* (ANEEL), and waterways by the *Agência Nacional de Transportes Aquaviários* (ANTAQ). All three agencies are key to the administrative procedures tied to the current administration's policies to privatise strategic components of the national economy.[183]

The expansion of the rail network in Brazil, outlined previously, is dominated by large corporations (Rumo/Cosan and VLI/Vale). The development of railroads is based on robust business models that have access to multiple sources of investment capital, including the Brazilian development bank (see below). Depending upon the outcome of their environmental review, two additional rail concessions should soon move into the construction phase: Ferrogrão (EF-171) and Ferrovia de Integração Centro-Oeste (EF-354). A third concession (Ferrovia Paraenese) is under development and state authorities in Pará have signed an agreement with a Chinese construction company to build the first phase of the project. Because the project does not cross state borders, its developers may escape oversight by federal regulators; consequently, the project may proceed quickly in comparison to the more problematic Ferrogrão.

The concessionaire system for highways is less lucrative and, consequently, resembles the system described for Peru, where the concessionaire manages the transportation asset for a fee that is partially funded by tolls collected by the concessionaire.

In the Legal Amazon, privately operated highway concessions are both new and uncommon. As of 2020, there was only one: Roto do Oeste (BR-163), the strategically important corridor between the farm landscapes of central Mato Grosso and the logistical hub at Rondonópolis (Figure 2.6). The thirty-year, 600-kilometre concession was awarded in 2014 to *Odebrecht Rodovias*,* which is contractually obligated to expand its capacity from two to four lanes over approximately half its length. These and other improvements are projected to cost R$ 5.5 billion,† a reasonable sum to collect from the ~70,000 trucks that operate on the transportation corridor that moves agricultural commodities south and manufactured goods north.

Four additional highway concessions in the Legal Amazon were being prepared for public auction in 2020 and, like the Roto do Oeste, all are important components in the truck-based bulk transport system that services the soy-maize complex of the Southern Amazon (Table 2.3). All four roads will be upgraded to accommodate heavy traffic, but only BR-364 in Rondônia is slated to be expanded from two to four lanes. Significantly,

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* Another subsidiary of Odebrecht S.A., which emerged from a court-supervised bankruptcy in 2020 as NOVONOR: see https://www.novonor.com.br/

† Exchange rate fluctuations make $US dollar estimates imprecise, but this equated to about $1 billion in Feb. 2021.

Table 2.3: Infrastructure projects supported by the PPI; values are projected cost of capital investments as reported by the PPI or based on methodology used by the Ministerio de Infraestrutura to calculate costs;[220] values expressed in $US are based on exchange rates at the end of 2020.

Support for Concession Process	R$	$US	**Support for Environmental Review**	R$	$US
Highways - operations			*Hydropower & Grid*		
BR-163/230 (MT/PA)	1,584	317	Bem Querer (RR)	5,000	1,000
BR-158/155 (MT/PA)	1,808	362	Castanheira (MT)	1,300	260
BR-153/080/414 (GO/TO)	8,661	1,732	Trabajara (RO)	1,000	200
BR 364 (RO/MT)*	8,212	1,642	LT Manaus - Boa Vista (AM, RR)	170	34
Rail Lines – construction			*Waterway Improvement*		
FICO (EF-354)	2,730	546	Pedral do Lourenço (PA)	650	130
Ferrogrão (EF-171)	8,400	1,680	*Highway construction*		
Ports - operations			BR-080 (MT/ GO)	1,742	348
Itaqui (MA)	594	119	BR-158 (MT)	2,912	582
Santana (AP)	42	8	BR-242 (MT)	2,090	418
Barcarena (PA)	571	114	BR-174 (RO/MT)	3,483	697
Airports (Legal Amazon)	380	76	BR-319 (AM/RO)	2,786	557
	32,982	**6,596**		**21,133**	**4,227**

ANTT has stipulated that preparations for the terms of reference for BR-163/230 (MT/PA) should include measures that facilitate the eventual construction of the Ferrogrão.[184] All five projects are being supported by the PPI, a high-profile programme established in 2016 to fast-track private sector investment in strategic infrastructure.

Evidence of the current administration's priorities was the inclusion within the PPI portfolio of financial support for the environmental reviews of projects delayed by social protests. The inclusion of BR-319 suggests that efforts to complete the highway between Manaus and Porto Velho will be successful; less notable, but of greater economic significance, are four highways in Mato Grosso that will improve farmers' capacity to move their harvests to logistical platforms on the rail transport systems under development (see Figure 2.6). Presumably, their inclusion within the PPI portfolio reflects a belief that they will pay for themselves and finance their construction via the concessionaire system.

PPPs are common in the electricity sector of Brazil and were used extensively during the administrations of Lula de Silva and Dilma Rousseff.

Typically, the state is represented by a subsidiary of Electrobras[*] as a minority shareholder in a joint venture with one or more private companies. The companies can be grouped into four categories: (1) construction companies who are contractors to the project;[†] (2) pension or investments funds domiciled in Brazil;[‡] (3) metallurgical and mining companies seeking to ensure power for their processing mills;[§] and (4) energy holding companies that acquire generation or transmission assets as part of their business model.[¶]

Energy holding companies, which attract investment capital from a variety of sources, are often characterised by complex corporate structures. For example, Neoenergia S/A owns ten per cent of Norte Energia (Belo Monte) and 51 per cent of the Teles Pires and Dardanelos facilities in Mato Grosso. Neoenergia is controlled by Iberdrola SA (51 per cent) a Spanish partnership with a large pension fund affiliated with Banco do Brasil (thirty per cent) however, approximately nineteen per cent of Neoenergias equity is a 'free float' that is held by investment funds from the United States and Europe.[**]

Most of these energy companies also operate generation and transmission concessions without the participation of Electrobras. As of 2020, there were nineteen privately operated hydropower plants in the Brazilian (Legal) Amazon, ranging from the 1.1 GW mega-dam at Estreito ($US 2.4 billion) to the 20 MW power plant ($US 40 million) operated at the Pitinga mine near Manaus. Altogether, private companies operate about 3.6 GW of installed capacity that required approximately $US 5 billion in investment capital, compared to the 23 GW of capacity operated by PPP ventures that required between $US 30 and $US 40 billion.[††] Legacy public-owned and operated power plants, such as Tucuruí, Balbina and Samuel, have a total of about 11 GW.

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* Electrobras: Electronorte, Chesf, Furnas, Electrosul

† Construction companies: Oderbrecht Energia, SAAG/Andrade Gutierrez, Camargo Correa

‡ Pension and investment funds: Petros, Fundação dos Economiários Federais (Funcef), Caixa FIP

§ Metallurgical companies SINOBRAS, Alcoa, BHP, Vale, Intercement.

¶ Energy companies: Neoenergia (Iberdarola, Spain), ENGIE (formerly Tractobel/Suez, France & Belgium), EDP- Brasil (Energia do Portugal), EDF - Flumenense (France), Alupar SA (Guarupart Participacoes Ltda), Amazonia Energia (Light/CEMIG),

** These include: America Funds/Capital Research & Management (USA), The Pictet Asset Management (Europe), BlackRock Investment Management (USA) and The Vanguard Group (USA), among others. Source: https://finance.yahoo.com/quote/NEOE3.SA?ltr=1

†† The exact amount is difficult to calculate because of cost overruns that have not been reported transparently and foreign exchange rates that ranged from near parity with the $US dollar (2000) to 0.25 (US/R) in Jan. 2021.

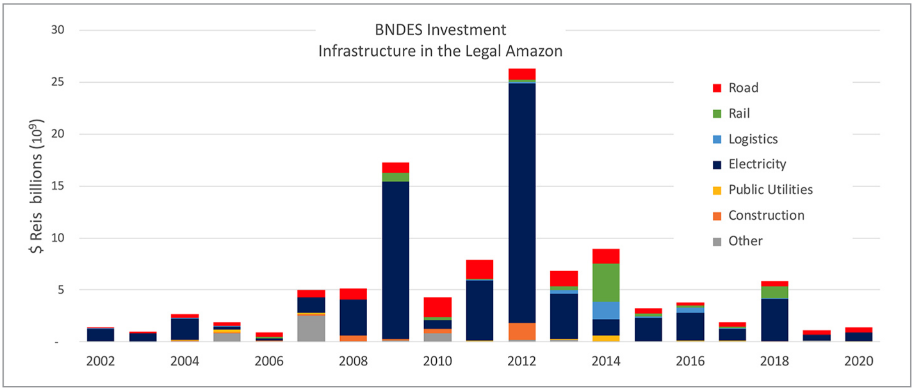

Figure 2.24: The distribution of disbursements made to infrastructure projects located in the Legal Amazon by the Brazilian Economic and Social Development Bank (BNDES). Data source: BNDES transparency portal.

Between 2000 and 2020, the most important source of infrastructure finance in Brazil was the *Banco Nacional de Desenvolvimento Econômico e Social* (BNDES), a quasi-autonomous fund that extends loans and makes grants to both public and private entities. BNDES has a broad portfolio that supports infrastructure, agriculture, technology, finance and manufacturing, as well as initiatives to reduce inequality and protect the environment (see Chapter 12). Total disbursements to projects in the Legal Amazon between 2002 and 2020 totalled R$ 171 billion (~ $US 78 billion); of this amount, approximately 65 per cent was allocated to infrastructure (Figure 2.24).[185]

Although BNDES is autonomous, its authorities respond to policy priorities established by elected officials. The administrations of Lula da Silva and Dilma Rousseff embraced policies that stressed hydropower and the extractive industries, priorities reflected in disbursements made to finance a gas pipeline between Coari and Manaus (2007) and the dams at Estreito* (2008), on the Rio Maderia (2009), and Belo Monte (2011, 2012). Investment in road construction and the electrical grid were present throughout the decade, including several regional highways in Mato Grosso (2012) and Pará (2005, 2006); investment in rail became a priority only after 2014.[186]

BNDES also functions as an export-import bank by providing credit to facilitate the sale of manufactured goods; in addition, it has a specialised division that supports the export of engineering services. Between 2009 and 2014, the bank loaned $US 2.9 billion to entities that contracted Brazilian

* The power plant at Estreito on the Tocantins is owned by a consortium of corporations that includes several mining companies – BHP, Vale and Alcoa – as well as the construction company and the operator Engie (formerly Suez).

construction companies building hydropower plants in Ecuador, Venezuela and Peru.[187]

The most noticable aspect of BNDES' recent history is the decline in its lending activities after 2014, following the collapse of commodity prices that triggered an economic crisis: National GDP fell by 3.5 per cent in 2015 and by 3.3 per cent in 2016. The economic recession was exacerbated by the inability of BNDES to act as a counter-cyclical source of fiscal stimulus, due in part to a lack of revenue from non-performing loans embroiled in the *Lava Jato* scandal. More important, however, was the macro-economic environment that caused foreign investors to abandon the country's capital markets, which limited BNDES' ability to raise fresh capital. More recently, the Bolsonaro adminstration has imposed budgetary restraints and obligated the bank to return hundred of billions of *reais*[*] to the federal government. Ironically, the government's privitasation policies may assist BNDES to renew its investment capital by liquidating its equity shares in Brazil's flagship companies.[188]

In Colombia, the concessionaire system is managed by the *Agência Nacional de Infraestructura*, which has overseen approximately $US 12 billion in highway investment in the country since 2010. Most of that activity occurred in extra-Amazonian regions and only two concessions have been awarded within the Colombian Amazon. The Malla vial del Meta, which is operated by a consortium of Colombian construction companies, is an important transportation asset that provides access to the oil palm landscapes of Meta. Portions of this highway network constitute the northern component of the Carretera Marginal de la Selva (see above) and functions as a gateway to the coca frontiers that surround La Macarena National Park (Figure 2.12).

The other concession consists of the Santana – Mocoa – Neiva (R-45) corridor that connects Bogotá with the oil fields of Putumayo. This highway was originally adjudicated to a Colombian consortium, but was recently acquired by China Construction America, a subsidiary of the world's largest construction company: China State Construction Engineering Corporation Ltd (CSCEC). The contract obligates the concessionaire to invest $US 21 million in its first year of operations (2021) and eventually reach a total target of ~ $US 440 million.[189]

Like many Chinese corporations, CSCEC is a publicly traded company; nonetheless, it is closely associated with the government of the People's Republic of China. Coincidentally, one of China's state owned oil companies, Sinochem, has acquired a half dozen oil concessions in the Putumayo region.[†] Both companies are considered to function as a branch

* The Brazilian currency is the *Real*, which is expressed in its plural form as *Reai*s.

† Sinochem acquired Emerald Energy PLC, a British company for $US 898 million in 2009.

of China's military-industrial complex and to coordinate actions to advance the strategic interest of the Chinese state.[190]

Investment from China

The increasing presence of Chinese companies in South America has become an issue of concern among social and political analysts. Security specialists argue they are a geopolitical threat to the interests of the United States and other Western nations, while supporting authoritarian governments that undermine democratic traditions.[191] Environmental advocates attest that companies from China are uninterested in sustainability and will maximise profits at the expense of biodiversity and ecosystem services.[192] Nationalists view them with suspicion because they represent a new type of imperialism that will lead to a loss of strategic industries while creating dependency via so-called debt traps.[193] Perhaps. Chinese banks and businesses have brought much-needed investment to the region, and their presence has advanced investments in infrastructure that would not have occurred or would have taken another decade or longer to finalise.

Investment from China falls into two major categories: loans to finance infrastructure and direct foreign investment (DFI) by corporations that seek to own or operate a business. Loans are the predominant form of investment in Venezuela, Ecuador and Bolivia because their 'socialist' governments are averse to foreign entities owning the means of production within their countries. There are exceptions, particularly in the mineral sector of Ecuador (see Chapter 5). DFI is the preferred model in Brazil and Peru, where Chinese companies have initiated new 'greenfield' investments or acquired existing business and infrastructure assets (Figure 2.25).*

Some, but not all, of this investment activity is occurring in the context of the 'Belt and Road Initiative' (BRI), a foreign policy and infrastructure development programme launched by the People's Republic of China in 2013. The BRI is best known for suites of coordinated projects that extend across the Eurasian landmass, Southeast Asia, and into Africa. The Latin American component, which is more modest in scope, was announced at the Asian Pacific Economic Cooperation (APEC) summit in Lima in 2016. Subsequently, Bolivia, Ecuador, Guyana, Suriname, Peru and Venezuela all signed agreements formally entering the BRI initiative.[194] Only Colombia, which has the smallest amount of Chinese investment, and Brazil, which has the largest, have declined to formally join the BRI. Nonetheless, both have bilateral agreements that facilitate trade and investment between their countries. China is Brazil's largest trading partner, and the flow of

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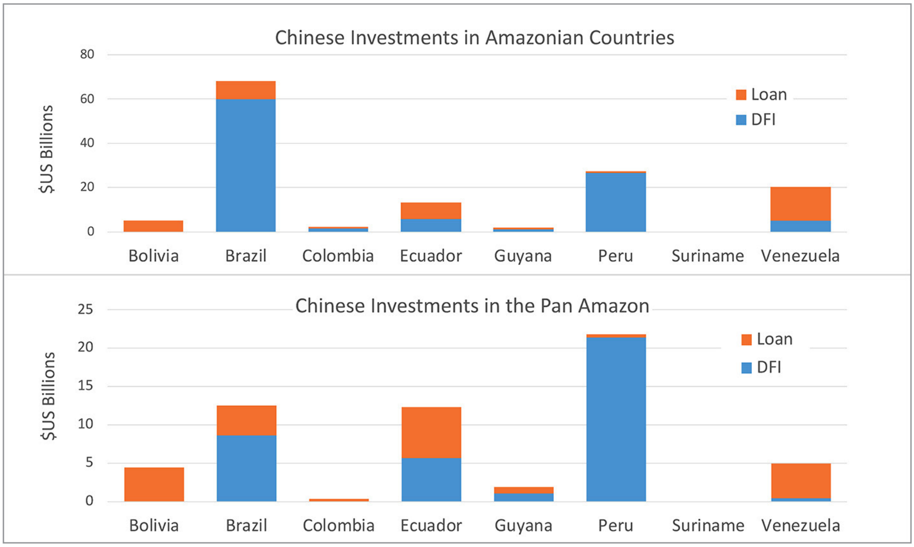
* The distinction between what is a loan and what is an equity investment is not always straightforward, since many loans are secured with equity, or the entity receiving the loan is partially owned by Chinese stockholders.



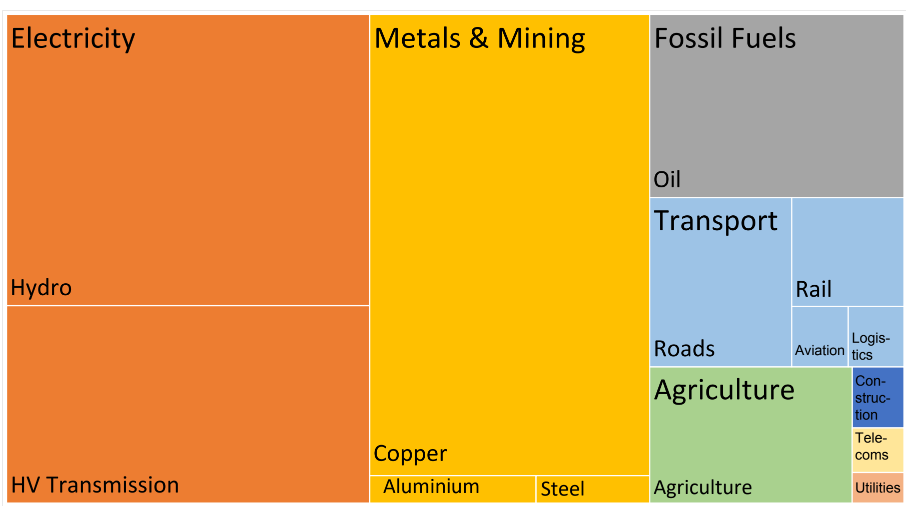


Figure 2.25: Distribution of investments by Chinese entities in Amazonian countries and within their Amazonian jurisdictions (ton) and by sector; DFI refers to direct foreign investment. Investment from China stratified by sector at the national level.
Data source: American Enterprise Institute.

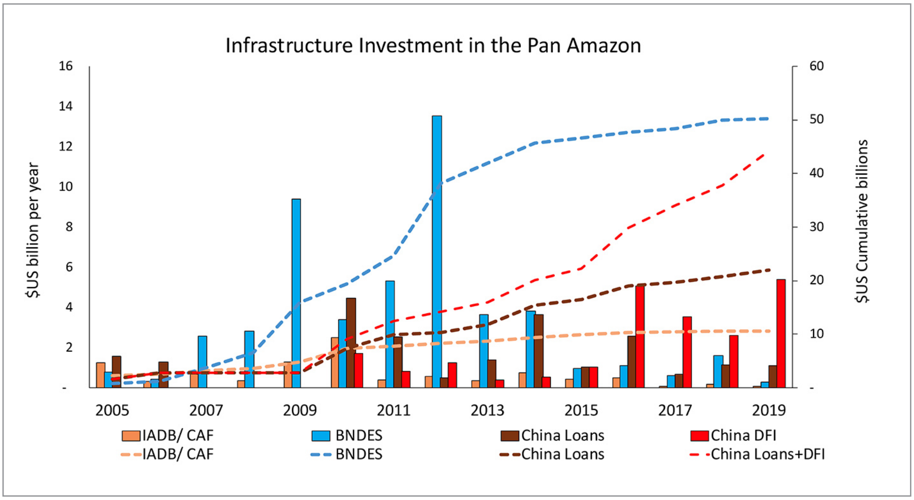


Figure 2.26: Financial flows for infrastructure investments in the Pan Amazonian countries (left axis – bar graph; right axis – line graph).

Investment from all sources includes only Amazonian projects. BNDES includes automatic and non-automatic disbursements for states within the Legal Amazon and loans to Andean countries for engineering services. Loans and direct foreign investment (DFI) from China are segregated annually, but DFI is added to the loan total in the cumulative line graph.

Data sources: IDB project database; CAF project database; BNDES transparency portal; China Global Investment Tracker, The American Enterprise Institute.

investment capital from China to Brazil is an important for maintaining the economic health of both nations.

Most of the financial assistance to Latin America has been channelled through public 'policy banks' that are superficially similar to the multilateral institutions based in Washington, Caracas and Brussels: Their primary mission is to assist client countries in developing their infrastructure and economies, but as self-financed banks they must also earn a satisfactory return on their investment. In the case of the China Development Bank and the Ex-Im Bank of China, these fundamental principles were modified between 2000 and 2015 as part of a deliberate strategy to secure supply chains for strategic commodities. After 2014, at least in Latin America, they became more pragmatic because of financial constraints in China, a surplus of commodities, and the weakened financial status of their clients.

The lending policies of Chinese institutions incorporate social and environmental standards that mimic those championed by the World Bank but, unlike the multilaterals, they are not subject to strict oversight by civil society. Chinese policy banks have a due diligence system, but their precautions against corruption and the rigour of their environmental reviews are significantly less thorough and, in some instances, may amount to window dressing. Consequently, Chinese banks and partner companies move quickly and in close coordination, which allows them to design, build and deliver a project in a fraction of the time required by a project financed by the multilateral agencies.

The total value of infrastructure investments by Chinese entities is greater in value than those deployed by the multilateral banks when considered over the same period of time (Figure 2.26). That is a false comparison, however, because Chinese policy banks tend to narrowly focus on the extractive industries, energy and infrastructure, while the multilaterals also invest in health, education, governance and water and sewage systems. Moreover, this comparison also ignores the leveraged contributions by the private sector and national treasuries, which are usually three to ten times larger than the contribution of the multilaterals. Increasingly, finance from China, the multilaterals, and the private sector are joining together to finance projects that make good 'business sense'.

Debt-trap countries

Most infrastructure lending is organised via the Chinese Development Bank (CDB) or the Export-Import Bank of China;[195] Jointly, they invested approximately $US 5 billion in South America between 2000 and 2009, a number that doubled in 2010 and by 2020 totalled more than $US 53 billion.[196] Approximately forty per cent of these loans were made to finance investments in the Pan Amazon, mainly in hydropower, electricity transmission and roads (Figure 2.25)[197] The volume of loan transactions has trickled to a stop since 2016, while DFI continues, although at reduced values.[198]

Ecuador was an early recipient of Chinese investment, in part because it had difficulty attracting investment capital due to political instability and economic mismanagement, a predicament that become particularly acute in 2008 when the country defaulted on its international debt obligations. President Rafael Correa, who was elected in 2007, aggravated the crisis by rejecting standard (neoliberal) advice to privatise state-owned infrastructure and energy assets; instead, he sought other sources of finance. The Export-Import Bank of China and the China Development Bank responded with loans that allowed the government to pursue the construction of several highways, modernise an oil refinery and expand hydropower. The loans were backed by future oil production and, eventually, revenues from a copper concession granted to a Chinese mining company.*

Although Ecuador largely used credit to finance its economic expansion during the commodity boom, it did allow a limited amount of DFI in the extractive industries. In 2006, the China National Petroleum Company (CNPC) and Sinopec created a joint venture, incorporated as Andes Petroleum, which they used to purchase one of Ecuador's most valuable infrastructure assets, the Oleoducto de Crudos Pesados (OCP), the pipeline between the Amazon and the Pacific coast, for $US 1.3 billion.[199]

Outside the extractive industries, the largest loans were used for the construction of two hydropower facilities in the Andean foothills: Coca Coda Sinclair ($US 1.5 billion) and Paute / Sopladora ($US 487 million), both of which will be operated by *Corporación Eléctrica del Ecuador* (CELEC) an electrical utility company owned and operated by the Ecuadorian state. A third complex is planned on the Santiago River that, presumably, will also be built by a Chinese company and financed by the Ex-Im Bank of China. The country has been unable to service its new debt obligations following the decline in the price of oil after 2015. Ecuador was forced to restructure its foreign debt in August 2020, which they undertook with the assistance of the International Monetary Fund (IMF) in coordination with their Chinese creditors.† As usual, oil revenues are a guarantee of future payment.

In Bolivia, Chinese credit has financed approximately ten per cent of the highways built over the last two decades. Between 2007 and 2017, fifteen separate projects were awarded to contractors from China at a combined value $1.78 billion; [200] however, the debt incurred for highway construction from Chinese banks over the same period totalled only $US 1.1 billion. Chinese construction companies were awarded all the contracts financed by the Ex-Im Bank, but several were successful in competing for contracts financed entirely by the Bolivian state (see Chapter 6).‡ Almost all of these roads are components of the IIRSA master plan and about two thirds are

* Chinese National Petroleum Company (CNPC) was guaranteed 90% of Petroecuador's production in return for a loan in excess of $US 9 billion; the China Railway Construction and China Nonferrous Company (CRCC) is the concessionaire of new copper mine in the Cordillera del Condor ($US 2.9 billion). Source: American Enterprise Institute 2017.

† The IMF will provide $US 6.5 billion, Chinese Banks will provide $US 2 billion; approximately ~$16 billion of bond debt will be restructured. Source: *The Financial Times*, 5 Sept. 2020, Ecuador basks in glow of debt-restructuring success, https://www.ft.com/content/1dd975c9-e3a1-4fcc-b049-f29dbd59f6fa

‡ Bolivia self-financed about 50% of the highway projects during the administration of Evo Morales, which grew from less than $125 million in 2005 to more than $1.0 billion in 2016. Source: ABC – *Administradora Boliviana de Carreteras*, Plan Estratégico Institucional 2016– 2020: http://www.abc.gob.bo/wp-content/uploads/2018/03/pei_abc_2016_-_2020.pdf

located within the Bolivian Amazon, including the Rurrenabaque – Riberalta corridor ($US 579 million) that connects the Andean highlands with the Department of the Pando and the Corridor Interoceanico (see Figure 2.8).

In the electricity sector, Sinohydro is building the dam and power plant at Ivirizo ($US 632 million), and the China Three Gorges (CTG) corporation was awarded the contract to build the Rositas Dam near Santa Cruz ($1.3 billion). Both power plants will be operated by a state-owned domestic utility company (ENDE), which has a near-monopoly on generation and transmission. The Rositas project was paralysed in 2019 because ENDE failed to conduct an environmental review that complied with the principles of Free Prior and Informed Consent (FPIC).* Indigenous communities have filed a legal challenge to halt the project, at least temporarily, but the project has strong support across multiple social and economic groups.[201]

Bolivia and China have engaged in an unusual infrastructure initiative in the form of a communications satellite, which was designed, built and launched by the Chinese space agency. Christened Tupac Katari -1, the satellite cost $US 300 million, of which 85 per cent was financed by the China Development Bank. The enterprise has been criticised as a white elephant because it has generated only $70 million in revenues since its launch in 2013.[202] Proponents argue the investment should not be evaluated solely on financial criteria, however, because it integrates remote indigenous communities into the national community by providing them with celular phone service and access to the internet.

Overall, Bolivia's foreign debt increased from $US 2.2 billion in 2007 to $US 11.3 billion in 2019, of which only about ten per cent is held by Chinese banks, an amount considerably less than either the IDB ($US 3.5 billion) and CAF ($US 2.9 billion); moreover, interest on the loans from China is concessionary, with interest rates of about 2.6 per cent compared to 3.3 to 3.6 per cent for the multilaterals.[203] Bolivia continues to service its debt, but financial analysts consider Bolivia to have reached a plateau in its ability to service any additional non-concessional debt. Chinese banks have made no new loans to Bolivian entities since 2018, and the two largest loans announced in 2016 (Rositas, $US 990 million) and 2017 (the El Mutun mine, $470 million) have not been executed due to bureaucratic delays.

The most heavily indebted country in Latin America is Venezuela. Between 2000 and 2014, the country reportedly borrowed $US 50 billion from Chinese entities to finance multiple components of the national economy, including the hydropower facilities on the Caroni river and industrial mines in Bolivar state. Most of the loans were to be repaid via direct oil shipments, but declining production and low prices caused Venezuela to

* The database curated by the American Enterprise Institute shows the loan commitment, even though no funds have actually been disbursed to initiate construction.

default in 2014, an outcome that followed several years of cosmetic debt roll-overs. Even investment in iron ore and bauxite mines of the Guyana highlands has failed to provide any type of cash flow or produced the mineral commodities that guaranteed debt payment (see Chapter 5). The debt was restructured in 2020 with a 'grace period' provided for $US 19 billion.

Both Venezuela and Ecuador could be considered to be caught in a 'debt trap'. The inability to repay loans has led to a loss of sovereign control over a strategic asset. In both countries, the state-owned oil companies now export almost all of their production to China to service past debt. Consequently, both countries are forfeiting potential revenues in an improving global market. Nonetheless, China has not benefited from these failed business ventures and, rather than acquire assets via bankruptcy proceedings, the policy banks of China have written off bad loans.* The debt trapped everybody.

The domain of direct foreign investment

The flow of capital into the private sector and PPPs was similar to the loan portfolios: Investment started in the early 2000s, with a surge in 2010 followed by more moderate flows thereafter.[204] Unlike loans, however, the flow has not stopped, as Chinese corporations continue to acquire companies with good cash flow and growth potential. Several sectors stand out. The most obvious examples are companies operating in the agricultural and the extractive industries, whose business models align with China's need for basic commodities (see Chapters 3 and 6). Investment in infrastructure is different, because it isn't built on a supply chain that extends back to China; instead, companies export engineering expertise to build and operate highways, railroads, airports, dams and electrical power systems.

Peru has welcomed significant quantities of DFI and completely avoided the debt trap that afflicts its neighbours (Figure 2.25). Approximately $US 15 billion has been invested in the polymetallic mines of the High Andes and another $US 3.5 billion in oil and gas.[205] The China Three Gorge (GTC) company owns the largest portfolio of infrastructure assets. It made its first investments in Peru via a joint venture in 2016 with a Portuguese energy firm at the San Gaban-III hydropower facility on the Rio Inambari ($US 185 million).[206] This was followed by the acquisition of the Chaglla dam and power station on the Rio Huallaga in 2018, as part of a deal forced on the beleaguered Peruvian subsidiary of Oderbrecht ($US 1.4 billion).† The largest acquisition (to date) was GTC's purchase of Luz Del

* Bolivia has avoided this outcome with its Chinese creditors, who have no lien on that country's natural resources, but Bolivia is facing a looming finanical predicament due to an over-reliance on mineral exports and a failure to invest in more sustainable enterprises.

† The Peruvian state has confiscated $US 312 million from the transaction to pay back taxes ($135 million) and a judicial fine ($US 200 million) as part of the

Sur ($US 3.6 billion), which it acquired from a US-based energy company in 2020. Among Luz Del Sur's assets are the electrical distribution system of Lima and the Santa Teresa dams under construction on the Urubamba River near Cuzco ($US 600 million). The Chinese company is the largest diversified electrical utility in Peru.

A more controversial investment is Sinohydro's participation in the consortium (*Sociedad Concesionaria Hidrovía Amazónica SA* – COHIDRO), which was awarded the contract to administer Peru's Hidrovía Amazónica in 2017. Presumably, Sinohydro is providing technical expertise and financial capital ($100 million), while their Peruvian partners manage the administrative and legal process regulated by OSITRAN. The controversy surrounding the project stems from accusations the consortium manipulated the bidding process[207] and claims by indigenous federations that they were not adequately or legally consulted during the environmental review.[208]

In Brazil, Chinese companies have invested more than $US 60 billion since 2005; this is the country's largest and most diversified investment portfolio in South America. It includes businesses that specialise in commercial real estate, finance, transportation, telecommunications, agriculture and minerals. As in Peru, a large portion of investment capital has been allocated toward minerals, including loans to Brazil's very large mining sector (> $US 5 billion) and a combination of loans and joint ventures with Petrobras (> $US 16 billion). Brazil's importance to China's food supply is reflected in investments made by COFCO, China's state-owned commodity trader (> $US 3.2 billion).

As large as these investments are, they are smaller than the combined acquisitions of CTG and State Grid Corporation of China (SGCC) in the generation, transmission and distribution of electrical energy ($US 23 billion). The vast majority of these investments are located in extra Amazonian Brazil, except for minority interest by GTC in two hydropower facilities in Amapá: Santo Antônio do Jari ($US 250 million) and Cachoeira Caldeirão ($US 130 million). The only large investments in the Brazilian Amazon is SGCC's controlling interest (51 per cent) in ultra-high voltage transmission lines between Belo Monte and Southeast Brazil: BMTE-I to Rio de Janeiro (> $US 2 billion) and BMTE-II to Estreito, Minas Gerais (> $US 2.8 billion) (Figure 2.3 and Figure 2.5).[209]

State Grid's partners in the BMTE projects are Electronorte (24.5 per cent) and Furnas (24.5 per cent), both of which are subsidiaries of Electrobras, which is being [partially] privatised by the Brazilian government.[210] At the corporate level, the government intends to reduce state ownership

ongoing resolution of the *Lava Jato* scandal. Source: *Latin Finance*, 16 July 201, Brazil's Odebrecht asks Peru for proceeds from Chaglla sale, Latin American Financial Publications: https://www.latinfinance.com/daily-briefs/2019/7/16/brazil-s-odebrecht-asks-peru-for-proceeds-from-chaglla-sale

The construction of mega-scale hydropower facilities on the Xingu and Madeira rivers was accompanied by investments in grid infrastructure, such as the ultra-high voltage transformers at the Altamira (Pará) sub-station (top) and high voltage direct current (HVDC) 750 kV transmission lines that move electricity from remote power plants to urban centres in Southeast Brazil (bottom).

from 62 to 45 per cent by offering shares (common stock) in public equity markets. Internally, management is also downsizing the company by selling subsidiaries and joint ventures.[211] The semi-privatisation via the stock market is not likely to attract Chinese investors, but they are most certainly interested in acquiring individual assets in distribution, transmission and generating. The presence of CTG and SGCC in the Brazilian Amazon is not extensive, but that could change if they acquired assets from Electrobras or from a private sector investor, such as those that operate the hydropower plants on the Madeira and Tocantins rivers. Conceivably, they could lead a greenfield investment if regulators (or the Brazilian Congress) open up hydropower development within the Legal Amazon.

There is less uncertainty about the role of Chinese companies in the development of railroads. In 2019, the governor of Pará signed an agreement with the China Communication Construction Company (CCCCSA)* that committed both parties to initiating construction on the first stage of Ferrovia Paraense by the end of 2021 (Figure 2.4 and Figure 2.6). Although the COVID crisis has undoubtedly delayed its implementation, the world's largest construction company will soon bring its hyper-efficient engineering systems to the construction of that railroad. Finance for the R$ 15 billion ($US 2.7 billion) project is available via the China – Brazil Fund, an investment vehicle created in 2017 that has been capitalised by the China-Latin American Production Fund ($15 billion) and BNDES ($US 5 billion). Chinese construction companies with expertise in rail can be expected to participate in the public auctions for the Ferrogrão and FICO railroads (Figure 2.6).

The activities of Chinese investors in Guyana and Suriname have historically reflected the size of their economy and, in general, could be characterised as overseas development assistance. Between 2000 and 2014, China's policy banks provided $US 350 million to Suriname and $US 309 million to Guyana. Most of these resources were allocated to road 'rehabilitation' and electricity power systems.

The discovery of the offshore oil field has led to an upsurge in direct investment. In Guyana, that includes a $950-million contribution to a joint venture between the Chinese National Oil Company (CNOC) and Exxon, a luxury hotel, improved port facilities, and, reportedly, paving the IIRSA-sponsored Letham–Georgetown highway. Less likely is the renewal of the Amalia Falls hydropower project, which was the object of a potential $US 850 million loan in 2009, co-financed by the IDB and China Development Bank. The Amelia Falls project was removed from the development pipeline in 2015 due to concerns over its financial viability.[212]

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* The practices of CCCCSA have been questioned by the World Bank, and the US Department of State has placed the company on a list of entities known to participate in human rights violations in Xinjiang province. See Prasso 2018.

In Suriname, oil discoveries lag those in Guyana, but geologists are confident of future production, and CNOC will participate. In the meantime, the country has contracted a Chinese engineering company to modernise its international airport.[213]

Sustainable Infrastructure: In Search of an Oxymoron

The macroeconomic hypothesis that infrastructure investments stimulate economic growth assumes that these physical assets overcome a logistical or systemic constraint on production. In practice, this requires that individual projects are subject to an objective feasibility analysis, are priced fairly, and have been approved after a full evaluation of their social and environmental impacts. Unfortunately, many infrastructure investments in the Pan Amazon have not met these three fundamental criteria. Some are poorly conceived or simply unnecessary, and many are foisted on society by vested interests or corrupt politicians.

Poorly designed or unnecessary infrastructure can create a negative economic impact if scarce financial capital is funneled into projects with limited benefit to society, thus diverting investment from more deserving initiatives. A poorly conceived project may provide a short-term economic boost but fail to provide the long-term benefits of a well-designed asset. In the Pan Amazon, the lack of an economic return from poorly conceived infrastructure initiatives is compounded by their large negative environmental and social impacts.

This chapter has focused on large-scale infrastructure built in the Pan Amazon over the last several decades. Some projects have been poor investments when evaluated using only economic criteria, but many more have been economically successful and politically popular because they benefit the actual (albeit recent) inhabitants of the Amazon. The most controversial have benefited stakeholders who are not residents of the Amazon, particularly companies that cater to extra-Amazonian consumers of energy and commodities. These assets and systems may be profitable, but they are not 'sustainable' when they fail to comply with the criteria of sustainable development.[*] Persistent high rates of deforestation, environmental degradation and social inequality are the most obvious manifestations of the failure to incorporate the concepts of sustainability into infrastructure development.

The concept of 'sustainable infrastructure' has been around since academic discussions first defined the concept of sustainable development; however, guidelines defining specific criteria for built infrastructure appeared

* The goal of sustainable development is the long-term stability of the economy, which is only achievable through the integration of economic, environmental, and social concerns throughout the decision-making process. Source: the Brundtland Commission, http://www.un-documents.net/wced-ocf.htm

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PAC collection at flickr.com; CC BY-NC-SA 2.0

The need for basic infrastructure extends beyond transportation and energy systems, and includes water treatment plants (top) and sewage systems (bottom).

only about a decade ago. The first efforts were little more than a laundry list of high-level standards for loan officers and corporate executives to consider when evaluating a potential investment.[214] More detailed systems that address the multiple and complex challenges required to transform the global economy in the face of climate crisis are now available.[215] These systems are not, however, particularly applicable to the unique situation of the Amazon, which also has an acute deficit in basic infrastructure.

What might define sustainable infrastructure in the Pan Amazon? First and foremost, it should benefit the inhabitants of the Amazon. Equally important, investments should yield economic benefits over the short, medium and long term, particularly those that contribute to GDP but also others that improve people's quality of life without generating an immediate increase in income. In some cases, an investment may be uneconomic in conventional terms but justified on humanitarian or ecological grounds and thus worthy of a subsidy.

The infrastructure investments that most obviously meet these criteria are the physical assets that are the foundation of the region's health care systems. The Covid pandemic of 2020/2021 revealed glaring deficiencies in the health care systems of all eight nations. The impact of the disease was particularly severe in their Amazonian jurisdictions, where it fell disproportionately on marginalised populations. Shortfalls in basic health infrastructure included not just a lack of hospital beds but also of the specialised equipment needed for acute medical conditions.

The Covid-19 pandemic also revealed that a significant portion of Amazonian populations were vulnerable to the coronavirus due to chronic conditions caused by infectious diseases associated with unsafe drinking water and poor sanitation. Public utilities provide water in most large and medium sized cities, but coverage is far from universal, particularly in the peri-urban neighbourhoods that house recent migrants. Investment in basic sanitation in urban areas is abysmal, and even the largest cities have woefully inadequate sewage systems (Table 2.4). Rural inhabitants are left to their own devices.

The situation is worse in the Andean Amazon, where administrative decentralisation and revenue sharing mechanisms have just begun to address decades of under-investment by central governments. Cities show radically different outcomes. Pucallpa (~370,000 inhabitants) provides only about 48 per cent of households with potable water, while Iquitos (477,000) approached ninety per cent coverage; neither city has any system to collect and treat sewage. In contrast, Santa Cruz de la Sierra (1.7 million) provides

Table 2.4: Comparison of potable water and sewage provision in major cities.

City	Population in 2015	% potable water	% sewage system	% sewage treatment	Investment ($R/5 years)
Manaus	2,130,264	88%	12%	48%	311
Belem	1,425,275	71%	13%	0.8%	266
São Luis	1,082,935	87%	50%	11%	346
Cuiabá	590,118	100%	54%	52%	379
Porto Velho	519,436	32%	5%	3%	62
Macapá	465,495	39%	9%	17%	38
Boa Vista	332,020	100%	64%	75%	214
Rio Branco	383,443	60%	24%	34%	72
Santarem	294,447	71%	6%	1%	
Palmas	286,787	98%	86%	60%	276
Varzea Grande	271,339	97%	35%	35%	

Data source: *Instituto Trata Brasil*, http://www.tratabrasil.org.br/estudos/estudos-itb/itb/novo-ranking-do-saneamento-2021

universal coverage for potable water and has extended basic sanitation to approximately half its population.*

Amazonian cities have invested in drinking water systems, typically with the assistance of the multilateral banks, but are still dumping nearly all their wastewater into the Amazon and its tributaries, operating under the assumption that the volume of water will provide a level of protection against contamination.† Unfortunately, that practice does not protect downstream populations from diseases caused by poor sanitation.

A similar infrastructure deficit exists in the region's primary and secondary schools, particularly in the public systems that serve rural communities and impoverished urban neighbourhoods. This deficiency is exacerbated by middle-class and affluent families who send their children

* Santa Cruz has the highest population growth in the Western hemisphere, averaging 5–7% annually between 1970 and 2000 and 2–3% after 2000. Water and sewage are managed by an independent cooperative (SAGUAPAC) owned by the city's inhabitants, but the phenomenal growth motivated real estate investors to develop neighbourhoods with full services while SAGUAPAC and the municipal government coordinated investments to provide service to '*barrios populares*'. For example, streets were not paved until sewage systems were installed to avoid wasted expenditures on street repair.

† The concept 'dilution is the solution to pollution' dominated waste-water treatment for decades. It is now questioned by environmental scientists but continues to be taught in engineering schools and employed widely across the planet.

The desire for improved infrastructure is exemplified by this family taking a newly purchased freezer back home to their riverside community.

to private schools, a common practice across South America that encourages under-investment in public school systems.[216]

Investments in education and health care might not meet the classic definition of built infrastructure (roads and bridges), but few would deny that sustained economic growth is wholly dependent upon a healthy and well-educated populace. Moreover, investments in schools, clinics and sanitation systems are labour-intensive and require significant amounts of concrete, lumber, and hardware, which ensures they meet the short-term objectives of infrastructure investment programmes – job creation and economic stimulus. Since schools and clinics are relatively simple structures, their construction can be contracted to local businesses, creating a positive feedback loop since the proprietors and employees of these spend the proceeds close to home.

Both health and educational systems would benefit from improvements in digital infrastructure, another non-traditional class of investment essential for economic growth and development in the twenty-first century.[*] Technology is an obvious antidote to the long distances and antiquated telecommunication systems that isolate rural communities. Exposure to computer technology would allow rural students to acquire basic information management skills essential for success in modern society, while access to

* In advanced economies the consumption of electrical energy has forced the tech sector to purchase renewable energy to operate their power-hungry server farms so as to avoid high GHG emission from conventional power grids.

the internet would democratise learning opportunities for tens of thousands of students and teachers. High-speed internet is the gold standard. It would not only allow students to participate in seminars and virtual events via the rapidly evolving 'zoom' technology, but would also permit health-care professionals to diagnose and treat many more patients remotely.

Providing high-speed internet to remote areas constitutes a significant technological challenge, and only a limited number of Amazonian cities have internet connections faster than 10 Mbs.[*] Speed is inherently limited because most connections are mediated by geostationary satellites with a response time limited by the speed of light. The cost of extending a fibre-optic network to the far-flung communities across the Pan Amazon would be exorbitant and precludes any attempt to expand high-speed internet service. This is about to change.

In 2020, the Brazilian government launched the *Projeto Amazônia Conectada*, an ambitious initiative to lay 8,000 kilometres of fibre-optic cable on the bottom of the Amazon river and its major tributaries (Figure 2.27). The initiative is being coordinated by the Brazilian army;[217] more importantly, it is being implemented as a public-private partnership with the backing of several large domestic and international telecom companies.[†] This initiative has the potential to provide a digital backbone that extends far beyond the region's major cities and could conceivably be expanded upstream to include isolated urban areas in the Andean Amazon. It will not, however, provide a solution for thousands of communities that are not located on a major river or connected to a cell phone network that could provide cost-effective internet services to the populace. Fortunately, there is a Plan B.

Two of the most innovative entrepreneurs on the planet, Jeff Bezos and Elon Musk, are competing to launch a network of low-orbit communication satellites with the express purpose of providing affordable high-speed internet services to remote regions.[‡] If successful, these will provide an alternative to the fibre-optic backbones and cell-phone towers that constrain the expansion of high-speed internet. Low-orbit satellites will communicate with a receiver that consists of an antenna and router, which will interface with a local area wifi network. The expected cost of a terminal is estimated at about $US 500, with a monthly service fee of $US 99. The business model

* Until 2020, Manaus, Belem, Cuiabá, Porto Velho and Rio Branco were connected through fibre-optic cables mounted on the electrical transmission grid. Source: Electronorte 2017.

† *Oi*, a Brazilian telecom company emerging from bankruptcy, has adopted a business model that will focus on fibre- optic networks; Huawei, the Chinese telecom giant is seeking to introduce its 5G technology into Brazil. Source: https://www.datacenterdynamics.com/br/not%C3%ADcias/huawei-fornece-infraestrutura-para-conectar-a-amaz%C3%B4nia/

‡ Starlink is a subsidiary of SpaceX Corporation (Elon Musk is CEO); Project Kuiper is a subsidiary of Amazon (Jeff Bezos is the chairman of the board).

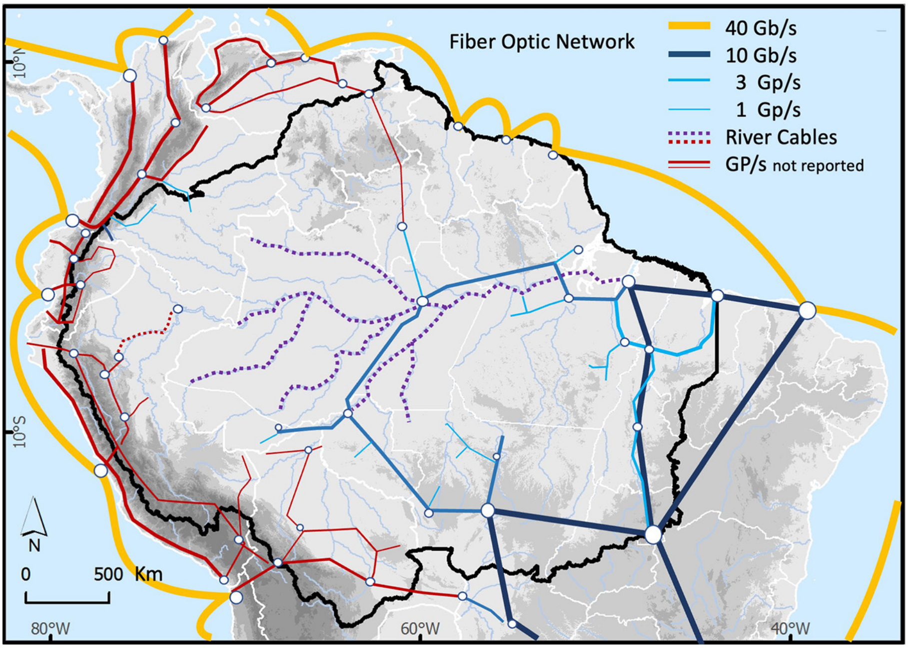

Figure 2.27: The major components of the fibre optic network in the Pan Amazon. The Projeto Amazônia Conectada, coordinated by the Brazilian Army in collaboration with private companies, is laying cable on the floor of the Amazon River and its major tributaries in the Central Amazon (Solimões, Madeira, Aripuanã, Purus, Juruã and Negro). Peru will lay a similar cable between Yurimaguas and Iquitos.

Data sources: Ministério da Defesa 2021; Electronorte 2018; Technoblog 2018; BNAmericas 2021.

is based on providing service to marine vessels, remote mine sites, industrial farms, vacation homes and rural communities isolated from fibre-optic networks. The technology represents a step-change in cost and quality; nonetheless, it will still be too expensive for most of the rural schools and clinics across the Amazon.* Presumably, the cost is negotiable, and citizens of the Amazon may be able to obtain a discount from the wealthiest men

* In 2018, there were 33,000 public schools in the Brazilian Amazon (source https://cidades.ibge.gov.br), and there are similar numbers of basic health clinics (*Unidad Básica de Saúde*). The Andean Amazon has about a quarter of the population and, presumably, health and educational infrastructure. A 'back-of-the-envelope' calculation for the cost of outfitting each school and clinic with a Starlink system would sum to only $US 25 million, and the monthly fees would sum to about $US 55 million annually. However, outfitting schools and clinics with computers to make the system functional would cost between $US 500 million and $1 billion.

on the planet.* Perhaps Mr Bezos could be convinced to donate systems to the communities of the region in compensation for appropriating their regional identity to brand his commercial enterprise.

Roads and bridges can also be sustainable. They are anathema to environmental advocates because of their association with logging, deforestation and settlement. However, these classic examples of built infrastructure contribute to sustainable economic growth when they improve secondary road networks within long-established agricultural frontiers. Almost all farmers lose a portion of their harvest due to spoilage, a problem that is particularly severe in humid tropical climates that accelerate decay and disease infestation. Supply and demand govern commodity markets and, according to macroeconomic theory, post-harvest losses will be replaced by production elsewhere; consequently, spoilage drives crop production onto frontier landscapes. Just as energy conservation should be part of a green energy strategy, so should investments in traditional infrastructure be part of a holistic development strategy when it enhances long-term productivity and profitability on existing farms.

The agricultural and consolidated frontiers across the Southern and Andean Amazon all suffer from poor secondary road networks. Improved secondary road networks will do more than reduce waste because bad roads delay planting, cause wear-and-tear on farm equipment and add to the cost of moving commodities to market. Small farmers suffer the most because they are more likely to depend on truckers who pro-rate their services based on the quality of the roads. Most small farmers would welcome the option to transport coffee or cacao via truck rather than mule, and the shift might motivate many of them to expand production.

Another underappreciated infrastructure class consists of the airports that support the aviation transportation system. Regional carriers have benefited from investments in airports in larger cities,† but the development of smaller airstrips is largely managed *ad hoc* by the military, loggers and (illegal) miners. The region once had a flourishing air taxi system organised by Evangelical and Catholic missionaries (see Chapter 11), but this has been replaced by commercially motivated operators, many of whom are complicit in the illicit drug trade. Examples in Alaska and Canada show that

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* Starlink is providing free internet to a limited number of Native American communities in Canada and Alaska; see https://nativenewsonline.net/business/rural-alaska-natives-hope-elon-musk-s-starlink-internet-service-can-level-playing-field

† The IIRSA programme has supported investments in Ecuador (2) and Peru (2); the *Programa de Aceleração do Crescimento* supported improvements in Amazonas (9), Pará (3), Rondônia (3), Acre (1), Mato Grosso (3), Amapá (2), Tocantins (1); the Ex-Im Bank of China financed work in Bolivia (1), Guyana (1), and Suriname (1).

air taxis can provide a cost-effective transportation solution for a roadless wilderness populated by indigenous villages, settlers and vacation resorts. Key to that system is an airstrip in every village and operating subsidies to ensure the services are affordable for the region's indigenous inhabitants. The lack of affordable air taxi services is the largest single constraint to the expansion of ecotourism, which is currently clustered around a handful of Amazonian cities with large airports (Manaus, Iquitos, Puerto Maldonado, Leticia, and Coca; see Chapter 7).

Energy systems will continue to figure prominently in future investments in the Pan Amazon. Historically, economic growth has been tightly correlated with energy consumption. As families become more affluent, they buy electrical appliances and consume more energy. Refrigeration is the first type of appliance purchased by families emerging from rural poverty; once they are solidly middle class, they buy air conditioning. The relationship between GDP and energy consumption may change in the next fifty years at the global scale as societies transition from fossil fuels to a low-carbon economy. It is not, however, the path that will characterise development in the Pan Amazon. Energy consumption will grow as the economy expands, because access to affordable and reliable sources of electrical energy improves the quality of the lives of its inhabitants.

The rapid decline in the cost of solar power – and the advantages of distributed solar – provide an interesting option for communities and households that are not connected to the electrical grid. However, the capital cost of solar will hinder its adoption by most Amazonian families, who prefer to be linked into a grid system and pay a small monthly fee. Some electrical utilities have technologies and consumer packages designed to build and expand distributed systems, but the incentive system inherent in their business models continues to favour the expansion of the grid. Utility-scale solar will become more important and the construction of large-scale hydropower plants may become less attractive as an investment due to opposition by environmental advocates and indigenous groups. If so, utility companies may increase their investments in medium- and small-scale hydropower, which will contribute resilience to a diversified portfolio of electricity generation assets.

The pandemic of 2021 highlighted the social and economic inequalities of Amazonian society, but no well-informed observer was surprised by the suffering that Covid-19 wrought on remote indigenous villages, smallholder landscapes and the marginalised neighbourhoods in rapidly growing urban centres. The asymmetric impact was not unlike the scenario that played out in the advanced economies, where other disadvantaged populations suffered disproportionately from a legacy of under-investment. The (promised) response, particularly in the United States, is to implement stimulus and recovery policies that benefit under-served populations. In addition, the Biden administration seeks to channel resources to the long-delayed campaign to invest in renewable energy and other technologies required to avoid a climatic catastrophe.

The same logic of favouring marginalised populations and promoting sustainable production models can – and should – be applied to the pandemic recovery in the Pan Amazon. There is a palpable need to compensate for longstanding inequalities and the need to reform the conventional economy is similarly urgent.

In July of 2020, a progressive think tank launched a petition signed by seven former presidents* calling on the International Monetary Fund (IMF) and other multilateral organisations to cancel the external debt of Latin American countries and for bondholders to accept a restructuring of sovereign debt that included a two-year interest-payment holiday. The petition argues that such actions are 'fair and necessary' given the extraordinary challenge posed by the pandemic. Multilateral institutions have recognised the need to respond to the crisis but, unfortunately, none has the financial capacity to provide (real) debt forgiveness, much less to allocate the capital resources required to transform the economies of the Pan Amazonian nations. Institutions from China are not capable or inclined to alleviate the debt burden. More likely, governments and their private sector partners will invest in mining ventures and industrial agriculture that can generate export revenues needed to shore up their economies. Consequently, the 2020/2021 pandemic will foster investments that promote another cycle of conventional economic development.

* All are associated with socialist or progressive political parties: Dilma Rousseff (Brazil), Evo Morales (Bolivia), Rafael Correa (Ecuador), Ernesto Samper (Colombia), Jose Luis Rodriguez Zapatero (Spain), Fernando Lugo (Paraguay), Luis Guillermo Solis (Cost Rica)

Annex 2.1: IIRSA investments

A summary of investments organised via the The Initiative for the Integration of the Regional Infrastructure of South America (IIRSA), also known as Consejo Suramericano de Infraestructura y Planeamiento (COSIPLAN); it is organised into Hubs, Groups and Projects (see Figure 2.1).

Group		# projects	US$ million
	Amazon Hub		
Am-1	Access to the Putumayo Waterway	5	378
Am-2	Access to the Napo Waterway	5	105
Am-3	Access to the Huallaga–Marañón Waterway	10	1,299
Am-4	Access to the Ucayali Waterway	14	3,634
Am-5	Connection Between the Amazon Basin and Northeastern Brazil	12	15,197
Am-6	Amazon Waterway Network	12	321
Am-7	Access to the Morona–Marañón–Amazon Waterway	5	415
Am-8	Porto Velho–Southern Northeastern Brazil Rail Connection	7	6,150
	Andean Hub		
Ad-6	Colombia–Ecuador (Bogotá–Mocoa–Tena–Zamora–Palanda–Loja) Connection	5	496
Ad-7	Peru–Ecuador (Loja–Puente de Integración–Yurimaguas) Connection	2	147
	Guiana Shield Hub		
Gu-1	Venezuela–Brazil Interconnection	5	407
Gu-2	Brazil–Guyana Interconnection	6	277
Gu-3	Venezuela (Ciudad Guayana)–Guyana (Georgetown)–Suriname	3	302
Gu-4	Guyana–Suriname–French Guiana–Brazil Interconnection	6	3,596
	Central Interoceanic Hub		
CI-2	Optimisation of the Corumbá–São Paulo–Santos–Rio De Janeiro Corridor	8	6,307
CI-3	Santa Cruz–Puerto Suárez–Corumbá Connection	4	443
CI-4	Santa Cruz–Cuiabá Connection	5	141
CI-5	Connections of the Hub to the Pacific: Ilo/Matarani–Desaguadero–La Paz + Arica–La Paz + Iquique–Oruro–Cochabamba–Santa Cruz	29	11,164
	Peru - Brazil - Bolivia Hub		
PBB-1	Corridor Porto Velho–Rio Branco–Assis–Puerto Maldonado–Cusco/Juliaca–Ports In the Pacific	8	2,934
PBB-2	Rio Branco–Cobija–Riberalta–Yucumo–La Paz Corridor	9	1,482
PBB-3	Madeira–Madre De Dios–Beni River Corridor	7	28,232
	Total	**167**	**83,426**

Annex 2.2: Selected attributes of the Human Modified Landscapes recognised in the Pan Amazon

This table shows the categories of information contained in Online Supplement 2.1 at https://www.whpress.co.uk/Books/Killeen.html. See Chapter 1 for definition, criteria and spatial distribution (Figure 1.1) and Figure 2.1 for location with respect to major highways.

Column	Title	Information
1	HML Code	1 to 60 (key to maps)
2	HML name	Geographic descriptor
3	Total Area within HML	Hectares
4	Original forest area within HML	Hectares
5	Total historical deforestation within HML	Precent of original forest cover
6	Stage of Development of HML	Forest Frontier
	See Chapter 1	Agricultural Frontier
		Consolidated Frontier
		Coca Frontier
		Gold Rush Frontier
7	Strategic Development Initiatives	POLOAMANZOIA, PAC, PIN, ENID, IIRSA, etc.)
	See Chapter 6	
8	Flagship Infrastructure Assets	Names of key highways, hydrodams, railways, etc.
9	Planned Development Initiatives	includes proposed and planned roads, railways, dams, etc.
10	Major Highways	Including those that are existing and actively beimng considered (planned but not proposed)
11	Paved (referring to highways)	Yes/no as of 2021
12	Secondary Road network	No/limited/moderate/extensive
13	Agricultural Production Models See Chapter 3	Beef, soy-maize, oil palm, coffee, cacao, food crops, plantation forestry, timber, non-timber forest products
14	Key Mineral Resources See Chapter 5	Iron ore, copper, bauxite, cassiterite, gold, diamonds polymetallic

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