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GLOBAL FOREST WATCH

WORLD RESOURCES INSTITUTE

WRI REPORT






PAULO BARRETO

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IN COLLABORATION WITH

JANICE WILES

HUMAN PRESSURE ON THE BRAZILIAN AMAZON FORESTS

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CONTENTS

LIST OF ACRONYMS

ARPA	Protected Areas in the Amazon Program
DNPM	National Department for Mineral Production
EMBRAPA/CPATU	Brazilian Agricultural Research Institute/Center for Agricultural Research in the Humid Tropics
FAO	Food and Agriculture Organization
GFW	Global Forest Watch
IBAMA	Brazilian Institute for Environment and Renewable Natural Resources
IBGE	Brazilian Institute for Geography and Statistics
IMAZON	Amazon Institute of People and the Environment
INCRA	Brazilian Institute for Colonization and Agrarian Reform
INESC	Institute for Socio-Economic Studies
INPE	Brazilian Institute for Space Research
ISA	Socio-Environmental Institute
MDA	Brazilian Agrarian Development Ministry
MMA	Brazilian Ministry of Environment
NOAA	National Oceanic and Atmospheric Administration
WRI	World Resources Institute
WWF	World Wildlife Fund

FOREWORD

Brazil has the largest expanse of tropical rainforest in the world, comprising some 40 percent of the world's remaining tropical forest cover. As such, it represents both an extraordinary resource for the people of Brazil, and also an invaluable asset for the people of the world.

Millions of my people depend, directly or indirectly, on the Amazon for their livelihood: farmers sell crops at home and into the world markets; the forest sector accounts for almost 8 percent of our country's annual wealth. And the great Amazon basin sustains millions of indigenous people who depend on the richness of this place to provide for their every need.

That the Southern hemisphere experienced its first hurricane in recorded history last year makes it even more critical that we recognize the value of such ecosystems as the Amazon Basin and the critical service they provide to the global community. They also serve as regulators of climate, vaults of biodiversity, and great natural cleansing engines.

As we become increasingly aware of the important role that large ecosystems play in our current and future lives, we begin to understand just how important it is that we mange them wisely and with a very long-term perspective.

This report provides us with an extraordinary set of tools to use in that effort. The scope and detail of these maps are vital if we are to make the necessary and unavoidable choices in the future to balance the needs of our people in Brazil with the legitimate needs of the world's people increasingly impacted by global environmental change.

We know that the Amazon is subject to significant human pressure, and we can see where it is, its nature, and its impact. What we can also see, however, is that human settlement—human incursions into the Amazon tend to take on a life of their own. Approved and defined development becomes the trigger for what this report terms "incipient" development, that is, emerging pressure on the Amazon that is not planned. The maps here are unequivocal about that.

One of the actions of which I am most proud as President of Brazil was the establishment of the Amazon Region Protected Areas. With our partners, this program recognizes the international environmental reach of the Amazon and it also accommodates the legitimate aspirations of Brazil's most impoverished.

What these incomparable set of maps, and the accompanying report show, however, is that while

there is more than sufficient unspoiled area in the Amazon to meet our preservation goals, we must be vigilant to the pressure on the Basin that radiates out from settlements, and, as importantly, the impact of isolated development that disrupts intact ecosystems and does damage in ways we have yet to fully understand. These maps paint a stark and compelling picture.

Brazil is acutely aware of the dual responsibility that nature, geography, colonial exploration, and statecraft have placed upon it. It does not shirk its unique obligation to the world community that the special circumstance of the Amazon Basin demands. Nor does Brazil intend to shirk its duty to its people to provide them with the opportunity for better, productive lives.

Balancing those enormous demands requires wise choices and the tools and information to inform those choices. That is the inestimable value of this report.

Fernando Henrique Cardoso
Former President of the Federative Republic of Brazil

Key Findings

• In 2002, approximately 47 percent of the Brazilian Amazon was under some type of human pressure including deforested areas, urban zones, agrarian reform settlements, areas allocated for mining and mining exploration as well as areas under pressure as indicated by incidence of fire.

• Our analysis suggests that in 2002 there remained enough forest area without evidence of human pressure to fulfill the government's goal to expand the protected areas system. This includes about one million km^2 of land considered priority for establishing new protected areas and public production forests. However, we can assume that the pressure has continued to increase in the region, so the government must act quickly to implement their protected areas goal. Establishing new protected areas in lands free of pressure will help prevent land use conflicts. Areas of incipient human pressure are still valuable for conservation—due to relatively low intensity of use—but the political costs of establishing protected areas in these zones will be higher given the interests already in place.

• About 80 percent of the total area deforested is located within 30 km of an official road. However, about half of the area of older fire zones (1996-1999) and two-thirds of more recent fire zones (2000-2002) are located farther than 30 km from roads. There is a need to better account for this environmental impact in the planning, building, and maintenance of transportation corridors.

EXECUTIVE SUMMARY

The Brazilian Amazon harbors about one-third of the world's tropical forests, an area covering some 4.1 million square kilometers. However, land-use conversion in the Brazilian Amazon is triggering forest loss and degradation and rapidly changing the regional landscape. FAO data reveal that Brazil accounted for approximately 42 percent of global net forest loss from 2000 to 2005; most of this deforestation occurred in the Brazilian Amazon.

In response to public demand for forest conservation many stakeholders are attempting to reconcile economic development and conservation through initiatives that include forestry regulation, enforcement of environmental legislation, and the creation of protected areas. Given the rapid expansion of activities such as cattle ranching, agriculture, and logging, these initiatives must quickly target priority areas to be successful. This demands

accurate and detailed information on the current state of Amazon forests and the pressures they face. Yet such information remains elusive. Despite advances such as satellite imaging, our understanding of the extent and degree of human activities in the Brazilian Amazon is only partial. Even deforestation (forest clear cutting) is not fully understood. Up to 1997, the Brazilian Space Agency (INPE) mapped deforested areas greater than 6.5 ha. Since then, INPE has improved mapping technique but it still misses deforested areas smaller than 3 ha.

Identifying small deforestation plots and other indicators of incipient human activities in forests could flag areas at risk of increased deforestation and forest degradation. Pinpointing these areas at risk would provide strategic guidance for conservation and sustainable development in the region. But despite this potential, no comprehensive analysis that integrates such spatial data with other standard measures of forest condition yet exists to help conservation and development planners understand the true extent of human activities in the region.

This report seeks to help fill this gap. It compiles and integrates geospatial information on various indicators to present a picture, roughly as of 2002, of the human pressure on forests in the Brazilian Amazon. *Human pressure*, for this report, is defined broadly as the presence of human activities that lead to forest loss and degradation.

The report distinguishes two major types of areas under human pressure:

Areas under pressure from human settlements. In these areas, human presence is fully established, settlements are permanent, and land use tends to be more intensive. Environmental impacts in these areas are higher than in occupation frontiers because of greater forest fragmentation as well as urban and industrial activities. Three indicators were analyzed in this category: *deforested areas, urban zones, and agrarian reform settlements*.

Areas subjected to incipient human pressure. In these areas human presence may be temporary, but in some cases people will settle in the future and influence the forest condition (for example, fragmenting the forest ecosystem). Logging, wildcat (part-time) mining, hunting, harvesting of non-timber forest products, and shifting cultivation are some of the human activities that occur in these areas. Two indicators were analyzed in this category: *fire zones* and *areas allocated for mining and mining exploration*. For the purposes of this analysis, *fire zones* are defined as areas of human activity associated with the incidence of forest fires.

At the time of the analysis, no comprehensive information on *roads* and *logging* in the Brazilian Amazon region was available. Thus, the map of human pressure we produced did not factor in these two important indicators of human activity. However, understanding the crucial role of these two factors in forest impact, we did examine the relationship among human pressure, roads, and logging using available information. Finally, we also examined the relationship between human pressure and *protected areas*.

FINDINGS

In 2002, approximately 47 percent of the Brazilian Amazon was under some type of human pressure, either as areas under pressure from human settlements (19 percent) or areas subjected to incipient human pressure (28 percent).

Areas under pressure from human settlement were found primarily along official roads in the so-called "arc of deforestation," comprising the eastern and southern edges of the forests in the states of Rondônia, Mato Grosso, and Pará. Other significant locations under human pressure were along the Trans-Amazon highway in the State of Pará, along the Amazon River between Manaus and Belém, along the Cuiabá-Santarém highway near the city of Santarém, and around the main urban centers in the states of Roraima and Amapá.

Areas showing incipient human pressure were generally clustered and adjacent to areas of human settlements, indicating frontier expansion. This was especially true in the states of Pará, Mato Grosso, and Rondônia. There were, however, isolated areas of incipient human pressure along navigable rivers throughout the region. Such areas appeared to be associated primarily with traditional *mestizo* communities and indigenous populations.

PRESSURE FROM HUMAN SETTLEMENTS

Deforested Areas. In 2001, deforested areas covered 11 percent of the Brazilian Amazon. Cattle ranching is the predominant land use in deforested areas throughout the region (Schneider et al 2002). Between 1990 and 2003, the cattle herd in the Legal Brazilian Amazon increased from 26.6 million to 64 million head, representing a 140 percent increase (IBGE 2005).

Urban Zones. The area under pressure from urban zones covered 6 percent of the Brazilian Amazon. Urban zones were identified as the area within a 20-km radius around the region's 450 municipal seats as of 1997 (the most updated dataset available at the time of the analysis) (IBGE 1999). The 20-km radius was based on field observations, and was intended to capture areas under pressure from urban populations, such as small-scale clearings used for periurban agriculture, spontaneous settlements, intensive extraction of forest products, waste deposits, and release of untreated sewage.

Agrarian Reform Settlements. The extent of Agrarian Reform Settlements (lands granted by the federal government to landless people) established as of 2002 (INCRA 2002) covered nearly 5 percent of the Brazilian Amazon. Of this area, about half is made up of forested areas that do not overlap with any other indicator of human pressure.

INCIPIENT HUMAN PRESSURE

Fire Zones. Approximately 28 percent of the Brazilian Amazon was subjected to incipient human pressure associated with fire activity. Fire zones are defined as the 10-km radius around a forest fire, as detected by satellite between 1996 and 2002.

Human pressure may vary within fire zones. Two-thirds of fire zones are concentrated near deforested or urban zones; forests in these areas have likely been subjected to intensive pressures such as logging. The remaining third is found in more isolated locations, indicating fires caused by shifting agriculture carried out by traditional *mestizo* communities or indigenous populations. Forests in these areas may be subjected to less intensive pressures such as hunting, harvesting of non-timber forest products, and selective logging.

There are overlaps between fire zones and other indicators of human activity:

- With areas affected by selective logging, including the location of half of the selective logging permits issued by the Brazilian Government;
- With the location of informal roads (identified from satellite imagery) in the northern portion of Mato Grosso and South-Central Pará.

Between 2000 and 2002 the number of annual forest fires nearly doubled from 22,000 per year to almost 43,000 per year, showing an acceleration of incipient human activity.

Areas Licensed for Mineral Exploration. In 1998, the total area legally allocated for mineral exploration and mineral reserves was approximately 2 percent of the Brazilian Amazon. More than half of the allocated area overlapped with other indicators of human pressure. However, should areas licensed for mineral exploration become economically viable in the future, improved access and services could spark rapid in-migration and deforestation. Gold mining, for instance, has been an important catalyst of colonization in the Tapajós Mining Reserve in western Pará.

LOGGING

The total area of selectively logged forests in the Amazon is unknown, although estimates indicate this activity may affect 10,000-20,000 km^2 of forest per year in the Brazilian Amazon (Nepstad et al. 1999; Matricardi et al. 2001; Cochrane 2000; Asner et al. 2005). Some of these forests are converted to agricultural and pasture land soon after timber is harvested, while other areas remain as logged forest. Evidence suggests that most logged forests are within the areas of human pressure identified in this report. However, analysis is needed to fully and accurately map the extent of logging.

A substantial share of the timber harvested in the Brazilian Amazon—estimated at 47 percent in 2001 and 43 percent in 2004—is thought to be illegal (Lentini et al. 2005). These figures probably represent an underestimate of illegal logging, since numerous licensed loggers fail to implement forest management plans or harvest illegally in public unclaimed lands. As conventionally practiced, logging causes substantial damage to the forest, especially when associated with wildfires. Some companies have adopted best practices and have obtained green certification. Nevertheless, there are no recent independent evaluations of approved logging outside certified operations. There is a need to combine fieldwork with interpretation of satellite

imagery to systematically monitor the impacts of logging throughout the Brazilian Amazon.

ROADS

About 80 percent of the total area deforested is located within 30 km of an official road. However, about half of the area of older fire zones (1996-1999) and two-thirds of more recent fire zones (2000-2002) are located farther than 30 km from roads.

Human activity in distant areas is possible given access by rivers and a growing network of unofficial roads opened by loggers, ranchers, and miners. In southern Pará, for instance, about 17,000 km of roads were built between 1985 and 2001, 60 percent of them on unclaimed public land. Protected areas seem to slow the advance of unofficial roads; average growth rates for unofficial roads inside protected areas are three times lower than those outside protected areas (Souza et al. 2004).

HUMAN PRESSURE AND PROTECTED AREAS

Some 28 percent of protected areas have been subjected to human pressure. This is significantly smaller than the percentage of forest areas showing human pressure outside protected areas, which totals 59 percent. As proximity to roads increases (< 25 km), there is a significant increase of deforestation and fires within protected areas. Increasing transportation infrastructure without a corresponding capacity for enforcement is likely to result in greater human pressure on protected areas. Better infrastructure may also increase demands to shrink existing protected areas to benefit the expansion of agribusiness, as the State Government in Mato Grosso approved in 2003.

Human Pressure in Non-Protected Priority Areas for Conservation

About 48 percent of the non-protected areas identified as a priority for biodiversity conservation (Capobianco et al. 2001) show evidence of human pressure. Lands under pressure from human settlements account for 18 percent and those areas subjected to incipient human pressure account for 30 percent. Most of the area under human pressure is in the eastern and the southern Brazilian Amazon, and along the largest rivers such as the Lower and Middle Amazon and the Upper Rio Negro.

Human Pressure in Potential Public Production Forests

Nearly 30 percent of the 1.5 million km^2 identified in 1999 (Verissimo et al. 2000) as having the potential to become public production forests show some type of human pressure. Furthermore, the majority of these areas showing human pressure overlap with the areas identified to be economically accessible for logging (Verissimo et al. 1999). Economic accessibility to logging would be beneficial to promote sustainable use of forests if appropriate concession regulation and enforcement capacity were in place. However, insufficient regulation and ineffective enforcement has spurred illegal and predatory occupation of some existing National Forests.

Risks and Opportunities for the Creation of Protected Areas

About one million km^2 of land considered priority for establishing new protected areas and public production forests have not yet been affected by human pressure, according to our analysis. This is enough land for the federal and state governments to achieve their stated goals, which are to expand the protected areas system to 270,000 km^2 of conservation-oriented lands by 2009 and 395,000 km^2 of public production forests by 2010.

Some areas remain valuable for conservation purposes even though they are subject to incipient human pressure. However, in some instances, the presence of settlers, loggers, and gold miners is hindering the establishment of protected areas in favor of other more popular alternatives, such as agrarian reform settlements or the establishment of titled land. In fact, the Brazilian Congress recently ratified legislation foregoing a bidding process for titling small land holdings (less than 5 km^2) on public lands in the Brazilian Amazon occupied before December 2004, thwarting any possibility for these lands to be considered for the establishment of protected areas. The Ministry of Land Reform expects to grant titles for more than 20,000 km^2 of public lands, benefiting 150,000 families (MDA 2005). The continued and rapid expansion of human pressure requires rapid action by governments to create protected areas even before incipient human pressure occurs.

Responding to a national demand for conservation and encouraged by the lending policies of Multilateral Development Banks, some state governments have supported the creation of public production forests and reserves for sustainable development. This has occurred despite local opposition to strictly protected areas and indigenous territories. Therefore, societal demand and rapid government action can work for the protection of priority areas for conservation.

POLICY IMPLICATIONS

As our analysis shows, mapping and monitoring deforestation alone is not sufficient to understand the full range of human pressure on forests in the Brazilian Amazon. A more comprehensive analysis of pressures from human settlements, logging, roads, fires, and other sources is required. The findings presented here have several implications for public policies:

Vast areas in the eastern and central portions of the Brazilian Amazon show evidence of human pressure, especially in the form of fires. Nonetheless, the area that does not show evidence of human pressure is large enough for the federal government to meet its goal to expand and consolidate the protected areas system by 2010. However, the opportunities are diminishing. Human pressures are expanding rapidly, as indicated by trends in deforestation, cattle ranching, human population growth, and others. This expansion requires rapid action. Recent federal legislation allowing temporary limitation of land use in areas of interest for conservation could be applied in areas identified in this report to establish new protected areas. This has already occurred in an 82,000-km^2 area in western Pará in which 68,000 km^2 of protected areas were created recently.

Roads are correlated with human pressure. In order to protect priority areas for conservation, planned investments in road infrastructure should

be accompanied by the creation of protected areas in identified priority areas for conservation. In addition, efforts must be made to shield existing protected areas within the reach of the new or improved infrastructure. In this regard, the effort by the Brazilian government to create protected areas before paving the Cuiabá-Santarém highway (BR-163) is commendable. This approach should be applied along other proposed road-paving routes.

As illustrated by the case in the State of Mato Grosso, when human pressure increases due to greater economic opportunities, the government's commitment to protection may waver. This may even lead, as it did in Mato Grosso, to the reduction of the size of protected areas. Further analysis and policy debate to foster a long-term government commitment to protected areas is needed.

The evaluation of human pressure in the Brazilian Amazon presented in this report is an initial effort that will benefit from further refinement. Data limitations prevent full and precise analysis, and more detailed information is needed. For instance, a comprehensive map of the road network in the region does not exist. Imazon is currently addressing this limitation by digitizing from satellite imagery visible roads in the Brazilian Amazon. Likewise, an accurate and complete map of logged forests as well as other forms of forest degradation (such as burned forests) is unavailable. Existing remote sensing techniques, complemented with ground-truthing at strategic sites, will allow mapping of these features. Investment in these types of research is crucial to bring a clearer understanding of the extent and intensity of human pressures in the forests of the Brazilian Amazon.

Despite these limitations our analysis provides a more complete picture than formerly available of the dimensions of human pressures in the Brazilian Amazon and the diverse forms these pressures take. As such, it can help guide strategic actions to improve forest conservation until better information becomes available.

1
INTRODUCTION

The Brazilian Amazon harbors about one-third of the world's remaining tropical forests in an area covering some 4.1 million square kilometers. However, land-use conversion is occurring at unprecedented scales and in a complex manner. The mean annual deforestation rate from 2000 to 2005 (22,392 km^2 per year) was 18 percent higher than in the previous five years (19,018 km^2 per year). FAO data (FAO 2005) reveal that Brazil accounted for approximately 42 percent of global net forest loss from 2000 to 2005; most of this deforestation occurred in the Brazilian Amazon. As in other humid tropical forest regions worldwide, the consequences of this rapid change include losses of biological and cultural diversity, changes in the regional and potentially the global climate, and social conflicts (see Box 1). Projections indicate that the forces driving deforestation and forest degradation—such as demand for timber and agricultural products—will continue to grow in the next decade (Zhu et al. 1998; USDA 2005; OECD/FAO 2005). Forests loss is likely to increase if current trends prevail.

In response to mounting public concern over deforestation and forest degradation in the region, many stakeholders are attempting to reconcile development and conservation through initiatives that include the enforcement of environmental and

BOX 1 | **DEFORESTATION AND BIODIVERSITY LOSS**

An estimated 10-20 percent of all known species live in Brazil (Capobianco et al. 2001; Guimaraes Vieira et al. 2005). Deforestation has important implications for this wealth of biodiversity, since many of these species inhabit the forests of the Amazon Basin. The number of individual organisms affected by deforestation in Brazil is unknown, but is bound to be high, given the density of organisms and species per hectare of Amazon forest. One recent estimate suggests that as many as 50 million birds could have been directly affected on the 26,000 km^2 deforested in Brazil between 2003 and 2004 (Guimaraes Vieira et al. 2005). The number of primates affected in this period was estimated at 2 million.

Biodiversity is not the only casualty of deforestation. Other ecosystem services are also affected. Soil erosion, nutrient depletion, loss of watershed regulation functions, and emission of greenhouse gases are some of the more damaging ecosystem costs of forest clearing and degradation (Fearnside 2005).

forestry legislation, the creation of protected areas, and proposals to regulate the use of public forests. Specific government action along these lines includes:

- **Increase in legal reserves**: by law, private landowners can only clear a proportion of their holdings; the portions that remain forested are known as legal reserves. In 1996, the Federal government increased the legal reserves from 50 percent of the landholdings to 80 percent. This means that private landowners can only clear up to 20 percent of their lands. The Brazilian Congress approved this measure in 2001.
- **Higher fines for environmental crimes**: in 1998, the Brazilian Congress passed legislation that raised fines for environmental crimes (including illegal logging, deforestation and fires) from a maximum of US$2,200 to a maximum of US$ 22 million per event.[1] The fine for illegal deforestation is nearly US$700 per ha (0.01 km^2).
- **Creation of protected areas**: protected areas (see Box 2) remain the central feature of efforts to conserve the region's biodiversity and promote sustainable use of natural resources. By May 2004 about 32 percent of the Brazilian Amazon was contained in 427 protected areas; a quarter of these were indigenous lands (Capobianco et al. 2001; Viana and Valle 2003; ISA 2004). In March 2000, the federal government launched the Protected Areas in the Amazon Program (ARPA), aiming to create new protected areas. The program's goals include establishing 270,000 km^2 in strictly protected areas and 90,000 km^2 in areas for sustainable development by 2009. The federal government also launched in 2000 the National Forest Program, which proposes to expand the area of National or State Forests (public production forests) from 85,000 km^2 to 500,000 km^2 by 2010 (MMA 2000a). Public production forests are to be sustainably managed for the production of forest and non-forest products. Under the forest concession legislation approved in February 2006 these areas would be leased for sustainable use through public bids.

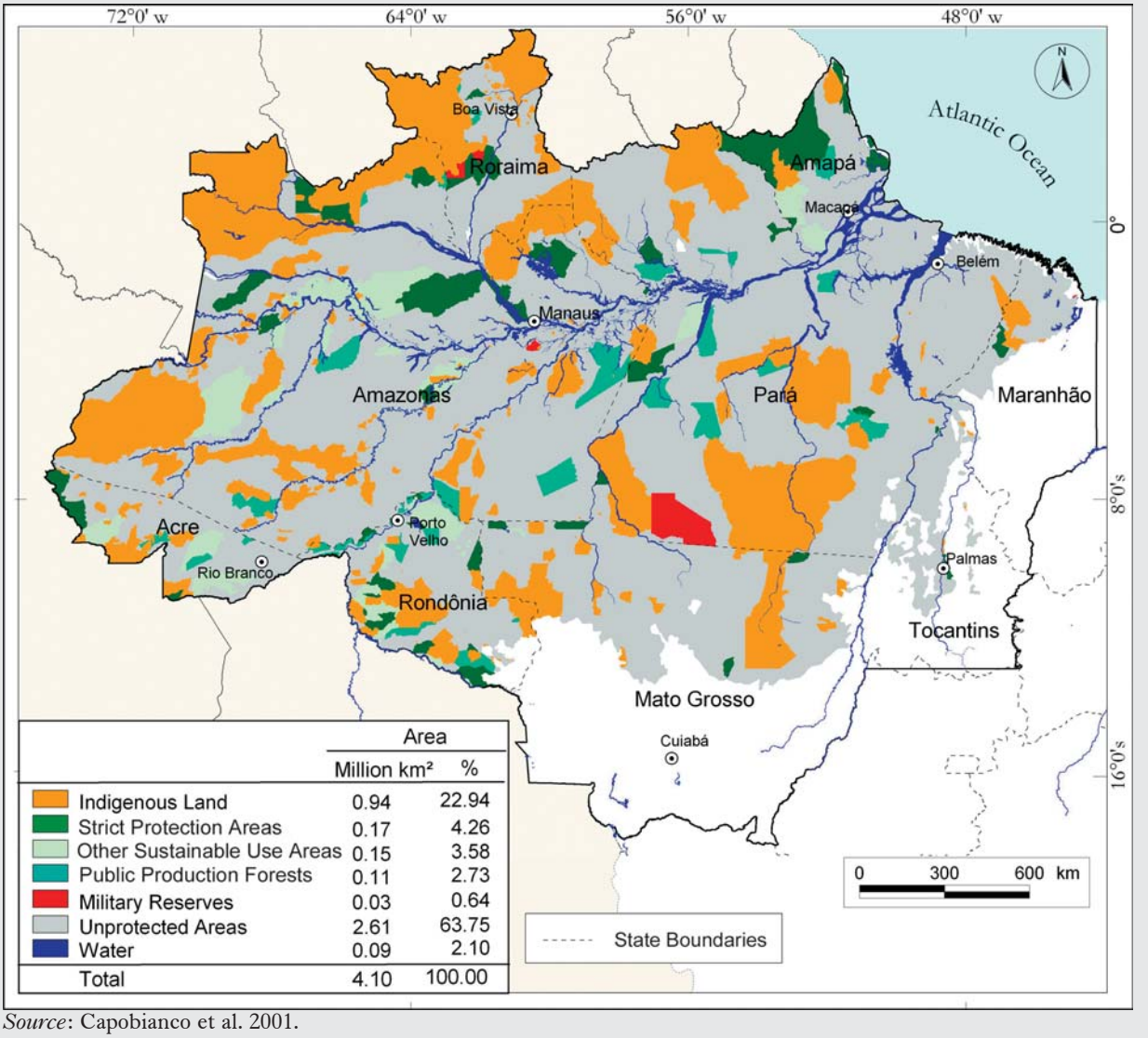
State governments have also established—or committed to establish—new protected areas, as part of projects financed by multilateral development banks. Such is the case in the state of Pará in a project financed by the World Bank, or in the state of Acre, in a project financed by the Inter-American Development Bank.

Given the rapid expansion of activities such as cattle ranching, agriculture, and logging, these initiatives must quickly target priority areas to be successful. This demands accurate and detailed information on the current state of the Brazilian Amazon forests and the pressures they face. Yet such information remains elusive. Despite technological advances, our understanding of the extent and degree of human activities in the region is only partial. Even deforestation (forest clear-cutting) is not fully understood. Up to 1997, the Brazilian Space Agency (INPE) mapped deforested areas greater than 6.5 ha. Since then, INPE has improved mapping techniques—using a digital system—but it still misses deforested areas smaller than 3 ha. Therefore, small scale shifting agriculture and incipient occupation may not be captured until they reach larger sizes.

BOX 2 | **PROTECTED AREAS IN BRAZIL**

The Brazilian protected areas system (*Sistema Nacional de Unidades de Conservação da Natureza*, or SNUC) encompasses federal, state and municipal protected areas (see map below). Appendix 1 show how SNUC categories relate to the IUCN (International Union for Conservation of Nature) categories.

PROTECTED AREAS IN THE BRAZILIAN AMAZON



	Area	
	Million km²	%
Indigenous Land	0.94	22.94
Strict Protection Areas	0.17	4.26
Other Sustainable Use Areas	0.15	3.58
Public Production Forests	0.11	2.73
Military Reserves	0.03	0.64
Unprotected Areas	2.61	63.75
Water	0.09	2.10
Total	4.10	100.00

Source: Capobianco et al. 2001.

Identifying these small deforestation plots and other indicators of incipient human activities in forested areas could flag areas at risk of increased deforestation and forest degradation. Pinpointing these areas at risk would provide strategic guidance for conservation and sustainable development in the region. But despite this potential, no comprehensive analysis that integrates such spatial data with other standard measures of forest condition yet exists to help conservation and development planners understand the true extent of human activities in the region.

This report seeks to help fill this gap. It compiles and integrates geographical information on major human pressures in the Brazilian Amazon (see Box 3). *Human pressure*, for the purposes of this study, is defined broadly as the presence of human activities that lead to forest loss and degradation.

This report distinguishes two major classes of areas under human pressure:

- **Areas under pressure from human settlements**. In these areas human presence is fully established, settlements are permanent, and land use tends to be more intensive than in occupation frontiers. Environmental impacts tend to be higher because of greater ecosystem fragmentation as well as urban and industrial activities.

Three indicators were analyzed in this category: *deforested areas*, *urban zones*, and *agrarian reform settlements*.

- **Areas subjected to incipient human pressure**. Incipient human pressure is associated with low density subsistence human settlements and initial occupation connected to market demand. In areas subjected to incipient human pressure, human presence may be temporary, but in some cases people will settle in the near future and influence the environment (for example, fragmenting forests and habitats). Logging, wildcat (part-time) gold mining, hunting, and harvesting of non-timber forest products are some of the human activities that occur in these areas.

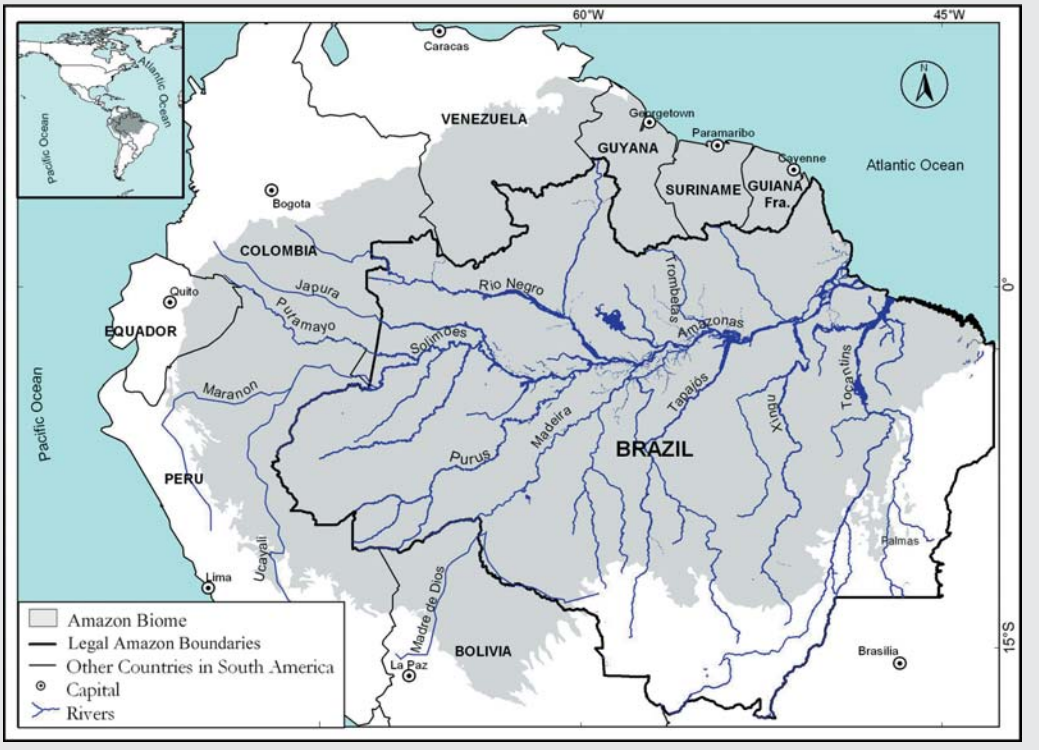
Two indicators were examined in this category: areas associated with forest fires or *fire zones* (which are also relevant to deforested plots smaller than 6.5 ha); and *areas allocated for mining and mining exploration*.

At the time of the analysis, no comprehensive information on *roads* and *logging* in the Brazilian Amazon was available. Thus, the map of human pressure did not factor in these two important indicators of human activities. However, understanding the crucial role of these two factors in forest impact, we did examine the relationship between human pressure, roads, and logging using available information. Finally, we also examined the relationship between human pressure and *protected areas*.

BOX 3 | **THE BRAZILIAN AMAZON, THE AMAZON BASIN, AND THE LEGAL AMAZON**

The Brazilian Amazon overlaps with two other geographic areas: the Amazon Basin and the Legal Amazon. The Amazon Basin extends over 6.8 million square km through Venezuela, Colombia, Ecuador, Peru, Bolivia, Brazil, French Guiana, Guyana, and Suriname (Goulding et al. 2003). Sixty percent of the Amazon Basin lie within Brazil's boundaries, and this portion is known as the Brazilian Amazon (shaded area within the black line in the figure below). The Legal Amazon (black line) contains more than 50 percent of Brazil's territory and is an administrative unit that encompasses the states of Acre, Amazonas, Roraima, Amapá, Pará, Rondônia, Mato Grosso, Tocantins, and Maranhão. Portions of the states of Maranhão, Tocantins, and Mato Grosso are outside of the Amazon Basin. While 86 percent of the original vegetation of the Brazilian Amazon consists of dense forests, it also includes open forests in the Amazon-Cerrado transition and savanna-shrub vegetation (Campinaranas) in the upper Rio Negro (Capobianco et al. 2001). Finally, most of the existing official statistics available are for the Legal Amazon.

THE BRAZILIAN AMAZON, THE AMAZON BASIN, AND THE LEGAL AMAZON



Source: Dinerstein et al. 1995.

2

BACKGROUND AND TRENDS IN HUMAN OCCUPATION IN THE BRAZILIAN AMAZON

For centuries, human settlement in the Brazilian Amazon occurred along the principal navigable rivers of the region. This pattern began to change in the 1960s due to three factors: a major infrastructure build up (roads, establishment of planned rural settlements, airports, and hydroelectric dams); the concession of subsidized credit channeled primarily to large-scale ranching; and the establishment of a free port in the city of Manaus. These initiatives provided a powerful incentive for immigration, opening up extensive areas for settlement primarily along the southern margins of the region and in the major urban centers. Starting in the mid-1990s, infrastructure investments by the state and federal governments have primarily targeted the paving of existing roads, developing ports, and building a pipeline for hydrocarbons. Market demands and these investments have resulted in increasing human activity in the Brazilian Amazon.

This new wave of investments has also fuelled disputes over land tenure and forest degradation. As of 2003, about 47 percent of the land in the Legal Brazilian Amazon was public, but with unclear tenure status (Lentini et al. 2003). Conflicts arise because enforcement of land tenure regulation is weak, and land titling is a long process. In addition, government land agencies can expropriate properties considered non-productive, leading to invasion of titled private properties or properties undergoing titling processes. In 2002, 26 rural labor leaders were assassinated in land conflicts in the region (CPT 2003). Premature deforestation occur because people can claim ownership by demonstrating that they have lived on and worked the land for at least one year.

These conditions are behind a number of trends and dynamics that change the landscape of the Brazilian Amazon. To understand these dynamics, it is important to understand the forces driving each indicator that was analyzed in this study.

DEFORESTATION

Forest clearing—or deforestation—has increased over time (see deforested areas in Figure 1). Cattle ranching is the most common land use in deforested areas throughout the region (IBGE 1995). Areas deforested for cattle ranching occupied about 70 percent of the total deforested

area by 1995 and pasture area continues to grow. Lower land prices and slightly higher productivity make mid- and large-scale pastures more lucrative in the Amazon than in other regions of Brazil (Margulis 2003; Arima et al. 2005).[2] Moreover, low-density ranching (i.e., less than one head per hectare) offers a lower financial risk than soybean, rice, or corn production (Schneider et al. 2002).

The cattle herd of the Brazilian Amazon grew from about 27 million head in 1990 to 64 million head in 2003, or a mean annual increase of 7 percent. In 2003, 35 licensed meat production plants and 16 licensed milk production plants were concentrated primarily in the southwestern and northeastern portions of the Brazilian Amazon (see Figure 2). In 2000, 87 percent of meat produced in the region was exported to other regions and the rest was consumed regionally (Arima et al. 2005). The location of slaughter houses and deforestation and distribution of cattle herd (Arima et al. 2005) indicates that ranching is expanding in eastern Pará, Mato Grosso, Tocantins, and Rondônia. Together these states contained 86 percent of the region's herd in 2003 (Arima et al. 2005, based on IBGE data).

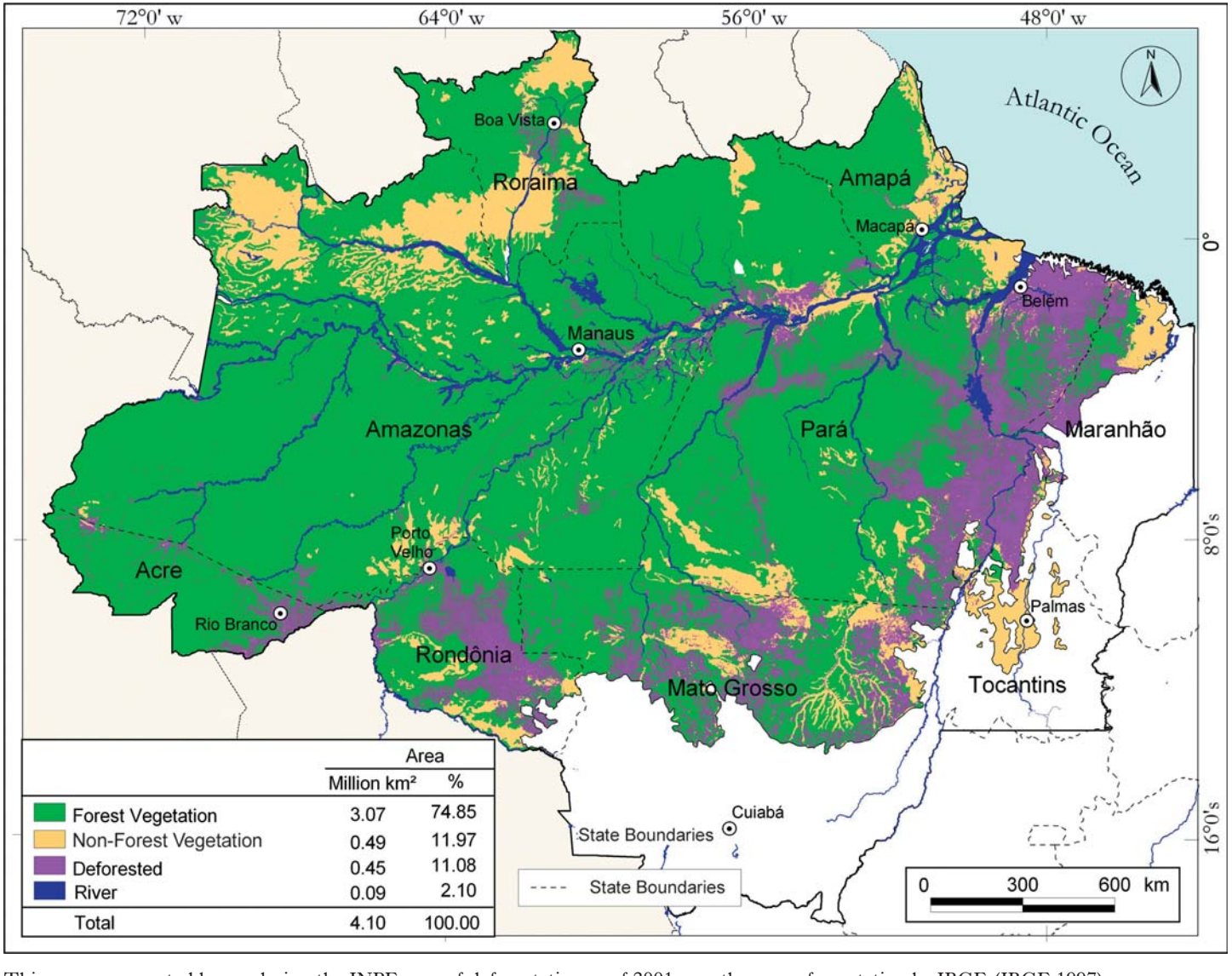
Annual crop areas (soybeans, rice, and corn) have seen notable growth. The area cultivated with annual crops increased from about 5 million ha in 1990 to about 8 million ha in 2002 (IBGE 2003b). Growth has been concentrated in relatively flat and dry zones along the eastern and southern margins of the Brazilian Amazon, usually on already deforested pastures or in areas originally covered by shrub-savanna vegetation (cerrado) in the states of Mato Grosso and Maranhão. In 2002, these two states contained 83 percent of the area planted to soybeans, rice, and corn in the Legal Amazon (IBGE 2003b).

The prospects for significant expansion of annual crops in the wetter parts of the Brazilian Amazon are uncertain. As rainfall increases so do the incidence of pests and diseases, and the high rainfall impairs mechanized harvesting. Forest fallows—indicating areas of low agricultural potential and subsequent high costs of chemical fertilizers—reflect this trend. In 1995 forest fallows represented about 8 percent of the total cultivated area in drier zones of the region, but they covered 28 percent in wetter zones (Schneider et al. 2002).

The planting of intensive annual crops (mechanized agriculture) in areas formerly used as pastures is displacing cattle ranching from the margins to the core of the region. An indicator of this displacement is the increase in land values along the road that connects Cuiabá and Santarém (BR-163) in the state of Pará: between November 2001 and April 2002 the land value of pastures and forestlands increased, respectively, by 29 percent and 250 percent (estimates based on data from FNP 2002).

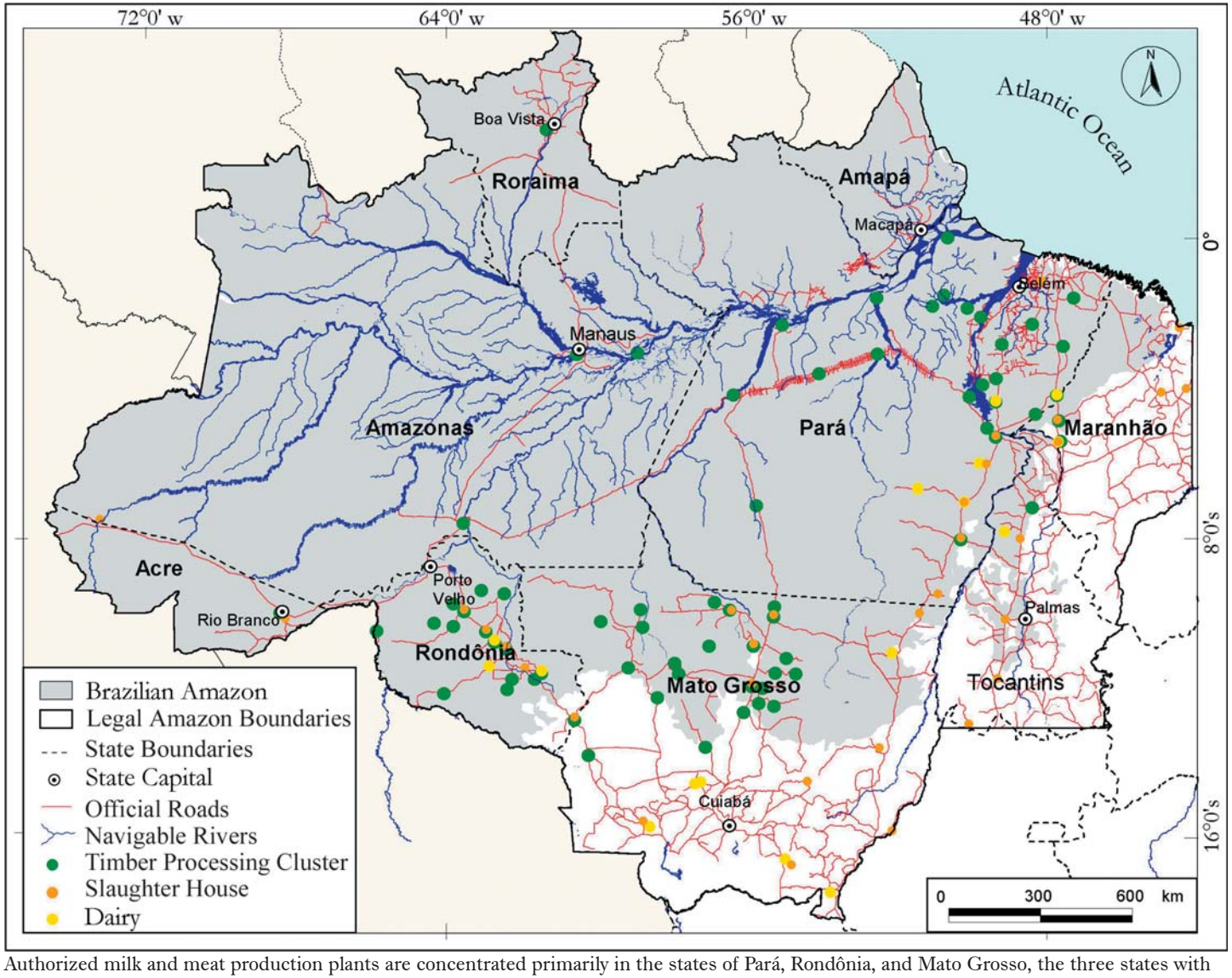
Despite legal restrictions, deforestation routinely impacts environmentally sensitive areas. Brazilian law requires that landowners protect riparian forests and conserve 80 percent of forest cover on their properties as legal reserves. Yet enforcement remains a challenge. A study in eastern Pará documented illegal removal of native forests in 60 percent of riparian forests along pastures and other deforested areas (Firestone and Souza 2002). Government officials in Mato Grosso found 71 percent of 1,600 rural properties visited in 2000 had violated forest laws—including deforestation of riparian forests and clearing of legal reserves (Souza and Barreto 2001).

FIGURE 1 | **VEGETATION AND DEFORESTATION IN THE BRAZILIAN AMAZON AS OF 2001**



This map was created by overlaying the INPE map of deforestation as of 2001 over the map of vegetation by IBGE (IBGE 1997).
Scales of maps: Deforestation (1:250,000). The scale of the vegetation map was 1:2,500,000. The scale of this which aggregates all types of forest is 1:1,000,000.

FIGURE 2 | **DISTRIBUTION OF TRANSPORTATION NETWORK, TIMBER PROCESSING CAPACITY, AND CATTLE PROCESSING CAPACITY**



Authorized milk and meat production plants are concentrated primarily in the states of Pará, Rondônia, and Mato Grosso, the three states with the largest cattle herd sizes in the Legal Amazon. *Sources*: Lentini et al. 2003 (Timber processing centers); IBGE 2005 (transportation network); www.ruralbusiness.com.br/industria.asp?secao=3 (Slaughter and dairy houses).

URBAN ZONES

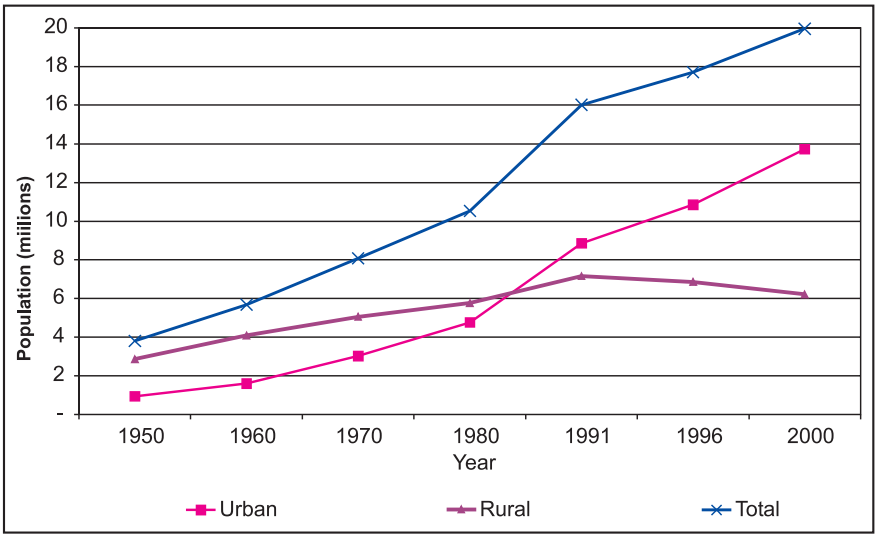
Between 1960 and 2001, the total human population of the Legal Amazon increased from about 4 million to over 20 million (IBGE 2002). The urban population almost tripled, growing from approximately 5 million to 14 million between 1980 and 2000. By contrast, the rural population began to decline after 1991 (see Figure 3). The growth in urban areas has led to deteriorating environmental quality and living conditions. The expansion of highly extensive ranching is linked to urban and national markets and appears to be a far more powerful driver of deforestation than rural population growth. Figure 4 shows the location of the 450 municipal seats in the Brazilian Amazon, mapped as of 1997.

AGRARIAN REFORM SETTLEMENTS

Since the late 1970s, landless and urban poor have pressured the government for lands. The federal government's Agrarian Reform Institute (INCRA) grants landless families rights to use land holdings as part of agrarian reform projects. The average growth of families in the Legal Amazon participating in agrarian reform projects was 52,500 families per year between 1994 (161,500 families) and 2002 (528,571 families) (see Figure 5). Each family has user rights to holdings between 50 and 100 ha.

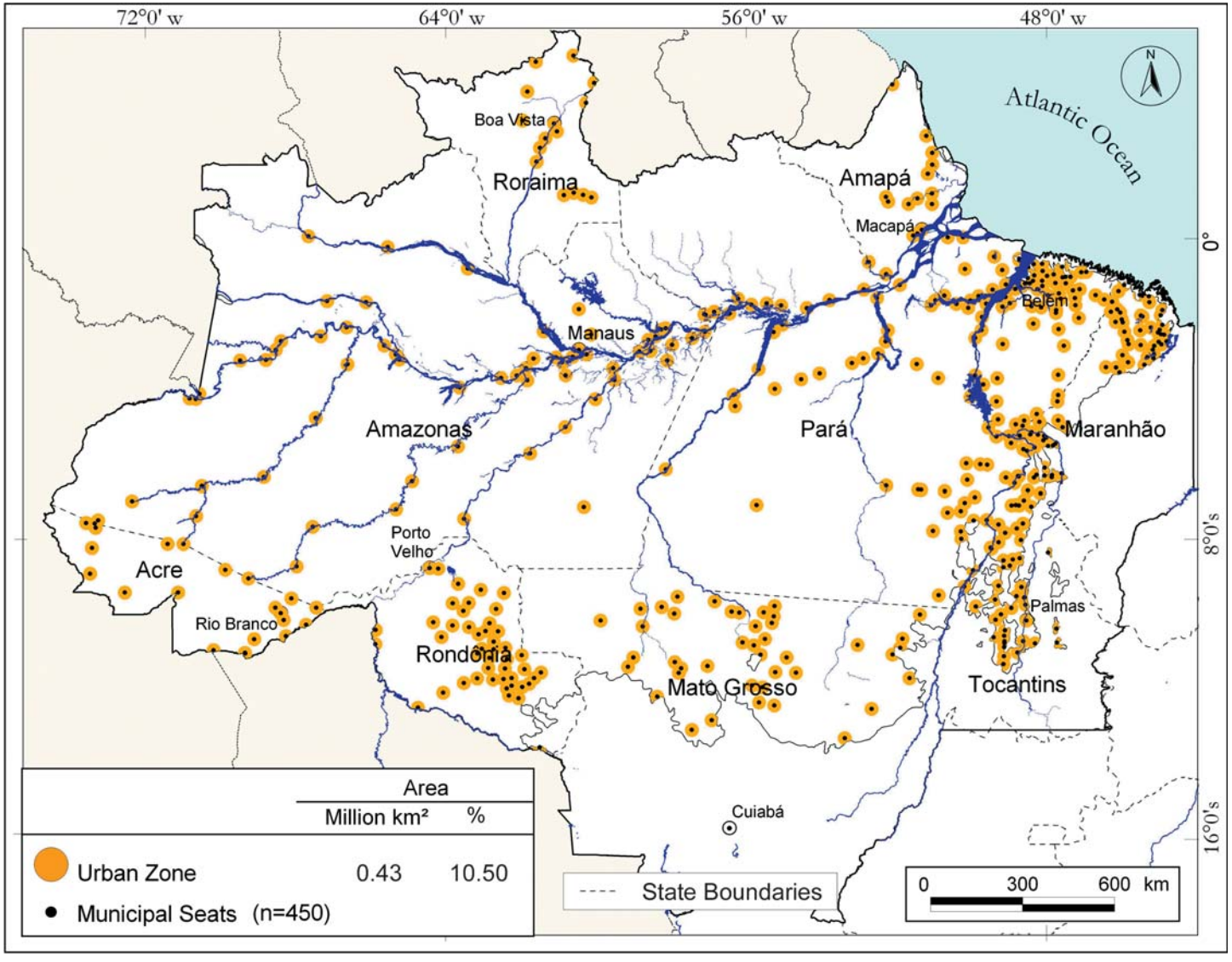
The federal government also provides subsidies to agrarian reform settlers in the form of food allowances, money for housing and credit at reduced interest rates. Combined with the

FIGURE 3 | **POPULATION IN THE LEGAL AMAZON BETWEEN 1950 AND 2000**



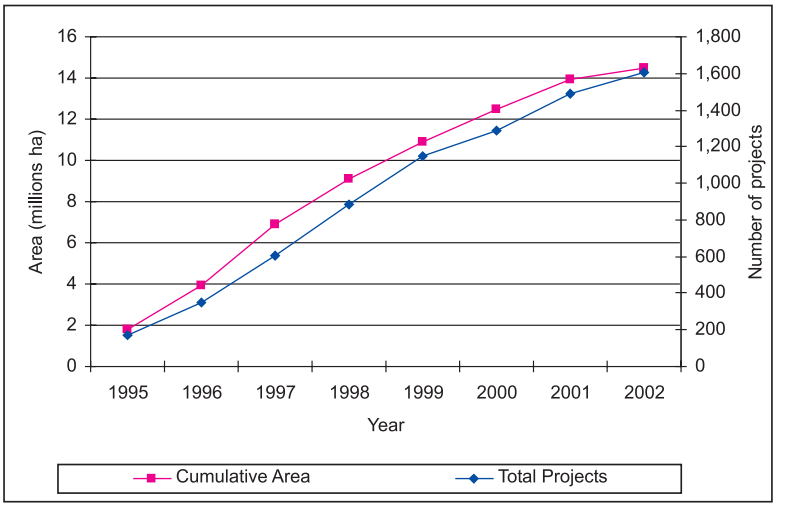
Data source: IBGE 2003a

FIGURE 4 | MUNICIPAL SEATS AND URBAN ZONES



A 20-km wide radius surrounds the location of the 450 municipal seats in the Brazilian Amazon, to estimate the extent of human pressure from these centers. See Section III for details. *Source*: IBGE 1997.

FIGURE 5 | **AREA OF AGRARIAN REFORM SETTLEMENTS AND NUMBER OF PROJECTS IN THE LEGAL AMAZON BETWEEN 1995 AND 2002**



Data source: INCRA 2002

adjudication of legal rights, this makes agrarian reform settlers more prone to deforest than small scale settlers elsewhere (Wood et al. 2003). Timber sales also make the initial occupation of such projects attractive for landless people.[3] However, after the depletion of timber resources, household income tends to be relatively low.[4] Thus, many families abandon or illegally sell their lots to seek new settlement areas or migrate to urban centers. An estimated 50-60 percent of land in agrarian reform plots in southern Pará has been illegally sold (Agência Estado 2004). Some of this land becomes consolidated in larger land holdings, which tend to be more economically efficient and profitable.

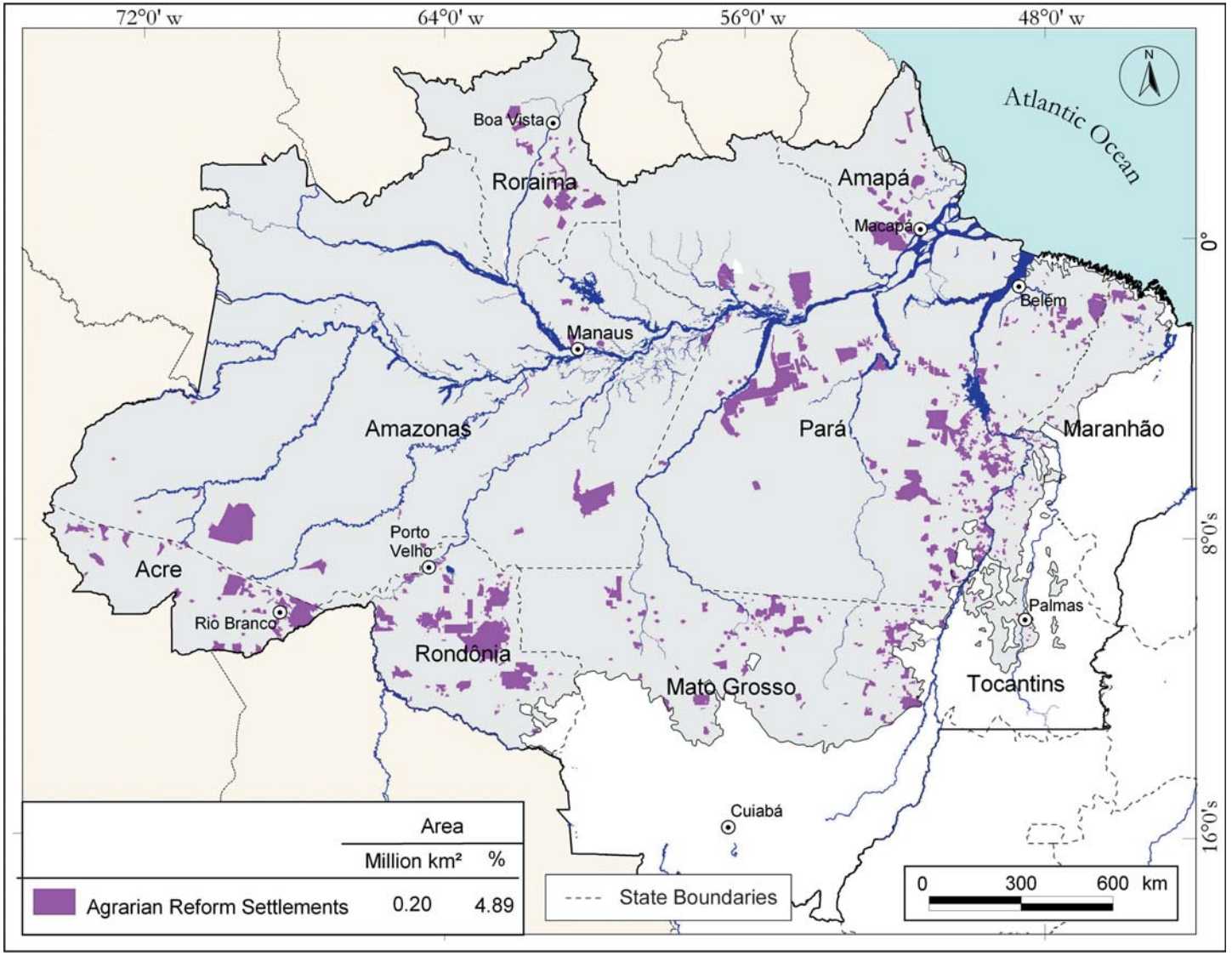
As of 2002, 8 percent of the total land area in land reform settlement projects in the Amazon Biome had been created to give legal land use rights to rubber tappers and Brazil nut collectors after Chico Mendes´ assassination. Most of these projects (9 of 14)—called "agro-extractive"—were created in the State of Acre where Mendes lived. In theory such projects would be more likely to be used for forest management and small agriculture.

Nevertheless, overall, the federal government acknowledges that land reform has led to "environmental and social losses, deforestation, and abandonment and subsequent concentration of land ownership" (Presidência da República 2004). Figure 6 shows the location and area of agrarian reform settlements as of 2002.

FOREST FIRES (FIRE ZONES)

Although many Amazonian forests have a strong capacity to resist burning, uncontrolled fires are a growing problem in the Brazilian Amazon (Nepstad et al. 2004; Cochrane 1999).

FIGURE 6 | **AGRARIAN REFORM SETTLEMENTS ESTABLISHED AS OF 2002**



Source: INCRA 2002. *Scale of Agrarian Reform Settlement*: 1:100,000.

Burned forests are greatly susceptible to recurrent fires, which in turn can be more severe in intensity and impact (Cochrane 1999). Fire is the principal tool used to clear land for planting soon after deforestation, and thereafter to maintain pasture. Fire accidentally escapes from agricultural lands to forested areas, mostly to logged areas that become more susceptible to burning. Half of the forest fires in the Amazon are accidental (Nepstad et al. 1999) and can occur either where human occupation is consolidated or in occupation frontiers. Data is available on the daily incidence of fire. Between 2000 and 2002 the number of fires nearly doubled from 22,000 per year to almost 43,000 per year, indicating the acceleration of human occupation (see Figure 7).

MINING

Mining activities often do not involve direct clearing of large forest areas, but they can serve as catalysts of deforestation and timber harvesting because they are associated with road building, capital accumulation, and immigration (Bezerra et al. 1996). For this reason, maps on mining operations can be used to flag areas of incipient and potential human activities (see Figure 8).

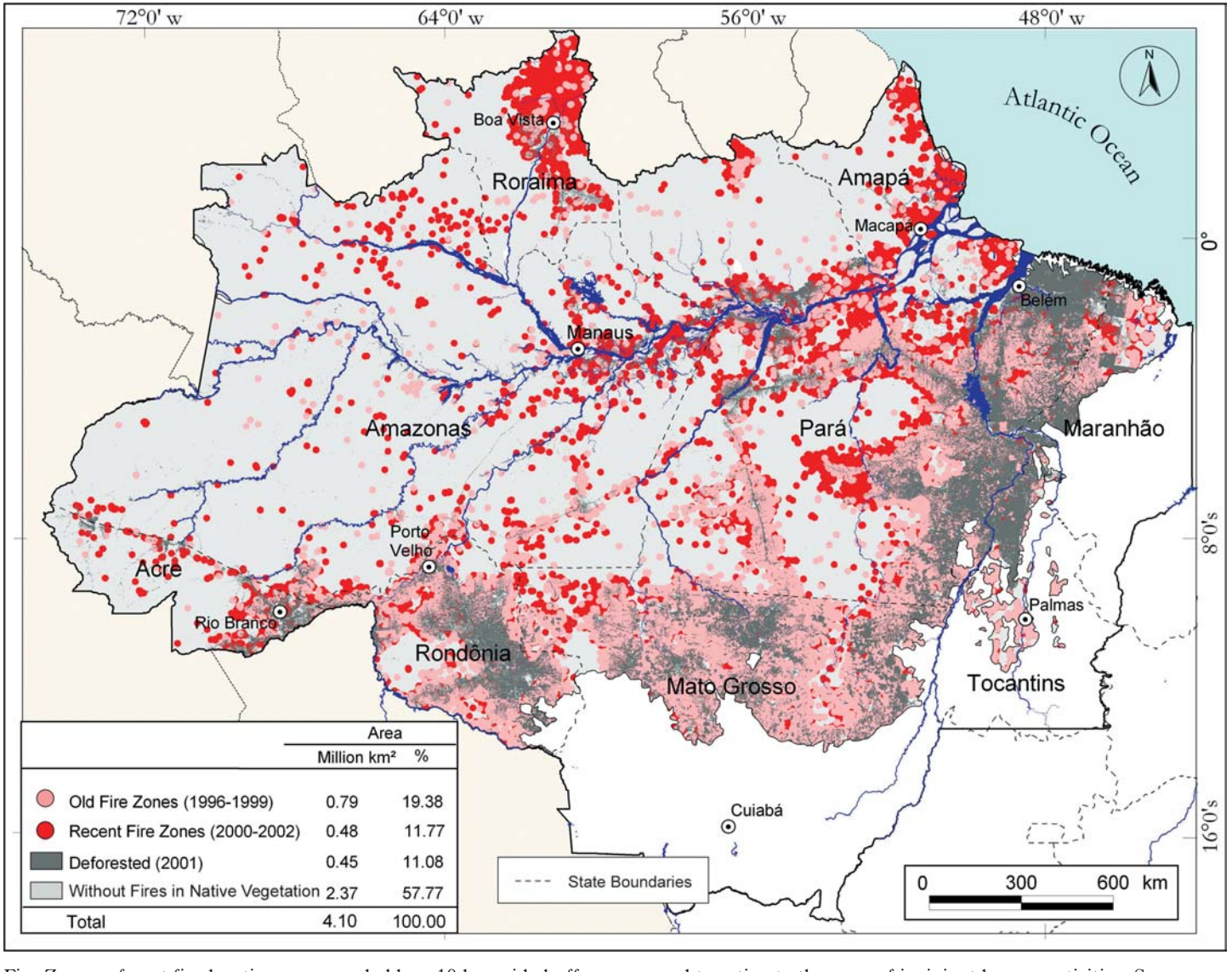
According to Brazilian law, mining takes priority over any other surface or sub-surface land use. Should areas allocated for mining activities or mineral exploration become economically viable, improved infrastructure, transportation, and other services could spark rapid in-migration and forest clearing.

In addition to legal mining operations, informal miners (wildcat mining) are also a source of human pressure in the Brazilian Amazon. In the early 1990s there were about 1 million gold miners (*garimpeiros*) in more than two thousand mining camps (Pinto 1993). Gold mining exerts direct environmental impacts from forest clearing for the mine and the adjacent mining camp (Bezerra et al. 1996), and indirect impacts such as soil erosion and mercury pollution (Mathis and Rehaag 1993). Construction of infrastructure and accumulation of capital provide a basis for other land-use activities and additional frontier expansion. This phenomenon occurred in the Tapajós River basin of western Pará, where around 245 gold mining camps used to employ roughly 30,000 people in the early 1990s (Bezerra et al. 1996). The gross value of the gold extracted reached US$110 million per year, which helped to finance land conversion to non-forest uses such as cattle ranches. When gold resources have been depleted, unsuccessful miners frequently seek agrarian reform settlements or move to urban centers.

LOGGING

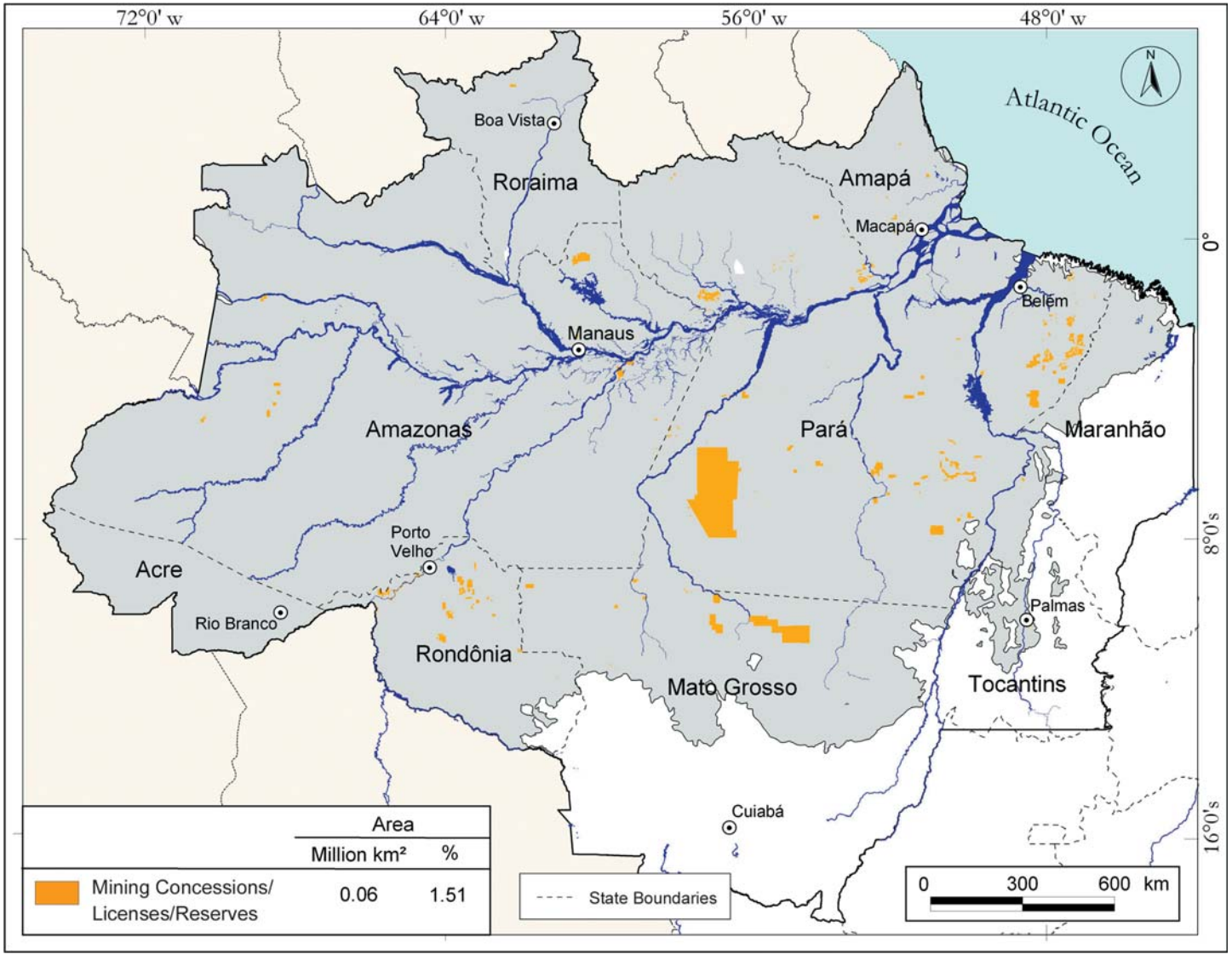
Logging has been a major catalyst for settlement in the Brazilian Amazon because loggers open roads and use navigable watercourses to reach native forests. In 2004 approximately 3,100 wood-processing mills (sawmills, veneer and plywood mills) processed 24.5 million cubic meters of logs; 36 percent of this timber was exported to other countries and the remainder consumed in Brazil (Lentini et al. 2005).

FIGURE 7 | **FIRE ZONES, 1996-2002**



Fire Zones—forest fire locations surrounded by a 10 km-wide buffer—are used to estimate the zone of incipient human activities. See Section III for details. Here, areas with exclusively recent fires zones show new frontiers of occupation. *Source*: INPE 2002.

FIGURE 8 | **AREA ALLOCATED FOR MINING OR MINING EXPLORATION AS OF 1998**



Source: DNPM 1998.

The environmental and ecological impacts of logging have only been partially evaluated, and they can be extremely variable due to the variety of logging methods and the occurrence of secondary impacts. Nevertheless, loggers have opened thousands of kilometers of roads in public and private areas that have become key channels for further colonization (Veríssimo et al. 1995; Greenpeace 2001; Brandão and Souza 2006).

Selective logging is widespread in large areas and can cause light to severe damage. Unplanned logging generates greater amounts of slash and opens larger gaps in the forest canopy than planned harvesting operations, making forests more susceptible to fires that originate in areas used for shifting cultivation or pastures (Veríssimo et al. 1992; Veríssimo et al. 1995; Uhl et al. 1991; Holdsworth and Uhl 1997; Johns et al. 1996; Gerwing 2002). Impacts from licensed logging operations are also negative when licensed loggers neglect to adopt the approved management procedures.[5] Some timber companies and communities have adopted best forest management practices, which in the Brazilian Amazon is mostly equated with the adoption of "green certification," since the credibility of non-certified operations is low. However, the total area of green certified timber production in the region remains small. As of November 2005, there were 12,619 km^2 of FSC certified lands (FSC 2005). This land is equivalent to only 3.4 percent of the estimated total area needed to supply the annual timber harvest in the Brazilian Amazon.

The total area affected by various timber harvesting methods in the Brazilian Amazon is unknown and datasets are temporally and spatially incomplete. The current status of licensed logging operations, for instance, is unclear, since the last status report released by IBAMA was based on data from 2001. Rough estimates of area impacted annually ranges from 10,000 to 20,000 square kilometers, with uncertainties from 17 percent to 100 percent (Nepstad et al. 1999; Matricardi et al. 2001; Cochrane 2000). Of special interest is the most recent analysis (Asner et al. 2005) that uses satellite imagery between 2000 and 2002 to identify areas affected by selective logging.

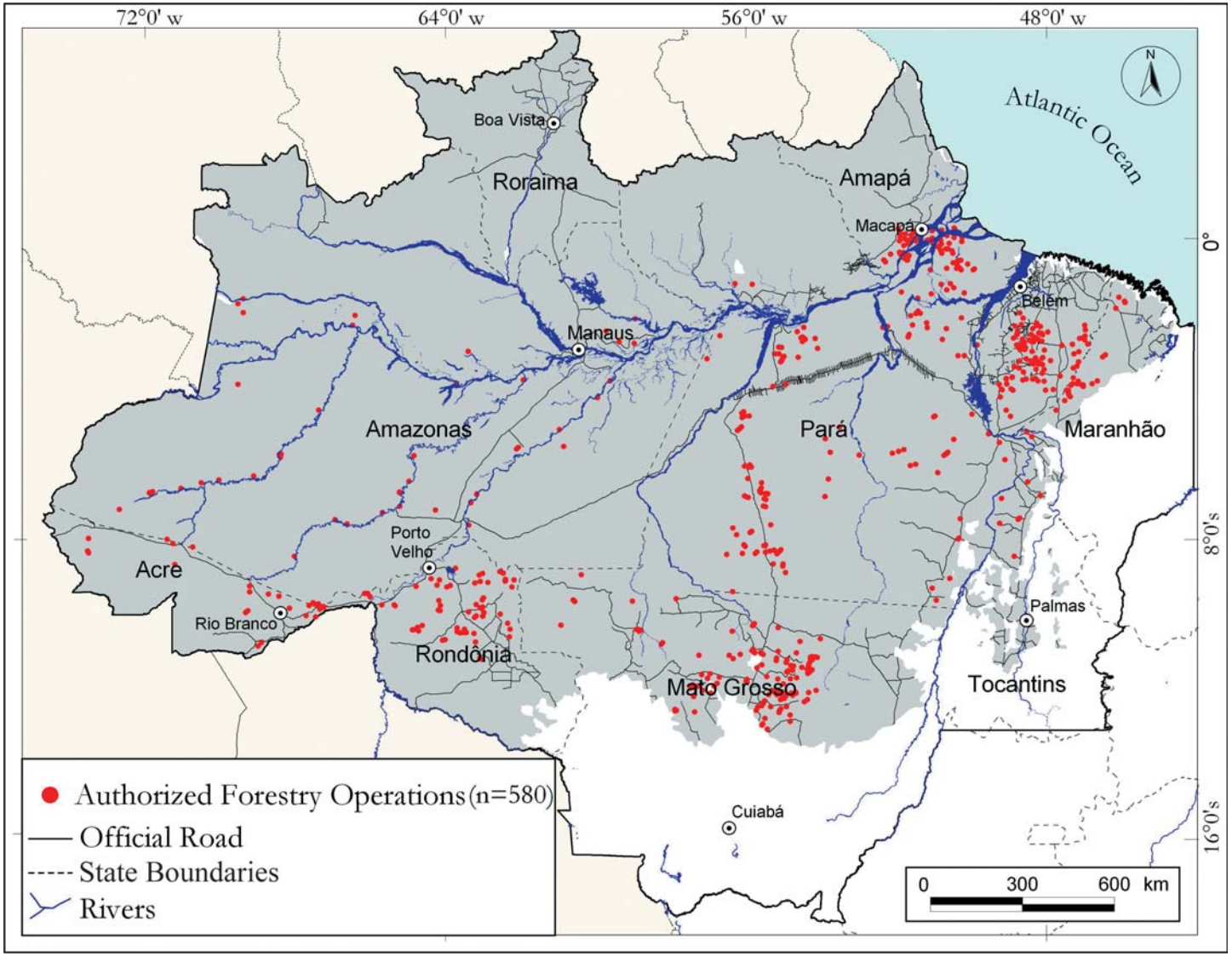
Comparing the information that is available, such as the location of logging permits issued by the government (see Figure 9) and maps of logged forests, could be used as a rough surrogate to identify areas where timber harvesting is occurring and how harvesting is distributed. Systematic interpretation of satellite imagery, combined with fieldwork, is a promising tool to evaluate the extent and impact of logging at a regional scale (see Figure 10).

ROADS

A number of studies demonstrate that roads, even those opened temporarily by loggers and gold miners, facilitate subsequent settlement. A few examples:

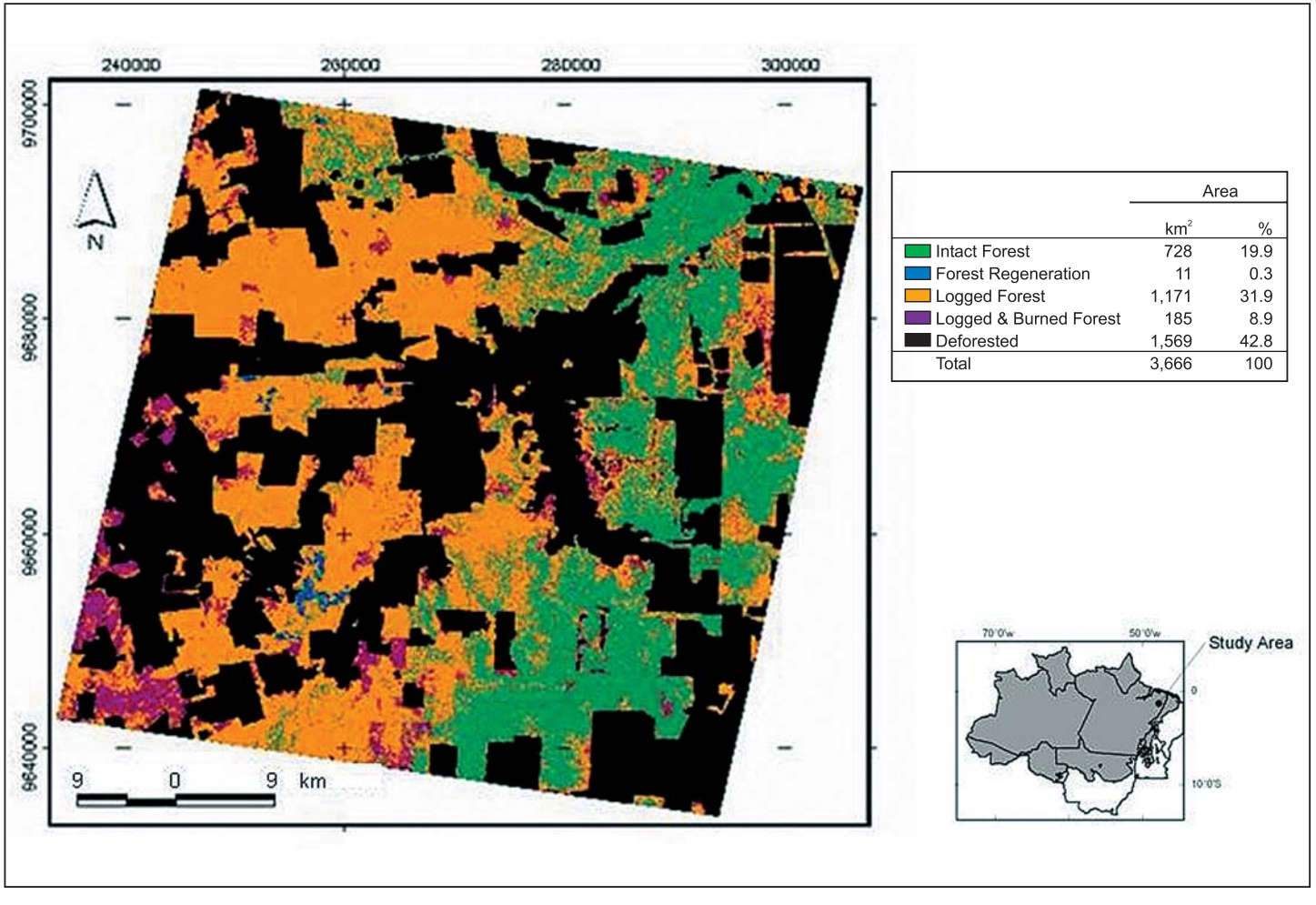
- Timber companies in search of mahogany (*Swietenia macrophyla*) were the major builders of logging roads in southern Pará during the 1980s; by 1992 this network extended nearly 3,000 km (Veríssimo et al. 1995) and has continued to proliferate since (Greenpeace 2001).

FIGURE 9 | **LOCATION OF LOGGING PERMITS IN 2000**



Source: Greenpeace 2000. Logging permits for forest management plans. Timber harvest from clear cut (deforestation) is not included.

FIGURE 10 | LAND COVER CLASSIFICATION IN EASTERN AMAZONIA



A pilot study in eastern Pará (Souza et al. 2003) found that approximately two-thirds of the forest in a 3,700-km^2 area had been harvested or severely degraded by logging and fire. This study demonstrates the potential of remote sensing and fieldwork to systematically monitor the impacts of logging throughout the Brazilian Amazon.

- During the 1980s, gold miners and mining companies also opened informal roads in southern Pará (Mertens et al. 2002). Settlers advanced along logging and mining roads wherever agriculture or ranching became feasible (Veríssimo et al. 1995; Mertens et al. 2002).
- Timber companies, settlers, and local governments have also constructed feeder roads along the Transamazon Highway in Pará, northeastern Mato Grosso, and southern Amazonas (Rodgers 2003; Greenpeace 2002), which could explain the high concentration of forest fires in these areas.

Of special concern are unofficial roads—roads being built without the planning and authorization required by law (see Box 4). In some cases, unofficial roads serve only for one-shot extraction of high-value resources, such as mahogany and gold, in areas isolated from official infrastructure. Loggers, ranchers and miners have opened a vast and growing array of unofficial roads, enabling temporary or permanent human occupation over extensive areas of the region. The vast proliferation of unofficial roads suggests an even wider impact and more rapid change in the Brazilian Amazon.

The intensification of human pressure depends largely on the continuation of investment in transportation infrastructure. This is happening in some areas because early settlers who build informal roads usually pressure government to maintain and improve such infrastructure.

BOX 4. | MAPPING UNOFFICIAL ROADS IN THE MIDLANDS OF PARÁ

Thousands of kilometers of roads are being built in the Brazilian Amazon without the planning and authorization required by law. Unofficial roads include private roads and illegal or informal roads. Until recently, the growth and extent of unofficial roads in the Brazilian Amazon had not been documented. With support from WRI and others, Imazon identified, mapped, and quantified the length and growth of unofficial roads in the Central-West region of the State of Pará (the Midlands, or *Terra do Meio*), an area that represents about half of the State. Analysis relied on visual interpretation of satellite imagery. Almost half of the Midlands are unclaimed public lands, while a network of protected areas extends over the other half (IBGE 1997; ISA 1999).

Three types of roads from Landsat satellite images were identified for three periods (1985-1990, 1991-1995, and 1996-2001):

- *Visible roads:* continuous linear features visible to the human eye in the images;
- *Fragmented roads:* non-continuous linear features visible to the human eye. Fragments may be traced to connect the hidden stretches to those that are visible in the image.
- *Partially visible roads:* linear features that are not explicit in the images and may only be identified based on their context and spatial arrangement (i.e. adjacent deforested areas).

Imazon found that 80 percent of the roads (~ 21,000 km) in the Midlands are unofficial. Moreover, almost 60 percent of these corridors are in unclaimed public lands penetrating large blocks of forests that are potentially appropriate for the creation of protected areas. The results suggest that protected areas slow the advance of unofficial roads because average growth rates for unofficial roads inside protected areas were three times lower than those outside protected areas.

Building on this experience, Imazon is extending the mapping of unofficial roads into other states of the Brazilian Amazon. A more detailed description of the mapping methods, the results and implications can be found in Brandão and Souza (2006).

3
MAPPING HUMAN PRESSURE IN THE BRAZILIAN AMAZON

The analysis of human pressure was conducted in two phases. The first phase was to create a map of human pressure by overlaying maps of various indicators on a map of native vegetation. The second phase was to use the map from the first phase to analyze human pressure in relationship with protected areas, roads, and logging. Overall, the scale of the analysis was 1:1,000,000.

HOW HUMAN PRESSURE WAS MAPPED

Five maps were superimposed on top of a native vegetation map (IBGE 1997) in the following order (note that the figures cited here are found in the previous section):

- **Deforested areas** as of 2001, using data from INPE (see Figure 1).
- Influence from **urban zones** as of 1997. To estimate the area under urban influence, 20 km-wide buffers around the region's 450 municipal seats were drawn (see Figure 3). The 20 km-wide buffer was based on field observations. At the time of the analysis, only location of municipal seats was available in spatial format; thus pressure from other population centers such as small towns and villages was not explicitly included. Additionally, different municipal seats have different population sizes and extent and level of pressure can vary according to population size. The use of a standardized 20-km threshold may not accurately capture pressure from varying population sizes, although other indicators such as deforestation and forest fires (see below) likely captured it.
- Polygons of **agrarian reform settlements** as of 2002 (see Figure 5). Such areas may be partially forested, but are under strong pressure because they have been allocated for human settlements and are priority areas for governmental investment in infrastructure.
- **Fire Zones.** In this analysis, *fire zones* refer to the estimated zone of incipient human activities associated with **forest fires**. Fire zones constitute a 10 km-wide buffer around fires that were identified by satellite from 1996 to 2002 (see Figure 7). The 10-km radius is an arbitrary threshold that does not respond to ecological, landscape, or physical features; instead, it is based on the estimated maximum distance a hunter would travel by foot for the most profitable game from a given point of access within the forest (Peres and Terborgh 1995). Forest fires also indicate

other human activities. Fire zones contain small areas (mostly less than 3 ha) that were deforested and burned, but were not included in the INPE deforestation map because they are smaller than the mapping threshold. Fire zones can also flag logged forests into which wildfires escaped from nearby deforested areas. In summary, this zone is a crude indicator of areas under incipient pressures from hunting, small deforestation, forest fires, and logging.

The validity of using the 10-km threshold was tested when examining the relationship between human pressure, roads, and logging (see below). The results seem to support the threshold: half of the authorized logging operations were within fire zones; and, in areas where detailed information on roads was available, 76 percent of the fire zone area was accessible by roads or navigable rivers. (See discussion of logging in Section IV).

Although forest fire data were available only after 1996 and the database is incomplete for 1996 and 1997-98, fire zones are likely to capture a significant portion of the incipient human pressure.[6] In areas with older signs of incipient occupation—for example, where forest fires occurred prior to 1996—deforestation either increased and, hence, the areas were included in the INPE deforestation map; or occupation remained incipient—that is, small farmers continue to practice small scale slash-and-burn agriculture. In this case, new forest fires were captured in the vicinity of old cultivated areas and were included in the 10-km buffer around fire zones.

Areas with exclusively newer forest fires may indicate zones where the occupation frontier is expanding. To show such zones, some of the maps distinguish exclusively newer fire zones (2000-2002) from older fire zones (1996-1999). To separate such zones, fire zones with both old and new forest fires were classified as old fire zones.

- Areas allocated for **mineral research and mineral reserves** as of 1998 (Capobianco et al. 2001). The areas licensed for mineral prospecting are not necessarily active, but they may become so if minerals of interest are found (see Figure 8).

This sequence indicates progressively lower hierarchy of data layers. Thus, maps with the most precise information and showing the greatest degree of transformation in the natural vegetation took precedence over information that was less precise or that indicated less pressure. A deforested area overlapping areas of influence from urban zones or an area licensed for mineral research, for instance, was classified as deforested.

In the absence of a map of all logged forests, a map of the location of official permits for logging in 2000 was overlaid on the human pressure map to provide a crude indication of regions pressured by timber harvesting (see Figure 9). The geographic coordinates of logging permits were compiled by Greenpeace Brazil using data from IBAMA.

In addition, a preliminary comparison between the map of human pressure and the map depicting selective logging between 2000 and 2002 (Asner et

al. 2005) was performed. The Asner study is the most recent analysis of selective logging throughout most of the region using satellite imagery.

HUMAN PRESSURE IN PROTECTED AREAS

The map of human pressure was overlaid on existing datasets of protected areas:

- **Existing protected areas** as of 2004 (ISA 2004; Viana and Valle 2003).
- **Priority areas for conservation outside protected areas.** These areas were identified by overlaying the map of priority areas for conservation (Capobianco et al. 2001) on the map of protected areas. Although the map of priority areas for conservation is the most updated compilation of available inventories of taxonomic groups in the region, the map is incomplete due to limited or non-existing sampling in more remote zones. As a result, the assessment of human pressure may underestimate the priority areas for conservation.
- Areas identified with **potential for the establishment of public production forests** (Verissimo et al. 2000).

The hypothesis that the human pressure on protected areas is influenced by the proximity of these protected areas to roads was tested by estimating the Spearman's non-parametric correlation coefficients between the proportions of protected areas within distance intervals from roads (< 25 km, 25-50 km, and >50 km) and the proportions that were (1) deforested and (2) within a 10-km radius around fire zones.

HOW THE RELATIONSHIP BETWEEN ROADS AND HUMAN PRESSURE WAS ANALYZED

Three approaches were used to assess the influence and relationship between roads and human pressure:

- Measuring the cumulative distribution (percent) of forest cover and human pressure within intervals of 10 km from each side of the official roads existing by 1999 (IBGE 2003a).
- Analyzing the association between official and unofficial roads in northern Mato Grosso (76,000 km^2) and central and southwestern Pará (546,000 km^2). This was done by measuring the cumulative distribution (percent) of unofficial roads within 10-km intervals from each side of the official road network.
- Measuring the area under incipient human occupation that was intercepted by at least one transportation route (official or unofficial roads or navigable rivers) in areas where the complete road network was available (Souza et al. 2004).

The analysis of human pressure is part of an effort coordinated by Global Forest Watch (GFW) to examine the extent and impact of human activities in important forested regions of the world. Analyses elsewhere include:

- Mapping forest intactness by identifying large forested landscapes least impacted by human activities visible in satellite imagery in boreal forests of Canada, Alaska, Russia,

Fennoscandia and Alaska, and in costal temperate rainforests of Canada, Alaska and Chile (Aksenov *et al*. 2002; Lee *et al.* 2003; Hájek 2000; Strittholt *et al*. in preparation, Verscheure *et al.* 2002).

- Mapping forests accessed through transportation routes in tropical forests of Indonesia (FWI/GFW 2002) and Central Africa (Minnemeyer 2002); tracking the expansion of logging roads to monitor forest development and to identify potential illegal logging (Van Pol *et al.* 2005).

Mapping methods used in these other global, regional and national analyses attempt to establish an overall consistency at the same time that they are sensitive to local realities (e.g. data availability and ecological differences).

4

HUMAN PRESSURE IN THE BRAZILIAN AMAZON

RESULTS AND DISCUSSION

As of 2002, approximately 47 percent of the Brazilian Amazon shows some indication of human pressure (see Table 1 and Figure 11). Areas under pressure from human settlements represent almost 19 percent of the study area, while areas subjected to incipient human pressure represent 28 percent (see Figure 12). Of the areas under pressure from human settlements, deforested areas accounted for 11 percent of the area, urban areas for nearly 6 percent, and agrarian reform settlements for nearly 3 percent. Fire zones accounted for the majority of the areas subjected to incipient human pressure.

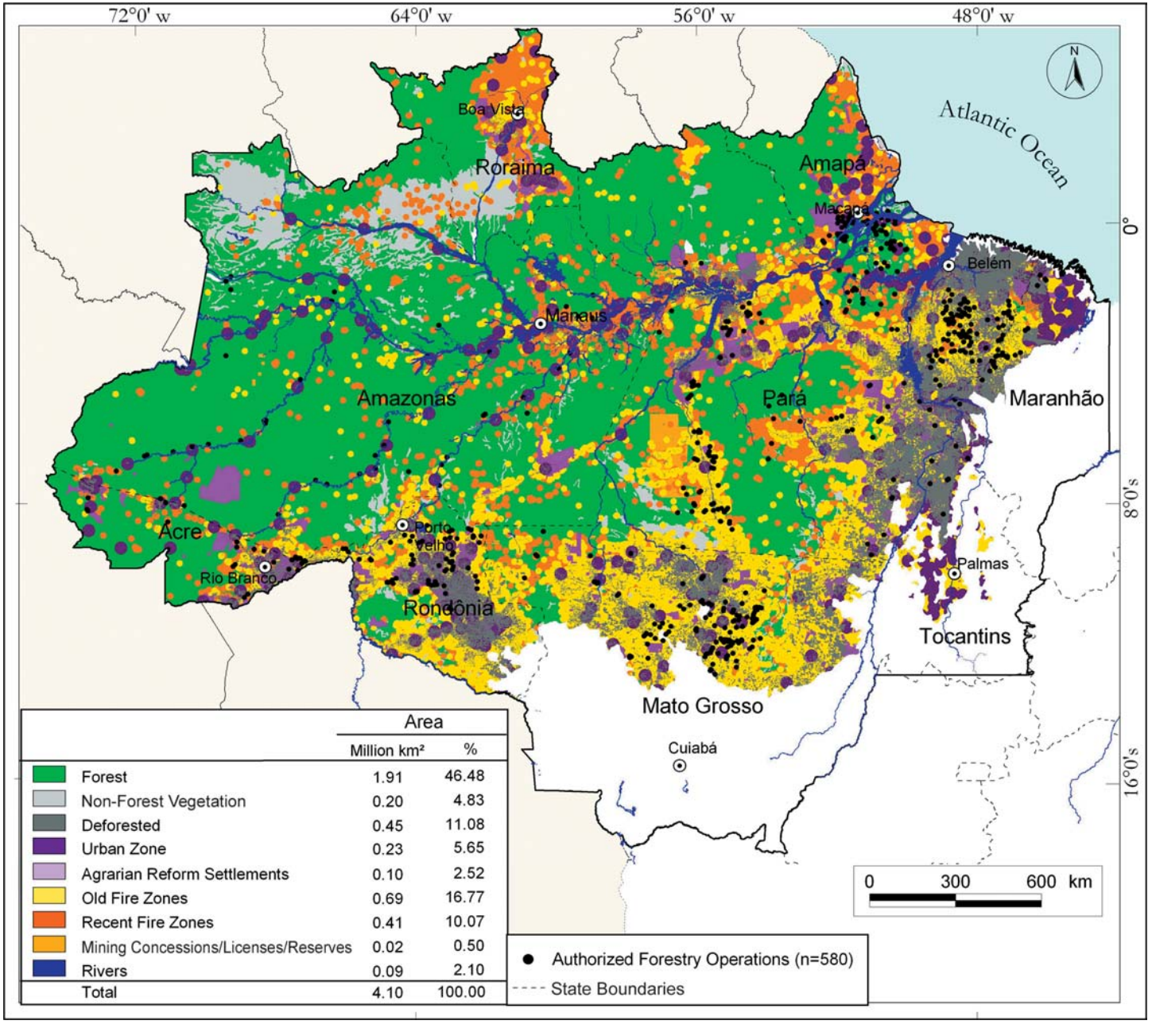
The relative area of non-forest vegetation under some type of pressure (66 percent) is much higher than the percentage of forest vegetation under pressure (44 percent). About 14 percent of all land-cover types are non-forest vegetation in the Brazilian Amazon, according to the vegetation map from IBGE.

Examining the distribution of human pressure between forested areas and non-forested areas, most areas of non-forest vegetation under some type of pressure are located in the eastern and southern portions of the Amazon biome and in eastern Roraima (in the upper northern Amazon). The pressure on non-forest vegetation is relatively smaller in *campinaranas* (or "heath forests")[7] of the northern Amazon and savannas of southern Roraima. In these areas pressure is mainly indicated by scattered fire zones mainly alongside navigable rivers.

TABLE 1 | HUMAN PRESSURE IN THE BRAZILIAN AMAZON

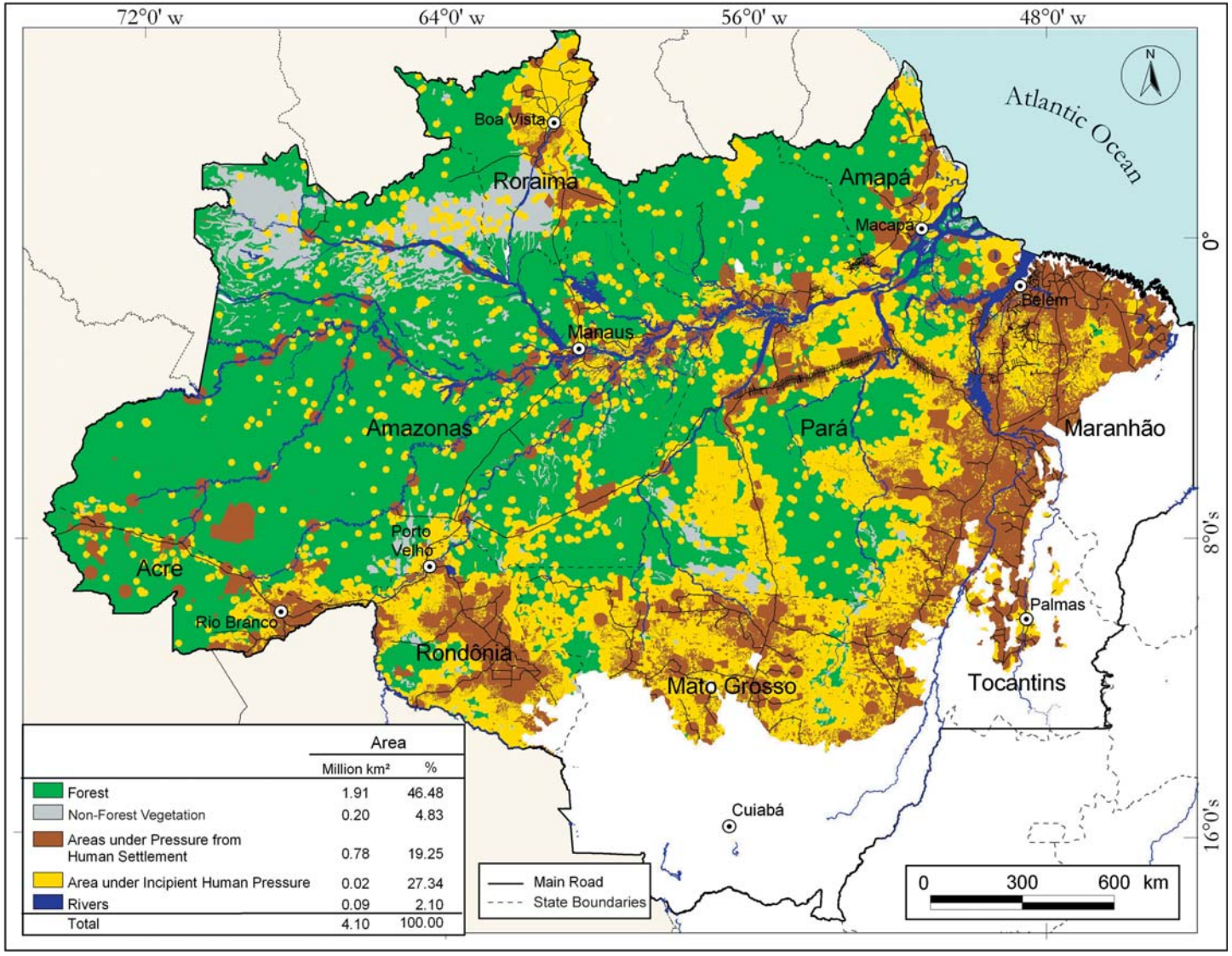
Type of Pressure	Brazilian Amazon		
	Percentage of Total Area	Percentage of Forest Vegetation	Percentage of Non-Forest Vegetation
Areas under Pressure from Human Settlements	**19**	**18**	**28**
Deforested Areas	11	11	14
Urban Zones	6	5	12
Areas of Agrarian Reform Settlements	3	3	2
Areas Subjected to Incipient Human Pressure	**27**	**26**	**38**
Fire Zones	27	26	38
Mining	<1	<1	<1
TOTAL*	**47**	**44**	**66**
***totals may not add up due to rounding**			

FIGURE 11 | HUMAN PRESSURE IN THE BRAZILIAN AMAZON - ALL INDICATORS



	Area	
	Million km²	%
Forest	1.91	46.48
Non-Forest Vegetation	0.20	4.83
Deforested	0.45	11.08
Urban Zone	0.23	5.65
Agrarian Reform Settlements	0.10	2.52
Old Fire Zones	0.69	16.77
Recent Fire Zones	0.41	10.07
Mining Concessions/Licenses/Reserves	0.02	0.50
Rivers	0.09	2.10
Total	4.10	100.00

FIGURE 12 | TWO TYPES OF HUMAN PRESSURE



Areas subjected to incipient human pressure include fire zones and areas allocated to mining. Areas under pressure from human settlements include deforested areas, urban zones, and lands allocated for Agrarian Reform Settlements.

AREAS UNDER PRESSURE FROM HUMAN SETTLEMENT

Areas under pressure from human settlements are heavily concentrated near roads; they are mostly located in the so-called arc of deforestation, stretching from eastern and southern Pará through northern Tocantins and Mato Grosso, cutting through Rondônia, and reaching into eastern Acre. Other major areas of pressure from human settlements occur along the TransAmazon Highway in Pará, the Amazon River between Manaus and Belém, the Cuiabá-Santarém highway near the city of Santarém, and around the main urban centers in Roraima and Amapá (Figures 11 and 12).

Deforestation

The results show that about 11 percent of the Brazilian Amazon was deforested as of 2001. Deforestation in the Brazilian Amazon is different than the estimated deforestation for the Legal Amazon. The Legal Amazon contains greatly modified areas in its southern and eastern boundaries and these southern and eastern areas are not considered part of the Brazilian Amazon; deforestation in the Legal Amazon is estimated at 15 percent for 2001. (See Box 3 for an explanation of the overlap between the Brazilian Amazon and the Legal Amazon.)

Deforestation fragments the landscape and creates more edges between forests and non-forested areas (Laurence et al. 2000). By 1988, the forest area at risk of edge effect (< 1 km from the forest edge) in the Amazon was about 150 percent larger than the total area deforested (Skole and Tucker 1993). Forest edges are affected by solar radiation, wind, and agricultural fires (Cochrane and Laurance 2002). Forest inventory studies have shown that the biomass of forest edges decreases drastically within 100 meters of the edge (Laurence et al. 1997). The species diversity and composition also change in the forest edges and the edge effect could contribute significantly to the emission of green house gases such as CO^2 (Laurence et al. 1997). All these factors lead to a more degraded forest environment within forest fragments and forest edges.

Most of the forest fragments in the Brazilian Amazon are found within settled areas. In areas of incipient human pressure, forest fragments are less common, but the length of forest edge tends to increase. Additionally, as more unofficial roads are built in the incipient human pressure frontier, large forest fragments tend to become isolated. In this report, we have not quantified the overall effects of forest degradation due to forest fragmentation.

Urban Zones and Agrarian Reform Settlements

Approximately 6 percent of the Brazilian Amazon lies within urban zones; this is, the location of municipal seats and the 20-km buffer around them. The total area of agrarian reform settlements accounts for nearly 5 percent of the Brazilian Amazon and about half of the agrarian reform settlements are either forested or outside urban zones (see Figure 11). In 2001, deforestation in the agro-extractives agrarian reform settlements (PAE, for the acronym in Portuguese) was much smaller (2 percent) than in

conventional land reform settlements (43 percent). The apparent success of PAEs to halt deforestation, however, may be misleading since, until recently, most of them were in remote areas. In the State of Acre, for instance, INCRA officials have reported that with improvements in infrastructure (mostly road paving) deforestation and illegal sale of land also occurs in PAE settlements (Página 20 2005). A highly publicized exception is the Chico Mendes PAE, where settlers are managing the forest for timber production. In 2002, 1,900 ha of forest management in the Chico Mendes PAE gained FSC certification (FSC 2005). This success has been possible due to extensive support from Acre´s state government and NGOs, and because the area allocated per family is relatively large. It remains a challenge, however, to replicate this success. It is relatively difficult to garner such a high level of support for all the land settlement areas and most of the per-family land allocations in agrarian reform settlements (usually less than 100 hectares) are not large enough to generate sufficient income from sustainable forestry. (See analysis in Menezes 2004).

AREAS UNDER INCIPIENT HUMAN PRESSURE

In contrast to areas under pressure from human settlements, a greater proportion of incipient human pressure was beyond 30 km from official roads (See Figure 11). Fifty-four percent of the area of old fire zones, two thirds of recent fire zones, and 96 percent of mining reserves/licenses were beyond this threshold. Human presence in such areas is possible due to navigable rivers and a growing network of unofficial roads.

Fire Zones

Approximately 28 percent of the Brazilian Amazon was subjected to incipient human pressure associated with fire zones, measured as a 10-km radius around a forest fire. This area represented over half of the total area in which some form of pressure was detected.

The presence of fires and roads within fire zones suggests the presence of several incipient human activities such as deforestation of small plots (mainly less than 3 ha), logging, extraction of non-timber forests products, and hunting.

Different patterns of fire zone distribution seem to indicate different densities of occupation. Nearly two thirds of the area of the fire zones is aggregated (i.e., more than three overlapping fire zones). These aggregated areas extend beyond the margins of major settlements in Rondônia, Mato Grosso, and Pará. Furthermore, areas subjected to incipient human pressure around fire zones also occur in northern Roraima, eastern Amapá, and southeastern Acre and Amazonas. This concentration suggests that new pressure is occurring mostly in proximity to areas with denser infrastructure and population.

About 34 percent of the fire zones occur either in low densities or isolated groups (three or less overlapping fire zones). These low-density fire zones indicate at least two distinctive types of pressure. First, those located closer to settled areas (e.g., deforested and urban zones) may mark the beginning of settlement in forested areas along or in the vicinity of newly opened roads (see example in Veríssimo et al. 1995). Deforestation

far from markets, where farming profitability tends to be small, is partly explained by land speculation. Colonizers establish pasture in these zones expecting to gain from future valuation of the land when infrastructure develops. Land speculation is also stimulated by the fact that colonizers can claim public land as their property by showing evidence that they are cultivating the area.

Many of the smaller clusters of fire zones occur in isolated areas along rivers in the states of Amazonas, Acre, and Pará. Traditional populations in these areas practice shifting subsistence agriculture in small plots (typically less than 2 hectares) that are cleared, burned, and used for planting cassava, corn, and other crops, after which they are left fallow. Local residents also hunt and harvest wood and non-timber forest products such as rubber, Brazil nuts, seeds, and fruits from the surrounding forests. The impacts of this land-use pattern vary greatly but are far less than those generated by intensive logging and large-scale deforestation, although it can lead to localized extinctions of game species (Nepstad, et al. 1992; Redford 1992).

Mineral Reserves and Areas Licensed for Mineral Prospecting

Less than 1 percent of the Brazilian Amazon was exclusively under incipient human pressure from mineral reserves and areas licensed for mining. The total area legally allocated for mining is equivalent to approximately 2 percent of the Brazilian Amazon.

Logging

The results of our analysis suggest that most logging has occurred within the areas under pressure from human settlements and areas subjected to incipient human pressure. Most of the authorized logging operations as of 2000 overlap with the map of human pressure, and only 15 percent of the operations are in areas free of other indicators (Table 2). The distribution of logging authorizations corresponds to the distribution of wood production: approximately 80 percent of the permits are in Pará, Mato Grosso and Rondônia states which harvested 93 percent of the total timber harvested in the Brazilian Amazon in 2001 (Lentini et al. 2003). There was no overlap between logging operations and mineral reserves and areas licensed for mineral exploration.

TABLE 2 **OVERLAP BETWEEN LOCATION OF LOGGING OPERATIONS AND OTHER INDICATORS OF HUMAN PRESSURE**

Human Pressure Indicator or Land Cover Type	Number of Logging Operations Found in Each Indicator Category or Land Cover Type	Percent (Rounded) of Logging Operations Found in Each Indicator Category or Land Cover Type
Non-Forest Vegetation	2	<1
Forests under No Human Pressure	85	15
Deforestation	111	19
Urban Zones	57	10
Agrarian Reform Settlements	32	6
Fire Zones	293	50
Total	580	100

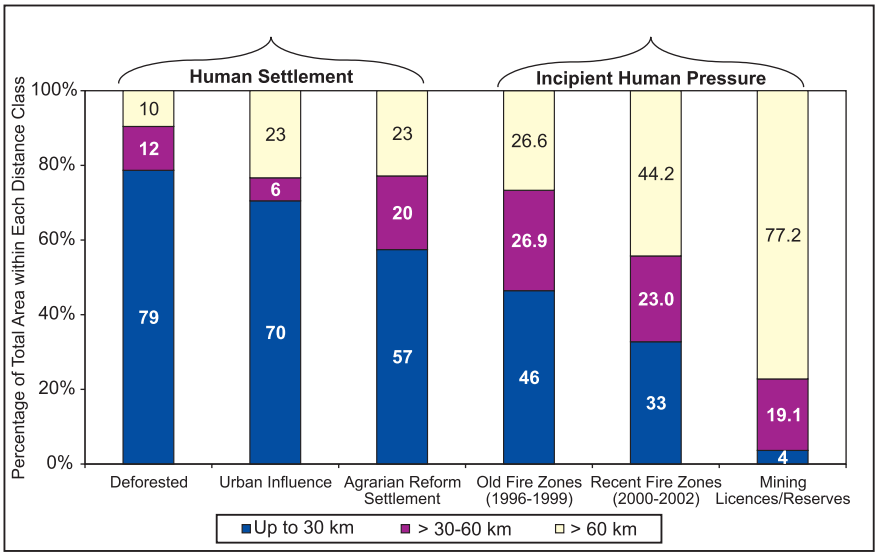
The methods used in our analysis complement and add value to existing maps of logging. Preliminary analysis suggests that the recent map by Asner et al. of selective logging from 2000 to 2002, derived from satellite imagery (Asner et al. 2005), coincides overall with most of the areas of human pressure. Selective logging missed by the Asner analysis is likely to be captured in the map of human pressure; for instance:

- Areas logged prior to 2000 are likely to be represented close to deforested areas or within fire zones.
- Areas identified in our analysis as subjected to incipient human occupation in states of Amazonas, Amapá, Tocantins, and Maranhão, were not included in the selective logging analysis by Asner et al. (2005).
- Analysis of satellite imagery alone is unlikely to identify area impacted by some types of logging. For example, soil and crown damage from logging is relatively small in *varzea* forests (flooded forests) (Uhl et al. 1997), and damage is reduced because logs are pulled through narrow canals or wood rails to the water (Barros and Uhl 1995). Nonetheless, our human pressure map captured such areas. Along the lower Amazon River in the State of Pará, for instance, these areas were captured because communities practicing this type of logging were identified by fire zones associated with small-scale agriculture.

Roads

Most deforested areas (80 percent), urban influence (70 percent) and area of agrarian reform settlements (57 percent) were within 30 km from an official road. Navigable rivers and a network of informal roads make possible the distribution of human settlement indicators beyond 30 km of informal roads, including: 20 percent of deforested areas, 30 percent of urban influence, and 43 percent of agrarian reform settlements (see Figure 13). This indicates that official roads are a key factor in consolidating human settlement.

FIGURE 13 | **CUMULATIVE AREA (PERCENT) OF HUMAN PRESSURE IN RELATION TO DISTANCE FROM OFFICIAL ROADS**



As is the case for deforestation, the distribution of unofficial roads is strongly influenced by the presence of official roads. In south-central Pará and northern Mato Grosso, for example, 82 percent of the total length of unofficial roads is within 50 km of official roads. Considering these two regions, unofficial roads appear to be associated primarily with the consolidation of settlements: 62 percent of the length of unofficial roads crosses areas under settlement; an additional 27 percent of the length of unofficial roads is located within fire zones; and 11 percent crosses forested areas without other signs of human pressure.

Our analysis confirms the effectiveness of using fire zones as a surrogate to identify incipient human pressure in areas where transportation data is incomplete. In the areas where detailed maps of the road network are available, the majority of the fire zones are accessible by unofficial roads and navigable rivers. In the areas of south-central Pará and northern Mato Grosso, 76 percent of the fire zones are accessible, 45 percent of them exclusively by unofficial roads; 17 percent by unofficial roads and other types of access; 13 percent by navigable rivers; and 1 percent by a combination of other forms of access (see Figure 14). An estimated 24 percent of the area of fire zones shows no evidence of access. In part, this could be due to the fact that unofficial roads have not been mapped for the entire Brazilian Amazon. Figure 15 shows the overlap between unofficial roads human pressure in south-central Pará.

FIGURE 14 | **TYPES OF ACCESS TO FIRE ZONES IN SOUTH-CENTRAL PARÁ AND NORTHERN MATO GROSSO**

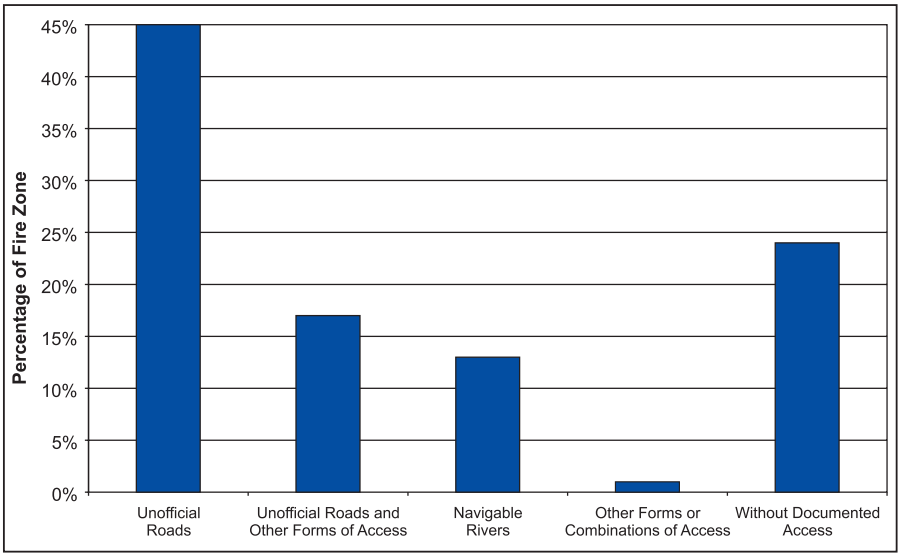
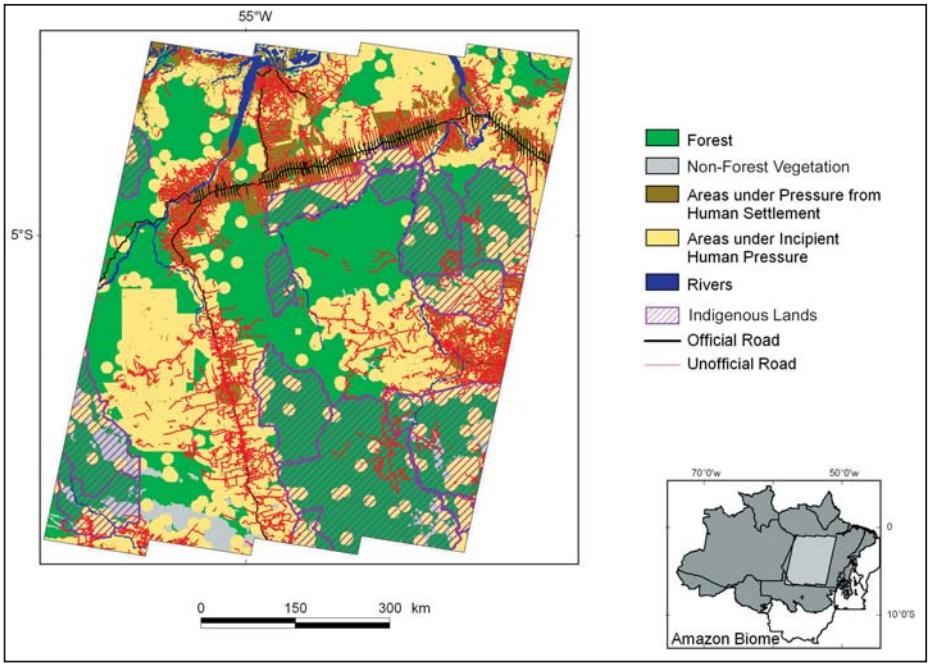


FIGURE 15 | **UNOFFICIAL ROADS, HUMAN PRESSURE, AND INDIGENOUS LANDS**



Ilustrates the overlap between official and unofficial roads, areas under human pressure, and Indigenous Lands.

5

HUMAN PRESSURE AND PROTECTED AREAS

RESULTS AND DISCUSSION

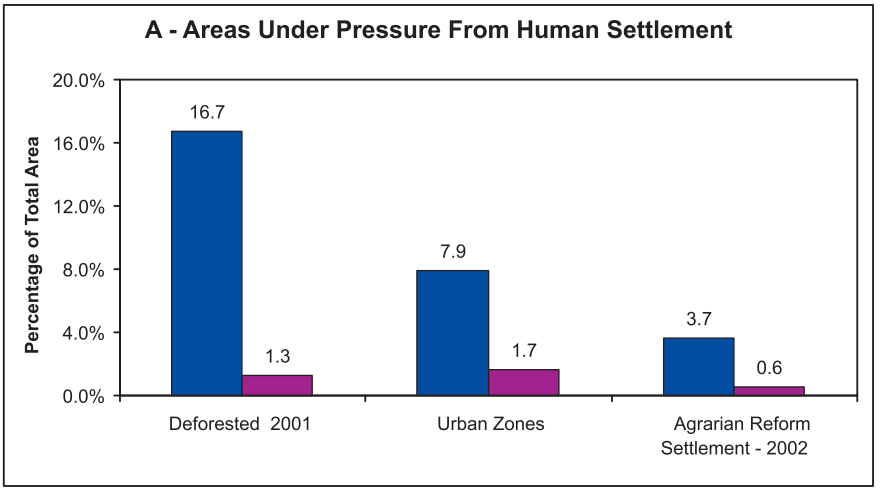
This section presents the extent of human pressure in current protected areas and in priority areas for the creation of new protected areas. This includes areas both for conservation and for public production forests. This section ends with a summary of risks and opportunities for the creation of new protected areas.

HUMAN PRESSURE IN EXISTING PROTECTED AREAS

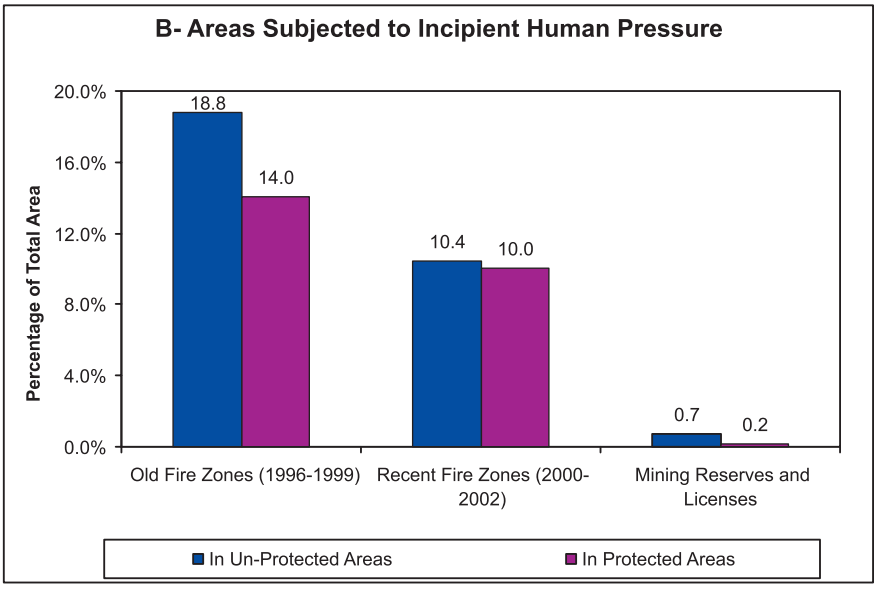
Overall, human pressure in protected areas is much smaller than in un-protected areas (see Figure 16). The proportion of areas under pressure from human settlements in non-protected areas (28 percent) was almost seven times higher than in protected areas (approximately 4 percent).

The area deforested in protected areas was equivalent to about 1.3 percent—much less than the 17 percent outside protected areas. Other indicators of pressure were also much higher in unprotected areas (see Figure 16A), and mostly in the form of areas subjected to incipient human pressure (see Figure 16B). The greatest concentration of fire zones within protected areas occurs in Pará, Rondônia, and Mato Grosso, and in the extreme north of Roraima, Pará, and Amapá. Areas with clusters of exclusively more recent fire zones (2000-2002)—indicating expanding pressures—appear mainly in central and northern Pará, Amapá and Rondônia (see Figure 17). Mining reserves or areas with mining licenses cover less than 1 percent of protected areas. Protected areas in the western Amazon, principally in the State of Amazonas, were overall under less human pressure.

FIGURE 16 | DISTRIBUTION OF HUMAN PRESSURE IN EXISTING PROTECTED AREAS AND IN UN-PROTECTED AREAS

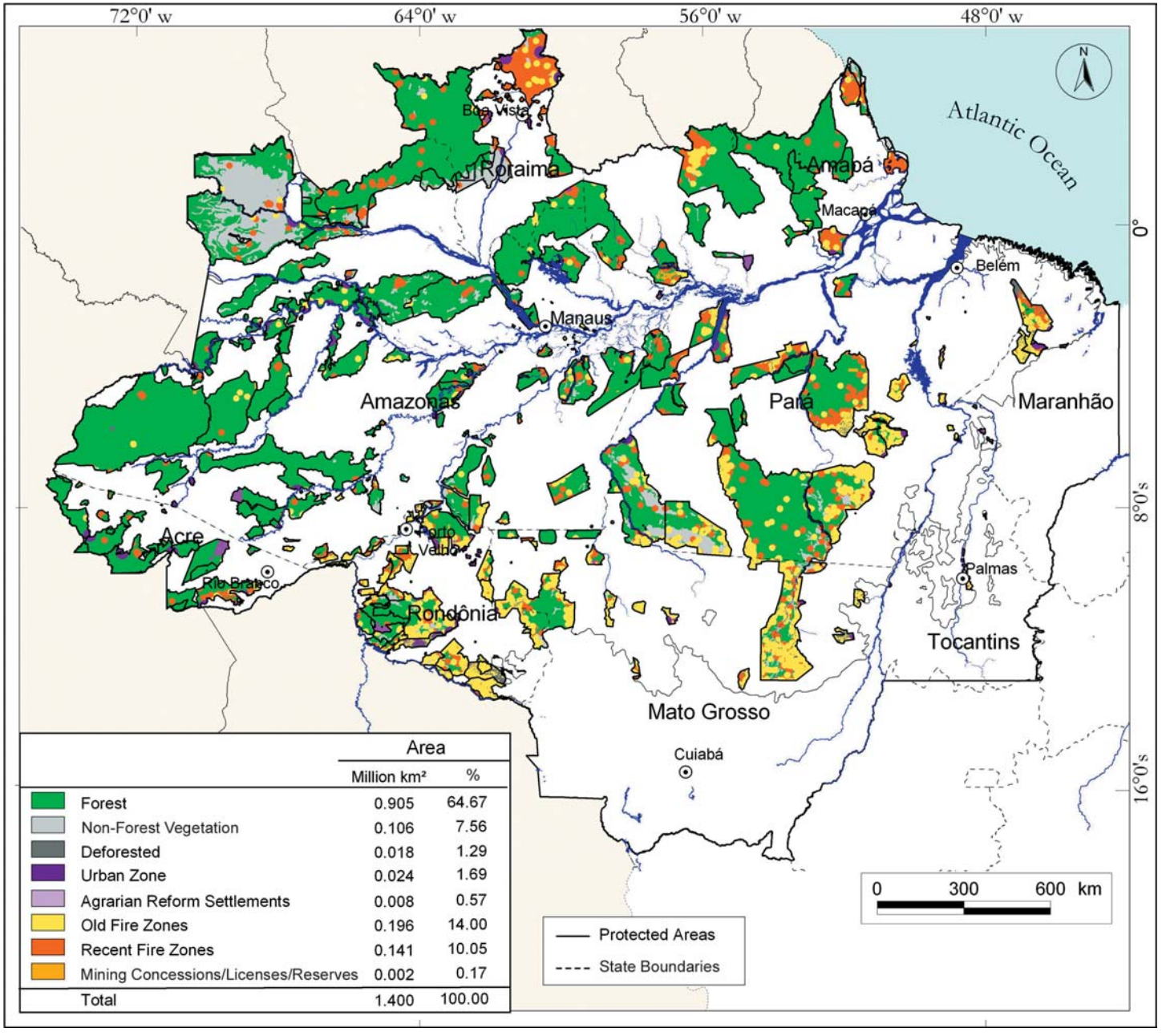


Note the conflicting land uses represented by the overlap between established protected areas and agrarian reform settlements.



Note that there is little difference between the area covered by recent fire zones in protected and non-protected areas. This is due to the fact that incipient human occupation is getting closer to several protected areas and the extent of incipient human pressure—the 10-km radius—is within such protected areas.

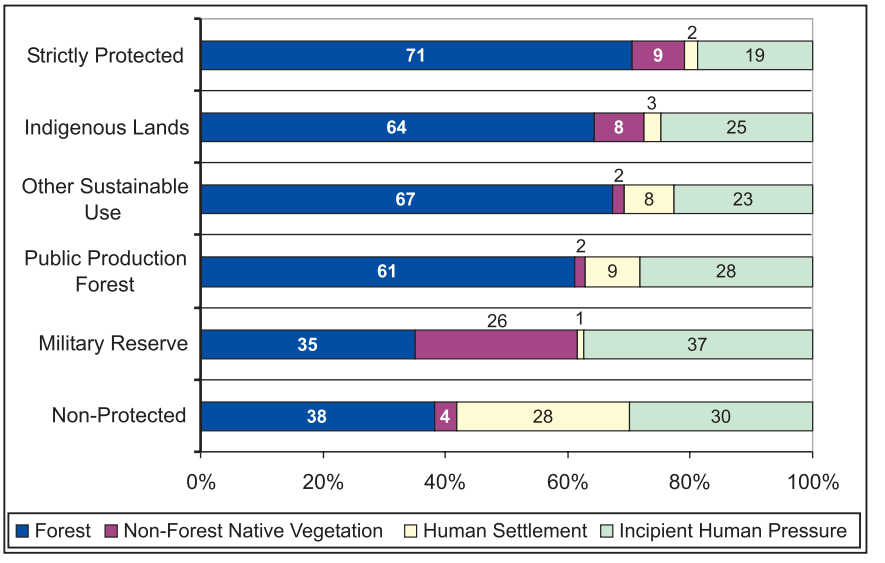
FIGURE 17 | **HUMAN PRESSURE IN PROTECTED AREAS**



	Area	
	Million km²	%
Forest	0.905	64.67
Non-Forest Vegetation	0.106	7.56
Deforested	0.018	1.29
Urban Zone	0.024	1.69
Agrarian Reform Settlements	0.008	0.57
Old Fire Zones	0.196	14.00
Recent Fire Zones	0.141	10.05
Mining Concessions/Licenses/Reserves	0.002	0.17
Total	1.400	100.00

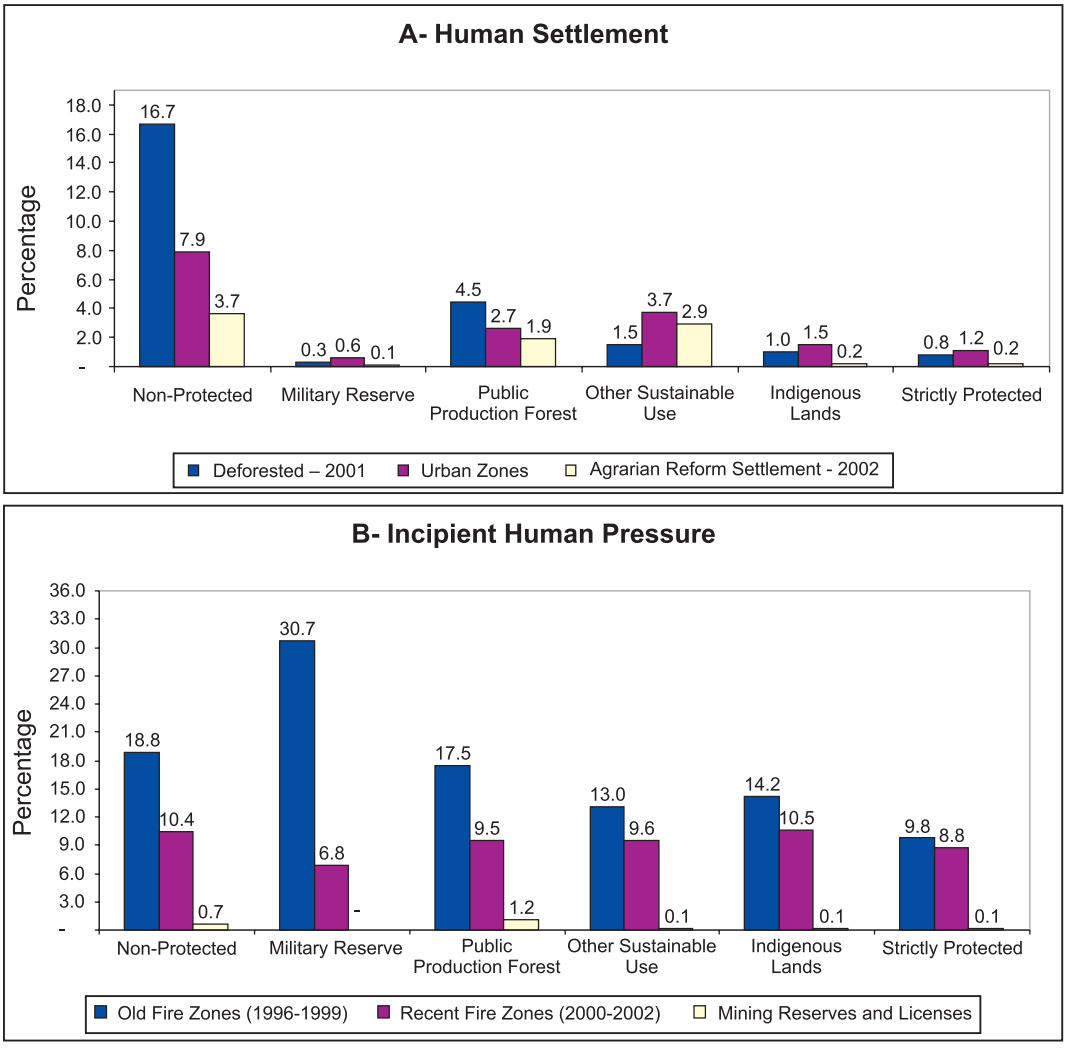
Human pressure varies among protected area types. Areas under pressure from human settlements vary from 1 percent on military lands to 9 percent in national and state public production forests. In contrast, outside of protected areas, areas under pressure from human settlement cover 28 percent of the land (see Figure 18). Deforestation in protected areas ranges from less than 1 percent on military land to nearly 5 percent in public production forests, while it is 17 percent outside protected areas (see Figure 19A). Within protected areas, incipient human pressure varies from 19 percent in strictly protected areas to 37 percent on military land. Outside of protected areas, the corresponding figure is 30 percent (see Figure 19B). Outside of protected areas, the corresponding figure is 30 percent (see Figure 19B). The relatively high incipient pressure in the Military Land – especially older fires – has resulted from illegal activities associated with the harvest of mahogany (Filho 2003). Moreover, this area contains a relatively high percentage of savanna and transitional forest, which are more prone to fires than other areas. Surveillance in this area has been reinforced (Oliveira 2004), which seems to have reduced new forest fires (see Figure 19B).

FIGURE 18 **DISTRIBUTION OF LAND COVER AND HUMAN PRESSURE IN UN-PROTECTED AREAS AND BY CATEGORIES OF PROTECTED AREAS**



Some level of human pressure in indigenous lands and other sustainable use areas (including extractive reserves) is expected since slash-and-burn agriculture is permitted in those areas. A significant portion of human pressure in those areas seems to be associated with traditional activities given that: (1) areas under pressure from human settlements were a small portion of human pressure in both areas (see Table 2); and (2) the presence of fire zones is compatible with slash-and-burn agriculture, which involves small deforestation not detected by INPE. Nevertheless, more studies are needed to differentiate "normal" or legal human pressure in these areas from illegal occupation.

FIGURE 19 | **DISTRIBUTION OF LAND COVER AND DISAGGREGATED HUMAN PRESSURE IN UN-PROTECTED AREAS AND BY CATEGORIES OF PROTECTED AREAS**



Deforestation and occurrence of fires in existing protected areas up to 2002 were significantly correlated with distance to official roads. With greater proximity to roads (< 25 km), deforestation and fires increased significantly within protected areas.[8] Thus, increasing transportation infrastructure without corresponding improvements in enforcement capacity is likely to lead to greater pressures on protected areas. Besides illegal pressures, protected areas in regions with better infrastructure might face even official pressures. For example, in 2003 the government of Mato Grosso proposed legislation to reduce the Xingu State Park by 30 percent (39,000 ha). Local populations supported the proposal in a public hearing, pleading for more area to expand agricultural production (Diário de Cuiabá 2003), and the state legislature approved the proposal. Since then, the state government has also proposed the reduction of 99,000 ha of another park (Greenpeace 2005). This situation raises the issue of how to guarantee long-term commitment to protect conservation areas.

HUMAN PRESSURE IN PRIORITY AREAS FOR CONSERVATION

About 48 percent of the non-protected priority areas for conservation are under human pressure (see Figure 20). Land under pressure from human settlements account for almost 19 percent of these areas, including deforestation (9 percent), urban zones (8 percent) and agrarian reform settlements (2 percent); areas under incipient human pressure occur in 31 percent of the total area, the majority (99 percent) in the form of fire zones and the remaining as mining licenses and reserves. Most of the area under human pressure is in the eastern and southern Brazilian Amazon, and along the largest rivers such as the Lower and Middle Amazon and the Upper Rio Negro.

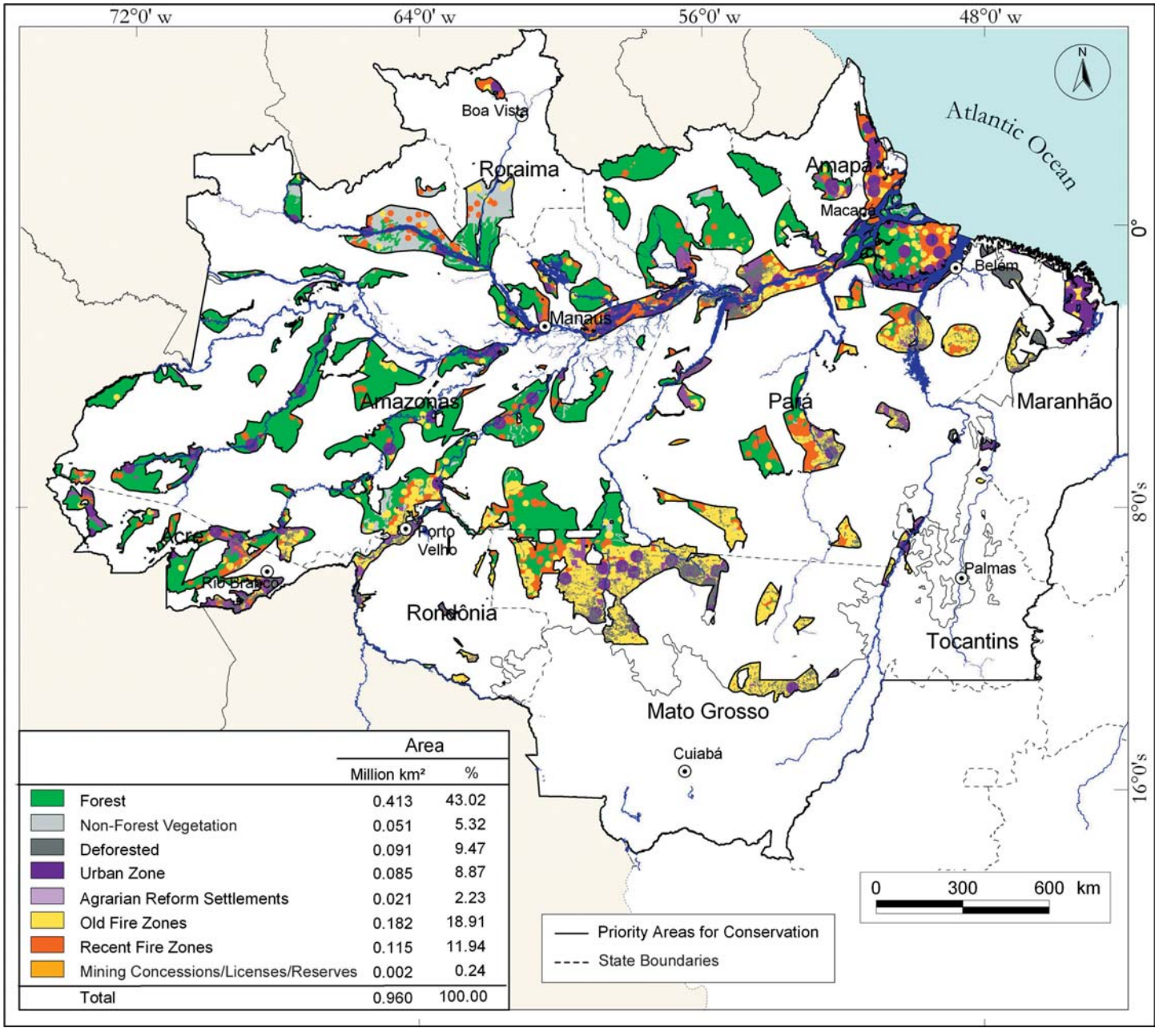
Because the map of priority areas for conservation is incomplete due to lack of sampling in more remote regions, the human pressure on potential protected areas not indicated on this map is unknown. Since they are remote regions, it is likely that such areas are currently under lower human pressure, although there is not enough information to confirm this. More biodiversity inventories are urgent, given the rapid expansion of occupation frontiers.

Potential Areas for the Establishment of Public Production Forests

The analysis shows increasing human pressure on the 1.55 million km^2 originally identified with potential for public production forests in 1999. In 2002 approximately 30 percent of that area showed signs of human pressure, while only 9.3 percent had been set aside as new protected areas (see Figure 21).[9]

Areas under incipient human pressure within fire zones account for about 76 percent of the human pressure on potential areas for public production forests; land reform settlements accounted for nearly 13 percent and deforestation for 6.4 percent. Unofficial roads and rivers provide opportunities for increased human pressure on public lands, thereby reducing the area potentially available for the establishment of new production forests.

FIGURE 20 | **HUMAN PRESSURE IN PRIORITY AREAS FOR CONSERVATION**



	Area	
	Million km²	%
Forest	0.413	43.02
Non-Forest Vegetation	0.051	5.32
Deforested	0.091	9.47
Urban Zone	0.085	8.87
Agrarian Reform Settlements	0.021	2.23
Old Fire Zones	0.182	18.91
Recent Fire Zones	0.115	11.94
Mining Concessions/Licenses/Reserves	0.002	0.24
Total	0.960	100.00

Data source: Capobianco et al. 2001.

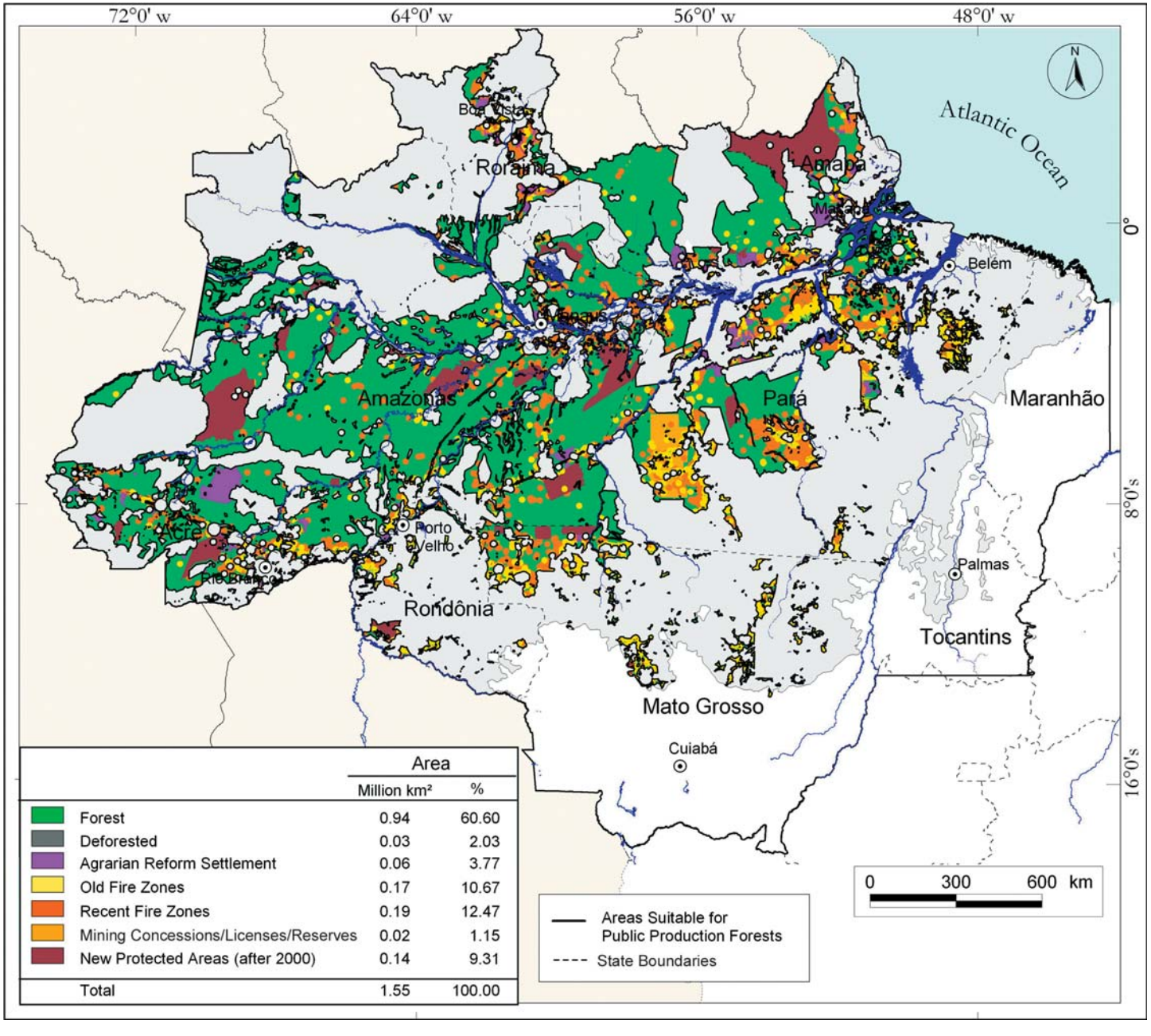
An additional four percent of areas with signs of human pressure had been licensed for mineral prospecting or defined as mineral reserves by 1998. While these designations do not necessarily mean that mining will take place, if mineral stocks of interest are found, mining would most likely be granted priority use. Regardless of the final status of these areas, however, industrial-scale mining tends to use only a small fraction of the total area designated and thus provides opportunities for environmental conservation. Some mining areas in the Amazon are within national forests, such as the Carajás mine in southern Pará, where a large part of the area is conserved and intact.

As expected, the vast majority (92 percent) of the area under human pressure within potential public forests in 2002 was economically accessible for logging in 1999, that is, loggers could profitably reach most of these areas using navigable rivers or existing roads, or by opening new roads (see Box 4). Economic accessibility to logging in public production forest would be beneficial assuming that appropriate concession regulation and enforcement capacity were in place. However, the current lack of a legal framework for regulating concessions in both national and state forests prevents allocation of such areas for forestry. In the absence of both regulation and effective enforcement, loggers and farmers have invaded some public production forests. For example, the Bom Futuro National Forest lost 8 percent of its forest cover between 1997 and 2003 due to illegal logging followed by deforestation.[10] Furthermore, illegal logging occurs in protected areas where forestry is not permitted, such as indigenous lands and biological reserves (CEDI 1992; Veríssimo et al. 1995; Grogan et al. 2002).

The federal government and some state governments in the Amazon region (Pará, Amazonas, Acre, and Amapá) are developing legal frameworks for forest concessions. Progressive timber companies and environmental NGOs have supported the creation of public production forest because this could facilitate the legalization of sustainable forestry and the control of unclaimed public lands.[11] In February 2006, the Brazilian Senate approved legal framework presented by the Ministry of Environment and the President is expected to sanction the new law in early March 2006. However, even with such a framework in place, increased enforcement against illegal operations will be necessary. Figure A in Appendix 2 shows protected areas that are economically accessible to logging and thus may require stepped-up monitoring and enforcement.

The establishment of new protected areas up to 2004 had been relatively slow within the area identified for potential production forests. From 2000 to 2004, the federal and state governments established protected areas in 8.3 percent (126,000 km^2) of this area, of which only about 23,000 km^2 were public production forest. The area showing incipient human pressure between 1999 and 2002[12] (about 437,398 km^2) within the zones with potential for establishing production forests was almost 16 times larger than the public production areas established from 2000 to 2004. This difference indicates a need to accelerate efforts to expand production forests in the Brazilian Amazon.

FIGURE 21 | **HUMAN PRESSURE IN AREAS SUITABLE FOR PUBLIC PRODUCTION FORESTS**



Source: Verissimo et al. 2000.

RISKS AND OPPORTUNITIES FOR THE CREATION OF CONSERVATION AREAS

The federal and state governments will need approximately 664,000 km^2 to reach their goals to expand the protected areas system to 270,000 km^2 of strictly protected areas by 2009 and 395,000 km^2 of public production forests by 2010.[13]

Although areas of incipient human pressure are valuable for conservation—due to relatively low intensity of use and occupation—it will be financially and politically costly to establish protected areas in these zones given the interests already in place. In areas identified to be subjected to incipient human pressure in western Pará, for instance, the presence of loggers, settlers, and gold miners is undermining efforts to establish protected areas in favor of other alternatives such as agrarian reform settlements or land titling. In November 2003 loggers in Pará protested against governmental attempts to limit illegal logging on public lands, instead demanding title to those lands (Greenpeace 2003; Agência Estado 2003; Jornal do Brasil Online 2003). As a result, in November 2005 the Brazilian Congress ratified new legislation foregoing a public bidding process for titling landholdings in public lands smaller than 500 ha in the Brazilian Amazon (Presidência da República 2005). Prior to this measure, a bidding process was required for titling landholdings bigger than 100 ha; the new legislation is valid for areas occupied before December 1, 2004. Therefore, the new legislation will speed the process of legalizing the occupation of areas that could be recommended for the establishment of protected areas. In fact, the Ministry of Land Reform expects to issue new titles for more than 20,000 km^2 of public lands that allegedly will benefit 150,000 families (MDA 2005).

The creation of new protected areas and public production forests will be less costly in areas with less human pressure. This report shows that about one million km^2 of land considered priority for establishing new strictly protected areas and public forests are free of human pressure. This is enough for the federal and state governments to achieve their goals. Most of this land (977,000 km^2) is forested and only a fraction (50,000 km^2) has non-forest vegetation.

However, given current trends, *human pressure* is likely to increase. For example, 73 percent of the remaining area for establishing public production forests is economically accessible for logging (see Appendix 2) and timber companies are already migrating to new logging frontiers (Schneider et al. 2002; Lentini et al. 2005). Moreover, government proposals to pave roads in the region increase the potential for the development of agribusiness (Arima et al. 2005). These trends have fueled strong local opposition to strictly protected areas and indigenous lands because they are perceived as contributing little or nothing to economic development (O Liberal 2003; Carta Maior 2004; Diário do Pará 2004; MMA 2004). Continued expansion of *human pressures w*ill require rapid action on the part of government to establish protected areas before the arrival of illegal loggers and settlers.

Nevertheless, despite local opposition to strict protected areas and indigenous lands, some state governments have supported the creation of

public production forests and sustainable development reserves. In the case of Pará and Acre, the support is associated with plans for rural development financed, respectively, by the World Bank and the Inter-American Development Bank. In addition, the majority of the Brazilian populace supports forest conservation: in a national opinion poll in 2000, 88 percent of respondents supported the increase in forest protection (ISA 2000).[14]

Demands for conservation and sensible development have recently led the federal and state governments (e.g., Acre, Amapá, Pará and Amazonas) to create new protected areas and to enact measures to facilitate the creation of other areas in the future:

- Between 2004 and 2005, the federal government created protected areas covering approximately 3 percent of the Brazilian Amazon.
- In 2005, the federal government enacted legislation [15] to safeguard areas of interest for conservation from illegal occupation, allowing the president to decree a temporary embargo (up to seven months) on land use in public lands of interest for conservation until completion of studies required for establishing protected areas.
- Using this new legislation, the federal government limited the occupation of approximately 82,000 km^2 in western Pará to conclude studies for the creation of national parks, national forests, and other conservation areas. In May 2005 and in February 2006, the federal government created nine protected areas totally 68,000 km^2 in western Pará, including 19,000 km^2 of strictly protected areas (Park and Biological Reserves) and 49,000 km^2 of sustainable use areas (National Forests and Environmental Protection Areas).

These recent trends show that societal demand and rapid government action can work for the protection of priority areas for conservation.

6
CONCLUSIONS AND RECOMMENDATIONS

This report compiles geographical information on several indicators of human pressure to provide a basis for monitoring land-use change and for planning conservation and sustainable land use in the Brazilian Amazon. The findings presented here provide a spatial assessment of the situation as of 2002, and an overview of current trends. The findings of this report have the following implications for public policies:

Roads are significantly correlated with human pressure, including in protected areas. Investments in road infrastructure, such as paving existing roads or opening new roads, should be accompanied by: a) the creation of protected areas in priority areas for conservation already identified; and b) investments in protecting conservation areas within the reach of new or improved roads. The recent effort by the federal government to design a sustainable development plan—including the creation of protected areas—along the Cuiabá-Santarém highway is commendable. This approach should be applied along other roads proposed for paving.

There is enough area without human pressure for the federal government to meet its goal to expand the protected areas system by 2010. However, the opportunities are diminishing rapidly, especially considering that local political pressure against conservation builds even in areas subjected to incipient human pressure. Therefore, rapid government action is needed to establish protected areas before human pressure increases in priority areas for conservation. The new federal legislation that allows temporary limitation of land use in areas of interest for conservation is a promising initiative to facilitate the creation of new protected areas. Maps in the present report flag priority areas for immediate application of this new approach.

The experience from the State of Mato Grosso indicates that when human pressure increases due to greater economic opportunities, government commitment for biodiversity protection may decrease and even lead to the reduction of protected areas. **Further analysis and policy debate on how to guarantee the long-term governmental commitment to safeguarding protected areas is necessary.**

Finally, as explained throughout the text, some of the data presented in this report are either incomplete or limited due to lack of precise information. **There is a need to improve data gathering and analysis of current forest conditions and trends.** For

example, there is no comprehensive map of the informal road network in the region. Likewise, an accurate and complete map of logged forests and other forms of forest degradation (such as burned forests) is unavailable. **Investments in this type of research are crucial to improve conservation and development decisions.**

Despite its limitations, the information presented in this report reveals a more comprehensive view of human pressures in the Brazilian Amazon than has been available before. This is useful to guide strategic actions to improve forest conservation until better information becomes available.

NOTES

[1] Currency exchange rate of US$1= R$2.2 as of December 2005.

[2] Between 1997 and 2000, land prices in the Brazilian Amazon averaged 11-20 percent of land prices in the state of São Paulo (Arima et al. 2005). The average productivity of large-scale cattle pastures, measured as weight gain per year, is almost 10 percent higher in the Brazilian Amazon than in other regions of Brazil. Productivity tends to be higher in zones of intermediate rainfall (1800 to 2200 mm per year) (Arima et al. 2005). In zones of higher rainfall—where soils tend to be less fertile and pests and diseases more common—productivity is generally lower.

[3] Near Santarém, in western Pará, families received US$ 600-3,500 for the sale of timber from agrarian reform settlement plots (Lima et al. 2003).

[4] One study based on 1996 data from Pará showed that the monthly income for 55 percent of the sampled families in agrarian reform settlements was less than US$65 (Abelém and Hébette 1998), which was equivalent to 60 percent of the minimum wage and only 46 percent of the average rural salary in Brazil at that time (Fundação Getúlio Vargas 2003). Lack of infrastructure also seems to contribute to failure, as suggested by the significant distance of many agrarian reform settlements from official roads (47 percent of total area was more than 30 km from an official road in 2002; see section with results of human pressure analysis).

[5] See EMBRAPA/CPATU (1996) for an evaluation in eastern Pará. Public complaints prompted IBAMA to review and then suspend or cancel approximately 86 percent of the existing 2,806 authorizations for forestry operations between 1998 and 2000, and 43 percent of the existing 1,059 authorizations in 2001 (Amigos da Terra 1995; Barreto and Souza 2001; IBAMA 2002). In 2001, IBAMA canceled authorizations to harvest mahogany after Greenpeace denounced illegal operations in southern Pará.

[6] Fire data for the entire region is available only after 1999, and data available for 1996 is only for south of the equator. Data from 1997-98 is only available for the area below 1° N.

[7] Campinaranas are mosaics which occur on the transition between the Guyana Shield and the Amazon basin. Vegetation ranges from open herbaceous savannas to closed canopy forests. The soil in campinarana sites—which is the main driver of this vegetation type—is usually sandy. Some patches cover thousands of square kilometers, while others are much smaller. Online at: http://www.nationalgeographic.com/wildworld/profiles/terrestrial/nt/nt0158.html (02/09/06)

[8] The correlation coefficients between the proportions of protected areas within 25 km of a road and the proportions that are (1) deforested (0.29) and (2) affected by fire (0.35) were significant in both cases.

[9] This estimate includes areas allocated as mining reserves and or licensed for mining (17,234 km^2) by 1999. Areas registered after 1999 accounted for 437,400 km^2, or 29 percent of the area originally estimated as potentially appropriate for the establishment of public production forests.

[10] This case was reported in a judicial process (2004.41.00.001887-3) brought by the public defender of the State of Rondônia against the occupation of protected areas.

[11] In December 2005, in a unique event, environmental and social NGOs together with representatives from the timber industry signed a letter demanding the Senate to approve the forest concession legislation proposed by the government. Online at: http://www.greenpeace.org.br/amazonia/?conteudo_id=2454&sub_campanha=0 (12/14/05).

[12] In this case, excluding the area of mineral reserves already existing prior to 1999

[13] The goal of 395,000 km^2 takes into account the area of existing public production forests by May 2004 (106,000 km^2) and the goal established by the National Forest Plan (500,000 km^2 by 2010).

[14] Vox Populi, an independent institute, conducted the survey through telephone calls. The research tended to capture the opinion of the urban population (equivalent to 81 percent of Brazilian population in 2000) because the availability of phone lines in rural areas is smaller. The opinion of the rural population, which is likely to bear more directly on local land use decisions, might differ from this survey. The margin of error of results was 5 percent. Data on population online at: www.ibge.ogv.br.

[15] The President enacted the new legislation as a provisional measure, but both houses of Congress have already confirmed the legislation in June 2005.

APPENDIX 1

PROTECTED AREAS IN BRAZIL

Brazilian protected areas are organized into two umbrella categories: *strictly protected areas*, and *sustainable use areas* which relate to the IUCN categories as follows:

SNUC Categories and Objectives (based on Silva 2005; MMA 2000)	IUCN Categories (IUCN 1994)
Strictly Protected Areas: to preserve biodiversity and allow scientific research	
National Park: ecosystem protection because of ecological relevance or scenic beauty.	Category II – National Park: mainly for ecosystem protection and recreation.
Biological Reserve: biodiversity conservation. **Ecological Stations**: biodiversity conservation and scientific research.	Category Ia – Strict nature reserve/wilderness protection area: mainly for science or wilderness protection.
Natural Monuments: conservation because of specific features or scenic beauty. **Wildlife Refuges**: preservation of faunal and floral communities.	Category III – Natural Monument: areas mainly for conservation of specific natural features.
Sustainable Use Areas: various forms and degrees of exploitation are allowed; biodiversity protection is a secondary management objective.	
Environmental Protection Areas: preservation of important attributes (biological, cultural, scenic) for the well-being and the quality of life of the human population.	Category V – Protected Landscape/Seascape: mainly for landscape/seascape conservation and recreation.
Areas of Particular Ecological Interest: preservation of extraordinary natural features or regionally rare species.	Category IV - Habitat/Species management area: mainly for conservation through management intervention.

Continuation of Appendix 1

SNUC Categories and Objectives (based on Silva 2005; MMA 2000)	IUCN Categories (IUCN 1994)
Sustainable Use Areas: various forms and degrees of exploitation are allowed; biodiversity protection is a secondary management objective.	
Public Production Forests: sustainable multiple uses of forest resources and for scientific research. These can be national or state forests. **Extractivist Reserves**: protect the culture and livelihoods of the traditional human populations that live there, and to and ensure sustainable use of resources. **Fauna Reserves**: scientific research and for the sustainable economic use of species of fauna. **Sustainable Development Reserves**: conservation but also to ensure that the well-being and quality of life of the populations of traditional peoples that live there are improved. **Private Natural Heritage Reserves**: private lands managed for biodiversity conservation; scientific research as well as tourism, recreation, and education activities are allowed.	Category VI – Managed Resource Protection Area: mainly for sustainable use of natural ecosystems.

APPENDIX 2

ECONOMIC ACCESSIBILITY OF LOGGING

In 2000, Veríssimo et al. mapped areas economically accessible to timber harvesting in the Brazilian Amazon. The Verissimo map showed areas that are economically viable for harvesting based on the estimation of the maximum distance loggers can pay for the transportation of logs.[1] The maximum distance varies according to timber species values. For example, a logger would travel a long distance to harvest a high-value species such as mahogany, but would only harvest low-value species closer to market. Following this rationale, harvest intensity should vary from higher intensity (i.e., higher volume of logs harvested per hectare) close to markets to lower intensity as the distance from markets increases. The map of economic accessibility is thus an indicator of potential logging operations in the future. To assess this logging pressure Imazon overlaid the map of economic accessibility for logging on the maps of existing protected areas and potential protected areas.

Potential Pressure on Established Protected Areas

About 50 percent of the land in existing protected areas—equivalent to 60 percent of the forest cover in those areas—is economically accessible to some form of logging (see Figure A). Of the total area of accessible forests within protected areas, 15 percent is accessible to more intensive logging (i.e., harvest of all commercial species). These forests—concentrated in central Pará and Amazonas, and in Rondônia—are the most accessible to settled areas or existing logging centers, and they stand the greatest risk of illegal logging and conversion to other land uses. In contrast, 31 percent of the total area of accessible forests within protected areas would be accessible exclusively for logging of mahogany, a species exceptionally high in value. These forests are generally more distant from official infrastructure and are likely to be less attractive—at least over the short term—for in-migration by new settlers.

Potential Pressure on Priority Areas for Conservation

In areas with potential for the establishment of new protected areas, logging operations could potentially access 58 percent of the land surface and 78 percent of the forests (see Figure B). About 37 percent of these forests would be accessible for harvesting all commercial species, and because of their proximity to official infrastructure, such areas are under the greatest threat of conversion. These areas are located in northern Mato Grosso, along the Amazon River

FIGURE A | **ECONOMIC ACCESSIBILITY FOR TIMBER HARVESTING WITHIN PROTECTED AREAS**

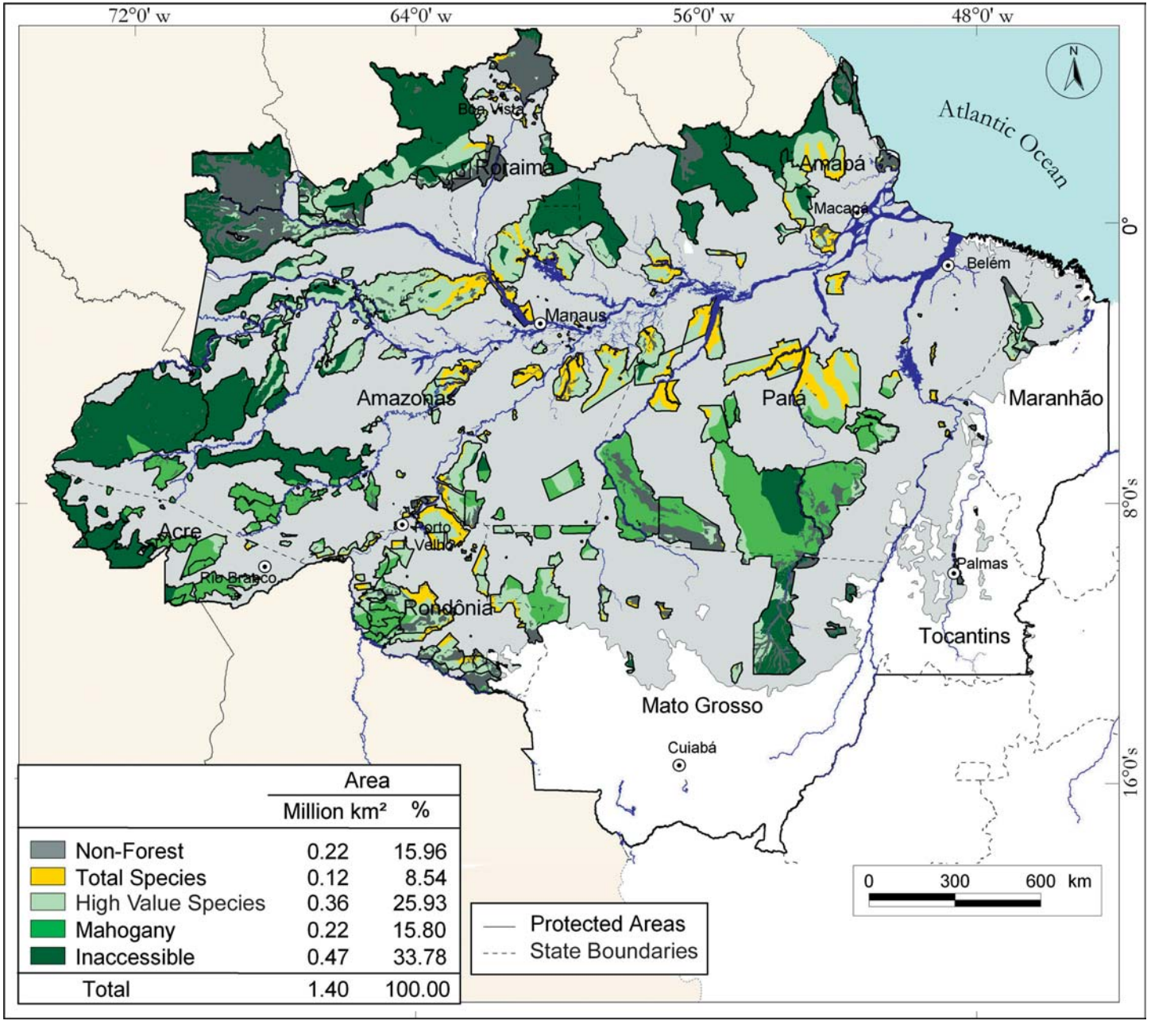
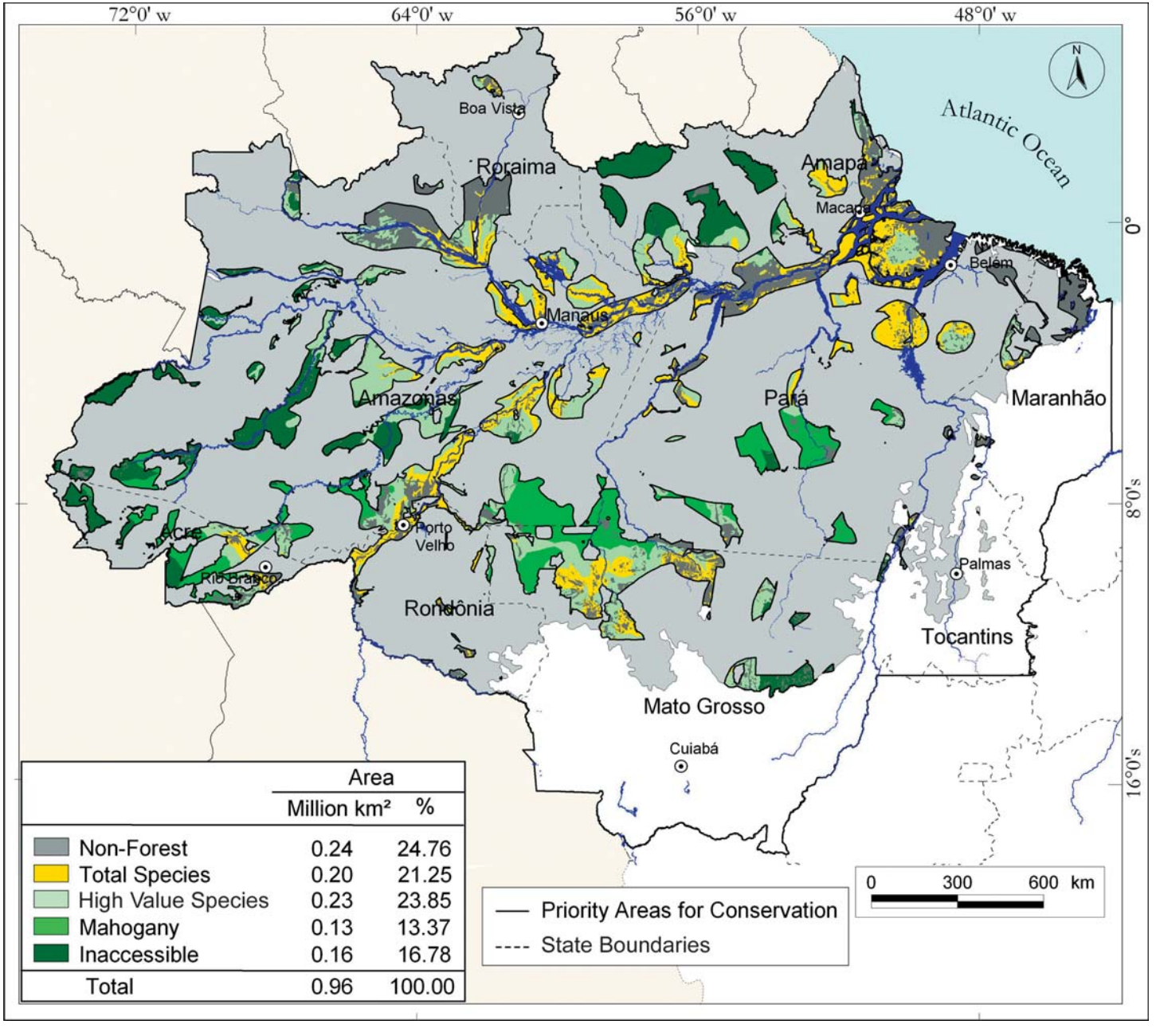


FIGURE B | **ECONOMIC ACCESSIBILITY FOR TIMBER HARVESTING WITHIN PRIORITY AREAS FOR CONSERVATION**



and its main tributaries in Amazonas, and in northeastern Pará states. An additional 41 percent of these forests would be accessible to logging of high-value species, involving operations that are intermediate in intensity. Finally, 22 percent would be economically accessible exclusively for low-intensity logging focused exclusively on mahogany.

Notes

[1] The estimation of the maximum economic distance for logging considered information on sawmill location; transportation corridors (roads and navigable rivers); land cover; logging, hauling and wood processing costs; and timber market prices. Estimates of transport costs incorporated distance and means of transport (for example, river transport is cheaper than road transport).

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ABOUT WRI

The World Resources Institute is an environmental think tank that goes beyond research to create practical ways to protect the Earth and improve people's lives. Our mission is to move human society to live in ways that protect Earth's environment for current and future generations.

Our program meets global challenges by using knowledge to catalyze public and private action:

- **To reverse damage to ecosystems**. We protect the capacity of ecosystems to sustain life and prosperity.
- **To expand participation in environmental decisions**. We collaborate with partners worldwide to increase people's access to information and influence over decisions about natural resources.
- **To avert dangerous climate change**. We promote public and private action to ensure a safe climate and sound world economy.
- **To increase prosperity while improving the environment**. We challenge the private sector to grow by improving environmental and community well-being.

In all of our policy research and work with institutions, WRI tries to build bridges between ideas and actions, meshing the insights of scientific research, economic and institutional analyses, and practical experience with the need for open and participatory decision-making.

GLOBAL FOREST WATCH

Global Forest Watch—a project of the World Resources Institute—is an independent monitoring network that tracks forest development in Central Africa, North America, South America, and Southeast Asia. GFW aims to promote transparency and accountability in the forest sector, by: (i) mapping the locations of logging concessions, mines, roads, and other development; (ii) documenting the key actors behind this development; and (iii) tracking the degree to which these actors are in compliance with existing environmental regulations. GFW operates through local organizations in order to build capacity for in-country, independent monitoring. Our mandate is strictly limited to providing quality, peer-reviewed data, at no cost, to public, government and other audiences. GFW fosters collaborative relationships with government agencies and the private sector in all of the countries where we operate, as these groups are key providers and users of GFW data.

ABOUT IMAZON

Imazon is a non-profit research institute whose mission is to promote sustainable development in the Amazon region through studies, information dissemination and professional training.

Research. Imazon's research activities include: (i) diagnosis of land use activities; (ii) development of methods for evaluating and monitoring land use activities; (iii) performance of demonstration projects; (iv) analysis of public land use policies; and (v) preparation of scenarios and models for sustainable development for these activities. The research activities have three basic characteristics in common:

- **Interdisciplinary.** The Imazon studies include economic, biological, legal, institutional and social aspects.

- **Search for solutions.** The studies carried out by Imazon are directed towards solutions for natural resource use problems in the Amazon.

- **Empirical approach.** Imazon emphasizes the importance systematic collection of primary data based on constant verification of the concrete conditions of natural resource use in the Amazon.

Professional capacity building. One of Imazon's objectives is to prepare researchers with analytical capacity and experience in the field, directed towards the understanding and solution of the Amazon region's environmental problems. The work involves preparation of a research project, data collection and analysis and presentation of the results in scientific articles and professional meetings.

Dissemination. Besides publishing in scientific journals, Imazon also disseminates its studies through more accessible media, such as manuals, videos, Série Amazônia, books, articles and special reports for mass circulation newspapers and magazines. Additionally, the Institute's researchers frequently participate as speakers in scientific and policy events in Brazil and internationally.

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