

# DEFORESTATION AND FOREST FRAGMENTATION IN THE AMAZON

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## Summary

The Amazon Basin sustains well over half of the world's remaining tropical rainforest and includes some of the most biologically rich ecosystems ever encountered. Historically, human development in this region has been limited. However, this is rapidly changing as more forests of the Amazon have been destroyed in the last few decades than during the previous 450 years since European colonization. Deforestation rates in the Amazon now roughly average 3-4 million ha per year—an area larger than Belgium. The causes of increased deforestation in the Amazon are several, including large-scale cattle ranching, industrial agriculture, slash-and-burn farming, and logging.

The rapid pace of deforestation and logging in the Amazon is leading to widespread forest fragmentation. Habitat fragmentation has myriad effects on Amazonian forests, such as altering the diversity and composition of fragment biota, and changing ecological processes like pollination, nutrient cycling, and carbon storage. The ecological changes that occur as a result of fragment isolation are generally proportional in magnitude to fragment area. As a consequence, small fragments usually contain less species overall (smaller species richness), and a lower density of species per unit area, than do larger fragments. Amazonian forest fragments appear particularly prone to edge effects. Under natural conditions, edges in tropical forests are rare, but when a forest is fragmented, the amount of edge increases dramatically. The new edges are artificial and abrupt, forming a stark boundary between the forest and the adjoining altered landscape. One of the most striking edge effects is a dramatic increase in tree mortality and damage, leading to increased canopy-gap formation. Edge effects in fragments also alter physical gradients, and species abundances. In general, species that are most vulnerable to fragmentation tend to respond negatively to edges, have large area requirements, or are intolerant of the surrounding “matrix” (i.e. the mosaic of modified habitats that surrounds habitat fragments), whereas species that are resilient to fragmentation usually have opposite sets of characteristics.

Forest fragmentation increases the vulnerability of Amazonian forests to fire, given that fragments have dry, fire-prone edges, and are juxtaposed with frequently burned pastures. Once-burned forests become highly vulnerable to recurring fires of even greater intensity, because the mortality of many plants reduces canopy cover and leads to increased dry litter on the forest floor. As a result of repeated fire incursions, the edges of rainforest remnants may recede over time, leading to fragment “implosion”.

## 1. Introduction

The Amazon Basin sustains well over half of the world’s remaining tropical rainforest and includes some of the most biologically rich ecosystems ever encountered. Closed-canopy forests in the basin encompass about 5.3 million square kilometers, an area the size of Western Europe. By far the most extensive forest type is *terra-firme*—forests that are not seasonally flooded. There also are large areas of seasonally flooded forest along rivers and in floodplains (termed *várzea* if they are flooded by relatively nutrient-rich white waters, and *igapó* if inundated by nutrient-poor black waters), and limited areas of bamboo forest and vine forest. In addition, scattered savannas and open forests occur in drier areas of the basin, where narrow strips of rainforest vegetation (termed “gallery forest”) often persist along permanent rivers and streams.

Most of the Amazon is flat or undulating, at low elevation (<300 m), and overlays very poor soils. Roughly four-fifths of the Amazon’s soils are classified as *latosols*, which are heavily weathered, acidic, high in toxic aluminum, and poor in nutrients. Somewhat more productive soils in the Amazon are concentrated along the basin’s western margin, in the Andean foothills and their adjoining floodplains. These areas are much more recent geologically than the rest of the basin and thus their soils are less heavily weathered.

Rainfall varies markedly across the Amazon. In general, forests in the basin’s eastern

and southern portions are driest, with the strongest dry season. Although evergreen, these forests are near the physiological limits of tropical rainforest, and can persist only as a result of having deep root systems that access groundwater during the dry season. The wettest and least seasonal forests are in the northwestern Amazon, with the central Amazon being intermediate; forests in these areas do not require deep roots.

Historically, human development in this region has been limited by the basin's poor soils, remoteness from major population centers, and diseases such as malaria and yellow fever. However, this is rapidly changing as more forests of the Amazon have been destroyed in the last few decades than during the previous 450 years since European colonization. Deforestation rates in the Amazon now roughly average 3-4 million ha per year—an area larger than Belgium. The most reliable deforestation statistics are for the Brazilian Amazon (Figure 1), which have been produced annually since 1989 (except 1993) by Brazil's national space agency based on interpretation of satellite imagery. Considerable year-to-year variation in deforestation rates (Figure 1) results from changing economic trends, evolving government policies, and climatic conditions. Rates of deforestation have been especially high from 2002 to 2004, when nearly 2.5 million ha of forest was destroyed annually.

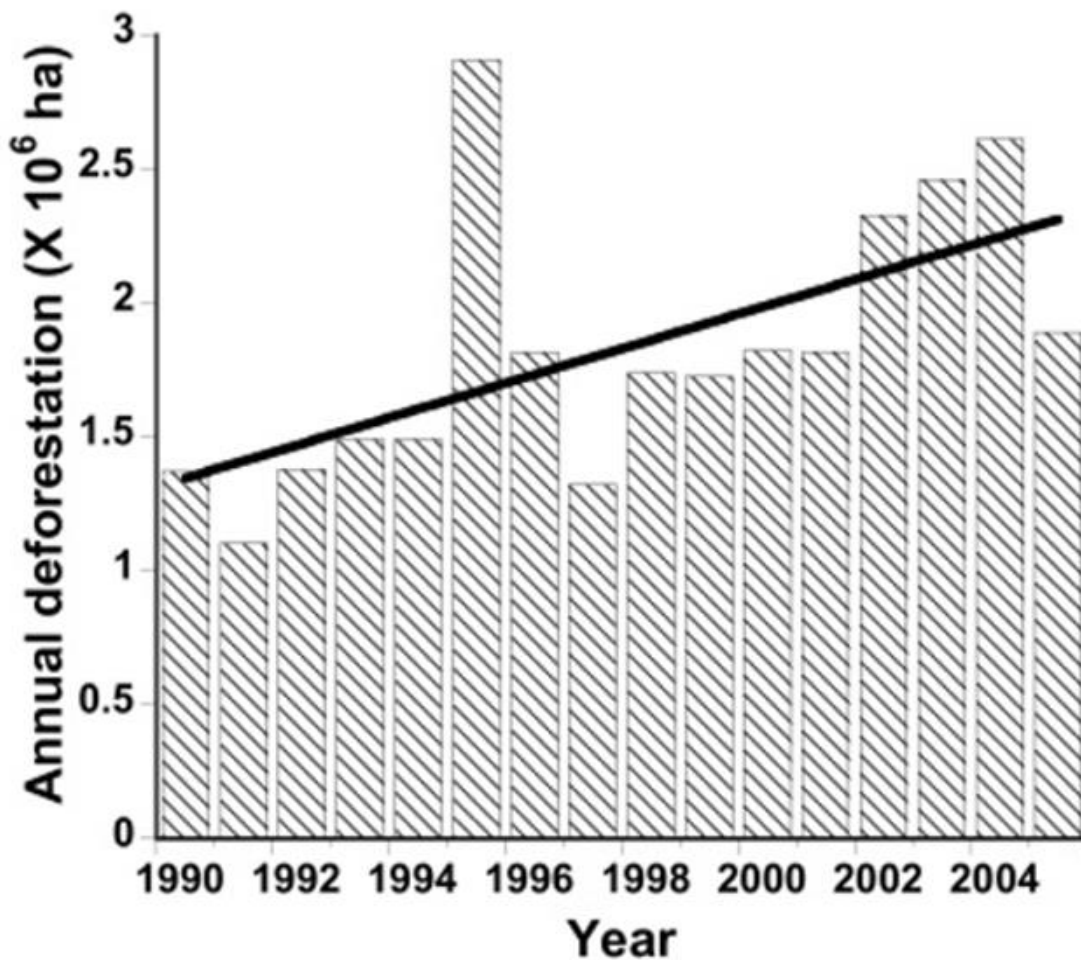


Figure 1. Estimated deforestation rates in Brazilian Amazonia from 1990 to 2005 (data from INPE 2005). The regression line shows the overall trend.

## 2. Causes of Deforestation

The causes of increased deforestation in the Amazon are several. The first is large-scale cattle ranching. Ranchers typically use bulldozers to extract timber prior to felling and burning the forest. Large- and medium-scale ranchers are estimated to cause 70-75% of all deforestation in the Brazilian Amazon, and are also responsible for much forest loss elsewhere in Latin America. The second major cause of deforestation is slash-and-burn farming, typically conducted by small landowners who clear limited areas of forest each year. The forest's understory is slashed with machetes and the debris is ignited during the dry season. The ash from the burned vegetation provides a brief pulse of plant nutrients, which supports crops for a few years before the area is left fallow and the farmer is forced to clear more forest. Slash-and-burn farming occurs both opportunistically and as a result of government-sponsored colonization programs that allocate forest plots of 50-200 ha to individual families.

A third cause of deforestation, industrial agriculture, is increasing rapidly in importance along the drier southern margins of the Amazon and its adjoining transitional forests and cerrado woodlands and savannas. Most of these farms are devoted to soybean farming, which involves clearing large expanses of flat land for crop production. Finally, industrial logging is increasing sharply in the Amazon. In the tropics, logging is usually selective in that only a small percentage of trees are actually harvested. Amazonian timber harvests are less intensive than the massive cuts typical in Asia, with most timber operations removing only 1-10 trees per hectare. This is because many Amazonian trees have poor to marginal wood properties or lack commercial markets.

The direct impacts of logging thus mostly arise from the networks of roads, tracks, and small clearings created by bulldozers, skidders, and other heavy equipment during cutting operations. These networks cause collateral tree mortality, soil erosion and compaction, vine and grass invasions, and microclimatic changes associated with disruption of the forest canopy. In addition, logging has important indirect effects: by creating labyrinths of forest roads, logging opens up areas for colonization by ranchers and migrant settlers who often use destructive slash-and-burn methods to clear the forest.

## 3. Forest Fragmentation

The rapid pace of deforestation and logging in the Amazon is leading to widespread forest fragmentation. One key study found that by 1988, the area of forest in Brazilian Amazonia that was fragmented or prone to edge effects (i.e., ecological changes associated with the abrupt, artificial edges of forest fragments) was over 150% larger than the area that had actually been deforested. As further detailed below, habitat fragmentation has myriad effects on Amazonian forests, such as altering the diversity and composition of fragment biota, and changing ecological processes like pollination, nutrient cycling, and carbon storage.

Forest fragmentation is occurring at many spatial scales. On a regional scale, the once-remote interior of the Amazon is being dissected by major highways, power lines, and transportation projects, which inevitably lead to rapid deforestation. On a local scale,

different land-uses tend to generate characteristic spatial patterns of fragmentation. Cattle ranchers, for example, typically destroy large, rectangular blocks of forest, and habitat fragments that persist in such landscapes are somewhat regular in shape (Figure 2). Forest-colonization projects, however, result in more complex patterns of fragmentation, creating irregularly shaped fragments and a very high proportion of forest edge. The resulting spatial pattern has been likened to the ribs of a fish (Figure 2).

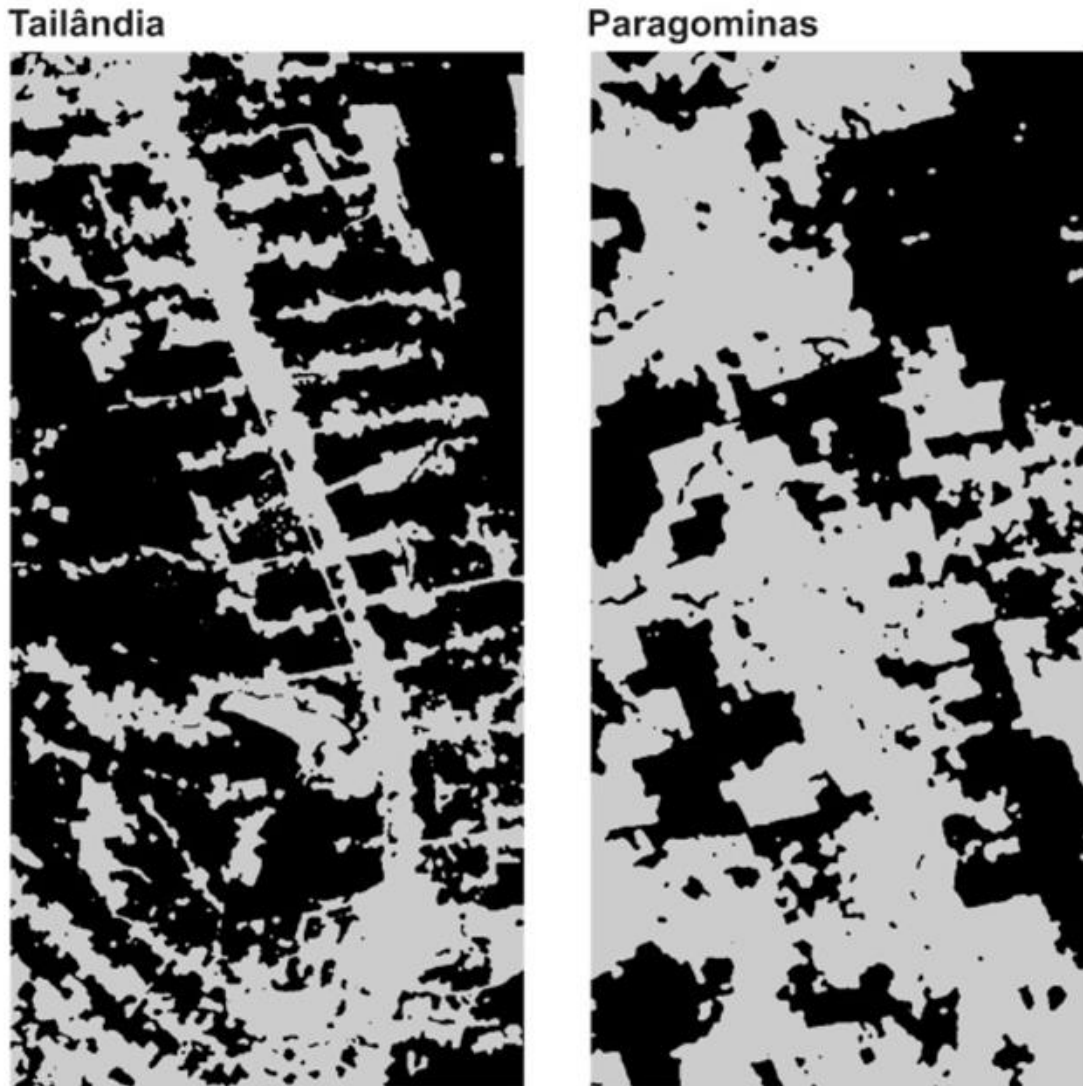


Figure 2. Different land uses in the Brazilian Amazon produce distinctive patterns of forest fragmentation. Government-sponsored colonization projects in Tailândia result in a “fishbone” pattern of fragmentation, which differs from the fragmentation pattern caused by cattle ranching near Paragominas. Each image shows an area of about 600 km<sup>2</sup>.

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### Biographical Sketches

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