



Subnational assessment of legal and illegal deforestation in the Colombian Amazon: consequences for zero deforestation commitments

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Abstract

Deforestation has been at the heart of the transformation of the Amazon. Global concerns over deforestation and its impact on climate change have resulted in the adoption of a number of initiatives in the framework of zero deforestation. However, undifferentiated application of the concepts of zero net, gross, and illegal deforestation has revealed a lack of understanding of their scope and of challenges to their implementation. Zero legal and illegal deforestation is, in particular, a controversial subject from the point of view of regulation and sovereignty but an essential aspect from the perspective of public policy design. In Colombia, zero deforestation commitments make no mention of legal deforestation. Papers that analyze deforestation and official data sources fail to incorporate the legal dimension in their analysis. This article addresses this gap by identifying areas where deforestation is legal and where it is illegal in one deforestation hotspot of the Colombian Amazon, the administrative department of Guaviare. Our results show that deforestation has increased since 2013, mainly occurs in illegal zones, and that Guaviare department, 85% of which is covered by forest, has very little legal deforestation potential. Our findings reveal that assessing the legality and illegality of deforestation is more complex than often assumed and must become a priority, especially in forested countries where regulation on forest and land management is shared between different level of governments and institutions.

Keywords Amazon · Zero deforestation · Public policies · Colombia · Subnational · Decentralization

Introduction

The Amazon River basin is a critical component of the Earth's climate system (Costa et al. 2021, p. 5). It plays a significant role in the global carbon cycle and is the scene of essential biogeophysical interactions (Moraes et al. 2021;

Val et al. 2021). The Amazon region also hosts a significant proportion of the world's biodiversity (Guayasamin et al. 2021), as well as a diverse range of social, ethnic, and cultural groups (Van Der Voort et al. 2021; Athayde et al. 2021). Colonization and agricultural expansion have endangered this richness (Larrea et al. 2021, p. 17). Deforestation, defined as the complete removal of forest cover, has been at

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the heart of the Amazon's transformation (Langerwisch et al. 2016; Berenguer et al. 2021).

Amazonian deforestation hotspots have moved from Brazil's notorious arc of deforestation to Bolivia, Peru, and Colombia (Kalamandeen et al. 2018). The Colombian Amazon, which comprises 42.3% of the country's continental area and accounts for 8% of the entire Amazon rainforest, underwent a rapid transition from a passive conservation zone (Armenteras et al. 2006) to one of the northwestern Amazon's most active deforestation fronts (Etter et al. 2006a, b; Armenteras et al. 2019; Correa Ayram et al. 2020).

Concerns about deforestation and its impact on climate change have led to the adoption of a variety of initiatives in the "zero deforestation" framework. However, undifferentiated application of the concepts of zero net, gross, or illegal deforestation revealed a lack of understanding of their scope, problematic implementation, and risk to forest conservation (Brown and Zarin 2013; Bregman 2015; Karsenty 2015; Jopke and Schoneveld 2018; Newton and Benzeev 2018; Lyons-White et al. 2020).

Zero legal and illegal deforestation is a controversial target from the standpoint of regulation and sovereignty, as well as from that of public policy design. The goal of zero illegal deforestation is to eliminate deforestation in locations where it is prohibited by law; however, this goal may not advance zero deforestation at all unless authorities forbid the conversion of forests to other uses (Pirard et al. 2015; Garrett et al. 2019). When they do, but the law on deforestation is not strictly enforced, obtaining zero illegal deforestation is quite an achievement.

The goal of zero legal deforestation is to eliminate deforestation even where it is permitted. Despite the many initiatives to halt legal deforestation, such initiatives can be perceived as threats to national sovereignty, like in Indonesia (Dermawan and Hospes 2018), or as threats to investment (Bregman 2015). Ideological and political disagreements between different levels of government may open up the debate on zero legal deforestation if it reaches the limits of subnational autonomy in land use regulation (Eaton 2017). From the standpoint of policy design, differentiating legal and illegal deforestation is acknowledged to be essential to determine which policy instruments should be used to address deforestation (Gregersen et al. 2010).

Few authors have attempted to improve assessment of the legality and illegality of deforestation in Amazonian countries. The existing studies focus on the Brazilian Amazon, where the impact of forest code reforms on the potential for legal deforestation has been analyzed and quantified (Soares-Filho et al. 2014; Freitas et al. 2018; Stabile et al. 2022), along with the effectiveness of one of the regulatory measures in preventing illegal deforestation (Azevedo et al. 2017). Some authors also point to the low level of law enforcement in 2019–2020 that may explain the increase in

illegal deforestation (Coelho-Junior et al. 2022). Challenges involved in distinguishing legal and illegal deforestation from a legal standpoint have also been highlighted (Benatti and Da Cunha Fischer 2018).

Concerning the Colombian Amazon, we only identified one paper that focused on the way illicit activities, which in this case, were defined as coca farming and cattle ranching, drive land use change patterns. The authors concluded that cattle ranching has been the main driver of forest loss outside the agricultural frontier in Colombia, a planning instrument defined in 2018 (Murillo-Sandoval et al. 2023). However, this planning instrument is not sufficient to distinguish where deforestation is illegal.

Like in most Amazonian countries, zero deforestation commitments have been defined and were recently renewed by Colombia in international scenarios (Gobierno de Colombia 2017, 2020; Furumo and Lambin 2020). However, these commitments make no mention of legal or illegal deforestation. Moreover, the literature that does analyze deforestation in Colombia and official data sources fails to incorporate the legal dimension in their analysis. This article aims to address this gap by identifying the areas where deforestation is legal and illegal based on the Colombian regulatory framework that addresses forest management and land use planning in the department of Guaviare, and by quantifying deforestation in these areas in the 2000–2020 period.

This case study highlights challenges to the definition of legal and illegal deforestation that need to be clarified and properly addressed in forested countries committed to zero deforestation. It is the first paper to propose a consistent analytical framework that makes it possible to differentiate legal and illegal deforestation in Colombia, an issue that must be properly and transparently addressed to avoid endless conflicts over the legitimacy of national and international policies aimed at zero deforestation. What is more, it evidences the need to revise and strengthen the funding of regional environmental authorities in territories where protected areas are predominant.

Analytical framework

The Colombian regulatory framework for land use and forest management consists of thirteen laws, decrees, and resolutions detailed in Online Resource 1. The functions, competencies, and restrictions of land use management at subnational levels are initially presented in this section. The specific environmental protection zones, which, for the purposes of this study, we refer to as "environmental units," are likewise defined by this analytical framework. Their characteristics are presented with a focus on authorized land uses. The forest harvesting regime, which established the legal framework for the extraction of forest products in 1996, is also detailed. This section concludes with the presentation

of the final analytical framework we used to distinguish legal and illegal deforestation in this paper.

Colombian land use planning regulation

Colombia's territorial organization comprises three types of subnational jurisdictions: departments, districts, and municipalities. The responsibility for planning and defining land uses belongs to the municipal authorities (Constitución Política de Colombia 1991, art. 330; Congreso de la República de Colombia 1993, art. 65,67, 1997, art. 1). A Land Use Plan is the primary instrument for implementing this process. Through this instrument, municipalities have the authority to zone their jurisdiction and define authorized and unauthorized uses within them (Presidencia de la República de Colombia 1998, art. 10,11,20, 2007, art. 5,9,16,17). This includes expanding or contracting urban and rural zones, and determining land use priorities in the zones, for example, housing, industrial, agricultural, or forestry uses (Congreso de la República de Colombia 1997, arts. 13–14). However, municipalities must include what we refer to as environmental units and indigenous reserves in their Land Use Plans but do not have the authority to regulate land use within these specific areas (Congreso de la República de Colombia 1994, art. 87, 1997, art. 2,10; Presidencia de la República de Colombia 2010, art. 19). Therefore, zones of the municipality that are outside of these special areas, where Land Use Plans are applicable, are what we refer to as “non-environmental units” for the purpose of our study.

Colombian environmental units

In 1959, seven areas in Colombia were designated as Forest Reserve Zones (Congreso de la República de Colombia 1959, art. 1). These zones represent about 45% of Colombia's continental area (~51 Mha). They were designated for conservation because they contain high-value species regardless of whether they are on public or private land (Presidencia de la República de Colombia 1953, arts. 2–3). The Amazon Forest Reserve zone encompasses eight departments in the southeastern part of Colombia, including Guaviare (Heno Sarmiento 2005).

The 1974 Colombian Natural Resources Code established the legal basis for forest management. The National Natural Park System was created including six different types of protected areas: national parks, natural reserves, unique natural areas, flora and fauna sanctuaries, and parkways (Presidencia de la República de Colombia 1974, art. 329). Uses other than conservation, research, education, recreation, and culture are prohibited within them (Presidencia de la República de Colombia 2010, art. 327,331–332).

Integrated Management Districts were also introduced by the Natural Resources Code (Presidencia de la República

de Colombia 1974, art. 310). In 1989, the law established that this environmental unit should be zoned according to four different categories, the “Production category” being the only one where productive activities are authorized (Ministerio de Agricultura y Desarrollo Rural 1989, art. 7). Although Integrated Management Districts were included in the category of protected areas as of 2010, the same norm established that Districts established prior to this date are only considered protected areas if they are registered in the National Registry of Protected Areas (Presidencia de la República de Colombia 2010, art. 10,22–24).

Civil Society Nature Reserves were also introduced as a type of environmental unit, created voluntarily on private property to safeguard a section of a natural ecosystem (Congreso de la República de Colombia 1993, arts. 109–110). This type of environmental unit can be zoned into four categories, two of which allow productive activities: the Agrosystem Zone and the Intensive Use and Infrastructure Zone (Presidencia de la República de Colombia 1999, art. 4).

Legal right to harvest timber

The forest harvesting regime was established in 1996 and acknowledges three types of Forest Harvest: Domestic, Persistent, and Single (Presidencia de la República de Colombia 1996, arts. 1–5). Single Forest Harvest legally allows the conversion of forest land to another use, i.e., legally allowing deforestation. Single Forest Harvest may be practiced in areas where it is permitted by law where there is evidence for a better aptitude for land use than forestry, or when there are reasons of public utility and social interest (Presidencia de la República de Colombia 1996, art. 5).

Single Forest Harvest is prohibited in forests located within the System of National Natural Parks, Forest Reserve Zones, and Indigenous Reserves. Single Forest Harvest is authorized in environmental units such as Integrated Management Districts and Civil Society Nature Reserves, when forests are not located in areas where they must be conserved in accordance with zoning by the regional environmental authority. Single Forest Harvest outside environmental units is permitted in zones where municipal Land Use Plans legally allow uses other than forestry.

The process of requesting authorization for a Single Forest Harvest includes presenting a technical study to the regional environmental authority that demonstrates a better aptitude for land use other than forestry or presenting the arguments for public utility and social interest that support it, as well as a forest harvesting plan (Presidencia de la República de Colombia 1996, art. 13,16). Additionally, in the case of private land, a document certifying ownership is required (Presidencia de la República de Colombia 1996, art. 13,16).

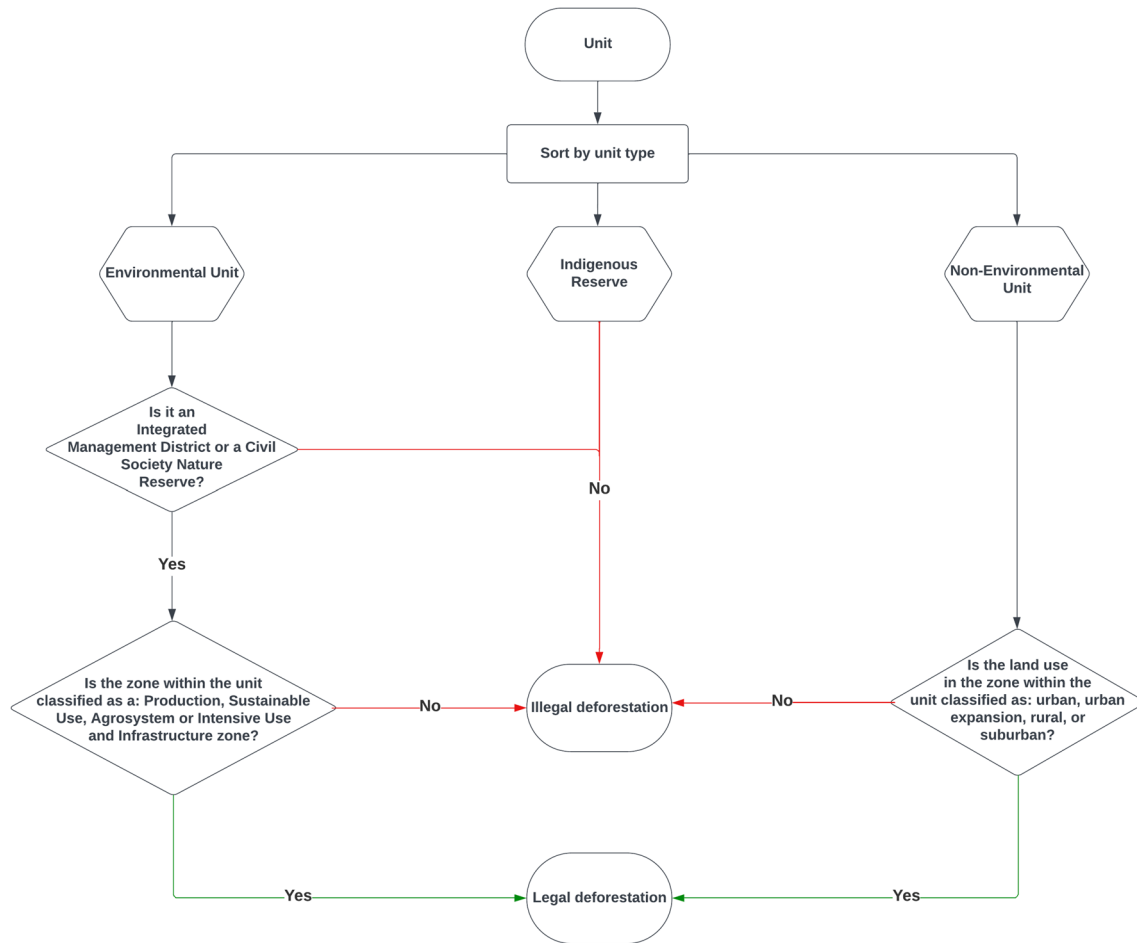


Fig. 1 Flowchart to determine the legality and illegality of deforestation

Legality is thus determined by both the area where the activity can be developed and the formal authorization issued by the environmental authority (Congreso de la República de Colombia 1993, art. 30). Such formal authorization is rarely requested (NEPCon 2017) and existing authorizations are not easy to locate. As it was not possible to access forest harvest authorizations for the purpose of this study, we decided to refer to legal and illegal deforestation for the removal of forest cover that occurs in respectively, zones of legal and illegal deforestation.

Final analytical framework

Drawing up a synthesis of the different regulations enabled us to create a flowchart to define the zones of legal and illegal deforestation (Fig. 1). First, the units are divided into three categories: environmental units, indigenous reserve and non-environmental units. Environmental units other than the Integrated Management District and Civil Society Nature Reserves, as well as Indigenous Reserves, prohibit deforestation in their area and are consequently automatically

classified as illegal deforestation zones. Deforestation is prohibited in the Integrated Management District and Civil Society Nature Reserves except in areas inside them zoned as Production, Sustainable Use, and Intensive Use, and Infrastructure. It is necessary to refer to the Land Use Plans of each municipality in the non-environmental units. The zone is classified as a legal deforestation zone if the municipal's Land Use Plan allows the expansion of productive activities; otherwise, deforestation is illegal.

Methods and data

Overview of the case study

The administrative department of Guaviare is located in eastern Colombia, on the northwestern side of the Colombian Amazon (Fig. 2). It covers a total area of 5,346,000 ha and has 82,767 inhabitants, 40% of whom reside in rural areas (DANE 2019). The region has an average altitude of 184 m above sea level, and a monomodal precipitation regime with annual

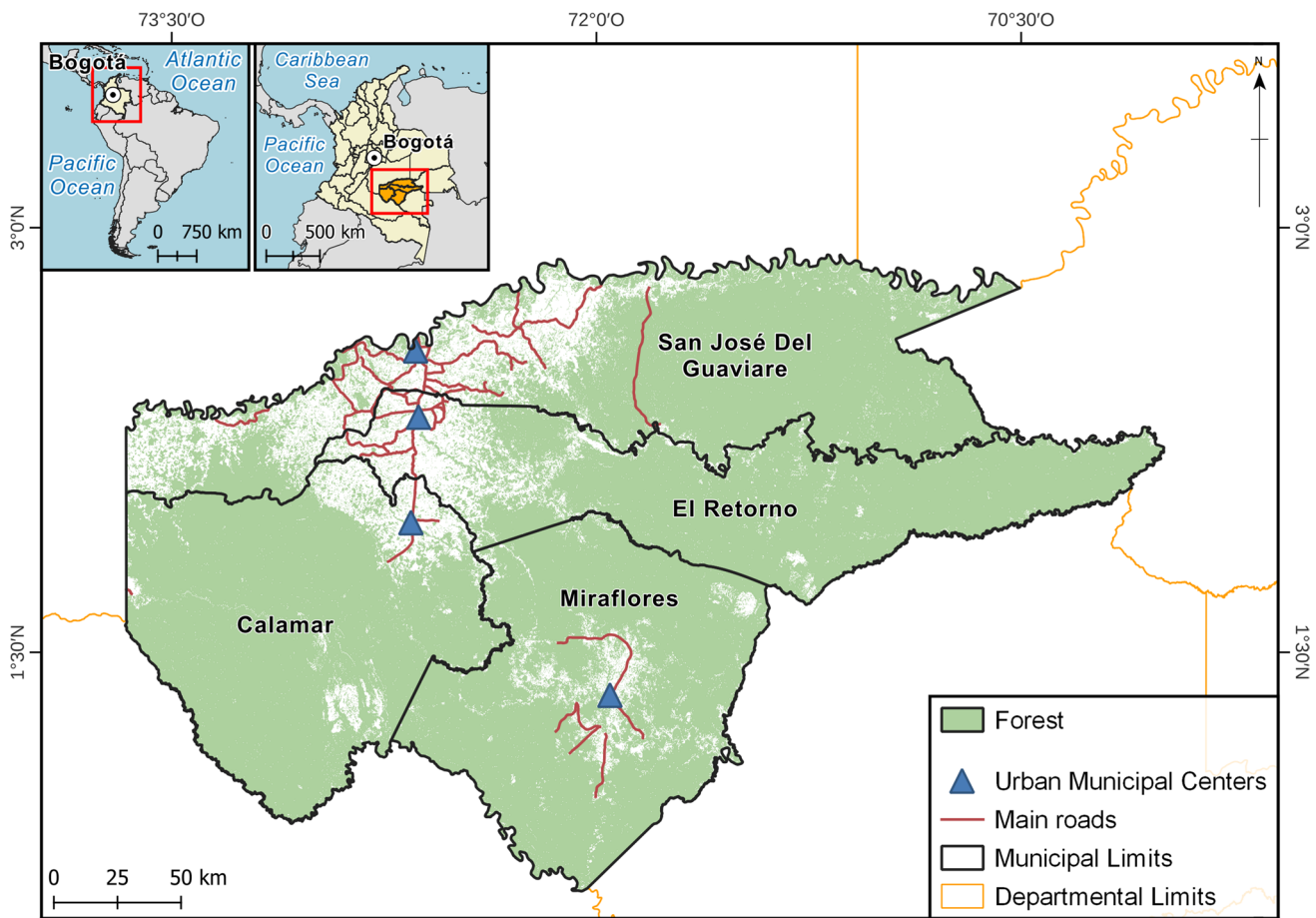


Fig. 2 Guaviare municipalities and forest in 2020 (sources in Online Resource 2)

average rainfall ranging from 2500 to 4000 mm. The climate is tropical, with an average annual temperature of 25 °C. The Amazon rainforest covers the vast majority of the department. Guaviare is comprised of four municipalities: San José del Guaviare, El Retorno, Calamar, and Miraflores (Gobernación Guaviare 2009) (Fig. 2).

Guaviare is one of the three departments in the northwestern arc of deforestation in the Colombian Amazon, which, since 2010, has accounted for almost 60% of the country's total deforestation (Etter et al. 2006a; Murcia et al. 2014; Armenteras et al. 2019; Correa Ayram et al. 2020). Guaviare lost around 283,000 hectares of primary forest between 2001 and 2020 (IDEAM 2022). Conversion of forest to grasslands is considered to be the main historical driver of deforestation in the region (Armenteras et al. 2006, 2013, 2019; Etter et al. 2006b; Dávalos et al. 2011; Murcia et al. 2014).

Method and data used to quantify illegal and legal deforestation

We quantified the dynamics of legal and illegal deforestation in Guaviare over the period 2000–2020 in two steps. First,

we identified areas where deforestation is legal and illegal. Then, based on the classification of these areas, we quantified deforestation over the same period.

Identification of areas of legal and illegal deforestation

We used data sourced from Colombian authorities to identify indigenous reserves, environmental and non-environmental units in Guaviare. We obtained the shapefiles for the Amazon Forest Reserves and Natural Protected Areas from the Colombian Environmental Information System, that contains all the geographic data produced by the country's environmental institutions (Online Resource 2). Information on Colombia's legally recognized Indigenous Reserves came from the National Land Agency (Online Resource 2). The shapes of these environmental units were matched with the official municipal boundaries of Guaviare. Guaviare FORLAND platform, which contains information on land use in the Guaviare department, served as source of information for regional environmental units such as the Integrated Management District (Online Resource 2). Municipal areas that were not overlaid on the Amazon Forest Reserve, Natural

Protected Areas, Indigenous Reserves, and the Integrated Management District are the areas classified as non-environmental units in our study. QGIS version 3.16.16-Hannover was used to prepare the shapefile data. Variations in the size of environmental and non-environmental units as well as zoning processes over time were taken into consideration in our assessment of the legality and illegality of deforestation.

The flowchart in Fig. 1 was applied to each of the aforementioned units within the boundaries of the department of Guaviare to determine whether they are a legal or illegal deforestation zone. For non-environmental units, Integrated Management Districts and Civil Society Nature Reserve, it is necessary to refer to their internal zoning to determine whether each of their zones correspond to areas of legal or illegal deforestation. We used Guaviare's municipal Land Use Plans to identify the Production and Sustainable Use zones within the non-environmental units, considered legal deforestation zones by our analytical framework (Online Resource 2). We used the administrative resolution that was used to create Guaviare's Civil Society Nature Reserve to identify the Intensive Use and Infrastructure zones (Online Resource 2).

Concerning the existing Integrated Management District in the department of Guaviare, there was an ambiguity in the law that made it difficult to determine whether deforestation was legal or illegal in the area before zoning that only took place in 2015 (Corporación CDA 2015). To fill this gap, interviews were conducted with the regional environmental authority in Guaviare as well as with the Division of Forests and Ecosystem Services of the Colombian Ministry of Environment and Sustainable Development, followed by a formal request to the Ministry of Environment and Sustainable Development, whose response resolved the legal ambiguity: Before 2015, this unit was entirely a zone of legal deforestation (Online Resource 3).

The time frame used for our study is 2000 to 2020 since all Colombian municipalities were required by law to have their Land Use Plans adopted by 2000 (Presidencia de la República de Colombia 2000, art. 1). In the municipalities of Guaviare department, the plans were adopted at different times between 2000 and 2004 (Online Resource 2). Despite the difference in timing, the study period from the year 2000 is applicable since until the development of the land use plan, regulations indicate that the authorities at other levels followed the current regulatory framework (Congreso de la República de Colombia 1997, art. 23; Presidencia de la República de Colombia 2000, art. 2).

Data used to assess deforestation

To quantify legal and illegal deforestation, we first referred to the dataset concerning changes in forest cover in tropical moist forest produced by the European Commission's Joint

Research Center (EC-JRC). We used data from EC-JRC because the Colombian Environmental Institute's (IDEAM) official deforestation data have only been annualized since 2013.

The EC-JRC produced a global dataset on forest cover change in tropical moist forests (TMF) using 41 years of Landsat time series (see Vancutsem et al. (2021)). The data are freely available from <https://forobs.jrc.ec.europa.eu/TMF>. This database contains information on the extent and the related disturbances (deforestation and degradation) and post-deforestation recovery (or forest regrowth) at 0.09 ha resolution (30 m), with 91% accuracy. We focused here on the deforestation disturbances, defined as a change in land cover (from forest to non-forested land) (Vancutsem et al. 2021).

We selected and downloaded the annual change dataset, a collection of 21 maps (from 2000 to 2020) of the department of Guaviare. For each year between 2000 and 2020, the selected dataset depicts the spatial extent of forest cover and any changes. We used Google Earth Engine scripts¹ to compute the annual deforestation area (see <https://forobs.jrc.ec.europa.eu/TMF/resources>). We matched the annualized deforestation and forest areas with our previously identified indigenous reserve, environmental and non-environmental units within the study area to estimate the extent of forest area in 2020 and annual deforestation area from 2000 to 2020.

Once the amount of deforestation in each indigenous reserve, environmental and non-environmental unit was determined, it was aggregated by category (legal or illegal), type of unit, and municipality using R version 4.3.1 (R Core Team 2000) as well as the ggplot2 package (Wickham 2009).

Results

In Guaviare, environmental units and indigenous reserves cover almost the entire department (99.9%). These include 26 legally recognized Indigenous Reserves, 10 Natural Protected Areas, 1 Forest Reserve Area, and 1 Integrated Management District. (Fig. 3). Indigenous Reserves, the National Natural Parks, and the Amazon Forest Reserve Zone account for 90.3% of the department (Table 1).

Legal and illegal deforestation zones in the department of Guaviare

Deforestation is only permitted in the Integrated Management District, Civil Society Nature Reserves, and in

¹ Google Earth Engine scripts code snapshot: <https://code.earthengine.google.com/6f3504e89f81e9f790acfe88b628bda1>

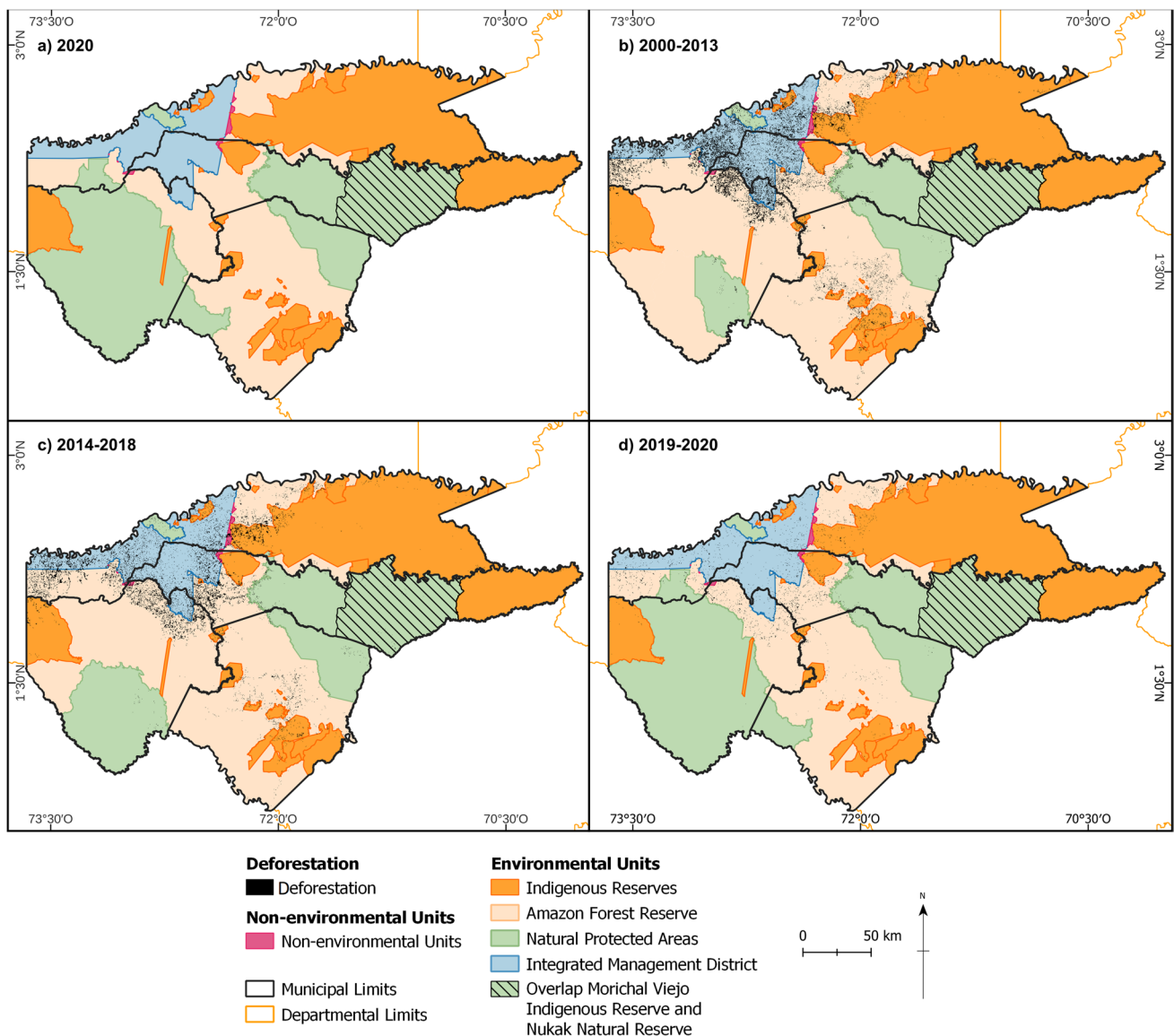


Fig. 3 Guaviare units and deforestation between **a** 2020, **b** 2000–2013, **c** 2014–2018, and **d** 2019–2020

non-environmental units, which since 2015, have represented 5% of the department’s total land area (Table 1). The surface area of legal deforestation within the Integrated Management District dropped from 100% of its jurisdiction to 64.3% due to a change in its regulation. From 2000 to 2020, the only change that affected delimitation of legal and illegal zones for deforestation was this zoning of the Integrated Management District in 2015.

Legal and illegal deforestation zones at the municipality level

San José del Guaviare and El Retorno municipalities have almost the same area of legal deforestation (after 2015) whereas the legal deforestation area is four times smaller

in Calamar than in the former two municipalities and non-existent in Miraflores (Table 2). The illegal deforestation zone represents 92.2% of the territory of San José del Guaviare, primarily Indigenous Reserves (58.4%) and the Amazon Forest Reserve Zone (18.8%) (Tables 1 and 2). El Retorno contains the second largest legal deforestation zone in the department, which accounts for 9.3% of its total land area after 2015 (Table 2). The municipality of Calamar has the smallest proportion of its surface area in a legal deforestation zone (2.2%) because its jurisdiction is mainly comprised of illegal deforestation zones such as the Serranía del Chiribiquete National Natural Park (68.8% of the total surface area of the municipality), the Amazon Forest Reserve Zone (18%), and the Indigenous Reserves (11.1%) (Table 1).

Table 1 Summary of the Guaviare units in terms of legal and illegal deforestation zones, along with their surface area (in hectares) in municipalities in 2020^{a,b}

Type of unit	Categories		Deforestation zone type		Municipalities				Total		
			Legal deforestation	Illegal deforestation	San José del Guaviare	Calamar	Miraflores	El Retorno			
Indigenous reserves				X	977,837	150,452	204,549	700,288	2,033,126		
Environmental	Natural Protected Areas	National Natural Parks		X	53,698	924,221	304,688	237,790	1,520,397		
		National Protected Forest Reserves		X	32,204	-	-	5288	37,492		
		Civil Society Nature Reserves ^c	X		-	-	-	277	277		
	Forest Reserve Areas of 1959 2nd Law	Amazon Forest Reserve Zone			X	323,670	251,071	770,139	154,685	1,499,565	
		Integrated Management District -IMD	After zoning in 2015	Preservation Zone		X	98,176	-	-	13,830	112,006
			Water Protection Zone		X	20,084	1786	-	-	11,688	33,558
			Restoration Zone		X	61,598	38	-	-	2639	64,275
	Sustainable Use Zone	X		132,475	28,271	-	-	126,716	287,462		
	Before zoning in 2015	Without Zoning	X		312,333	30,095	-	-	154,873	497,301	
Non-Environmental			X		5738	1142	-	-	1569	8449	
Total area					1,705,480	1,356,981	1,279,376	1,254,770	5,596,607		

^aThere is a 412,000 hectare overlap between the Nukak Nature Reserve and the Indigenous Reserve *Resguardo Morichal Viejo, Santa Rosa, Cerro Cucuy, Santa Cruz, Cao Danta*. We included the surface area of the overlap area in that of the Nukak Nature Reserve, a category of Natural Protected Area, to avoid double counting in the region. ^bThe surface area of the zones mentioned is that of the year 2020, except for the Integrated Management District where the periods before and after 2015 are differentiated since this is the only change that altered the surface area of legal and illegal deforestation zones. ^cThe Civil Society Natural Reserves in Guaviare were all created in 2018. The reported shape of these environmental units does not include the division based on their zoning. We chose to classify legal deforestation in these environmental units for our study because, despite the absence of the zoning shapefile, the administrative resolution used to create them contains two zones where deforestation is possible: Agrosystem and Intensive Use and Infrastructure

The change in the regulation in 2015 significantly reduced the area of legal deforestation in the municipality of San José del Guaviare and to a lesser extent in the municipalities of El Retorno and Calamar.

Deforestation in legal and illegal zones

Until 2013, annual deforested areas in the department of Guaviare were almost the same in legal and illegal zones (Fig. 4). From 2014, illegal annual deforestation was from two to five times higher than legal annual deforestation (Figs. 4 and 5). Total deforestation in Guaviare between 2000 and 2020 reached 322,160 hectares, with an average of 15,341 hectares deforested each year. Illegal deforestation increased from an average of 53% of annual deforestation between 2000 to 2012 to an average of 75% of Guaviare annual deforestation between 2013 and 2020.

Annual deforestation accelerated between 2013 and 2018 due only to the expansion of illegal deforestation, as legal deforestation has decreased continuously in Guaviare

since 2013. Moreover, after 2018, the accelerating trend ended and the level of annual deforestation is now far below its pre-2013 levels.

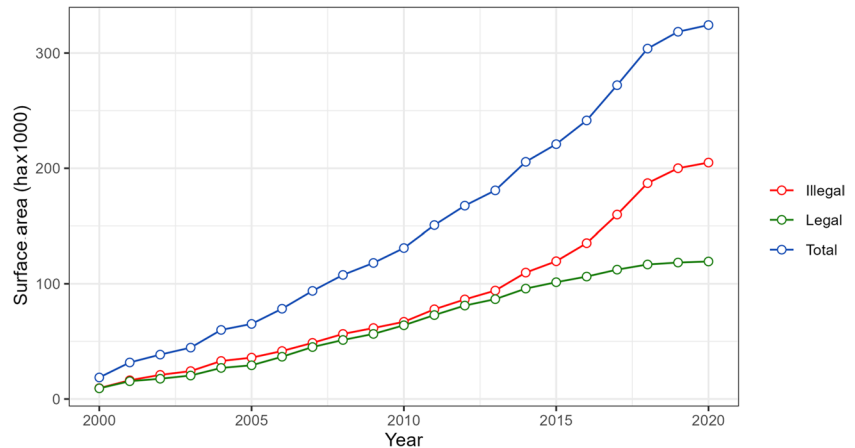
Concerning the situation in the different municipalities, more illegal annual deforestation took place than annual legal deforestation in San José del Guaviare, El Retorno, and Calamar from 2013 to 2020. Illegal deforestation has always been higher than legal deforestation in Miraflores (Fig. 5). In San José del Guaviare, the proportion of legal deforestation decreased from an annual average of 62% of total municipal deforestation in the 2000–2012 period to 30% in the period 2013–2020. A similar pattern was observed in the municipality of El Retorno. With a few exceptions in 2001 and 2006, illegal deforestation in Calamar has averaged more than 70% of the municipal total each year, and sometimes exceeded 90%.

The peak of illegal deforestation that occurred between 2013 and 2018 was concentrated in San José del Guaviare and to a lesser extent in Miraflores and El Retorno.

Table 2 Total area of legal deforestation zones (in hectares) in municipalities and their proportion of the total jurisdictional area, before and after 2015

Municipalities		San José del Guaviare	El Retorno	Calamar	Miraflores	Total
Area in legal zone before 2015	Hectare	312,333	154,873	30,095	-	497,301
	%	18.3%	11.4%	2.4%	0.0%	8.9%
Area in legal zone after 2015	Hectare	132,475	126,716	28,271	-	287,462
	%	7.8%	9.3%	2.2%	0.0%	5.1%

Fig. 4 Accumulated legal (green line with white circles) and illegal (red line with white circles), and total, deforestation (blue line with white circles) (in hectares) in Guaviare from 2000 to 2020



Remaining forests

In 2020, forest covered 85% of the total area of the department of Guaviare, which corresponds to over 4.7 million hectares (Table 3). Nearly 99% of the remaining forest is in areas where deforestation is prohibited. In Calamar and Miraflores, nearly all the forest is located in places where deforestation is illegal.

Discussion

Our findings indicate that the increase in deforestation in Guaviare occurs primarily in illegal zones and that this department, which is 85% covered by forest, has very limited potential for legal deforestation. Assessing the legality and illegality of deforestation must become a priority to move forward with the implementation of zero deforestation commitments.

In the department of Guaviare, the pattern of legal and illegal deforestation changed in 2013, with illegal deforestation increasing and prevailing from then on. However, the accelerated rate of increase during the negotiation and signing of the Peace Agreement with the Revolutionary Armed Forces of Colombia (FARC) (Negret et al. 2019; Prem et al. 2020; Rodríguez-de-Francisco et al. 2021; Murillo-Sandoval et al. 2021, 2023; Bautista-Cespedes et al. 2021) ended in 2019. Our results are in line with

those of Murillo-Sandoval et al. (2023); albeit we show that the definition of illegal and legal deforestation is more complex than they assumed. To define the legality and illegality of activities related to deforestation in Colombia, these authors used the Colombian Ministry of Agriculture’s 2018 resolution that established the country’s agricultural frontier (Ministerio de Agricultura y Desarrollo Rural 2018). However, this planning instrument does not prevail over the existing environmental units nor over the land uses determined by the municipalities (Ministerio de Agricultura y Desarrollo Rural 2018, art. 5,8). Our analytical framework demonstrates how the legality of deforestation depends on both the environmental regulatory framework and on the land uses defined by the municipality. Deforestation in regions outside protected areas, within what Murillo-Sandoval et al. (2023) consider as the agricultural frontier, may also be illegal. This is precisely what happened in Guaviare with the zoning of the Integrated Management District by the regional environmental authority in 2015.

Guaviare and other Amazonian departments have experienced periods of State encouragement of colonization, long periods of absence of the legal State because of the conflicts, and, most recently, the irregular return of the Colombian State as a result of the Peace Agreement (Del Cairo and Montenegro-Perini 2015; Hein et al. 2020). During this transition period, the Amazon was settled, and as a result, de facto property rights were created at the local level (Del Cairo and Montenegro-Perini 2015; Hein

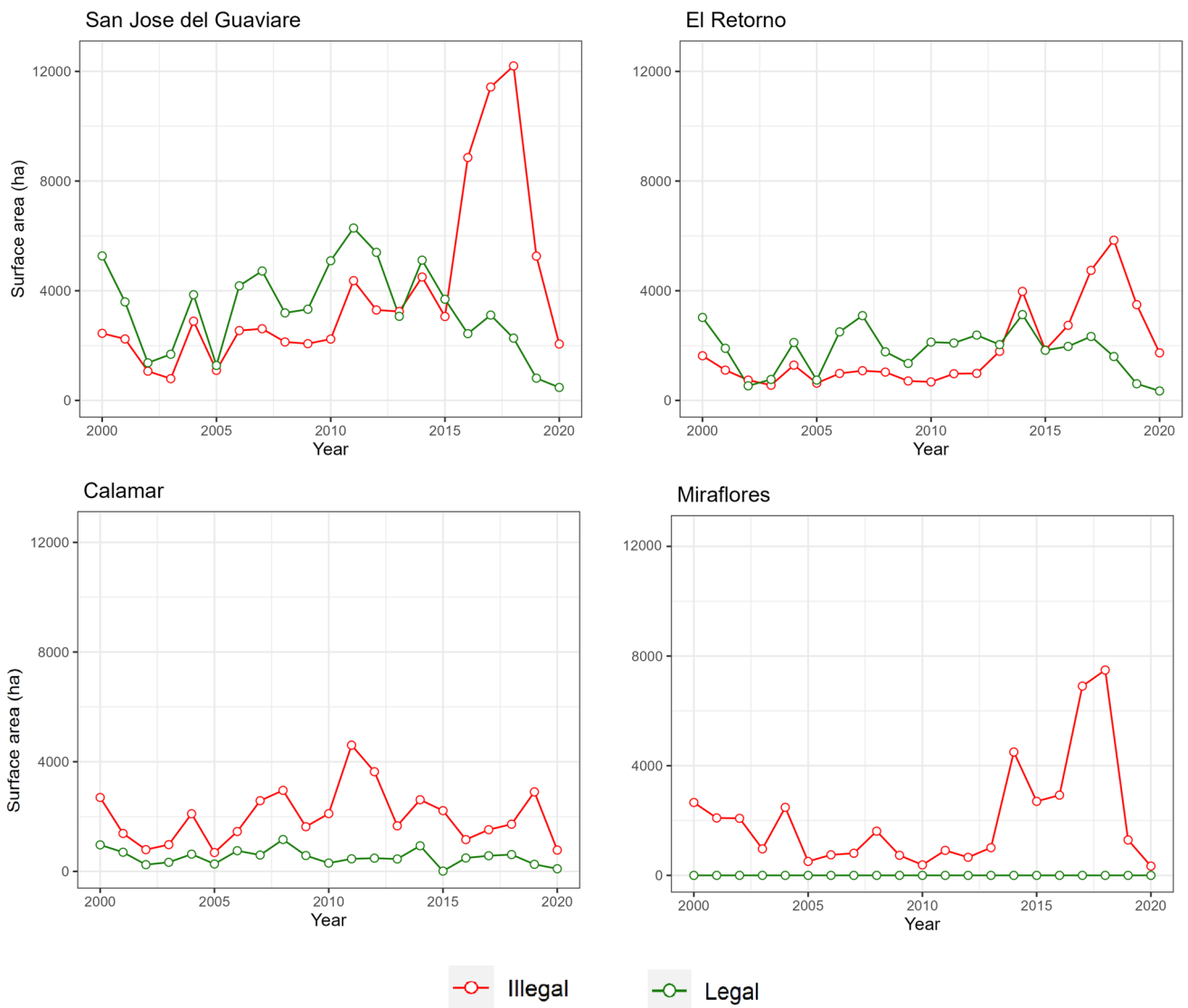


Fig. 5 Annual legal (green line with white circles) and illegal (red line with white circles) deforestation (in hectares) in **a** San José del Guaviare, **b** El Retorno, **c** Calamar, and **d** Miraflores municipalities from 2000 to 2020

Table 3 Total forest area and remaining forests in 2020 that can be legally deforested (in hectares) and their proportion of the total jurisdictional area in the Guaviare Department and its municipalities

	San José del Guaviare	El Retorno	Calamar	Miraflores	Total
Forest area (hectares)	1,168,971	1,092,051	1,084,820	1,060,556	4,710,648
% of the municipality	69%	88%	80%	83%	85%
Forests that can be deforested legally	23,579	18,388	3932	-	45,899
% of the remaining forest	2.0%	1.7%	0.4%	0.0%	1.0%

et al. 2020) across environmental and non-environmental units. This is not far from what happened across the other Amazon countries (Hecht et al., 2021) and in other tropical forests in Africa such as Ivory Coast (Dieng and Karsenty 2023). In such contexts, the fact that deforestation is

illegal has not discouraged it. Quite the contrary, it may have contributed to its advancement by acting in synergy with the absence of State control (Del Cairo and Montenegro-Perini 2015; Rodríguez-de-Francisco et al. 2021). The intermittent and heterogeneous presence of the State

in the territory over time (Vásquez 2014) has resulted in overlapping partial sovereignties. In this scenario, the rural population's social representations of what is legal and illegal, as well as what is legitimate, may be fluid. As *Ciro Rodríguez (2020)* points out, in the peasant culture of colonization, what is legal may not be perceived as legitimate, just as there may be legitimacy in illegality. From the perspective of the sociological concept of agency (*Giddens 2006*), this situation places peasant settlers in a position of constant negotiation with the State, reflected in selective acceptance or evasion of norms. Consequently, the uncontrolled expansion of deforestation in illegal deforestation areas is also due to flexible representations of what is legal and legitimate, which characterize the social agency of the actors involved in colonization.

To support the implementation of zero deforestation commitments, decisions must thus be made at the local level, including defining the status of *de facto* property rights, deciding on the many areas that have already been deforested, even illegally, and, most importantly, reaching binding agreements between the inhabitants of the territory and the Colombian State. These decisions represent long-term political changes that must arise from negotiations between political and social actors and lead to binding agreements (*Finnegan 2022*). Efforts of this nature have recently been noted in Brazil, where the Federal Government has called on municipal governments to collaborate in the process of decreasing deforestation rather than forcing them to do so (*Cravo 2023*). As in many Amazonian departments, in Guaviare, concertation has started to operationalize the stabilization of the various agricultural frontiers. It is indispensable but will take time and requires financial resources that are currently lacking.

Our study also reveals that the proper assessment of legal and illegal deforestation in Colombia must be conducted at the municipal level. The analytical framework proposed in *Fig. 1* can be applied to all municipalities. This adds to the authors who have highlighted the importance of addressing deforestation in Colombia at this scale (*Armenteras et al. 2013*; *Arias-Gaviria et al. 2021*). At the level of the Amazon region, Brazil is the only country where such an assessment has already been accomplished. *Camara et al. (2023)* showed, for example, that approximately 84% of deforestation in the Brazilian Legal Amazon in 2020 was illegal. *Rajão et al. (2020)* demonstrated that 62% of all potentially illegal deforestation in the Brazilian Amazon and Cerrado was concentrated on 2% of properties. Aside from Brazil, studies in Argentina are the only ones in Latin America that have assessed the legality of deforestation, and revealed the predominance of illegal deforestation (*Camba Sans et al. 2018*; *Vallejos et al. 2021*). Like in our case study, the legality of deforestation is generally determined by both the area where deforestation is allowed and the request for

formal authorization. However, such formal authorizations are most often neither requested nor easy to locate and are thus not taken into consideration by authors. This limitation is common to studies that have evaluated the legality and illegality of deforestation in other countries (*Rajão et al. 2020*; *Vallejos et al. 2021*; *Reis et al. 2021*; *Camara et al. 2023*), since information on licenses given by environmental authorities is neither regularly digitized nor readily accessible. The logic of our analytical framework could inspire similar assessments in the other Latin American countries, where most subnational governments have specific competencies that influence the delimitation of legal and illegal deforestation (*Rodríguez Becerra and Espinoza 2002*, chap. 8; *Busch and Amarjargal 2020*), and more generally in forested countries where the regulation of land use and forest management is shared between different levels of governments and institutions.

Our results show that Guaviare has very little legal deforestation potential. Illegal deforestation zones cover at least 90% of the municipalities' surface area and contain at least 98% of the remaining forest. This scenario is not far from the reality of the entire Colombian Amazon. The Amazon Forest Reserve Zone, where deforestation is illegal, comprises roughly 37.8 million hectares, or practically the whole Colombian Amazon rainforest (39 Mha) (*Henao Sarmiento 2005*). This is a noteworthy difference from the Brazilian Legal Amazon, where between 6.5 and 15.4 Mha could still be legally deforested (*Freitas et al. 2018*; *Stabile et al. 2022*). A situation other than committing to zero illegal deforestation in the Colombian Amazon appears difficult to achieve without, at least, strong support to make sustainable forest management viable and to sustainably intensify areas that are already deforested. To avoid a commitment to zero illegal deforestation being undermined by a revision of the legal boundaries, as recently occurred in Peru (*Gabay 2024*) or that may occur in Brazil (*Reis et al. 2021*), this commitment could be conditional on the current zoning of the forest estate and environmental units. In any case, this reinforces the need to clarify the issue of the illegality and legality of deforestation in tropical countries.

This clarification is also important for the design and implementation of public policies aimed at zero deforestation. In theory, policy instruments for tackling legal deforestation differ from those used to combat illegal deforestation (*Gregersen et al. 2010*). Incentives, such as Payment for Environmental Services, should primarily target regions where deforestation is legal, whereas efficient command-and-control policies are required where deforestation is illegal. Brazil, for example, introduced a number of initiatives that resulted in increased targeted control and enforcement and resulted in a significant reduction in illegal deforestation in the Amazon (*Assunção et al. 2012*; *Arima et al. 2014*; *Piketty et al. 2015*; *Tacconi et al. 2019*). However,

in practice, discussions about the design of public policies involve consideration of economic efficiency as well as a discussion of social equity and environmental justice criteria (Gregersen et al. 2010; Robinson et al. 2010; Karsenty et al. 2017; Wehkamp et al. 2018). Contexts of poverty and dependence on resource extraction, as well as limited funds available for enforcement often make full enforcement impossible (Robinson et al. 2010). Colombia is typical of such contexts. Although, theoretically, incentives should not be used to enforce existing regulations that prohibit deforestation, financial incentives that socially target small-scale producers could be used temporarily in complex illegal situations subject to specific conditions in order to balance efficiency and social equity. A prerequisite to justify and operationalize such hybrid approach is better clarification of legal and illegal situations.

Moreover, the need to distinguish between legal and illegal deforestation has increased with Forest Law Enforcement, Governance and Trade—FLEGT opportunities, regulatory reforms in United States and United Kingdom,² and most recently the new European Union regulation (EU) 2023/1115 on deforestation-free products (Karsenty 2022). The European Agreement, for example, prohibits the placing on its market or export from the European market of products that have contributed to deforestation or forest degradation after 31 December 2020, while also making the demonstration of legal environmental compliance compulsory (Karsenty 2022).

Finally, environmental units in Guaviare represent about 99% of the department's surface area. The issue of monitoring and controlling them remains critical. In Colombia, regional environmental authorities are responsible for controlling both legal and illegal deforestation in environmental and non-environmental units within the jurisdiction in which they legally operate. The Corporation for the Sustainable Development of Northern and Eastern Amazonia (Spanish acronym CDA) has jurisdiction over the departments of Guaviare, Vaupés, and Guainía that collectively occupy almost 18 million hectares.

The regional environmental authority's funds come from national transfers, from their own revenues from the use of the natural resources under their control, and from their share of the municipalities' property tax receipts in the jurisdiction in which they operate (Azuero and Rodríguez 2016; Díaz Salgar et al. 2022). The very large proportion of environmental units in Guaviare, like in most Amazon departments, means that municipal property tax receipts are limited. For example, the municipality of Miraflores, which

is entirely made up of environmental units, cannot collect property tax outside its urban area, so its contribution to the funding of the regional environmental authority is necessarily small. Calamar's deforested areas are mainly located in illegal zones, which also renders the collection of property tax impossible. This condition also results in a consistently low level of revenue being transferred to environmental authorities. The absence of legal land tenure also has a direct impact on the collection of property taxes, which is normally a significant source of revenue for environmental authorities (Azuero and Rodríguez 2016). Moreover, national transfers are proportional to the size of the municipality and to the population of the department, and are consequently also limited in the Amazon (Azuero and Rodríguez 2016). Funding for regional environmental authorities should doubtless be reviewed, given the preponderance of environmental units, that cannot easily host taxable economic activities. National transfers could also be linked to some ecological indicators—such as the share of protected areas in the department—as now applied in countries including Brazil, India, Portugal, China, and France through ecological fiscal transfers (Ring 2008; Busch et al. 2021).

Conclusion

Assessing the legality and illegality of deforestation in forested countries is more complex than often assumed, especially when regulation on forest and land management is shared between different level of governments and institutions. Yet, the distinction is essential to enable progress towards zero deforestation.

This assessment must be urgently undertaken to achieve the long-term goal of zero deforestation at national and international levels and requires concertation and coordination with subnational authorities. Building and applying transparent analytical frameworks, such as the one we present for Colombia in our study, can improve communication and concertation between the different stakeholders and institutions involved in the long term over zero deforestation commitments. Our framework is particularly appropriate for use in Pan-Amazon territories, where land use competencies and socio-economic complexity resemble those in Colombia.

Assessing legal and illegal deforestation will better inform the design of policy instruments to address the issue. Where zero illegal deforestation is especially difficult to achieve, concertation is indispensable and calls for better suited and localized instruments combining incentives and command and control. Assessing legality also makes it possible to more finely target the areas that have already been deforested, even illegally, where the priority is to rule on the status of de facto property rights.

² The U.K. Environment Act 2021 and the forthcoming U.S. Fostering Overseas Rule of law and Environmentally Sound Trade Act prohibit the admission of products derived from illegal deforestation only.

Identifying the share of forests in legal and illegal deforestation zones at subnational levels makes it possible to address the specific issue of funding criteria for subnational governments and environmental authorities. What is more, distinguishing illegal and legal deforestation will also make it easier for future research to correctly assess their specific impacts on local livelihoods and development.

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Data Availability All relevant information used in this study is available from the Supplementary file 2 and from the Google Earth Engine script in footnote 1.

Declarations

Conflict of interest The authors declare no competing interests.

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