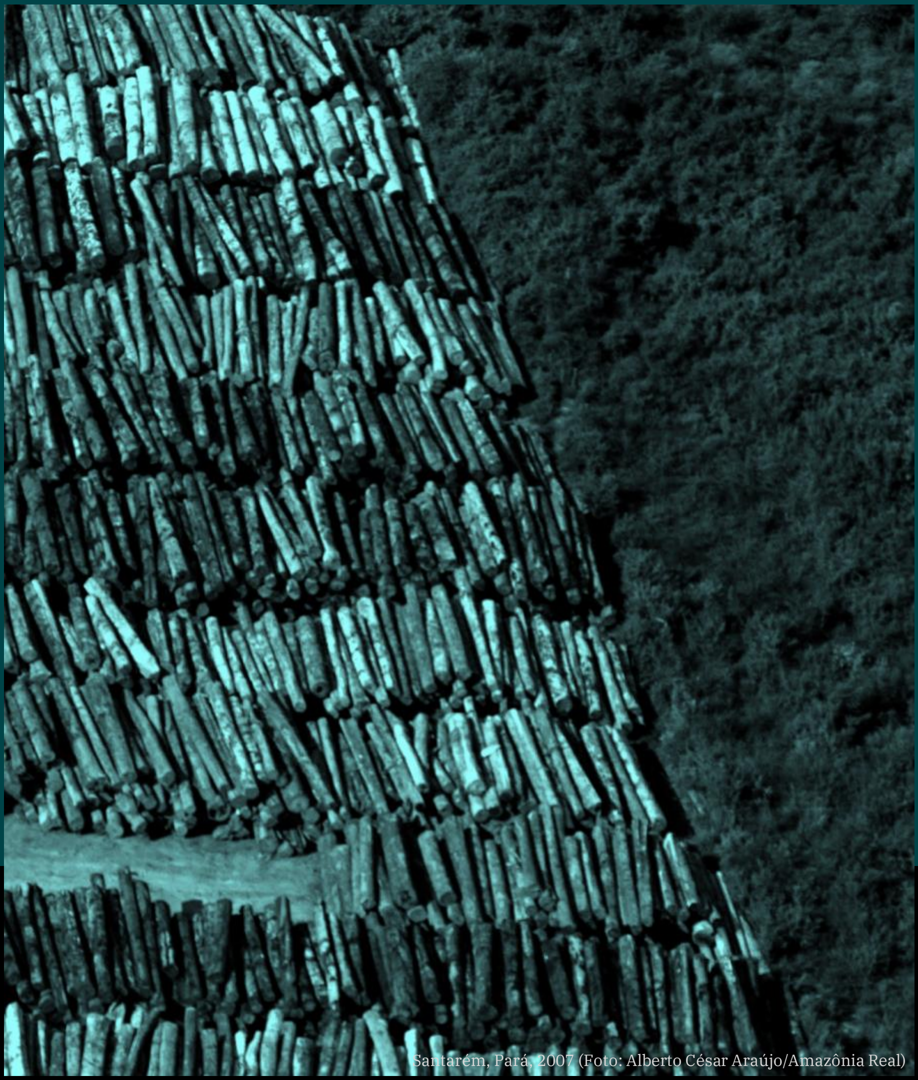
Chapter 19 In Brief

Drivers and ecological impacts of deforestation and forest degradation



Santarém, Pará, 2007 (Foto: Alberto César Araújo/Amazônia Real)

THE AMAZON WE WANT
Science Panel for the Amazon

Drivers and ecological impacts of deforestation and forest degradation

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Key Messages & Recommendations

1) As of 2018, the Amazon has lost approximately 870,000 km² of primary forest, equivalent to 14% of its original cover.
2) There are at least 1,036,080 km² of degraded Amazonian forests. It is estimated that 366,300 km² of Amazonian forests were degraded between 1995 and 2017.
3) Cattle ranching is the main driver of deforestation.
4) Deforestation and degradation result in local, regional, and global impacts, including changes in local temperature and precipitation, increased CO_2 emissions, and species extinctions.
5) Governments, the private sector, and civil society need to take urgent action to avoid further deforestation in the Amazon, particularly of primary forests. Avoiding loss of primary forest is by far the highest priority to avoid carbon emissions, biodiversity loss, and changes to the region's hydrology.
6) Large-scale infrastructure projects, such as roads and mining concessions, must consider their indirect impacts on deforestation, which are much greater than the forest loss they directly cause.
7) There is an urgent need to implement an integrated monitoring system to track deforestation and forest degradation across the basin, with comparable, transparent, and accessible datasets. Datasets can be generated through partnerships between governments and the scientific community. It is no longer acceptable for deforestation to be the sole focus of forest monitoring.

Abstract This chapter discusses the main drivers of deforestation and forest degradation in the Amazon, particularly agricultural expansion, road construction, mining, oil and gas development, forest fires, edge effects, logging, and hunting. It also examines these activities' impacts and synergies between them.

Introduction Deforestation is defined as the complete removal of an area's forest cover[1], while forest degradation is the reduction of the overall capacity of a forest to supply goods and services[2],

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representing a loss in the ecological value of the area affected[1]. Across the Amazon, deforestation and forest degradation result from the interplay between various indirect and direct drivers acting at global, regional, and local scales[3–6]. Direct drivers of deforestation are the human actions that impact nature[7], including the expansion of pastures and croplands, the opening of new roads, the construction of hydroelectric dams, and mineral and oil exploitation[8–10] (see also Chapters 14, 15, and 20). Indirect drivers are factors that influence human actions[11], such as poor governance or commodity market conditions[12–14]. Drivers act simultaneously; because multiple drivers affect deforestation rates, it is very difficult to estimate their individual impacts. The impacts of both deforestation and forest degradation can have local, regional, and global consequences[15–17]. The most obvious impacts of deforestation are the loss of structural complexity and biodiversity as species-rich forested areas are converted to species-poor agricultural land. However, there are more cryptic impacts, such as changes in local temperatures, regional precipitation regimes, and global greenhouse gas (GHG) emissions[18,19].

Deforestation In the Amazon biome, 867,675 km^2 have been deforested as of 2018[20] – an area larger than Turkey (Figure 19.1). Most deforestation has occurred in Brazil, which lost approximately 741,759 km^2 of forest[20], an area 15 times greater than that lost by Peru (50,867 km^2), the country with the second largest deforested area. In relative terms, the country that lost the most forest was Brazil (18%), followed by Ecuador (13%). Deforestation in the Amazon peaked in 2003, reaching 63,656 km^2. Between 2004 until 2013, deforestation dropped to its lowest level, increasing again from 2014 onwards.

Agricultural expansion Agricultural expansion, particularly cattle ranching, is the most important driver of Amazonian deforestation[21]. In the Brazilian Amazon it is estimated that 80% of deforested areas are occupied by pastures[22]. In the early 2000s, the expansion of large-scale croplands, particularly soy, significantly increased as a driver of deforestation, a pattern that reversed[23] following conservation policies, including the soy moratorium (see Chapter 15) and the creation of several protected areas in Brazil (see Chapter 16) where most soy-related deforestation was taking place[12,24]. In Bolivia, soy is still expanding; the region of Santa Cruz has been identified as the largest deforestation hotspot in the Amazon, mainly due to forest conversion to soy fields[25,26]. Starting in the mid-2000s, palm oil became a threat to Amazonian forests, especially in Colombia, Ecuador, Peru, and in the eastern part of the Brazilian Amazon[27]; while palm oil plantations often replace other agricultural land uses, especially cattle ranching, sometimes it replaces primary forest[28–30]. Cultivation of illicit crops, specifically coca, is also a driver of deforestation in the region, particularly in Colombia, but also in Bolivia, Ecuador, and Peru[31,32].

Pastures and croplands are completely different from forests in terms of taxonomic, phylogenetic, and functional composition of their biota[33,34], leading to an almost complete loss of forest-dependent species. Among agricultural land uses, pastures hold significantly more diversity than mechanized agriculture[35]. Tree plantations also harbor an impoverished subset of forest species; for example, less than 5% of bird species captured on an oil palm plantation in Peru were also found in forests[36]. In summary, the contribution of agricultural lands to Amazonian biodiversity conservation is negligible[37], highlighting the irreplaceable value of forests[34]. There are also indirect impacts stemming from forest conversion - in addition to GHG emissions released during the deforestation process, pastures further contribute emissions due to regular burning and enteric fermentation[38]. Significant changes in the physical and chemical properties of the soil, such as soil compaction and changes in nutrient concentration[39–41], also result from forest conversion to pastures and croplands. Pesticide use on agricultural lands is often excessive[42,43]; however, their impacts on terrestrial systems have not been adequately quantified.

Roads Official roads and highways (i.e., those built by the government) extend deep into the Amazon; only the western part of the basin is free of roads.

Even if unpaved, official roads often spawn a network of unofficial roads (those built by local actors), providing access to previously inaccessible forests, and resulting in the classic 'fishbone deforestation' pattern. By 2016, the network of unofficial roads was so extensive that it surpassed official ones by almost 13-fold, reaching 551,646 km.

The direct impacts of road construction include increased roadkill[44] and fragmentation of habitats, isolating animal populations that have low mobility or aversion to open spaces[45,46]. However, the greatest impact of road building in the Amazon is indirect. The construction and paving of official and, subsequently, unofficial roads reduces transportation costs, increasing the value of land and making agriculture and ranching more profitable[47]. This leads to land speculation and increased deforestation to secure tenure[48] (see also Chapters 14 and 15). As a result, the presence of roads is strongly

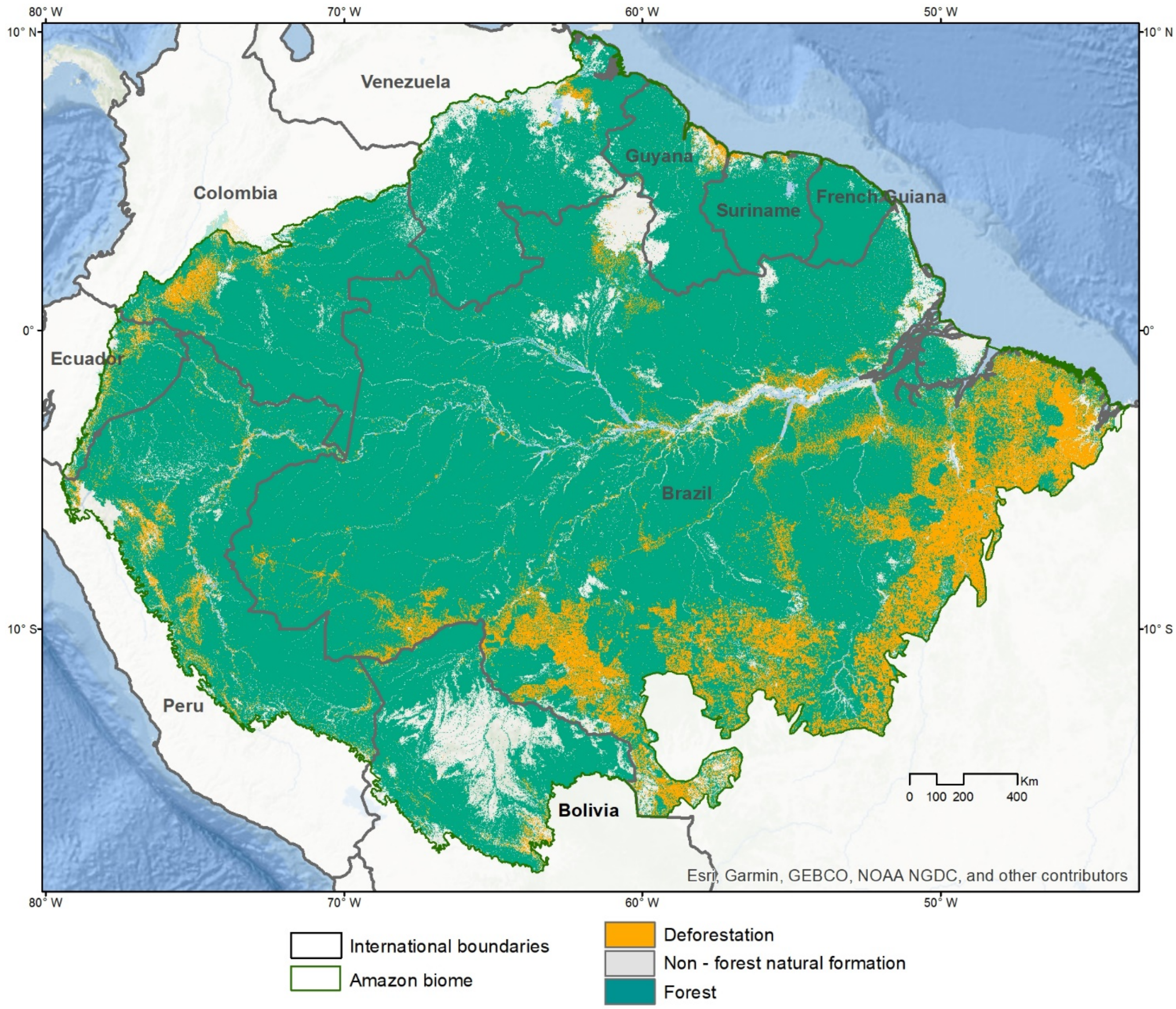

Figure 19.1 Current land occupied by either natural vegetation or pasture and agriculture across the Amazon biome. Cumulative deforestation data is shown until 2018 [19] and analyzed according to Smith et al.[115].

associated with deforestation in the Brazilian[49,50], Peruvian[51–53], and Ecuadorian Amazon, although in the latter road construction is linked to oil concessions[54,55] (see also Chapter 18). Roads also stimulate forest degradation, including selective logging[56–58], as they provide machinery access (e.g., logging trucks, skidders) to areas that contain valuable timber.

Mining Mining is a major source of environmental impact in the Amazon, with approximately 45,000 mining concessions either in operation or waiting for approval, of which 21,536 overlap with protected areas and Indigenous territories. While some minerals, such as bauxite, copper, and iron ore[59], are extracted legally by large corporations[60], gold mining is largely illegal[61,62] (see also Chapters 14 and 18). Despite its illegality, gold mining is a semi-mechanized activity, employing large and expensive machinery such as exploration drills and hydraulic excavators[63–65].

The amount of forest loss directly attributable to mining is immensely smaller than that caused by agriculture. Still, it represents the main driver of forest loss in French Guiana, Guyana, Suriname, and parts of Peru[66,67]. Moreover, as is the case with roads, the indirect impacts of mining are much greater than the direct ones. In Brazil, for instance, mining was responsible for the loss of 11,670 km^2 of Amazonian forests between 2000 and 2015, corresponding to 9% of all deforestation in that period[60], with effects extending 70 km beyond the boundaries of mining concessions. Mining also stimulates forest loss by motivating the construction of roads and other transportation infrastructure that lead to deforestation[10,68].

Oil and gas Oil and gas exploitation occur mainly in the western Amazon, where 192 oil and gas leases are under production and 33 are being prospected. Additionally, there are plans to exploit oil and gas across a vast area of Brazil in Amazonas state [69]. As with mining, deforestation caused by oil and gas exploitation is minimal when compared to that caused by agriculture expansion. Still, these operations can lead to severe oil spills, as has occurred on numerous occasions in Colombia, Ecuador, and Peru[70–72], impacting people and wildlife[73,74]. Indirect impacts of oil and gas activities include the opening of roads, which significantly increases deforestation as described above.

Degradation While deforestation is binary (i.e., either the forest is present or absent), forest degradation is characterized by an impact gradient, ranging from forests with little, although significant, loss of ecological value to those suffering severe disruption of functions and processes[75]. It is estimated that an area roughly the size of Germany, or 366,300 km^2, of Amazonian forests were degraded between 1995 and 2017[76]. Several anthropogenic disturbances can lead to forest degradation in the Amazon, such as forest fires, selective logging, edge effects, and hunting[77–80].

Forest fires In most years, and in most undisturbed forests, high moisture in the understories of Amazonian forests keeps flammability levels close to zero[81–83]. However, every year thousands of hectares of forests burn across the basin[84,85] as fires escape nearby pastures or recently deforested areas. Forest fires spread slowly, have flame heights of 30-50 cm, and release little energy (≤ 250 kW/m)[86,87]. Notwithstanding this, their impacts can be enormous as Amazonian moist forests have not co-evolved with fire. They cause high levels of stem mortality, negatively affect carbon stocks[75,88,89], and take years to recover.

It is estimated that burned forests in the Amazon have carbon stocks that remain 25% lower even 30 years after a fire, with growth and mortality dynamics suggesting that recovery has plateaued[90]. High tree mortality caused by understory fires leads to significant taxonomic and functional changes in the plant community; species with high-wood density are lost, while light-wood pioneer species dominate[91,92]. It is currently unknown whether burned forests will eventually return to their original composition. Climate change scenarios predict increased frequency of extreme weather events and warmer climatic conditions[93,94] (see also Chapters

22-24), exacerbating fire concurrency across the biome.

Edge effects Deforestation has promoted, over the past few decades, forest fragmentation, creating man-made forest edges, which are impacted by a number of edge effects[95,96]. Between 2001 and 2015, around 180,000 km^2 of new forest edges were created in the Amazon[97]. Edge effects lead to changes in evapotranspiration rates, increases in light intensity and wind exposure, and increased desiccation[98], which may extend hundreds of meters into adjacent forests[99]. This leads to increased plant mortality in edge habitats and, as a consequence, increased carbon losses. Recent estimates of carbon losses associated with edge effects in the Amazon (947 Tg C) corresponded to one-third of losses from deforestation (2,592 Tg C). Carbon losses are not offset by tree growth or recruitment; forest edges suffer a drastic change in species composition, becoming dominated by lianas and small, less-dense trees which store less carbon[100,101]. Furthermore, forest edges are more susceptible to other types of disturbances[89], such as fires[102–104]. This may lead to local extinctions of specialist species unable to adapt to new, disturbed conditions. It favors edge- and gap-specialist species and could facilitate colonization and range expansion for non-forest species[105].

Logging Amazonian countries represent 13% of the world's tropical sawn wood timber production; Brazil alone is responsible for more than half (52%), followed by Ecuador (11%), Peru (10%), and Bolivia (10%). Venezuela, Colombia, Suriname, and Guyana make up the remaining 17%[106]. In the Brazilian Amazon, selective logging annually affects an area the same size as that deforested[107–109], concentrated mostly along the deforestation frontier and surrounding the major logging centers[110]. In Peru and Bolivia, selective logging practices are concentrated in forest concessions[111–113]; however, illegal, unsustainable logging practices prevail across the basin[77] (see also Chapter 14), and the industry is beset by high levels of illegality, including false permits and weak enforcement[111,113–115]. The prevalence of illegal timber discourages sustainable logging practices and prevents governments and society from reaping the important ecological and economic benefits offered by better forest management practices[116,117]. Logging affects energy and water dynamics due to changes in albedo and surface roughness caused by high levels of canopy openness, mainly in the short-term (1-3 years)[118]. These practices also promote warmer temperatures inside the forest[19], and, depending on the intensity of extraction, biomass recovery for future harvesting is compromised.

Hunting Commercial exploitation of animals for furs, hides, and feathers in the 20th century was intense; it is estimated that 23.3 million wild mammals and reptiles of at least 20 species were commercially hunted between 1904 and 1969[119]. Exploitation is now predominantly for food, with Peres et al.[120] estimating that hunting affects 32% of remaining forests in the Brazilian Amazon (~1M km^2), with a strong depletion of large vertebrate populations in the vicinity of settlements, roads, and rivers[121].

The impacts of hunting vary by species depending on their life histories; taxa that are long-lived and have low birth rates are the most vulnerable to local extinction[122]. Habitat loss, fragmentation, and forest degradation interact with hunting to reduce and isolate populations, inhibiting 'rescue' and repopulation from neighboring forests. This is exacerbated by edge effects, which increase accessibility by hunters[123]. Over-hunting may have pervasive impacts on Amazonian forests by disrupting or entirely removing 'top-down' control on ecosystems mediated by large-bodied animals, leading to widespread and potentially irreversible loss of ecosystem resilience and function[124].

Conclusions Deforestation and degradation are major drivers of biodiversity loss and GHG emissions, with dire consequences for human and natural systems at the local, regional, and global levels. Over the past 35 years, over 700,000 km^2 of forests have been completely removed across the Amazon, while an additional ~360,000 km^2 have been degraded. Although deforestation has been mostly driven by agricultural expansion, large infrastructure development projects, mining (both legal and illegal), and oil and gas exploitation have also played a significant role. Major impacts include the extinction and/or impoverishment of plant and animal communities, reductions in carbon sinks, and decreased evapotranspiration. The impacts of forest degradation, driven by forest fires, edge effects, selective logging, and hunting are much more cryptic, although they can lead to severe and long-term impacts in affected forests. The impacts of both deforestation and forest degradation will likely be exacerbated by climate change, an underlying pressure on all Amazonian forests.

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