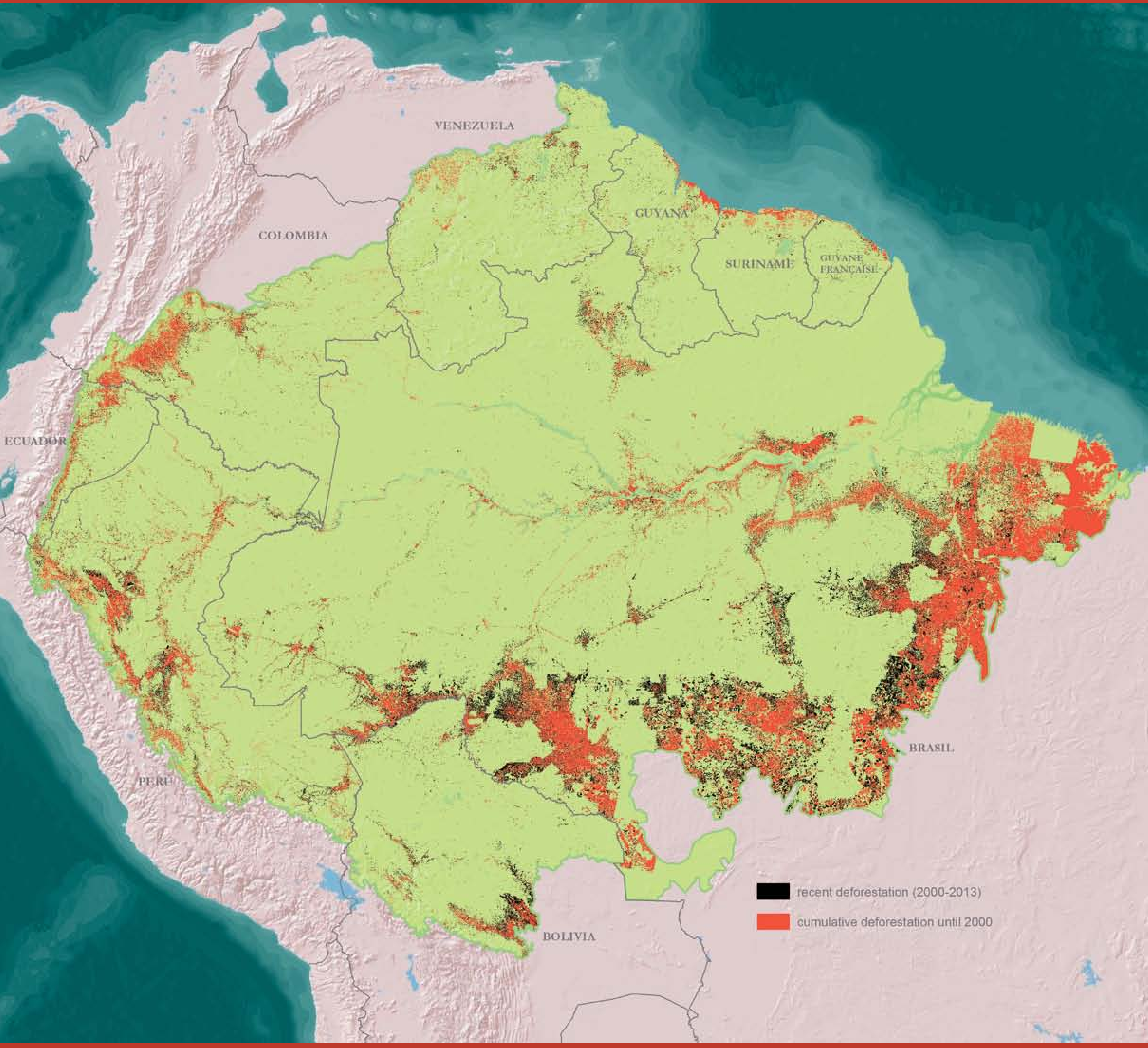
DEFORESTATION in the AMAZONIA (1970-2013)



RAISG AMAZONIAN NETWORK OF GEOREFERENCED SOCIO-ENVIRONMENTAL INFORMATION

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Suggested citation of the document: RAISG, 2015. Deforestation in the Amazonia (1970-2013). 48 pages. (www.raisg.socioambiental.org)

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RAISG Support:

** RAISG has chosen to maintain the names of the countries written in the original language in all versions of its publications.*

Dados Internacionais de Catalogação na Publicação (CIP)
(Câmara Brasileira do Livro, SP, Brasil)

Deforestation in the Amazonia (1970-2013) / RAISG Amazonian Network of Georeferenced Socio-Environmental Information. -- São Paulo : Instituto Socioambiental, 2015.

Vários colaboradores.
ISBN 978-85-8226-028-9

1. Áreas protegidas - Amazônia 2. Bacias hidrográficas - Amazônia 3. Desmatamento - Amazônia 4. Florestas - Amazônia 5. Monitoramento ambiental 6. Povos indígenas - Territórios I. RAISG Amazonian Network of Georeferenced Socio-Environmental Information.

15-07339 CDD-304.2809811

Índices para catálogo sistemático:
1. Região Amazônica : Florestas : Desmatamento : Monitoramento : Aspectos socioambientais 304.2809811

DEFORESTATION GREW BY 37% OVER 13 YEARS AND EXERTS GREAT PRESSURE ON THE HEADWATERS OF AMAZONIAN RIVERS

Deforestation in the Amazonia (1970-2013) is an unpublished study about forest loss in each of the countries comprising the Amazonia Region. It is estimated that throughout the historical occupation of the Amazonia, by 2000 up to 9.7% of the region was deforested; and between 2000 and 2013 it rose to 13.3%; representing a 37% increase in only 13 years.

The study reviews, through a regional lens, pre-colonial settlement patterns; and analyzes contemporary occupation movements in the Amazon, which began around 1930, at a time when State policies sought to modernize agriculture via settlements and deforestation. Then, based on satellite imagery analysis, it evidences the cumulative deforestation that took place up to and through the 2000s, which is a result of a number of factors entailing the first major changes in the Amazonia rainforest; changes that took place in the1970s. Finally, it evaluates changes in forests loss in three periods: 2000-2005, 2005-2010, and 2010-2013.

The study reveals that, apart from the rapid deforestation that characterizes the Brazilian Amazon, the pressures generated by economic exploitation in Andean countries are concentrated on the headwaters of several major watersheds, posing a major risk to the quality and quantity of forests and bodies of water. Many threats are common to all Amazonia countries, such as large scale agriculture, or the pressures caused by major infrastructure endeavors. Other pressures are country-specific, like the illicit growth of coca in areas of Perú and Colombia.

The Amazonian Network of Georeferenced Socio-Environmental Information (RAISG) is a collective of civil society organizations of Amazonian countries dedicated to the production of easily available information and analysis for decision makers and civil society in order to support the construction of a sustainable future and the strengthening of the socio-environmental diversity of the Amazonia Region.

In the second semester of 2008, RAISG established as a priority the elaboration of a deforestation analysis to estimate forest loss in the entire region as an indicator of the speed at which the landscape is being transformed, and as a key element in the monitoring process. Existing data was fragmentary, had partial coverage - even within each country -as it was generated following different conceptual and methodological focuses. Other characteristics of the heterogeneous origins of the data were the differences on geographic scales, time periods, and notation. The RAISG Protocol - a common analytical framework with standardized concepts and tool kit - was developed and introduced to address this issue. This standard incorporates a broad perspective for the entire Amazonia region, and other territorial analysis units.

There are two sections to **Deforestation in the Amazonia (1970-2013)**: the first summarizes the main deforestation drivers and processes up to the year 2000, and presents an estimate of current deforestation (2000 to 2013) for the entire region. The second section discusses recent and historic deforestation in each Amazonia country. In both sections the results for the 2000-2013 period are presented at Protected Natural Areas (PNAs), Indigenous Territories (ITs) and hydrographic basins, which are the unit of analysis used in previous RAISG studies.

DEFORESTATION in the AMAZONIA

> Despite the regional trend of decreasing deforestation, some countries display an accelerating loss increase in their Amazonia rainforests

The Amazonia contains the largest expanse of tropical rainforest in the planet, with an area of almost 6 million km², approximately 35% of the continent of South America. In carbon terms, and considering only woody vegetation, this represents close to 38% (86,121 MtC) of the 228,700 MtC found in the tropical areas of America, Africa, and Asia[1]. Additionally, the Amazon River drains an area of 6.2 million km² with an average annual discharge of 6,300 km³ of water into the Atlantic Ocean, equivalent to 15% to 20% of the global freshwater flowing into the oceans[2]. Moreover, it comprises a complex water cycle where rivers tend to flow from west to east, while the water returns to the Andes from east to west through an airborne transport system where cloud circulation is a key part. This process is known as "flying rivers", or "Amazon biotic bomb"[3].

These features attest for the region's importance in terms of global climate regulation and planetary resilience in light of the effects human-induced global warming and climate change have, even as new controversies have arisen regarding the role of the Amazonia rainforest in carbon fixation[4,5]. Moreover, the Amazonia is much more than water and carbon, as it is home to the largest biodiversity in the planet, housing between one third and half of all known life forms[6].

This highly complex natural space is inhabited by more than 33 million people, including 385 indigenous peoples, with an estimated population of 1,4 million people living in 2,244 indigenous territories in different stages of recognition by Amazonia countries. To this number one has to add indigenous peoples living in urban zones, as well as an unknown number living in voluntary isolation from modern society from 71 indigenous groups[7]. Besides indigenous peoples, there are thousands of traditional communities (*Caboclos*, Afro-descendants or farmers of different origins) who depend on the Amazonia's biodiversity for their livelihood.

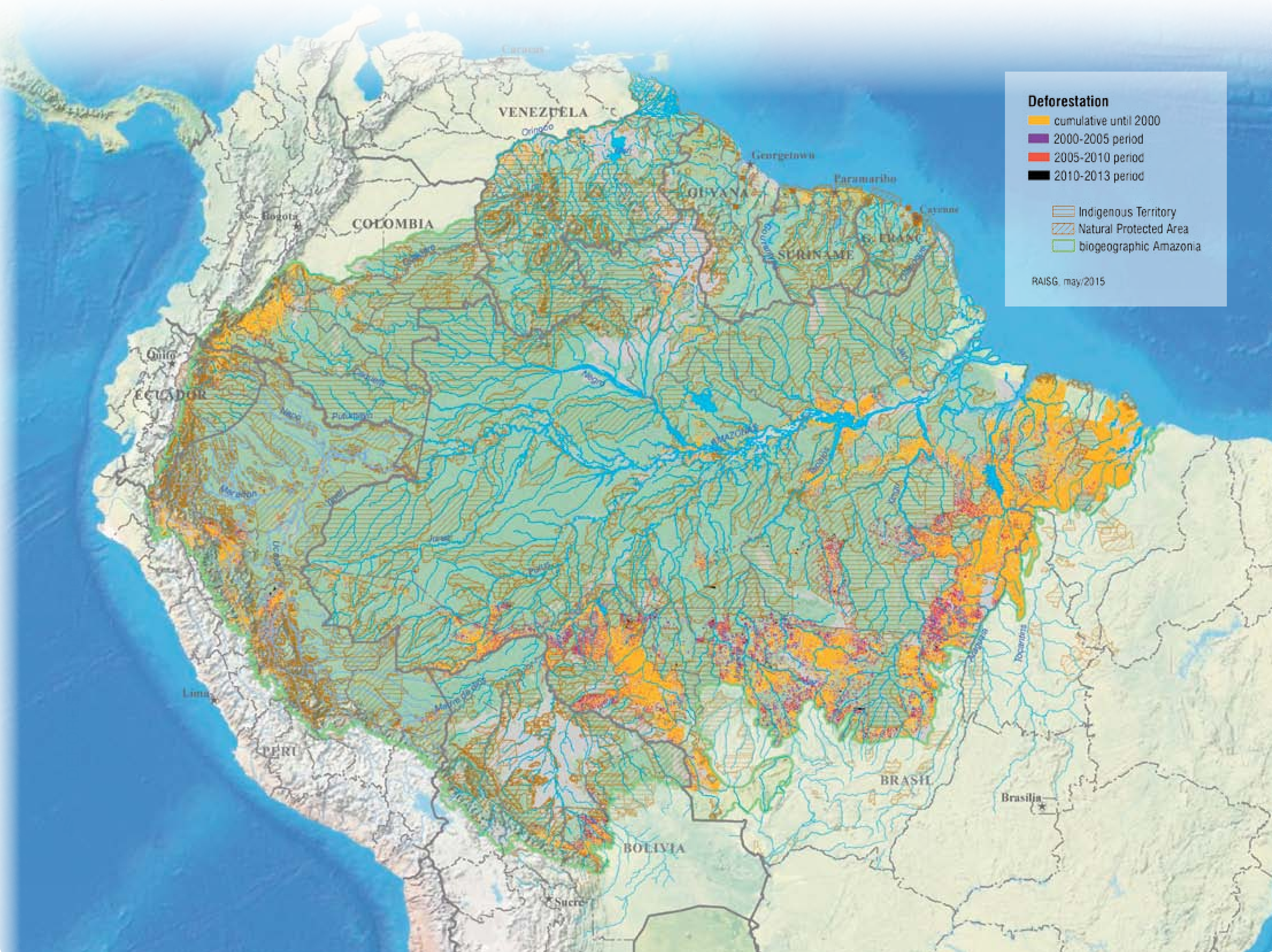
Nowadays, the expansion of the market and the expansion of colonization and deforestation frontiers are generating increasingly acute cultural and environmental impacts at a larger scale[8]. These dynamics have led to a reduction of biological diversity[9] and environmental[10] and cultural services[11] in the Amazon, while exerting pressure for the abandonment of traditional forms of territorial and land management.

In this sense, the loss of forest cover as a consequence of deforestation caused by large-scale agriculture, mining, infrastructure development and the lack of urban and territorial planning represents one of the greatest threats facing the Amazon[12]. The 2007 estimates indicate that in the Brazilian Amazonia alone, deforestation causes the emission of 200 to 300 million tons of carbon a year. When considering all Amazonian countries together, carbon emissions reach 400 to 500 million tons a year, even without taking into account forest fire emissions[13]. However, this process of transformation and forest cover loss in the region dates from the 1950s[14].

Historical context of deforestation

During the 1970s, conservation and indigenous rights spheres began to warn about the growing rate and global importance of deforestation in the Amazon[15]. But the history of this phenomenon dates back to earlier times and to a colonial expansion that altered indigenous forms of occupation and management of their territories. Little is known about pre-colonial settlement patterns, but relatively recent discoveries in archeology and ethnohistory point to an important competition between indigenous peoples to occupy the more productive riverbanks of the main rivers and valleys of the Andean foothills[16].

Map 1. Deforestation in the Amazonia



Denevan[17] has suggested that the várzea zones were occupied and managed through strategic hills that allowed large populations to control lands fertilized by annual floods. This is how the first Spanish and Portuguese explorers reported the sighting of highly populated indigenous villages at different points along the Amazon River. At the same time, there is evidence of occupation of fertile valleys in Andean headwaters, with settlements estimated between 200 and 300 inhabitants that lasted over two thousand years[18].

The groups that lost access to the more fertile lands – or were never able to win any – were relegated to interfluvial spaces, with lower-density occupation and a more itinerant character. These populations relied primarily on hunting and gathering, with very low scale agriculture for their sustenance.

A key aspect to this approach of different pre-colonial settlement patterns was the domestication of cultivated plants, such as squash and tubers, which were crucial to sustain large settlements, a process started more than 8,000 years ago[19]. For several reasons, these pre-colonial settlement patterns had low and reversible impacts. The few traces left from those times include the *terra preta* (black soil) created through human intervention[20], diverse engineering works[21], and urban and agricultural areas[22, 23].

During colonial times, mining activity derived from the search for El Dorado by the Spanish in the Andean-Amazonia foothills and in the "Zona Tórrida" by the Portuguese had a strong impact[24]. During the 16th century, European colonists began to enter into Amazonia lands, especially the Portuguese, who trespassed the limits set by the Tordesillas Treaty between Spain and Portugal (1493), reaching into the foothills of the Andes mountain range and the Río de la Plata basin. Until the mid-19th century a few forest areas around colonial cities (such as Belém in Brasil, or Moyobamba in Perú) or Jesuit and Franciscan missions were converted into pastures and sugar, rice, and cacao fields, with limited impacts.

With the birth of today's Republics began the extractive period. Various non-timber Amazonian resources caught the attention of the northern countries, producing several cycles of boom and bust. The rubber (known also as *siringa* or *shiringa*) boom in particular had the greatest impact[25], expanding the exploitation of the indigenous workforce for the extraction of a natural resource. The rapid growth of the automobile industry in Europe and the USA led to the exploitation of rubber in the southeast Amazon, inducing migration to these forests and the formation of new settlements like the prosperous city of Manaus (Brasil). This boom provoked the deforestation of relatively small areas, and allowed the formation of many of the major Amazonia cities that still exist to this day. (Ex. Iquitos in Perú, Tena in Ecuador, and Leticia in Colombia), generally linked to river ports.

The need to supply these centers brought about cattle ranching, which had a low impact on deforestation. Additionally, the *várzea* region of the lower Amazonia saw the semi-industrial production of cacao[26]. In 1913, the influx of British rubber plantations in Asia provoked the end of the first rubber boom in the Amazon. Other resources exploited in this period include the cinchona tree in the foothills and upper jungle, and Brasil nut in the southwest Amazon, still economically important to date[27].

Rubber was the precedent for the modern Amazonia *fazenda* or *hacienda*, and initiated the replacement of Amazonia forests with the establishment of agricultural estates in the so-called "vacant lands" in areas that were hard to access, but considered to have great potential. Around 1930, the Amazon's contemporary occupation period began[28]. Most of the deforestation in this period took place in the Brazilian Amazon, where forest replacement by cattle ranching and (unproductive) estates was used, in ideological and political terms, by the military government in 1964 to justify, in the context of inflationary economies, a land-based accumulation pattern aligned with two formulas, since then consolidated as Pan-Amazonian policies: "land without men for men without land" (colonization) and " integrate so as to not relinquish" (borders with sovereignty)[29].

Just as it happens in other countries, the construction of highways in Brasil was and continues to be one of the main factors in the loss and fragmentation of forests and other Amazonian ecosystems: the route between Brasilia (DF) and Belem (PA) constructed in the 1960s; the Trans-Amazonia highway in the 1970s; the construction of the Cuiaba highway (MT) to Porto Velho (RO) in the Northeast Pole Project; the North Perimeter highway; the highway connecting Boa Vista to Manaus, and more recently, the Cuiaba-Santarem highway[30]. The same has happened with the Carretera Marginal Highway in the Peruvian rainforest, which was started in 1964. The construction of roads intensified colonization and to this day takes place without consideration of indigenous peoples' displacement from their traditional areas of occupation. Often considered an "obstacle" to the expansion of the agricultural frontier, it is only in recent times that indigenous peoples are being taken into account, especially after gaining some official recognition and control over their current lands and territories.

Starting in the mid-20th century, many factors galvanized national governments to occupy the contemporary Amazon. One can mention in first place, allegations of national security, and second, the boost agrarian reforms – long demanded by peasants and farmers - provided to the consolidation of national "sovereignty" by occupying "vacant" spaces. Many countries implemented plans for the agricultural development of Amazonian lands, often with international funding. Amongst them are Brasil (Plan for the Valorization of the Amazon)[31], Perú (Creation of the Office of Eastern Issues, Colonization and Eastern Territories)[32], and Bolivia (Plan Bohan)[33]. Later, beginning in the seventies, came the creation of institutions in charge of the agrarian reform, which often required clearing or deforesting of the land, as proof it was "being worked"as a pre-condition to land titling.

This interest in the integration of lands in the Amazon River basin came later in Ecuador, Colombia, Venezuela, and the Guianas due to their low accessibility, prioritizing instead timber exploitation of their forests along their Pacific and Caribbean coasts. The seventies saw a second wave of governmental efforts to integrate the through directed and/or massive colonization efforts. Unlike previous programs, these led to the construction of large infrastructure works of pan-importance, such as the trans-highway that connects Brasil with the Andean countries[34], or all the oil access roads and cities derived from hydrocarbon exploitation in Ecuador[35]. The granting of lands to "settlers" didn't just increase deforestation but also fostered the displacement of indigenous peoples and the loss of their traditional occupation spaces in favor of landless farmers in the Andean countries and the northeast of Brasil, a region facing frequent droughts back then.

As a result, several colonization zones were established and persist to these days, primarily in the Andean foothills (such as the Chapare zone in Bolivia, the Selva Central in Perú, and the department of Caquetá in Colombia). However, the majority of the 1970s programs failed, often due to the absence of support for settlers, who remained isolated in the middle of vast expanses of forest and unable to succeed in their agricultural endeavors. At the same time, the extensive cultivation of coca in the took hold in the Andean countries, leading to moderate deforestation and the opening of access to new areas. The deforestation that took place at the time constituted the central axis for what is today the agricultural frontier's expansion area. Probably its largest impact was related to the opening of roads that correspond to the axes of current deforestation.

By the mid-1980s, national economies began to open, leading to an agroindustrial period set in the context of a more globalized economy. Plans for Amazonian development no longer focused only on the replacement of food imports, but on export-oriented production as well. In this neoliberal period, the role of the National State was reduced in many countries through structural adjustment programs[36]. In Bolivia (Santa Cruz), mechanization of production to industrial levels began in earnest. In Brasil (Mato Grosso) soybean cultivation was introduced to poor soils in the southern borders of the Amazon[37]. In the central part of the Amazon, cattle ranching became the primary cause of deforestation. In this period the global demand for "forest risk commodities" grew, leading to rapid increase in deforestation rates in the region. Furthermore, the devaluation of the Brazilian Real encouraged the overexploitation of primary resources, with a strong increase of deforestation in the country around 2000[38].

Subsequently, a rise in the international prices of hydrocarbons and gold increased dramatically the impact of illegal mining not just on the forests, but on the soils and waters of the Amazon, particularly in the Andean countries (Colombia, Ecuador, and Perú). It also reinforced the occupation of southern Venezuela for the construction of hydroelectric plants, the laying out of transmission lines, and the exploitation of mineral resources, particularly iron and aluminum. In Brasil the construction of enormous hydroelectric dams and planning for cross-border interconnectivity began, particularly with Perú.

Possibly due to the steep increase of deforestation in previous years, but most of all due to the strengthening of the indigenous and ecologist movement, the 1990s saw the consolidation of a conservation and indigenous rights period. National protected areas systems were created and consolidated in several countries. Furthermore, the countries that had not done so yet (Ecuador and Bolivia) recognized large areas as indigenous peoples' territories, based on their traditional or current occupation of lands. As a whole, natural protected areas and indigenous territories concentrate much of the rainforest. According to new data analyzed by RAISG for this publication, in 2013 protected areas covered 21.8% of the region and indigenous territories 27.5%, with variation between countries ranging from 16% to 37% of coverage for protected areas, and from 22% to 67% for indigenous territories. In some cases, these figures include the spatial overlap between both types of protection units.

Historic and recent forest loss and deforestation rates

According to the assessment carried out by RAISG, the original forest cover of the was around 6.1 million km²: 41.2% for the Andean and Guyanese and 58.8% for Brasil (Table 1). By the year 2000, a total of 9.7% was lost, with Brasil having the biggest loss with 12.8%, followed by Ecuador with 9.6%, and finally Colombia and Perú with 7.4% and 7.0% respectively. Forest cover continued to decrease, and by 2013 13.3% of it was lost. Taking into account that 27.1% of the cumulative forest loss took place in only 13 years, the 2000-2013 period shows an acceleration in deforestation. Bolivia and Venezuela stand out as the countries that proportionally lost the most in the recent period, with 42.6% and 34.2% loss respectively. On the other hand, Brasil is the country with the largest relative proportion of forest loss by 2013 (17.6%), followed by Ecuador with 10.7%, and Colombia and Perú with more than 9%. Consequently, Brasil is the country with the highest loss in absolute terms (Figure 1), both in historical and recent deforestation.

Regionally, a decreasing trend in deforestation (Figures 1 and 2) was verified, clearly correlated in Brasil, Bolivia, and Ecuador. There are certain variations on this trend in some countries, with rebounds during intermediate periods, or indications of stabilization (Figure 2) (Colombia, Perú, Guyane Française, and Guyana). The only country with an opposing trend is Venezuela, which shows signs of acceleration of its forest loss rate. In other cases, (Guyane Française, Suriname, and Venezuela) should they maintain the rhythm seen in the 2010-2013 period will see an increase in deforestation.

According to the RAISG database, the total extension of Protected Natural Areas (PNAs) by December 2013 was 1,814,947 km², of which 1,472,051 km² were originally covered by forests39. By 2013 some 31,034 km² or 2.1% of these forests were lost (Table 2). These figures show that deforestation is higher outside of the PNAs. The largest expanse of destroyed forest corresponds – in absolute terms – to national direct use areas (10,958 km²), followed by indirect use national areas (10,869 km²). It is worth noting that in the 2005-2010 period, the total cumulative deforestation for department-level areas of direct use was 2.9%; and that the loss rate in areas of direct use was 2.5 times greater than in those of indirect use. In direct use areas, recent forest loss is equivalent to 56.3% of the cumulative total, and 40% in indirect use areas, while recent deforestation inside PNAs corresponds to 49.8% of the cumulative total. In general, deforestation tends to decrease in these areas.

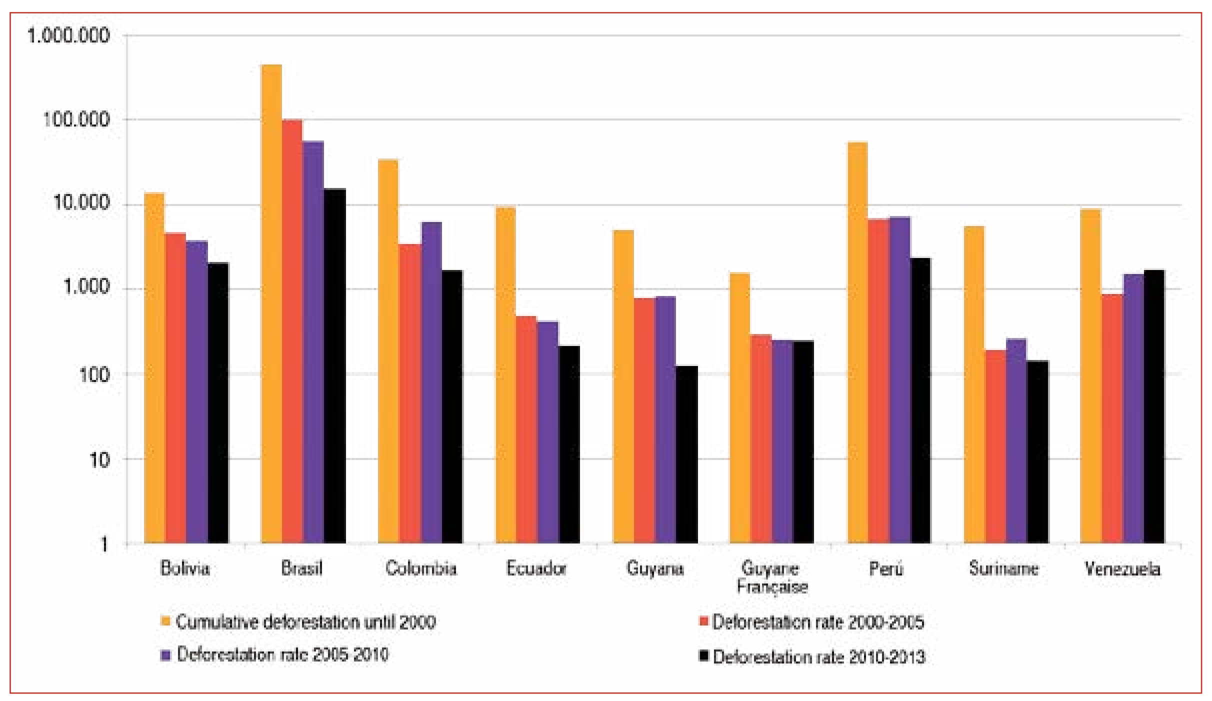
While this analysis did not take into consideration the date in which the areas were created, there is a glaring difference between the deforestation that takes place within PNAs of direct use, compared to those of indirect use. As is to be expected, the areas where human activities are relatively restricted seem to show a better capacity for forest conservation. However, in order to be certain about the effectiveness of PNAs, more detailed analysis is required.

In terms of Indigenous Territories (ITs), the RAISG database had registered 2,090,705 km² by 2013, including officially recognized territories, areas of traditional use without official recognition, territorial reserves, and proposed territorial reserves. Of these, 1,906,029 km² (91.0%) were originally covered

Table 1. Deforestation in Amazonia countries (km²)

	Surface of original forest cover	Cumulative deforestation until 2000	Deforestation rate			% of the original forest	
			2000-2005	2005-2010	2010-2013	2000-2013	Cumulative total
Country	km²	km²	km²	km²	km²	%	%
Bolivia	333,004	14,035	4,614	3,733	2,049	3.1	7.3
Brasil	3,587.052	458,500	101,138	57,399	15,395	4.8	17.6
Colombia	465,536	34,673	3,446	6,167	1,684	2.4	9.9
Ecuador	97,530	9,343	487	424	216	1.2	10.7
Guyana	192,405	3,097	785	821	125	0.9	2.5
Guyane Française	83,195	1,539	295	257	248	1.0	2.8
Perú	792,999	55,649	6,680	7,225	2,306	2.0	9.1
Suriname	150,254	5,664	194	263	144	0.4	4.2
Venezuela	397,812	8,914	890	1,521	1,742	1.0	3.3
total Amazonia	6,099.788	591,414	118,530	77,809	23,909	3.6	13.3

Figure 1. Historical and recent deforestation in the Amazonia (km²)

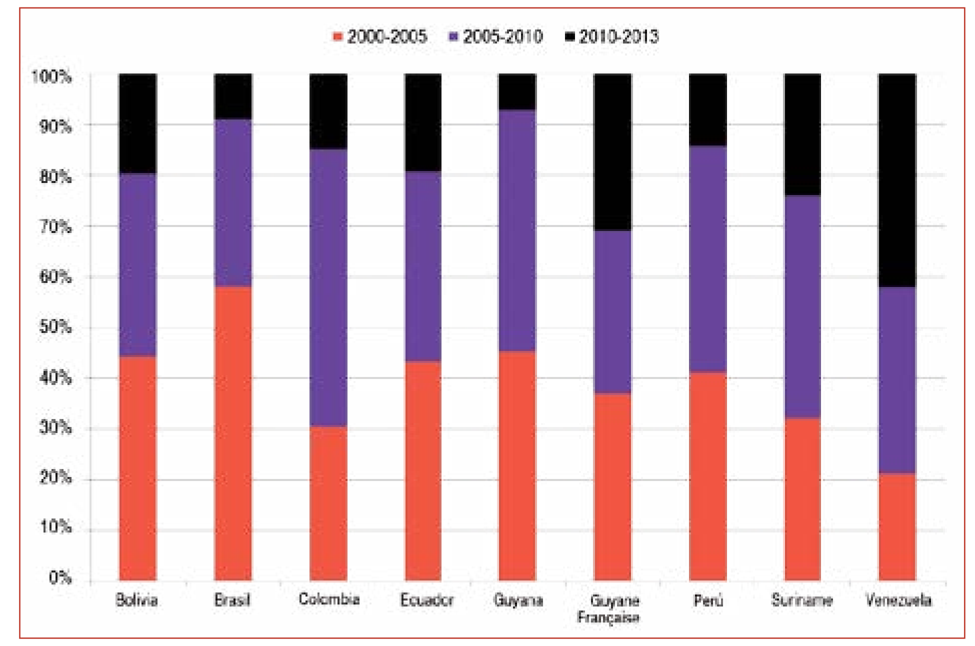


by forests. By 2013 there was a loss of 44,156 km² (2.3%) of original forest (Table 3). As is the case of PNAs, the relative loss of forests within ITs is lesser than in the rest of the region. This difference becomes more apparent when comparing ITs, PNAs, and exterior areas (Figure 3). In the period under study (2000-2013), 35.8% of the cumulative deforestation was registered in these areas.

There are interesting discoveries regarding PNAs. For example, the cumulative deforestation both in absolute and relative terms was higher in ITs than in PNAs. However, in the recent period forest loss in PNAs was 49.8%, compared to 35.8% in ITs. This means that the speed of forest loss was higher for ITs until the year 2000. Since, the speed of deforestation has increased faster in the PNAs. As a result, the area lost is, in absolute terms, practically the same for both: (15,466 km² in PNAs and 15,825 km² in ITs).

Forest loss is far greater outside PNAs and ITs than within, at 24.6% and 2.2%, respectively. The cumulative deforestation outside the PNAs and ITs represents 91.8% of the total for the (Figure 3). However, the relationship between deforestation inside and outside of PNAs and ITs changed between the historical and recent periods. Until 2000, the loss within PNAs and ITs did not exceed 7.5% of total deforestation, whereas it rose up to 14.2% in the 2000-2013 period. These changes could be the

Figure 2. Variations in the annual forest loss rate, by period analyzed



result of increased pressure on these unit types, or could derive from the existence of direct use units where changes in forest cover are expected. As previous mentioned, a more detailed analysis is required to account for the dynamics behind these variations, and even considering and taking into account the dates of creation of PNAs and the recognition of ITs.

The major deforestation frontiers where forests are being converted at a faster pace can be found in the southern – the states of Mato Grosso, Pará, Rondônia and Acre in Brasil, and the department of Santa Cruz in Bolivia – where the great expansion of agriculture has changed large areas of landscapes outside of the limits used in our analysis. By contrast, new deforestation frontiers in Colombia, Perú, and Ecuador have been opened within the biogeographic limits analyzed.

The 18 most deforested sub-basins (order 3) by 2000 and also by 2013, with more than 40% loss in the original forest, are in Brasil and correspond to those historically occupied: the states of Maranhão, north of Tocantins and east of Pará, along the Cuiabá-Porto Velho highway, and between Mato Grosso and Rondônia (Table 4, Maps 2 and 3). Of these, 12 had already reached a 40% loss by 2000 and continued being deforested afterwards (Map 1). Between 2000 and 2013, 17 sub-basins lost more than 10% of their forest cover to deforestation; almost all of them located along the agricultural frontier of the states of Mato Grosso (headwaters of the Xingu and Tapajós rivers), Pará, and Rondônia.

Other basins that stand out include the upper basins of the Caquetá, Guaviare and Putumayo rivers in the northwest arc of the Colombian Amazon; the basins of the Alto Marañón, Apurímac and Pachitea rivers in Perú, and the basins of the Mamoré, Beni and Itonomas rivers in Bolivia.

Recent causes of deforestation

The causes for deforestation associated with human activities vary within and between countries. The direct drivers of deforestation in the consist predominantly of large-scale industrial agriculture (mainly soybean) and extensive cattle ranching. Illicit crops and small-scale agriculture contribute to a lesser degree. Next, and predominantly in some countries, are mining and the secondary effects of hydrocarbon exploitation and infrastructure works[40, 41]. Climate change will exacerbate these threats, for despite any resilience the Amazonia may have, its interaction with rising temperatures, forest fires, and floods leads one to think of a system dominated by

Table 2. Deforestation in Amazonia PNA (km²)

	Surface of original forest cover[1]	Cumulative deforestation until 2000	Deforestation rate			% of the original forest	
			2000-2005	2005-2010	2010-2013	2000-2013	Cumulative total
	km²	km²	km²	km²	km²	%	%
Protected Natural Areas[2]	1,472.051	15,568	6,981	5,910	2,576	1.1	2.1
state/departamental-direct use	274,122	1,331	2,972	2,586	1,001	2.4	2.9
state/departamental-indirect use	104,857	576	281	85	80	0.4	1.0
national-direct use	381,110	6,905	1,721	1,626	706	1.1	2.9
national-indirect use	678,641	6,546	1,977	1,569	777	0.6	1.6
national-direct and indirect use	4,097	16	1	11	1	0.3	0.7
national-transitional use	29,223	193	29	34	10	0.3	0.9

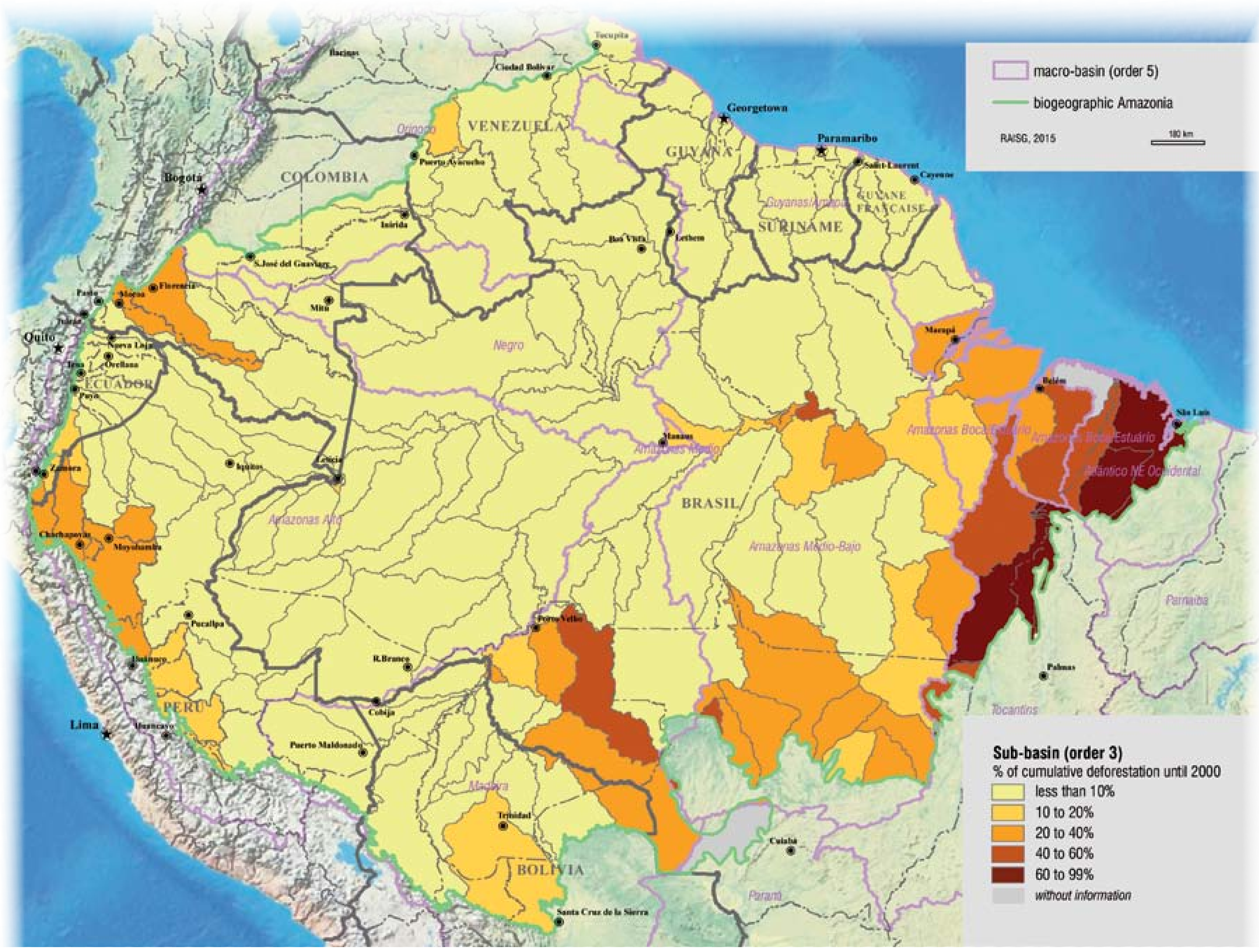
[1] Original forest cover refers to forest formations within the biogeographic limit of the Amazon, within which exist non-forested areas, like enclaves of savannas or fields. For the evaluation of deforestation only originally forested areas were considered.
[2] The situation of existing ITs and PNAs was considered in December 2013.

Table 3. Deforestation in Amazonia IT (km²)

	Surface of original forest cover[1]	Cumulative deforestation until 2000	Deforestation rate			% of the original forest	
			2000-2005	2005-2010	2010-2013	2000-2013	Cumulative total
	km²	km²	km²	km²	km²	%	%
Indigenous Territories[2]	1,906.029	28,331	6,413	6,505	2,907	0.8	2.3
IT not officially recognized	415,285	7,496	1,269	1,471	1,115	0.9	2.7
Proposed Territorial Reservation	39,656	334	21	37	15	0.2	1.0
Territorial Reservation	29,246	199	26	33	5	0.2	0.9
IT officialy recognized	1,421.841	20,303	5,096	4,963	1,772	0.8	2.3

[1] Original forest cover refers to forest formations within the biogeographic limit of the Amazon, within which exist non-forested areas, like enclaves of savannas or fields. For the evaluation of deforestation only originally forested areas were considered.
[2] The situation of existing ITs and PNAs was considered in December 2013.

Map 2. Sub-basins with the greatest proportional deforestation until 2000



Map 3. Sub-basins with the greatest proportional deforestation until 2013

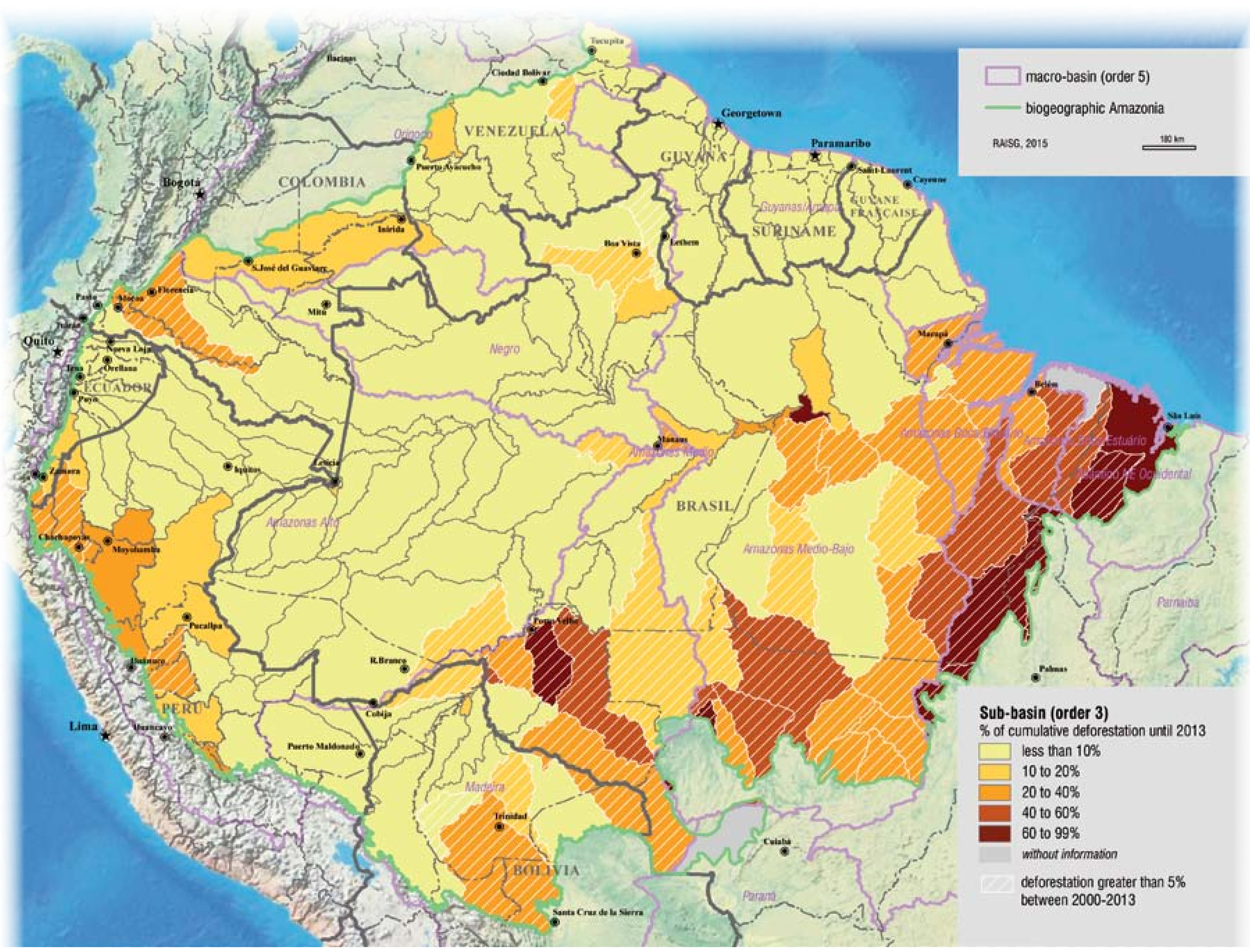
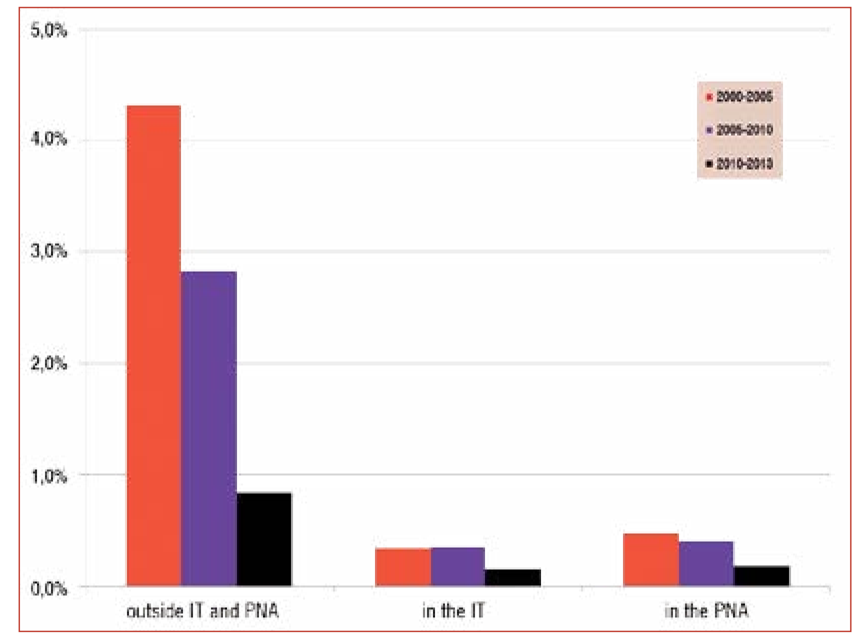


Figure 3.Recent deforestation in the PNA and IT of the Amazonia



disturbances of great magnitude, particularly in the South and East regions[42].

In the recent period (2000-2013), cattle ranching-induced deforestation is the most direct, high impact deforestation cause at a Pan-Amazonia level. There are no exact figures for the majority of countries, but it is known that in Brasil and Bolivia it is responsible for more than half of its deforestation[43, 44]. Considering the biogeographic limit used in this document, cattle ranching's contribution to deforestation probably reaches around 80% given that large part of the soy cultivating zone is in forest transition zones and savannas (Santa Cruz and southern Mato Grosso). Nevertheless, the "push" phenomenon of the cattle ranching frontier towards the interior of the Amazonia observed in Brasil[45] constitutes an indirect impact of agriculture.

Industrialized agriculture, primarily soy's, also has a strong impact in the states of Pará and Mato Grosso on the Amazonia in Brasil[45]. In the meantime, in Perú, Colombia and northeast Ecuador, the cultivation of African oil palm with mechanized methods also started causing deforestation[46, 47]. The production of these commodities (agriculture/cattle ranching) in the Amazonia responds to international demand[48, 49, 50].

Small-scale agriculture causes deforestation in the vicinity of the Andes mountain range and in many parts of the Amazonia interior in Brasil, though much less than industrial agriculture in terms of extension and contribution. Additionally, the Andean-Amazonia countries there is deforestation associated to coca cultivation, whose extension corresponds to the small size of cultivated plots[51], and a variable area in each country: Bolivia, 23,000 ha; Perú, 49,800 ha; and Colombia, 48,189 ha in 2013[52].

Mining in Colombia, the Guianas[53, 54, 55] and Venezuela, as well as hydrocarbon exploitation[56] in Ecuador are important sources of deforestation, mainly through the facilitated access provided by the construction of the roads required for these productive activities. It is foreseeable that deforestation related to these activities will increase in the next years.

The flooding associated with hydroelectric plants is also a direct cause in the destruction of forests, particularly in certain regions like the southeast-northeast axis of the Brazilian Amazon. It is estimated that the construction of all planned hydroelectric plants in the region would flood around 100,000 km², approximately 3% of Brasil's Amazonia rainforest, creating greater disruptions in the forest than the dams themselves[57].

Timber exploitation in the Amazonia is usually done in a selective manner, and as such is not considered a direct cause of deforestation. However, it

Table 4. Cumulative deforestation in the Amazonia by sub-basins (basins with more than 20% cumulative deforestation)

Sub-basins (order 3)	Surface of original forest cover	Cumulative deforestation until 2000	Deforestation by period			% % of the original forest	
			2000-2005	2005-2010	2010-2013	2000-2013	Cumulative total
	km²	km²	km²	km²	km²	%	%
Tocantins (MB2)	5,649	5,162	263	141	25	7.6	99.0
das Mortes	570	436	47	23	1	12.5	89.1
Araguaia (B)	60,583	44,484	5,692	3,119	193	14.9	88.3
Atlântico NE O S	47,364	36,565	285	613	181	2.3	79.5
Pindaré	31,268	21,776	1,087	1,605	258	9.4	79.1
Araguaia (MB)	9,834	5,704	1,205	421	87	17.4	75.4
Am. MB4	3,138	1,766	67	73	16	5.0	61.3
Candeias do Jamari	26,589	10,615	3,638	1,723	264	21.2	61.1
Juruena	3,726	2,020	173	43	15	6.2	60.4
Tocantins (B)	71,553	35,409	3,597	2,661	366	9.3	58.7
Guama	45,415	22,473	1,625	1,623	414	8.1	57.5
Ji-Paraná ou Machado	67,541	30,263	5,355	2,354	691	12.4	57.2
Gurupi	29,277	14,398	684	884	148	5.9	55,0
Juruena (M)	5,088	1,872	483	190	51	14.2	51.0
Fresco	36,901	10,899	3,078	3,139	122	17.2	46.7
Arinos	35,618	10,157	4,817	986	460	17.6	46.1
Madeira MB1	3,564	829	477	150	23	18.3	41.5
Teles Pires (S.Manuel)	98,455	29,184	8,269	2,401	570	11.4	41.1
Xingú (MA)	22,031	5,929	2,289	447	59	12.7	39.6
Do Sangue	16,441	4,025	1,700	437	99	13.6	38.1
Madeira MB2	22,613	3,025	3,058	1,808	451	23.5	36.9
Manissaua-Missu	25,989	5,418	3.127	802	216	16.0	36.8
Ronuro	17,309	3,021	2,133	755	395	19.0	36.4
Xingú	14,605	3,123	1,260	319	32	11.0	32.4
Am. MB3	2,295	671	34	30	8	3.1	32.3
Marañón	36,957	7,999	1,442	1,774	662	10.5	32.1
Guaporé	76,207	19,196	3,503	1,237	245	6.5	31.7
Curuá-Una	29,490	6,116	1,519	1,048	339	9.9	30.6
Caquetá	68,156	16,460	916	2,665	440	5.9	30,1
Am. Estuário	61,746	14,230	1,256	1,654	571	5.6	28.7
Xingú (M)	68,956	11,159	4,467	3,095	716	12.0	28.2
Am. Medio	4,487	794	209	64	11	6.3	24.0
Huallaga	76,21	17,191	188	322	108	0.8	23.3
Apurímac	4,882	956	61	72	26	3.3	22.8
Pachitea	26,869	3,892	1,032	794	385	8.2	22.7
Tapajós (B)	38,577	6,071	1,233	679	251	5.6	21.3
Xingú (B)	61,726	8,310	1,813	2,252	715	7.7	21.2
Am. MB2	1,269	237	17	11	2	2.4	21.1
Pacaja	50,675	6,252	2,050	1,946	349	8.6	20.9
Mamoré	74,955	9,942	3,040	1,809	845	7.6	20.9

causes forest degradation, increases the risk of forest fires, and facilitates access for agricultural use through the construction of roads[58, 59].

At an underlying level, deforestation is also due to multiple factors acting synergistically. Economic factors such as low internal costs (for land, labor, fuel or timber) and the increase in the price of products (especially cash crops or timber) stand out[60]. Institutional factors include formal measures that favor deforestation, land use policies and economic development programs associated with colonization, transport, and subsidies for land-based activities. Existing land tenure systems and failed policies (like the corruption or mismanagement of the forestry sector) are also important drivers of forest loss[61].

Cultural and sociopolitical factors have also been reported as underlying causes for deforestation, primarily in the form of the public's indifference towards forest environments. Amongst demographic factors, the migration of settlers to scarcely populated forests areas, and the consequent increase in population density, show a significant influence on deforestation. It is worth noting that contrary to popular belief, the increase of population due to high reproduction rates is not a main factor in deforestation at a local scale[62].

Future forest loss scenarios

Many studies suggest that forest loss will continue to occur in the entire Amazonia region, with very similar projections. Soares Filho and collaborators predict a loss of 23% of forest cover in 30 years, and 37% loss after 50 years[63]. A more recent study carried out by the same authors predicts a 55% loss in the next 20 years[64]. It is estimated that losses in Brasil will concentrate mainly around the so-called "Deforestation Arc" located in the states of Mato Grosso, Rondônia, Amazonas and Pará[65]. Deforestation models for Mato Grosso, even under the government's deforestation-reduction policies, suggest that more than 6 million hectares will be lost between 2006 and 2020[66]; while changes in land-use as a result of biofuels could cause the loss of more than 12 million hectares of forest by 2020[67]; with increased losses due to the expansion of projected oil palm cultivation in Perú. General estimates based on published predictions range between 107 and 369 million hectares by 2030[68,69].

According to Soares Filho, current agricultural expansion tendencies will translate into a loss of 40% of Amazonia rainforests by 2050, including at least two thirds of the forest cover of six large hydrographic basins and 12 eco-regions, with the release of 32 ± 8Pg of carbon into the atmosphere.

Additionally, consideration must be taken of the known drivers known of future pressure, including the expansion of the agricultural frontier and increase in the demand for African palm oil in Perú, Colombia, and Ecuador[70]. The construction of large hydroelectric plants is by itself a factor of considerable impact[71]. Construction and improvement of road infrastructure, such as the framework of the IIRSA program, will facilitate the access and especially the transport of agricultural products to markets, rendering production and deforestation more profitable.

Mining and hydrocarbon exploitation could have a major impact as direct sources of deforestation in the future, particularly in the Andes-Amazonia countries and the Guianas. In the case of mining, the exploitation of gold in particular could have a significant impact on Amazonia forests since a relationship between international demand for gold and deforestation of areas under exploitation in the Amazonia region has been reported[72]. The link between hydrocarbon exploitation and deforestation is well known, and indicates that an increase in hydrocarbon exploitation would similarly increase deforestation, particularly in countries like Ecuador and Bolivia.

Finally, a less predictable factor is the impact of climate change on the Amazonia rainforests' vulnerability to droughts and forest fires[73], which could boost deforestation impacts and result in the loss of the socio-environmental services the rainforests provide. The combined effects of land use change, climate change, and fire were the research subject of an earth's area model. The results show that the impacts of climate change, including higher temperatures and a longer dry season, are amplified when one includes land use changes and forest fires. Models that paired climate and vegetation show that when deforestation is low, a generalized savanization caused entirely by climate change by 2100 is unlikely. However, we cannot rule out a fast decline as there still is much uncertainty about the Amazonia rainforests' sensibility to climate and land use change, particularly in relation to the fertilization effect, the forest fires dynamics, droughts and socio-economic development. The work done by AMAZALERT indicates that the south and east regions of the Amazonia basin are more vulnerable to changes than the north and northeast[74].

This dynamic process in the expansion of the agricultural frontier, mining and hydrocarbon exploitation associated deforestation, and climate change reveals once more the necessity for reliable and solid information about Amazonia forest loss.

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DEFORESTATION in the BOLIVIAN AMAZONIA

Of the three main deforestation threats, cattle ranching is the most important in recent years

The Bolivian Amazonia covers around 489,000 km², or of 43.7% of the country's area. It consists of a mosaic of extensive tropical rainforests, flood savannas, transitional semi-humid forests towards the Cerrado and the Chaco, and tropical sub-Andean forests. Close to 7.3% of this area (~244,000 km²) was lost in the last 43 years (1970-2013) at an average annual rate of approximately 568 km²/year. Between 1970 and 2000 (historic deforestation) about 14,000 km² of forests were lost, while between 2000 and 2013 (recent deforestation) forests loss reached around 104,000 km² (Table 1).

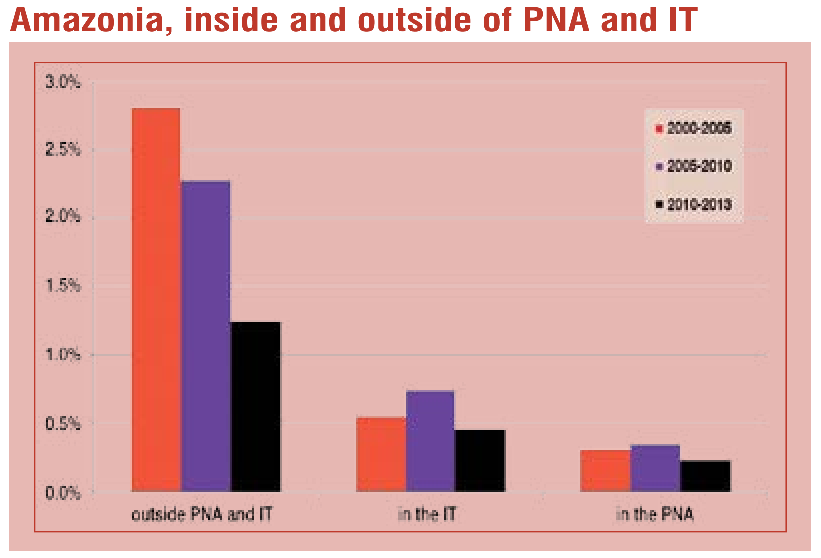
Historical and recent forest loss and deforestation rates

By 2013, protected natural areas (PNAs) covered close to 29.3% of the Bolivian Amazonia (~141,000 km²), of which some 2,000 km² were lost (8% of the loss that occurred between 1970 and 2013 in the Bolivian Amazonia). Between 1970 and 2000, close to 1,000 km² of forests were lost, with an additional thousand lost between 2000 and 2013 (9.3% of the loss happened in this period).

Similarly, by 2013 indigenous territories (IT) covered close to 27% of the Bolivian Amazonia (~1 29,700 km²), where close to 2,500 km² of forests were lost (10.1% of the loss that occurred between 1970 and 2013 in the Bolivian Amazonia). Approximately 800 km² were lost between 1970 and 2000, while close to 1,7000 km² were lost between 2000 and 2013 (16.1% of the loss occurred in this period).

Hydrologically, the Bolivian Amazonia encompasses 17 hydrological basins. The Mamoré and Beni rivers basins exceed 100,000 km² in area, and are also the basins that in 43 years (1970-2013) have suffered the highest forest loss through deforestation (Mamoré: ~156,000 km² of forest, 14% of the basin's area; Beni: ~29,000 km², 2.7% of the basin's area). Between 1970 and 2000, the Mamoré River basin suffered the highest deforestation (~10,000 km², 71% of the deforestation that happened in that period), followed by the Beni River basin (18,000 km², 12.9%) and the Itonomas River basin (400 km², 2.9%). This trend continued in the 2000-2013 period (Mamoré: 57,000 km², 54.8% of the deforestation that took place in that period; Beni: 11,000 km², 10.2%; Itonomas: more than 1,000 km² of deforestation, 9.8%) (Table 2, Map 2).

Figure 1. Recent deforestation in the Bolivian Amazonia, inside and outside of PNA and IT



Map 1. Deforestation in the Bolivian Amazonia

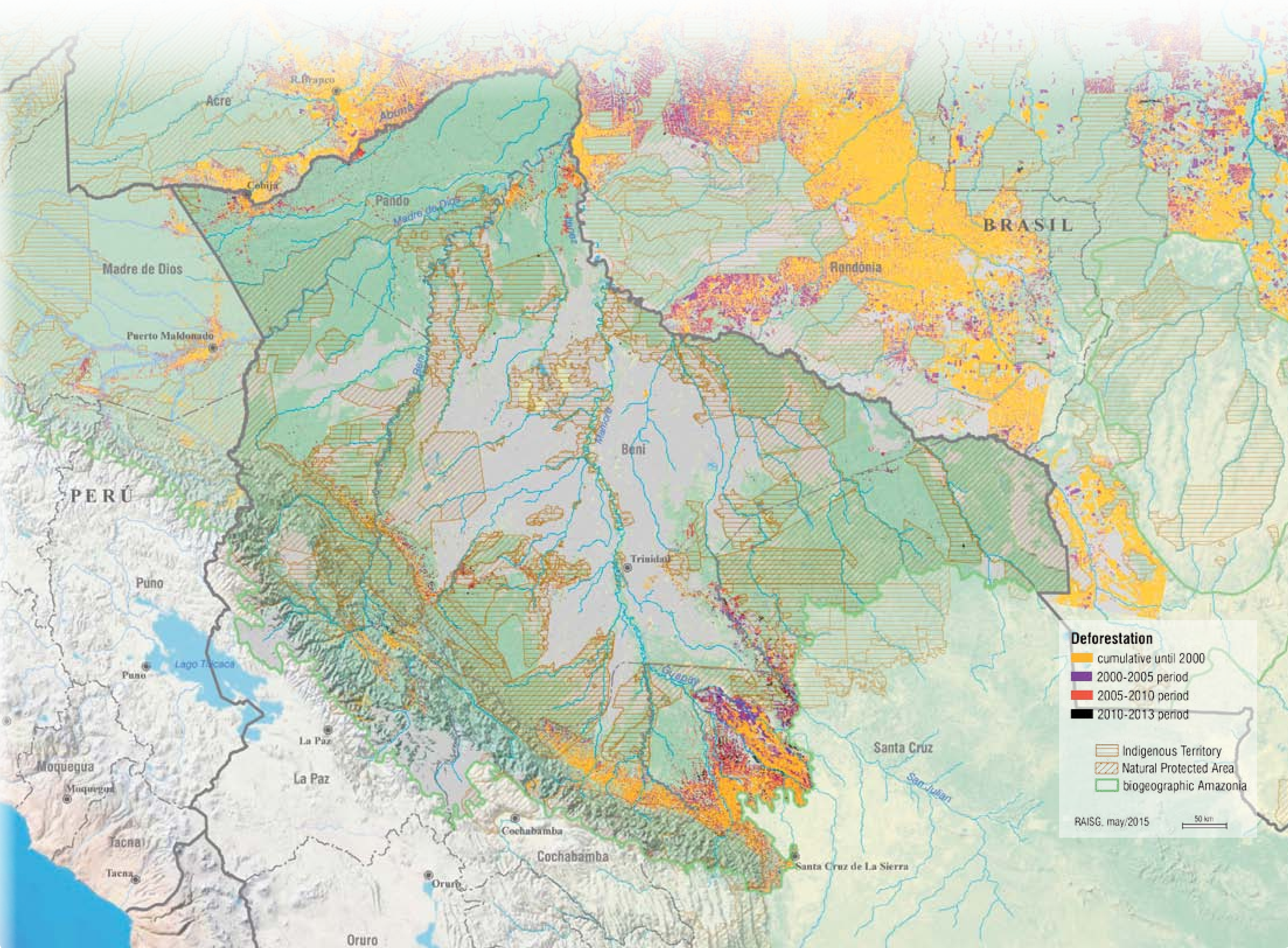


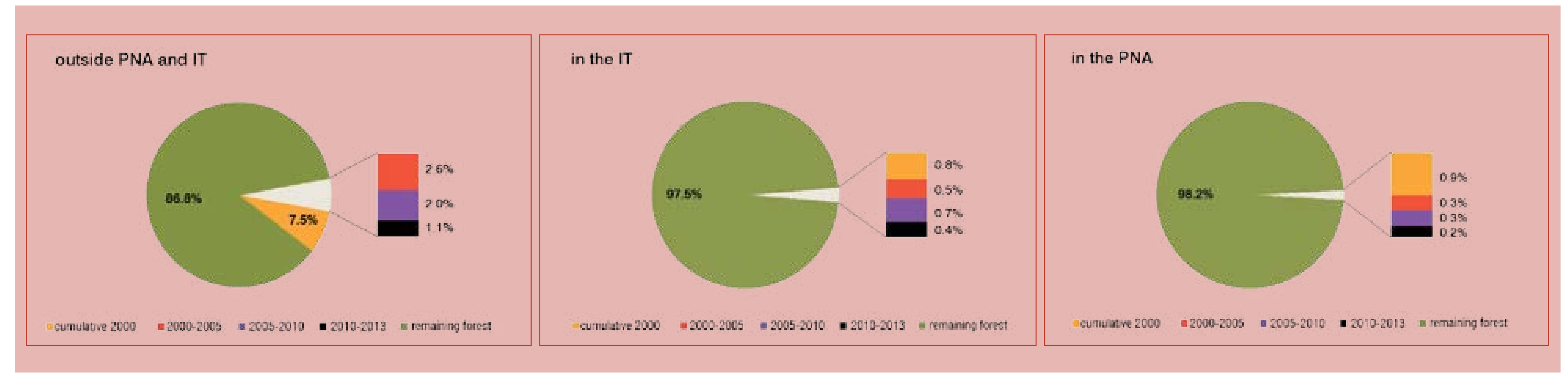
Table 1. Deforestation in the Bolivian Amazonia

	Surface of original forest cover[1]	Cumulative deforestation until 2000	Deforestation rate			% of the original forest	
			2000-2005	2005-2010	2010-2013	2000-2013	Cumulative total
	km²	km²	km²	km²	km²	%	%
Bolivian Amazonia	333,004	14,035	4,614	3,733	2,049	3.1%	7.3%
outside PNA and IT	164,498	12,346	4,272	3,359	1,798	5.7%	13.2%
Indigenous Territories[2]	97,096	797	530	708	435	1.7%	2.5%
IT not officially recognized	24,181	515	420	420	213	4.4%	6.5%
IT officialy recognized	72,915	283	110	287	222	0.8%	1.2%
Protected Natural Areas[2]	110,289	978	342	374	251	0.9%	1.8%
state/departamental-direct use	45,049	151	105	165	108	0.8%	1.2%
national-direct use	31,018	587	160	130	112	1.3%	3.2%
national-direct and indirect use	363	12	0	0	1	0.3%	3.7%
national-indirect use	33,858	228	76	79	30	0.5%	1.2%

[1] Original forest cover refers to forest formations within the biogeographic limit of the Amazon, within which exist non-forested areas, like enclaves of savannas or fields. For the evaluation of deforestation only originally forested areas were considered.

[2] The situation of existing ITs and PNAs was considered in December 2013.

Figure 2. Distribution of deforestation in the Bolivian Amazonia



Historical context of deforestation

Deforestation in Bolivia was slight until the mid-1980s, mainly caused by a policy of lowlands occupation through colonization and the allocation of lands for the expansion of industrial agriculture in the vicinity of the city of Santa Cruz, in the southern limit of the Amazonia[1], and the increase in coca cultivation in the Chapare zone (department of Cochabamba) and North Yungas (department of La Paz). With the allocation of lands to small-scale agriculture in the Upper Beni, Chapare and Santa Cruz, the State promoted migration to the lowlands[2]. Other important factors in the colonization and subsequent deforestation of these areas were settlements of foreign nationals, primarily Japanese[3].

Between the 1970s and mid-1980s, state policies focused on food production for national consumption[4], but beginning in 1985, private investments in industrial agriculture was encouraged, opening the economy to international markets and giving space for the rapid growth of production and exportation of soy[5]. In the 1990s, agriculture was stimulated via credits, infrastructure, increased access to lands, and technical support, thus generating the expansion of soy cultivation towards the east of the city of Santa Cruz. In the last ten years, the soy cultivation area increased from 600,000 hectares to around 1 million hectares.

The 1990s saw the renovation of the forestry law in the search of a more organized, efficient and sustainable use of forests[6]. Additionally, important sections of forests were declared protected areas. However, the impact of these measures on deforestation was low because they focused on areas removed from the agricultural frontier. In 1996, the National Institute of Agrarian Reform (INRA) was created, initiating a process of land titling and recognition of indigenous territories, currently known as *Territorios Indígenas Originarios Campesinos* (TIOC). The recognition of TIOCs had low impact on deforestation due to their distance from the agricultural frontier. However, the regulation of forests clearance in areas within the agricultural frontier was ineffective due to the lack of coordination between the state agencies charged with control and oversight. One perverse incentive for deforestation was the need to prove the "social and economic function" (FES) of lands, which established that if the land was not used agriculturally, it was either reduced in size or its ownership rights were revoked. Thus, deforestation took place in order to justify the need of land ownership. In conclusion, the policies of the nineties entailed increased deforestation[7], especially in the southern boundaries of the Amazonia.

Direct and indirect causes of recent deforestation

Three main causes of deforestation stand out in the 2000-2013 period: industrial agriculture, small-scale agriculture, and cattle ranching[8].

Industrial agriculture encompasses the export-oriented production of soy, sugar cane, rice, and sunflower or sorghum[9] conducted by Bolivian and foreign companies and Mennonite and Japanese colonies. The low production costs and scarce regulation attracted important Brazilian and Argentinian investments. Industrialized agriculture concentrates in the east and northeast of the city of Santa Cruz, having expanded towards the northern portion of this department starting in the year 2000. However, the contribution of industrial agriculture to deforestation decreased, from more than 50% in the 1990s to 30% presently[8, 10].

Small-scale agriculture comprises the manual production of rice, corn, yucca, banana, cacao, coffee and coca[11] in small land areas and with a slash-and-burn method. It is mainly oriented towards local and national markets and self-subsistence, carried out by the national intercultural communities settled in the northeastern slopes of the Andes mountain range (north of the department of Cochabamba) and west of the department of Santa Cruz. Small-scale agriculture's contribution to deforestation remained relatively stable, between 15% and 20% from 1990 to 2010[8,12].

Cattle ranching takes place mainly in the lowlands, primarily in the natural grasslands of the Beni region, although cultivated pastures have expanded, mainly through illegal clearing[13]. Here, land use is inefficient: 0.5 animals per hectare of planted pastures in the department of Pando[14]. Cattle ranching production mainly supplies the national market, and to a lesser degree international markets, primarily Perú. Expectations of export markets are mounting following the declaration of large production areas as being free from foot-and-mouth disease, which in the past restrained international trade. Since 2000, cattle ranching is the main cause of deforestation in

Table 2. Cumulative deforestation in the Bolivian Amazon by sub-basins (basins larger than 500 km²)

Sub-basins (order 3)	Surface of original forest cover	Cumulative deforestation until 2000	Deforestation by period			% of the original forest	
			2000-2005	2005-2010	2010-2013	2000-2013	Cumulative total
	km²	km²	km²	km²	km²	%	%
Abunã	22,925	121	166	170	59	1.7	2.3
Baures	39,494	177	63	98	110	0.7	1.1
Beni	78,434	1.813	297	406	362	1.4	3.7
Beni (B)	3,306	227	54	47	46	4.4	11.3
Beni (M)	221	37	3	4	3	4.7	21.5
Guaporé	26,400	13	12	30	43	0.3	0.4
Guaporé (B)	1,653	5	0	1	5	0.4	0.7
Itonomas	11,287	400	398	453	169	9.0	12.6
Madeira MB1	960	4	7	6	3	1.7	2.1
Madre de Dios	27,103	88	27	88	46	0.6	0.9
Mamoré	74,955	9,942	3,040	1,809	845	7.6	20.9
Mamoré (B)	12,314	339	132	215	111	3.7	6.5
Mamoré (M)	5,308	12	5	8	26	0.7	1.0
Purús	1,917	206	100	55	15	8.8	19.6
Tahuamanú	17,798	316	181	140	62	2.2	3.9
Yacuma	8,926	334	129	203	144	5.3	9.1

Bolivia. It is estimated that between 2005 and 2010 it was responsible for 60% of forest clearings.

The impacts of timber extraction and mining on deforestation are relatively low and little studied. An important threat is the imminent flooding of large areas of forest as a result of the construction of hydroelectric dams in the Madera River and its tributaries.

There are many and complex underlying causes to deforestation in Bolivia. Chief amongst the important factors for the advancement of the agricultural frontier are the international demand for soy; the presence of Brazilian and Argentine capital in agricultural production, attracted by low land prices and the sector's scarce regulation[15]. International demand for beef is another important vector for deforestation, as are high export markets expectations (in 2013, more than 2,000 tons of beef were exported, the largest quantity in the last 30 years). Other factors to be considered are the expansion and improvement of road infrastructure, the migration to the lowlands, and population growth in colonization areas.

From 2006 onwards, the government has modified public policies related to deforestation. However, their rather modest impact can be attributed to institutional weakness[16] and the government's own contradictory goals, and what it wants to achieve in terms of conservation of the natural patrimony and national development where agriculture has a central role yet it is not as important as hydrocarbons. In Bolivia, the environmental clashes with the agrarian[17]: despite its large expanse of Amazonia forests and other biomes, the country has an agricultural vocation, and as such the value of forest-covered lands is not perceived if it does not also have an agricultural use. Environmental policies are sector-oriented and centered on forestry and conservation, and are not integrated with public policies on land use.This is reflected at regulatory levels, which apparently result in a highly regulated forestry sector and a scarcely regulated of agricultural sector.

Future scenarios

Amongst the factors that may influence the spatial pattern of agricultural expansion are: soil suitability, climate conditions, the price of soy, access to markets[18], and national public policies focused on the production of food and the consequent expansion of the agricultural frontier. The best soils, east of the city of Santa Cruz, are labored with mechanized industrial methods,potentially expanding eastward and in most likelihood affecting the relatively intact biodiversity of the Chiquitano-Amazonia transitional forests[19]. As revealed by a spatial model, the Mennonite colonies could expand industrialized agriculture to the east and south of the Chiquitanía. Another area threatened by the conversion to industrial agriculture is San Buenaventura (north of the department of La Paz), by the construction of a state-owned sugar mill. (http://easba.produccion.gob.bo).

While small-scale agriculture is relatively flexible to environmental conditions, it tends to be practiced in areas of high humidity due to the needs of their main crops. Soil fertility is less relevant since the extensive practice of slash-and-burn allows farmers to take advantage of the nutrients stored in the burnt vegetation. Currently, small scale agriculture is concentrated in the El Chapare region (department of Cochabamba), but new deforestation fronts are opening up in the El Choré Forestry Reserve (department of Santa Cruz)[20], in the north of Chiquitanía, and in the northern portion of the Bolivian Amazonia (department of Pando, and parts of Beni and La Paz).

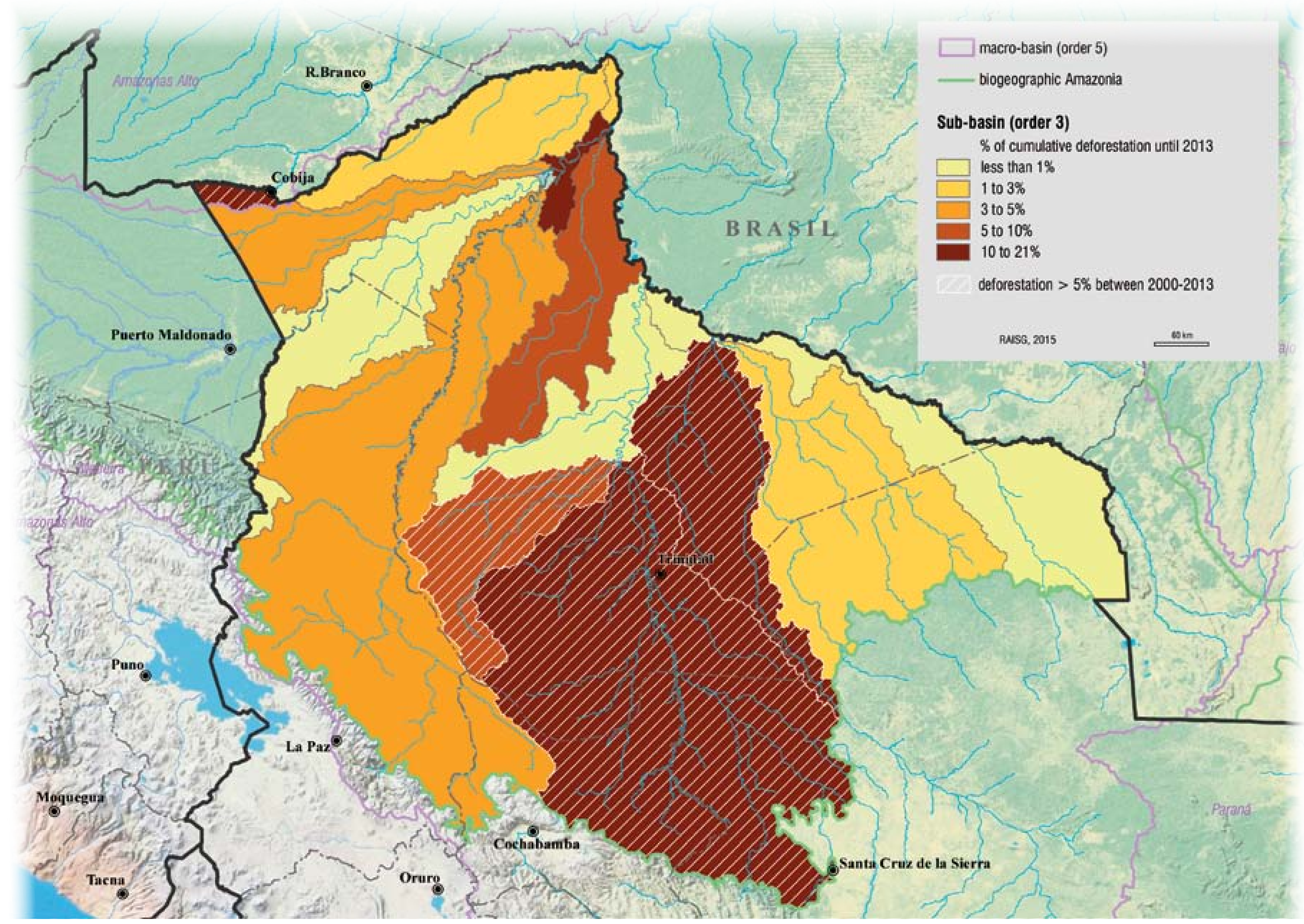
Cattle raising is independent of environmental factors. As noted, the main factors in its expansion are the influence of Brasil, foreign investment, and the possibility of exporting. Studies reveal that in the future, use of land for cattle ranching implies the biggest threat for Bolivian forests[21].

The Plurinational State of Bolivia is developing an ambitious forest governance and management agenda as an alternative to the REDD+[22] mechanism, which promotes living in harmony with forests and sustainable development following ecological criteria and traditional use practices. In this sense, under the protection provided by the Framework Law on Mother Earth and Integral Development to Live Well, the mitigation and adaptation mechanism for forest management, which includes the planning for land use management at a local level, has been created (Ministry of Foreign Affairs 2012). This mechanism, while centered on indigenous and intercultural communities, considering that they are not the major actors on deforestation, the mechanism's impact is aimed more at ITs, rural communities and PNA forest management, and not at a direct reduction of deforestation that would require different types of incentives and regulations.

The agricultural current of all governments since the 1950s has advocated the expansion of the agricultural frontier, an increased migration of intercultural communities to the lowlands, and the promotion of Japanese (past) and Mennonite (past and current) colonies, with the subsequent potential impact of deforestation. Law 337 for the Support of Food Production and Forest Restitution allows the regularization of post-1996 illegal clearings, giving green light and sanction to these clearings. In theory, the law also involves a stricter regime for the approval of clearings, with land reversion being the penalty. However, practical application remains to be seen. Lastly, the public policy for food production has projected, in alliance with production and business sectors, the expansion of the food production area by 10 million more hectares, mainly the region of Santa Cruz. This trend could have significant impacts on forest cover, since it does not mention factors like productivity or the need to restore unused or degraded lands (already deforested in the past).

The reconciliation of these two agendas – environmental vs agricultural – is one of the major challenges in the land use agenda in Bolivia. Land use patterns with a strong agricultural vision have been predominant since the 1950s, and it seems this pattern is not likely to change.

Map 2. Sub-basins with the greatest proportional deforestation



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DEFORESTATION in the BRAZILIAN AMAZONIA

The rate of deforestation decreased beginning in 2006, although the region lost 174,000 km², almost 5%, between 2000 and 2013

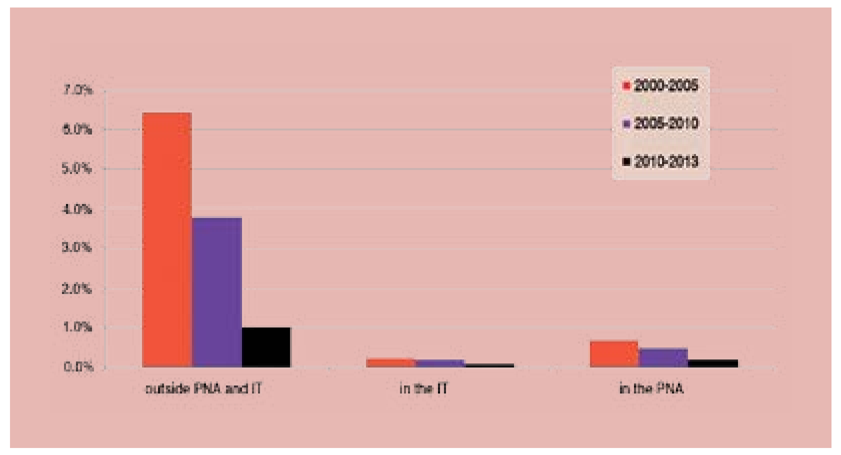
The Brazilian Amazonia covers close to 5 million km², about 58.8% of the country's area and 64.3% of the Pan-Amazonia region. The Brazilian Legal Amazonia ("Amazonia Legal") is a territory where the Brazilian state is responsible for planning and investment decisions. It includes the Amazonia biome and parts of the savannas (locally called "cerrado") of the North and Center-West regions of Brasil. The Amazonia biome (with 4.2 million km²) comprises a wide variety of environments, predominantly interfluvial plains covered by evergreen tropical rain forests and patches of submontane forests associated with low elevations. It also includes a transition zone demarcated between rainforest and savanna, and large extensions of sandy soils, with structural and floristic patterns of forest and sand savanna, which are locally called "campinaranas" and "praderas", respectively. Its flood plains possess formations that range from wetland forests to riparian strips and forests. The current deforestation analysis covers the tropical forests area of the Amazonia biome.

Historic and recent forest loss and deforestation rates

The area analyzed through satellite images from 2000 reached 3,885,181 km² (95.9% of the biome). Of these, some 3,587,052 km² were originally covered by forests. The authors estimate that 632,433 km² have been lost in the last forty years (1970-2010) and that the cumulative deforestation by the year 2000 reached 458.500 km² or 12.8% of the original forest. Based on satellite image interpretation, the forest loss between 2000 and 2013 (recent deforestation) reached 173,933 km² or 4.8% of the original forest. The largest loss took place between 2000 and 2005: 101,138 km² lost, compared to 57,399 km² lost in the 2006-2010 period. In the 2010-2013 period 15,395 km² have been lost (Table 1).

By 2013, Protected Natural Areas (PNAs) comprised close to 19.7% (950,097 km²) of Brasil's Amazonia biome. The analysis conducted based on satellite images of the year 2000 covered 821,372 km² (Table 1) that were originally covered by forests. The cumulative forest loss due to deforestation up to 2013 reached 16,887 km² (2.7% of the total deforestation of the Brazilian Amazonia up to 2013), while the cumulative deforestation in PNAs by 2000 reached 5,852 km² (0.7% of the original forest). Between 2000 and 2013 (recent deforestation), forest loss in these areas reached 11,035 km², which corresponds to 1.3% of the original forest.

Figure 1. Recent deforestation in the Brazilian Amazonia, inside and outside of PNA and IT



Map 1. Deforestation in the Brazilian Amazonia

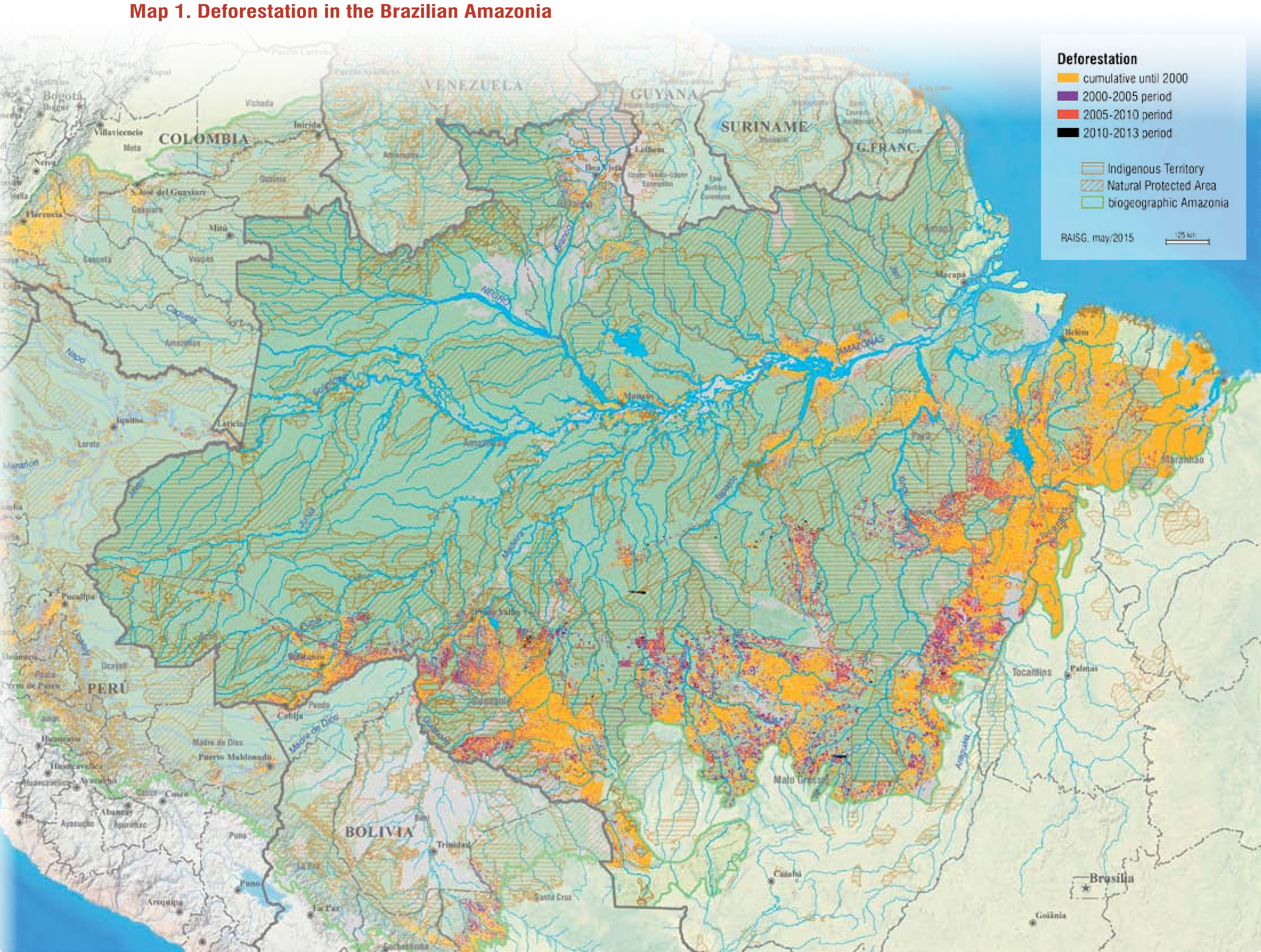


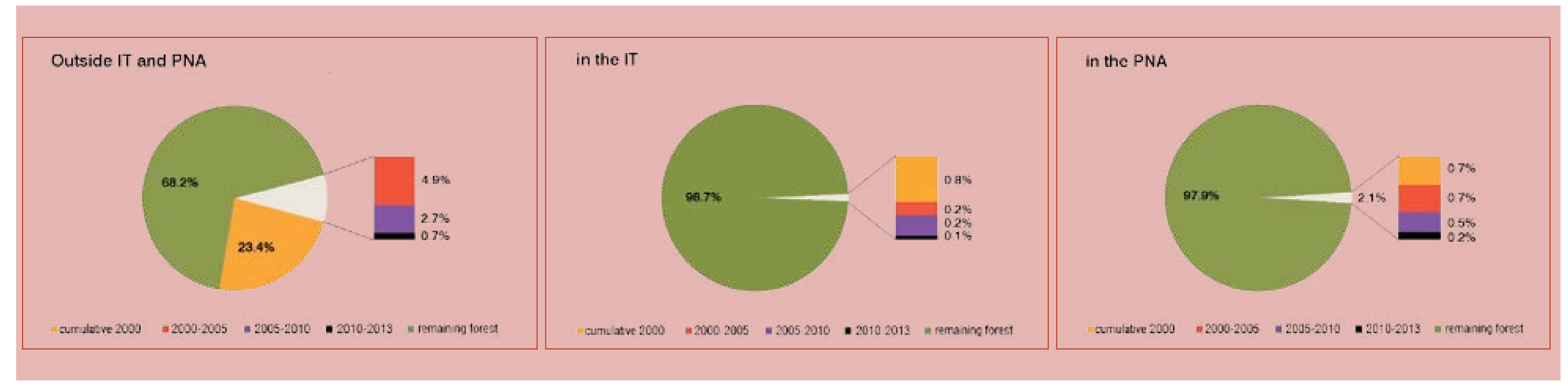
Table 1. Deforestation in the Brazilian Amazonia

	Surface of original forest cover[1]	Cumulative deforestation until 2000	Deforestation rate			% of the original forest	
			2000-2005	2005-2010	2010-2013	2000-2013	Cumulative total
	km²	km²	km²	km²	km²	%	%
Brazilian Amazonia	3,587.052	458,500	101,138	57,399	15,395	4.8	17.6
outside PNA and IT	1,898.507	445,142	93,586	51,641	13,174	8.3	31.8
Indigenous Territories[2]	931,112	7,648	2,178	1,818	713	0.5	1.3
IT officialy recognized	931,112	7,648	2,178	1,818	713	0.5	1.3
Protected Natural Areas[2]	821,372	5,852	5,482	4,013	1,540	1.3	2.1
state/departamental-direct use	229,073	1,180	2,866	2,421	893	2.7	3.2
state/departamental-indirect use	104,857	576	281	85	80	0.4	1.0
national-direct use	247,847	3,038	1,276	1,050	459	1.1	2.3
national-indirect use	239,595	1,058	1,060	457	108	0.7	1.1

[1] Original forest cover refers to forest formations within the biogeographic limit of the Amazon, within which exist non-forested areas, like enclaves of savannas or fields. For the evaluation of deforestation only originally forested areas were considered.

[2] The situation of existing ITs and PNAs was considered in December 2013.

Figure 2. Distribution of deforestation in the Brazilian Amazonia



The loss was greater between 2000 and 2005 (5,482 km² lost) compared to 4,013 km² lost in the 2005-2010 period and the 1,540 km² lost between 2010 and 2013. The PNAs with the highest deforestation rates in the 2000-2013 period were those of direct use, with losses of 6,180 km² (department-level) and 2,785 km² (national level) (Table 1). It is important to keep in mind that these calculations were based on the PNAs' status in 2013, without taking into account their date of creation, as would be required should one wish to analyze the effectiveness of these areas in impeding deforestation.

By 2013, the Indigenous Territories (IT) covered close to 22.1% of the Amazonia biome in Brasil (1,024,961 km²). Satellite image based analysis of the year 2000 covered the 931,112 km² originally covered by forests. The cumulative forest loss to deforestation up to 2013 was 12,357 km² (2.0% of the total deforestation of the Brazilian Amazonia up to 2013). Between 2000 and 2013 (recent deforestation), forest loss in these areas reached 4,709 km². From 2000 to 2005 the loss was 2,178 km², compared to the 1,818 km² lost in the subsequent 2005-2010 period and the 713 km² lost between 2010 and 2013 (Table 1).

The 15 sub-basins (order 3) that saw the most deforestation up to 2013, with more than 50% loss of their original forest, are those that were historically occupied in the state of Maranhão, north of Tocantins and east of Pará, and along the Cuiabá-Porto Velho highway between western Mato Grosso and Rondônia (Tocantins MB2; Araguaia B; Atlântico NE O S; Pindaré; Araguaia MB; Amazonas MB4; Candeias do Jamari; Juruena; Tocantins B; Guamá; Ji-Paraná; Madeira MB1; Gurupi; Abunã and Juruena M) (Map 2). These same 15 sub-basins lost more than 30% by 2000, and continued being deforested, with seven of them losing more than 10% of cover between 2000 and 2013. Between 2000 and 2013, 17 sub-basins lost more than 10% of their forest cover to deforestation, mostly in the agricultural frontier of Mato Grosso (headwaters of the Xingu and Tapajós rivers) and Rondônia. (Table 2, Map 2).

Within the area of the Brazilian Amazonia originally covered by forest until 2013 outside of PNAs and ITs, cumulative deforestation up to 2013 reached 590,259 km², or 93.3% of the total forest loss in the Amazon, 31.1% of the original forest in these areas (Figure 1).

Historical context of deforestation

Until 1970, the Brazilian Amazonia forests had been affected by the low impact human activities of indigenous peoples, the extraction of medicinal plants in the colonial era, and the exploitation of rubber at the end of the 19th century. Mining began only in the 1950s.

Within the framework provided by the Federal Constitution of 1946, structured plans for the region took shape and derived in the creation in 1953 of the Superintendence for the Economic Valuation of the Amazonia (SPVEA), charged with promoting the occupation and economic development of the Amazonia region, providing incentives for agriculture and cattle ranching. The main project developed by SPVEA was the construction of the Belém-Brasília highway (BR-010), finished in 1960 during Juscelino Kubitschek's government, which constituted the first road linking the region with the rest of the country, launching the process of occupation and the consequent socio-environmental degradation of the Amazonia.

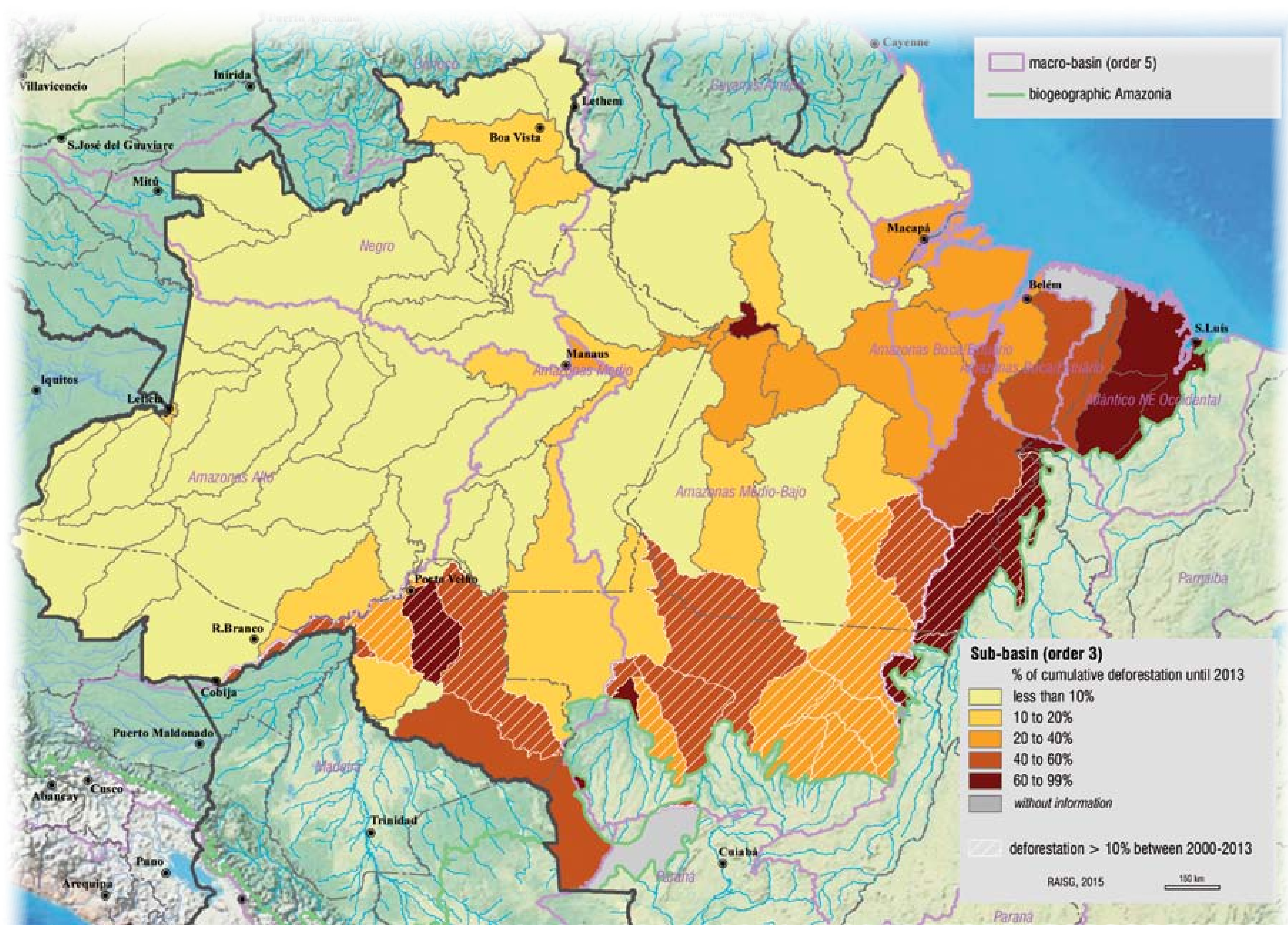
During the military dictatorship (1964-1984) the State promoted the occupation of the Amazonia based on a doctrine centered on transforming Brasil into an attractive multinational investment area, and the control of internal security. In 1966, the military government created the Superintendence for Development of the Amazonia (SUDAM) with the purpose of promoting the occupation of the region and the extraction of its natural resources, particularly minerals. To facilitate its feasibility, the government launched a series of tax incentives favoring the Amazonia region. In addition to income tax exemptions, federal rates, industrial, agricultural and cattle ranching activities and basic services, it established tax and rate exemptions for the import of machinery and equipment as well as goods donated by foreign entities destined for the Amazon.

In 1970, the National Integration Plan (PIN) included the construction of two highways bisecting the rainforest from north to south and east to west: the Cuiabá-Santarém and the TransAmazonia Highways. The government wanted that the population of the semi-arid northwestern regions to colonize what were considered the fertile lands of the Amazon. Thus, it

Table 2. Cumulative Deforestation in the Brazilian Amazon by sub-basins (sub-basins with more than 30% de deforestation)

Sub-basins (order 3)	Surface of original forest cover	Cumulative deforestation until 2000	Deforestation by period			% of the original forest	
			2000-2005	2005-2010	2010-2013	2000-2013	Cumulative total
Tocantins (MB2)	5,649	5,162	263	141	25	7.6	99.0
das Mortes	570	436	47	23	1	12.5	89.1
Araguaia (B)	60,583	44,484	5,692	3,119	193	14.9	88.3
Atlântico NE O S	47,364	36,565	285	613	181	2.3	79.5
Pindaré	31,268	21,776	1,087	1,605	258	9,4	79.1
Araguaia (MB)	9,834	5,704	1,205	421	87	17.4	75.4
Amazônia MB4	3,138	1,766	67	73	16	5.0	61.3
Candeias do Jamari	26,589	10,615	3,638	1,723	264	21.2	61.1
Juruena	3,726	2,020	173	43	15	6.2	60.4
Tocantins (B)	71,553	35,409	3,597	2,661	366	9.3	58.7
Guamá	45,415	22,473	1,625	1,623	414	8.1	57.5
Ji-Paraná ou Machado	67,541	30,263	5,355	2,354	691	12.4	57.2
Madeira MB1	2,604	825	471	144	20	24.4	56.1
Gurupi	29,277	14,398	684	884	148	5.9	55.0
Abunã	8,919	2,880	1,227	534	73	20.6	52.9
Juruena (M)	5,088	1,872	483	190	51	14.2	51.0
Guaporé	49,807	19,182	3,491	1,207	202	9.8	48.4
Fresco	36,901	10,899	3,078	3,139	122	17.2	46.7
Arinos	35,618	10,157	4,817	986	460	17.6	46.1
Teles Pires (S.Manuel)	98,455	29,184	8,269	2,401	570	11.4	41.1
Xingu (MA)	22,031	5,929	2,289	447	59	12.7	39.6
Do Sangue	16,441	4,025	1,700	437	99	13.6	38.1
Madeira MB2	22,613	3,025	3,058	1,808	451	23,5	36.9
Manissauá-Missu	25,989	5,418	3,127	802	216	16.0	36.8
Ronuro	17,309	3,021	2,133	755	395	19.0	36.4
Xingu	14,605	3,123	1,260	319	32	11.0	32.4
Am. MB3	2,295	671	34	30	8	3.1	32.3
Curuá-Una	29,490	6,116	1,519	1,048	339	9.9	30.6

Map 2. Sub-basins with the greatest proportional deforestation



established a colonization and agrarian reform program within 10 km either side of the highways. However, the majority of the colonization projects failed and left scars in the forest and in the population as a result from an unplanned settlement that led to serious environmental impacts.

In the mid-1970s, the government plans focused on large companies interested in mining and the streamlining of logging in the Amazon, while investing in the preparation of the savanna for soy production.

It is estimated that by 1997 the deforestation of the Amazonia had reached 169,900 km^2[1]. As a result of the government's incentives, land speculation became an important driver of deforestation around 1987. By then, deforestation had already multiplied: it is estimated that between 1978 and 1987 around 20,400 km^2 of forest were lost annually[2], for a cumulative total of 357,300 km^2,[3, 4]. From the 1980s onwards, Brasil underwent a change on its perception of environmental issues and the problems of deforestation. In 1981, Law 6938 was approved, establishing the National Environmental Policy of that period. Until then, large scale forest loss was merely seen as a necessity for regional development, and was directly stimulated through public programs and funds, but the broad dissemination of verified information on the high rates of deforestation loss in the 1970s and 1980s stirred an international scandal. The murder of Chico Mendes – an environmental and union leader who played an important role in the creation of the National Council of Siringueiros (Rubber tappers) and in drafting of proposals for Extractive Reserves – and the dissemination of the countless number of forest fires marked 1988 as a crucial milestone in this process[5].

The predatory escalation of the Amazon, which included not just the destruction of forests, but the violent disaggregation of indigenous communities and extractive activities-based communities moved from the headlines of the global mainstream media to the agendas of intergovernmental meetings, involving the United Nations and the multilateral Banks, which now had to justify their investments in the country, and their recurring impacts.

Amidst this intense mobilization of international and national public opinion in the 1980's, Brasil took its first legal stride towards changing its vision on the future of its rainforest, approving the 1988 Federal Constitution (CF) that defined, in article 255, the Amazonia as a national heritage and establishing conditioning constraints for its exploitation.

After the enactment of the CF, the Federal Government set up the Program for the Defense of the Ecosystem Complex of the Legal Amazon, currently called the "Our Nature Program", and the National Congress approved many legal provisions with the goal of controlling the deforestation of the Amazon. Despite the importance of these initiatives for the creation of Brasil's environmental legal and institutional framework, their positive results in terms of control of forest degradation only lasted a short time.

Contrary to expectations and the institutional effort generated by the 92 Rio Summit, where the Brazilian government made firm commitments towards the protection of its forests, the rate of deforestation rose again, reaching a record figure in 1955, with almost 30,000 km^2 of forest cleared. Since then,

Prodes/INPE x Imazon/RAISG

The comparison of the deforestation data for the Brazilian Amazonia generated by Imazon in the RAISG framework for the 2000- 2013 period with data from PRODES (Project for the Monitoring of Deforestation in the Brazilian Legal Amazon) (Figure 1) shows that PRODES detected 5% more deforestation than RAISG. The 2005-2010 period has the greatest difference in absolute terms: PRODES data shows there were 10,800 km2 more in deforested areas, equivalent to an 11% difference from what RAISG reported. For the 2005-2010 period, the deforestation detected by RAISG was higher than PRODES by 4,000 km2. Finally, the 2010-2013 period has the smallest difference, with PRODES recording only 1.5 km2 more of deforestation.

These differences require an explanation. Some indications suggest that what PRODES detected as deforestation (logging/felling) during the 2000-20005 period were actually areas of degraded forest. In the subsequent period (2005-2010) these degraded areas became deforested areas, but since they had been detected by PRODES previously, they were detected only by RAISG, which resulted in a larger deforested area detected by RAISG in the second period. The results are also explained by the differences in terms of the methodology and database used by both institutions for the detection of deforestation and measurement of the annual rate of forest loss.

Carlos Souza Jr./Imazon

the deforestation rate maintained an upwards trend until 2004, with the only important recorded decrease in 1997[6].

Incentives and investments in infrastructure, particularly highways, made the federal government into the major promoter of forest cover change in the Amazonia until the end of the 20th century. Between 1978 and 1994, around 75% of the deforestation of the Amazonia took place less than 50 km along both sides of paved highways[7].

While settlers and small landowners contributed significantly to this environmental impact until the end of the century, beginning in 2000, deforestation was driven by the financial viability of large and medium-scale agriculture in the established frontier[8], and agrobusiness[9].

A study by the World Bank points out that cattle ranching occupied more than 75% of the converted lands up to the mid-2000s, and constituted a key factor in deforestation. Cattle ranching is dominated by sophisticated and well capitalized agents "that… have access to other investment sources, after the (apparent) withdrawal of subsidies"[10].

The selective logging of forests has and continues to play an important role in deforestation for two reasons: firstly, because of the thinning of forest cover through the removal of tall trees (like caoba) allows the sun and wind to reach the ground, reducing humidity and favoring forest fires, and secondly because the explored area tends to be cleared afterwards as the forest remaining after caoba extraction has a lower economic value than cattle ranching[11].

In 2001, the Amazonia Development Agency (ADA) substituted SUDAM with a smaller structure and budget. In 2007 the ADA was dissolved and SUDAM re-created, and is now attached to the Ministry of National Integration. The government's plan of action, Avance Brasil (2000-2007), invested heavily in Amazonia infrastructure, particularly where needed for soy transportation[12].

Furthermore, 2003 was marked by the exacerbation of deforestation of the Amazonia. The data presented by the National Institute of Space Research (INPE) showed rapidly increasing deforestation rates, with an increase of close to 10% by 2004, exceeding 27,000 km^2, the second highest rate seen since the space agency started monitoring in 1988.

In response to these successive and eloquent increases in deforestation rates in the Amazonia, the federal government launched the first integrated plan to combat deforestation, involving 11 ministries and an assigned budget of 394 million reales: the Action Plan for Prevention and Control of the Legal Amazonia Deforestation(PPCDAm).

Amongst the PPCDAm's first drastic actions was the creation of close to 20 million hectares of nature conservation units, which corresponds to a 70% increase in the units, and the homologation (or official recognition of a IT through the President's signature) of close to 10 million hectares of Indigenous Territories. In order to fight the misappropriation of lands (a process known in Brasil as "grilagem"), around 66,000 titles that were not able to prove the legality of their origin were canceled, and changes introduced to the mechanisms and procedures for the registration of ownership.

At the same time, several large oversight operations were undertaken, leading to the closure of up to some 1,500 illegal logging companies, the confiscation of more than 1 million cubic meters of timber, and the arrest of 700 people, including some federal and departmental government officials amongst this number.

The Plan promoted improvements in INPE's deforestation monitoring system, like the development of tools like Deter (Detection of Deforestation in Real Time) and Detex (a tool allowing for the monitoring of selective logging).

During PPCDAm's first six years of operations between 2004 and 2010, there was a significant decrease in deforestation, except for 2008. The cumulative reduction for the period was 74.79%.

Direct and indirect causes of recent deforestation

The expansion of mechanized planting is a key factor in the deforestation dynamic. While it is primarily found in the savanna areas, it has also been implemented in pastures previously cleared amidst in the forest. This reduces installations cost and forces cattle ranching to move over to existing forested areas. The expansion of soy particularly affects transition forests found between densely forested areas and the central savanna, mainly in the states of Mato Grosso and Pará[13].

In a similar manner, in 2007 more than 60% of the deforested areas of the Amazonia were dedicated to pastures, and approximately 8% to agriculture[14].

A recent study determined that the internal consumption and export of soy, beef and other products cultivated in the Amazonia are the main drivers of deforestation for this region[15].

Between 2000 and 2010, cumulative deforestation nearly doubled, from 202,000 km^2 in 1999 to 385,000 km^2 in 2010. This assessment, conducted by Imazon, corroborates official estimates[16].

It is important to highlight that the economic and geopolitic rationale that led to the sequential model and the permanent degradation and suppression of the Amazonia rainforest relied on the absence of land tenure regularization policies. Until 2012, Brasil did not have a clear rural land registry system. Various initiatives for regularization were unsuccessful: a new land registry system for properties over 10,000 ha in 1999; a new land registry in selected municipalities in 2001, 2004, and 2008 – and by late 2006 there still were major disputes about the formalization of land use and occupation of public lands in the Amazon[17].

Future scenarios

In 2012, Congress approved considerable changes in the Brazilian Forestry Code (Laws 12.651 and 12.727). The new law not only reduces Permanent Conservation Areas (APP), but allows some properties to be exempted from the protection of the highlands and slopes regime.

This law came as success for the Confederation of Agriculture and Cattle Ranching of Brasil (CNA). While the greatest impact of these changes does not affect the Amazonia biomes, some of its titles will have a direct impact on Amazonia deforestation. Among the most disputed aspects of the new law is the amnesty for landowners of properties that have been deforested prior to 2008, the reduction of APPs, the lack of criteria for the restoration of vegetation (mandatory in many cases), and the reduction of the Legal Reserve area (private property area where original vegetation cannot be cleared).

The new law was enacted in May 2012. According to PRODES, in the first year since its inception, deforestation in the Brazilian Amazonia was 5,843 km^2, an increase of 28% from the previous year. Thus the decreasing trend of deforestation registered since 2004 has reverted. The states with the most deforestation between 2012 and 2013 were Mato Grosso, Pará, and Roraima, where the agribusiness frontier is pushing forward.

In November of 2013, the National Agency of Petroleum (ANP), allocated new areas for the exploitation of oil and natural gas in Acre. While these areas are not intended for the exploitation of shale gas, the terms of tenders permit its exploitation should it be found, which could further damage the environment.

In 2009, Brasil committed to a voluntary reduction of greenhouse gas emissions down to 38.9% by 2020. One of the measures adopted is the reduction of 80% of the annual rates of deforestation of the Legal Amazonia relative to the average from the period between 1996 and 2005. From 2005 to 2012, rates decreased, with the exception of 2008 and 2013. It should be noted that deforestation is not under control, and that the wrong policies could lead to a new increase.

The increasing demand for beef and biofuels, as pointed out by Nepstad[18], the increase of petroleum concessions, and the reduction of forest protection through the new Forestry Law should be the top concerns in the near future.

Democratization of data and analysis of deforestation in the Brazilian Amazonia

The monitoring of the Brazilian Amazonia implemented by INPE (the National Institute of Space Research) through PRODES (Amazonia Deforestation Satellite Monitoring Program) began as part of the efforts made by Brasil to respond to the tremendous international repercussions of the the escalating predation recorded in the Amazon, which implied not just the destruction of the rainforest, but also the violent disintegration of indigenous and extractive activities-based communities that took place in the 1970s and 1980s.

PRODES emerged in 1989 from a series of conservation initiatives that marked the end of the 1980s, as well as the launching of the Our Nature Program (Federal Decree 96.944, October 1988); the creation of IBAMA (Brazilian Institute for the Environment and Renewable Natural Resources; Law 7535, February 1989); cessation of the tax incentives for projects that would have implied deforestation in the Legal Amazonia (Decrete 97.637, April 1989); and the creation of the National Environmental Fund (Law 7.797, July 1989).

Since its inception, PRODES was surrounded by controversy. The first one arose because the calculation of the percentage deforestation was originally based on the area of the Legal Amazonia (Law 1806, January 1953). Since the area covered by rainforest is significantly smaller, the rate of deforestation was a deliberately low estimate, giving place to a strong reaction from researchers and environmentalists, severely impacting its credibility.

Throughout the 1990s up to 2003, data was released with a maximum delay of two years, always with generic calculations and little desegregation (at state level at best), which rendered this information useless for the design of public policies. Reports contained no geographical information about the location of deforestation, and access to the cartographic base was denied even to governmental entities themselves.

The lack of transparency on deforestation information meant no validation from other government agencies or civil society, allowing for intense political manipulation. A well-known case refers to the attempt to reduce the impact in public opinion about the maximum deforestation that took place in the 1994-1995 period. The data was made public only in 1996 and during the presentation event emphasis was placed on the decrease observed in the following period (1995-1996), in a blatant attempt at minimizing the 95% deforestation increase registered in the previous period.

This situation prevailed until 2003, when the release of PRODES' digital cartographic base was negotiated following a strong stance on the part of the Ministry of the Environment under the management of Marina Silva. This impasse required the direct intervention of President Lula, given the reaction of the conservative areas of government.

Since then many improvements were introduced in PRODES: (i) images and and data interpretation analysis became available on internet, adding to the transparency of the estimated annual rates of gross deforestation. Data was desegregated by state, municipal and other spatial unit levels; (ii) improvement of the cartographic quality of analysis; (iii) increased number of sensors used to generate the estimated annual rate of deforestation by minimizing the effect of cloud coverage; (iv) increase of the technical personnel and infrastructure in order to reduce the time needed to generate annual estimates from eight to five months, and (v) creation of a consolidated database (TerraAmazonia system) with the digital PRODES data.

Simultaneously, investments were made in the development of a new system, DETER (Detection of Deforestation in Real Time) that acts as a permanent alert system for deforestation in the Amazon. Every 15 days, georeferenced information about changes in the region's forest cover is generated, allowing a faster response in terms of supervision and planning of integrated control operations.

Despite the fact that the information is generated through the use of less precise and lower resolution satellite images (250 meters), DETER has proven to be a very helpful tool in expediting the fight against illegal logging, since it provides more frequent data. INPE also made DETER images available on the internet (www.obt.inpe.br/deter), allowing unrestricted download and use to all interested parties.

Additionally, a new system called DETEX (System for the Detection of Forestry Exploitation) was developed and implemented to monitor the impact of the selective logging of forest, such as the construction of roads, clearings to store logs, and the removal of trees.

In the 2003-2009 period, the ministries of Environment and Science and Technology held yearly technical and scientific workshops, involving governments at the federal, state and municipal levels, universities, non-governmental organizations and social movements. The goal was to analyze deforestation data and foster debate around the public policies required to sustain the reduction in deforestation rates that had started in 2004. Two civil society organizations worth mentioning for their contributions to this discussion are Imazon and ISA, which have a significant capacity in the operation of geographic information systems and territorial analysis, the discussion of methodology and data evaluations with a keen awareness of the reality of specific regions in the Amazonas. (See Box PRODES/INPE x Imazon/RAISG). These workshops ceased to take place in 2010, and during the government of Dilma Rousseff the DETER data that once was widely available became restricted.

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DEFORESTATION in the COLOMBIAN AMAZONIA

50% of deforestation is found in the northwestern arc, mainly by the expansion of the agricultural frontier and illegal mining

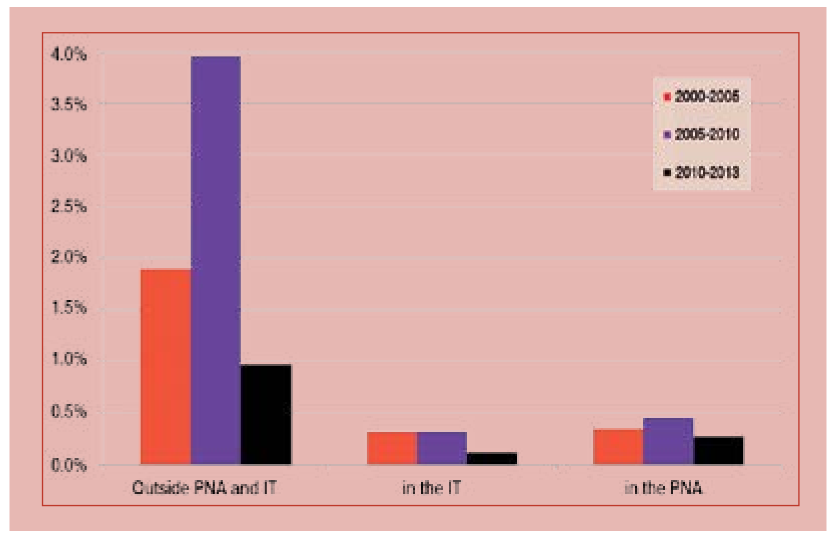
According to the Amazonia Scientific Research Institute (SINCHI), the Colombian Amazonia encompasses 483,164 km², equal to 42.3% of the Colombian mainland[1], and 6.2% of the Amazonia[2]. Its outstanding natural beauty marks this region that also stands out for its hydrological importance, high concentration of biodiversity, and linguistic diversity. It is primarily comprised by forest zones located in the tropical humid climate band. These formations are predominantly dense tropical forests, semi-humid transitional forests, tropical forests, deciduous and semi-deciduous seasonal forests, extensive savannas, sandy soils and a mosaic of pioneer formations that become transition areas to other ecosystems from neighboring regions. Its western portion constitutes an important natural bridge allowing the exchange between species in the high moors, andean forests, and dense Amazonia forests.

Historic and recent forest loss and deforestation rates

Satellite images for the year 2000 reveal the Colombian Amazonia had 430,863 km² of forest, with a 7.4% cumulative deforestation (34,672 km²). Based on satellite image interpretation, forest loss between 2000 and 2013 (recent deforestation) reached 9,613 km². The loss between 2000 and 2005 (3,445 km²) was lower than the loss that occurred in the subsequent 2005-2010 period (6,167 km²). For the first period analyzed (2000-2005), which is equivalent to a change of 0.7% from the original forest cover, and a change of 1.3% for the 2005-2010 period. For the period 2010-2013, the deforested area was 1,684 km², equivalent to a loss of 0.36% compared to the original forest area. The total cumulative deforestation of the original forest was approximately 10% (Table 1).

The Colombian Amazonia has 18 Natural Protected Areas (PNAs) within the National Parks system, with an extension of 94,464 km², and 206 Indigenous Reserves covering 257,420 km².As there is some spatial overlap between both categories, the actual total expanse covered by both National Parks and Reserves is of 319,769 km² (69% of the Colombian Amazonia). It has been noted that forest loss in Amazonia parks was low (2.5% in Indigenous Reserves and 2.7% in National Parks) in relation to the deforestation in the areas without legal protection.

Figure 1. Recent deforestation in the Colombian Amazonia, inside and outside of PNA and IT



Map 1. Deforestation in the Colombian Amazonia

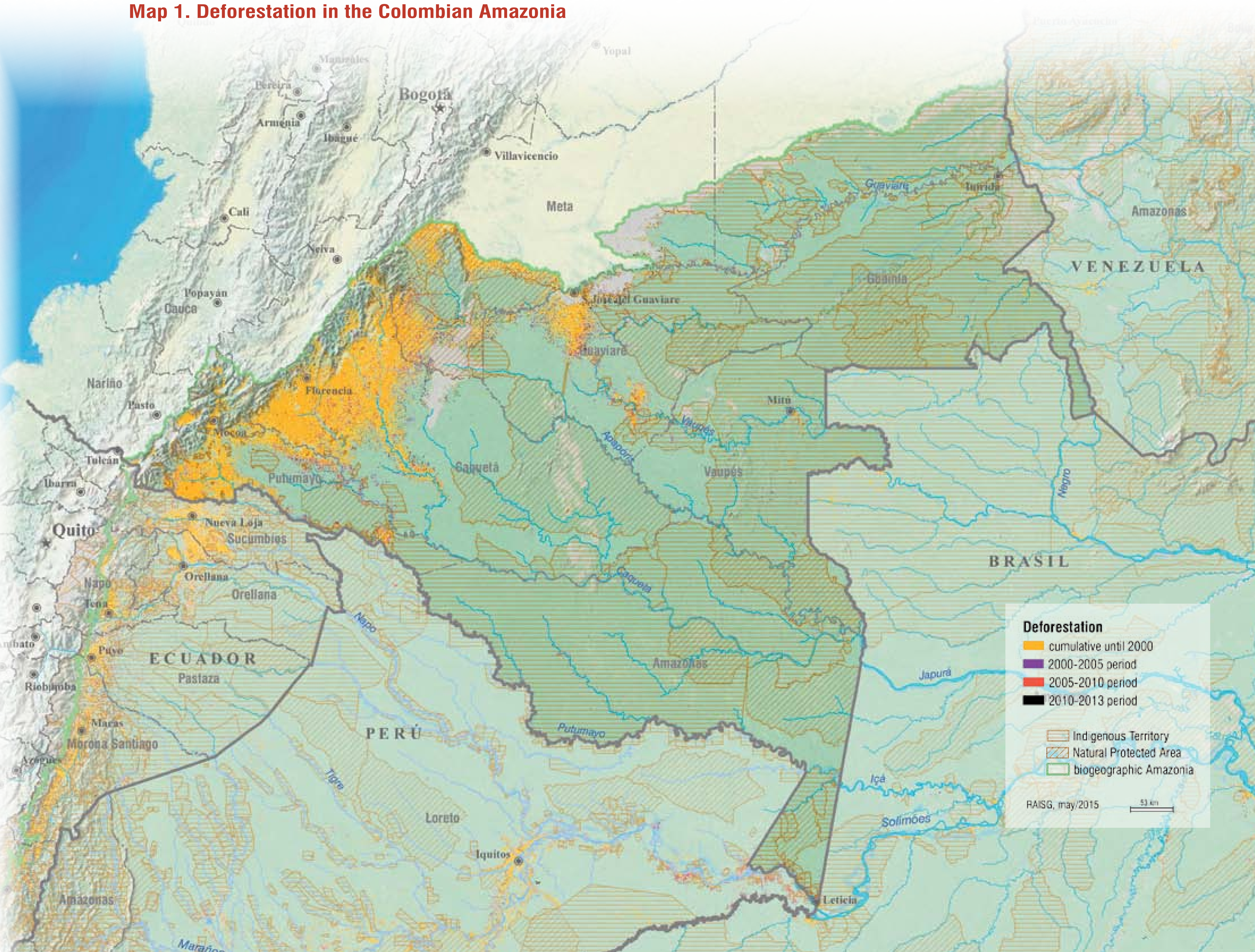


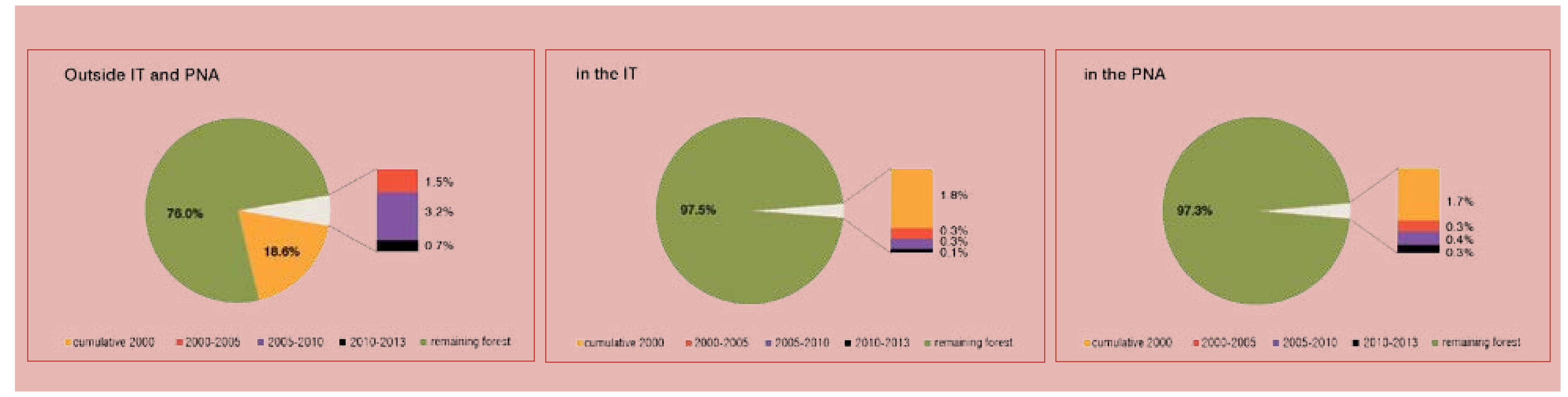
Table 1. Deforestation in the Colombian Amazonia

	Surface of original forest cover[1]	Cumulative deforestation until 2000	Deforestation rate			% of the original forest	
			2000-2005	2005-2010	2010-2013	2000-2013	Cumulative total
	km²	km²	km²	km²	km²	%	%
Colombian Amazonia	465,536	34,673	3,446	6,167	1,684	2.4	9.9
Outside PNA and IT	156,369	29,058	2,419	4,947	1,167	5.5	24.0
Indigenous Territories[2]	248,772	4,420	775	788	294	0.7	2.5
IT officialy recognized	248,772	4,420	775	788	294	0.7	2.5
Protected Natural Areas[2]	92,148	1,564	318	406	246	1.1	2.7
national-indirect use	92,148	1,564	318	406	246	1.1	2.7

[1] Original forest cover refers to forest formations within the biogeographic limit of the Amazon, within which exist non-forested areas, like enclaves of savannas or fields. For the evaluation of deforestation only originally forested areas were considered.

[2] The situation of existing ITs and PNAs was considered in December 2013.

Figure 2. Distribution of deforestation in the Colombian Amazonia



By 2013, PNAs – based on official area figures – comprised around 17% of the Colombian Amazonia; analysis of which shows that 92,148 km² of this area were originally covered by forests. The cumulative forest loss due to deforestation up to 2010 reached 724 km²), with cumulative deforestation for the 2000-2005 period reaching 318 km². The greatest loss (406 km²) took place between 2005 and 2010, equivalent to a change of 0.3% and 0.4% respectively. While deforestation in Protected Areas generally is low, there are some areas, like the Sierra de la Macarena PNN that stand out, with a forest loss of 142 km² for the 2000-2005 period, and a forest loss of 86 km² by 2005-2010 relative to the previous period. The loss for the 2010-2013 period was 45.9 km².Following it come the Tinigua PNN (141 km²) and the Nukak RN (131 km²) both for the 2000-2013 period.

Regarding indigenous territories, according to the digital information of the Austin Codazzi Geographic Institute and INCODER's resolutions, the total area of the 206 Indigenous Reserves of the Colombian Amazonia is 248,772 km². Of these, 775 km² were deforested by 2005, which is equivalent to a 0.3% change relative to the original forest area. The deforested area by 2010 was 778 km² or 0.3%. In the 2010-2013 period, the area deforested was 294 km², 0.1%.

Finally, the largest deforestation can be found in the upper basins of the Caquetá, Guaviare and Putumayo rivers, which corresponds to the northwestern arc of the Colombian Amazonia. Presently these upper basins are primarily covered by pastures, secondary vegetation of anthropogenic origin, and mosaics of grasses and crops. Small discontinuous forest fragments connect the highlands with the lowlands. It is worth noting that deforestation in the lower basins of the Colombian Amazonia has a characteristic look, showing as small isolated patches, as a result of indigenous groups' practice of establishing areas of transitory cultivation (Table 2).

Historical context of deforestation

Diverse indigenous groups have occupied the Colombian Amazonia since time immemorial[3]. Due to its climate, geography (difficult access) and salubrity, the region is considered an isolated area, and consequently has had little relevance at the national level and has been addressed by few management policies.

While the first religious missionaries reached the region through the Amazonia River in the 17th century, the first occupation by Andean settlers did not take place until the early 19th century. At the time, a number of settlements were established in the foothills of the departments of Meta, Caquetá and Putumayo, spurred by the commercialization of cinchona and rubber. Later, the government began the construction of access and communication roads. There was a second wave of migration in the 1930s, promoted by the State given its need to secure national sovereignty. In the mid-thirties the agrarian reform caused the migration of farmers from the southern Andean region.

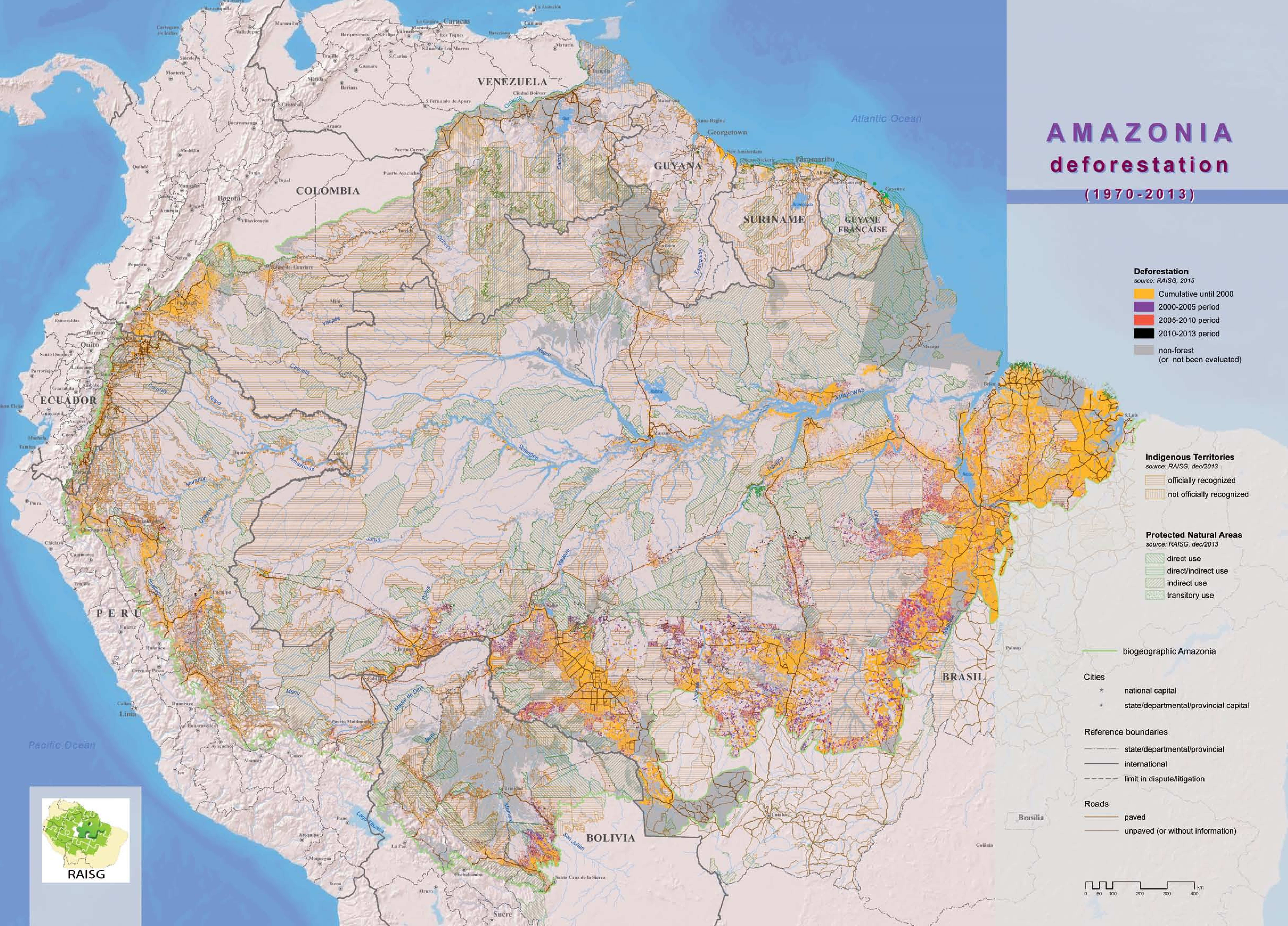
In the 1940s, migration and displacement of the Andean population increased due to the country's internal conflict intensifying. Settlement frontiers were established in three specific locations by the end of the 1950s: La Mono, Maguaré and Valparaíso in the department of Caquetá (Law 20 of 21 September 1959), aimed at occupying 6,920 km².

Migration driven by oil exploration in the foothills of the Putumayo took place during the 1950s[4]. The settlements established in those years mainly affected the municipalities of San José del Guaviare and El Retorno. The growth of urban centers in the Amazonia region was a result of the economic booms associated with rubber and cinchona, as well as the exploitation of timber, marihuana, and coca. These transient booms left a settlers population with no income sources[5] in the area, leading to coca cultivation and attracting a new migrant population in the late 1950s.

The establishment of extensive illicit crops began in the 1980s. In the following two decades this clandestine agribusiness generated a loss of approximately 110,026 hectares of primary forests[6]. 55.1% of these crops were concentrated in the lower forests and foothills of the Orinoco and Amazon River basins in the departments of Meta, Guaviare, Putumayo and Caquetá; and to a lesser degree in the departments of Vichada, Guainía, Vaupés and Amazonas.

The case of the department of Guaviare is symptomatic: even though it ancestrally suffered the extraction of rubber and animal hides, its deforestation history began in the 1950s with the arrival of the population displaced by the country's political violence. According to ECLAC and *Patrimonio Natural*[7], the cumulative deforestation up to the 1980s was estimated at 19,973 km², reaching 27,942 km² by the 1990s. This increase was due to the expansion of the agricultural frontier, extensive cattle ranching, forest fires, and the timber industry.

In the 1990s, the settlements' advance came from the southwest of department of Meta and the population displacement from the San José-El Retorno-Calamar axis[8].

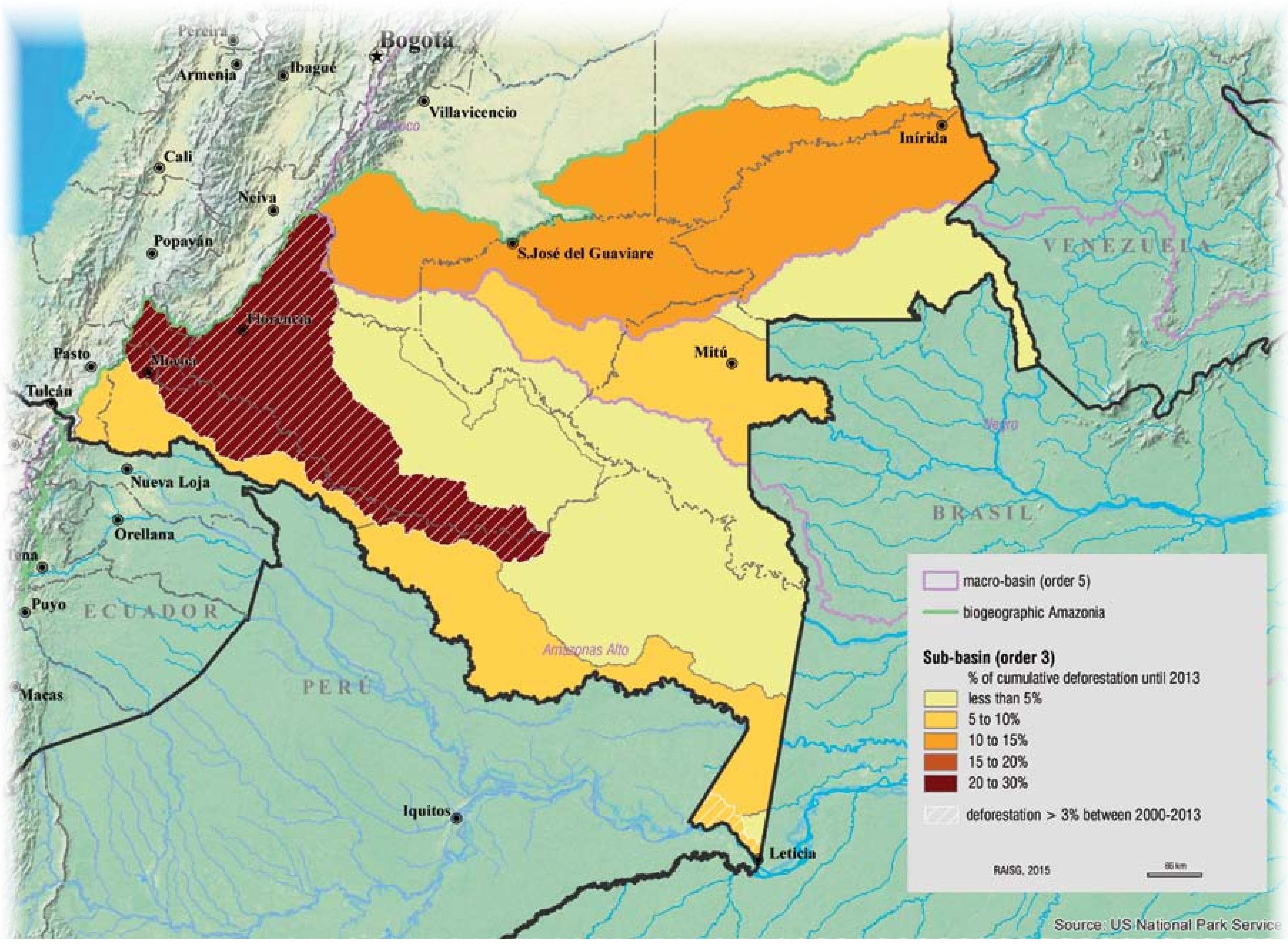


AMAZONIA
deforestation
(1970-2013)
Deforestation
source: RAISG, 2015
Cumulative until 2000
2000-2005 period
2005-2010 period
2010-2013 period
non-forest
(or not been evaluated)
Indigenous Territories
source: RAISG, dec/2013
officially recognized
not officially recognized
Protected Natural Areas
source: RAISG, dec/2013
direct use
direct/indirect use
indirect use
transitory use
biogeographic Amazonia
Cities
national capital
state/departmental/provincial capital
Reference boundaries
state/departmental/provincial
international
limit in dispute/litigation
Roads
paved
unpaved (or without information)
0 50 100 200 300 400 km
Atlantic Ocean
Pacific Ocean
VENEZUELA
COLOMBIA
GUYANA
SURINAME
GUYANE FRANÇAISE
ECUADOR
PERU
BOLIVIA
BRASIL
Caracas
Georgetown
Paramaribo
Cayenne
Bogotá
Quito
Lima
Brasília
Amazonas
Negro
Solimões
Madeira
Xingu
Tapajós
Juruá
Purus
Orinoco
RAISG

Table 2. Cumulative deforestation in the Colombian Amazonia by sub-basins (basins larger than 500 km²)

Sub-basins (order 3)	Surface of original forest cover	Cumulative deforestation until 2000	Deforestation by period			% of the original forest	
			2000-2005	2005-2010	2010-2013	2000-2013	Cumulative total
	km²	km²	km²	km²	km²	%	%
Caquetá	68,156	16,460	916	2,665	440	5.9	30.1
Guaviare	118,212	9,028	1,156	1,685	633	2.9	10.6
Putumayo/Içа	57,287	4,505	286	369	88	1.3	9.2
Uaupés	36,929	1,846	508	443	147	3.0	8.0
Am. Alto (B)	2,455	73	36	55	2	3.8	6.8
Yarí	34,492	580	178	571	215	2.8	4.5
Caquetá/Japurá (M y B)	103,493	1,722	289	297	125	0.7	2.4

Map 2. Sub-basins with the greatest proportional deforestation



Economic policies implemented in Colombia gave rise to an unprecedented oil and mining boom beginning in the year 2000. This was manifest in the Andean foothills, where several areas in the upper basin of the Putumayu River were opened to oil exploitation. Parallel to that, other factors, such as the price of illicit crops, the armed conflict, the lack of a state presence and the oil and mining boom, aggravating a dynamic that already had high deforestation in this arc.

Historically, the following economic factors have had an impact on deforestation: the consolidation of the urbanization trend and growing industrialization of the major cities; the saturation of smallholders land property in the Andean region, and its subsequent increase in migration to the frontier areas of the lowland forests of the Amazonia and the foothills of the Andes; the stable growth and development of drug-traffic, progressively invading the agricultural frontier; the unequal distribution of land tenure; and the important effects on the labor market resulting from the structural problems that social mobility creates[9]. Added to these, the lack of adequate territorial organization policies and measures have generated the chaotic management of these territories.

According to the Forest Policy[10] and the Annual Report on the State of the Environment and Renewable Natural Resources in Colombia[11], the primary causes of forest cover loss have been the expansion of the agricultural frontier, mining, colonization, infrastructure construction, illicit crops, the use of firewood, forest fires, and timber production for industry and commerce.

In conclusion and in agreement with the Forest Policy and the Annual Report on the State of the Environment and Renewable Natural Resources in Colombia, it can be affirmed that deforestation is related to socioeconomic and environmental factors. The primary agents have been the expansion of the agricultural frontier; the increase of urban areas and road infrastructure construction[12,13]; the navigability of large rivers[14], oil exploitation[15], the expansion of the cultivation of coca[16,17,18,] and more recently, mining[19]. These processes have brought on the reduction of the natural forest mass, with the subsequent loss of biodiversity, soil degradation, changes in the hydrological cycle and low quality of the areas remaining amongst other impacts[20]. Four groups of main agents at a national level have been identified for the analysis of the transformation processes of forest cover: farmers, cattle ranchers, mining companies, and armed actors[21].

Direct and indirect causes of recent deforestation

Although the deforestation of the Colombian Amazonia does not present alarming figures per se, it is showing a tendency to increase. Analysis by RAISG shows the areas with the highest deforestation are those on the Amazonia foothills and its northern forests. This is a worrisome trend and a cause of major concern as these areas include the headwaters of some of the rivers that feed the Amazon basin. It's worth noting that forest loss in natural protected areas and indigenous territories is low, whereas areas without legal protection show higher deforestation.

The analysis reveals that deforestation has been linked for years to migratory flows, primarily those in the Andean-Amazonia transition zone. This same area is where present oil and mining exploitation is taking place, with the consequent advance of settlements. Biodiversity in the region has been severely undermined by the legal and illegal implementation of a resource extraction model over recent decades that threatens its eco-systemic integrity.

According to Murcia *et al*[22], deforestation is primarily due to cattle ranching and the creation of pastures, which are sometimes later used for the cultivation of illicit crops as reported by SIMCI-UNOD (2002 to 2007). Deforestation impacts the National Parks on the Andean foothills, specifically, those of the department of Meta (Sierra de la Macarena PNN, Cordillera de Picachos PNN, and Tinigua PNN).

The Forest Policy[23] ranked the causes of deforestation at the national level by order of importance: expansion of the agricultural frontier, human settlements expansion, infrastructure construction works, illicit crops, the use of firewood, forest fires, and timber production for industry and commerce. The *Visión Colombia 2019* document[24] attributes deforestation processes to the expansion of the agricultural frontier and human settlements, including illicit crops, followed in importance by timber extraction and forest fires[25].

Current dynamics are driven by agricultural developments and mining on the frontiers and in the interior of the foothills area; as well as by armed conflict and drug-traffic, generating new settlements and increasing population density in already existing ones. The increased migration taking place is nourished by increased labor demand from agricultural and mining developments, particularly in the departments of Guianía, Meta, and Vichada[26]. Settlement dynamics are taking place in uncultivated lands and forest reserve areas, leading to actions allowing for the subtraction, titling, and sale of properties. Illegal mining is concentrated on the basins of the Caquetá, Orteguaza, Vaupés and Guainía rivers, where it persists given the lack of state surveillance, the absence of economic options, the high price of gold and other minerals in the international market, the public force's pressure on illicit crops, and the presence and funding of illegal groups in the Caquetá basin[27].

Future scenarios

The lower deforestation in protected areas and indigenous territories revealed by this study is reason enough for the importance of maintaining these areas and strengthening their environmental governance. As is the need for maintaining a deforestation monitoring system for follow up and the taking of preventative and corrective measures. This initiative must come from the central, regional, and local governments in order to stop forest loss and for that matter, the loss of an entire system.

Along these lines, Colombia currently has an international commitment to zero net deforestation by 2020, carried out by the Ministry of Environment through its *Visión Amazonía 2020* policy and the green growth strategy of the "National Development Plan 2015-2020". Both policies are committed to supporting and strengthening the governance in ITs and PNAs[28].

ECLAC and *Patrimonio Natural*[29] both concur in asserting that the Colombian Amazonia may be confronted by distinct scenarios and very diverse futures outcomes, depending on the decisions the country takes on those issues highly relevant for the region: the state's geopolitical and border protection vision, the importance given to climate change, the conservation and protection of indigenous culture and knowledge; the growing pressure for natural resources like minerals, land, water and oil; the productive activities and steering of research; infrastructure development; and the fight against illegality.

Additionally, the post-conflict scenario and peace-building scenario that could possibly result from the ongoing negotiations between the Colombian State and the FARC-EP in Havana will be of enormous importance to the governance and deforestation processes in the Amazonia. A post-conflict context will bring both great opportunities and great challenges and responsibilities regarding the mitigation of the environmental impacts of economic growth in the Amazonia region, and the encouragement of a differentiated and sustainable development strategy.

In conclusion, even though Colombia has made advances in the construction of regulatory frameworks for the protection of National Parks and Reserves, it does not yet have a coherent vision of the Amazonia region to guide the development of specific policies. Consequently, this allows for a fragmented, and in many cases, contradictory vision amongst the many institutions and actors with influencing roles in the region. It is worth mentioning that there are important advancements at the local level, as is the case of the indigenous governments and entities systemically working and contributing to the protection and management of the Amazonia territory. The challenge lies in how to articulate political initiatives from the central State level with existing local advances and proposals to build a joint political vision for the Amazonia, combining economic development with the region's social, cultural and environmental resilience and sustainability.

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DEFORESTATION in the ECUADORIAN AMAZONIA

Crude oil opens the way for exploitation of timber and will remain the main threat in the following years

In Ecuador, the Amazonia is officially defined following the political-administrative limits (provinces) and covers 116,588 km², or 45.5% of the country's area and less than 2% of the Amazon macro-basin. From an ecological perspective, and in accordance with the "Ecosystems Map of Continental Ecuador"[1], Amazonia biogeography consists of the following ecosystems: shrubland, flood and flooded forests, riparian woodland, semi-deciduous forests, evergreen peneplain forests, plains, montane and foothill forests, sandstone mesa forests on the Condor mountain range, and flood and montane grasslands. The present evaluation was undertaken in the area corresponding to the biogeographic Amazonia (Amazon biome), covering an estimated 103,426 km², or 41.2% of the country's area. The study defines cumulative deforestation as that which took place between 1970 and 2000 and recent deforestation as the one recorded between 2000 and 2013.

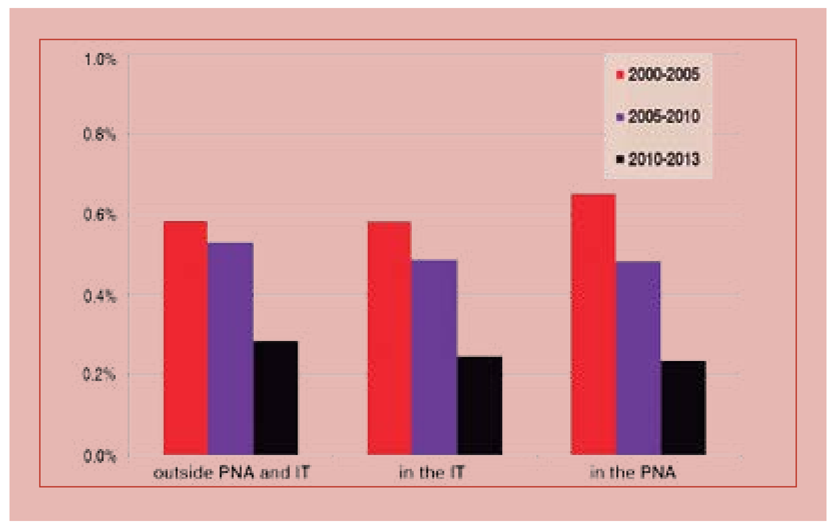
Historic and recent forest loss and deforestation rates

The total area of the biome, including 97,530 km² of original forest cover, was analyzed through satellite images from 2000. It is estimated that 10,470 km² of original forests were lost between 1970 and 2013. Deforestation before the base year (cumulative deforestation until 2000) reached 9,343 km², equivalent to 9.6% of original forests. Based on satellite image interpretation, forest loss between 2000 and 2013 (recent deforestation) reached 1,127 km². The loss of 487 km² during the 2001-2005 period was greater than the loss of 424 km² in 2005-2010 and the subsequent loss of 216 km² in the 2010-2013 period.

By 2013, Protected Natural Areas (PNAs) covered an area of 30,977 km² of the biogeographic Amazonia (31.8%). Based on satellite images from 2000, some 29,090 km² were identified as covered by forests in PNAs (Table 1). In this year, cumulative deforestation in PNAs (1970-2000) reached 500 km². Between 2000 and 2013 (recent deforestation), forest loss in these areas reached 398 km². Forest loss was higher in the first period (2000-2005) with 190 km² lost, while the following period (2005-2010) reached 140 km², and in the most recent period 68 km² were recorded in only three years.

Additionally, by 2013, the Indigenous Territories (IT) covered an estimated area of 62,474 km² of the Ecuadorian biogeographic Amazonia (60.4%),

Figure 1. Recent deforestation in the Ecuadorian Amazonia, inside and outside of PNA and IT



Map 1. Deforestation in the Ecuadorian Amazonia

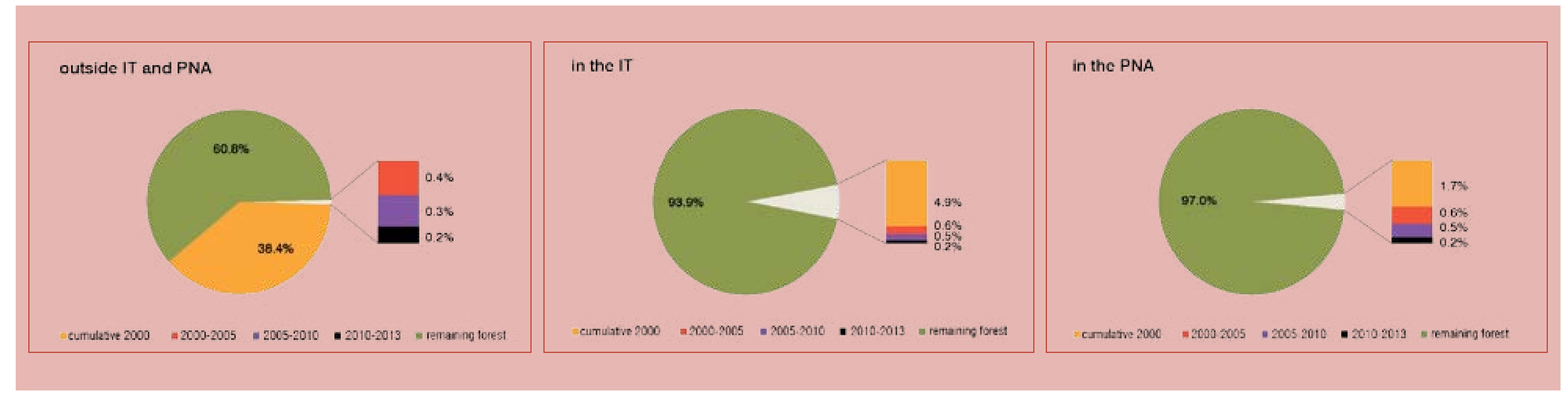
Table 1. Deforestation in the Ecuadorian Amazonia

	Surface of original forest cover[1]	Cumulative deforestation until 2000	Deforestation rate 2000-2005	Deforestation rate 2005-2010	Deforestation rate 2010-2013	% of the original forest 2000-2013	% of the original forest Cumulative total
	km²	km²	km²	km²	km²	%	%
Ecuadorian Amazonia	97,530	9,343	487	424	216	1.2	10.7
Outside PNA and IT	23,026	8,836	83	75	40	0.9	39.2
Indigenous Territories[2]	60,240	2,924	334	278	140	1.2	6.1
Traditional occupation without recognition	48,701	1,049	281	218	115	1.3	3.4
IT officialy recognized	11,539	1,875	53	60	25	1.2	17.4
Protected Natural Areas[2]	29,590	500	190	140	68	1.3	3.0
national-indirect use	29,590	500	190	140	68	1.3	3.0

[1] Original forest cover refers to forest formations within the biogeographic limit of the Amazon, within which exist non-forested areas, like enclaves of savannas or fields. For the evaluation of deforestation only originally forested areas were considered.

[2] The situation of existing ITs and PNAs was considered in December 2013.

Figure 2. Distribution of deforestation in the Ecuadorian Amazonia



with an estimated 60,240 km² being originally forest cover. Based on analysis of satellite images it was determined that forest cover in ITs in 2013 covered 56,564 km² (35.1% of forest loss in the biogeographic Amazonia till 2013), with an estimated forest loss of 3,676 km² between 1970 and 2013. Between 2000 and 2013 (recent deforestation) forest loss in these areas reached 752 km², distributed in a decreasing manner over time periods as follows: 334 km² between 2000 and 2005, 278 km² between 2005 and 2010, and the remaining 140 km² in the three year period between 2010 and 2013 (Table 1).

In Ecuador's biogeographic Amazon, three hydrographic units (order 3) had lost more than 15% of their original forest cover by 2013: Marañón (Numbaia), Santiago, and Putumayo (Table 2). The combined loss of these three units represents 54.2% of the total loss in the period. The two sub-basins with the greatest deforestation (Marañón and Santiago) are located in the extreme south of the Ecuadorian Amazon. The third sub-basin (Putumayo), is located in the extreme north (border with Colombia). In the 2000-2005 period, the sub-basins with the highest forest loss were Napo and Putumayo, both in the northeast sub-region. In the following period, 2005-2010, deforestation decreased in three sub-basins (Napo, Numbaia, and Tigre), remained the same in one (Santiago), and increased in the remaining three (Morona, Pastaza, and Putumayo). Between 2010 and 2013, the sub-basins with the highest deforestation areas recorded were the northeast and central sub-regions of the Ecuadorian Amazonia (Napo, Putumayo, and Pastaza).

Historical context of deforestation

To safeguard Ecuadorian sovereignty in a territory involved in an international dispute, a "living borders" policy promotion was introduced around the middle of the 20th century, reflecting an existing perception of the Amazonia being an empty space. This concept was later defined as vacant lands, taking up the policy of the Brazilian dictatorship known as "Land without people for People without land"[2]. State policies fostered agrarian reform (1964) and the colonization of the Amazonia rainforest (1973), the expansion of extractive frontiers, a market economy and a policy of "integrationist indigenism", the latter to the detriment of the identity, culture, and territory of Amazonia populations. Within this context, a black market for land, and the indiscriminate timber exploitation and selective logging of Amazonia forests arose in what came to be known as "frontier societies". However, the factor that decisively transformed the natural and cultural landscapes of the Amazonia was the exploitation and transport of crude oil in the northeast of the Ecuadorian Amazonia Region (EAR), beginning in 1967 when the Lago Agrio 1 well started pumping out crude. The process continued on until the consolidation of today's oil-rich sub-region in 1987[3].

Until the mid-nineties, the occupation of "vacant lands" had to follow official guidelines to ensure the possession and subsequent titling of the land, which required the clearing of up to half the farm (50 ha) to show "work" that generated rights of exclusion of forest use, under the concept of "land for deforestation". The process started with selective harvesting of timber species in high demand in the formal market or in illegal traffic circles. One of the determining factors was the construction of roads, which facilitated access to the market and reduced the costs of exploitation and transport time. The process continued with the establishment of permanent or short-cycle crops for self-subsistence, and later the establishment of paddocks for extensive cattle ranching without major management practices from the colonist or mestizo sector. On the other hand, indigenous maintained their primary production subsistence patterns, with little cattle ranching on their lands, possibly with the exception of some Shuar centers in the Upano valley south of the EAR, and the Kichwa cooperatives in the higher Napo, north of the region.

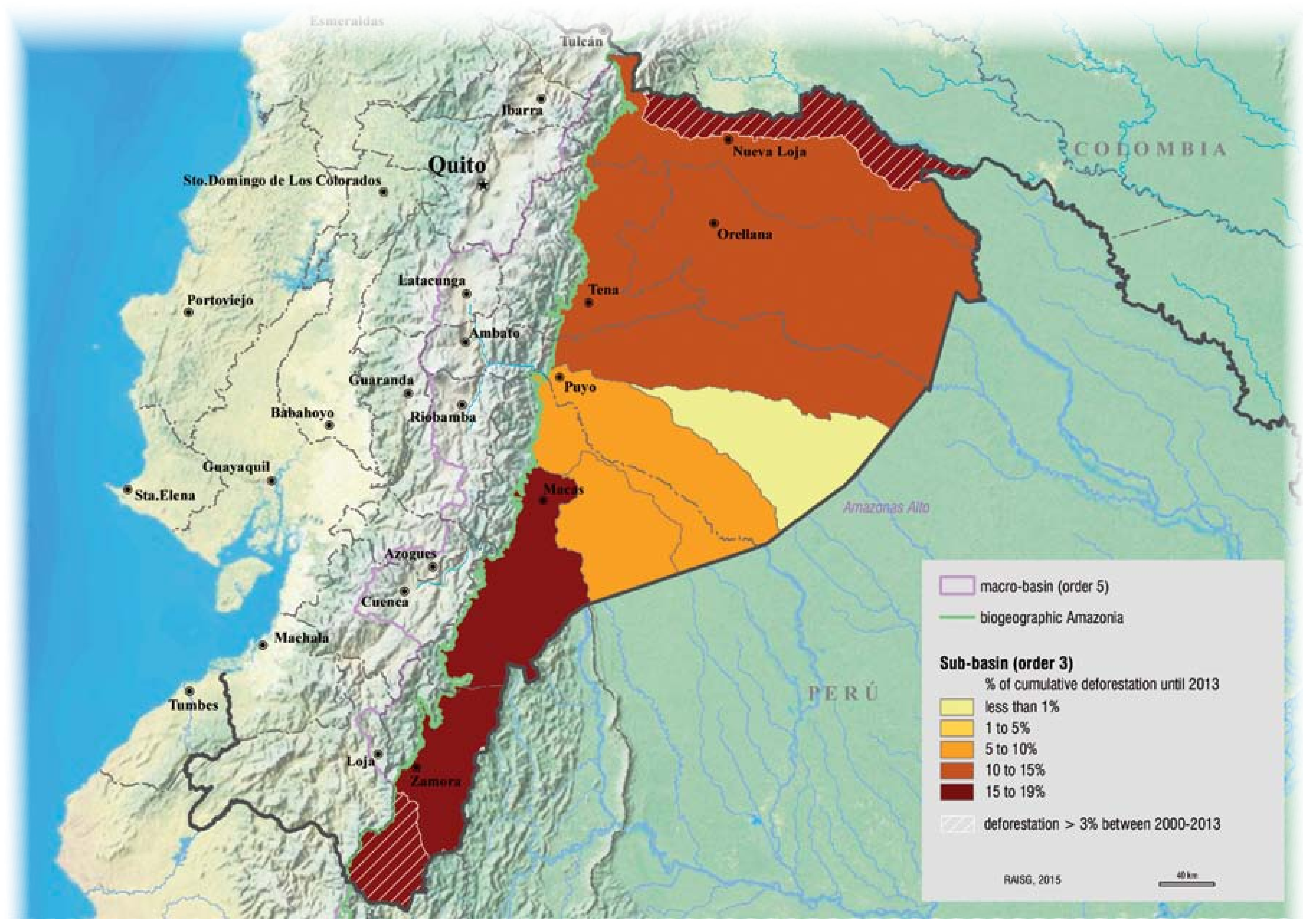
Given the rapid advance of the extractive (non-renewable resources and logging) and unsustainable agricultural frontier during the seventies and eighties, conservation policies for biologically important areas were established, aiming for the creation of protected natural areas, beginning with the foothills and the upper rainforest, and following with the lower rainforest. Meanwhile, the indigenous sector pressured for collective territorial rights under a new approach, quite different from the community land tenure regime defined by the agrarian reform and colonization laws as well as the Communities' Law of 1937 and its more recent codes[4]. While it is clear that these areas halted relatively the expansion of deforestation in biologically or culturally important zones, recent studies show there is forest loss in the PNAs and forest degradation is on the increase in indigenous lands and territories[5, 6,7].

More than two thirds of the deforestation in the last two decades took place in the 1990-2000 period, where an annual national net deforestation rate of 0.88% was recorded, while the following decade saw it decrease to 0.56%,

Table 2. Cumulative deforestation in the Ecuadorian Amazonia by sub-basins (basins larger than 500 km²)

Sub-basins (order 3)	Surface of original forest cover	Cumulative deforestation until 2000	Deforestation by period			% of the original forest	
			2000-2005	2005-2010	2010-2013	2000-2013	Cumulative total
	km²	km²	km²	km²	km²	%	%
Marañón (Numbaia)	2,877	436	60	28	23	3.8	19.0
Santiago	13,709	2,428	34	33	17	0.6	18.3
Putumayo/Içа	5,221	600	75	78	33	3.6	15.1
Napo	49,087	4,752	224	166	84	1.0	10.6
Pastaza	11,853	862	48	56	30	1.1	8.4
Marañón (MA) (Morona)	6,043	258	20	39	14	1.2	5.5
Tigre	8,733	8	26	23	15	0.7	0.8

Map 2. Sub-basins with the greatest proportional deforestation



as indicated by a recent study based on information provided by MAE (2013)[8]. This study of the Sierra suggests that only two provinces registered an increase in their annual net deforestation rate in both periods at national level. One such being the Amazonia province of Morona Santiago, the data being consistent with the regional studies referred to before, and clearly linked to road construction in a province with low road density until 2007.

The advance of *minifundios* (smallholdings) in the region was confirmed, with a record 108,707 agriculturally productive unites (APU), registered for an area of 988,229 ha – an average of 9 ha per APU – per the National Agricultural Research Institute (INIAP)[9]. The same study also shows that the crop loss area (difference between area planted and the area harvested) reached worrying levels. Together, these two bring forth a loss in cost effectiveness and a decrease of family income, exacerbating rural poverty in the EAR. Early and recent deforestation are the environmental correlative to these boom and bust cycles fueled by the price of "risk commodities" in the forest, especially in the international raw materials market [10].

As a conclusion, it can be said that the present study shows that by 2013, the estimated forest loss area reached 10,470 km², or 10.7% of Ecuador's Amazonia biome. The forests area remaining by the same year equals87,060 km², which corresponds to 89.3% of the original forest cover of the country's biogeographic Amazonia.

Direct and indirect causes of recent deforestation

Changes in land use and the loss of vegetation cover have configured spatial patterns of deforestation, particularly alongside the access roads opened to facilitate exploration, extraction, and transport of crude in the northeastern EAR. Taking into account these practices, colonization lines (1st, 2nd, 3rd line, etc.) for timber exploitation and non-sustainable agricultural production were determined, using a "fish spine" pattern. At the extreme western and southern edge of the EAR, rivers allow, under a "multimodal" primary extraction scheme, the illegal movement of undetermined volumes of timber (selective logging), from their source to a transitable or passable road alongthe border with Colombia and Peru. In the south central area of the EAR, colonization and agrarian reform policies from the mid-1950s sought to consolidate settlements and agricultural units with landless farmers from the coastal and Andean regions, particularly in the better and more accessible lands of the Upano, Santiago, and Morona valleys. Left to the traditional subsistence economy of indigenous peoples were the the Cóndor and Kutukú mountain ranges, as well as the flood plains of the southeast (Trans-Kutukú).

The RAE's land and aquatic ecosystems and local populations face threats and pressures linked to the access and control of the Amazonian space, its resources, and population. They are also linked to the extractive economic specialization assigned to the Amazonia and to the transfer of rural poverty – through colonization and agrarian reform – from regions affected by land scarcity, overexploitation and smallholdings, or by extreme environmental deterioration (like certain Andean valleys and dry coastal forests). The impacts of the occupation of the contemporary Amazonia are relatively recent (beginnings of the 20th century in the central and southeast Amazonia and 1967 in the northeast), and have transformed the natural and cultural landscape of the indigenous Amazonia prior to the waves of change historically recorded. To halt these impacts, a series of environmental, conservation and safeguarding policies have been implemented regarding the environment, conservation, and safeguarding of peoples or groups in voluntary isolation, although with questionable results.

Both the oil (oriented to crude oil export) and the agrarian reform and colonization policies favored timber exploitation and promoted changes in land-use practices. The opening of the extractive frontiers (for mining, hydrocarbons, and timber) required the construction of access roads, which favored the expansion of demographic frontiers (colonization) and the consolidation of market spaces (cities). Given that the Amazonia soils are fundamentally apt for forests, changes in soil-use and vegetation cover imply a deterioration of the ecosystems and limits the cost effectiveness of agricultural production systems, as the climatic constraints of the different sub-regions are very difficult to overcome.

Finally, the decrease in deforested area recorded by different units of analysis can be mainly explained by the depletion of forest resources in these areas, whereas their increase in other units of analysis corresponds to the expansion of extractive frontiers, be it through agro- industrial (African palm) or hydrocarbon and mining activities. Such situations have been recorded on the new extractive frontiers throughout all biogeographic areas of the Amazonia provinces.

Future scenarios

The expansion of the petroleum frontier within intangible zones (IZ), indigenous territories (IT), and protected natural areas (PNAs) is an imminent threat associated to the State's latest policy decisions to begin the exploitation of the ITT block in the Yasuní National Park and the Tagaeri-Taromenane IZ, both inhabited by extremely vulnerable indigenous groups in voluntary isolation[11]. Further, the tender for the XI Oil Round of the South East is underway. It represents a potential threat to the EAR center south, where the Pastaza and Morona ITs still have forest cover (although human ecology studies record high degradation in the forests due to primary extraction, and in aquatic ecosystems). Thus, pressure is increased on a sub-region of great importance given its large socio-environmental diversity (headwaters of the Pastaza, Tigre and Morona rivers). The State's expectation, and that of the interested companies, is to expand the oil exploitation frontier, from the northeast and into the Achuar, Andoa, Sapara, Wao, Shiwiar and Kiwchwa of Pastaza indigenous territories, where paradoxically, there is only one protected forest and not a single State natural heritage unit (PANE). Should this take place, the foreseeable construction of oil roads, camps and urban markets would add to the factors encouraging forest degradation and deforestation in tropical areas.

Another identified threat includes the expansion of large-scale mining frontiers in the center south provinces of the EAR (Morona and Zamora). But the most serious threat to environmental management and energy security is the one posed by the power lines (up to 500 kV), required for the transmission of electricity generated by hydroelectric projects currently under construction. A threat mostly due to the rigidity of the easement strip requirements (rights of way and service), and its potential impacts on settlements, agriculture units, natural heritage and protective forests. The environmental impact studies for these lines and their layout design require and deserve an informed debate with the public, well beyond simple management and communication tools.

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DEFORESTATION in the PERUVIAN AMAZONIA

Infrastructure investments will determine the more vulnerable areas for the next decades

The Peruvian Amazon, located in the eastern portion of Perú, covers 783,000 km², comprising 60.9% of the country's land area. The gradient of ecological floors between the Andes and the Amazonia plain give origin to a varied mosaic of ecosystems housing a vast diversity of high-value species, both flora and fauna, making them a conservation priority at the local, regional, national and global levels.

Historic and recent forest loss and deforestation rates

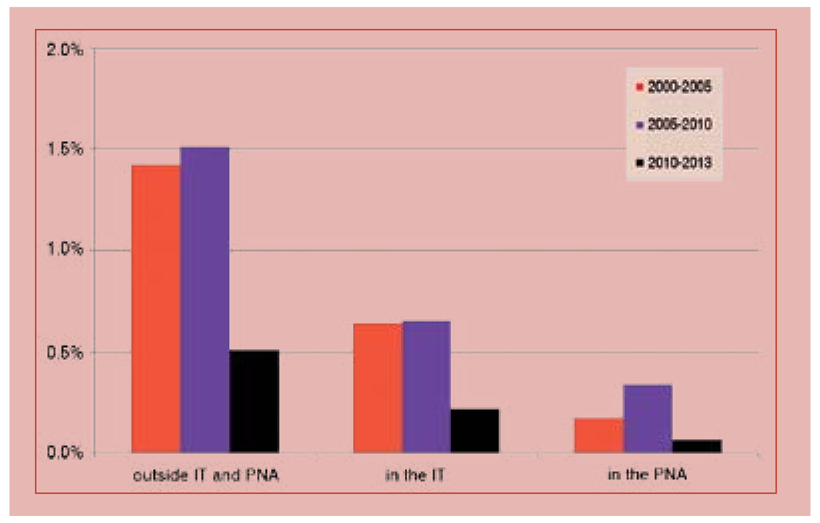
It is estimated that 8.7% of forest cover (~56,000 km²) was lost by the year 2000. Between 2000 and 2013, forest loss reached 16,000 km². (Table 1, Map 1).

By 2013, Protected Natural Areas (PNAs) comprised 23.7% of the Peruvian Amazonia (~188,600 km²). By 2007, 4,000 km² were lost to forest deforestation (7.0% of the total deforestation that took place in 2000). Between 2000 and 2013, PNAs lost more than 1,000 km² of forest (7.0% of the total deforestation of the Peruvian Amazonia that took place in this period). Altogether, by 2013 the PNAs of the Peruvian Amazonia had lost close to 5,000 km² of forest cover to deforestation, corresponding to 6.8% of the total area of deforestation of the Peruvian Amazonia during the period, or 2.5% of the total area of the PNAs in 2013.

By 2013, the Indigenous Territories (ITs) registered in the database of the Native Communities of the Peruvian Amazonia Information System (SICNA-IBC) comprised 26.1% of the Peruvian Amazonia (~205,750 km²). Close to 6,000 km² of forest in ITs were lost to deforestation by 2000 (11.4% of the total deforestation that took place in 2000). Between 2000 and 2013, ITs lost more than 3,000 km² of forest (19.0% of the total deforestation that took place in the same period in the Peruvian Amazonia). In total, by 2013, TIs in the Peruvian Amazonia lost more than 9,000 km² of forest to deforestation, corresponding to 13.0% of the total deforestation that took place in the Peruvian Amazonia in the same period.

Deforestation trends in ITs and PNAs vary between 2000 and 2013. While ITs show decreasing numbers (1,282 km² between 2000 and 2005; 1,292 km² between 2005 and 2010; 428 km² between 2010 and 2013), PNA numbers fluctuate from one period to the next (319 km² between 2000 and 2005; 625 km² between 2005 and 2010; 120 km² between 2010 and 2013).

Figure 1. Recent deforestation in the Peruvian Amazonia, inside and outside of PNA and IT



Map 1. Deforestation in the Peruvian Amazonia

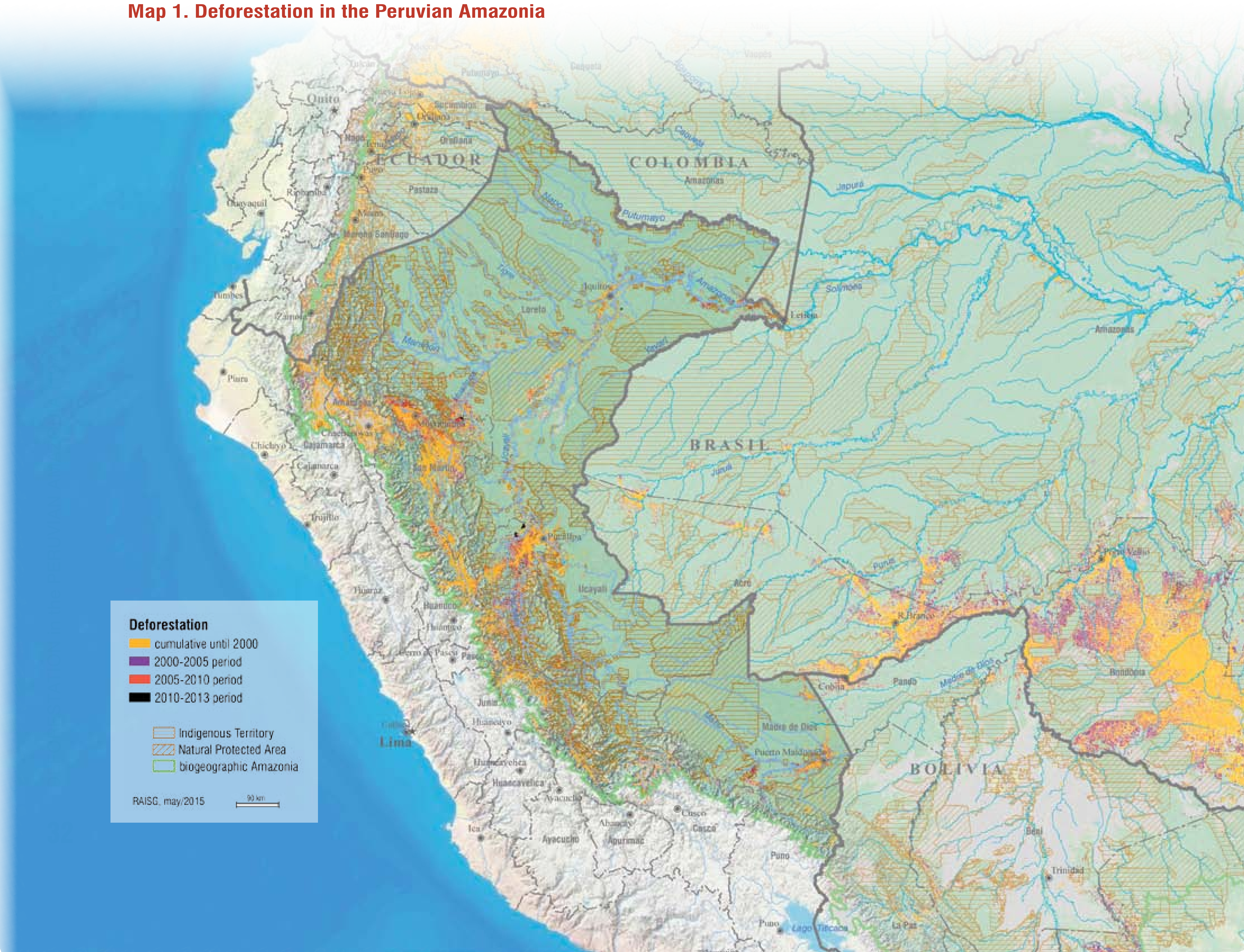


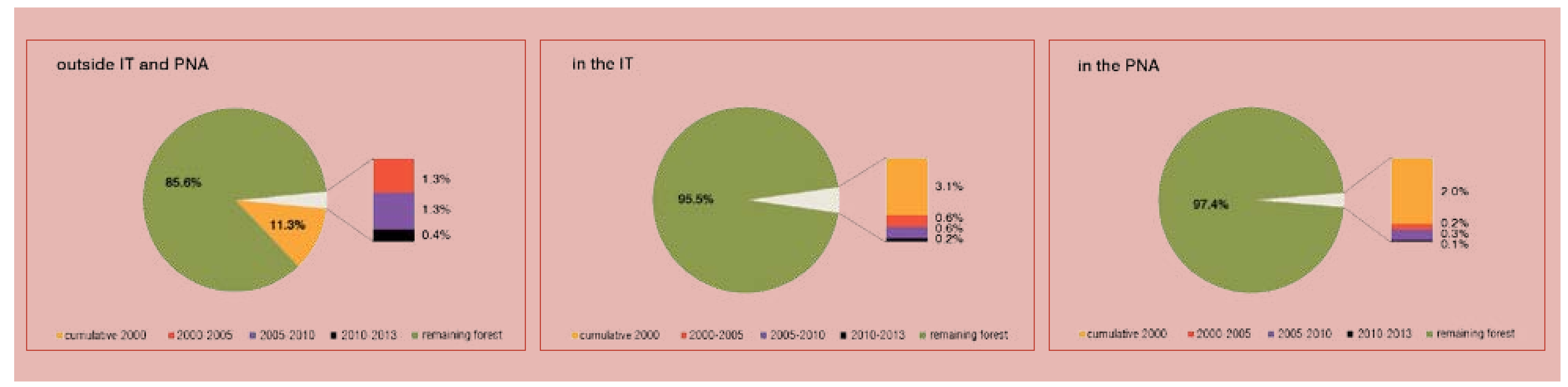
Table 1. Deforestation in the Peruvian Amazonia

	Surface of original forest cover[1]	Cumulative deforestation until 2000	Deforestation rate 2000-2005	Deforestation rate 2005-2010	Deforestation rate 2010-2013	% of the original forest 2000-2013	% of the original forest Cumulative total
	km²	km²	km²	km²	km²	%	%
Peruvian Amazonia	792.999	55.649	6.680	7.225	2.306	2.0	9.1
Outside PNA and IT	404.103	45.856	5.105	5.353	1.771	3.0	14.4
Indigenous Territories[2]	205.750	6.328	1.282	1.292	428	1.5	4.5
Traditional occupation without recognition	12.978	308	45	43	23	0.9	3.2
Proposed Territorial Reservationl	39.656	334	21	37	15	0.2	1.0
Territorial Reservation	29.246	199	26	33	5	0.2	0.9
IT officialy recognized	123.869	5.487	1.189	1.179	385	2.2	6.7
Protected Natural Areas[2]	188.599	3.858	319	626	120	0.6	2.6
national-direct use	81.167	2.120	199	368	84	0.8	3.4
national-indirect use	78.209	1.545	92	224	26	0.4	2.4
national-transitional use	29.223	193	29	34	10	0.3	0.9

[1] Original forest cover refers to forest formations within the biogeographic limit of the Amazon, within which exist non-forested areas, like enclaves of savannas or fields. For the evaluation of deforestation only originally forested areas were considered.

[2] The situation of existing ITs and PNAs was considered in December 2013.

Figure 2. Distribution of deforestation in the Peruvian Amazonia



The Peruvian Amazonia contains 28 level 3 sub-basins according to the RAISG classification. The river basins that have lost in absolute terms, the largest percentage of their original forest cover are the Upper Marañón (33.2%), Huallaga (23.3%), Apurímac (22.8%) and Pachitea (22.7%). For the 2000-2013 periods, the basins that lost the highest percentage of their cover are those of the Marañón (11.1%), Santiago (9.6%), Pachitea (8.2%), and Lower Yavarí (6.4%) rivers. (Table 2, Map 2).

Historic context of deforestation

The Amazonia began entering the Peruvian consciousness towards the end of the 19th century, during the rubber boom. The harvest of this sap, indispensable for the manufacturing of tires for the growing automobile industry, triggered the industrial-scale exploitation of rubber in the Peruvian rainforest.

The center of commerce for rubber in Perú was the city of Iquitos, closely linked to a marketing chain that used the Amazon River, exporting through the river to the European and United States markets. This economic boom allowed an enormous accumulation of wealth which regrettably relied on the slave-like labor of indigenous peoples.

Beginning in 1910, the demand for Amazonia rubber declined in the face of competition by the British plantations from Malaysia. Since then, boom and bust cycles have characterized the Peruvian Amazon's economy. Resources like rosewood, jute, cinchona, gold, timber and oil have fed these cycles, without any of the wealth leading to sustainable investments and employment in the region.

From the 1940's onward, roads construction and improvement in the Selva Central region attracted waves of migration by Andean settlers, who saw the Amazonia as a rich and empty land. State policies encouraged settlers' migration to help expand the agricultural frontier. The logging and the burning of forests were seen as civilizing actions.

The 1950's saw the birth of a timber industry in Oxapampa (Selva Central Region) where modern technology imported from Germany was used by more than two-dozen sawmills. Regrettably, the concept of sustainable forest management did not take hold in the industry until the late 1990's. By then, the forests of the Selva Central had suffered from the combined impact of agriculture and logging, with only two small sawmills left active in Oxapampa. However, despite this, the Oxapampa model of timber industry was exported to other forest areas.

Between the 1970s and 1980s, president Belaunde believed the Amazonia had infinite agricultural possibilities and potential for settling the natural overflow of Andean populations. This vision propelled the construction of the Carretera Marginal highway, which would cross the eastern flank of the Andes from north to south, integrating a series of access roads. However, this initiative did not lead to the much-anticipated profitable and sustainable agriculture dreamed of by Belaunde and others.

Decades of colonization brought on a new crisis for the Amazon's indigenous peoples. In 1969, the indigenous organization of the Yánesha people – the first of its kind – submitted a Claim to the President of Perú, demanding recognition of their rights and guarantees to their territories. Titling of the Amazon's indigenous communities began in 1974, following the approval of the Law on Native Communities and Agrarian Development for the Jungle Regions of Perú. Since then, more than 1,300 indigenous communities have been granted property titles for almost 130,000 km².

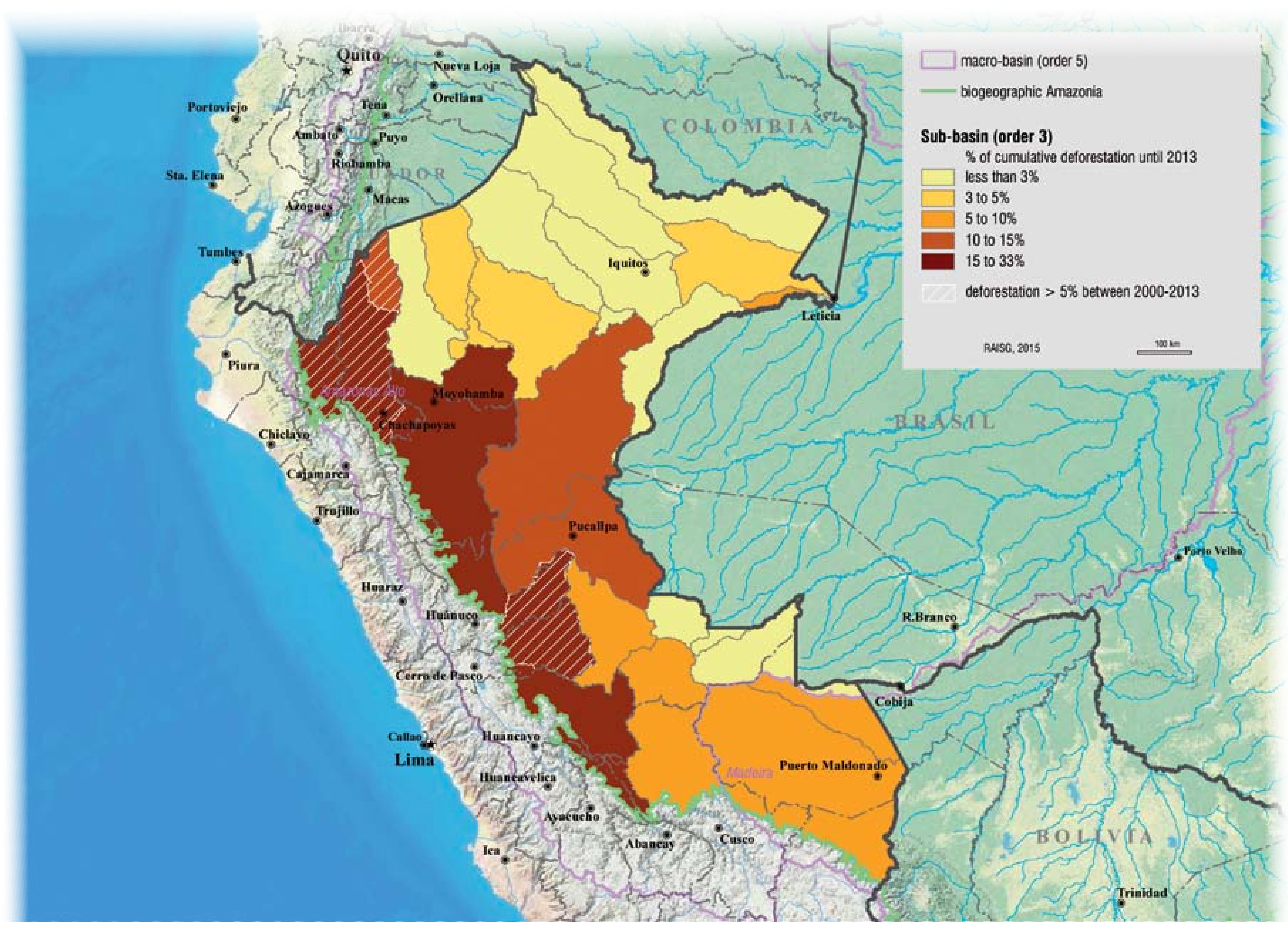
During this period, the State promoted Special Projects (SP) in the Peruvian Amazon, complementary to road construction. These projects sought to increase agricultural production levels through the distribution of technology packages and training for settlers. A first change came in 1982, when the Pichis Palcazú SP applied a new approach to the management of timber and non-timber forest resources, agroforestry systems, and to the work done with indigenous communities and the populations that had settled the area for many generations.

Regrettably, in the 1980s and 1990s these special projects turned into cocaine paste production areas, linked to drug traffic and guerrilla

Table 2. Cumulative deforestation in the Peruvian Amazonia by sub-basins (basins larger than 500 km²)

Sub-basins (order 3)	Surface of original forest cover	Cumulative deforestation until 2000	Deforestation by period			% of the original forest	
			2000-2005	2005-2010	2010-2013	2000-2013	Cumulative total
	km²	km²	km²	km²	km²	%	%
Alto Marañón	34,080	7,563	1,382	1,745	639	11.1	33.2
Huallaga	76,521	17,191	188	322	108	0.8	23.3
Apurímac	4,882	956	61	72	26	3.3	22.8
Pachitea	26,869	3,892	1,032	794	385	8.2	22.7
Mantaro	2,493	449	13	17	4	1.3	19.3
Tambo	24,394	3,671	408	206	71	2.8	17.9
Santiago	7,808	93	248	360	139	9.6	10.8
Bajo Ucayali	108,256	8,693	1,018	1,021	392	2.2	10.3
Alto Ucayali	21,348	1,278	218	173	68	2.1	8.1
Madre de Dios	83,749	3,277	675	771	87	1.8	5.7
Urubamba	42,200	1,730	236	337	83	1.6	5.7
Tahuamanú	15,101	591	106	92	14	1.4	5.3
Medio Yavarí	2,852	57	33	52	9	3.3	5.3
Pastaza	18,461	444	152	304	20	2.6	5.0
Bajo Amazonas	28,386	793	216	325	66	2.1	4.9
Medio Marañón (I)	35,792	1,433	83	153	25	0.7	4.7
Medio Marañón (II)	4,005	164	2	4	0	0.1	4.2
Napo	41,255	956	145	81	22	0.6	2.9
Medio Marañón (III)	25,449	540	58	85	24	0.7	2.8
Alto Amazonas	26,969	384	139	76	66	1.0	2.5
Tigre	34,011	539	81	51	10	0.4	2.0
Purús	22,192	269	42	65	7	0.5	1.7
Bajo Marañón	2,022	5	12	11	6	1.5	1.7
Juruá	9,719	125	14	6	3	0.2	1.5
Alto Yavarí	22,327	245	20	27	10	0.3	1.4
Putumayo/Iça	44,372	295	83	66	19	0.4	1.0
Tarauacá	2,566	8	0	1	0	0.1	0.4

Map 2. Sub-basins with the greatest proportional deforestation



movements. To this day, this illicit crop is still cultivated in the departments of San Martín, Huánuco, Junín, Ayacucho, Cusco and Puno.

Beginning in 1990, Peruvian civil society pressured the State to identify unique forest areas in the Amazonia for conservation as protected natural areas (PNAs). That same year, Peru's National System of Protected Areas (SINANPE) was created. Over the last 25 years, 39 PNAs were created in the Peruvian Amazon, covering more than 188,000 km². These units succeeded at slowing down colonization and the accelerated rate of increase of deforestation in some areas.

Direct and indirect causes of recent deforestation

The development of the Peruvian Amazonia in the last seventy years has been guided by an agrarian vision that considers the forests as an obstacle for agricultural development. Many sources concur that agriculture and cattle ranching are the main direct causes of deforestation in Perú[1, 2,3].

The extensive cultivation of coca, both legal and illegal for drug trafficking, causes deforestation of vast extensions. According to the UN, coca growing occupies close to 55,000 ha annually. The Peruvian State has been unable to reduce the total area used for coca growing. Until very recently, the development of large-scale agro industrial plantations in the Peruvian tropical forests was insignificant. However, in 2009 the regional government of Loreto granted in concession more than 7,000 ha of primary forests to the Romero Group for the cultivation of African palm. Since then, the number of requests for concessions for the cultivation of palm and cacao has increased dramatically[4,5].

The historical analysis of deforestation in the Peruvian Amazonia prepared by the *Instituto del Bien Común* (IBC) in the context of RAISG shows that the highest rates of deforestation are found in 20 km wide strips stretching along both sides of the main roads. This impact is evident along the northeastern interoceanic corridor, the Carretera Marginal of the southern rainforest, and the IIRSA-South highway connecting Cusco and Madre de Dios with Brasil. The expectation of a new road alone is sufficient enough cause to create pressure on the lands and forests along its projected route.

The previously mentioned agrarian vision that permeates the concept of economic development at State level is in contradiction with the role of custodian that the Peruvian forestry legislation assigns to the same State. Even though the Forestry Act of 2001 created the Permanent Production Forest category to promote its sustainable use, the forestry sector soon lost what little control it had on logging. On the other hand, in 2010 the Ministry of Environment launched the National Program of Forest Conservation for the Mitigation of Climate change, which intends to conserve 540,000 km² of forest.

Due to its selective nature, timber exploitation is not considered a direct cause of deforestation, but rather, of forest degradation. It is estimated that the area affected in Perú by degradation through selective logging is as wide as the area deforested5. Further, roads opened for timber extraction also serve as penetration and access roads for settlers. In general, activities like mining, hydrocarbon extraction and infrastructure construction do not directly generate large deforested areas in Perú's Amazon.

Future scenarios

IBC's deforestation analysis reveals that 89.5% of the 782,820 km² of the Peruvian Amazonia was covered by forests in 2000. During the 2000-2005 period, 6,680 km² were deforested, and an additional 7,225 km² between 2005 and 2010. In these ten years, 2% of the Peruvian Amazonia rainforest was been lost. A conservative projection suggests that by 2020 another 16,330 km² of Amazonia rainforest will be deforested.

According to Dourojeanni[1], there is a long list of projects to be developed in the Peruvian Amazonia between 2009 and 2021:

- 54 hydroelectric plants, which would produce 24,500 MW, of which 26 would be located in Amazonia rainforests and would add an as yet undetermined number of kilometers of electric transmission lines.
- 53 oil blocks with 353,000 km² in concessions, with seismic tests already carried out on 10,659 linear km (with 8,6890 new linear km more planned) and where 648 exploratory wells have been drilled (with 90 new wells planned).
- 7,455 km of improved roads, 880 km of new roads, and 2,089 km of paved roads.
- 7 proposals for access railways in the Peruvian Amazon.
- 6 proposals for waterways with 4,213 km of length.
- 51 proposals for investment in biofuel in an area of 4,835 km².
- 584 contracts on 1,182 units of forest management, for a total of 73,000 km².

Dourojeanni's projections for 2021 are alarming: he estimates there will be more than 430,000 km² impacted by deforestation and degradation.

In light of this scenario, what role do the 188,599 km² of protected natural areas and the 205,750 km² of indigenous territories play? PNAs and ITs as a group are very important for the conservation of forests in the Amazon. The deforestation analysis done by IBC shows that in the year 2000 forests in these units covered 384,163 km². During the 2000-2005 period 1,601 km² were lost, 1,918 km² in the next five years, and 548 km² between 2011 and 2013.

An improvement on the management of the national system of protected natural areas is to be expected as a result of the international commitments assumed by Perú and through the support it is receiving. In this context, a highlight is the National Program of Forest Conservation's goal to reduce net deforestation to zero in 10 years, with an emphasis on the creation of PNAs and the conservation of forests in demarcated indigenous territories.

The inhabitants of the Amazonia region demand basic services like water, sanitation systems, electricity, education and health from the State. It is possible these demands could justify the deforestation of some areas of the Amazonia in the name of development. The question stands:what area of forest must be sacrificed?

Efforts to improve the management of protected natural areas and indigenous territories must be articulated with larger scale efforts, seeking a paradigm change in the national development model. Such a model should value the environmental services of the PNAs and ITs, and also consider the integration of these spaces into municipal, regional, and basin development plans so as to take advantage of the natural capital through inclusive government systems and sustainable development.

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DEFORESTATION in the VENEZUELAN AMAZONIA

Data shows growing deforestation, and it is expected that 2010-2015 will be the worst period yet

Based on biogeographic, hydrologic, and political-administrative criteria[1,2,3,4], the Venezuelan Amazonia encompasses three states: Amazonas, Bolívar and Delta Amacuro. With an approximate area of 469,000 km², this region comprises around 52% of the country's land area, and is characterized by the great diversity of its biological communities, a large numbers of endemic species[1, 5,6], and predominant forest vegetation[7]. From a geological viewpoint, the largest unit in the Venezuelan Amazonia is the Guiana Shield, one of the oldest formations in the planet marked by granite table-top mountains known as *tepuis*[8].

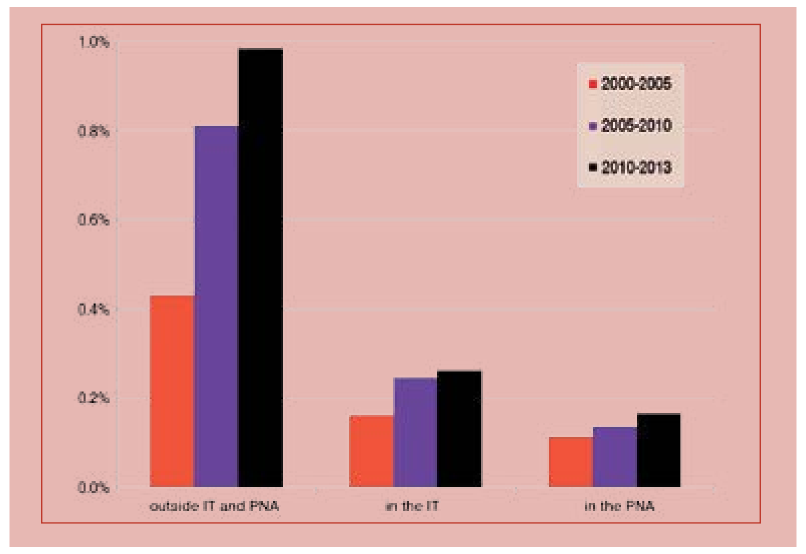
Historic and recent forest loss and deforestation rates

By 2000, Venezuela's Amazonia rainforests spanned almost 398,000 km², the largest extension of forest in the country[9] and 85% of Venezuela's territory. Deforestation was greatest north of the Orinoco River[9, 10,11,12], a zone where more than 94% of Venezuela's population resides[13]. It is estimated that the Venezuelan Amazonia had lost approximately 8,900 km² (2.2%) of its original forests by 2000. Between 2000 and 2013, deforestation reached around 4,150 km², or 47% of the cumulative loss up to 2000. Annual loss from August 2000 onwards has increased in each subsequent period (Table 1), as opposed to the general decrease in the Pan-Amazonia region.

Deforestation has not taken place uniformly. The largest forest loss took place outside of PNAs and ITs (Table 1 and Figure 1), with 6.3% of the original forest cover lost by 2013. The forest cover of this unit is the smallest of the Venezuelan Amazonia rainforest (28%). ITs come second in deforestation terms, with a loss of 2.3%. However, as mentioned earlier, forest loss is increasing in a sustained though heterogeneous manner in all three units in the three periods analyzed. For example, the loss in ITs was larger during the 2006-2010 period relative to the 2000-2005 period, while the PNA loss is proportionally larger in the 2010-2013 period than it was in the previous five years, showing an increase in the deforestation rate. It is worth nothing that in Venezuela, PNAs were all recognized by 1992, while the official recognition of ITs began only in 2005 in the Delta Amacuro state[1].

When assessing deforestation loss within each unit type, it can be observed that ITs, which encompass 67% of Venezuela's rainforest, had the largest proportional loss (2.4%) of their original forests by 2013. On the other hand, PNAs record a loss of less than 1% of their original forest area (Figure 2).

Figure 1. Recent deforestation in the Venezuelan Amazonia, inside and outside of PNA and IT



Map 1. Deforestation in the Venezuelan Amazonia

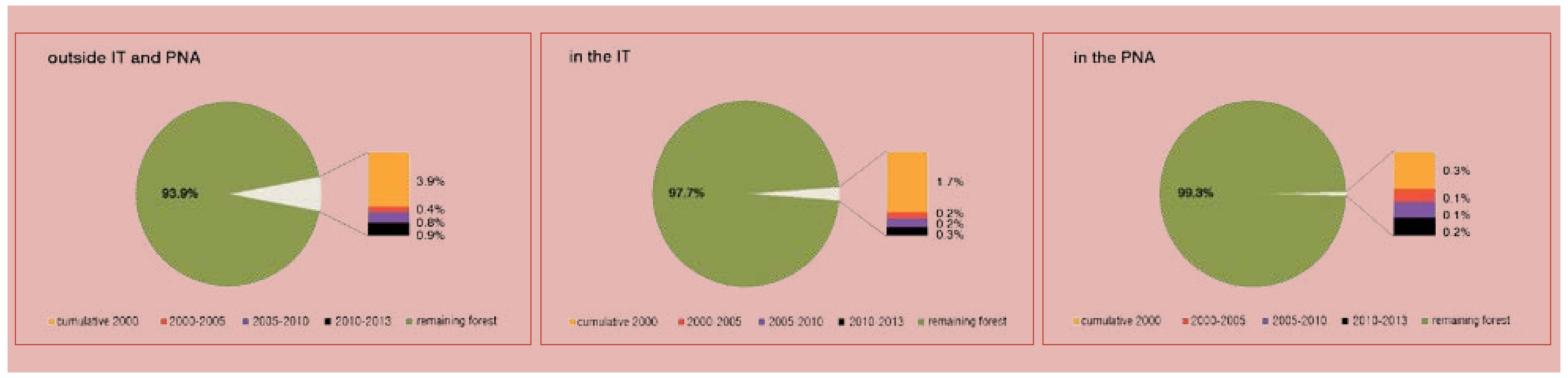
Table 1. Deforestation in the Venezuelan Amazonia

	Surface of original forest cover[1]	Cumulative deforestation until 2000	Deforestation rate 2000-2005	Deforestation rate 2005-2010	Deforestation rate 2010-2013	% of the original forest 2000-2013	% of the original forest Cumulative total
	km²	km²	km²	km²	km²	%	%
Venezuelan Amazonia	397,812	8,914	890	1,521	1,742	1.0	3.3
Outside PNA and IT	110,503	4,348	459	858	1,032	2.1	6.1
Indigenous Territories[2]	266,956	4,513	423	648	687	0.7	2.3
Traditional occupation without recognition	266,956	4,513	423	648	687	0.7	2.3
Protected Natural Areas[2]	155,089	511	178	211	254	0.4	0.7
national-indirect use	155,089	511	178	211	254	0.4	0.7

[1] Original forest cover refers to forest formations within the biogeographic limit of the Amazon, within which exist non-forested areas, like enclaves of savannas or fields. For the evaluation of deforestation only originally forested areas were considered.

[2] The situation of existing ITs and PNAs was considered in December 2013.

Figure 2. Distribution of deforestation in the Venezuelan Amazonia



However, the fact that PNA original forest loss happened mostly in the last 13 years, exceeding the cumulative deforestation loss prior to 2000 is concerning (Figure 2).

The cumulative deforestation amongst the region's sub-basins is not homogeneous (Table 2, Map 2). The sub-basins with the highest deforestation loss percentage are in the state of Bolivar, and the northern part of the state of Amazonas, which corresponds with traditional land occupation patterns. Those sub-basins concentrate both the state capitals, as well as the highest number of productive activities (agriculture, cattle ranching, mining, hydroelectric plants, road infrastructure, amongst others). Furthermore, deforestation has varied through time. In some sub-basins, the largest deforestation took place before 2000 (Table 2), namely, the Upper Orinoco B sub-basin, where bauxite and iron mines have been active for more than 30 years. The decrease in loss rate observed in the last 13 years in these sub-basins coincides with a drop in the production of both metals.

The forest loss in the Caroní B, Orinoco Mouth, Cuyuní and Caroní sub-basins between 2000 and 2013 and before 2000 were similar, indicating an accelerated recent deforestation rate. Despite the relatively low values of deforestation in the Orinoco Delta, Paragua and Orinoco sub-basins, there is cause for concern as the majority, if not all of the deforestation loss in those sub-basins took place after 2000. Furthermore, this loss is associated with illegal mining. Moreover, there has been an upturn in deforestation loss at the Guaviare sub-basin in the last three years, associated with illegal mining and incursions from illegal armed groups.

Historic context of deforestation

Forests were the predominant vegetation of Venezuela (evergreen forests, semi-deciduous and deciduous forests, among others)[15,11], covering more than 74% of the country[11]. Regrettably, information about deforestation is scarce, contradictory, and in many cases, restricted to isolated locations[10]. Amongst the data available at national level is the FAO's[16] data, according to which Venezuela lost 240,000 ha of forest a year between 1960 and 1970, showing an accelerating trend for the following decades (280,000 ha/year between 1970 and 1980, and 600,000 ha/year between 1980 and 1990), with a slowdown in the decrease rate between 1990 and 2000. According to these numbers, Venezuela's deforestation rate in the 1980s was double that of Brasil's, and three times larger than Perú's, positioning Venezuela as the tropical country with the highest rate of deforestation[17]. Pacheco *et al.*[11] point out existing variations in the estimates for the annual rates of deforestation in Venezuela between 1920 and 2001. According to the authors, the period of greatest deforestation was 1982-1995, with a rate of 0.93%, followed by the 1960-1982 with 0.73%, and 0.46% for 1995-2001. The lowest rate (0.02%) corresponds to the 1920-1960 period. Thus, both estimations broadly coincide.

An important aspect to consider is that the calculations for the rate of deforestation could have used different areas as a reference for the Venezuelan Amazon[3, 11]. In general, the entirety or partial area of the states of Amazonas, Bolívar and Delta Amacuro[18, 7,8,19, 9] are considered, but some authors[11] completely exclude the last state.

Much like the information available for the rest of the country, the data available regarding forest cover in Amazonian states is local and scattered in time (e.g.20). Bevilacqua *et al.*[10] report, using official sources, that the forest cover in 1995 was 18,242,552 ha in Bolívar, 16,556,408 ha in Amazonas, and 3,322,572 ha in Delta Amacuro. Based on this they estimated the annual deforestation rates for the 1982-1995 period as follows: 0.25% in Bolívar, 0.03% in Amazonas, and 0.11% in Delta Amacuro, values that are well below the national average rates for the same period[11].

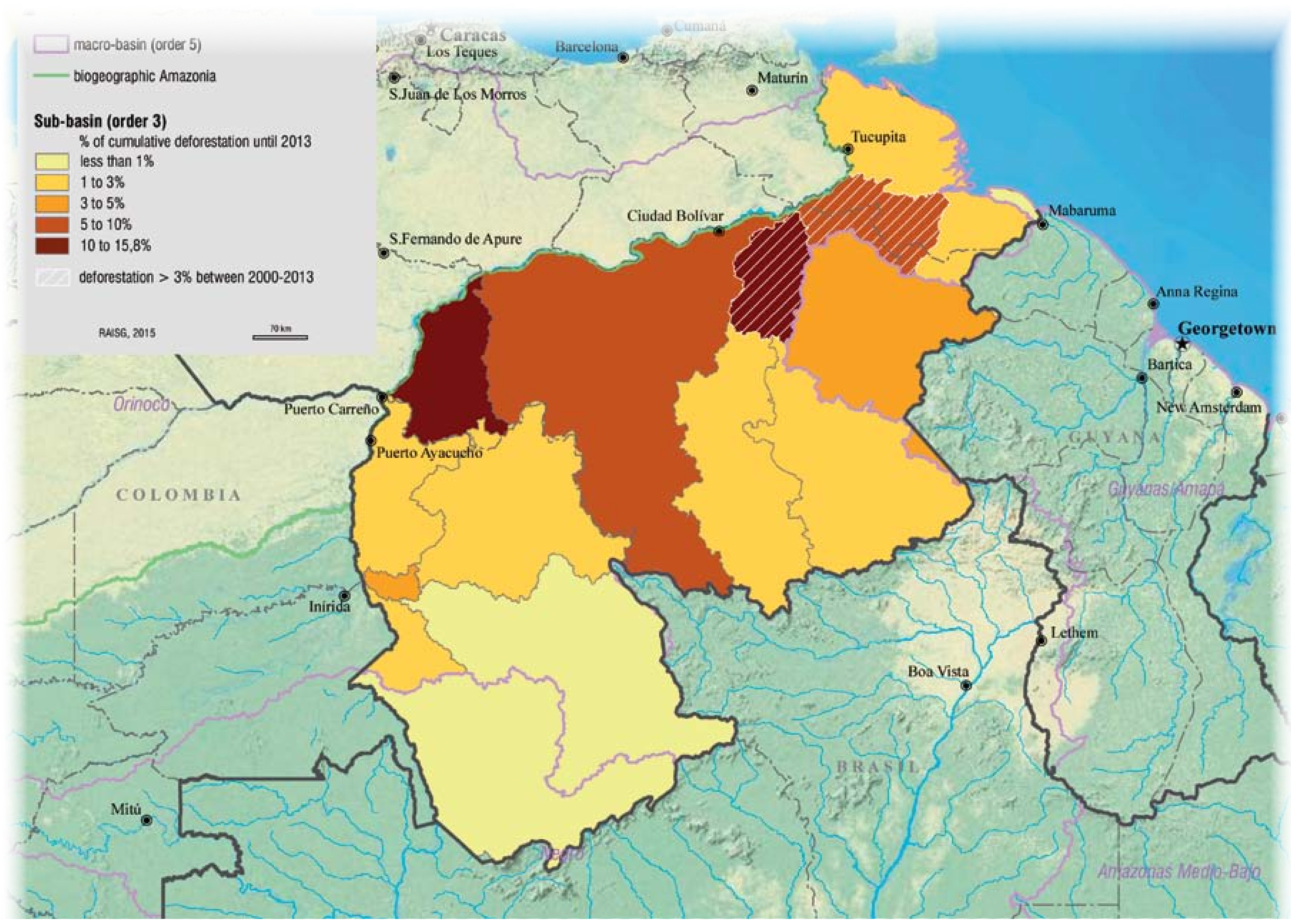
Low deforestation rates have been associated with this region's virtual isolation, which also influenced the late creation of protected areas, as for a long time they were considered unnecessary[21]. It took until 1961 for the first protected area in the Venezuelan Amazonia to be established: the Imataca forest reserve for timber production. The national parks and natural monuments considered in this analysis were established between 1962 and 1992, and encompass approximately 31% of the region (excluding spatial overlap).

Up to 2000, the major sources for change in land use were legal iron and aluminum mining and the construction of reservoirs and dams, followed by road infrastructure construction, the expansion of agricultural settlements, and to a lesser degree, illegal mining. In the case of illegal gold mining, the major threat it poses is associated with river pollution, rather than the magnitude of deforested areas, given the extraction methods used. Meanwhile, the exploitation of iron and aluminum was responsible for the increased cumulative deforestation in the Upper Orinoco-B basin in this period (Table 2).

Table 2. Cumulative deforestation in the Venezuelan Amazonia by sub-basins (basins larger than 500 km²)

Sub-basins (order 3)	Surface of original forest cover	Cumulative deforestation until 2000	Deforestation by period			% of the original forest	
			2000-2005	2005-2010	2010-2013	2000-2013	Cumulative total
	km²	km²	km²	km²	km²	%	%
Caroní (B)	4,666	364	52	193	125	7.9	15.8
Or. Alto (B)	12,790	1,381	49	32	50	1.0	11.8
Or. Boca	12,881	499	70	176	150	3.1	6.9
Orinoco (B)	75,954	3,920	131	297	593	1.3	6.5
Cuyuní	32,253	656	229	270	216	2.2	4.3
Or. Alto (A)	1,662	46	5	7	7	1.2	4,0
Or. Alto (M)	18,026	372	31	72	42	0.8	2.9
Caroní	30,153	328	125	81	117	1.1	2.2
Ventuari	36,173	596	66	51	55	0.5	2.1
Guaviare	6,961	88	2	8	41	0.7	2.0
Orinoco Delta	23,666	163	27	143	103	1.2	1.8
Paragua	35,505	152	72	79	75	0.6	1.1
Negro	50,800	306	12	48	92	0.3	0.9
Orinoco	54,845	41	20	64	73	0.3	0.4
Guyana-Esequibo (Costa)	1,172	0	0	0	3	0.3	0.3

Map 2. Sub-basins with the greatest proportional deforestation



Direct and indirect causes of recent deforestation

The relative importance of the forest cover of the Venezuelan Guyana within the national context has grown over the last few years, given the deforestation that took place in the north of the country[9,22]. FAO[23] gives a deforestation rate of 0.6% per year for the 2000-2010 period, placing Venezuela tenth among countries with the highest annual forest loss. These values are consistent with the 84% increase in the intervened (or transformed) land area in the country, obtained by comparing vegetation formations from 1988 and 2010[9].

The main causes of deforestation reported are:

- Legal and illegal mining (metal and non-metal) including gold, diamond, iron and bauxite[24,20,25]. Metal mining takes place at both small and large scale. The latter resulted from the nationalization of key basic sectors in 1975. Small-scale alluvial gold mining[26] was fueled by international market prices.
- The increase and consolidation of agricultural settlements in the states of Amazonas and Bolívar[10, 27,25].
- The expansion of the agricultural frontier, illegal logging in natural forests, poor planning in mining, the execution of hydroelectric and infrastructure projects, oil industry, tourism related activities, and forest fires[23,28,29,16,10,30,26,31,25].

Agricultural and cattle ranching activities are more relevant in the north of Bolívar, the surroundings of Puerto Ayacucho and the west of Delta Amacuro; mining, in Bolívar and Amazonas; hydrocarbon extraction in Delta Amacuro; and logging in Bolívar and Delta Amacuro. Some transects have higher deforestation impacts, like the highway that connects Puerto Ordaz with Brasil; and the Ciudad Bolívar (Bolívar) - Puerto Ayachucho (Amazonas) highway; in the western part of the Amazonas state near the border with Colombia, along the Negro and Orinoco rivers; and north of the Caura River basin[23, 32,9,33]. On the other hand, the use of fire (slash and burn) is an integral part of the ancestral customs of indigenous groups in some states[34], a tradition in agriculture tightly related with the process of modeling landscape and the elimination of forest cover[35, 36].

Demographics are an important factor to consider in order to understand the dynamic of this region: the increase of the indigenous population and its contacts with the western world has generated a transculturation process, with emerging needs and demands for new goods and services, and the subsequent extraction of more resources from the forest. This factor has led the transformation from small scale agricultural systems (family or community fields) into commercial or semi-commercial agricultural systems. High national and international prices have also contributed to the incorporation of indigenous groups to small scale mining for gold and diamonds[11,24].

The deforestation of the Venezuelan Amazonia continues to increase, and it is quite possible that the 2010-2015 period will have the highest deforestation yet. In this period, illegal mining is emerging as one of the major causes of deforestation. In this regard, Venezuela maintains a trend that is the opposite of that of the Amazonia as a whole.

Future scenarios

In 2013 the Strategic Region for Integrated Development (REDI) Guyana was established by decree, encompassing the states of Amazonas, Bolívar, and Delta Amacuro (Official Gazette 401.087 of the Bolivarian Republic of Venezuela, April 22 2013). The entity seeks to coordinate programs and policies and the execution of governmental initiatives, and involves coordinating actions with other actors and stakeholders in the region. This could result in an opportunity for the Venezuelan Guyana to develop a new, more inclusive development strategy that fulfills the criteria for sustainable socio-environmental development. However, it could also lead to the implementation of actions more akin to a classical resource development model, as has happened in the past.

The national government has taken already some steps framed within this potential contradiction. On the one hand, it has stressed the importance of monitoring and surveillance of the Venezuelan Amazonia rainforest, given its large size of 330,000 km² (180,000 in the Amazonas state, and the rest in the Bolívar department, even though it includes the states of Delta Amacuro and Apure as well, http://www.asambleanacional.gob.ve/noticia/show/id/5488); and it has passed the Forestry Act (August 2013), which regulates forest conservation and production, where the government is the competent authority on forest management and in principle, should favor increased planning for the exploitation of forest resources. Further, there is an important discussion taking place over the creation of a new national park (PN Caura), which takes the boundaries of the Caura River's hydrographic basin as its guideline for the definition of its borders. Should it be created, it would become the largest national park in the world. And this is not taking into account two proposals from civil society supporting the creation of two ecological corridors: 1) the Triple A (Andean, Amazonia and Atlantic) ecological corridor, and 2) the Bi-national (Guyana and Venezuela) ecological corridor in the Essequibo River basin.

On the other hand, and in parallel to the above mentioned measures, the government has passed Decree 841 (March 2014), which provides for the Protection, Development, and Promotion of Legal Mining in the Guiana Region. Under the aegis of this decree arises the possibility of repealing an existing law that forbids extractive activities in the state of Amazonas. Several indigenous institutions like COIAM in 2014 have opposed this decree, claim that it violates the rights of indigenous peoples[37] and have called for its moratorium. A few months after this decree was passed, the Supreme Court of Justice emitted precautionary environmental measures against the illegal mining of gold, iron, diamond, bauxite and coltan in the national parks and natural monuments of the region (Duida Marawaka, Yapacana, Parima Tapirapeco, la Neblina, El Siapa, Cerro Arcamoni, and the Alto Orinoco Biosphere Reserve, amongst others). All these measures are somewhat paradoxical, for if activities such as illegal gold mining are already illegal, no further precautionary measures and prohibitions should be required. Notwithstanding, the precautionary measures dictated by the Supreme Court order the dismantling of camps and the disposal of all inputs and supplies required for mining, the remediation of the affected areas, and the prohibition of the access, transport and mobilization by land or river of heavy machinery, accessories and parts that serve mining. (http://www.elmundo.com.ve/noticias/actualidad/noticias/acuerdan-medidas-de-prohibicion-de-mineria-ilegal-.aspx).

Thus it remains unclear what course the steering of deforestation will take in the coming years. On the one hand are the development plans with a purely classical resource development approach, and on the other there are clear responses from the authorities to the demands of indigenous peoples and local actors. Furthermore, judging from the changes around the Ministry of People's Power for the Environment, which was first eliminated, attached to another ministry, and later "restored" through the creation of the Ministry of Ecosocialism and Water, what path will Venezuela will take regarding the environment remains uncertain.

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37 COIAM 2014

DEEFORESTATION in the GUYANA, GUYANE FRANÇAISE, and SURINAME AMAZONIA

Economic growth increased energy demand; ecotourism could be a positive pressure

Following biogeographic criteria, Guyana, Guyane Française and Suriname are completely within the Amazon, corresponding to 465,000 km² and 6% of the Pan-Amazon.

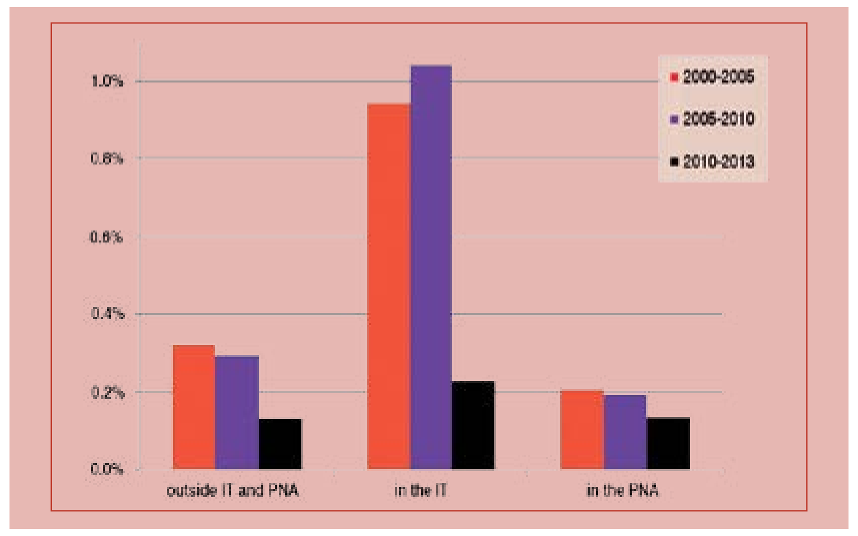
Historical and recent forest loss and deforestation rates

The area of the region that was analyzed through satellite images from 2000 comprised 425,000 km² (91.5% of the region) originally covered by forests. It's estimated that 13,432 km² were lost in between 1970 and 2013, with cumulative deforestation in 2000 reaching more than 10,000 km² (2.4% of the original forest). Based on satellite interpretation, forest loss between 2000 and 2013 (recent deforestation) reached more than 3,000 km². The highest loss occurred from 2005 to 2010 (1,341 km²), compared to the 1,275 km² lost in the previous 2000-2005 period, even though the 2010-2013 period showed a similar loss in less time (Table 1).

By 2013, Protected Natural Areas (PNAs) covered close to 17% of the three countries' Amazonia biome (76,130 km²), of which 74,966 km² (Table 1) were originally covered by forests, as analyzed through satellite images from 2000. Cumulative forest loss up to 2013 exceeded 2.6 million km² (20% of the total deforestation in the region up to 2013), while cumulative deforestation in PNAs reached 2,300 km² by 2000 (3.1% of the original forest). Between 2000 and 2013 (recent deforestation) forest loss in these areas reached 388 km². The loss was similar in all evaluation periods. The PNAs that had the highest recent deforestation rates were those of Guyane Française, with 204 km² (indirect use) and 94 km² (direct use) (Table 1).

Moreover, by 2013 Indigenous Territories (ITs) covered close to 22.9% of the territory of the three countries (102,683 km²). Based on the analysis of satellite images from 2000, 96,103 km² were originally covered by forests. These lands had a cumulative loss of over 3,700 km² of forest (28.1% of the total deforestation of their Amazonia up to 2013). Between 2000 and 2013 (recent deforestation), forest loss in these areas reached 2,075 km², more than 50% of all cumulative deforestation. This loss in the 2005-2010 period was 972 km² (Table 1). Guyana has the highest forest loss in indigenous territories, with 1,731 km² of recent deforestation.

Figure 1. Recent deforestation in the Guyana, Guyane Française, and Suriname Amazonia, inside and outside of PNA and IT



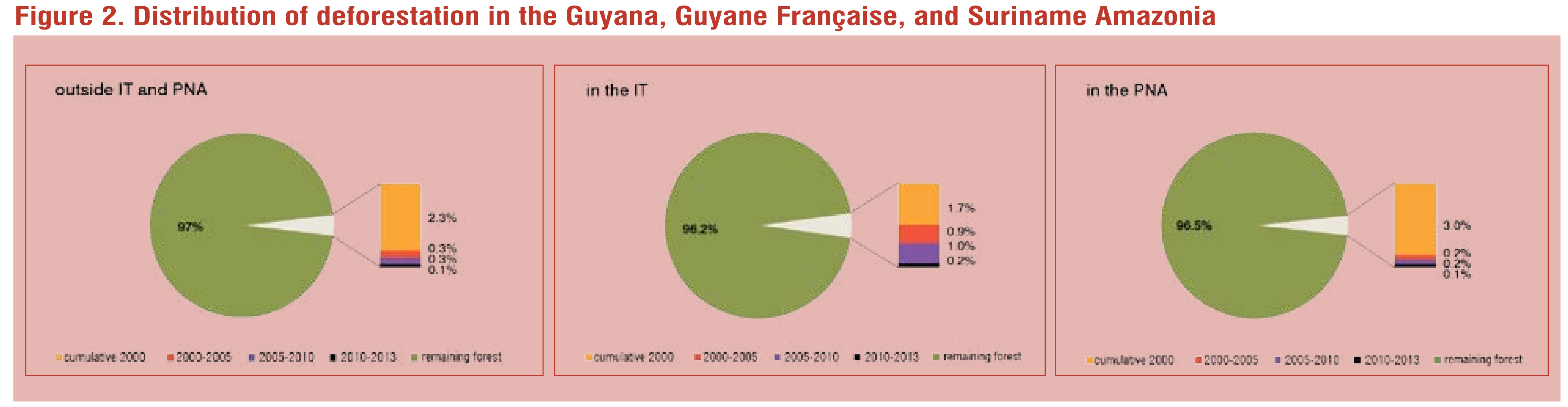
Map 1. Deforestation in the Guyana, Guyane Française, and Suriname Amazonia

Table 1. Deforestation in the Guyana, Guyane Française, and Suriname Amazonia

		Surface of original forest cover[1]	Cumulative deforestation until 2000	Deforestation rate 2000-2005	Deforestation rate 2005-2010	Deforestation rate 2010-2013	% of the original forest 2000-2013	% of the original forest Cumulative total
		km²	km²	km²	km²	km²	%	%
Amazonia		425,855	10,300	1,275	1,341	517	0.7	3.2
Guyana		192,405	3,097	785	821	125	0.9	2.5
Guyane Française		83,195	1,539	295	257	248	1	2.8
Suriname		150,254	5,664	194	263	144	0.4	4.2
Outside PNA and IT		269,265	6,506	846	766	344	0.7	3.1
Guyana		156,785	2,549	586	559	106	0.8	2.4
Guyane Française		39,285	916	181	153	160	1.3	3.6
Suriname		73,195	3,131	79	54	78	0.3	4.6
Indigenous Territories[2]		96,103	1,701	891	972	211	2.2	3.9
Guyana	IT officialy recognized	26,550	545	785	821	125	6.5	8.6
Guyane Française	IT officialy recognized	7,083	45	6	11	9	0.4	1.0
Suriname	Traditional occupation without recognition	62,470	1,111	100	141	78	0.5	2.3
Protected Natural Areas[2]		74,966	2,305	151	141	97	0.5	3.6
Guyana	national-direct/indirect use	3,734	4	1	11	0	0.3	0.4
	national-indirect use	6,298	89	17	8	0	0.4	1.8
Guyane Française	national-direct use	19,144	364	79	75	50	1.1	3.0
	national-indirect use	24,245	257	33	27	34	0.4	1.4
Suriname	national-direct use	1,935	797	7	3	1	0.6	41.8
	national-indirect use	19,609	794	13	17	11	0.2	4.3

[1] Original forest cover refers to forest formations within the biogeographic limit of the Amazon, within which exist non-forested areas, like enclaves of savannas or fields.
For the evaluation of deforestation only originally forested areas were considered.
[2] The situation of existing ITs and PNAs was considered in December 2013.

Figure 2. Distribution of deforestation in the Guyana, Guyane Française, and Suriname Amazonia



The Tacutu sub-basin on the Brasil-Guyana frontier shows the highest proportional deforestation, with a total loss of 8.6%, and the highest loss for the 2000-2013 period: 4.2% of its forested area. It is followed by the coastal sub-basins of Suriname, Guyana, and Guyane Française, which were historically occupied and show a 18.5% loss of its original forests (8.5%, 5.1%, and 4.8% respectively, Map 2).

Historical context of deforestation

The three countries of the Guiana Shield have small populations, high forest cover, and low deforestation, conserving a high proportion of original forest cover: 97% (Guyana), 96% (Suriname) and 97% (Guyane Française). Additionally, they have the highest ratio of forest area per capita of any country in the world.

According to the FAO (2010), the loss of forest cover in the 1990-2009 period was about 0.3% per year, very low compared to other regions of the world, but relatively high for the Guiana Shield region (approximately 542 ha lost per year).

Prior to 2000, deforestation rates in **Guyana** were insignificant; the result of logging, mining, fuel wood gathering, and conversion to agriculture. Things changed in the 1990s when large international mining companies were attracted to Guyana. Gold production comprised 22.6% of national exportations. The production of bauxite and diamonds was also important. As a result, the mining sector was responsible for the largest impact on Guyana's forest resources. However, its relative contribution to deforestation prior to 2000 cannot be quantified.

In **Suriname**, commercial forestry activities before 2000 were limited to 2.5 million ha close to the coast. Agricultural and plantation activities were restricted almost exclusively to the coastal zone. Deforestation as a result of bauxite and gold mining were practically insignificant. By 2000 there was little evidence of severe threats to forest resources. The potential for land use changes in the coastal zone were low. The construction of the Brokopondo hydroelectric plan in the early 1970s flooded 160,000 ha.

Similarly, the deforestation rate before 2000 in **Guyane Française** is virtually non-existent according to the FAO (2005). Logging was minimal, and the impact of some small-scale gold prospecting insignificant. The construction of the Petit-Saut hydroelectric dam between 1989 and 1999 flooded 310 km² of forest.

Direct and indirect causes of recent deforestation

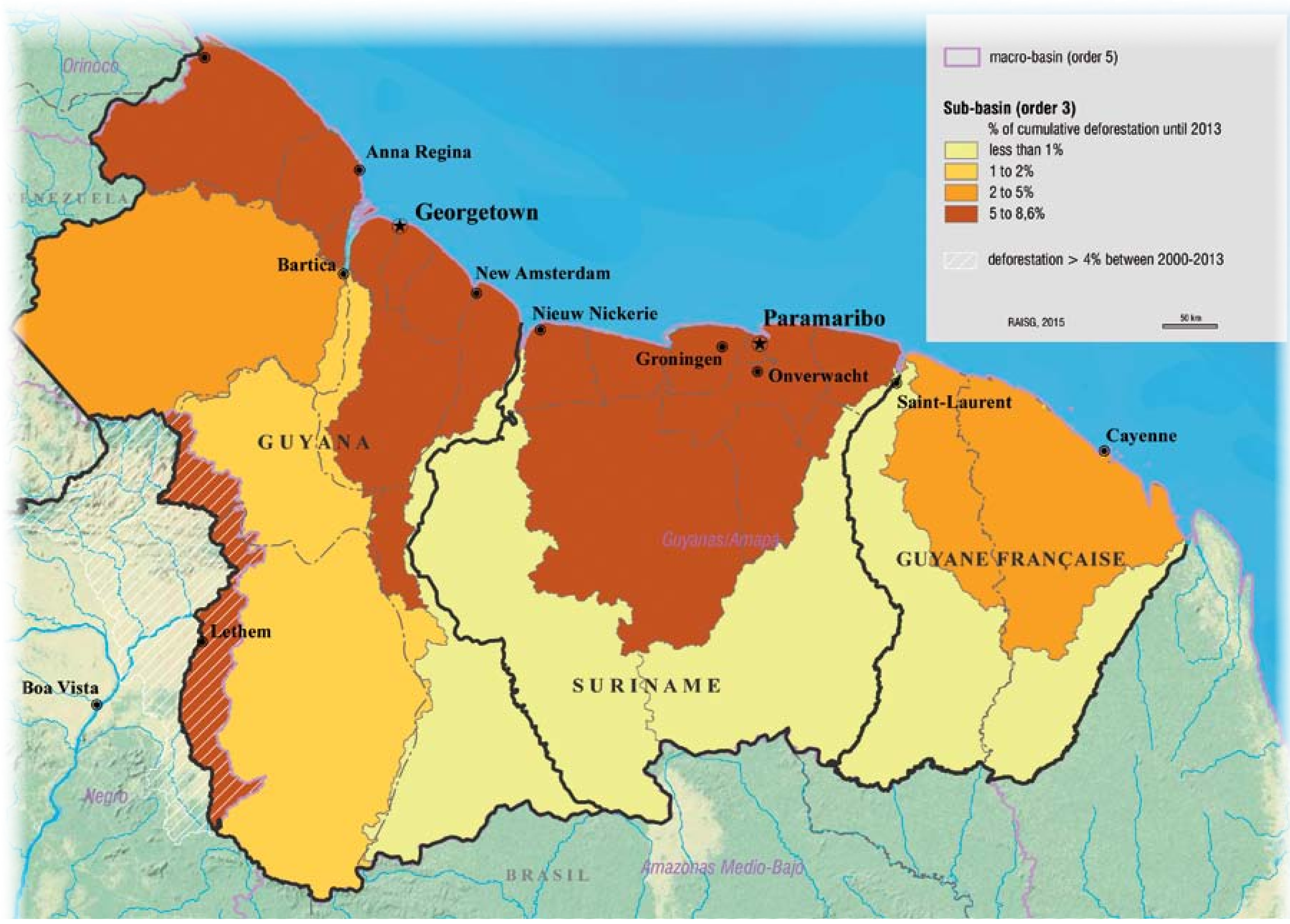
In **Guyana**, the deforestation rate increased from an average of 0.03% between 1990 and 2009 to 0.06% between 2009 and 2010, an increase that can be attributed to mining. Mining (gold and bauxite) is crucial for Guyana's economy, representing 11% of its GDP in 2009, and making up over half of all exports in 2010.

The legal framework for the forest and environmental sector was updated between 1989 and 2009: Mining Act (1989), Environmental Protection Act (1996), Forestry Act (2009), Protected Areas System (2011), and

Table 2. Cumulative deforestation in the Guyana, Guyane Française, and Suriname Amazonia by sub-basins (basins larger than 500 km²)

Sub-basins (order 3)	Surface of original forest cover	Cumulative deforestation until 2000	Deforestation by period 2000-2005	Deforestation by period 2005-2010	Deforestation by period 2010-2013	% of the original forest 2000-2013	% of the original forest Cumulative total
	km²	km²	km²	km²	km²	%	%
Tacutu	5,652	249	93	137	4	4.2	8.6
Suriname (Costa)	67,309	5,348	138	161	91	0.6	8.5
Guyana-Esequibo (Costa)	51,346	1,893	385	301	57	1.4	5.1
Guayana Fr. (Costa)	41,540	1,405	259	180	176	1.5	4.9
Cuyuní	44,485	522	211	99	41	0.8	2.0
Esequibo	64,680	378	91	272	17	0.6	1.2
Marowijne	73,027	275	64	134	89	0.4	0.8
Amapá (Costa)	13,354	53	9	13	4	0.2	0.6
Corantijn	63,680	136	21	43	37	0.2	0.4

Map 2. Sub-basins with the greatest proportional deforestation



the Amerindian Act (2006) that guarantees land rights of indigenous populations (strongly criticized nationally and internationally).

In 2009, Guyana adopted a Low Carbon Development Strategy (LCDS) to combat climate change and simultaneously promote economic growth and development. Guyana signed a Memorandum of Understanding with Norway for funding over five years. Moreover it also led to the establishment of the Guyana REDD+ Investment Fund (US$ 250 million) for the implementation of the LEDS strategy up to 2015.

Between 1998 and the 2000s, **Suriname**'s forest and environmental management structures were revised: National Environmental Council, National Institute for Environment and Development in Suriname, and the Foundation for Sustainable Forest Management. In 2006 a National Forest Policy was formulated. In 2009, a Green Development Strategy with carbon storage payments was planned.

The main driver of deforestation and forest degradation in Suriname is mining, including small, medium and large-scale mining (bauxite, gold, kaolinite and diamonds). Other drivers consist of logging, infrastructure development, energy production, housing development, and forest fires.

It is estimated that the number of illegal miners operating in **Guyane Française** in 2005 range from 3,000 to 8,000. According to the ONF (National Office of Forests), illegal and legal mining contaminated and directly impacted 1,333 km of watercourses in 2005, and a further 4,671 km affected by secondary pollution. By 2012, illegal mining was considered a threat to the forests of Guyane Française.

While timber extraction is increasing, it is still small in comparison with other Amazonian countries. The average annual figure for the 2000-2009 period is estimated at 60,000 m³ of timber (reaching 86,000 m³). During the 2000s, an estimated 1,500 to 2,000 ha were illegally cleared annually for the expansion of agriculture and human settlements.

Future scenarios

The growth of forest extraction and mining is increasing pressure on the interior forests of the region, particularly in Suriname and Guyana. Both countries receive support from the Forest Carbon Partnership Facility for the implementation of REDD+ national programs (Guyana since 2012, and Suriname since 2013). These countries are developing national monitoring, reporting and verification systems (MRVS) for deforestation, forest degradation, and carbon stocks.

The Guiana REDD+ Project, financed by France and the European Union, supports low carbon development in Suriname, Guyana, and the Brazilian State of Amapá since 2013, modeling management scenarios and REDD+ implementation mechanisms. The Guiana Shield Facility (GSF) is currently financed by the EU and the Dutch Government, and will implement multilateral environment agreements.

Notwithstanding the commitments by Guiana Shield countries to the adoption of low carbon emission, development strategies and the reduction of deforestation and forest degradation, and the increasing international support for these policies, the threats to forests in the region are growing, and the implementation of agreed policies and projects is proving difficult.

The estimated total deforestation rate of Guyana for 2012 was 0.079%. Should the increase be confirmed, it will lead to a reduction of payments to Guyana under its agreement with Norway. The main variables when considering deforestation in Guyana are the prices of its mineral exports – bauxite, diamonds, and above all gold. Another factor is the IIRSA program, with plans for the construction of three road corridors: the proposed Georgetown Lethem corridor; the connection between western and northern Brasil with Manaus, Boa Vista, Venezuela and Guyana; the third will offer an alternative to the Manaos-Caribe connection. The Amaila waterfall hydroelectric dam project on the Kuribrong River has stalled (fuel imports for electricity generation amounted to a third of GDP in 2008).

Suriname was the economy with highest growth in South America in 2012. To fulfill its electric demand, it is considering building more hydroelectric dams: it is estimated that Grankriki would result in 47,000 ha of forested land converted, with substantial amount of secondary forest degradation and deforestation. Additionally, Suriname has plans for the expansion of sugarcane fields for ethanol, converting large portions of forest. It is also encouraging investments in hydrocarbons. In the IIRSA framework, it plans to expand the road joining Paramaribo with Brasil, opening access to a region with high biodiversity value, and bauxite, gold and diamond deposits.

The economy of **Guyane Française** depends predominantly on the Korou space center, and financial transfers from metropolitan France. Illegal mining will continue to be a deforestation driver, but at a much smaller scale than Brasil or Andean countries, and given its low population, comparative wealth, and administrative capacity, it is likely to maintain its low levels of deforestation.

In all three countries ecotourism is rising, although its real contribution to their economies remains to be seen. While it is unlikely that these sectors will grow due to the economic crisis in Europe and the United States, it could contribute to the reduction of deforestation drivers.

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DEFORESTATION ANALYSIS METHODOLOGICAL FRAMEWORK

The RAISG Protocol applied to the analysis of deforestation in the Amazonia region[1] is shown in Figure 1. It is based on the integration and synergy of the knowledge and capacities existing within the RAISG network's member institutions. As mentioned before, by 2008 deforestation data on the region was unavailable, as were other approximations allowing for estimations at the right scale in order to understand change processes and their impact. This was reason enough to justify the endeavor of linking existing experiences with the goal of obtaining standardized products recording the forest-loss processes in the region. Imazon (Instituto do Homem e Meio Ambiente da Amazônia) assumed Technical Support in the form of software tools development as well as training members on their use. This organization possessed significant prior experience in the study of deforestation in Brasil, and had introduced indexes and improvements in existing analyses in order to better identify forest degradation[2]. Other member institutions of the Network (EcoCiencia, FAN, Gaia, IBC, ICV, ISA, IVIC, Provita) contributed their knowledge of the Andean-Amazonia and Guianese Amazon, and their experience in remote sensing and spatial analysis.

Thus it was possible to:

- have a standard conceptual and methodological framework allowing comparative analyses between different countries, incorporating sub-regional and local differences that express the environmental heterogeneity present in the Amazonia region;
- establish a technical team that was tutored by Imazon on the use of semi-automatic analysis tools;
- incorporate the group knowledge on Andean-Amazonia and Guianese Amazonia to improve and broaden the capacity of ImgTools (Image Processing Tools)3 developed by Imazon to apply to the entire Pan-Amazon.

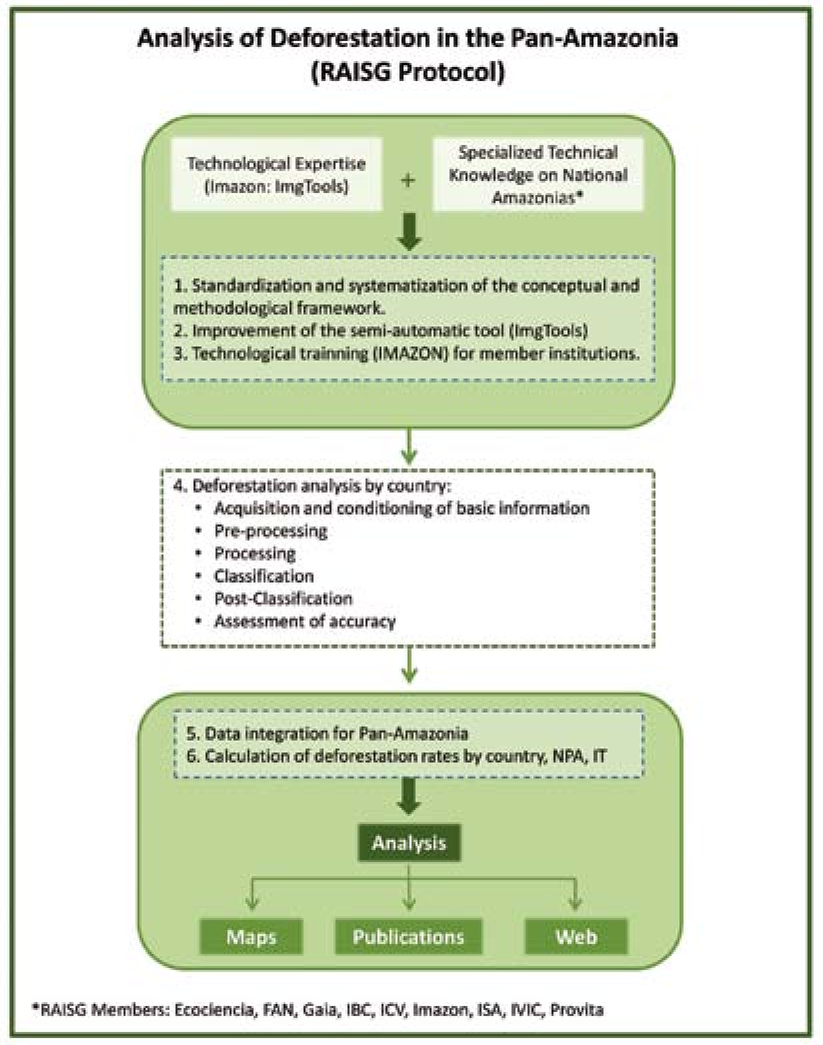
At present RAISG possesses consolidated methodology and tools that have been tested and applied to the Brazilian Amazonia through various remote sensors (Cbers, Modis, SPOT 5 MS, Aster, Landsat 5/TM, 7/ETM+, 8)[4] and in the Pan-Amazonia context[5].

This publication presents a multi-temporal deforestation analysis for the 2000 – 2005, 2005 – 2010 and 2010-2013 periods, where the base line for the entire Amazonia is the year 2000. Historic deforestation was estimated, as defined as the cumulative forest loss up to the year 2000. Specific procedures for both processes are explained in the subsequent sections.

Contemporary deforestation

From an operational point of view RAISG protocol includes various steps, which are described as follows (Figure 1):

Figure 1. RAISG protocol for deforestation analysis of the Pan-Amazonia



A. Acquisition and conditioning of base information

1. Creation of the database storage structure: a structure of directories and sub-directories was defined for the storage and handling of images that made possible the organizing, manipulating and analyzing of data for pre-processing, processing and subsequent integration of the information generated by each one of the countries.
2. Acquisition of satellite images: Landsat 5/TM, 7/ETM+ and 8 are used, ideally with less than 20% cloud coverage. Images of 30 m resolution for the required bands, covering an approximate 180 km x 180 km were acquired through the University of Maryland website (http://www.glcf.uniacs.umd.edu), the Instituto de Pesquisas Espaciales (INPE) (http://www.inpe.br), Earth Resources Observation and Science Center (EROS) (http://glovis.usgs.gov) and The United States Geological Survey (http://earthexplorer.usgs.gov). Approximately 294 Landsat images cover the Amazonia region. The year 2000 is defined as the base line, and the years 2005, 2010 and 2013 are set as analysis breakpoints. Due to the fact that there are not enough good quality images for one given year, images taken between June 1998 and July 2002 are considered for the year 2000; for 2005, images taken between June 2003 and July 2007 are considered; and for 2010, images taken between June 2008 and September 2011. Finally, for the 2013 period, images between August 2012 and March 2014.
3. Legend Definition. The following classes are considered:

Forest: land with wooded vegetation with a canopy cover superior to 10% of the area and a surface superior to 0,5 hectares, and trees taller than 5 meters high, or able to reach these minimum limits *in situ*[6].

No-forest: areas with no forest cover, either because they have been deforested prior to the year 2000 (base line), or because they correspond to non-forested ecosystems, such as rocky outcrops, moors, savannas, grasslands, cultured lands, burned areas, beaches and sandy soils.

Deforestation: area where the original forest cover has been eliminated completely within the study period.

Water: areas with bodies of water, such as rivers, lakes, ponds, meanders, etc.

Clouds and shadows: areas covered by clouds and shadows in any given analyzed period of time.

Unclassified: areas with lack of data at the origin as a result of problems with the original images, e.g. faults in Landsat ETM+ sensor generating images of bands containing no information.

B. Pre-processing

1. Band compilation: refers to the process of selecting and grouping bands of satellite images in a determined order according to the sensor. This is how bands Blue, Green, Red, Near Infrared (NIR), Mid Infrared (MIR) and SWIR were compiled from Landsat 5/TM and 7/ETM images. However, compilation for sensor included the following bands: Landsat 8 are Coastal aerosol, Blue, Green, Red, Near Infrared (NIR), SWIR 1, SWIR 2, Cirrus, Thermal Infrared (TIRS) 1 and Thermal Infrared (TIRS) 2.
2. Orthorectification: this process allows the correction of spatial and relief distortions in satellite image data that originate in optical characteristic of the sensor, topographical variations in the surface of the earth, and the tilt of the satellite or aerial sensor. To this end, previously orthorectified images are used as well as Shuttle Radar Topography Mission (SRTM) 90-meter spatial resolution data set as produced by the Global Landcover Facility (http://glcf.umd.edu). The images are orthorectified, resulting in terrain displacement lower than 2 pixels and a maximum mean square error value of 0.5 (R2 ≤ 0.5), which is widely accepted. This rectification is made when necessary on Landsat 5/TM and Landsat 7/TM images.
3. Definition and resizing of lines and columns: in order to compare different period images, they must have the same size in terms of number of lines and columns. This prevents pixels location displacement, which would generate errors in Land Cover Change Analysis. Thus, small images are used as base for large image resizing.
4. Radiometric and atmospheric correction: in order to correct distortions caused by sensors or atmospheric conditions related to the effects of wavelength dispersion affecting multi-spectral image bands with shorter wavelength (Blue, Green and Red bands), corrections are made at the pixel level on Landsat 5/TM and 7/ETM images based on ImgTools' Haze Correction Module algorithms. Later digital values (DN) are converted to surface radiance and reflectance values, and then applied to the Spectral Mixture Analysis (SMA). For this end, the following tools are applied: Radiometric Calibration from ImgTools, and Fast Line-of-sight Atmospheric Analysis of Spectral Hypercubes (FLAASH) from ENVI. In some cases, this conversion was made through LEDAPS (Landsat Ecosystems Disturbance Adaptive Processing System) for Landsat 5 and 7 images – http://ledapsweb.nascom.nasa.gov.

C. Processing

1. Spectral Mixture Analysis (SMA)[7]. Through this process, spectral fractions are obtained (GV, NPV, Soil and Cloud), which allow the identification of photosynthetically active vegetation areas, non-photosynthetically active vegetation areas, bare soil areas, and clouds/shadows.
2. Spectral mixture analysis (SMA) determines the component parts of mixed pixels by predicting the proportion of a pixel that belongs to a particular class or feature based on the spectral characteristics of its endmembers. It converts radiance to fractions of spectral endmembers that correspond to features on the ground. These images are used as input for the final classification. For instance, the Soil fraction identifies with precision the structure of forest use, like roads and timber gathering places; the NPV fraction helps identifying degraded forest areas, and the GV fraction, helps identifying dense forest areas.
3. Masking: the collection of information about bodies of water, clouds, and shadows in satellite images is necessary to avoid confusing them with other classes of cover in the final classification.
4. Calculating the Normalized Difference Fraction Index (NDFI)[8]: this index is obtained from fraction images, and enhances spectral signals of changes in forests, allowing the differentiation between degraded forests and intact forests, and detecting deforested areas. The NDFI uses values between -1 and 1, where values close to 1 correspond to dense forest and values close to -1 correspond to exposed soil.

D. Classification

A decision tree classification method is applied to all images with ImgTools. The data input used for the classification are fraction images (SMA), the NDFI, and optionally water and cloud/shadow masks. This allows the identification of classes in all images: forest, no forest, water and clouds, and starting in 2005, deforestation.

The area of the Amazonia effectively analyzed represents 95.8% of the total. The missing 4.2% corresponds to areas in Brasil lacking evaluation.

E. Post-Classification

1. Review and editing of results: to avoid the classification of multiple elements within one class with similar spectral results, classification results are compared with pre-processed satellite images. These inaccuracies are relatively common when using automatic and semi-automatic classifiers. One example is the case of forest plantations, which are frequently classified as forests. When detected, their classifications are manually edited. To perform this procedure reliably and accurately requires high-quality reliable supplementary information and analysts with a certain level of experience.
2. Temporal Filter: the temporary information of each image pixel (minimum unit of satellite image) is used to correct inconsistencies and adjust the classification within a certain period. Certain rules that validate each pixel's history are used to take full advantage of all possible information in each image. For example, if a pixel is identified as a forest in the years 2000 and 2010, but identified as clouds in 2005, it is reassigned to forest.

F. Accuracy Assessment

Accuracy of the final classification is calculated in order to estimate its correspondence with the terrain cover. The classifications of randomly selected points are compared with high resolution images (SPOT 1.5m, SPOT 10m, IKONOS 5m, CBERS 5m and GeoEye), field data, or both.

The first step is the generation of a sample through the random selection of point sets within classes. At each point the pixel classification is compared with the images or field data provided and used to estimate the initial error, and with it, the size of a representative point sample for verification of the area classified. The combined reference pixels are compared with high resolution images or field data, and an error matrix and classification accuracy calculated for the entire region.

G. Data Integration

The classification results are included in the RAISG database housed in ISA, where it is reviewed and prepared for the elaboration of regional mosaics for analysis, mapping, and internet dissemination.

H. Calculating deforestation rates

The deforestation rates are estimates of the forested areas affected by forest loss caused by human activities within a period of time. They can be expressed in units of area by time unit (for example, km^2/year, or ha/year) or in percentages. They are calculated using a method adapted by the Food Administration Organization (FAO) which assumes that forest area decreases due to deforestation in an exponential manner[9]. For the calculation, breakpoints are assigned to the 1st of August of a year, for example 2000, until the 31st of July of the next year, which in this case is 2001. All periods are defined the same way, from the 1st of August of 2000 to the 31st of July of 2005, the 1st of August of 2005 to the 31st of July of 2010, and the 1st of August of 2010 to the 31st of July of 2013. Additionally, this method allows the consideration of the real dates of each image evaluated, which guarantees comparison between the same periods in different scenes throughout the whole region. The rates are estimated at the level of country, protected areas, indigenous territories, and hydrographic basins, using the data layers RAISG has been consolidating and standardizing.

Historic deforestation

As previously mentioned, the No-forest class assigned to 2000 groups three categories of data that without prior information cannot be differentiated, specifically: natural non-forest formations, transformed non-forest areas, and deforested areas. Consequently, the non-forest areas detected for the year are evaluated with the goal of assessing which extension is the result of recent historic deforestation. In the case of Bolivia, Brasil, and Ecuador, data available at a national level is used[10,11,12,13]. For the remaining countries, data from Global Land Cover[14], a DEM of 90m, and the expertise of each analyst with national data is used. The various approaches are evidence and the result of the lack of systemic studies in the field for the entire Amazonia region.

In order to carry out the analysis, the No-forest class is removed from the mosaic, which is analyzed with the data available according to each nation's situation. Based on this information it is possible to estimate the forest cover lost up to 2000 and up to 2013.

After this historical analysis, the Forest class, 2000 is added to the Deforestation class, 2000 (sub-class within the No-forest class, 2000) to determine the region's original forest cover.

Protocol concerns

The deforestation estimates presented in this study can differ from those found in previous RAISG publications for the same period. This is the consequence of several factors, but is mainly due to the approximation used in the calculation of forest loss. For example, in Amazonia under Pressure[15], estimates were made by country and for the entire region from a mosaic of images, where areas of spatial overlap were considered relative to their decreased coverage by clouds. This could result in differences regarding the scope used in each image. However, this publication is produced scene by scene and the area used for calculations is the same in each image since areas of spatial overlap are divided in equal parts. Additionally, this study uses a greater number of images and tools – like the temporal filter – which allows a larger number of corrections and decreases the number of pixels classified as clouds, cloud shadows, or unclassified due to problems originating in the sensor. This increases the surface effectively analyzed within each of the forest, no-forest, water, and deforestation classes.

Likewise, the continuous improvement of the method and the inclusion of new data makes future variations in the forest loss estimates and deforestation rates presented here compared to later evaluations for the same time periods likely. This will possibly primarily be due to:

- The reclassification of pixels currently classified as clouds/shadows or unclassified/without information, and its assignation to any of the other categories (forest, no-forest, water, deforestation).
- Adjustments in the classifications in response to new scientific information.
- The deforestation rate calculation is directly related to the amount of information available, so increased numbers of images (annual classifications) will result in more exact estimates.
- The spatial resolution of the sensors used as technological advances increase the availability of high-resolution images and improve the accuracy and precision of estimates in all the types of cover considered.

In this manner, possible changes in the estimates are likely to be the result of increased quality and quantity of data, hand in hand with improved methodology.

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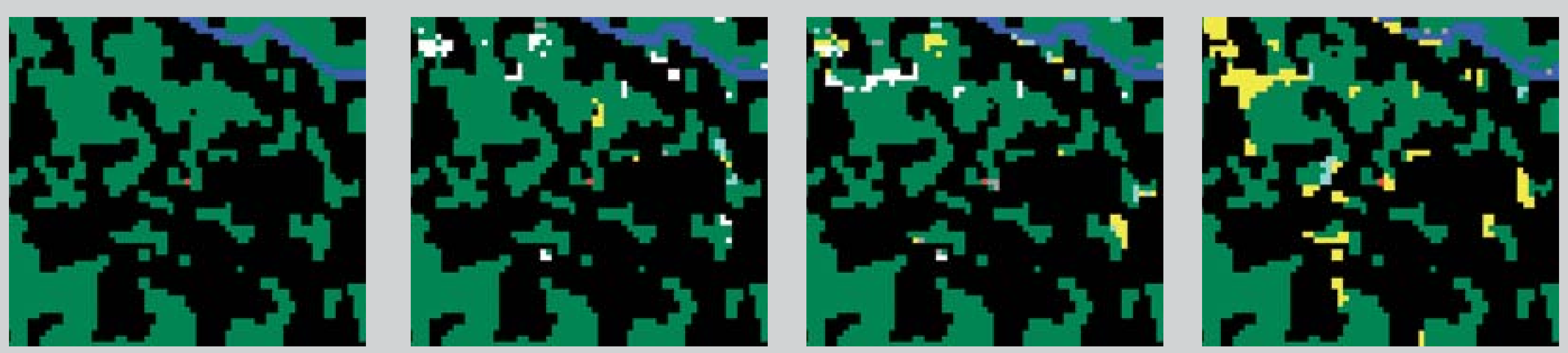
Examples of the lessons learned with methodology use

Remote sensing methods in the Ecuadorian Amazonia allow the identification of zones were human activity generates deforestation. In Ahuano, province of Napo, a hydroelectric plant and related infrastructure were constructed (red dot in the next images). During the construction, EcoCiencia staff verified the construction site. Deforestation analysis (2000-2013) shows the disruption of the site by detecting "pixels" corresponding to forest loss or deforestation (yellow).

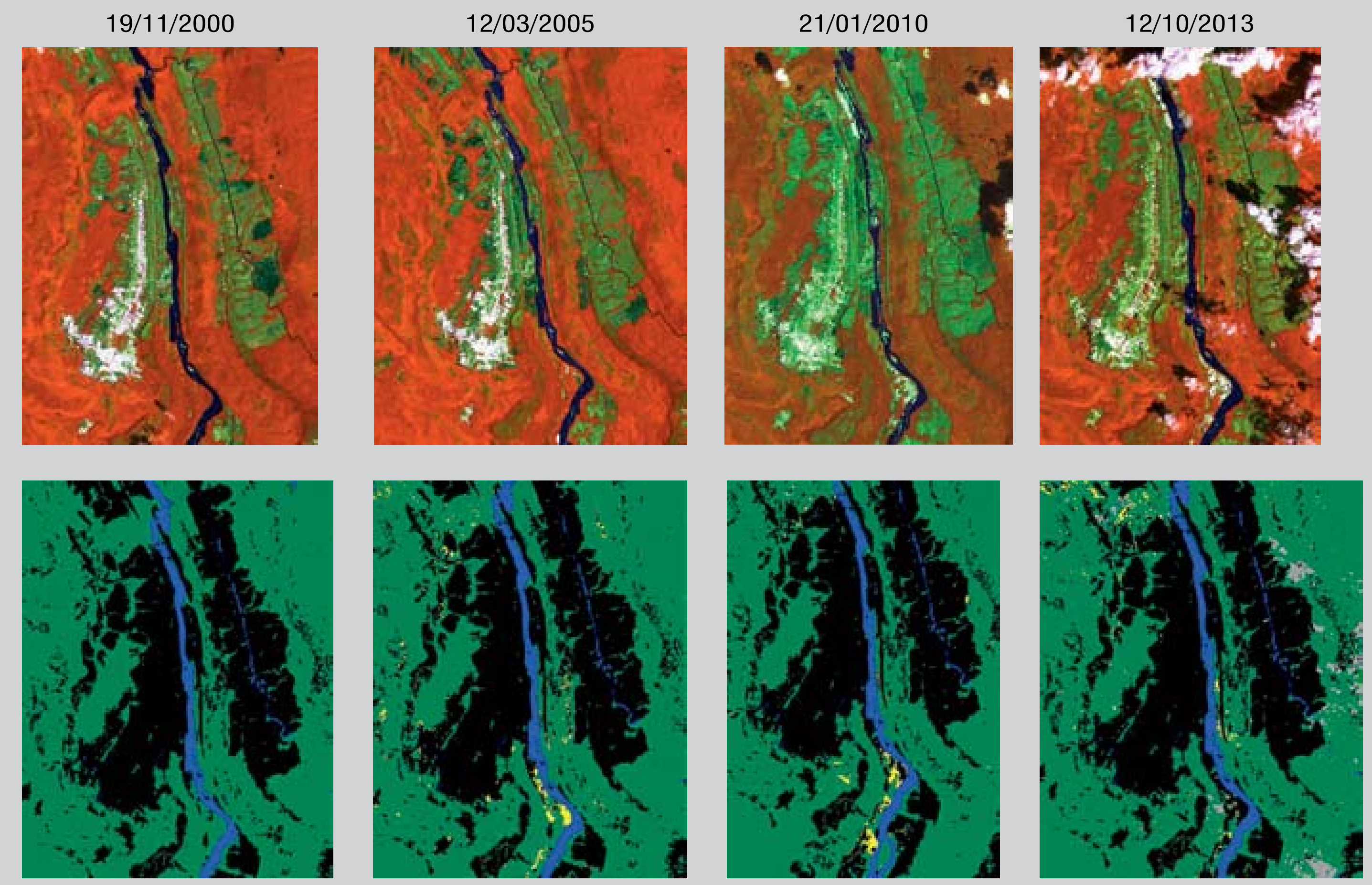
Photo taken on site during the hydroelectric plant's infrastructure construction phase. (Victor López, Nov. 2014).



Construction site in 2000. The dot (red) is located in forest (green)

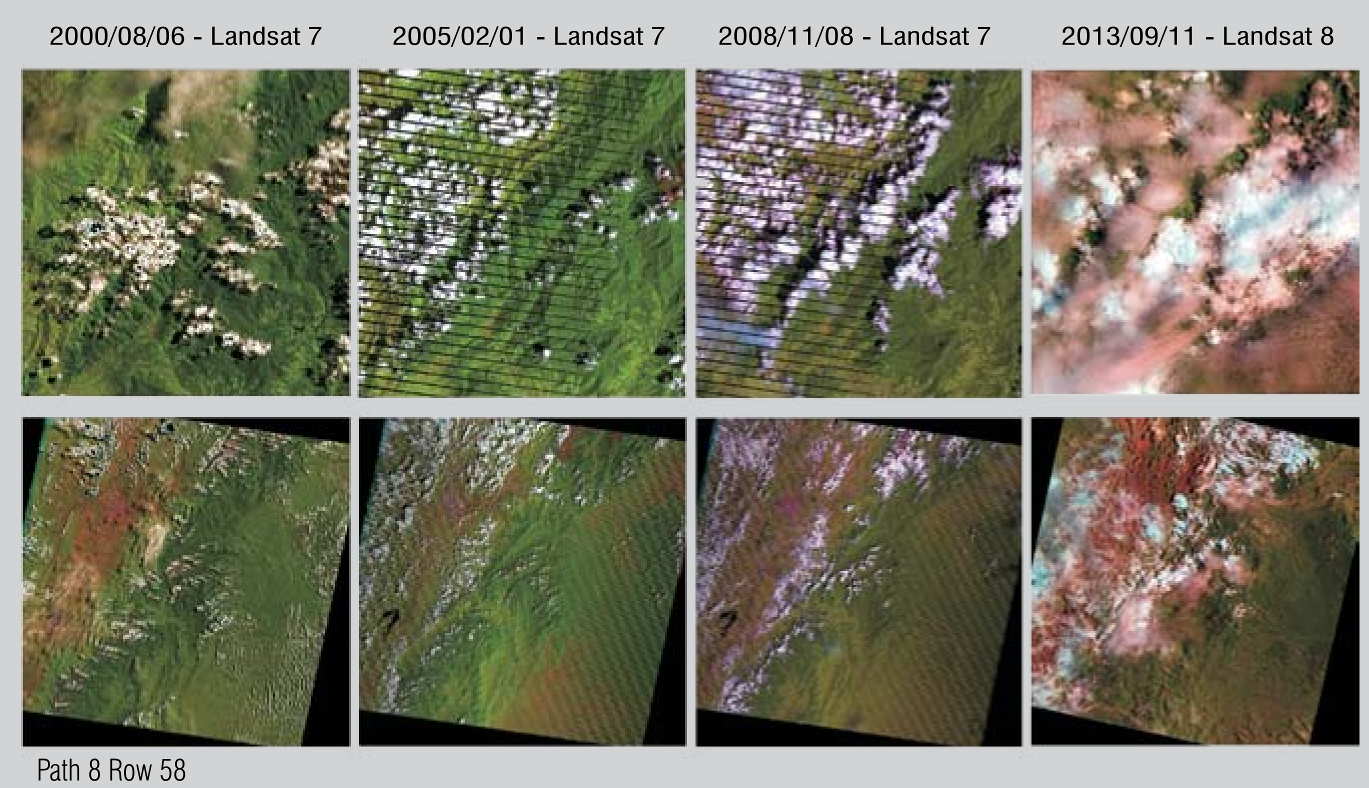
Construction site from 2005 to 2010. The dot is still located in forest, but changes in the zone have been detected.

Construction site in 2013. The dot's surroundings were deforested and are indicated in yellow..



Mining along the Caroní River and its tributaries (Carrao River) in Venezuela. In images (above), the changes caused by mining are visible as white zones, while in the classification (below) they appear in yellow (deforestation) if they took place in the images' period, and later change to black (no forest). Photos of the areas taken by the end of 2014 follow them.

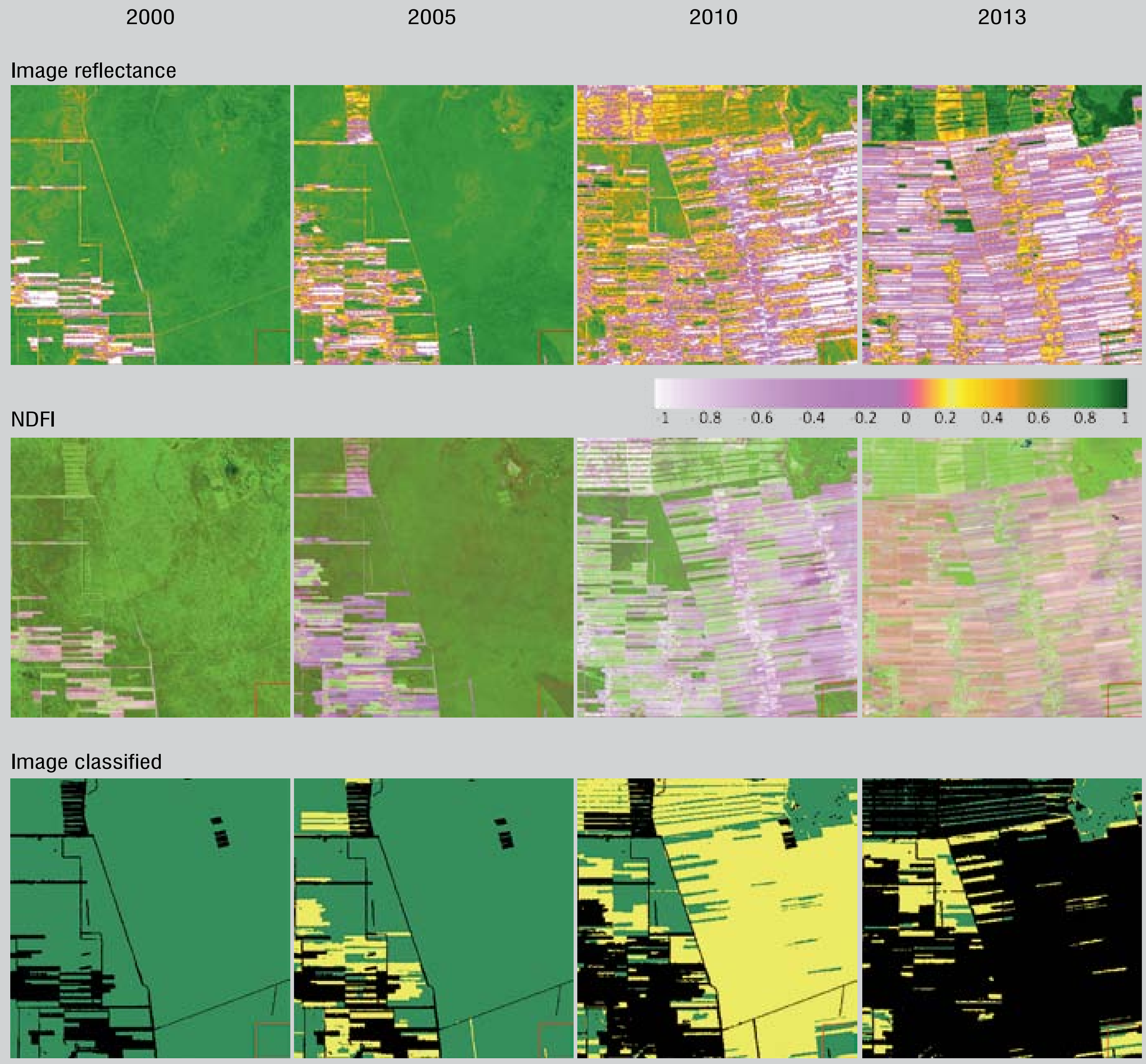
Photos: Valentina Quintero, October 2014



One of the great challenges in the elaboration of the deforestation map of Colombia through the different study periods was the high cloud coverage in the Andean areas and the Amazonia foothills. These images have between 15% and 45% clouds, hampering the identification of deforested areas in one of the zones most affected by the advance of the agricultural frontier in the departments of Meta and Caquetá. Additional gaps in the center of images are the result of damage in the Landsat 7 satellite's sensor.

cont./ Examples of the lessons learned with methodology use

Example of a classified scene for the 2000-2005-2010-2013 periods and its correspondence with the NDFI image (Normalized Difference Fraction Index) and image reflectance. Landsat Scene 232-72 located east of the city of Santa Cruz, Bolivia.



DEFORESTATION in the AMAZONIA (1970-2013)

This is a regional study on Amazonia forest loss undertaken through analysis developed with a unique methodology for all the countries that comprise the Amazon. Information is generated according to a protocol that allows the production and integration of data from each Amazonia country.

It is a product of the Amazonian Network of Georeferenced Socio-Environmental Information (RAISG), a collaborative space open to all those interested in a sustainable future and the strengthening of the Amazon's socio-environmental diversity.

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ISBN 978-85-8226-032-6
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