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Unveiling policy gaps to better address the causes and drivers of tropical deforestation: A case study from the Colombian Amazon

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ABSTRACT

Despite a clear understanding of the factors driving deforestation and the acknowledged need to control it, tropical deforestation remains a significant social and environmental challenge. Public policy can play a crucial role in combating tropical deforestation, yet gaps in policy formulation, operationalisation, and implementation can hinder its effectiveness. There is currently a lack of detailed analysis on policy gaps, especially concerning tropical deforestation. Our study analysed the policy gaps in a deforestation frontier in the Colombian Amazon during the post-conflict period to enhance our understanding of why public policies might be inadequate in curbing deforestation. This analysis involved identifying potential gaps in the formulation, operationalisation, and implementation of a major national policy framework aimed at controlling deforestation in Colombia. To identify and delineate these policy gaps, we combined secondary literature on deforestation drivers, existing databases, institutional capacity analyses, and national statistics. Our findings indicate that land speculation, a power vacuum, the expansion of pastures, cattle ranching, and infrastructure development are driving tropical deforestation in the study area. Additionally, this process of deforestation is linked to systemic and structural challenges in institutional capacity, broadening policy gaps, such as the exclusion of the main drivers in policy formulation, a lack of local capacity and resources for policy implementation, diverging visions and preferences for regional development, centralisation, and policy obsolescence, which affect both policy operationalisation and implementation. Based on these identified gaps, we discuss potential policy interventions to address them in the study area and other tropical regions.

1. Introduction

In 2022, the world lost 4.1 million hectares of primary tropical forests, falling short of the commitments to halt deforestation by 2030 (Forest Declaration Assessment Partners, 2023). This loss continues despite the increased public commitment and pressing need to control and mitigate it (Ellwanger et al., 2020; FAO, 2022; Lawrence et al., 2022), as well as growing knowledge about deforestation processes and their drivers across regions and scales (Geist and Lambin, 2002; Curtis et al., 2018; Balboni et al., 2023; Hänggli et al., 2023). Additionally, the harmful social and environmental consequences of tropical deforestation are well documented (Seymour and Harris, 2019; FAO, 2022; Lapola et al., 2023; Pendrill et al., 2023).

Persistent deforestation can be analysed at multiple interconnected levels (Meadows, 1999; Abson et al., 2016). At a deeper level, deforestation can be seen as the result of unsustainable development narratives imposed by powerful actors who shape and benefit from the (absence of) rules and policies (Schmink et al., 2019; Hecht et al., 2021; Kröger, 2024). At the intermediate level, it can be analysed in terms of insufficient, misaligned, or unenforced policies and institutional capacities (Kissinger, 2020). At a more shallow level, deforestation can be studied as a dynamic frontier process, where increased spatial and market accessibility determine deforestation rates (Browder et al., 2008; Meyfroidt et al., 2024).

The focus of this study is on the intermediate level, recognising that public policy is a fundamental component of the broader strategies required to effectively control deforestation (Arima et al., 2014; Nepstad et al., 2014; Furumo and Lambin, 2021). For instance, changes in

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environmental policies between different Brazilian governments in the early 2000s caused fluctuations in deforestation rates in the Amazon (de Area Leão Pereira et al., 2019; Silva Junior et al., 2021).

Governmental action can be weakened by policy gaps (Locatelli et al., 2017; Ménard et al., 2018; Cashore et al., 2021). A major gap is the failure to address well-known causes and drivers of deforestation (Seymour and Harris, 2019; Bos et al., 2020; Rodríguez-de-Francisco et al., 2021). Another critical gap is the lack of institutional capacity to effectively implement existing policies (Ménard et al., 2018; Abdullahi and Othman, 2021). An integrated analysis is needed to better identify these gaps, improving decision-making processes and ensuring that policy expectations translate into tangible outcomes (Foxell and Cooper, 2015; Abdullahi and Othman, 2021).

The literature on policy gaps covers a wide range of environmental issues, such as meeting climate objectives (Hoberg et al., 2016; Gallagher et al., 2019; Nascimento et al., 2022), energy transitions (Greim et al., 2020; Kati et al., 2023), biodiversity conservation (Duffus et al., 2023), water services (Ménard et al., 2018), and afforestation (Clement and Amezaga, 2009). Studies on tropical deforestation (Nurfatriani et al., 2015; Kalaba, 2016; Aleixo and Junior, 2022) have generally focused on assessing the effectiveness of interventions rather than identifying potential gaps in the policy formulation and implementation (Ferrer Velasco et al., 2023; Hänggli et al., 2023). Additionally, these efforts have largely examined policy gaps at the national level (Kissinger, 2020), overlooking regional differences in the causes and drivers of deforestation.

A policy gap analysis of a policy framework aimed at controlling deforestation at the territorial level over a defined time period is essential to capture the complexity of deforestation processes and evaluate the effectiveness of policy instruments (Arias-Gaviria et al., 2021; Bautista-Cespedes et al., 2021; Vanegas-Cubillos et al., 2022; Hänggli et al., 2023). This also allows for an analysis of how local institutional capacities and policy implementation are integrated, providing a clearer understanding of where policies need to be better aligned with local needs and capabilities.

This study aims to better understand why public policies may be ineffective in controlling tropical deforestation in a specific territory in Colombia by examining gaps in policy formulation, operationalisation, and implementation. This study focuses on the department of Guaviare, a deforestation frontier in the Amazon that includes collective territories, national parks, and forest reserves. Guaviare has faced significant deforestation, driven by land speculation, agriculture, and cattle ranching, particularly after the 2016 peace agreement with a major guerrilla group (Baptiste et al., 2017; Prem et al., 2020). Following the peace deal, deforestation increased by 44 % due to land grabbing and infrastructure development. Despite conservation efforts, such as the REDD+ Program, forest loss remains a major challenge (Rodríguez-de-Francisco et al., 2021; FCDS, 2023).

We integrate concepts and methodologies from public policy and land use research to bridge academic and policy-making domains. We also aim to advance understanding of the drivers of tropical deforestation. We begin by outlining the conceptual background, followed by an analysis of deforestation drivers in the study area based on secondary literature, with a focus on the post-conflict period. We then assess whether a key national policy framework addresses these drivers and examine both the institutional capacity for implementation and the extent to which the policy has been put into practice.

2. Causes and drivers of deforestation, policy gaps and institutional capacity: a conceptual background

To address the objective of this study, we integrated three key concepts: proximate causes and drivers of deforestation, policy gaps, and institutional capacity. First, proximate causes are land-use changes that directly cause deforestation on a smaller scale, while underlying factors are indirect forces that trigger deforestation by affecting these causes (Hänggli et al., 2023). Deforestation is a varied and dynamic process, frequently resulting from a combination of multiple proximate causes and underlying drivers interacting over time (Geist and Lambin, 2002; Curtis et al., 2018).

For the Amazon, Hänggli et al. (2023), based on Geist and Lambin (2002), identified four major proximate causes (agriculture, mining, infrastructure, others), and six major underlying drivers (economic, technological, institutional, environmental, demographic, and cultural factors). For Colombia, Vanegas-Cubillos et al. (2022) identified cattle ranching, agriculture, illicit crops, and infrastructure and mining as the most common proximate causes of deforestation. They also found that policy and institutional drivers, socio-economic conditions, conflict dynamics, demographic factors, and environmental conditions were the most frequent underlying drivers of deforestation. These proximate causes and underlying factors also varied across different regions and time periods (Vanegas-Cubillos et al., 2022).

Second, policy gaps are defined as the failure to address specific challenges due to inadequate knowledge, and the discrepancies between the stipulations of a policy and their actual implementation. Such gaps can arise at any stage of the policy-making process, including formulation (i.e. develop policy options and proposing solutions), operationalisation (i.e. development of actionable plans), and implementation (i.e. put policy into action), involving different institutional actors and levels. During the formulation stage, a gap may occur if the policy fails to consider the drivers of change, as well as the realities of the targeted areas and the institutions involved (Ménard et al., 2018). For instance, a national policy to control deforestation, in trying to meet international commitments, may set unrealistic objectives that are not aligned with the local context and institutional capabilities. At the operationalisation stage, gaps often emerge between the responsibilities given to local governments or territorial regulatory bodies and their actual capacity to act, known as institutional capacity (Ménard et al., 2018). This is particularly common in centralised environmental policies, where the implementation territories are often far from the government centres where the policies were formulated.

At the implementation stage, policy gaps reflect the ability of territorial and local entities to effectively execute and coordinate policies in collaboration with key local stakeholders. For example, deforestation control policies often involve a wide range of actors, including community, private, and international organisations. This diversity can lead to conflicting interests, and the presence of influential local actors or coalitions can impede policy implementation (Weible et al., 2009). These challenges are particularly evident in countries and regions with weak institutions, prevalent corruption, and high institutional fragility (Ménard et al., 2018), especially in post-conflict scenarios.

Last, institutional capacity is "a set of formal and informal rules, norms, procedures, as well as values, beliefs, knowledge, and skills, enabling the reconciliation of composite policy goals, harmonisation of multiple policy instruments and coordination of relevant policy actors" (Domorenok et al., 2021). Thus, capacity refers to an organization's ability to perform effectively and efficiently in a dynamic environment. Analysing institutional capacity can help government entities to effectively fulfil their roles in regulating and controlling deforestation (Davids, 2009).

Challenges in institutional capacity can emerge and be examined within both the systemic and organisational dimensions (Domorenok et al., 2021). In the systemic dimension, the analysis aims to understand how the organisation's adaptation to the institutional arrangement allows its action and establishing a governance structure. This structure involves interactions and interdependencies to achieve the fulfilment of its missionary objectives. Thus institutional capacity is directly affected by the effectiveness of the relations that exist between and among government entities (Davids, 2009), and between these and social actors. "Effectiveness is understood here as the degree of co-operation, support and mutual respect that they have with each other in policy formulation and implementation" (Davids, 2009).

In this dimension, capacity involves building a strong framework of rules, instruments, and policies that enable cross-sectoral collaboration and ensure consistent policymaking across actors (Domorenok et al., 2021). This dimension focuses on governance structures and coordinated actions throughout the policy cycle, encompassing seven key subdimensions: coordination dynamics, collaboration across government levels, engagement of social actors, regulatory constraints, legitimacy, cultural factors, and belief systems.

Effective coordination between institutions is crucial in combating deforestation. While resources are national, local authorities understand the territory better and have greater legitimacy. Therefore, collaboration between both levels of government is essential. Also, it is necessary to have a regulatory instrumental that allows effective action by the authorities, as well as confidence in the institutions. Without this, resistance to change will be a serious obstacle to policy.

In the organisational dimension, capacity refers to the internal structures and administrative resources that enhance coordination within organisations and enable well-defined roles and management. This includes teams and collectives, as well as structures, information systems, processes, documents, databases, and other resources that form the capacities of an organisation (Camões et al., 2017). It also involves information mobilisation capabilities to support timely and relevant policy decisions (Mukherjee et al., 2021).

The organisation level includes two subdimensions: bureaucratic skills and organisational effectiveness. Bureaucratic skills involve the number, diversity, and roles of officials, as well as their knowledge, motivations, and task-related capabilities. Organisational structure pertains to the technical and administrative capacity to achieve both policy and mission-oriented objectives, including the effectiveness of planning, the existence of monitoring systems within the coordination dimension, financial resources, proper function allocation, accountability, and decision-making processes (Camões et al., 2017; Domorenok et al., 2021).

In conclusion, policy gaps refer to deficiencies in the design, operationalisation, or implementation of public policy that result in a mismatch between intended policy objectives and the outcomes achieved through government action. These gaps can arise or be exacerbated by low institutional capacity, understood as the ability of institutions to effectively carry out the actions required to fulfil their mandate.

Addressing deforestation drivers involves broad organisational capacity. Even the monitoring of deforested areas alone requires significant technological capability, which is essential for effective action. Additionally, the policy relies on trained personnel with sufficient physical and logistical resources to cover large areas.

3. Methodology

3.1. Study area, deforestation and context

Guaviare is one of the 32 departments of Colombia, covering 53,460 km^2 in the Amazon basin. It borders the natural savannas of "Los Llanos" to the north, strategically connecting the ecosystems of the Amazon, Orinoquia, and Andes regions. The department is home to the Nukak Natural Reserve and part of the Serranía de Chiribiquete National Natural Park, a UNESCO World Heritage site. Guaviare has an estimated population of 92,000 inhabitants, including indigenous communities. Numerous rivers cross the landscape, providing unique access routes to the region (Fig. 1).

For decades, the region has experienced deforestation and landscape transformation. The early 20th century rubber boom significantly impacted indigenous communities and led to the development of main urban centres and trails across the area (Arcila et al., 1999). By the mid-20th century, this transformation expanded further with extensive agriculture and cattle ranching near urban centres and along rivers (Acosta, 1990).

In the late 20th and early 21st centuries, landscape changes were driven by fluctuating migration patterns, the expansion and decline of illegal crops, armed conflict, the presence of illegal groups, and weak government control (Acosta, 1990; Taborda, 2002; Unigarro Caguasango, 2020). By the 2010s, a significant portion of the region was under the control of the guerrilla group FARC E.P, which both limited and regulated deforestation. In 2016, a historic peace agreement was reached between the government and FARC-EP. However, the lack of government presence and investment created a power vacuum, contributing to a 44 % increase in deforestation both within the study area and across the country (Baptiste et al., 2017; Prem et al., 2020). This surge was largely driven by powerful actors exploiting the vacuum,

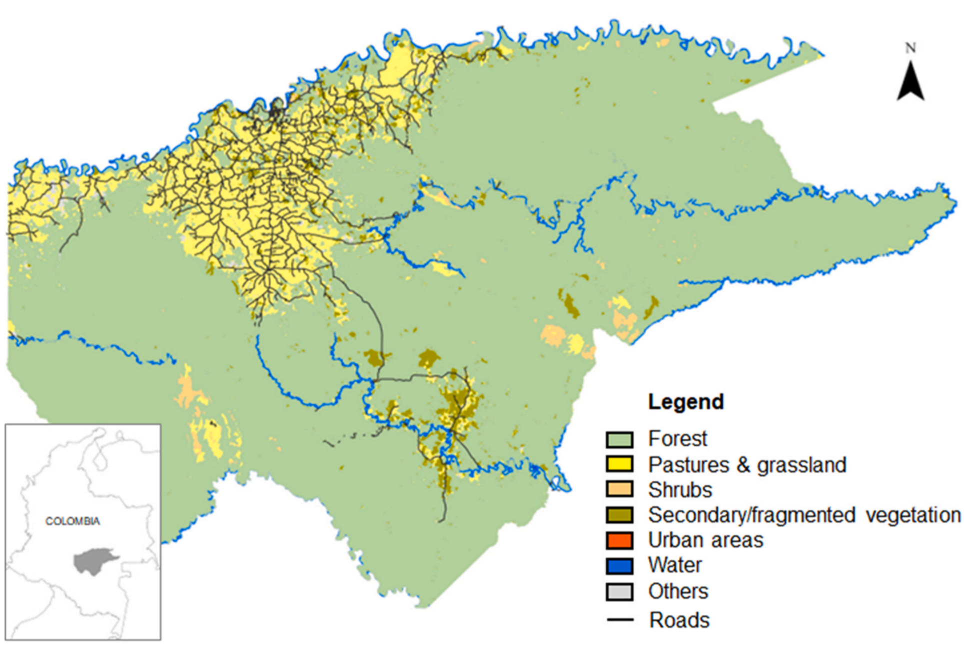

Fig. 1. Location and land cover of the study area in 2022, including roads. The shaded area on the map in the lower left corner shows the location of the study area in Colombia. Source: SINCHI, HDX.

intensifying drivers such as land grabbing and infrastructure development (Rodríguez-de-Francisco et al., 2021).

These historical dynamics have shaped the rate and distribution of deforestation in the region (Fig. 2). According to the Tropical Moist Forest dataset of the European Commission – Joint Research Centre (Vancutsem et al., 2023), dense tropical forest covered approximately 93 % of the study area in 1990. By 2022, however, 645,880 ha (12.5 % of that forest cover) had been lost. Most deforestation occurred near urban areas, pastures, roads, and rivers (Fig. 2), while deforestation rates were generally lower in protected natural areas and indigenous reserves compared to surrounding regions (Armenteras et al., 2009). This pattern is also reflected in 2022 land use data from the "Instituto Amazónico de Investigaciones Científicas" SINCHI, which show that the area remained predominantly forested (79 %), with pastures covering 11 %, and secondary/fragmented vegetation making up the rest. Agricultural land (0.07 %) and built areas (0.02 %) remained very limited in extent (Fig. 1).

Public policy and land tenure are two major factors shaping landscape transformation and deforestation in the region. Since the 1950s, the Colombian government has enacted various policy and regulatory frameworks to manage forest and control deforestation. By mid-2010's, peace negotiations, international support, and commitments led to the REDD+ for Early Movers Program (REM), aimed at curbing deforestation (Rodríguez-de-Francisco et al., 2021). In 2020, the government introduced CONPES 4021, a comprehensive public policy framework that provides clear guidelines and enables intersectoral, structural, and territorial actions. The framework aligns national and international efforts (e.g. REM) and sets a target of zero net deforestation by 2030. It outlines four strategic priorities: sustainable forest use to enhance local community livelihoods, cross-sectoral actions for forest management and conflict resolution, prevention and territorial control to curb illegal activities, and improved information for decision-making. These priorities are supported by 50 specific actions across 2–4 action lines each.

Deforestation dynamics in Colombia are also closely tied to historical land tenure conflicts (Centro Nacional de Memoria, 2016; Castro-Nunez et al., 2017). Beyond private property, three main types of designated areas play a significant role in forest governance. First, the Forest Reserves (FR), established by Law 2 of 1959, aim to protect soil, water, and biodiversity while supporting forest-based economies. These include both public and private lands (IDEAM, 2005). Second, the same law created protected areas under the National Natural Parks System (NNPS) to conserve native flora and fauna (PNN, 2024). Thirdly, Collective Territories legally recognise land rights for indigenous peoples, Afro-descendants, and peasant communities, and peasants, including Indigenous Reservations, Afro Communities Lands and Peasant Reserve Zones. These areas are also important for their biodiversity (Alonso et al., 2017).

3.2. Data collection and analysis

3.2.1. Causes and drivers of deforestation

A hybrid search strategy combining peer reviewed and grey literature was conducted in December 2023 to identify recent (2017–2023) main causes and drivers of deforestation in the study area (Wohlin et al., 2022). The initial search was carried out on Google Scholar using keywords in both English and Spanish: (drivers AND deforestation AND Guaviare) OR (motores AND deforestación AND Guaviare). Then, references in the preselected publications related to the topic were also reviewed and included in the search. A document analysis was then conducted to determine whether specific deforestation drivers for the study area were mentioned. Additionally, existing databases were identified and used to quantify the selected causes and drivers, including the magnitude and temporal changes in the last decades.

3.2.2. Policy gaps and institutional capacity

To identify the main policy gaps, the methodological design followed the three stages of the policy cycle: formulation, operationalisation, and implementation (Abdullahi and Othman, 2021). For the formulation stage (de jure), a content analysis was conducted by coding each action line of CONPES 4021 against the identified deforestation drivers. The CONPES was selected because it consolidated and articulated all state actions aimed at combating deforestation, with the goal of establishing a cohesive inter-institutional framework at the national level. When it was released, it became the main policy reference for addressing deforestation, and it is reinforced by other sectoral policies. Since some actions could indirectly address certain drivers, a distinction was made between direct and indirect actions. This qualitative classification was conducted individually by two coauthors and subsequently validated by a third.

The institutional analysis, initially focused on the operationalisation stage, also identify gaps across all stages of the policy cycle. Similar to Cardona-Cardona et al. (2017) and Bjärstig et al. (2024), it utilised co-diagnosis tools with local and national officials conducted between

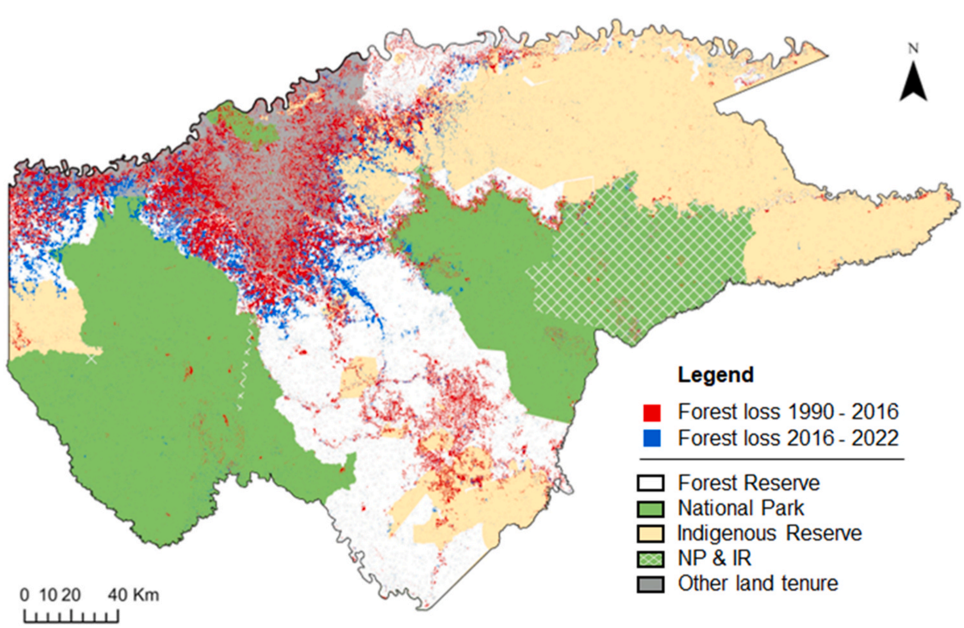

Fig. 2. Deforestation from 1990 to 2022, and the different land tenure systems in the study area. Source: EC JRC.

2021 and 2023. Five co-diagnosis sessions were carried out to assess institutional capacity for deforestation control, with a focus on both the systemic and organisational dimensions. These sessions followed three main steps: organising knowledge, building common understanding, and identifying potential solutions.

Additionally, 18 semi-structured interviews were conducted with local leaders, national officials, and public administrators to validate the co-diagnosis findings and offer a broader analysis of institutional capacity and policy challenges related to deforestation and its drivers. Rather than focusing on the diversity of stakeholder perceptions, the interviews aimed to identify general patterns in common challenges and to triangulate the information gathered during the co-diagnosis sessions. The data were coded based on deforestation drivers and key themes, including inter-institutional coordination, national government guidelines and legitimacy, actors' interests, institutional limitations, corruption, and political dynamics. Challenges mentioned in either a co-diagnosis session or an interview were given equal weight in the analysis.

For the implementation stage (de facto), progress on the CONPES 4021 actions were monitored using the Action and Monitoring Plan (PAS) available on SisCONPES platform (https://sisconpes.dnp.gov.co/). This is an official online tracking tool developed by the DNP to report on, monitor, and validate the implementation of a CONPES, including the progress of each action line. The qualitative assessment of each CONPES is the responsibility of the technical director leading the document at the DNP.

4. Results

We identified the recent proximate causes and underlying factors driving deforestation in the study area. Considering these factors, we analysed the challenges of the main policy framework throughout the policy cycle.

4.1. Current causes and drivers of deforestation in Guaviare

Multiple interacting proximate causes and underlying drivers of deforestation for the selected period in the region were identified through an analysis of 14 documents from the secondary literature (Table 1). In terms of proximate causes, pasture expansion for cattle ranching was a major agricultural cause of forest loss (KPMG, 2020; Rodríguez-de-Francisco et al., 2021; Camacho Peña, 2022; FCDS, 2023). Data from FEDEGAN (Federación Colombiana de Ganaderos) showed that although cattle population had been increasing over the last decades, it almost doubled after the peace agreement in 2016, reaching more than half a million cattle by 2022. Similarly, land cover data from SINCHI indicated that the area of pasture increased from half a million to three-quarters of a million hectares from 2016 to 2022. Simultaneously, the annual rate of forest loss significantly increased, jumping from 17,952 ha in 2016–50,697 ha in 2017 (Fig. 3).

Table 1
Proximate causes and underlying drivers identified for the study area in the post conflict period. Sources: Secondary literature (please refer to Supplementary Material S1).

Proximate causes	Agriculture	*Pasture expansion & cattle ranching*[1–4]
		Illicit crops[1–7]
	Infrastructure	*Illegal & planned*[1–6,8,9]
	Other	*Predisposition (accessibility)*[2,5]
		Fire[3,10,11,12]
Underlying drivers	Economic	*Land speculation*[1,4]
	Environmental	*Topography*[2]
	Institutional	*Conflict dynamics & power vacuum*[1,4,6,13]
		Land tenure, grabbing & corruption[1,3,4,6,14]
	Demographic	*Migration*[1]
		Population growth[2]

Rodríguez-de-Francisco et al. (2021), Camacho-Peña (2022), FCDS (2023), KPMG (2020), Bautista-Cespedes et al. (2021), InSight Crime and Igarapé Institute (2021), UNODC (2023), FCDS (2021), FZC (2023), Tebbutt et al. (2021), Armenteras et al. (2019), Armenteras and Retana (2012), Clerici et al. (2020), Cheston et al. (2023).

Although illegal crops were identified as a cause of deforestation (FCDS, 2023), the reported area has drastically decreased from 27, 380 ha in 2002 to less than 5000 ha after 2016. However, after years of decline, with almost a 50 % of the cultivated area abandoned over the last decade, the area under illicit crops increased by 11 % between 2021 and 2022, particularly within National Parks (UNODC, 2023).

Infrastructure expansion and improvement were a major cause of deforestation in Guaviare (Bautista-Cespedes et al., 2021; Rodríguez-de-Francisco et al., 2021; Camacho Peña, 2022; FCDS, 2023). A recent study revealed that 93 % of the areas affected by deforestation, including in Guaviare, occurred within less than 2 km from a road (FCDS, 2021). Although the origins of these illegal and planned roads trace back to previous decades, infrastructure is currently impacting deforestation in three distinct levels. At national level, an official initiative exists to endorse green infrastructure guidelines for the development and expansion of major road infrastructure (MADS et al., 2020). A pilot of this initiative is the extension of the "Troncal de la Orinoquía", a road 73 km long, that connects the northern part of the department with the centre of the country, included in the CONPES 4021 (WWF, 2021).

The second level encompasses the tertiary roads network, which consists of smaller, local roads that connect remote rural areas to major roads or urban centres. This network accounts for approximately 70 % of Colombia's roads, with many located in regions designated for biodiversity conservation. These roads are identified as a main cause of deforestation, leading to the formulation of public policy guidelines in the CONPES 3857, 2016 (DNP, 2016). Since 2016, Guaviare has implemented the Departmental Road Plan, developed through participatory processes within the Strategic Axes of Economic and Territorial Integration (Gobernación del Guaviare, 2016).

A clear tension arises between this road development plan and efforts to control deforestation, exemplified by the La Ye-Miraflores road linking Miraflores and Calamar municipalities. While this road was a priority in the 2016 PVG, it is now subject to conservation measures that restrict movement to protect nature, highlighting the conflict between local government and community expectations versus Amazon conservation needs. Miraflores witnessed significant tree and primary forest cover loss between 2001 and 2021, leading to substantial CO_2 emissions. The last level includes the so-called "illegal roads". According to the Frankfurt Zoological Society, the extensive logging for road construction in the departments of Meta, Guaviare, and Caquetá results in the loss of approximately 241 m of dense forest per day (FZC, 2023).

Other causes of deforestation in the study area included predisposition and fires. Predisposition refers to the accessibility of the cleared forest, represented by factors such as the previous level of fragmentation and/or the distance to the deforestation frontier (Bautista-Cespedes et al., 2021; Camacho Peña, 2022; FCDS, 2023). Although often classified as a cause, predisposition also indicates locations where deforestation is more likely to occur. In this sense, predisposition can be understood as a function of all drivers combined, rather than a distinct cause on its own.

A significant increase of fires was also reported in protected areas after 2016 (Armenteras et al., 2019; Tebbutt et al., 2021). In fact, according to data from SINCHI, the year 2016 marked a steep rise in heat points, increasing from fewer than 1000 events before to nearly 24,000 in 2022, which serve as a proxy for fires (Fig. 3). Heat points are defined as thermal anomalies on the ground, identified through remote sensing data. These events are influenced by climatic phenomena such as El Niño Southern Oscillation and are also positively correlated with deforestation (Armenteras and Retana, 2012).

Regarding underlying drivers, the close interaction between economic and institutional factors was driving deforestation in the study

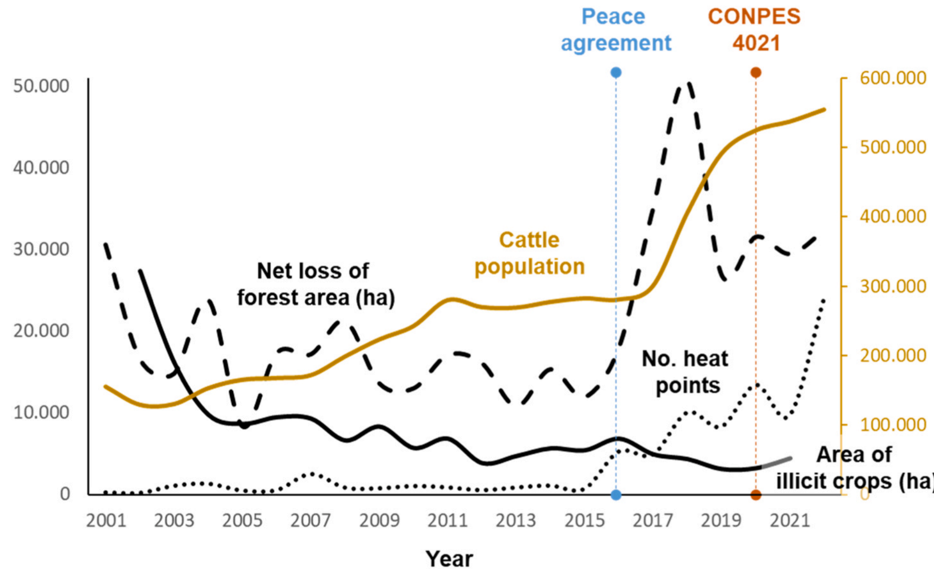

Fig. 3. Amount of annual forest loss in ha (dashed black line; source EC JRC), illicit crops in ha (solid black line; source DNP), number of heat points (dotted black line; source SINCHI) (left Y-axis), and cattle population (right Y-axis; source FEDEGAN) in the study area.

Table 2
Comparison between policy formulation (de jure) and the implementation level of CONPES 4021 (de facto) in relation to the main drivers identified in the study area. The numbers under formulation represent the number of actions that directly or indirectly address each driver. Implementation figures were retrieved from the official tacking website.

CONPES 4021	Formulation		Implementation		
Identified drivers	No. direct actions	No. indirect actions	Weight in policy formulation (%)	Action with no data on timely progress (%)	Timely progress up to Jun 2023 (%)
Pasture/cattle	1	12	28.2	69.2	50.0
Illegal Crops	1	0	2.1	100	-
Infrastructure	2	0	3.3	100	-
Fires	1	0	1.7	0.0	100
Power Vacuum	9	4	21.6	76.9	44.5
Land tenure	3	1	6.7	25.0	34.4
Monitoring	7	0	10.0	28.6	72.5
Coordination	3	0	5.0	66.7	100
Value chains	3	0	5.0	100	-
Other	9	0	16.4	44.4	68.2
Total	39	17	100	61.1	67.1

Source: SisCONPES.

area (InSight Crime and Igarapé Institute, 2021; Rodríguez-de-Francisco et al., 2021; Cheston et al., 2023; FCDS, 2023). The existing public land tenure system and lack of robust governance have created opportunities for investors to engage in land speculation. To achieve this, clearing the land is a necessary step, while political corruption has facilitated the formalisation of land ownership, often resulting in land grabbing. Land grabbing has led to the displacement of smallholder settlers to new areas inside the forest, who, in turn, contributed to the further expansion of the deforestation frontier (FCDS, 2023). Parallelly, recent conflict dynamics, particularly the peace process, coupled with the persistent absence of government authority, created a power vacuum. This vacuum enabled a significant increase in land speculation and clearing activities in the study area (Rodríguez-de-Francisco et al., 2021), including protected areas (Clerici et al., 2020). The interaction between conflict dynamics, land tenure, and land grabbing had already been documented in the study area prior to the peace process (Castro-Nunez et al., 2017).

The only environmental factor driving deforestation reported for the study area was topography. Like predisposition, topography also indicates locations where deforestation is more likely to occur. Drier, higher areas were more likely to be deforested than lower, prone to flooding parts of the landscape (Camacho Peña, 2022). Finally, while migration and population growth were identified as demographic drivers of deforestation, they were either weak or more relevant in the past (Rodríguez-de-Francisco et al., 2021; Camacho Peña, 2022).

4.2. Policy formulation

The analysis in policy formulation showed that most of the actions, whether directly or indirectly, focus on only a few of the main identified causes and drivers of deforestation in the study area, such as pasture/cattle, power vacuum and other key elements like monitoring and education (Table 2). Most of those addressing pasture/cattle were considered indirect actions, mainly focused on the development of an alternative local economy. Actions directly addressing the power vacuum aimed to strengthen organisations and enforcement mechanisms to curb deforestation, while indirect actions focused on enhancing coordination among various organisations working to prevent deforestation. For a detailed description of each action, please refer to Supplementary Material S2.

In contrast, few policy actions were related to the other identified causes and drivers. For illegal crops, there was only one action aimed at crop substitution. For fires, there was also one action focused on implementing an action plan to prevent and mitigate fires. Regarding infrastructure, there were two direct actions: one related to the implementation of the official green infrastructure guidelines, and another to develop and implement a sustainable regional transport system. Lastly, for land tenure, there were three direct actions aimed at organising property rights and granting usage rights to the local population, including indigenous communities.

4.3. Institutional capacity regarding policy phases and drivers

The analysis results of the co-diagnostic tools and interviews regarding institutional capacity showed that although most of the reported challenges affected the operationalisation of the policy aimed at deforestation control (n = 31), they also impacted its formulation (n = 18) and implementation (n = 13) across different domains (Table 3). Specifically, policy formulation was significantly hindered by systemic issues tied to coordination dynamics (n = 8), mainly at the regional level. For example, an interviewed mentioned that "*They (the governor's office) present their projects, and we (municipality) present ours. The municipalities compete for resources… we don't submit regional projects (in collaboration with other municipalities).*" Interviewees also highlighted delays in securing necessary resources attributable to excessive procedural requirements and a lack of coordination among national entities.

In terms of policy operationalisation, similar systemic challenges were observed (n = 8), alongside structural organisational issues (n = 12), such as disparities between national policy allocation objectives and municipal needs, limited financial resources and capacity, and high staff turnover, all of which affected operational effectiveness. For example, a local official said, "*The capacity of these municipalities is minimal. Imagine all that we have to do in planning, from waste management to subsidies. And there's also the entire control of routes and environmental matters.*" Similarly, another interviewee stated, "*The Amazon and Pacific regions are the CARs (environmental entities) with the greatest responsibilities (in controlling deforestation) but the fewest resources. They lack financial, technical, and training resources*". However, some of these organisational challenges appear to be tied to deep-level challenges that hinder the necessary distribution of resources across environmental agencies. As the same official explained, "*The proposal is to reform Law 99, which includes adjustments for the CARs… There have been 37 reform proposals, and some didn't even make it out of the ministry, while others were dropped as soon as they reached the Ministry… There is a very impressive bureaucratic stronghold there to maintain political clientele.*" In addition, the co-diagnosis sessions revealed strong rigidity and centralisation in resource management at the national level, resulting in a high dependence on political connections and lobbying to secure project funding.

Additionally, policy implementation faced difficulties related to both coordination dynamics (n = 3) and regulatory constraints (n = 3), including unclear verification processes for carbon credits and political favouritism in the employment and resource distribution in the regulatory environmental regional entities. A national official illustrated this by stating: "*With the carbon market, there is a lot of corruption and speculation. What proliferates are carbon credits, but there is no monitoring system.*" Similarly, a local administrator remarked: "*You are often very motivated to get things done, but the system is market-driven, private, and political. You go and present your project, but you need a sponsor, a political backer. You have to have someone's approval or ensure it benefits someone.*" These challenges not only complicated action implementation but also created barriers to controlling and monitoring deforestation effectively. For a comprehensive description of each challenge, please refer to Supplementary Material S3.

Looking at the specific causes and drivers of deforestation, the analysis of the institutional capacity revealed that the reported challenges are primarily linked to deeper levels of the existing power vacuum in the study area. Poor horizontal and vertical institutional coordination, unequal distribution of funds, insufficient technical staff with high turnover, influence of local elites and illegal groups are some of those reported challenges. For example, the analysis highlighted the hierarchical interaction of the national government with local stakeholders, reflecting centralisation and limiting the local agency. Indeed, the results showed that the national government finances various policy actions to control deforestation without accounting for the local capacities, resulting in the adoption of blueprint policies that may not be well-suited to the local context. As a local official lamented, "*The national entities are not playing their role. They formulated a project for us, and you should have seen how poorly it was done… The documents submitted to the DNP and the Ministry are, sorry to say, an embarrassment—poorly written, with the problem tree all wrong….*" Additionally, a clear mismatch between the actions and objectives of international cooperation agencies and the government plans of local authorities was identified. In fact, some officials expressed their frustration with cooperation agencies that have conducted multiple activities within their authority without notifying them. However, a national official mentioned that the Ministry of Environment "*started mapping these 17 points (hotspots of deforestation), reaching out to cooperation agencies, donors, and asking them: Where are you working? What are you supporting? The goal was to reduce the dispersion because no one was adding value… let's coordinate in the hotspots, and each one should have an institutional government stakeholder, along with their allies.*"

Infrastructure development was also affected by the current challenges in institutional capacity (n = 9). It was mentioned that the expansion of illegal road relates to the lack of oversight of the national government, low political commitment, and limited resources for control. For instance, despite a judicial restriction, the Ye-Miraflores road remains in use. Additionally, road projects that were initially included under the guidelines for green infrastructure initiatives were subsequently withdrawn. These cases illustrate the shortcomings in the enforcement and follow-through of environmental governance and infrastructure development plans. Lastly, the analysis highlighted the interaction between the expansion of the road network and the expansion of pasture, cattle ranching and land speculation.

Regarding land tenure and the expansion of pastures, there were notable challenges related to institutional capacity (n = 5), which are

Table 3
Summary of the number of respondents identifying key institutional capacity pressures related to major drivers of deforestation across policy phases (f = formulation, o = operationalisation, i = implementation).

Challenge		Cause/driver				TOTAL
Domain	Sub-domain	Pasture/ cattle	Infrastructure	Power Vacuum	Land tenure	
		f · o · i	f · o · i	f · o · i	f · o · i	f · o · i
Systemic	Coordination dynamics	0 · 0 · 0	3 · 3 · 0	4 · 4 · 2	1 · 1 · 1	8 · 8 · 3
	Cultural factors	0 · 0 · 0	0 · 0 · 0	1 · 0 · 2	0 · 0 · 0	1 · 0 · 2
	Regulatory constraints	0 · 1 · 1	1 · 0 · 0	2 · 2 · 2	0 · 1 · 0	3 · 4 · 3
	Engagement social actors	0 · 0 · 0	0 · 0 · 0	1 · 2 · 0	0 · 0 · 2	1 · 2 · 2
Organisational	Bureaucratic skills	0 · 1 · 0	0 · 0 · 0	2 · 4 · 1	0 · 0 · 0	2 · 5 · 1
	Structure	0 · 0 · 0	1 · 1 · 0	2 · 11 · 2	0 · 0 · 0	3 · 12 · 2
TOTAL		0 · 2 · 1	5 · 4 · 0	12 · 23 · 9	1 · 2 · 3	18 · 31 · 13

Source: Focus groups, Interviews.

systemic and present a significant structural obstacle. Predominantly, outdated environmental regulations, such as Law 2 of 1959, impose considerable limitations on the management of property land ownership. This results in a misalignment between formal policies and the informal institutions that guarantee property rights, leading to limited control over pasture expansion and a weak implementation of alternative agricultural projects. Additionally, there exists a divergence between political objectives and the personal interests of those in power and illegal armed groups involved in land grabbing and pursuing an extractive development model. These interests are primarily concentrated on money laundering and speculating on land values. A high-ranking official from the central government mentioned, "*a well-defined development project is underway with clear geographical plans since the deforestation process following FARC's departure*." This indicates a strategy of land appropriation that deviates significantly from forest preservation. Although this strategy is recognised in the policy against deforestation, it is not a central focus, leading to one of the most significant policy gaps identified.

Finally, the interviews also revealed the inherent complex interaction between shallow and deep-level drivers in the processes of deforestation. As a national official summarised, "*They (the drivers) are coordinated, part of the same economic development package. The 'other territorial development agenda.' … They open up the road, clear the land, set up the farm, and bring in a few cows—it's pure speculation, cattle ranching is just the excuse. What happens is that they have an economic portfolio, they bring in cattle, set things up, and illegal mining takes off.*" This official further elaborated on the potential future drivers, deforestation processes and possible interventions, "*You see the next wave of colonisation. You see the solitary men clearing the land… Then, after 3 or 4 years, they might have a woman, and maybe a child. It's a medium- and long-term investment… We need to rethink the Amazonian cities to contain this phenomenon. But we also need to improve the liveability so that people can stay there.*"

4.4. Policy implementation

The data on policy implementation as of June 2023 also indicates a significant gap in progress reporting, with 61 % of actions lacking updates, mostly those targeting issues like pasture/cattle expansion (69 %), power vacuums (77 %), illegal crops, and infrastructure. Among the actions for which progress was reported, 67 % were advancing according to schedule, particularly those related to fire management, monitoring, and other categories. However, timely progress was less common for reported actions related to pasture/cattle expansion (50 %) and power vacuum (44.5 %).

5. Discussion

We begin by discussing the causes and drivers of deforestation in the study area, followed by an analysis of the main policy gaps. Lastly, we present recommendations and highlight limitations relevant to the study area and similar deforestation frontiers in the tropics.

5.1. Causes and drivers of tropical deforestation

The analysis of secondary literature and related databases for the study area supports three main findings on the causes and drivers of tropical deforestation. The first finding is that there already exist relevant information and knowledge concerning the processes of deforestation, including its proximate causes and drivers at a spatial scale that are pertinent for the policy-making process. Such knowledge exists across relevant temporal and spatial levels, particularly for the Amazon region (Bautista-Cespedes et al., 2021; Santos et al., 2021; FCDS, 2023; Hänggli et al., 2023; Lapola et al., 2023). Nevertheless, it is still necessary to revisit some causes, as their current importance might be overstated (Murillo-Sandoval et al., 2023). For instance, although illicit crops previously played a substantial role in deforestation (Dávalos et al., 2011) and continue to be politically significant, the extent of their impact in terms of area in Guaviare has diminished at least according to the published results that we analysed.

The second finding confirmed the need to understand the interactions and dynamics among the causes and drivers of deforestation at different levels. This understanding is essential for better contextualising policies aimed at controlling and mitigating deforestation (Lim et al., 2017; Arias-Gaviria et al., 2021; Hänggli et al., 2023). Particularly, despite the central role of pasture and cattle expansion reported, there is evidence that cattle can strengthen land claims and be used as financial collateral rather than reflecting an increasing beef demand (Dávalos et al., 2014). This suggests that deforestation, pasture expansion and cattle are common results of key drivers influencing landscape transformation, particularly land speculation and grabbing. The importance and lack of policy prominence of these drivers has been similarly reported for other regions of the Amazon and the tropics (Carrero et al., 2020; Liao et al., 2024; Schilling-Vacaflor and Gustafsson, 2024). In addition, the significant increase of deforestation observed in the study area after the peace agreement demonstrated that rapid shifts in the dynamics and interactions of its causes and drivers can occur (Bautista-Cespedes et al., 2021). This event represents a social triggering event as outlined by Geist and Lambin (2002).

A final finding in terms of causes and drives is the potential increased risk of the interaction of tropical deforestation and climate change, which would require further research. Although climate change was not identified as a major driver, the sharp increase in heat points evidenced in the study area may reflect the increasing interaction between forest clearing and climate related impacts. This pattern aligns with findings from other regions of the Amazon (Valente and Laurini, 2023), impacting the resilience and recovery capacity of these tropical ecosystems (Drüke et al., 2023).

5.2. Policy gaps in a deforestation frontier in Colombia

By analysing the interaction between the three main stages of the policy-making process within a major policy framework for curving deforestation, and the causes and drivers of deforestation alongside institutional capacity, several key policy gaps were identified. A first gap is related to excluding or avoiding the main causes of deforestation either by not explicitly addressing them in the policy formulation and/or not investing in the institutional capacity to enforce them. This is the case of two major drivers of deforestation in the study area: power vacuum and land speculation. While the policy does make some efforts in tackling these drivers, the results of this study suggest significant limitations in both its formulation and operationalisation. On the one hand, land speculation remains a largely unaddressed driver of tropical deforestation in the case study and similar tropical regions (Roebeling and Hendrix, 2010; Campbell, 2015; Miranda et al., 2019; Davis et al., 2020; Rodríguez-de-Francisco et al., 2021; Pendrill et al., 2023), enabling forest clearing to demonstrate "effective possession" of the land for inflated land sales and hampering environmental enforcement as informal claims continue to spread.

On the other hand, long-standing power vacuums have left the environmental governance of the area in the hands of opportunistic illegal groups and corrupt official actors, whose priorities are misaligned with the sustainable and equitable development of the territory. This can lead to increased violence, deepened inequalities and accelerated deforestation, as already reported for both the study area (Rodríguez-de-Francisco et al., 2021) and Brazil (Kröger, 2024). These stakeholders successfully shift the focus away from significant political and economic forces behind pasture expansion and cattle ranching for land tenure. Instead, they redirect attention to narratives about small-scale farmers and their vulnerable status, portraying them as a primary issue. For example, farmer leaders in the region express concerns that despite their efforts in socialising and implementing policies, large businessmen or landowners never participate. A similar pattern has been also documented in processes related to water accessibility (Ménard et al., 2018), and other deforestation frontiers where local elites and potential impunity led to land speculation, accumulation, and grabbing (Carrero et al., 2020; Kröger, 2024; Schilling-Vacaflor and Gustafsson, 2024). This policy gap reinforces the findings of earlier research emphasising the necessity to align public policy with the causes and drivers of tropical deforestation (Lim et al., 2017; Kissinger, 2020; Ferrer Velasco et al., 2023).

A second policy gap reflects structural challenges in the institutional capacity at organisational level, including the lack of resources, capacity, and responsibility among agents in the territory. These challenges reinforce gaps in the operationalisation and implementation of policy actions in the study area, leading to mismatch between the responsibilities and resources. This is evident in the absence of necessary bureaucratic expertise, the lack of technical and regulatory resources to carry out the activities outlined in CONPES 4021, and a deficiency in the capacity to monitor and enforce the agreed norms. For example, municipalities struggle to control and monitor fires, which are used to expand grasslands. Despite increased pressure from the Ministry of Environment during the fire season, essential resources are not provided to address all complaints. This is consistent with recent findings from an analysis on deforestation, highlighting a clear correlation between institutional capacity and deforestation rates worldwide (Moreira-Dantas and Söder, 2022).

Another policy gap stems to more systemic challenges in the institutional capacity and resource allocation driven by diverging narratives and preferences among stakeholders regarding the development model of the study area. On the one hand, the Amazon is home to diverse communities and their leaders, who possess essential expertise for implementing effective public policies. This local understanding and ownership play a pivotal role in policies success. However, our results indicate that local officials often feel excluded by central authorities, and that the preferences of local communities frequently conflict with the conservation-oriented approach promoted by national environmental agencies. The exclusion of local expertise and the interests of local communities, which are essential for sustainable forest management, has also been observed in other tropical regions (Horning, 2018; Jodoin, 2019; Hecht et al., 2021).

On the other hand, the dominant narrative of agricultural expansion as a means to “modernise” tropical forested regions continues to be reinforced (Hecht et al., 2021), conflicting with the need to control deforestation. A recent report illustrates how the expansion of pastures and cattle ranching has been systematically and increasingly supported through public investments in the study area, not only in livestock production systems but also in infrastructure (FCDS, 2024). While in some parts of the Amazon, this policy incoherence is more closely tied to extractive economies linked to global agricultural commodities such as soybeans and oil palm (Bunker, 1984), the results of this study show that in Guaviare, it is more related to cattle expansion, land grabbing, and power imbalances, as has been reported in Brazil (Schmink et al., 2019; Kröger, 2024).

A fourth policy gap is related to a centralisation bias related to both systemic and organisational challenges in the institutional capacity. Although Colombia’s environmental management is formally decentralised through institutions such as the Regional Autonomous Corporations (CARs), interview findings indicate that institutional centralism continues to undermine regional effectiveness. CARs and local Amazonian authorities often lack the financial and technical resources needed to act independently of the Ministry of Environment, with most environmental management capacity concentrated at the national level. Key actions such as productive conversion actions, alternative development to replace illicit crops, research and development, green infrastructure planning, and environmental education require meaningful participation from local authorities and communities. Yet these initiatives remain primarily managed by central government offices. This disconnect between centralised policy formulation and local implementation realities poses a significant barrier to effective deforestation control, as also observed in other tropical regions. As Wright et al. (2016) argue, decentralisation can only succeed when supported by strong local institutional capacity and environmental governance.

A final gap concerns policy obsolescence rooted in regulatory constraints. For example, outdated regulations have facilitated numerous colonisation processes that have occurred without regulatory oversight and state monitoring, allowed that processes of land grabbing were supported by other informal mechanisms of guaranteeing property rights. For example, it was mentioned that the national environmental system is outdated, lacking the capacities and instruments required to address current environmental challenges, including climate change and illegal activities related to deforestation. This has also resulted in structural challenges that hinder the implementation of policy tools meant to empower communities and local authorities. An example of this is Law 2 of 1959 and its forest reserve delimitation, which has created tensions and restricted the actions of public policies and community initiatives. This is due to the challenges it presents in managing land property rights and in developing actions to support landholders in reforestation processes or in changing economic activities, as a result of land use restrictions imposed by the law.

5.3. Addressing policy gaps in tropical deforestation

Reflecting the policy gaps identified in the previous section, there are several recognised policy interventions designed to address some of these gaps in the study region and similar tropical regions.

A first intervention is to develop and adapt policies according to the current and foreseeable causes and drivers of deforestation (Schweikart et al., 2022; Ferrer Velasco et al., 2023). This requires moving beyond simplistic and static narratives to grasp the complex interactions among these causes and drivers, with a particular focus on those that are primary drivers of deforestation processes. For example, while developing alternative local economies that do not encourage the expansion of cattle ranching and pasture is vital for community wellbeing, concentrating on these alternatives may divert attention and efforts from addressing power vacuum and land speculation in the case study area and similar regions (Bautista-Cespedes et al., 2021).

Another key policy intervention involves enhancing the institutional capacity of implementing agents and organisations to develop strong local environmental governance. High levels of governance can translate into reduced levels of tropical deforestation (Fischer et al., 2020). In particular, the government requires more effective regulatory tools to encourage individuals and social organisations to engage within the formal sector. Ensuring effective mechanisms necessitates a clear understanding of land ownership, usability, and conservation boundaries. Additionally, it is crucial to equip local authorities with the necessary technical skills and resources to navigate the bureaucratic processes involved in implementing anti-deforestation policies. Initiatives like the one by the municipality of Calamar to establish an office of environment and development should receive support from the central government to strengthen local environmental governance.

A third intervention entails ensuring policy coordination and integration. This is crucial for addressing the interconnected and evolving causes and drivers of tropical deforestation effectively. Policy coordination and integration can be approached at two different but complementary levels: horizontal and cross-sectoral. The horizontal level relates to the mixing or sequencing of public policies, REED+ and supply chain initiatives that directly influence processes of deforestation (Souza-Rodrigues, 2019; Furumo and Lambin, 2021). A prominent example is the rapid expansion of the carbon markets in the study and many tropical countries (Koh et al., 2021). Carbon markets are promoted as an economic model for tropical forest protection and restoration. However, like other nature-based market tools, they demand high transparency (Delacote et al., 2024) and significant public sector involvement to regulate and to assess outcomes against global deforestation goals. Moreover, there is a concern that such market mechanisms could turn nature into a single commodity, disregarding biodiversity (Ferreira et al., 2018), continuing cycles of environmental degradation as seen in Indonesia (Maxton-Lee, 2018), leading to market failures like those observed in Brazil (West et al., 2020), or not fulfilling restoration promises as noted in Australia (Macintosh et al., 2024). There is an urgent need for research and policy to identify and avoid main social and environmental risks associated with the expanding carbon markets in the Amazon and other tropical forests, evaluating their effects and scrutinising how well institutions and policies are aligned with them.

The cross-sectoral level pertains to an inter-institutional policy coordination and integration, minimising trade-offs between different sectoral policies (e.g. poverty alleviation, economic development, biodiversity conservation), or integrating deforestation targets into sectoral policies (Runhaar et al., 2024). However, this requires a very high level of inter-institutional coordination that is not readily forthcoming at present in Colombia and in many other tropical countries (Korhonen-Kurki et al., 2016). A clear example is the mentioned misalignment between the main environmental policy framework (SINA) and the road plans at national, departmental and municipal levels. Specifically, the road Ye-Miraflores was approved despite its lack of environmental viability, as it crosses protected areas. These irregularities generate dissatisfaction among local governments and inhabitants and lead to the development of illegal roads in which the need for interconnection takes precedence over the protection of the forests. This discrepancy between the interests of local and national/global stakeholders has also been identified as a contributing factor to tropical deforestation in other tropical regions (Horning, 2018; Kissinger, 2020). Future interventions should explicitly account for both agreements and conflicts among stakeholders, particularly those within local communities, regarding the causes of deforestation and the strategies to address them, in order to reduce trade-offs and enhance the effectiveness of policy responses.

A fourth intervention involves identifying and removing major structural obstacles that can perpetuate these policy gaps. For example, it was also mentioned in the interviews that the current budget allocation for the regional environmental agencies is outdated and unequal, restricting the funding for agencies operating in the Amazon. Additionally, the financing model for these agencies and municipalities is based on property taxes, yet significant conservation areas lack titled lands. This means that the ability to collect funds for operations in areas with extensive conservation areas is constrained. Consequently, the law that created the SINA (Law 99) would need to be updated, which has not been substantially adjusted since 1999. Future policy formulation should also analyse and take into account structural policies and barriers that, while not directly causing policy gaps, indirectly contribute to their persistence.

A final intervention is to have in place an integrated and functional monitoring system. This system will guide policy decisions by providing insights into the existing and likely future causes and drivers behind deforestation. This system could be based or complement proposed national and global biodiversity monitoring systems (Sierra et al., 2017; Bellingham et al., 2020; Gonzalez et al., 2023). Additionally, this monitoring system should integrate relevant policy indicators to track both human development and environmental sustainability effectively (Valbuena et al., 2025), moving beyond basic forest/non-forest classifications. Lastly, this monitoring system should also support some early warnings of potential future causes and drivers of deforestation (Kissinger, 2020). For example, key potential drivers such as the expansion of mining, oil palm cultivation, and new waves of colonisation driven by land speculation should be considered in this monitoring system. Including these emerging threats could support more preventive measures and help avert rapid deforestation processes in the study area and other tropical regions in the near future.

6. Conclusions

Our study contributed to a better understanding of major bottlenecks in the effectiveness of public policy in controlling tropical deforestation in a region in Colombia. While it focuses on policy gaps related to a main policy framework for deforestation control, it does not address the broader social and political impacts. By examining the link between policies intended for implementation, available capacities, and deforestation drivers, our findings offer a useful perspective on enhancing governance for deforestation control in northern Amazonia. The study identifies structural, systemic, and agency-related factors that could strengthen capacity for policy implementation and effective action.

This was achieved by examining potential gaps in the formulation, operationalisation, and implementation of a key policy framework in a deforestation frontier in Colombia. Through a review of secondary literature and existing databases, we identified key causes and drivers of deforestation, including land speculation, a power vacuum, the expansion of pastures, cattle ranching, and infrastructure development. By comparing these causes and drivers with current policies and integrating this comparison with an institutional analysis, we uncovered significant systemic and organisational challenges exacerbating gaps in policy operationalisation and implementation. Specifically, the exclusion of main causes and drivers, insufficient local resources and capacity, divergent visions for the region's development, a pronounced bias towards centralisation, and normative obsolescence are contributing to the creation of gaps in the formulation, operationalisation, and implementation of the principal policy framework aimed at controlling deforestation in the study area and similar tropical regions.

To design and implement more effective policies for controlling tropical deforestation, addressing these gaps is essential. This effort would necessitate a multifaceted approach, including closely aligning with both the current and potential future main causes and drivers of deforestation; enhancing local and regional environmental governance; ensuring thorough policy coordination and integration; identifying and removing significant structural barriers and establishing an integrated and functional monitoring system.

While identifying policy gaps can highlight key entry points for improving deforestation control, understanding the causes of these gaps reveals deeper challenges that require systemic transformation. This includes addressing fundamental leverage points, such as changing worldviews and paradigms about the model for controlling deforestation while ensuring the wellbeing of local communities. It also involves readdressing power imbalances to avoid models that allow the concentration of land and resources in the hands of local and regional elites. Additionally, fostering and empowering local institutional capacity and environmental governance is crucial so that decisions to control deforestation are adapted to the specific local context and needs.

Limitations and future research

Given the extend and complexity of the topic, this study faces several limitations. First, while it focuses on a major policy framework that consolidated and articulated all state actions aimed at combating deforestation at that moment, other parallel policies and programmes might also influence deforestation processes and their drivers, both directly and indirectly, across different levels and sectors (Korhonen-Kurki et al., 2016). Further research on the roles and interactions of these additional policies could offer a broader and more comprehensive understanding of the policy gaps identified in this study.

Second, this study specifically focuses on policy gaps related to deforestation control, without addressing key interacting dimensions such as its social and political impacts (Barraclough and Ghimire, 1995). Future research could explore how identified policy gaps influence, and are influenced by, broader social and political dynamics related to deforestation.

Third, this study focuses on the intermediate level of analysis, overlooking deeper systemic factors such as dominant narratives and power imbalances (Schmink et al., 2019; Hecht et al., 2021; Kröger, 2024). Further research that more explicitly examines how these drivers influence policy formulation, implementation, and the persistence of policy gaps could offer clearer pathways for action to curb tropical deforestation.

Fourth, the interviews and co-diagnosis sessions were not specifically designed to capture the diversity of narratives and responses among stakeholders from different backgrounds, sectors, or levels of influence. Yet, understanding common perceptions, miscommunications and misunderstanding of view and responsibilities is critical for addressing deforestation while also tackling existing inequalities (Armenteras et al., 2023). Future research could enhance the analysis by examining how diverse stakeholders perceive, influence, or are affected by the challenges related to local capacity and policy gaps.

Fifth, the assessment of policy implementation relied on a database that reports only a subset of actions and does not account for potential interactions among them. However, individual policy actions may vary in their effectiveness in controlling deforestation, and their combined effects could generate additional outcomes (Seymour and Harris, 2019; Furumo and Lambin, 2021). Further research is needed to better understand how these actions are implemented on the ground and how they interact to influence deforestation dynamics, in order to more accurately assess the effectiveness of policy implementation.

Finally, this paper focuses on the process of deforestation, without addressing forest degradation, which is also a major process impacting the integrity and functionality of the Amazon and other tropical forested regions (Lapola et al., 2023; Bourgoin et al., 2024). Future research should incorporate both deforestation and degradation processes, along with their drivers, to provide a more integrated understanding of the policy gaps related to the conservation and management of these fundamental ecosystems.

CRediT authorship contribution statement

Javier García-Estévez: Data curation, Writing – original draft, Validation, Investigation, Formal analysis. **Jairo Santander:** Writing – original draft, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization. **Diego Valbuena:** Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Conceptualization. **Nathalia Franco:** Writing – review & editing, Validation, Investigation, Formal analysis, Data curation.

Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this work the author(s) used ChatGPT in order to edit and improve the readability of the text. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the publication.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships which have, or could be perceived to have, influenced the work reported in this article.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.landusepol.2025.107697.

Data availability

Added as supplementary material

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