Deforestation during the implementation of peace accord in Colombia: a panel data analysis (2005-2018)

A Research Paper presented by:

ANDRÉS FELIPE ZAPATA TORRES
(Colombia)

in partial fulfillment of the requirements for obtaining the degree of

MASTER OF ARTS IN DEVELOPMENT STUDIES

Major:
Economics of Development
(ECD)

Specialization
Econometrics: Analysis of Development Policies

Members of the Examining Committee:

Dr Lorenzo Pellegrini L.
Prof. Dr Mansoob Murshed

The Hague, The Netherlands
December 2019

Disclaimer:

This document represents part of the author's study programme while at the International Institute of Social Studies. The views stated therein are those of the author and not necessarily those of the Institute.

Inquiries:

International Institute of Social Studies
P.O. Box 29776
2502 LT The Hague
The Netherlands

t: +31 70 426 0460
e: info@iss.nl
w: www.iss.nl
fb: http://www.facebook.com/iss.nl
twitter: @issnl

Location:

Kortenaerkade 12
2518 AX The Hague
The Netherlands

Abstract

Deforestation is a relevant topic in socioeconomic and environmental studies. It is estimated that three-quarters of terrestrial biodiversity is covered by forest and 15% of all greenhouse emissions are produced by deforestation globally. Colombia contains 4.1% of the rainforest at the global scale and has a long-armed conflict. The vacuum of power left by FARC's retreat has promoted that pre-existing illegal armed groups and the emergence of new actors began to occupy the municipalities where FARC used to have a presence. This dynamic has increased the rapacious behavior of illegal armed groups, exerting pressure over natural resources and thereby increasing alarmingly deforestation. The present paper demonstrates through an impact evaluation that uses *fixed effect* as an empirical strategy, that FARC discouraged deforestation before the unilateral ceasefire in the municipalities where they used to have presence, even though the heterogeneity of its force armed structure also generate negative impacts on forest land. Likewise, the paper also shows that the socioeconomic dynamics both legal and illegal that are promoting deforestation in Colombia should be examined jointly since these dynamics are interlinked.

Relevance to Development Studies

Deforestation has become now a days a buzzword that is usually intended to be explained from a large range of multidisciplinary approaches among the social sciences. However, in the context of armed conflicts, studies tented to focus on the political and socio - economic components rather than the environmental factors, which implies that deforestation in the context of armed conflict has not been extensively addressed in scholarly literature. The Colombian case offers a unique opportunity to analyze the factors of deforestation from a multidimensional perspective that contributes to close the gap in academia that states that Colombia conflict usually is analyzed in relation to their economic and political effects, rather than for their environmental implications.

Keywords

Deforestation, Colombia, Armed Conflict, Peace Accord, Fixed Effect, FARC.

List of Acronyms

FARC	Revolutionary Armed Forces of Colombia
ELN	National Liberation Army
AUC	United Self-Defense of Colombia
UN	United Nations
FAO	Food and Agriculture Organization
ISS	Institute of Social Studies
DNP	National Planning Department
IDB	Inter-American Development Bank
GFW	Global Forest Watch
UNDP	United Nations Development Programme
CERAC	Conflict Analysis Resource Center
CNMH	National Center of Historical Memory
FIP	Foundation Ideas for Peace
OCD	Drug Observatory of Colombia
UPME	Energy Mining Planning Unit
ICA	Colombian Agricultural Institute

Contents

List of Tables

List of Figures

List of Maps

List of Appendices

Chapter 1: Introduction

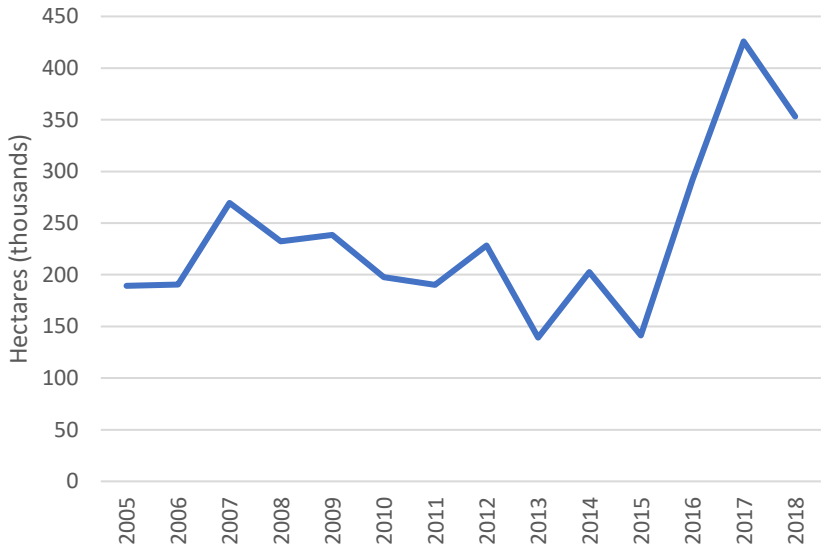
Forest land and trees are vital elements of the life cycle. They make substantial contributions that maintain the balance of the planet and provide food, medicine, clean air, and water to all living beings. According to FAO (2018), forests represent three-quarters of the world's terrestrial biodiversity and are therefore of tremendous socioeconomic importance for hundreds of millions of people across the world. Most of these people are located in developing countries, where there is significant pressure exerted on forest land, which is converted for agricultural use, cattle ranching, and to facilitate urban sprawl (Robalino, Pfaff, 2012, Prem, Saavedra & Vargas, 2018). By 2050, it is estimated that the world population will reach around 10 billion and that this will create a greater demand for ecosystem services from forests that are mainly located in poor countries(Food and Agriculture Organization of the United Nation (FAO), 2018). This situation represents a challenge for the conservation of forests because it increases the likelihood that valuable ecosystems will be lost, land degraded, soil eroded, clean water reserves depleted, and that more carbon is released into the atmosphere. As a result, all life is threatened because deforestation and the degradation of forest lands reduce the natural absorption of carbon. World Wildlife reports that these events produce around 15% of all greenhouse gas emissions and are a key factor of global climate change (World Wildlife Fund (WWF), 2019).

In the case of Colombia, which contains 4.1% of the global rainforest, the country's long armed conflict has made the deforestation phenomenon particularly worrisome. A 2014 study by the National Planning Department (DNP) and Inter-American Development Bank (IDB) warns of the great threat that climate change poses to the country's economy. For instance, the loss of hydric resources and native species that represent 4.3% of the current GDP is projected to generate losses equivalent to 3.7 times the current GDP from 2010 to 2100 (Departamento Nacional de Planeación (DNP), 2014).

Before the signing of the November 2016 peace accord between the Colombian Government and the Revolutionary Armed Forces of Colombia (FARC), the level at which tree cover was being lost was already increasing at an alarming pace. According to the Global Forest Watch Database (Hansen, 2013), the average annual tree cover loss between 2005 and 2015 was about 201,000 hectares. However, from 2016 onwards, the above-average increased

by around 356,000 hectares more per annum, registering a peak in 2017 of 425,780 hectares[1] (see figure 1). Even though the concept of tree cover loss defined by GFW does not establish a distinction between "*permanent land cover change (deforestation) or temporary loss (in which forest will recover), or between natural or human causes of loss*"[2] (Goldman L, 2019), these huge increases may not solely be the result of non-anthropogenic causes, meaning it is plausible to, therefore, consider the role of deforestation.

FIGURE 1 NUMBER OF HECTARES DEFORESTED IN COLOMBIA (2005-2018)



Source: Global Forest Watch (GFW), 2019. Own elaboration; data accessed on July 23, 2019.

Such a problematic situation would seem to indicate that the retreat and demobilization of FARC forces may be what is driving the sharp increase in Colombia's recent deforestation. Consequently, this research paper will explore the extent to which there is a relationship between the process of FARC retreat and demobilization and the increase in the deforestation. It is estimated that the retreat occurred following December 20, 2014, when FARC announced the unilateral ceasefire, and June 22, 2016, when a bilateral ceasefire

[1] The Colombian official organization Forest and Carbon Monitoring System (SMBC) offers different outcomes about number of hectares deforested, although, the tendencies are similar. Additionally, SMBC does not provide information at the municipal level and its information is just available since 2013, owing to a change of methodology in 2012. Before of this year, the data was collected five-year term (Galindo et al., 2014).

[2] In line with SMBC deforestation in Colombia is any anthropogenic activity that changes permanently forest which defined by the following thresholds: one hectare, five meters height (in situ) and a canopy of 30% (see appendices I A) (Galindo et al., 2014).

was announced by the national government[3]. Although the former date should not be assumed to be the exact moment when FARC laid down their weapons, it can be assumed that some fronts reduced their presence after this, which started a gradual rearrangement of the dynamics of the armed conflict. The date marks the emergence of new actors and the mobilization of pre-existing illegal armed groups, who would try and capitalize on the absence of FARC in certain municipalities to generate revenues from various shadow economic activities (Escobedo, 2018). As both dates have differing impacts on Colombia's forest cover, this paper will look at them both. The aim of this paper is to develop an impact evaluation that uses *fixed effects* as an empirical strategy to determine the factors behind the increase in Colombian deforestation before and after the unilateral ceasefire as part of the peace negotiation. This research aims to contribute to a better understanding of deforestation in the context of armed conflicts, a topic that has not been extensively addressed in scholarly literature.

In that sense, this paper demonstrates the impact of several illegal armed groups and socio-economic dynamics on deforestation following the unilateral ceasefire. The topic is evaluated in 1,062 municipalities between 2005 and 2018. Consequently, this paper focusses on understanding the presence of FARC in municipalities with a vast extension of forest land and how the vacuum of power left by them promoted a rearrangement of Colombian conflict. The presence is estimated through a proxy variable of violent actions undertaken by illegal armed groups, giving the same weigh to these municipalities that registered one or several violent actions. This methodology, besides of reducing the bias that states at higher territorial sovereignty have less violence, helps to evaluate the presence of conflict actors from a heterogeneous and complex perspective, underpinning the assumption that illegal armed groups should not be analyzed as homogenous and hierarchical structures. The findings suggest that FARC discourages deforestation in municipalities where they used to have presence, mainly in the municipalities where they have a historical relationship. This does not mean that FARC did not negatively impact forest land, but rather that they regulated environmental issues and discouraged other stakeholders from entering these municipalities and promoting deforestation an increasing pace. Certainly, following the unilateral ceasefire there emerged new political and socio-economic dynamics that were both legal and illegal.

[3] After bilateral ceasefire between the national government and FARC, government enacted the temporary pre-grouping points on in order to concentrate FARC troops, expecting the total demobilization and disarming in the first semester of 2017 (Presidencia de la República de Colombia, 2016).

Even though the legal and illegal issue is usually analyzed irrespective, the findings suggest that these dynamics are interlinked and are interplaying jointly in the increasing of deforestation. This is because high-value natural resources and certain agricultural commodities, such as coca crops, have a positive effect on rapacious behaviour in territories previously affected by conflict and characterized by low state capacity.

Historically, studies of the Colombian armed conflict have tended to focus on its political and economic components, despite the impact of the conflict on the country's rich ecosystems (Negret et al., 2017). Maria Alvarez (2003) outlines how environmental issues have not been a central topic of investigation, outside of cases where petroleum pipelines have been exploded. The present paper contributes to close such gap, evaluating the impact of several illegal armed groups and socio-economic dynamics on deforestation using fixed-effect estimation at the municipal level. In fact, this paper builds on the literature that has found that insurgents are more successful when their operations are developed on rough terrain that is far from the centre of state power. This indicates that there is a pattern of forest land conservation by illegal armed groups using forest cover to hide from air surveillance (Fearon, Laitin, 2003, Alvarez, M. D., 2003, Andrade, 2004, Camacho, Rodriguez, 2013, Sánchez-Cuervo, Aide, 2013, Fergusson, Romero & Vargas, 2014, Castro-Nunez et al., 2017). This paper develops a methodology that empirically evaluates the presence of illegal armed groups from a heterogeneous perspective in order to highlight the complexity of these apparent hierarchical and homogenous structures. Even though illegal armed groups share central identities, this perspective evidences how these identities that are operationalized in the field may change. For example, the forest land of municipalities that registered a presence of FARC up to six years were more affected than the municipalities that registered a presence for more than seven years.

The above is linked with the assumption that the municipalities that registered a presence of several illegal armed groups may be understood as a territory of dispute. This is a characteristic that may lead to a rise in conflict intensity and promote rapacious behaviour over natural resources. These findings are in line with the theoretical approximation from (Kalyvas, 2008, Kalyvas, 2001, Collier, 2008, Dal Bó, Dal Bó, 2011, Janus, 2012, Dube, Vargas, 2013, Delgado, 2013). Likewise, this paper is built on the literature from Prem et al, (2018) and Rodriguez et al, (Rodriguez et al., 2019) who have studied the recent increase of deforestation in Colombia with diverse approaches. Meanwhile Prem et al, (2018) used an

empirical strategy that found a certain increase in deforestation following the unilateral ceasefire, Rodriguez et al, (2019) used a qualitative approach in the Amazon region of San Jose del Guaviare to analyse several socio-economic dynamics that are triggering deforestation. Although both studies contribute to understanding this complex and multidimensional phenomenon, the present paper goes beyond and identifies the actors that are promoting deforestation and their relationship with several socio-economic dynamics at the municipal level.

In that sense, socio-economic dynamics, such as coca crops, cattle ranching, mining both legal and illegal, forced human displacement, state capacity and poverty have an impact on deforestation. Many scholars have studied these socio-economic dynamics in relation to deforestation, see (Geist, Lambin, 2002, Alvarez, 2003, Bradley, Millington, 2008, Carr, David, 2009, Carr, David L., Suter & Barbieri, 2005, Dávalos et al., 2011, Sánchez-Cuervo, Aide, 2013, Armenteras et al., 2013, Rodríguez Eraso, Armenteras & Alumbreros, 2013, Armenteras et al., 2011, Fergusson, Romero & Vargas, 2014, Chadid et al., 2015, Castro-Nunez et al., 2017, Castro-Nunez, Mertz & Quintero, 2016, Baptiste et al., 2017, Negret et al., 2017, Hoffmann, Márquez & Krueger, 2018, Prem, Saavedra & Vargas, 2018, Rodriguez et al., 2019). However, this paper contributes to understanding the impact of these dynamics on deforestation in territories that have been affected by conflict. Furthermore, the results suggest that these dynamics should be analysed and assumed to be interlinked. For example, the paper demonstrates that there is a positive relationship between coca crops and cattle ranching based on the work of Chadid (2015). Likewise, this paper, through a robustness check estimation at the department level, builds on the literature that indicates the impact of poverty on deforestation and households involved in economic activities, legal and illegal, in order to cover their basic needs.

1.1 Research question

The mains research question for the present paper is: *To what extent is there a relationship between the vacuum of power left by the FARC's retreat and the sharp increase in deforestation that followed the unilateral ceasefire at the end of 2014?* In order to unpack the above question, the paper addresses secondary guiding questions:

1. Was the FARC an actor that discouraged deforestation in municipalities where they registered a presence?

2. Is the recent sharp increase of deforestation a consequence of a conflict rearrangement where other illegal armed groups are trying to occupy the spaces that the FARC have vacated?
3. Which other economic activities, both legal and illegal, are driving deforestation in Colombia?

1.2 Chapter outline

The paper is organized as follows: Chapter 2 provides the theoretical framework which is divided in two moments. First, it offers some contextual background regarding illegal armed groups in Colombia and their relationship with forest land and their changes in economic and political terms over time. Second, it postulates the hypotheses that will guide this paper. Chapter 3 describes the data and present the empirical strategy. Chapter 4 present the estimations concerning the hypotheses posited in chapter 2 and finally chapter 5 concludes.

Chapter 2: Theoretical framework

2.1. Colombian conflict and deforestation: a contextual background.

From its foundation in 1964 until 1982, the core areas of FARC expansion were located in the departments of Meta, Caquetá, Guaviare, Huila, and subsequently in the zones of Magdalena Medio[4] and Urabá in North-west Colombia (Echandía, 2015, Estrada et al., 2017) (see figure 2). Although several of these zones were declared as National Forest Reserve Zones (ZRF) following law 2 that was signed in 1959, many colonizers[5] - *colonos* - ignored the law and changed the use of forest land these protected areas. Likewise, the FARC conceived of these territories as geographical and political spaces that had been historically denied of peasant struggles and suffering from persistent inequality in land distribution, as well as food insecurity[6] (Andrade, 2004, Pizarro et al., 2015, Rodriguez et al., 2019). As a result, the tropical forest became, on the one hand, a provider of natural resources for the first stages of peasant-run economies and, on the other, a strategic refuge for military figthers (Fearon, Laitin, 2003, Alvarez, 2003, Andrade, 2004, Camacho, Rodriguez, 2013, Sánchez-Cuervo, Aide, 2013, Fergusson, Romero & Vargas, 2014, Castro-Nunez et al., 2017). Later, between 1982 and 2002 and following the VII Conference in 1982, FARC started to deploy a military strategy that allowed them to have at least one guerrilla front in every department in Colombia (Andrade, 2004, Pizarro et al., 2015) . Thus, while in 1982 FARC had around 1,000 combatants by 2002, they had between 16,000 and 20,000 fighters (Saab, Taylor, 2009, Dube, Vargas, 2013, Pizarro et al., 2015). This situation was boosted by FARC's adoption of new sources of funding like the collection of a protection tax (*gramaje*) on drug trafficking and production[7], kidnapping, extorsion; cattle theft, and the assault and robbery of

[4] It is an inter-Andean valley of Magdalena river that involved municipalities from 8 departments: Antioquia, Bolívar, Caldas, Cesar, Cundinamarca, Santander and Tolima (see appendices map II A)

[5] They may be understood as farmer migrants from the Andean region without land that colonized vacant lands in the north-western Amazon region, between 40s and 70s (Rodriguez et al., 2019).

[6] Many scholars argue that this agrarian problem is a pivotal factor to explain Colombian conflict. Nonetheless, other scholars question such approach since Colombia conflict *per se* has amalgam of factors, such as political game or the complexity of the violence and its ambivalences (Pizarro et al., 2015).

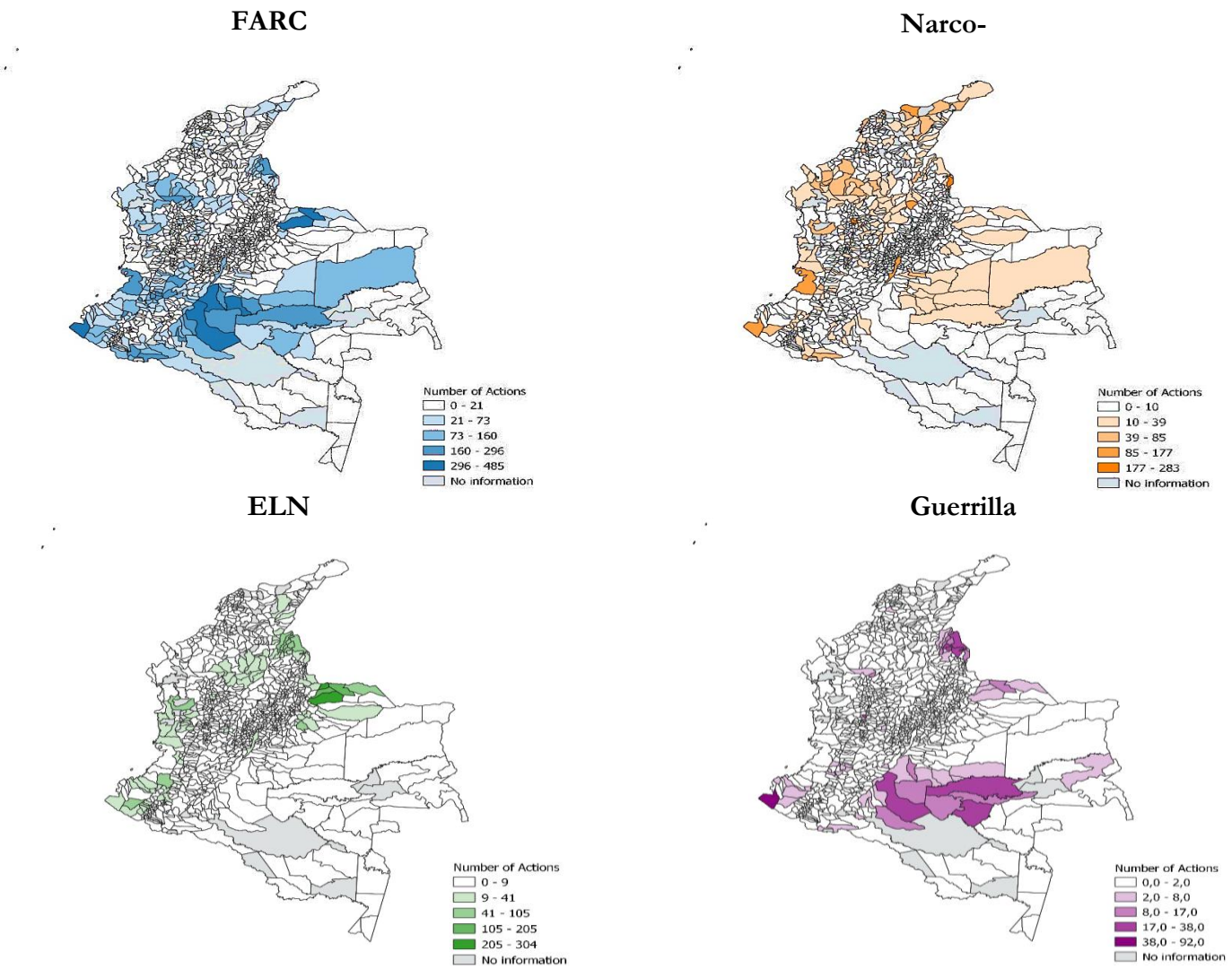
[7] This is that "*every large coca plantation, every kilo of base or cocaine HCL, every 55 gallons of processing chemicals… and every truck or aircraft operating in guerrilla-held zones is subject of protection fee*" defined by FARC (Saab, Taylor, 2009: 464-465). For instance, based on Saab et al. (2009), in 1999 the prices were standardize by FARC as follows: $15.70 per kilo of coca paste and $52.60 per kilo of cocaine produced inside its territory; $10.50 per kilo of cocaine and $45.00 per kilo of opium gum transported inside its territory. Additionally, they charged a fee for every aircraft that used their air strip: $2,631 for national flights and 5,263 for international flights. Even though this explanation, it is important to mention that some FARC fronts were involved in other stages of the chain production, for example transnational trading (Saab, Taylor, 2009).

businesses (Palacios, 2003, Saab, Taylor, 2009, Otis, 2014). According to Saab and Taylor (2009), in 2005 the FARC was estimated to have an income of between $100 to $300 million per year, with between one and two thirds of their income coming from the drug economy. Nevertheless, there is no consensus in this respect and other studies suggest that their income from the drug economy represented between 60 and 90 percent of their total budget (Saab et al. 2009).

After several unsuccessful peace process attempts over the last 30 years, in October 2012 FARC initiated a peace negotiation process which prolonged until the successful November 2016 peace accord with the national government, which led to disarmament and demobilization during the first semester of 2017. The process, according to Mounu Prem et al. (2018), was characterized by advances and setbacks. For instance, after the unilateral ceasefire on December 20, 2014 and the suspension of air raids ordered by the Colombian president in March 2015, FARC killed 11 soldiers in April 2015. The air raids were resumed and left 26 guerrilla combatants dead. Afterwards, FARC announced the end of unilateral ceasefire which lasted until July 20, 2015 (Semana, 2015). Even though the unilateral ceasefire in 2014 was non-permanent, it is understood as a milestone because FARC started to withdraw their troops from remote areas that other actors could not access (Prem, Saavedra & Vargas, 2018). In fact, Prem et al. (2018) quote the Conflict Analysis Resource Center (CERAC) to indicate that it is over this period that FARC's violent actions dropped by 98%. Nevertheless, it is important to highlight that those fronts that decided not to be a part of the peace accord before its signing worked to capitalize on the vacuum of power that came out of the retreat[8]. As a result, these fronts should be understood as dissidents due to the fact they started their actions before the demobilization and disarmament in 2017. Reunification after the first semester of 2017 should be considered as recidivism (Alvarez, E., Pardo & Vélez, 2018).

[8] On June 2016, the Front 1 Armando Rios announced their exit from peace accord to continue their armed hostilities. Later, the national government and the public forces also confirmed other guerrilla dissidents, fronts: 7, 14, 15, 16, 27, 40, 48, 62, 63 and mobil column Acacio Medina which have presence in the South and the East of Colombia (see map 1). Today, it is estimated that their ranks have between 1,200 and 1,400 combatants who have undertaken war actions, selective killing, kidnapping, population attacks, property damage and even deforestation (Alvarez, Pardo & Vélez, 2018) .

MAP 1 PRESENCE (ACTIONS) OF ILLEGAL ARMED GROUPS ON AVERAGE BY MUNICIPALITY (2005-2018)*



Source: CNMH and FIP , 2019. Own elaboration; data accessed on July 28 and September 13, 2019.
Note: *time trend of FARC is 2005-2016.

Another important left-wing guerrilla group is the National Liberation Army (ELN) whose beginnings also date back to the 60s. They emerged in departments such as, Norte de Santander, Santander and in various municipalities in the Magdalena Medio region (see map 1). In the 90s, when the conflict reached its highest peak of intensity, the ELN could had around 5,000 fighters in their ranks (Pizarro et al., 2015). However, in 2001 the illegal armed group's presence started to decrease and today they are estimated to have around 1,500 combatants (Otis, 2014). This is because, among other political and military reasons, they were reluctant to profit from the drug economy (Echandía, 2015). According to Otis (2014), this changed between 2005 and 2007 and allowed them to expand their actions on the Pacific Coast and by the Venezuelan border (see map 1). Despite this, Velez (2001) found empirical evidence that ELN are more likely to settle down in zones where there are deposits of oil and gold, rather than areas with illicit crops[9] (Vélez, 2001). For example, Alvarez (2003) indicates that certain zones with vast deposits of gold, such as the tropical forest in Serrania de San Lucas in the North of Colombia, have been protected by the ELN through the use of land mines, warnings aimed at discouraging investors, and hiding from air surveillance (Alvarez, 2003). Either way, this situation has generated that the unregulated artisanal mining of gold which has had many negative impacts on the environment and attracted many immigrants, changing the use of land in the region (Alvarez, 2003).

On the other hand, the United Self-Defense of Colombia (AUC) were formed in 1997. This group evolved out of a coalition of local right-wing paramilitary groups. These local groups were organized and promoted by rural landowners and drug cartels in order to counter the expansion of left-wing guerrilla forces, and worked alongside certain public force factions (Sánchez et al., 2013, Dube, Vargas, 2013, Fergusson, Romero & Vargas, 2014). The AUC were more concentrated in the Uraba and Magdalena Medio regions and had around 15,000 fighters between 2001 and 2003 (Sánchez et al., 2013, Dube, Vargas, 2013). Most of the group's violent actions involved selective massacres and forced human displacement, which enabled them to grow coca crops and expropriate lands to conduct legal mining and agribusiness operations, specifically in palm oil (Fergusson, Romero & Vargas, 2014). Fergusson et al. (2014) used a quasi-natural experiment to show the impact of AUC's actions and activities on forest cover. Notably, the authors clarify that the impact should be analysed in two ways. First, they demonstrate that AUC presence has a positive correlation with the

[9] Other studies claim that ELN incomes are derived largely by collecting taxes from drug production, in the same way as FARC did it (Angrist, Kugler, 2008).

proportion of forest. Jungles and rough terrain zones are characterized by vast crown cover and allowed the AUC to hide from public forces. Second, they confirm that an increase in AUC actions led to an increase in deforestation, which is confirmed by the reduction in the deforestation rate that followed the demobilization of AUC between 2005 and 2006 (Fergusson, Romero & Vargas, 2014).

Despite the peace agreement, many AUC units did not disarm and have continued to remain active in many places across Colombia (see map 1). In this paper they are clustered under the umbrella of 'narco-paramilitaries groups' based on the theoretical approximation suggested by Espitia et al. (2018). Thus, they may be understood as a modality of paramilitary group that have concentrated their business activities on drug trafficking and asset laundering. In addition, they offer public security functions and, occasionally, counterinsurgency services with the complicity (or omission) of state agents. Likewise, the AUC exert pressure over territories to capture state institutions, grab rents, and promote corruption. Their operations are confined to the national, regional and municipal level (Espitia et al., 2018: 16).

2.2. Hypothesis

2.2.1. FARC presence and deforestation.

The aforementioned paragraphs support the assumption that, across different contexts, illegal armed groups can take advantage of forest cover to both hide from public forces and to obtain profits from both high-value natural resources, and legal and illegal economic activities, such as oil palm and/or coca cultivation (Sánchez-Cuervo, Aide, 2013, Fergusson, Romero & Vargas, 2014, Castro-Nunez et al., 2017). Furthermore, the fact that these zones are characterized by rough terrain, dirty roads, jungle, weak local institutions, and low population density suggests an increase in the likelihood of illegal armed groups being present (Alvarez, 2003, Fearon, Laitin, 2003, Andrade, 2004, Fergusson, Romero & Vargas, 2014, Castro-Nunez et al., 2017, Escobedo, 2018). In that sense, the presence of FARC is related in these areas with what may be described as "*gunpoint conservation*". According to Alvarez (2003), this "*involves the exclusion of most productive activities from certain areas*" through "*land mines and civilian curfews*" (Alvarez, 2003). Camacho et al. (2012) empirically found that an increase of guerrilla and paramilitary attacks increases the likelihood of firms exiting a region by 5.5 percentage points or 0.28 standard deviations (Camacho,

Rodriguez, 2013) . Similarly, Prem et al. (2018) found that deforestation increased by an average of 0.12 percentage points or 0.23 standard deviations after the unilateral ceasefire of December 2014 in municipalities where FARC used to have presence (Prem, Saavedra & Vargas, 2018). In addition, during the 90s' they started to adopt an environmental sustainability discourse in order to highlight the protection of biodiversity hotpots [10] (Andrade, 2004). Accordingly, the following hypothesis is put forward:

> H_1: FARC presence in municipalities that may be assumed as "*gunpoint conservation*" zones, owing to FARC's coercive actions, decreases the likelihood of deforestation.

Nevertheless, as with the other illegal armed groups, the FARC should be not be understood as a monolithic body acting in a homogeneous and hierarchical manner. Instead they are able to mutate, transform and make alliances with other antagonistic actors (Alvarez, Pardo & Vélez, 2018). Equally, Delgado (2013), uses San Vicente del Caguán (Caquetá) [11] as an example to suggest that the relationship with the territory that was heterogeneous because the state was neither completely absent nor did FARC have complete control over the territory. Therefore, FARC looked to incessantly regulate the social and economic lives of people, which were constantly changing because the regulation depended on the levels of conflict intensification and the peace negotiations (Delgado, 2013). Thus, FARC's presence in several municipalities should be understood from by the military, political and economic dimensions which generated diverse relationships and disputes regarding the territory, legal and illegal economies, and the population (Delgado, 2013). In this respect, Kalyvas (2008) has produced research analysing the macro-dynamic of the civil war in order to understand the logic of the conflict at the subnational level, which may be permeated by alliances, adaptations, pragmatisms, or resistances over time (Kalyvas, 2008). For that reason, Delgado (2013) proposes studying the spatial and temporal dynamics of the conflict in the following three ways: a) territories of rear-guard or parastatal or counter-state order; b) intermediate territories and disputed order; and c) integrated territories and state order (Delgado, 2013).

[10] Despite of it, Andrade (2004) sustains that FARC , at their beginnings, related the environmental sustainability discourse with the bourgeoisie which was changing over time (Andrade, 2004).

[11] FARC had historical presence in this territory (Alvarez, Pardo & Vélez, 2018). In fact, San Vicente del Caguán, together with four municipalities in Meta, set the Demilitarized Zone – 42,139 km² - at the end of the 90s' (Sánchez et al., 2013).

The first type indicates territories where illegal armed groups have successfully embedded themselves in the territory and the conflict dimension is part of the population's identity and regional society. The second type may be understood as those territories that are contiguous of previous territories and thereby experiencing territorial fragmented sovereignty[12]. As a result, the social, economic and political setting is *ex ante* of the armed conflict, leading to illegal armed groups being unable to effectively embed themselves in the zone. Finally, the third type refers to those territories that have occasional illegal armed group presence and sporadic violent actions that may have a great impact at the national and regional levels as they may be conducted in the centre of state power (Delgado, 2013).

Under this framework, municipalities that registered a continuous FARC presence for more than seven years are classified as the first category proposed by Delgado (2013). Those municipalities that registered a FARC presence of between four and six years can be labelled under the second category, because of suggestions of territorial fragmentation. Finally, those municipalities that registered a FARC presence between one and three years are part of the third category[13]. The second hypothesis therefore posits:

> H_2: The heterogeneity of FARC presence may lead to different deforestation outcomes, highlighting the complexity of the Colombian conflict

2.2.2. Illegal armed groups presence and deforestation.

Paul Collier (2008) argues that economies characterized by natural resource dependency are more likely to have a civil war. In fact, it is through natural resources that guerrillas and paramilitary groups finance their violent actions on the field (Collier, 2008). In this respect, Janus (2012) demonstrates through the Coob-Douglas production function that there is a link between agricultural activities, resource extraction, and armed conflict. The parties involved react in relation to their credit-constraints, which are given by exogenous factors. These include bans on buying conflict resources, weapons embargoes, or increases

[12] It refers to those territories where there are more than one illegal armed group, driving an increase of violent actions since none has sovereignty in the territory. Thus, conforming to Kalyvas (2001), when there is total sovereignty over a territory the violence would be limited and the population decrease their likelihood of desertion because the coercion is higher (Kalyvas, 2001). In that respect, Alvarez et al. (2018) emphasizes that some interviewees in Caquetá recognized that FARC regulated by means of code of conduct and punishments (Alvarez, Pardo & Vélez, 2018).

[13] It is clarified that this type of FARC presence may be also related to territorial fragmentation since those territories could have suffered a process of conflict rearrangement.

in agricultural productivity. This is due to a constant substitution elasticity of capital-labour, which affects where there is an intensification of the conflict or not. Consequently, an intensification is occurring, there might be a reduction of natural resource extraction or agricultural activities because the capital-labour allocation is mainly focused on the conflict. To the contrary, when the capital-labour is allocated to natural resource extraction or agricultural activities there is a reduction in conflict (Janus, 2012).

Dube and Vargas (2013) empirically found that credit-constraints should be analysed in relation to the labour intensity that is demanded by a specific commodity. For instance, they demonstrate that a negative price shock on a commodity that uses relatively more labour, decreases the wages within that sector and leads conflict intensifications when the illegal armed groups can offer higher wages (e.g. coffee or coca crops). Meanwhile, a positive price shock on a commodity that uses less labour intensity may lead to a conflict intensification by triggering rapacious behaviour towards high-value natural resources (e.g. oil or gold) (Dube, Vargas, 2013). This complex relationship is underpinned mathematically by Dal Bó and Dal Bó (2011) who go on to suggest that policymakers should subsidize productive labour through taxes on capital in order to reduce the likelihood of conflict intensification. Similarly, they suggest that trade policy and peace-keeping initiatives should be pursued simultaneously. In that sense, trade agreements should promote the reduction of barriers to trade on exports to ensure that labour intensive economic activities do not suffer dramatically because of volatile commodity prices (Dal Bó, Dal Bó, 2011). Nevertheless, the retreat and demobilization of the FARC may have resulted in several illegal armed groups conflicting over the vacuum of power left behind. These areas can subsequently be used either to mine high value of resources and/or to expand the agricultural frontier by through deforestation. The third hypothesis states:

> H_3: Deforestation is increasing by the higher demand for capital inputs that is triggered by the rise of conflict intensification in areas where several illegal armed groups have caused a higher territorial fragmentation of sovereign land.

2.2.3. FARC presence, socio-economic dynamics and deforestation.

As mentioned previously, economies characterized by an abundance of natural resources may experience conflict. Illegal armed groups involved in the conflict can use these resources or agricultural commodities both to fuel conflict intensity and to increase personal

wealth (Collier, 2008). Angrist et al, (2008) found that the presence of coca crops suggests a higher probability of conflict intensification and also generates economic benefits for farmers that are already involved with coca. This is because the regions where coca is cultivated are characterized by poor institutional and socio-economic conditions (Lopez et al., 2019). Illegal armed groups used these regions as strategic strongholds for their economic and political goals; while the national government and military wholly focus their efforts on the eradication of coca crops through both manual means and/or aerial spraying. This context creates a permanent dilemma for coca growers. On the one hand, illegal armed groups force them to keep producing coca despite difficulties[14] through coercion. Furthermore, the Government does not impose any measures to tackle their poor socio-economic conditions (Escobedo, 2018)[15]. As a result, coca growers move to other areas and expand the agricultural frontier at the expense of forest land (Alvarez, 2003, Lopez et al., 2019).

In the case of FARC, many scholars suggest that their involvement in the drug trade was limited to the early stages of the production chain (see section 2.1). Alvarez, 2003, Saab, Taylor, 2009, Delgado, 2013, Otis, 2014, Escobedo, 2018 show that most of FARC's income came from limited domestic drug activities and that they depended on other illegal armed groups (e.g. narco-paramilitary groups) to distribute, traffic and refine the coca cultivated in their territories. Lopez et al (2019) found empirical evidence that the steady increase of coca crops during the peace negotiations between FARC and the national government (2012-2016), only occurred 31% of the time in municipalities where FARC had a presence. Therefore, it is possible to assume that there are other factors, such as the rearrangement of the Colombian conflict following the unilateral ceasefire, that are promoting the increase in coca crops and environmental degradation (Escobedo, 2018). For example, Estrada et al., (2017) states that the recent expansion of pre-existing illegal armed groups, such as ELN and narco-paramilitary groups, is because these groups are funding from shadow economies like coca and illegal mining. In effect, in some territories there are alliances between illegal armed groups in order to traffic drug (Estrada et al., 2017). Furthermore, it is well known that cattle ranching has an impact on deforestation and involves the large-scale clearing of

[14] For example, Alvarez (2003) indicates that in territories where FARC had presence, the farmers required to "*grow three hectares of food for every hectare of coca*" (Alvarez, 2003: 59).

[15] By 2018 the Foundation Ideas for Peace (FIP) together with United Nation Office on Drug and Crime (UNDC) found that the revenue of a coca grower, for one hectare of coca, represented only a 56% of Colombian minimal wage (approximately $139). Even though these revenues are tiny in proportion to the total revenues of drug industry ($559 million in 2016), coca growers state that coca at least give them an income in territories where there are not facilities to transport, store and merchandize licit crops (Garzon, Gelves, 2018).

forest land (Alvarez, 2003, Andrade, 2004, Bradley, Millington, 2008, Armenteras et al., 2013, Chadid et al., 2015, Castro-Nunez et al., 2017). Many actors in marginal areas that were previously affected by the conflict have been promoting land grabbing for speculation in order to gain significant profits (Rodriguez et al., 2019). In the end, this land is used to increase coca crops, cattle ranching and/or illegal mining (Chadid et al., 2015). Chadid, et al., (2015) found that the revenues from coca crops are invested in cattle ranching to give the owners access to credit and revenues from trading. Moreover, it is relevant to consider that out of the 43 million hectares used for agricultural purposes in Colombia, 34.4 million are used for livestock (80%), with the remaining 20% used for crop production. The land used for livestock proposes mainly belongs to rich landlords with high capacity of political incidence at the national and regional level (Rodriguez et al., 2019)

Another economic activity that exerts pressure on forest land is mining. The quick profits gained through this economic activity trigger the arrival of several stakeholders into areas that have high-value natural resources. In Colombia, most of these areas are beyond the scope of oversight bodies and miners do not use 'clean' mining technology because of the high opportunity costs generated by the conflict (Alvarez, 2003). It is estimated that 85% of gold production is illegal and that 36% of this occurs in conflict areas (Dávila, Azcárate & Kørnøv, 2019). As Güisa (2018) suggests, this economic dynamic has three main causes. First, the increase of gold prices saw the state promote the arrival of mining companies 2002, which encouraged rapacious behavior from illegal armed groups and artisanal miners. The second cause is the high opportunity cost that governmental constraints placed coca growing, which crowded illegal armed groups out the drug industry and pushed them into gold production. Lastly, the weak capacity of state to provide better socio-economic conditions and to regulate mining allowed illegal armed groups to co-opt these spaces. It is estimated that 20% of FARC incomes came from such activities. It is notable that information about this is underreported because the channels used by illegal armed groups are diverse and heterogeneous. An example of such an activity is the extortion of mining companies and the instrumentalization of social protest against them (Güisa, 2018).

Evidently, these activities generate a humanitarian crisis in several ways. For example, Fergusson et al, (2014) argue that AUC used forced human displacement as a mechanism to grab valuable land from local leaders and peasants for profitable activities (e.g. coca crops, cattle ranching and/or oil palm). Similarly, Güisa (2018) states that the rapacious extraction

of high-value natural resources involves serious human rights violations including, threats, intimidation, selective killing, kidnapping, and forced displacement. The last of these is frequently used against indigenous and afro Colombian communities because their collective territories are located in key hotspots of natural forest (Güisa, 2018). However, while some scholars suggest this mobilization may lead to a process of ecosystem recovery by moving populations to urban areas (Aide, Grau, 2004), other scholars suggest that the relationship between population and deforestation is not linear and depends on spatial and temporal contingencies (Carr, Suter & Barbieri, 2005).

The theoretical framework has hitherto made implicit and explicit postulations about the capacity of the state. To operationalize this in a conflict context, Hendrix (2010) proposes three categories: military capacity, bureaucratic/administrative capacity and political coherence and quality. Although Hendrix (2010) suggest that research should use the aforementioned multivariate approach, this research paper only uses the second category. The bureaucratic/administrative capacity category allows is to go beyond the typical conception of the state understood through the monopoly on violence, as well as institutional perspectives that are based on path dependencies that are constructed in alien historical contexts. As a result, the bureaucratic/administrative capacity category reflects the state's ability to collect and manage information in areas where illegal armed groups are present (Fearon, Laitin, 2003, Hendrix, 2010). This approach makes it possible to postulate whether better public servants (professionalization process) would result in a reduction of information asymmetries in the field, the collection of more taxes, the enhancement of socio-economic conditions, and the defeat of shadow economic activities and illegal armed groups (Hendrix, 2010, Besley, Persson, 2010, Mildner, Lauster & Wodni, 2011, Acemoglu, García-Jimeno & Robinson, 2015).

The previous paragraphs therefore make it plausible to suggest that:

> H_4: The abundance of natural resources conflict contexts triggers deforestation through various interlinked and ill/legal socio-economic factors.

Chapter 3: Data and methodology

3.1. Data

Deforestation is a multidimensional phenomenon. Accordingly, this paper builds a dataset from several secondary sources at the municipality level between 2005 and 2018[16]. The deforestation dataset has a sample that covers 1,062 out of 1,122 municipalities recognized by the National Administrative Department of Statistics (DANE). The missing municipalities were not included since the deforestation data has been collected from the Global Forest Watch (GFW) and this dataset only covers 1,062 municipalities. This data has been collected since 2001 by the University of Maryland´s GLAD laboratory in partnership with Google. The imagery is captured through Landsat and remote sensing-techniques with a resolution of 30 X 30m per pixel in order to identify primary forest[17] canopy structures at low albedo and with high texture (Hansen et al., 2013). Even though GFW does not differentiate between the concepts of deforestation and tree cover loss, the sharp increase of these phenomena in Colombia in recent times (see figure 1) indicates that this is not just a consequence of forest degradation (see appendices I-A.). In this paper, deforestation is estimated by looking at the share of deforested area per municipality in relation to forest land. This measurement allows us to see the municipalities that have the highest rate of deforestation considering the total number of hectares of the municipality that is covered by forest (see map 2 and 3).

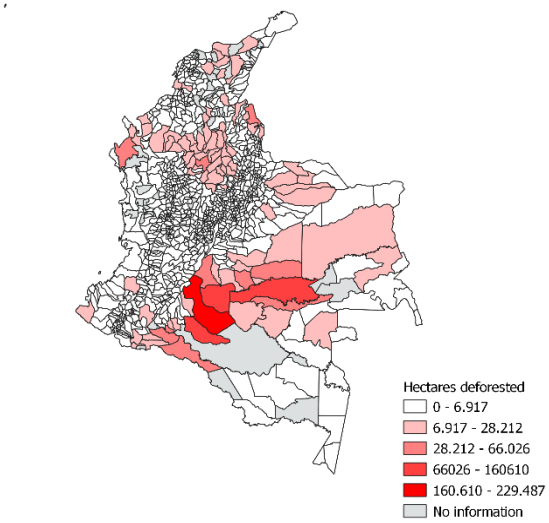
This paper's second dataset looks at the presence of illegal armed groups. The paper took into account the methodologies already defined by (Restrepo, Spagat & Vargas, 2003, Arjona, 2011, Delgado, 2013, Fergusson, Romero & Vargas, 2014, Echandía, 2015, Espitia et al., 2018, Prem, Saavedra & Vargas, 2018), all of whom have researched the presence of illegal armed groups using proxy variables of violent actions. As a result, the objective location of every illegal armed group become very challenging and thereby is used the actions conducted by them in a municipality between 2005 and 2018. The secondary sources used are from the National Center of Historical Memory (CNMH) and the Foundation Ideas for

[16] The time trend was defined considering that in 2006 and onwards, after demobilization and dismantling of AUC between 2003 and 2006, started a recidivism process of new paramilitary groups in places where AUC used to have presence (North-Eastern of Colombia). These new groups have not just consolidated their presence in these regions through shadow economic activities, but also have extended their influence in regions where, for example FARC, use to have presence (see map 1).

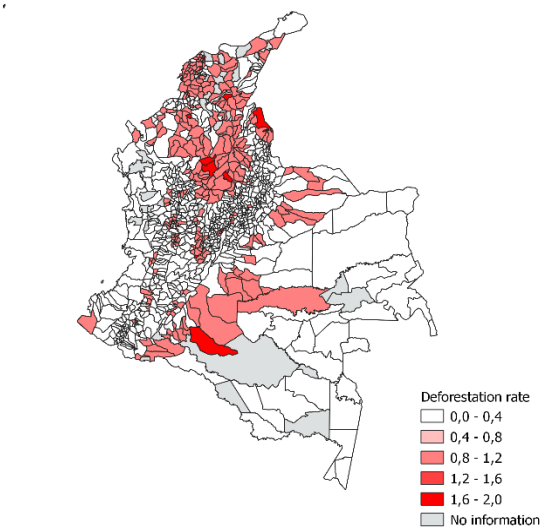
[17] That is natural areas where mature forest which has not been removed and regrown in recent times (less than 30 to 50 years).

Peace (FIP) which is a prestigious think-tank in Colombia and Latin America. The latter organization provides updated information about the actions and locations of illegal armed groups between 2015 and 2018. According to CNMH, the information is collected from 580 sources that are both official and social. Sources include the military forces, public entities, testimonies, social and religious organizations, NGOs, Academia, etc. Meanwhile, most of FIP's sources are press reviews.

MAP 3 NUMBER OF HECTARES DEFORESTED ON AVERAGE BY MUNICIPALITY (2005-2018)



MAP 2 RATE OF DEFORESTATION ON AVERAGE BY MUNICIPALITY (2005-2018)



Source: GFW, 2019. Own elaboration; data accessed on July 23, 2019.

Because there are several types of actions, the categories used to cover the actions are the same categories delimitated by CNMH. The categories are war actions, selective killing, population attacks, terrorist attacks, property damage, enforced disappearance, land mines and unexploded ammunition, massacres, kidnapping, sexual violence, and the use of child soldiers[18]. Each category has its own subcategories and variables, including the perpetrators of each action, thereby making each one an independent dataset. The dataset built for this paper selected the subcategories and variables that help with understanding the intensity of the conflict and the presence of illegal armed groups across municipalities. The subcategory type of action or channel[19] were selected for conflict intensity before number of

[18] To explore in detail all the categories and subcategories, what includes and what excludes, the information is available here: http://centrodememoriahistorica.gov.co/observatorio/metodologia/categorias/.
[19] The variables include assaults, ambush, capture, torture, illegal checkpoints, threats, thefts, persecution, false positive, etc.

times that each action was committed in a municipality was counted for every year. This method enables us to have one observation per municipality and year. In the same way, the subcategory of perpetrator was selected for the presence of illegal armed groups. This explored the multiple illegal armed groups spread across Colombia. Even though the CNMH datasets provide information on more than twenty illegal armed groups, the variables were clustered in four illegal armed groups: FARC, ELN, narco-paramilitary groups and guerrilla dissidents. Whereas FARC and ELN guerillas are unequivocally denominated from their early stage, narco-paramilitary groups have had several denominations, particularly after their recidivism in 2006 and 2007. For this reason, narco-paramilitary groups were clustered from fourteen different denominations based on the work of Espitia et al. (2018).

Guerrilla dissidents are understood as an undetermined number of illegal armed groups that were formerly part of a bigger body[20]. They reflect a fragmentation where there is a loss of command and the disintegration of an authority structure (Kenny, 2010 quoted by Alvarez, Pardo & Vélez, 2018). The most recent guerrilla dissidents used to be members of FARC and started their actions before the peace accord was signed in 2016. As with any illegal armed group in Colombia, they should be analyzed as components of a complex and dynamic process where shared central identities do not detract from the formation of malleable alliances and of divergent interests (Bakke et al., 2012; Pearlman & Cunningham, 2012 quoted by Alvarez, Pardo & Vélez, 2018: 45; Delgado, 2013). Consequently, economic activities from guerilla dissidents embrace drug trafficking and rent grabbing from natural resources (Espitia et al., 2018, Alvarez, Pardo & Vélez, 2018).

The method used to build the presence dataset was the same as that used to build the intensity dataset. For each category, there was a count of the number of times that each illegal armed group perpetrated an action in a municipality per year. It should be noted that presence (actions) may be biased because of the underreporting of violent actions in situations where illegal armed groups successfully embed themselves in the territory and with the local population (Kalyvas, 2001, Kalyvas, 2008, Delgado, 2013). Therefore, Arjona, (2011) suggest that it is necessary to develop a more accurate proxy variable that creates more

[20] This paper clustered three different guerrilla dissidents. The guerrilla dissidents from Ejército de Liberación Popular (EPL) – Los Pelusos – who emerged in 1991 when was signed the peace accord between government and EPL (Villarraga Sarmiento, Democrática, 2016). The guerrilla dissident from ELN known as Ejército Revolucionario Guevarista (EGR) which rose in 1992 and handed their weapons in 2008 (Semana, 2008) and, recently, guerrilla dissidents from FARC in 2016.

efficient future estimations. Despite this, the method used in this paper has been widely used by scholars to determine presence of illegal armed groups (Restrepo, Spagat & Vargas, 2003). As a result, dummy and categorical variables were generated as indicators (imperfect) of presence (actions). The former equates to one in situations where an illegal armed group undertook at least one action in a municipality between 2005 and 2018, and zero if they did not. This helps to reduce any possible bias on the estimators since the dummy variable gives the same weight to the municipalities that registered one or more actions undertaken by illegal armed groups. The categorical variable captures the information about the number of municipalities that were affected by the same illegal armed group per year in relation to the conflict intensity. This refers to the number of years that a municipality registered a presence (actions) of the same illegal armed group between 2005 and 2018. Accordingly, the presence of illegal armed groups is split into permanent presence (higher than seven years), interrupted/consolidated presence (between four and six years) and finalized/rearranged presence (between one and three years).

In terms of other control variables, this paper includes several datasets from a variety of sources in order to identify the socio-economic factors have either been increasing or decreasing deforestation after the unilateral ceasefire in 2014. A dataset estimating the number of hectares of coca crops over municipality area between 2005 and 2018 is provided. This data was obtained from the Drug Observatory of Colombia (ODC), which uses remote sensing-techniques to capture the number hectares cultivated with coca at the municipal level. The number of municipalities identified with coca crops was an average of 183, while the remaining were treated as non-coca growers. This means that an average of 879 municipalities did not register coca crops out of a sample of 1,062 municipalities. Similarly, this paper includes data of cattle ranching from the Colombian Agricultural Institute (ICA), which is relevant because cattle ranching is one of the main factors driving deforestation in the country and is what most of Colombia's agricultural land is used for. The data was obtained through a right of petition and was available at the municipal level between 2008 and 2018. The variable is transformed into a logarithmic form to evaluate its elasticity in relation to the rate of deforestation.

This paper uses two sources for mining data. Legal mining data was collected from the official Energy Mining Planning Unit (UPME), which is an organization that provides information about the legal exploitation of various minerals in municipalities between 2012

and 2018.In this research paper, only data about gold production was used because of this precious mineral's apparent effect on the rapacious behaviour of miners. This variable was also transformed into its logarithmic form to estimate the percentage changes over deforestation. Secondly, data on illegal mining was collected through the use of a proxy variable of environmental pollution, the illicit exploitation of minerals, and hydrocarbons complaints reported to the Attorney General's office between 2005 and 2018[21]. As expected, this data was underreported because the majority of illegal mining exceeds the scope of governmental entities. However, it remains the best method to estimate illegal mining at the municipal level. The control variable of illegal mining was also analysed in percentage changes instead of level form.

To measure the bureaucratic/administrative capacity of the state (in accordance with the work of Hendrix, 2010, Besley, Persson, 2010, Mildner, Lauster & Wodni, 2011, Acemoglu, García-Jimeno & Robinson, 2015 data about municipal tax incomes and operation expenditure between 2005 and 2017 was used from the National Planning Department (DNP). Tax incomes contain information about property taxation, industry and business tax, fuel surcharge, and other taxes clustered an 'other' category. Operation expenditure collects information about individual services, overhead costs, salary payments, and payment providers, amongst other entities. Both variables were analysed in the logarithm form.

Additional information is included to evaluate the impact of alternative factors that may be related to deforestation. Among them are coffee and plantain crops, monetary poverty, the Gini coefficient, and a supplementary method to measure bureaucratic/administrative capacity suggested by Hendrix, 2010: tax incomes/GDP. All variables are estimated at the department level (33 departments including the capital city, Bogotá) from the years 2005 to 2018, conforming to data availability. Coffee and plantain crop data was collected from the Agricultural Ministry and is estimated in rates. This is the number of hectares cultivated of each commodity over the area of each department. Information about monetary poverty and Gini coefficient variables was available in just 24 departments, and the years 2006 and 2007 missing because DANE did collect sufficiently accurate information to provide suitable estimates for these years (DANE, 2009). Finally, tax incomes/GDP at the department level is calculated with the variables tax incomes depicted

[21] See criminal Colombian code sections 333 and 338.

above over GDP data provided by DANE. Table 1 displays the summary statistics of the variables presented in this subsection.

3.2. Methodology

This paper uses a *fixed effect* estimation as an empirical strategy to evaluate the rate of deforestation in Colombian municipalities both before and after the unilateral ceasefire that was announced by FARC at the end of 2014[22]. Therefore, the treatment group is the municipalities that were affected by the vacuum of power left by FARC, and the control group is the remaining municipalities that were not affected by its decisions in the framework of the peace negotiations with the national government. However, because the unilateral ceasefire is exogenous and makes the design or selection of the treatment and control groups a consequence of the peace negotiations, this research is a quasi- rather than a natural experiment.

In accordance with this approach, the empirical strategy employs time variation across municipalities over a period of 14 years. The dependent variable (the rate of deforestation) is the share of deforested area per municipality in relation to number of hectares covered by forest land in each municipality. The main independent variable is the presence (actions) of FARC across municipalities conforming to H_1. The basic model is denotated as follows:

$$Y_{mt} = \beta_1 prefarc_{mt} + \beta_2 typepres_{mt} + \beta_3 cefire_{mt} + a_m + \lambda_t + u_{mt} \qquad (1)$$

where Y_{mt}, the rate of deforestation (dependent variable in percentage change) at the municipal level m and a time t. The estimator β_1 recollects the information about the presence of the FARC, which is a dummy variable that indicates one whether the left-wing guerrillas undertook at least one action in a municipality between 2005 and 2016[23] and zero otherwise. β_2 is a categorical variable that captures the heterogeneity of FARC presence

[22] It is important to remain that unilateral ceasefire it is the breakdown point since FARC started the process of retreat in municipalities where they used to have presence. However, as mentioned on section 2.1, this process was characterized by advances and setbacks until the bilateral ceasefire announced on June 22, 2016.
[23] It is not considered the whole period of the analysis since the peace accord was signed at the end of 2016.

TABLE 1 SUMMARY STATISTICS

Variable	Scale		Mean	SD	Min	Max
Deforestation	Hectares	overall	220.72	1,015.01	0	31,465
		between		880.33	0	16,391.93
		within		505.91	-9,216.21	18,276.86
Tree cover extension	Hectares	overall	76,883.7	271,452	110	4,844,410
		between		271,571	110	4,844,410
		within		0	76,883.7	76,883.70
Deforestation rate	Percentage change	overall	0.37	0.56	0	16.5
		between		0.35	0	2.36
		within		0.43	-1.69	14.13
Municipality area	Hectares	overall	106,950.10	310,911	1,586	4,967,616
		between		311,047	1,586	4,967,616
		within		0	106,950.1	106,950.1
FARC presence	Actions	overall	0.19	0.40	0	1
		between		0.26	0	0.86
		within		0.30	-0.66	1.12
FARC and unilateral ceasefire	Actions following unilateral ceasefire	overall	0.28	0.45	0.00	1
		between		0.00	0.28	0.28
		within		0.45	0.00	1
FARC and unilateral ceasefire	Actions following sign of peace accord	overall	0.21	0.41	0.00	1
		between		0.00	0.21	0.21
		within		0.41	0.00	1
FARC permanent	Actions in the same municipality > 7 years	overall	0.12	0.33	0	1
		between		0.26	0	0.85
		within		0.19	-0.73	0.62
FARC interrupted/consolidation	Actions in the same municipality b/w 4 & 6 years	overall	0.04	0.18	0	1
		between		0.10	0	0.42
		within		0.15	-0.39	0.74
FARC finalized/rearrangement	Actions in the same municipality b/w 1 & 3 years	overall	0.04	0.18	0	1
		between		0.06	0	0.21
		within		0.17	-0.17	0.96
FARC non-presence	Municipalities without presence	overall	0.80	0.39	0	1
		between		0.26	0.14	1
		within		0.29	-0.12	1.66
Coca rate	Percentage change	overall	0.05	0.31	0	8.65
		between		0.23	0	3.59
		within		0.2	-2.04	5.56

Log cattle ranching	Percentage points (heads)	overall	8.94	1.76	0	13.63
		between		1.71	0	13.32
		within		0.44	-0.28	16.24
Log gold production	Percentage points (tons)	overall	-0.49	1.66	-12.14	2.05
		between		1.16	-7.14	1.75
		within		1.18	-10.90	6.64
Log illegal mining complaints	Percentage points (cases)	overall	0.12	0.42	0	3.76
		between		0.27	0	2.32
		within		0.32	-1.87	2.95
Log tax incomes	Percentage points (Colombian pesos)	overall	6.9	1.87	-0.26	15.92
		between		1.73	0	15.36
		within		0.71	-2.92	9.97
Log operation expenditure	Percentage points (Colombian pesos)	overall	8.39	1.55	0	9.56
		between		1.15	0	9.30
		within		1.03	-0.17	11.64
GDP	Colombian pesos (thousands of million)	overall	19,455.55	33,904.5	79.62	250,575.60
		Between		32,328.8	170.17	163,873.90
		within		11,568.6	-54,905.8	106,167.70
Coffee rate	Percentage change	overall	2.14	4.36	0	25.42
		between		4.33	0	19.45
		within		0.88	-5.03	8.11
Plantain rate	Percentage change	overall	1.02	3.20	0	30.16
		between		2.83	0	15.75
		within		1.56	-14.72	26.97
Log Gini coefficient	Coefficient	overall	-0.67	0.07	-0.86	-0.47
		between		0.05	-0.79	-0.53
		within		0.04	-0.83	-0.57
Log monetary poverty index	Index	overall	3.62	0.42	2.31	4.31
		between		0.38	2.61	4.17
		within		0.19	3.16	4.34
Log state capacity	Ratio	overall	-4.23	0.47	-5.95	3.03
		between		0.42	-5.22	-3.29
		within		0.23	-5.03	3.03

N=14868
n=1062
T=14
Note: Log cattle ranching is between 2008 and 2018; log gold production is between 2012 and 2018, log tax incomes and log operation expenditure are 2005 and 2017. GDP, coffee and plantain rate, log Gini coefficient, log monetary poverty index, log state capacity are at department level, clarifying that log Gini coefficient and log monetary poverty are just available for 24 departments and excluded the years 2006 and 2007.

through three different categories: permanent, interrupted/consolidated and finalized/rearrangement. All categories were transformed into dummy variables and evaluated individually (see figure 2). As a result, each category is one if the category fulfils the conditions defined in section 2.1.1 and zero otherwise. β_3 (interaction variable) is also a dummy variable that is one if a municipality did not register a FARC presence following the unilateral ceasefire and zero otherwise. The vectors a_m and λ_t are the municipality and time fixed effect, which controls any macroeconomic shocks or legal and/or political shifts in order to evaluate the net impact over deforestation during the period of the analysis.

The vacuum of power left by FARC in several municipalities resulted in other illegal armed groups beginning to fill these areas in order to extract the natural resources and/or expand their agricultural frontiers. This dynamic increases the conflict intensity by turning certain municipalities into territories of dispute, demanding more capital inputs for the conflict and, subsequently, increasing deforestation. A second equation is present that considers this complex relationship between territory and illegal armed groups:

$$Y_{mt} = \beta_1 prefarc_{mt} + \beta_2 presgr_{mt} + \beta_3 cefire_{mt} + a_m + \lambda_t + u_{mt} \qquad (2)$$

where the rate of deforestation Y_{mt} (dependent variable in percentage change) is again evaluated against the dummy variable of FARC presence (β_1), adding the presence of other illegal armed groups as control variables. β_2 captures information about the presence of narco-paramilitary groups, the ELN, and dissident guerrillas. Each illegal armed group is an independent dummy variable that is one if one of these groups (narco-paramilitary groups, ELN or guerrilla dissidents) undertook at least one action in a municipality over the period of the analysis. β_3 is again the interaction variable explained previously.

Another specification has been added to this paper to evaluate several socio-economic dynamics and their relationship with deforestation in a conflict context. The specification is as follows:

$$Y_{mt} = \beta_1 prefarc_{mt} + \beta_3 cefire_{mt} + \beta_4 sc_{mt} + \lambda_t + a_m + u_{mt} \qquad (3)$$

where, once again, Y_{mt} is the dependent variable in percentage change, β_1 is the presence of FARC and β_3 is the interaction variable that evaluates the impact of the unilateral ceasefire on deforestation. Meanwhile, β_4 is the socio-economic dynamics depicted in section 3.1.: coca rate, *log* cattle ranching, *log* gold production, *log* illegal mining, *log* forced human displacement, *log* tax incomes, and log operation expenditure. The logarithmic form is used to estimate the outcomes as a percentage change. Subsequently, included in the same equation is β_2 (narco-paramilitary groups, ELN and guerrilla dissidents), which evaluates if the estimations and patterns obtained in equations 1 to 3 remain similar or if there are changes. The specification is:

$$Y_{mt} = \beta_1 prefarc_{mt} + \beta_2 presgr_{mt} + \beta_3 cefire_{mt} + \beta_4 sc_{mt} + a_m + \lambda_t + u_{mt} \quad (3a)$$

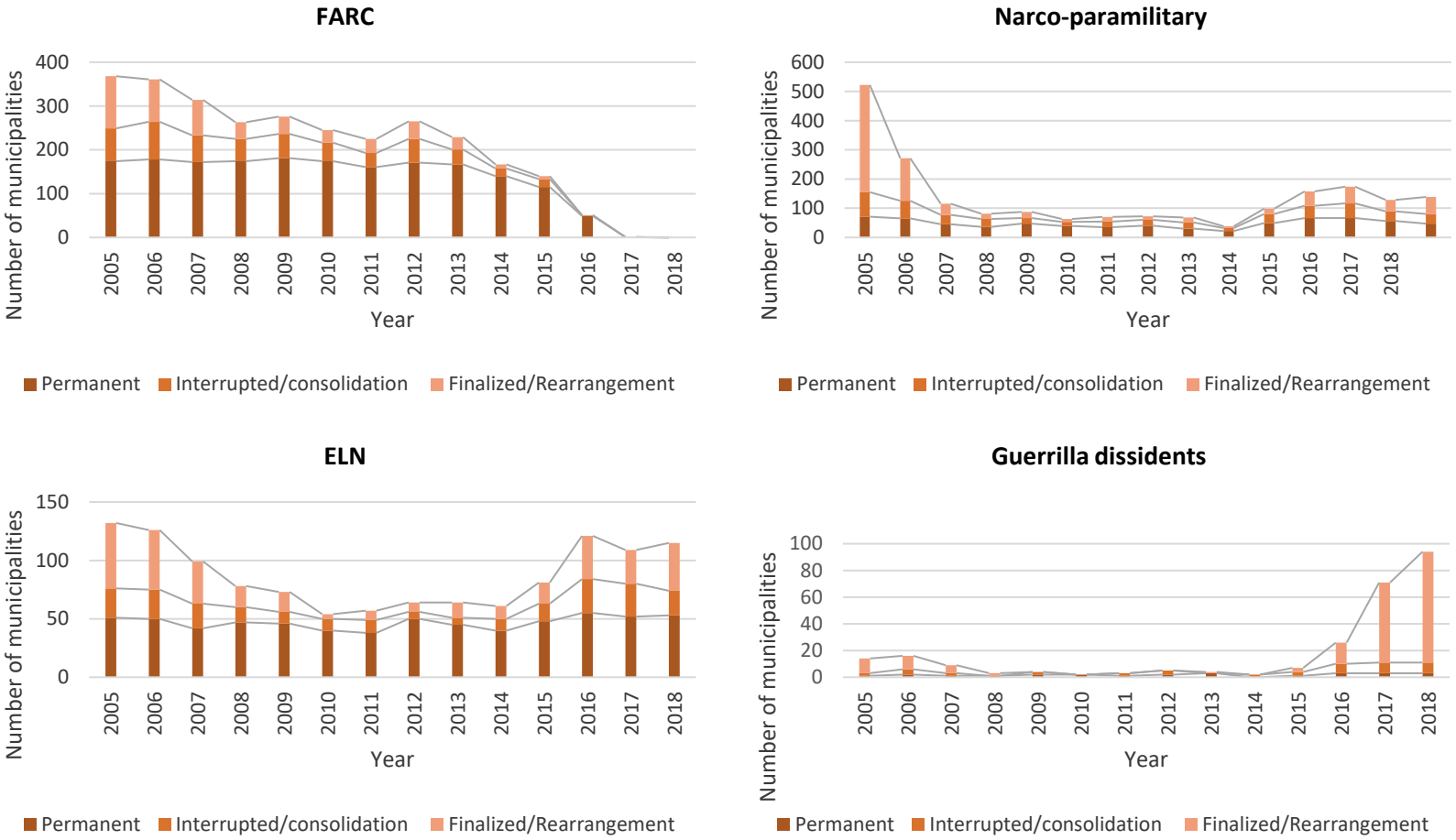
Now, the same regression specified in equation 3 is run as a robustness check, but on this occasion removing any possible endogeneity concerning the presence of illegal armed groups. To do so, it is estimated:

$$Y_{mt} = \beta_3 cefire_{mt} + \beta_4 sc_{mt} + a_m + \lambda_t + u_{mt} \quad (3b$$

Finally, another specification is presented to evaluate other socio-economic dynamics in relation to deforestation at the departmental level. The variables are coffee and plantain rates, *log* monetary poverty index, *log* Gini coefficient, and log state capacity. The logarithmic form is, once again, used to estimate the outcomes as a percentage change. Coffee and plantain rates are the number of hectares cultivated with these commodities over the department area. Monetary poverty index is the proportion of household families that are below the poverty line, and Gini coefficient measures income inequality on a scale which goes from 0 to 1, where 0 is perfect equality and 1 is perfect inequality. Finally, state capacity is the ratio between tax incomes over GDP at the departmental level based on Hendrix, 2010. The specification is given by

$$\psi_{dt} = \pi_1 cefire_{dt} + \pi_2 sc_{dt} + \rho_d + \gamma_t + \epsilon_{dt} \quad (4)$$

FIGURE 2 NUMBER OF MUNICIPALITIES WITH TYPE OF PRESENCE (ACTIONS) BY ILLEGAL ARMED GROUPS (2005-2018)



Source: CNMH and FIP , 2019. Own elaboration; data accessed on July 28 and September 13, 2019.
Notes: The presence (actions) of illegal armed groups was defined conforming to the categories postulated in the theoretical framework (see section 2.1.1).

where ψ_{dt}, the rate of deforestation (dependent variable as a percentage change) at the departmental level d and a time t. π_1 is a dummy variable that captures the information about the department that did not register a FARC presence following the unilateral ceasefire at the end of 2014. Even though this estimation substantially reduces the sample (1,062 municipalities to 33 departments including the capital city, Bogotá), it still allows us to evaluate the presence of FARC in certain departments where they used to have presence. This, for instance, refers to departments located in the Amazon and Orinoquia region in the southeast of Colombia. π_2 captures the information related to other socio-economic dynamics which were explained above. ρ_d and γ_t are the municipality/time fixed effect.

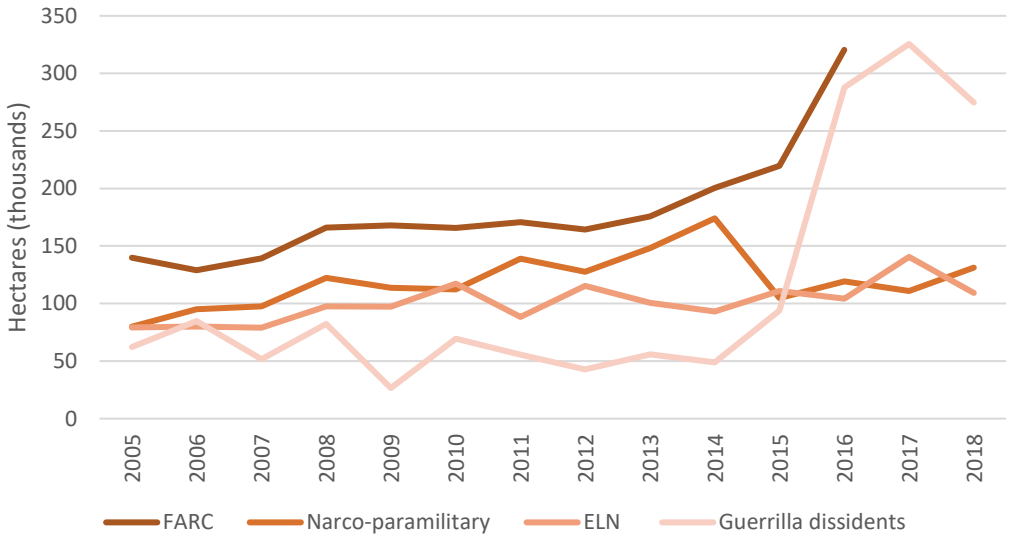
All error terms are clustered at municipal level u_{mt} and at the department level ϵ_{dt} , which is robust in relation to autocorrelation and heteroskedasticity.

Defined the empirical strategy is presented some descriptive generalities. As mentioned in section 2.1., the number of actions undertaken by FARC dropped by 98% following the unilateral ceasefire at the end of 2014. Figure 2 shows that the presence of FARC started to lower gradually after this year, while the other illegal armed groups increased their presence in certain municipalities. In that sense, figure 2 provides a visual illustration of the rearrangement process in the Colombian conflict following the unilateral ceasefire. However, the group that expanded their presence the most was the guerrilla dissidents that primarily separated from the FARC structure before the signing of the peace accord. It can be suggested that they are the illegal armed groups that are gaining the most from the vacuum of power left by the FARC.

Accordingly, figure 3 reveals the mobilization of illegal armed groups across municipalities between 2005 and 2018 in relation to the number of hectares of land covered by forest. FARC used to have a presence in municipalities with high amount of forest land; 163,000 hectares on average, which could underpin the assumption that most of these areas were characterized by "*gunpoint conservation*" to allows FARC to hide from air surveillance. In fact, it is apparent that they concentrated in zones with a higher amount of forest cover after the unilateral ceasefire, which can be understood as the municipalities where they had a registered a permanent presence (of over seven years: see figure 2). Figure 3 also shows how the mobilization of guerrilla dissidents across municipalities began to change after 2014, supporting the assumption that these illegal armed groups filled the vacuum of power left by

FARC. Meanwhile, the remaining illegal armed groups, such as the narco-paramilitary groups and ELN, kept their presence in regions with 110,000 hectares of forest land.

FIGURE 3 FOREST COVER EXTENSION OF THE MUNICIPALITIES THAT REGISTERED ILLEGAL ARMED GROUPS PRESENCE (2005-2018)

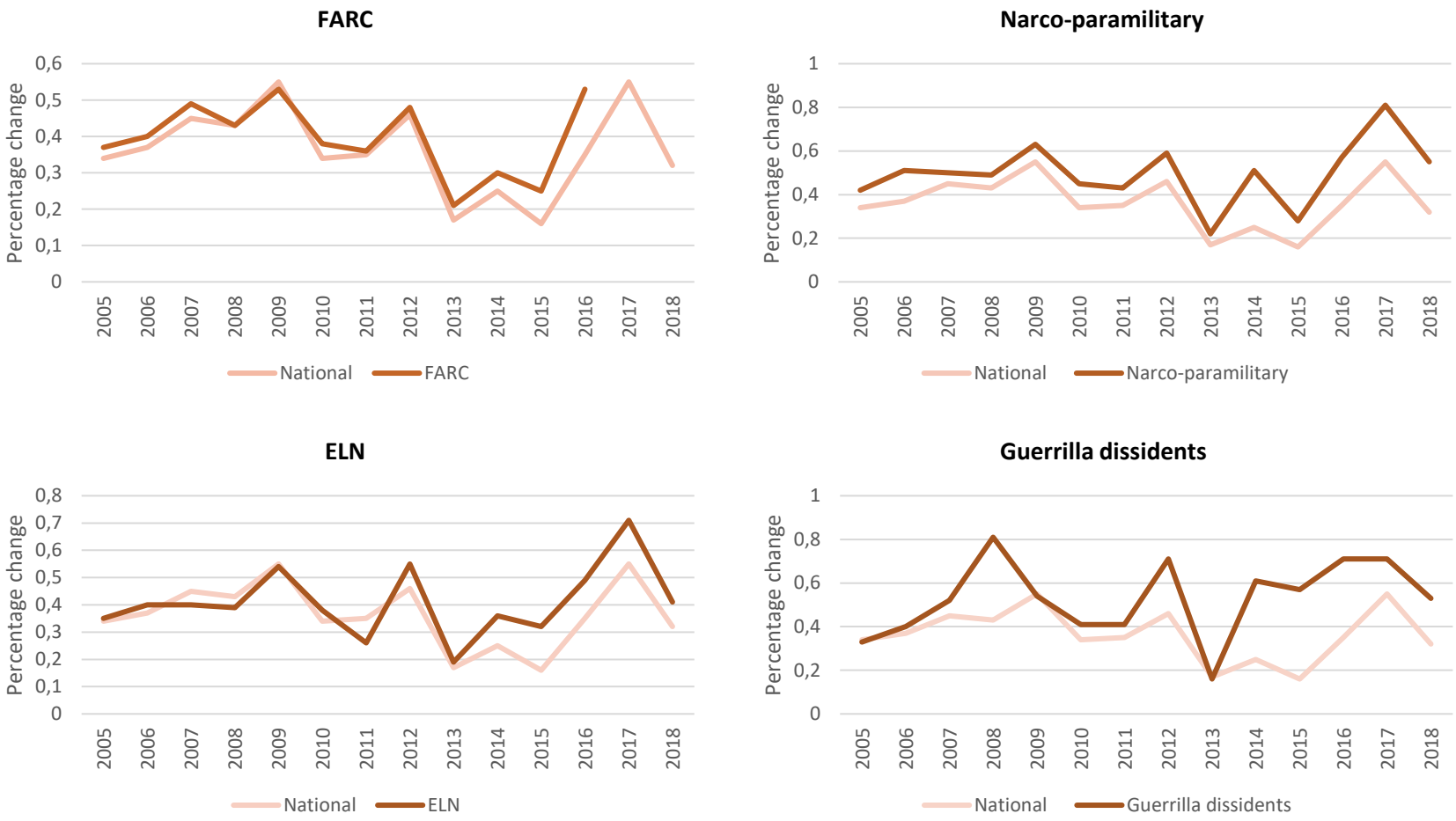


Source: GFW, CNMH and FIP, 2019. Own elaboration; data accessed on July 23, 28 and September 13, 2019.

Nevertheless, the presence of illegal armed groups should be evaluated in relation to the impacts made by these groups on forest land. In that respect, figure 4 depicts that narco-paramilitary groups and guerrilla dissidents had a higher impact on deforestation than the national rate[24]. Although, it is important to note that the environmental harm of narco-paramilitary groups is more alarming because the municipalities where they have a presence have less forest land. Figure 4 also shows an upward pattern of the deforestation rate following the unilateral ceasefire. This pattern could be related to two issues. First, there could be a conflict intensification resulting from the rearrangement of the Colombian conflict. Secondly, there could be an increase of illegal armed wealth, triggering the extraction of high-value natural resources and/or the expansion of agricultural frontiers at the expense of forestry.

[24] By 2013 there is also a downturn of deforestation in all cases which might be related with a higher allocation of national resources in the Forest and Carbon Monitoring System (SMBC). This might have promoted that the oversight bodies could have better channels to follow up and then tackle mildly deforestation across Colombian regions.

FIGURE 4 RATE OF DEFORESTATION BY ARMED GROUPS VERSUS NATIONAL RATE OF DEFORESTATION (2005-2018)



Source: GFW, CNMH and FIP, 2019. Own elaboration; data accessed on July 23, 28 and September 13, 2019.

To summarize, the figure presented in this subsection illustrates that several changes followed the unilateral ceasefire that are negatively impacting the amount of land covered by forest. This helps to acknowledge that this paper is important, not just to understand the complexity of the conflict itself, but also its environmental implications for people in a country that is highly dependent on natural resources. However, because the figures presented in this subsection only present a general picture about the topic being studied, the next section will discuss the empirical strategy that is being used to provide more accurate estimations of the impact of illegal armed groups on deforestation.

Chapter 4: Results

4.1 FARC presence and deforestation.

This subsection is an evaluation of the relationship between FARC and the rate of deforestation in Colombia. Table 2 and columns 1 and 2 indicate the main empirical specification determined previously in equation (1). The coefficients display that FARC presence (actions) has a negative relationship with deforestation rate. At first glance, this suggests that those municipalities that registered at least one action by FARC between 2005 and 2018 discouraged the economic conversion of forest land by 0.05 percentage change (column 1) and 0.06 percentage change (column 2) after the unilateral ceasefire was announced on December 20, 2014. The latter coefficient's increase of 0.01 percentage points over the former coefficient following the retreat of FARC may indicate the emergence of different socio-political and economic dynamics in the regions. A way to corroborate this estimation is look at the interaction variable (FARC and unilateral ceasefire) which has a positive relationship with the deforestation rate of 0.08 percentage change (column 2). To gauge the magnitude of this, it is first necessary to consider some descriptive generalities. The average amount of land covered by forest in the 601 municipalities where FARC registered a presence between 2005 and 2016 was 163,000 hectares (see figure 3). This is approximately twice the area of New York City. The mean deforestation rate in the same municipalities over the same period was 0.40 percentage change (see figure 4), representing an average of 652 hectares ($163{,}000 \times 0.40$). Consequently, the increase of the deforestation rate by 0.08 percentage change in municipalities where FARC had retreated in the four years following the unilateral ceasefire represents an average of 130 hectares. This increase is significant in relation to the national average of hectares deforested (221 hectares)

because represent almost 60%, but smaller in relation to the average deforested in municipalities where FARC had presence (652 hectares); almost 20%.

The above paragraph assumes a homogenous FARC presence across the 601 municipalities. However, in order to account for variations in the forms and rates of deforestation, it is important to acknowledge the diversity and heterogeneity present under the 'FARC' label as was posited in the theoretical framework. This is because conflicts are incredibly complex and there is a great deal of variable diversity across actors, places and times. Accordingly, columns 3 to 5 illustrate the variable FARC presence controlled by a categorical variable. The categorical variable has three different categories of FARC presence: permanent, interrupted/consolidated, and finalized/rearrangement. The FARC permanent variable concerns those municipalities that registered a continuous FARC presence of more than seven years (an average 138 municipalities[25]) and has an inverse relationship of 0.08 percentage change (column 3) with the rate of deforestation. By contrast, the interaction variable has a positive relationship with a coefficient of 0.09 percentage change (column 3). The rationality used in the previous paragraph is also useful for understanding the effect of these results. The amount of forest cover present in the municipalities with a permanent FARC presence was 219,650 hectares. Therefore, a discouraging of the conversion of forest land of 0.08 percentage change in those municipalities indicates a discouraging of an average of 176 hectares in areas where FARC used to have a permanent presence. Nevertheless, in the municipalities where FARC began to retreat after the unilateral ceasefire there was an average increase in the number of hectares deforested to 198 (219.650×0.08). This represents 90% of the national average (221 hectares).

Meanwhile, in municipalities that registered a FARC presence of less than seven years, only one of the categories (FARC finalized/rearrangement) is statistically significant with a coefficient of 0.05 percentage change (column 5). According to this data, an increase of FARC presence by 10% in municipalities where they did not have a permanent presence would have generated an increase in the deforestation rate of 0.5 percentage change. This would be 0.13 percentage points higher than the national deforestation rate of 0.37 percentage change, and appears substantial when it we consider that the national mean of land area covered by forest is 76,883 hectares per municipality.

[25] This is the factor between FARC permanent presence mean (0.13) and the sample (1,062).

TABLE 2 DEFORESTATION RATE AND FARC PRESENCE (ROBUST STD ERROR)

	(1)	(2)	(3)	(4)	(5)
FARC presence	-0,05***	-0,06***	-0,02	-0,07***	-0,07***
	(0,01)	(0,01)	(0,02)	(0,02)	(0,02)
FARC permanent			-0,08***		
			(0,03)		
FARC interrupted/consolidation				0,04	
				(0,04)	
FARC finalized/rearrangement					0,05*
					(0,03)
FARC and unilateral ceasefire		0,08***	0,09***	0,08***	0,08***
		(0,03)	(0,03)	(0,03)	(0,02)
Constant	0,35	0,36	0,36	0,36	0,36
Municipalities	1062	1062	1062	1062	1062
Observations	14868	14868	14868	14868	14868
R2-within	0,07	0,07	0,07	0,07	0,07
R2-between	0,01	0,01	0,01	0,01	0,01
R2-overall	0,04	0,04	0,04	0,04	0,04
Municipality FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes

Notes: This table presents the estimations based on equation (1). Deforestation rate (dependent variable in percentage change) is the number of hectares deforested over forest cover extension in hectares by 2010. FARC presence (actions) is a dummy variable that takes value of one when a municipality suffered at least one action by FARC between 2005 and 2016. FARC permanent, interrupted/consolidation and finalized/rearrangement is a categorical variable that measures the heterogeneity of the FARC presence based on theoretical approximations of Kalyvas, (2001; 2008) and Delgado, (2013). FARC and unilateral ceasefire is a dummy variable that is one when a municipality did not register FARC presence (actions) after the announcement of unilateral ceasefire on December 20, 2014 and zero otherwise. All regressions include municipality and year fixed effect. Robust standard errors clustered at the municipality level are shown in parenthesis.
*** p<0.01, ** p<0.05, * p<0.1

A sensitive specification to evaluate whether the previous empirical strategy is consistent would generate a different interaction variable. In this case, the breakdown point would be the signing of the peace accord at the end of 2016; two years after unilateral ceasefire. Table III A (see appendices) shows the same tendency of FARC presence over the deforestation rate, although, the interaction variable (FARC and peace accord) has a higher coefficient that is almost the double the coefficients displayed in table 2 (columns 2 to 5). This suggests that the complete retreat and demobilization of FARC generated a significant impact on forest cover in those municipalities where such left-wing guerrilla had a presence. Similarly, another supplementary specification may be an evaluation of whether there is reverse causality between the deforestation rate and FARC presence. It is plausible to think that deforestation would suggest an increased likelihood of FARC presence. Table III B (see appendices) points out that the guerrilla group lagged one-year decreased the deforestation rate by 0.05 percentage change which is consistent with previous results. However, when the reverse causality is evaluated, the deforestation rate lagged one-year decreases the presence of FARC by 0.02 percentage change. Once again, such coefficients confirm the existence of

an inverse relationship between FARC presence and the deforestation rate, irrespective of analyses of causality.

In sum, these coefficients are consistent with the assumption that the permanent presence of the FARC discourages the conversion of forest land because said territories are occupied and used as strategic shelter from air raids (Fearon, Laitin, 2003, Alvarez, 2003, Andrade, 2004, Camacho, Rodriguez, 2013, Sánchez-Cuervo, Aide, 2013, Fergusson, Romero & Vargas, 2014, Castro-Nunez et al., 2017). Elsewhere, those municipalities that registered less than seven years of FARC presence, could have been looted and used as an economic resource[26] to help fuel armed conflict and therefore increase the deforestation rate. This ambivalence suggests it is important not to view the FARC as homogenous body that behaves singularly as a part of hierarchical structure (Kalyvas, 2001, Kalyvas, 2008, Delgado, 2013). Furthermore, it is important to state that the results do not suggest that municipalities with permanent FARC presence did not suffer the loss of forest, but rather that the FARC presence prevented other stakeholders from entering the municipalities, most of which are considered as biodiversity hotspots (Negret et al., 2017), and increasing the likelihood of deforestation (Alvarez, 2003, Andrade, 2004, Castro-Nunez et al., 2017). In fact, the time-trend after the unilateral ceasefire indicates that the exit of FARC alongside the arrival of new stakeholders and a weakening of local state capacity has a significant impact on deforestation. The complexity of this will be analysed in the following sub-sections.

4.2 Illegal armed groups presence and deforestation.

The theoretical framework postulates the idea that territorially fragmented sovereignties that contain several illegal armed groups experience greater conflict intensification[27], which increases capital inputs to the conflict (soldiers, weapons, etc.) and triggers deforestation. This sub-section evaluates the impact of this on the deforestation rate and its linkage with illegal armed groups who have a presence in several municipalities, according to the equation (2). In addition, all regressions are analysed controlling for the effect that has (FARC and unilateral ceasefire) as the interaction variable over deforestation in order to test whether the analysis in section 6.1 is consistent.

[26] Such as drug industry, illegal mining, extorsion, kidnappings and cattle theft (Saab, Taylor, 2009).
[27] This may include war actions, selective killing, population attack, terrorist attacks, property damage, forced disappearance, land mines, massacres, kidnappings, sexual violence, forced human displacement, etc.

With the aim of understanding how conflict intensity exert pressure over natural resources, such as forests the first part step is to examine whether a higher fragmentation of territorial sovereignty leads to an increase in conflict intensity (Kalyvas, 2001, Kalyvas, 2008). The specification model is: (5)

$$\eta_{mt} = \theta_1(mun\ x\ armed\ gruop)_{mt} + \varphi_t + \upsilon_m + \varpi_{mt}$$

where η_{mt} is is the conflict intensity (*log*) measured through the total number of actions committed by one group or several illegal armed groups in a municipality m and year t. θ_1 is a categorical variable that captures the information of sixteen possible combinations regarding the presence of one or more illegal armed groups in a municipality between 2005 and 2018[28]; φ_t, υ_m and ϖ_{mt} are time and municipality fixed effects and error term, respectively. The results are displayed in Table 3 which illustrates that those municipalities that had a presence of one-illegal armed group between 2005 and 2018 experienced a lower conflict intensity (columns 1 to 3) than those municipalities that hosted more than one illegal armed group (column 4 to 6). For example, column 1 indicates that an increase of 1% in actions undertaken by FARC intensified conflict by 37 percentage change. By contrast, column 4 suggests that an increase of 1% of actions perpetrated by FARC and/or a narco-paramilitary group in the same municipality creates a conflict intensification of 96 percentage change. Running all the categories jointly makes it possible to evaluate the impact on conflict intensity with more comprehensiveness. Column 7 shows that a 1% of actions in municipalities that hosted more than one illegal armed group led to a 138-percentage change average intensification of conflict. Meanwhile, in those municipalities that registered a presence of one-illegal armed group, an upsurge of 1% in actions would have promoted the conflict intensity by an average of 37 percentage change, unless the group were FARC, which would mean an increase of 71 percentage change. This greater likelihood could be the result of their high number of combatants, which have been estimated as numbering between 16,000 and 20,000 (Saab, Taylor, 2009, Dube, Vargas, 2013, Pizarro et al., 2015).

[28] After generating the categorical variable, each category was separated and transformed in a dummy variable in order to evaluated them individually.

TABLE 3 CONFLICT INTENSITY (LOG) AND TERRITORIAL FRAGMENTATION (ROBUST STD ERROR)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
mun x FARC	0,37***						0,71***
	(0,03)						(0,03)
mun x narco-paramilitary		-0,04					0,23***
		(0,34)					(0,03)
mun x ELN			-0,17***				0,16***
			(0,04)				(0,03)
mun x FARC, narco-paramilitary and ELN				0,96***			1,62***
				(0,07)			(0,07)
mun x FARC and narco-paramilitary					0,85***		1,33***
					(0,04)		(0,04)
mun x FARC and ELN						0,72***	1,21***
						(0,06)	(0,06)
Constant	0,97	1,01	1,02	0,96	0,87	1,00	0,55
Municipalities	1062	1062	1062	1062	1062	1062	1062
Observations	14868	14868	14868	14868	14868	14868	14868
R2-within	0,23	0,21	0,21	0,23	0,26	0,23	0,42
R2-between	0,29	0,01	0,00	0,25	0,41	0,20	0,81
R2-overall	0,17	0,09	0,10	0,15	0,20	0,15	0,54
Municipality FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: This table presents the estimations based on equation (5). Conflict intensity (*log*) (dependent variable) is calculated by the total number of violent actions undertaken by all armed groups per year. The independent variables (mun x FARC, mun x narco-paramilitary, mun ELN, mun x FARC, narco-paramilitary and ELN, mun x FARC and narco-paramilitary, mun x FARC and ELN) are dummy variables that come from a categorical variable that captures information of sixteen possible combinations regarding presence of illegal armed groups. This is in order to calculate the territorial fragmentation. All the combinations are not estimated and presented in this table since was chosen those that have the highest percentage, excluding the municipalities that did not register illegal armed groups presence between 2005 and 2018 (see appendices table III C). All regressions include municipality and year fixed effect. Robust standard errors clustered at the municipality level are shown in parenthesis.
*** p<0.01, ** p<0.05, * p<0.1

After testing that territorial fragmented sovereignty does indeed increase conflict intensity, the second step is to evaluate the impact of several illegal armed groups on deforestation. Table 4 shows (column 1 to 4) that the presence of FARC regularly decreases the deforestation rate by an average of 0.05 percentage change. Conversely, guerrilla dissidents increase the conversion of forest land by 0.10 percentage change (column 3 and 4). This is 0.15 percentage points more than FARC. However, it is also important to clarify that most of this increased conversion is attributed to the guerrilla dissidents that left FARC prior to the signing of the peace accord in November 2016. This would therefore suggest that the impact of guerrilla dissidents on the deforestation rate would have been lower before the FARC breakup[29].

[29] To corroborate this statement, it was run a regression to see the impact of guerrilla dissidents on deforestation rate between 2005 and 2015 (EPL and ERG). The coefficient is positive (0.001) and non-statistically significant which would indicate that the deforestation rate increases since 2016 and onwards when some fronts - 1, 7, 14, 15, 16, 27, 40, 48, 62, 63, etc.- decided to relinquish the peace accord (Alvarez, Pardo & Vélez, 2018).

TABLE 4 DEFORESTATION RATE AND ILLEGAL ARMED GROUPS PRESENCE (ROBUST STD ERROR)

	(1)	(2)	(3)	(4)
FARC presence	-0,06***	-0,06***	-0,05***	-0,05***
	(0,01)	(0,01)	(0,01)	(0,01)
Narco-paramilitary presence	-0,00			-0,00
	(0,01)			(0,01)
ELN presence		-0,02		-0,02
		(0,02)		(0,01)
Guerrilla dissident's presence			0,10**	0,10**
			(0,05)	(0,05)
FARC and unilateral ceasefire	0,08***	0,08***	0,08***	0,08***
	(0,03)	(0,03)	(0,03)	(0,03)
Constant	0,36	0,36	0,36	0,36
Municipalities	1062	1062	1062	1062
Observations	14868	14868	14868	14868
R2-within	0,07	0,07	0,07	0,07
R2-between	0,01	0,01	0,00	0,00
R2-overall	0,04	0,04	0,04	0,04
Municipality FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes

Notes: This table presents the estimations based on equation (2). Deforestation rate (dependent variable in percentage change) is the number of hectares deforested over forest cover extension in hectares by 2010. FARC presence (actions), narco-paramilitary presence (actions), ELN presence (actions) and guerrilla dissidents (actions) are dummy variables that take the value of one when a municipality suffered at least one action by these armed groups between 2005 and 2018. FARC and unilateral ceasefire is a dummy variable that is one when a municipality did not register FARC presence (actions) after the announcement of unilateral ceasefire on December 20, 2014 and zero otherwise. All regressions include municipality and year fixed effect. Robust standard errors clustered at the municipality level are shown in parenthesis.
*** p<0.01, ** p<0.05, * p<0.1

The above argument was rationalized in the following way. The average number of municipalities that registered a guerrilla dissident presence before the peace accord was signed in 2016 was 6. However, between 2017 and 2018 the average number increased to 81 with most of the dissidents located in territories where FARC used to have a presence in the south of Colombia (see figure 2). Assuming that the former 6 municipalities continued to be occupied by guerrilla dissidents other than FARC, it is reasonable to say that the number of municipalities occupied by FARC dissidents was around 75. The average number of hectares contained in these municipalities is around 307,396 which indicates that an increase of guerrilla dissident presence by 1% may lead to an average increase of deforestation by 307 hectares per municipality ($307.396 \; x \; 0.10$). If we multiply the number municipalities, 75, by the number of hectares deforested, 307, we obtain a result of is 23,093 hectares deforested per year. This is four times the area of Loch Ness in Scotland (which has an area of 5,460 hectares).

In general, FARC presence is once again shown to discourage deforestation; while the presence of guerrilla dissidents, especially those that separated from FARC before the signing of the peace accord, increased the rate of conversion of forest land. This is undoubtedly linked to the increase of actions, conflict intensity, taken by guerrilla dissidents previously to the signing of the peace accord (see figure 2). This may suggest a higher demand of capital inputs to fuel conflict and increase the deforestation rate in municipalities where they have presence; some of them in dispute with other illegal armed groups. These results suggest rapacious behaviour concerning natural resources (Collier, 2008, Dal Bó, Dal Bó, 2011, Janus, 2012, Dube, Vargas, 2013). However, this subsection has no way to directly calculate how guerrilla dissidents are generating such deforestation[30] as this would require an analysis of socio-economic dynamics and, certainly, further qualitative approach. Consequently, though consistent, the evidence presented here is indirect.

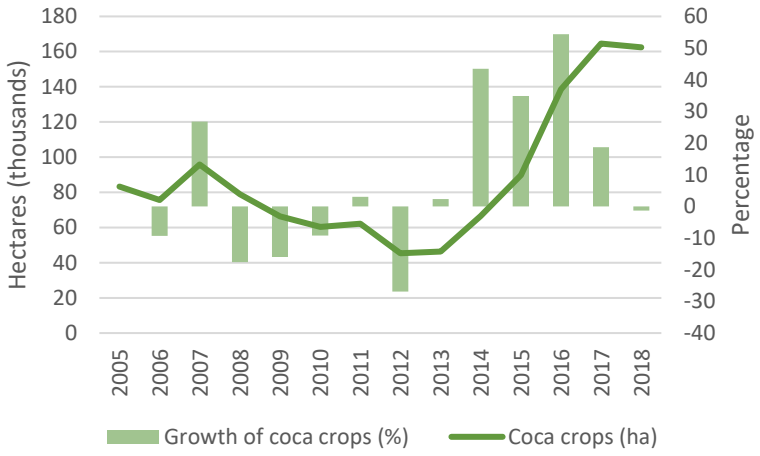
4.3 FARC presence, socio-economic dynamics and deforestation.

This sub-section evaluates the FARC presence against several alternative socio-economic factors that may have been driving deforestation in Colombia after the unilateral ceasefire in 2014. Table 5 (column 1 to 4) shows that coca crops, cattle ranching, gold production and illegal mining have a positive relationship on the rate of deforestation. Angrist et al. (2008) argue that coca crops have a positive impact on violence because they increase the capital inputs demanded by illegal armed groups, which hampers, on the one side, the state owned monopoly over violence and, on the other, illegal armed groups willingness to enter peace negotiations because of the high economic revenues generated by the conflict (Angrist, Kugler, 2008, Lopez et al., 2019).

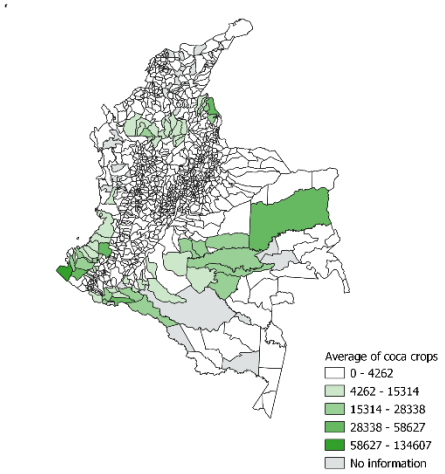
Despite all of this, in 2012 the national government and FARC started peace negotiations which were finalized with the signing of the November 2016 peace accord. Over this period the number of hectares cultivated with coca did not decrease. Instead numbers of coca crops increased gradually, escalating by an annual average of 38% between 2014 and 2017 (see figure 5). Undoubtedly, this alarming growth of coca crops had an impact on deforestation.

[30] It means which mechanism and/or economic activities are using to increase deforestation.

FIGURE 5 NUMBER OF HECTARES AND GROWTH OF COCA CROPS



MAP 4 NUMBER OF HECTARES OF COCA CROPS ON AVERAGE BY MUNICIPALITY (2005-2018**)**



Source: Drug Observatory of Colombia (ODC), 2019. Own elaboration; data accessed on August 22, 2019.

TABLE 5 DEFORESTATION RATE AND ALTERNATIVE FACTORS (ROBUST STD ERROR)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
FARC presence	-0,05***	-0,06***	-0,07***	-0,05***	-0,05***	-0,04***	-0,04***	-0,03
	(0,01)	(0,02)	(0,02)	(0,01)	(0,01)	(0,01)	(0,01)	(0,02)
Coca rate	0,09**							0,08**
	(0,04)							(0,04)
Log cattle ranching (heads)		0,03***						0,02
		(0,01)						(0,02)
Log gold production (tons)			0,01*					0,01*
			(0,00)					(0,00)
Log illegal mining complaints (cases)				0,03**				-0,00
				(0,01)				(0,02)
Log forced human displacement (people)					-0,02***			-0,02***
					(0,00)			(0,01)
Log tax incomes (Colombian pesos)						0,02		0,01
						(0,01)		(0,02)
Log operation cost (Colombian pesos)							0,01	0,02***
							(0,00)	(0,01)
FARC and unilateral ceasefire	0,06**	0,08***	0,05**	0,08***	0,08***	0,08***	0,08***	0,05**
	(0,03)	(0,02)	(0,03)	(0,03)	(0,03)	(0,03)	(0,03)	(0,02)
Constant	0,36	0,36	0,48	0,36	0,45	0,26	0,31	0,37
Municipalities	1062	1062	1062	1062	1062	1062	1062	1062
Observations	14868	11682	7434	14868	14868	13806	13806	6379
R2-within	0,07	0,09	0,15	0,07	0,07	0,07	0,07	0,17
R2-between	0,00	0,13	0,01	0,00	0,05	0,06	0,00	0,02
R2-overall	0,05	0,09	0,06	0,04	0,02	0,05	0,05	0,09
Municipality FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: This table presents the estimations based on equation (3). Deforestation rate (dependent variable in percentage change) is the number of hectares deforested over forest cover extension in hectares by 2010. FARC presence (actions) is a dummy variable that take value of one when a municipality suffered at least one action by these armed groups between 2005 and 2016. Coca rate (percentage change) is the number of hectares cultivated of coca over municipality area in hectares between 2005 and 2018. Log cattle ranching is calculated by the number of cattle heads per municipality between 2008 and 2018. Log gold productions is measured by the total of gold production in tons between 2012 and 2018. Log illegal mining is the number of complaints reported to the public persecutor regarding environmental pollution and illicit exploitation of minerals and hydrocarbons between 2005 and 2018. Log forced human displacement is calculated by the number of people displaced between 2005 and 2018. Log tax incomes and log operation cost are proxy variables to measure state capacity between 2005 and 2017; both variables are in Colombian pesos. FARC and unilateral ceasefire is a dummy variable that is one when a municipality did not register FARC presence (actions) after the announcement of unilateral ceasefire on December 20, 2014 and zero otherwise. All regressions include municipality and year fixed effect. Robust standard errors clustered at the municipality level are shown in parenthesis.

*** p<0.01, ** p<0.05, * p<0.1

For instance, if we consider that the growth of coca in 2016 was around 54% (see figure 5), the increase in deforestation would have been around 4.86 percentage change per municipality ($54\ x\ 0.09$) (see table 5: column 1)[31]. This is around 11,429 hectares per municipality, when we consider that the number of municipalities that registered coca crops in 2016 was 167 and the amount of land covered by forest of these municipalities is around 235,167 hectares.

Historically the zones where coca crops are cultivated are characterized by the presence of illegal armed groups, non-suitable soils for large-scale licit crops, dirt roads, poor social conditions, and a weak state capacity (see map 4). These are all circumstances that enable the expansion of illicit crops (Lopez et al., 2019). In fact, Angrist et al., (2008) empirically demonstrate that coca crop production is strongly related to those departments that have experienced guerrilla activity. Even though columns 1 to 7 in table 5 indicate that FARC presence discourages deforestation by 0.05 percentage change on average, which is consistent with previous results, it does not mean that they were not involved in the increased production of coca crops before the peace accord was signed in 2016. This raises the question about the extent to which FARC promoted the increase of coca crops before 2016 and thereby the deforestation rate. Answering this question requires caution because there are many interplaying factors that could have been having an effect.

Firstly, the eradication of coca, both manual and through aerial spraying, began to decrease at the end of 2000 decade, suggesting a possible late impact on the growth of coca crops (Lopez et al, 2019). Secondly, the fall of gold prices in 2012 reduced the opportunity cost of cultivating coca in places where gold was being extracted (see appendices figure II A). Thirdly, the depreciation of the Colombian Peso led to the coca industry becoming more profitable in spite of a decrease in the price of cocaine in the United States and Europe after 2012 (see appendices figure II A). Fourthly, there is an assumption that the fourth point of the peace accord regarding illicit drugs was distorted and then misunderstood by rural coca growers (Lopez et al., 2019). The growers believed that the allocation of national resources was only for rural households and municipalities with coca crops, which generated a perverse incentive to increase the number of hectares of coca fields. Lastly, Lopez et al,. (2019) empirically found that only 31% of the increase in coca crops between 2012 and 2016 was

[31] The basic reasoning is an increase of coca crops by 1% promotes an increase of the rate of deforestation by 0.09 percentage change.

directly related to municipalities where FARC used to have presence. Consequently, it is conceivable that most of the coca growth, and therefore deforestation was due to the vacuum of power left by the FARC after the unilateral ceasefire (see table 5, column 1: FARC and unilateral ceasefire) (Escobedo, 2018).

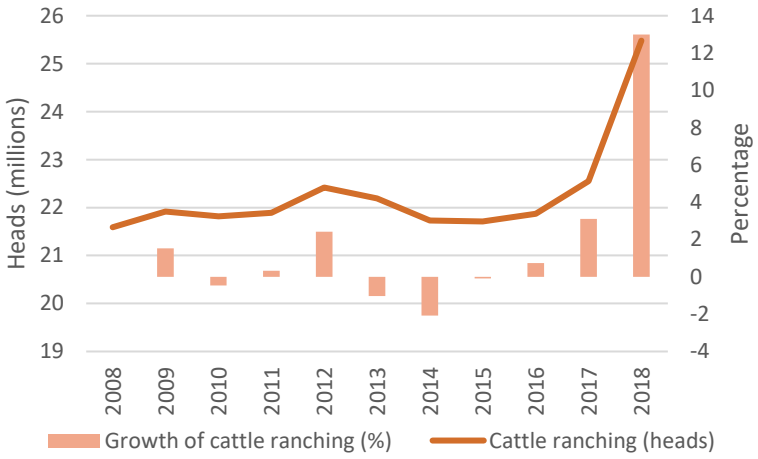
In many areas where coca crops have been cultivated, it is plausible to suggest that the revenues gained by coca growers are invested in cattle ranching (Chadid et al., 2015). Many scholars have found that cattle ranching is an important factor of deforestation, as was mentioned in the theoretical framework (see section 2.1.3). In this sense, the increase of cattle ranching may be endogenous to the increase of coca crops and therefore have an impact on deforestation. To test this possible endogeneity, a regression was run that took cattle ranching as a dependent variable and the coca rate as an independent variable, and vice versa. Table III D (see appendices), panel A, illustrates that an increase of coca crops by 1% led to a growth of cattle ranching by 4 percentage change[32]. This is much higher than the opposite relationship whose coefficient is 0.01 percentage change (panel B). To better understand this relationship, we can look at table 5, column 2, which shows that an increase of 1% in cattle ranching impacts deforestation by 0.03 percentage change.

Despite all of this, Figure 6 enables us to make an even more accurate evaluation. According to the data provided by ICA, the total growth of cattle ranching between 2015 and 2018 was around 17% (3.75 million cattle heads), which indicates that this could have driven an increase in the deforestation rate of an average of 0.51 percentage change at the national level ($17 \; x \; 0.03$). Nevertheless, in municipalities like San Vicente del Caguán (Caquetá, southern Colombia: see map 5) where FARC had a permanent presence and the main economic activity is cattle ranching on forest land that covered around 1,448,773 hectares, the rate of deforestation may well be higher. Indeed, the rate in this municipality was an average of 1.4 percentage change following the unilateral ceasefire, which equates to 20,993 hectares per year ($1{,}448{,}773 \; x \; 1.4$). Over the last four years this would be around 91,972 hectares in San Vicente del Caguán[33] alone.

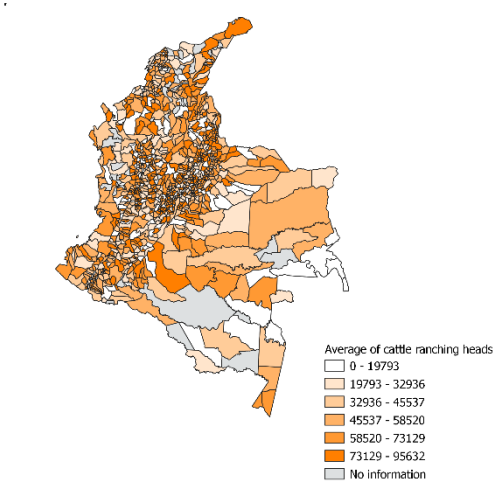
[32] Notwithstanding the relationship is positive, this magnitude would require a further qualitative approach in order to analyse other factors that are interlinked, for instance, land speculation.

[33] In line with Oswaldo Zafirecudo Kuyoteca, an indigenous leader interviewed by Semana magazine in 2018, asserted that deforestation began to increase in Caquetá after the retreat of FARC. This situation enabled that colonizer – *colonos* – began to arrive offering 100,000 Colombian pesos ($ 34 around) for each tree cut down in a community with high rates of poverty. In addition, Zafirecudo claimed that most of this land is changed for cattle ranching, triggered by mafias (Semana, 2018).

FIGURE 6 NUMBER OF HEADS AND GROWTH OF CATTLE



MAP 5 NUMBER OF CATTLE RANCHING HEADS ON AVERAGE BY MUNICIPALITY (2008-2018)



Source: Colombian Agricultural Institute (ICA), 2019. Own elaboration; data accessed on October 10, 2019.

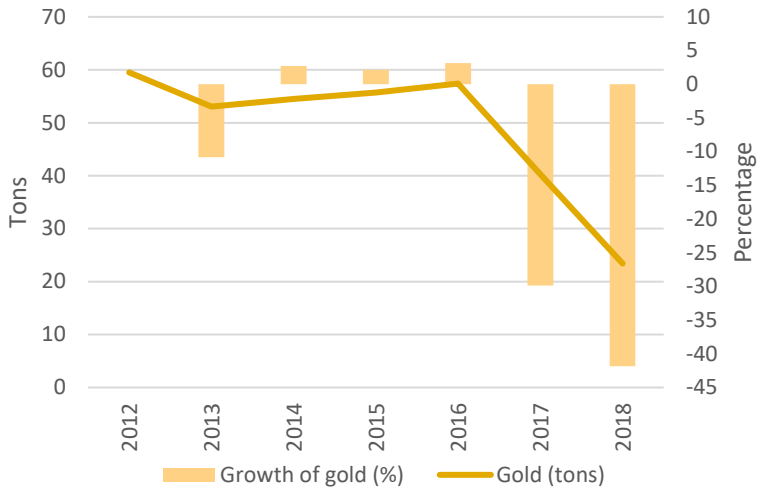
Another activity that has a significant impact on deforestation is mining. This economic activity triggers rapacious behavior because high-value natural resources like gold generate substantial revenues not just for the nation, but also for the illegal armed groups in the Colombian conflict (Collier, 2008, Dal Bó, Dal Bó, 2011, Janus, 2012, Dube, Vargas, 2013). Table 5, columns 3 and 4, shows that there is a positive relationship between mining and deforestation (see *log* gold production and *log* illegal mining complaints). However, it is important to remind that *log* gold production recollects information about legal mining while *log* illegal mining is a proxy variable calculated through environmental pollution, the illicit exploitation of minerals, and hydrocarbons complaints registered to the Attorney General's office. Even though illegal mining complaints may be underreported as 63% of this mining production in Colombia does not pay royalties[34] (Contraloría General de la Nación, 2017), this variable is a good proxy that helps us to capture the dynamics of this shadow economic activity (see figure 8 and map 7).

As a result, it is conceivable that legal mining has a lower impact on deforestation than illegal mining because of the oversight bodies that monitor mining production. Accordingly, Table 5 shows that an increase of gold production by 1% impacts the deforestation rate by 0.01 percentage change. Meanwhile, an increase of 1% in illegal mining complaints leads to an increase in the deforestation rate of 0.03 percentage change[35]. The difference between both types of mining production seems to quite small at 0.02 percentage points. However, this difference should be understood to be a result of solely evaluating that the information that is provided by the Attorney General's office, which as we have already stated, is underreported. The number of complaints filed about illegal mining can therefore be assumed to be much larger. Despite this, Figures 7 and 8 provide us with a general picture about mining production in Colombia and its negative impact on the amount of land covered by forest. Certainly, the production of gold, both legal and illegal, may have been encouraged in biodiversity hotpots where FARC used to have a presence (Güisa, 2018), jeopardizing the ecological wealth of these areas (see map 6 and 7).

[34] The percentages of the main minerals that do not pay royalties are as follows: precious metals: 85%, building materials: 60% and coal: 40% (Contraloría General de la Nación, 2017).

[35] 473 municipalities registered illegal mining between 2005 and 2018 (see figure 14). These municipalities are covered by 93,086 hectares of forest on average which multiplied by 0.03 percentage points would be 28 hectares on average per municipality. Nevertheless, due to the 37% of illegal mining is addressed on conflict areas and these areas may be covered by vast extension of forest, then the number of hectares deforested could be higher.

FIGURE 8 TONS AND GROWTH OF GOLD (2012-2018)



MAP 6 TONS OF GOLD ON AVERAGE BY MUNICIPALITY (2012-2018)

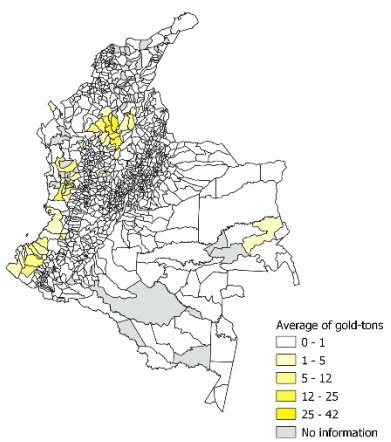
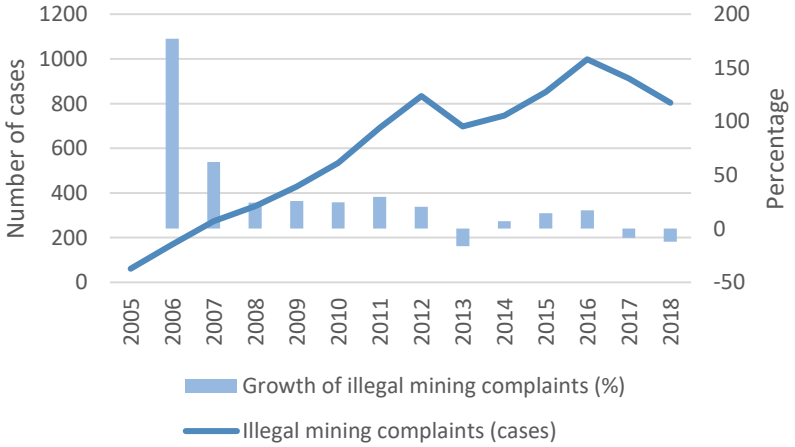
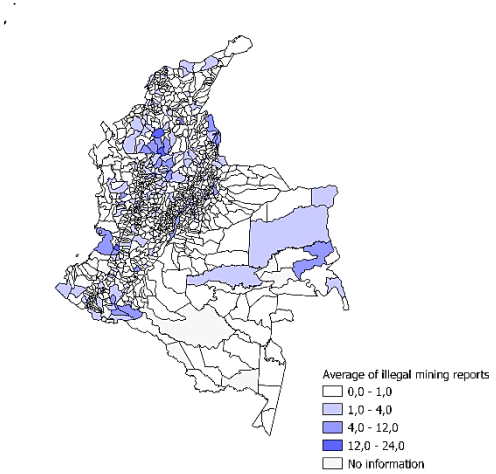


FIGURE 7 NUMBER AND GROWTH OF ILLEGAL MINING COMPLAINTS (2005-2018)



MAP 7 NUMBER ILLEGAL MINING COMPLAINTS ON AVERAGE BY MUNICIPALITY (2005-2018)



Source: Energy Mining Planning Unit (UPME) and Attorney General's office, 2019.
Own elaboration; data accessed on August 26, 2019 and October 10, 2019.

Shadow economic activities require illegal armed groups to be able to act autonomously in the territories where they are active. This political and economic issue promotes forced human displacement and land grabbing because local communities in remote areas may be seen as obstacles preventing the groups from reaching their goals. For instance, it is estimated that 46% of the natural forest in Colombia is under collective property and managed by indigenous and Afro Colombian communities who help to discourage deforestation (Baptiste et al., 2017, Rodríguez-Piñeros et al., 2018). Nevertheless, Table 5, column 5, shows that forced human displacement reduced deforestation by 0.02 percentage change, underpinning the assumption that the migration of people from rural areas to urban areas in conflict contexts reduces the pressure over forest land (Aide et al., 2004). Despite this assumption, forced human displacement should still be analyzed in relation to other variables. Column 8 shows us that forced human displacement is still a factor that decreases deforestation by 0.02 percentage change, although, the coca rate and gold production have a positive impact on deforestation of 0.08 and 0.01 percentage change, respectively. Moreover, following the unilateral ceasefire, there has been an increase in the deforestation rate of 0.05 percentage change which may suggest that forced human displacement is a channel through which both legal and illegal activities are conducted (Fergusson, Romero & Vargas, 2014).

On the other hand, column 8, also shows that the *log* operation cost, which is a proxy variable to measure state capacity, has a positive relationship with deforestation of 0.02 percentage change. Even though this may seem counterintuitive, it is relevant to consider that perhaps many of these resources could be allocated to governmental entities that are not directly related to the conservation of the environment. Indeed, Rudas (2011), who has extensively studied the funding sources of the National Environmental System (SINA), argues that environmental oversight bodies, such as the Regional Autonomous Corporations (CARs), depend on the national transfer of property taxation; power generation, oil, and mining compensation on the one hand; direct royalties from legal mining on the other. Therefore, those CARs that are located in more productive zones have a higher capacity to decrease the likelihood of environmental degradation (Rudas, 2011).

Table III E (see appendices) offers additional information to evaluate the equation (3a) that adds the other illegal armed groups. In general, the coefficient and patterns shown in Table III E (see appendices) are similar to those shown in Table 5. Although guerrilla

dissidents have a significant impact on deforestation when their relationship, we analyze their relationship with coca crops, legal and illegal mining, cattle ranching, and forced human displacement it is the last two variables that have the highest impact on forest cover levels (columns 2 to 5). This indicates that guerrilla dissidents are involved several legal and illegal economic activities that fuel conflict and/or increase their wealth. Thus, as Hoffmann, Márquez & Krueger, 2018, Prem, Saavedra & Vargas, 2018, Rodriguez et al., 2019 argue, it is plausible to state that, in municipalities where FARC had a presence, there is a phenomenon of large-scale cattle and land speculation that is being triggered by guerrilla dissidents. Moreover, the different channels that guerrilla dissidents are using to reach their goals (kidnapping, threats, persecution, extortion, illegal checkpoints etc.) are generating a humanitarian crisis through the displacement of people.

4.4 Robustness check

Now, it is presented other empirical specifications in order to evaluate robustness of previous results. To do so, it is running equation (3b), although, removing the variable of FARC presence. This is addressed in order to eliminate any possible endogeneity. The results are displayed on table III F (see appendices) which show a consistent pattern regarding the results presented on sub-section 6.3. Nevertheless, coca rate has higher impact on deforestation with a coefficient of 0.10 percentage change, confirming that the increase of coca crops in recent times is due to the vacuum of power left by FARC. Undoubtedly, as it was argued, there could have other factors that may be leading such growth of coca, they are beyond of the scope of this research. In consequence, it is necessary to continue exploring, from different methodologies, the linkage between coca crops and deforestation, taking into account several socio-economic dynamics involved in a conflict context.

Additionally, this sub-section examines other factors that may increase or decrease deforestation, pointing out that all the regressions were run at the department level between 2007 and 2017 since the information is not available at the municipal level and the whole period analyzed in this paper (see appendices table III G). In that way, the selection of the commodities coffee and plantain are based on two criteria. First, these are the main permanent agricultural commodities concerning the number of hectares cultivated per year which contribute largely to the Colombian economy. Second, coffee and plantain crops use high labor intensity and hence a price shock may lead to lower wages, promoting that farmers

move to other activities more profitable, for example, coca crops (Angrist, Kugler, 2008, Dal Bó, Dal Bó, 2011, Dube, Vargas, 2013). Similarly, it was considered the monetary poverty index, which measure the proportion of households whose incomes are below of poverty line, and Gini coefficient that measures inequality. Finally, it is measured bureaucratic/administrative capacity of state based on the empirical findings made by Hendrix (2010). Thus, state capacity is calculated by the total collection of taxes over total GDP per department, assuming that if the state has a higher bureaucratic/administrative capacity would be able to collect more taxes and thereby the ratio tax income/GDP would be larger (Hendrix, 2010).

Notwithstanding the foregoing, table III G (see appendices) shows that just monetary poverty index has an effect on deforestation by 0.38 percentage change (column 4) when it is evaluated together with the interaction variable (FARC and unilateral ceasefire) and 0.40 percentage change (column 6) when it is estimated all the specification model. Examining the last coefficient jointly with the results already explained in section 6, it is conceivable to think that those households that are below of line poverty will promote deforestation since their wages are not sufficient to fulfill their basic needs (Carr, 2009, Rodríguez Eraso, Armenteras & Alumbreros, 2013, Castro-Nunez et al., 2017). As a consequence, people in remote areas will look for other economic alternatives, both legal and illegal to fill such gap (Alvarez, 2003). In this context, Colombian state should address policies that not just focus in the visible factors that are promoting deforestation (e.g. actors; coca crops, etc.), but also in the social and political issues that are locally embedded due to historical reasons. Thus, despite it is a long run task, deforestation can be tackled in Colombia, if it is assumed as a multidimensional phenomenon that implies measures top-down, such as local institutional strengthening, articulated with the realities and claims of each region, specifically those that come from the local communities that have a historical relationship with forest.

Chapter 5: Conclusions

This paper has evaluated the increase of deforestation following the unilateral ceasefire announced by FARC at the end of 2014. To do so, it used a *fixed effect* empirical strategy to evaluate the before and after of unilateral ceasefire from a sample of 1,062 municipalities between 2005 and 2018. This strategy controls time-invariant municipal characteristics. The paper demonstrates that each municipality in Colombia that registered a presence of FARC *discouraged* the rate of deforestation, which occurred even more in municipalities where they

had a historical relationship. This refers to municipalities that registered a FARC presence higher than seven years. In these areas, several stakeholders, including the population settled down in these municipalities, were prevented from increasing deforestation at a greater pace. These results are in line with the qualitative and quantitative approaches that state that illegal armed groups have used forest as a strategic shelter from air raids (Fearon, Laitin, 2003, Alvarez, 2003, Andrade, 2004, Camacho, Rodriguez, 2013, Sánchez-Cuervo, Aide, 2013, Fergusson, Romero & Vargas, 2014, Castro-Nunez et al., 2017). Furthermore, this paper confirms the findings of Prem et al, (2018) who make the assumption that the unilateral ceasefire resulted in several stakeholders filling the vacuum of power left FARC and increasing deforestation at an alarming rate. However, it is pivotal to consider that illegal armed groups are heterogenous, rather than homogenous and hierarchical structures where all members act under the same guidelines. In that sense, this paper demonstrates that municipalities that registered a presence of FARC of up to six years had a changed experience with forest land. This means that FARC promoted deforestation instead of discouraging it. As result, it is possible to view these municipalities in the context of conflict and understand them as territories of dispute between several illegal armed groups (Kalyvas, 2001, Kalyvas, 2008, Delgado, 2013). This dynamic increases the intensity of the conlict and generates a higher demand for weapons, soldiers, etc., which has an impact on natural resources, and, for instance, depletes, forest land (Collier, 2008; Dube et al, 2010; Dal Bo et al, 2011; Janus, 2011).

The arrangement of the Colombian conflict following the unilateral ceasefire at the of 2014 generated a situation where pre-existing illegal armed groups began to occupy the municipalities where FARC used to have a presence. This paper demonstrates that guerrilla dissidents from FARC are the main conflict actor that is promoting deforestation. For many scholars these municipalities are considered as biodiversity hotpots (Andrade, 2004; Batispte et al., 2017, Negret et al, 2017) which would suggest that they contain high-value natural resources and/or may be used to expand the agricultural frontier. This context increases, together with the low state capacity, the likelihood of rapacious behaviour in a conflict context, as Dube et al (2010) and Dal Bo et al (2011) argue both empirically and theoretically. Accordingly, it is showed that increases in economic dynamics such as coca crops, cattle ranching and both legal and illegal mining have a negative impact on forest land cover. However, the complexity of these economic activities following the unilateral ceasefire is that they are interlinked and are playing a joint role in the increase of deforestation. For instance,

it has been revealed that the increase of coca crops has a positive impact on the increase of cattle ranching, supporting the assumption of Chadid, et al, (2015) that cattle ranching may be a channel to access credits and gain revenues from trading. Similarly, due to most of the mining production being out of the scope of oversight bodies, the governmental measures to tackle deforestation may be insufficient. In fact, the rapacious behaviour in municipalities that the FARC have vacated is generating a humanitarian crisis through forced human displacement. This phenomenon, which may be understood as a proxy variable of population and how it decreases pressure over forest land (Aide et al, 2004), should be analyzed cautiously in conflict contexts (Alvarez, 2003). Although this paper found a negative relationship between forced human displacement and deforestation, it is certain that this humanitarian crisis is a channel for illegal armed groups to reach their military and economic goals in strategic municipalities.

Additionally, this paper found that the bureaucratic/administrative state capacity measured through the proxy variable of operation expenditures has a positive impact on deforestation. Even though this may be counterintuitive conforming to the findings from Fergusson et al, 2014 and Prem et al, 2018, these results suggest that the government budgets are not mainly allocated to entities related to the conservation of the environment at the municipal level. Certainly, the capacity of oversight bodies such as the Regional Autonomous Corporations (CARs) depends on national transfers and direct royalties, which are linked with the more productive zones (Rudas, 2011). Therefore, it is plausible to think for those oversight bodies that are in conflict territories, capacity is very low since the majority of economic activities are illegal and the national government is focusing more of their efforts on overthrowing illegal armed groups and eradicating coca crops (Escobedo, 2018; Garzón et al, 2018). The latter is also linked with the finding that poverty has an impact on deforestation at the department level. Consequently, households that are below of poverty line will look for economic activities, both legal and illegal, that allow them to fulfil their basic needs, increasing the likelihood of clearing forest in remote areas (Alvarez, 2003; Lopez et al., 2019). Despite the consistency of these findings, it is necessary to continue exploring the multiple factors that are triggering deforestation in Colombia from a multidisciplinary perspective.

Finally, these results bring forward a further discussion about how deforestation and conflict have been addressed in public policies in Colombia. First, the economic activities that are triggering deforestation may be tackled with the understanding that they are operating jointly

in remote areas. As a consequence, a public policy that focuses its efforts on one economic activity, legal or illegal, may be insufficient. Second, even though a stronger bureaucratic/administrative state capacity may lead to a decrease of deforestation in conflict areas, it remains highly dependent on the resources that are allocated to the oversight bodies that are dealing with environmental conservation. This implies that the national government should promote public policies that go beyond security and military perspectives in territories where there is an upward pattern of environmental degradation because a conflict.

Appendices

I. Additional concepts.

A. **Conceptual boundaries of deforestation** in Colombia.

Conforming to the book title *Sourcebook of methods and procedures for monitoring and reporting anthropogenic greenhouse gas emissions and removals associated with deforestation, gains and losses of carbon stocks in forest remaining forest, and forestation*, (Achard et al., 2014) the concept of deforestation has several interpretations and it is bound to the regulation of every country. For that reason, it is convenient, based on United Nations Framework Convention on Climate Change (UNFCCC) and Kyoto Protocol, to define some boundaries (Unfccc, 2009) concerning forest land and forest degradation. The former concept is understood as all land cover with woody vegetation defined by its area, tree size and canopy density or crown cover which are delineated by every country. Thus, such thresholds may vary country to country, however, in line with Fréderic Achard et al., (2014), Kyoto Protocol reference manual (2009) settles some minimum ranges which include those young trees that have not reached the appropriate level:

i. Minimum area: 0.05 to 1 hectare.
ii. Minimum height (potential at maturity in situ): 2 to 5 meters.
iii. Minimum level of canopy: 10 to 30%.

Consequently, any forest land that is below 10% of the canopy is considered as non-forest land. Nonetheless, the classification depends on threshold defined by every country and hence the trees that are below of such level are considered as non-forest. On the contrary, if the cover forest does not imply a change of land uses, for instance, timber harvest where it is expected a regrowth, this economic activity does not generate a change in the classification of forest land (Achard et al., 2014).

In the case of Colombia, which signed and ratified the Kyoto Protocol, has its minimums: area is one hectare, height (in situ) is five meters and level of canopy is 30%. Hence, in consonance with the official organization Forest and Carbon Monitoring System (SMBC)], forest land includes trees that contain bushes, palms, guaduas, herbs and lianas and excludes oil palm plantations and other commercial or agricultural plantations. Likewise, it excludes urban parks (Galindo et al., 2014).

Regarding the second concept, forest degradation is caused by anthropogenic net emissions during a given period of time which has an impact on the crown cover, decreasing the biomass density in forest land. In this respect, even though the forest cover loss is human induced, the change of canopy cover should be not lower than threshold defined by every country, in this case 30%. Furthermore, the decreasing of forest cover may be persistent which is measured by means of tons of carbon stock during a long period of time, for example, 20 years or spatially, a loss of a large area which used to be covered by forest land. Consequently, the interaction between tree cover forest loss and gain may be reported as forest degradation, rather than deforestation. Nevertheless, Fréderic Achard et al. (2014)

clarifies that determine which forest land has been degraded might be difficult because it depends on how well is defined in practice those concepts and what is the interpretation of the sustainable activity. In addition, it is crucial the technical capacity which enables to monitor the changes in canopy cover through time series analysis and register the activities that cause forest degradation and not deforestation. In the case of Colombia several activities, both legal and illegal, might be contributing to forest degradation and deforestation, such as mining, farming, livestock, logging, forest fires and even the inappropriate delimitation of environmental protection zones, like the Natural National Parks (FEDESARROLLO, 2017); specially, when the Colombian state, in the process of the Peace Accord implementation, has not able to consolidate its local institutional capacity after the retreat and demobilization of FARC from certain municipalities that contain huge amounts of carbon stock.

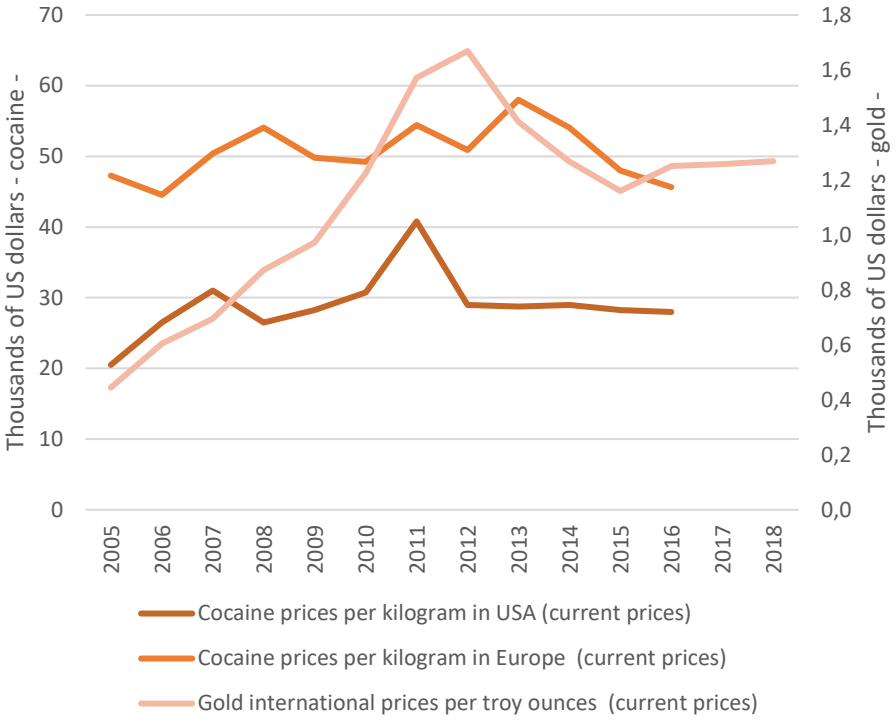
Taking into account the aforementioned conceptual boundaries, deforestation is understood as the conversion from forest land to another type of land use. As mentioned, Colombia has some minimums and thereby below of them, cover forest change is treated as deforested. In that sense, the activities that produce deforestation may be: "*conversion of forest to annual cropland, conversion to pasturelands, conversion to perennial plants (oil palm, shrubs) and conversion to urban lands or other human infrastructure*" (Achard et al., 2014: 13).

II. Additional information

MAP II A POLITICAL-ADMINISTRATIVE DIVISION OF COLOMBIA, SIGAC (2002).

Source: Instituto Geográfico Agustín Codazzi (IGAC), 1999.

FIGURE II A COCAINE PRICES IN USA AND EUROPE AND GOLD INTERNATIONAL PRICES (2005-2018)



Source: United Nation Office on Drug and Crime (UNDC) and World Gold Council (WGC), 2019. Own elaboration; data accessed on October 31, 2019.

III. Additional estimations

TABLE III A DEFORESTATION RATE AND FARC PRESENCE- AFTER PEACE ACCORD- (ROBUST STD ERROR)

	(1)	(2)	(3)	(4)	(5)
FARC presence	-0,05***	-0,05***	-0,02	-0,06***	-0,07***
	(0,01)	(0,01)	(0,02)	(0,02)	(0,02)
FARC permanent			-0,08***		
			(0,03)		
FARC interrupted/consolidation				0,04	
				(0,04)	
FARC finalized/rearrangement					0,05*
					(0,03)
FARC and peace accord		0,13***	0,15***	0,14***	0,14***
		(0,05)	(0,05)	(0,03)	(0,02)
Constant	0,35	0,36	0,36	0,36	0,36
Municipalities	1062	1062	1062	1062	1062
Observations	14868	14868	14868	14868	14868
R2-within	0,07	0,07	0,07	0,07	0,07
R2-between	0,01	0,01	0,01	0,01	0,01
R2-overall	0,04	0,04	0,04	0,04	0,04
Municipality FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes

Notes: This table presents estimations based on equation (1). Deforestation rate (dependent variable in percentage change) is the number of hectares deforested over forest cover extension in 2010. FARC presence (actions) is a dummy variable that takes value of one when a municipality suffered at least one action by FARC between 2005 and 2018. FARC permanent, interrupted/consolidation, finalized/rearrangement is a categorical variable that measures the heterogeneity of the FARC presence based on theoretical approximations of Kalyvas (2001; 2008) and Delgado (2013). FARC and peace accord is a dummy variable that is one when a municipality did not register FARC presence (actions) after the sign of peace accord in 2016 and zero otherwise. All regressions include municipality and year fixed effect. Robust standard errors clustered at the municipality level are shown in parenthesis.
*** p<0.01, ** p<0.05, * p<0.1

TABLE III B DEFORESTATION RATE AND FARC PRESENCE (ROBUST STD ERROR)

	(1)	(2)
Panel A: Deforestation rate versus FARC presence		
FARC presence (lag 1)	-0,05***	
	(0,01)	
Panel B: FARC presence versus deforestation rate		
Deforestation rate (lag 1)		-0,02***
		(0,00)
Constant	0,35	0,35
Municipalities	1062	1062
Observations	13086	13086
R2-within	0,07	0,13
R2-between	0,01	0,01
R2-overall	0,04	0,07
Municipality FE	Yes	Yes
Year FE	Yes	Yes

Notes: Panel A illustrates the relation between deforestation rate and FARC presence (actions) lagged one year. Panel B shows the inverse relationship, taking as a dependent variable FARC presence (actions) and as independent variable deforestation rate lagged one year. All regressions include municipality and year fixed effect. Robust standard errors clustered at the municipality level are shown in parenthesis.
*** p<0.01, ** p<0.05, * p<0.1

TABLE III C TERRITORIAL FRAGMENTATION BY ILLEGAL ARMED GROUPS (2005-2018)

	(1)	(2)
mun x FARC	1762	11,85%
mun x narco-paramilitary	936	6,30%
mun x FARC and narco-paramilitary	568	3,82%
mun x ELN	453	3,05%
mun x FARC and ELN	325	2,19%
mun x FARC, narco-paramilitary and ELN	197	1,32%
mun x narco-paramilitary and ELN	157	1,06%
mun x guerrilla dissidents	94	0,63%
mun x ELN and guerrilla dissidents	49	0,33%
mun x narco-paramilitary and guerrilla dissidents	38	0,26%
mun x narco-paramilitary, ELN and guerrilla dissidents	26	0,17%
mun x ELN, guerrilla dissidents and FARC	18	0,12%
mun x guerrilla dissidents and FARC	13	0,09%
mun x guerrilla dissidents, FARC and narco-paramilitary	13	0,09%
mun x FARC, narco-paramilitary, ELN and guerrilla dissidents	9	0,06%
mun x FARC, narco-paramilitary, ELN and guerrilla dissidents (non-violent actions)	10210	68,67%
Total	14868	100%

Note: This table shows sixteen possible combinations regarding illegal armed groups in order to estimate territorial fragmentation. Column 1 presents the total number of actions undertaken by one or several illegal armed groups between 2005 and 2018. Column 2 illustrates the percentages of these combinations.

TABLE III D CATTLE RANCHING AND COCA RATE FACTORS (ROBUST STD ERROR)

Panel A	(1)	(2)
Dependent variable	Log cattle ranching	
Coca rate	0,04** (0,02)	
Panel B		
Dependent variable		Coca rate
Log cattle ranching		0,01** (0,00)
Constant	8,9	-0,03
Municipalities	1062	1062
Observations	11682	11682
R2-within	0,02	0,03
R2-between	0,00	0,00
R2-overall	0,00	0,00
Municipality FE	Yes	Yes
Year FE	Yes	Yes

Note: Coca rate (percentage change) is the number of hectares cultivated of coca over municipality area in hectares between 2005 and 2018. Log cattle ranching is calculated by the number of cattle heads per municipality between 2008 and 2018. All regressions include municipality and year fixed effect. Robust standard errors clustered at the municipality level are shown in parenthesis.
*** p<0.01, ** p<0.05, * p<0.1

TABLE III E DEFORESTATION RATE, ILLEGAL ARMED GROUPS AND ALTERNATIVE FACTORS (ROBUST STD ERROR)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
FARC presence	-0,04***	-0,04***	-0,05***	-0,05***	-0,05***	-0,04***	-0,04***	-0,02
	(0,01)	(0,01)	(0,02)	(0,01)	(0,01)	(0,01)	(0,01)	(0,02)
Narco-paramilitary presence	-0,00	0,01	0,03	-0,00	-0,00	-0,01	-0,01	0,03
	(0,01)	(0,02)	(0,02)	(0,01)	(0,01)	(0,01)	(0,01)	(0,03)
ELN presence	-0,02	-0,0	-0,01	-0,02	-0,02	-0,02	-0,02	-0,01
	(0,01)	(0,02)	(0,02)	(0,01)	(0,01)	(0,01)	(0,01)	(0,02)
Guerrilla dissidents	0,07*	0,13***	0,09**	0,10**	0,11**	0,06	0,05	0,04
	(0,04)	(0,04)	(0,04)	(0,05)	(0,05)	(0,05)	(0,05)	(0,05)
Coca rate	0,08*							0,08**
	(0,04)							(0,04)
Log cattle ranching (heads)		0,03***						0,02
		(0,01)						(0,02)
Log gold production (tons)			0,01*					0,01*
			(0,00)					(0,00)
Log illegal mining complaints (cases)				0,03**				-0,00
				(0,01)				(0,02)
Log forced human displacement (people)					-0,02***			-0,02***
					(0,00)			(0,01)
Log tax incomes (Colombian pesos)						0,02		0,02
						(0,01)		(0,02)
Log operation cost (Colombian pesos)							0,00	0,02***
							(0,00)	(0,01)
FARC and unilateral ceasefire	0,07**	0,07***	0,05**	0,08***	0,08***	0,09***	0,08***	0,05**
	(0,03)	(0,02)	(0,03)	(0,03)	(0,03)	(0,03)	(0,03)	(0,02)
Constant	0,36	0,16	0,47	0,36	0,45	0,26	0,26	0,09
Municipalities	1062	1062	1062	1062	1062	1062	1062	1062
Observations	14868	11682	7434	14868	14868	13806	13806	6379
R2-within	0,07	0,09	0,15	0,07	0,07	0,07	0,07	0,17
R2-between	0,00	0,15	0,01	0,00	0,06	0,05	0,00	0,02
R2-overall	0,05	0,10	0,08	0,04	0,02	0,06	0,04	0,09
Municipality FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: This table presents the estimations based on equation (3a). Deforestation rate (dependent variable in percentage points) is the number of hectares deforested over forest cover extension in hectares by 2010. FARC presence (actions), narco-paramilitary presence (actions), ELN presence (actions) and guerrilla dissidents (actions) are dummy variables that take value of one when a municipality suffered at least one action by these armed groups between 2005 and 2018. Coca rate (percentage change) is the number of hectares cultivated of coca over municipality area in hectares between 2005 and 2018. Log cattle ranching is calculated by the number of cattle heads per municipality between 2008 and 2018. Log gold productions is measured by the total of gold production in tons between 2012 and 2018. Log illegal mining is the number of complaints reported to the public persecutor regarding environmental pollution and illicit exploitation of minerals and hydrocarbons between 2005 and 2018. Log forced human displacement is calculated by the number of people displaced between 2005 and 2018. Log tax incomes and log operation cost are proxy variables to measure state capacity between 2005 and 2017; both variables are in Colombian pesos. FARC and unilateral ceasefire is a dummy variable that is one when a municipality did not register FARC presence (actions) after the announcement of unilateral ceasefire on December 20, 2014 and zero otherwise. All regressions include municipality and year fixed effect. Robust standard errors clustered at the municipality level are shown in parenthesis.
*** p<0.01, ** p<0.05, * p<0.1

TABLE III F DEFORESTATION RATE AND ALTERNATIVE FACTORS – WITHOUT FARC PRESENCE - (ROBUST STD ERROR)

	(1)	(2)	(3)	(4)	(5)	(7)	(8)	(9)
Coca rate	0,10**							0,09**
	(0,04)							(0,04)
Log cattle ranching (heads)		0,03***						0,02
		(0,01)						(0,02)
Log gold production (tons)			0,01*					0,01*
			(0,00)					(0,00)
Log illegal mining complaints (cases)				0,03**				-0,00
				(0,01)				(0,02)
Log forced human displacement (people)					-0,02***			-0,02***
					(0,01)			(0,01)
Log tax incomes (Colombian pesos)						0,02		0,02
						(0,01)		(0,02)
Log operation expenditure (Colombian pesos)							0,01	0,02***
							(0,00)	(0,01)
FARC and unilateral ceasefire	0,04	0,05**	0,05	0,05***	0,06***	0,07***	0,06**	0,03
	(0,02)	(0,02)	(0,03)	(0,05)	(0,02)	(0,03)	(0,03)	(0,02)
Constant	0,33	0,13	0,47	0,34	0,44	0,25	0,29	0,37
Municipalities	1062	1062	1062	1062	1062	1062	1062	1062
Observations	14868	11682	7434	14868	14868	13806	13806	6379
R2-within	0,07	0,09	0,15	0,07	0,07	0,07	0,07	0,17
R2-between	0,01	0,14	0,01	0,00	0,07	0,08	0,01	0,02
R2-overall	0,05	0,10	0,07	0,05	0,02	0,06	0,05	0,09
Municipality FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: This table presents the estimations based on equation (3b). Deforestation rate (dependent variable in percentage change) is the number of hectares deforested over forest cover extension in hectares by 2010. Coca rate (percentage change) is the number of hectares cultivated of coca over municipality area in hectares between 2005 and 2018. Log cattle ranching is calculated by the number of cattle heads per municipality between 2008 and 2018. Log gold productions is measured by the total of gold production in tons between 2012 and 2018. Log illegal mining is the number of complaints reported to the public persecutor regarding environmental pollution and illicit exploitation of minerals and hydrocarbons between 2005 and 2018. Log forced human displacement is calculated by the number of people displaced between 2005 and 2018. Log tax incomes and log operation expenditure are proxy variables to measure state capacity between 2005 and 2017; both variables are in Colombian pesos. FARC and unilateral ceasefire is a dummy variable that is one when a municipality did not register FARC presence (actions) after the announcement of unilateral ceasefire on December 20, 2014 and zero otherwise. All regressions include municipality and year fixed effect. Robust standard errors clustered at the municipality level are shown in parenthesis.

*** p<0.01, ** p<0.05, * p<0.1

TABLE III G DEFORESTATION RATE AND ADDITIONAL ALTERNATIVE FACTORS (ROBUST STD ERROR)

	(1)	(2)	(3)	(4)	(5)	(6)
Coffee rate	0,00 (0,01)					-0,01 (0,01)
Plantain rate		0,00 (0,01)				0,00 (0,00)
Log Gini coefficient			0,49 (0,32)			-0,32 (0,41)
Log monetary poverty index				0,38*** (0,13)		0,40** (0,16)
Log state capacity					0,05 (0,04)	0,13 (0,10)
FARC and unilateral ceasefire	0,11 (0,10)	0,11 (0,10)	0,06 (0,12)	0,05 (0,12)	0,12 (0,10)	0,08 (0,07)
Constant	0,29	0,29	0,67	-1,16	0,52	-0,84
Departments	33	33	24	24	33	24
Observations	462	462	288	288	429	264
R2-within	0,30	0,30	0,36	0,38	0,32	0,40
R2-between	0,00	0,01	0,14	0,04	0,04	0,11
R2-overall	0,15	0,16	0,17	0,19	0,14	0,27
Department FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes

Notes: This table presents the estimations based on equation (4). Deforestation rate (dependent variable in percentage change) is the number of hectares deforested over forest cover extension in hectares by 2010. Coffee and plantain rate (percentage change) is the number of hectares cultivated of these commodities over municipality area in hectares between 2005 and 2018. Log monetary poverty index and Gini coefficient are calculated to measure if a household can fulfill their basic needs and incomes inequality, respectively. The information is available at the department level between 2005 and 2018. Although, the statistics bureau from Colombia just offer information from 24 departments of out 33, excluding Amazonas, Arauca, San Andres Islands, Casanare, Guainía, Guaviare, Putumayo, Valle de Cauca, Vaupés and Vichada. Likewise, the years 2006 and 2007 are excluded due to statistics bureau did not have the accurate and sufficient information to estimate these years (DANE, 2010). Log state capacity is calculated by total tax collection over department GDP between 2005 and 2017. This ratio helps to measure bureaucratic/administrative state capacity conforming to Hendrix (2010). FARC and unilateral ceasefire is a dummy variable that is one when a municipality did not register FARC presence (actions) after the announcement of unilateral ceasefire on December 20, 2014 and zero otherwise. All regressions include department and year fixed effect.

Robust standard errors clustered at the department level are shown in parenthesis.

*** p<0.01, ** p<0.05, * p<0.1

References

Acemoglu, D., García-Jimeno, C. & Robinson, J.A. 2015, "State capacity and economic development: A network approach", *American Economic Review,* vol. 105, no. 8, pp. 2364-2409.

Achard, F., Boschetti, L., Brown, S., Brady, M., DeFries, R., Grassi, G., Herold, M., Mollicone, D., Mora, B. & Pandey, D. 2014, "A sourcebook of methods and procedures for monitoring and reporting anthropogenic greenhouse gas emissions and removals associated with deforestation, gains and losses of carbon stocks in forests remaining forests, and forestation", , pp. 1-268.

Aide, T.M. & Grau, H.R. 2004, "Ecology. Globalization, migration, and Latin American ecosystems", *Science (New York, N.Y.),* vol. 305, no. 5692, pp. 1915-1916.

Alvarez, E., Pardo, D. & Vélez, A. 2018, *, Trayectorias y dinámicas territoriales de las disidencias de las FARC* [Homepage of Fundación Ideas para la Paz (FIP)], [Online]. Available: http://ideaspaz.org/media/website/FIP_Disidencias_Final.pdf [2019, August 1].

Alvarez, M.D. 2003, "Forests in the time of violence: conservation implications of the Colombian war", *Journal of Sustainable Forestry,* vol. 16, no. 3-4, pp. 47-68.

Andrade, G. 2004, "Selvas sin ley. Conflicto, drogas, globalización de la deforestación de Colombia", *Colombia.Guerra sociedad y medio ambiente,* , pp. 107-174.

Angrist, J.D. & Kugler, A.D. 2008, "Rural windfall or a new resource curse? Coca, income, and civil conflict in Colombia", *The review of economics and statistics,* vol. 90, no. 2, pp. 191-215.

Arjona, A. 2011, *, Presencia vs violencia: problemas de medición de la presencia de actores armados en Colombia* [Homepage of Foro Económico: un blog Latinoaméricano de economía y política], [Online]. Available: http://focoeconomico.org/2011/12/20/presencia-vs-violencia-problemas-de-medicion-de-la-presencia-de-actores-armados-en-colombia/ [2019, September 18].

Armenteras, D., Cabrera, E., Rodríguez, N. & Retana, J. 2013, "National and regional determinants of tropical deforestation in Colombia", *Regional Environmental Change,* vol. 13, no. 6, pp. 1181-1193.

Armenteras, D., Rodríguez, N., Retana, J. & Morales, M. 2011, "Understanding deforestation in montane and lowland forests of the Colombian Andes", *Regional Environmental Change,* vol. 11, no. 3, pp. 693-705.

Baptiste, B., Pinedo-Vasquez, M., Gutierrez-Velez, V.H., Andrade, G.I., Vieira, P., Estupiñán-Suárez, L.M., Londoño, M.C., Laurance, W. & Lee, T.M. 2017, "Greening peace in Colombia", *Nature Ecology & Evolution,* vol. 1, no. 4, pp. 0102.

Besley, T. & Persson, T. 2010, "State capacity, conflict, and development", *Econometrica,* vol. 78, no. 1, pp. 1-34.

Bradley, A. & Millington, A. 2008, "Coca and colonists: quantifying and explaining forest clearance under coca and anti-narcotics policy regimes", *Ecology and Society,* vol. 13, no. 1.

Camacho, A. & Rodriguez, C. 2013, "Firm exit and armed conflict in Colombia", *Journal of Conflict Resolution,* vol. 57, no. 1, pp. 89-116.

Carr, D. 2009, "Population and deforestation: why rural migration matters", *Progress in Human Geography,* vol. 33, no. 3, pp. 355-378.

Carr, D.L., Suter, L. & Barbieri, A. 2005, "Population dynamics and tropical deforestation: state of the debate and conceptual challenges", *Population and Environment,* vol. 27, no. 1, pp. 89-113.

Castro-Nunez, A., Mertz, O., Buritica, A., Sosa, C.C. & Lee, S.T. 2017, "Land related grievances shape tropical forest-cover in areas affected by armed-conflict", *Applied Geography,* vol. 85, pp. 39-50.

Castro-Nunez, A., Mertz, O. & Quintero, M. 2016, "Propensity of farmers to conserve forest within REDD projects in areas affected by armed-conflict", *Forest Policy and Economics,* vol. 66, pp. 22-30.

Chadid, M., Dávalos, L., Molina, J. & Armenteras, D. 2015, "A Bayesian spatial model highlights distinct dynamics in deforestation from coca and pastures in an Andean biodiversity hotspot", *Forests,* vol. 6, no. 11, pp. 3828-3846.

Collier, P. 2008, *El club de la miseria: qué falla en los países más pobres del mundo,* Turner.

Contraloría General de la Nación 2017, *, Informe sobre el estado de los recursos naturales y del ambiente 2016-2017* [Homepage of Contraloría General de la Nación], [Online]. Available: http://www.andi.com.co/Uploads/17.%20Informe%20sobre%20el%20Estado%20de%20los%20Recursos%20Naturales%20y%20del%20Ambiente%202016%20-%202017-1.pdf [2019, November 5].

Dal Bó, E. & Dal Bó, P. 2011, "Workers, warriors, and criminals: social conflict in general equilibrium", *Journal of the European Economic Association,* vol. 9, no. 4, pp. 646-677.

DANE 2010, *, Misión para el Empalme de las Series de Empleo, Pobreza y Desigualdad MESEP* [Homepage of DANE], [Online]. Available: https://www.dane.gov.co/files/noticias/Metodologia_pobreza_dane_DNP.pdf [2019, October 31].

Dávalos, L.M., Bejarano, A.C., Hall, M.A., Correa, H.L., Corthals, A. & Espejo, O.J. 2011, "Forests and drugs: Coca-driven deforestation in tropical biodiversity hotspots", *Environmental science & technology,* vol. 45, no. 4, pp. 1219-1227.

Dávila, J.G., Azcárate, J. & Kørnøv, L. 2019, "Strategic Environmental Assessment for development programs and sustainability transition in the Colombian post-conflict context", *Environmental Impact Assessment Review,* vol. 74, pp. 35-42.

Delgado, T.V. 2013, "Una retrospectiva de la metodología para analizar las regiones afectadas", *Revista Controversia,* , no. 201, pp. 17-57.

Departamento Nacional de Planeación (DNP) 2014, *, Impactos Económicos del Cambio Climático en Colombia* [Homepage of DNP], [Online]. Available: https://colaboracion.dnp.gov.co/CDT/Ambiente/Impactos%20economicos%20Cambio%20clim%C3%A1tico.pdf [2019, May/15].

Dube, O. & Vargas, J.F. 2013, "Commodity price shocks and civil conflict: Evidence from Colombia", *The Review of Economic Studies,* vol. 80, no. 4, pp. 1384-1421.

Echandía, C. 2015, "Cincuenta años de cambios en el conflicto armado colombia (1964-2014)", *Zero,(33),* .

Escobedo, R. 2018, *, Capítulo I. Narcotráfico, actores armados e impacto humanitario* [Homepage of Defensoría del Pueblo], [Online]. Available: http://www.defensoria.gov.co/public/pdf/economiasilegales.pdf [2019, August 10].

Espitia, C., Cabezas, J., Rondon, J., Arias, A., Jimenez, J. & Gonzalez, C. 2018, *, Conflictos Armados Fozalizados: Informe Sobre Grupos Armados Ilegales Colombia 2017-2018* [Homepage of INDEPAZ], [Online]. Available: http://www.indepaz.org.co/wp-content/uploads/2018/12/ConflictosArmadosFocalizados-Indepaz-4.pdf [2019, May 15].

Estrada, F., Leon, S., Rodriguez, S. & Arcia, C. 2017, *, Grupos Armados ilegales y nuevos escenarios de riesgo en el posacuerdo* [Homepage of Defensoría del Pueblo], [Online]. Available: http://desarrollos.defensoria.gov.co/desarrollo1/ABCD/bases/marc/documentos/textos/Grupos_Armados_ilegales_y_nuevos_escenarios_de_riesgo_en_el_posacuerdo.pdf [2019, May 14].

Fearon, J.D. & Laitin, D.D. 2003, "Ethnicity, insurgency, and civil war", *American political science review,* vol. 97, no. 1, pp. 75-90.

FEDESARROLLO 2017, *, Acuerdo de paz: reforma rural, cultivos ilícitos, comunidades y costo fiscal* [Homepage of FEDESARROLLO], [Online]. Available: https://www.fedesarrollo.org.co/sites/default/files/visorPDF%20(18).pdf [2019, July 15].

Fergusson, L., Romero, D. & Vargas, J.F. 2014, "The environmental impact of civil conflict: the deforestation effect of paramilitary expansion in Colombia", *Documento CEDE,* , no. 2014-36.

Food and Agriculture Organization of the United Nation (FAO) 2018, *, The state of the word's forests - Forest pathways to sustainable development.* [Homepage of Food and

Agriculture Organization of the United Nation (FAO)], [Online]. Available: http://www.fao.org/faostat/en/#country/238 [2019, February 16].

Galindo, G., Espejo, J., Rubiano, C., Vergara, K. & Cabrera, E. 2014, *Protocolo de procesamiento digital de imágenes para la cuantificación de la deforestación en Colombia. V 2.0.*, Instituto de Hidrología, Meteorología y Estudios Ambientales – IDEAM., Bogotá.

Geist, H.J. & Lambin, E.F. 2002, "Proximate Causes and Underlying Driving Forces of Tropical DeforestationTropical forests are disappearing as the result of many pressures, both local and regional, acting in various combinations in different geographical locations", *Bioscience,* vol. 52, no. 2, pp. 143-150.

Goldman L, W.M. 2019, *, Technical blog: Gobal Forest Watch's 2018 Data Updated Explained* [Homepage of Global Forest Watch], [Online]. Available: https://www.globalforestwatch.org/ [2019, 05/02].

Güisa, L. 2018, *, Capítulo II. Capítulo Minería ilegal no artesanal y nuevos escenarios de riesgo en el posacuerdo.* [Homepage of Defensoría del Pueblo], [Online]. Available: http://www.defensoria.gov.co/public/pdf/economiasilegales.pdf [2019, August 10].

Hansen, M.C. 2013, *, High-Resolution Global Maps of 21st-Century Forest Cover Change* [Homepage of Global Forest Watch], [Online]. Available: http://earthenginepartners.appspot.com/science-2013-global-forest. [2019, April/25].

Hendrix, C.S. 2010, "Measuring state capacity: Theoretical and empirical implications for the study of civil conflict", *Journal of Peace Research,* vol. 47, no. 3, pp. 273-285.

Hoffmann, C., Márquez, J.R.G. & Krueger, T. 2018, "A local perspective on drivers and measures to slow deforestation in the Andean-Amazonian foothills of Colombia", *Land Use Policy,* vol. 77, pp. 379-391.

Janus, T. 2012, "Natural resource extraction and civil conflict", *Journal of Development Economics,* vol. 97, no. 1, pp. 24-31.

Kalyvas, S.N. 2008, "Promises and pitfalls of an emerging research program: The microdynamics of civil war", *Order, conflict, and violence,* vol. 41, no. 8, pp. 1043.

Kalyvas, S.N. 2001, "La violencia en medio de la guerra civil: esbozo de una teoría", *Análisis Político,* , no. 42, pp. 3-25.

Lopez, M., Guarín Núñez, Carlos Andrés Carlos, Medina, O. & Zuleta, H. 2019, "Proceso De Paz Con Las Farc Y Cultivos De Coca En El Período 2013-2017 (Peace Process with the FARC and Coca Crops in the Period 2013-2017)", *Documento CEDE,* , no. 2019-32.

Mildner, S., Lauster, G. & Wodni, W. 2011, "Scarcity and abundance revisited: A literature review on natural resources and conflict", *International Journal of Conflict and Violence (IJCV),* vol. 5, no. 1, pp. 155-172.

Negret, P.J., Allan, J., Braczkowski, A., Maron, M. & Watson, J.E. 2017, "Need for conservation planning in postconflict Colombia", *Conservation Biology,* vol. 31, no. 3, pp. 499-500.

Otis, J. 2014, "The FARC and Colombia's illegal drug trade", *Wilson Center,* , pp. 1-26.

Palacios, M. 2003, *Entre la legitimidad y la violencia: Colombia 1875-1994,* Editorial Norma, Bogotá.

Pizarro, E., Moncayo, V., De Zubiria, S., Duncan, G., Estrada, J., Fajardo, D., Giraldo S.J., J., Giraldo, J., Gutierrez, F., Molano, A., Pecaut, D., Torrijos, V., Vega, R. & Wills, E. 2015, *, Contribución al entendimiento del conflicto armado en Colombia* [Homepage of Ediciones Desde Abajo], [Online]. Available: http://www.altocomisionadoparalapaz.gov.co/mesadeconversaciones/PDF/Informe%20Comisi_n%20Hist_rica%20del%20Conflicto%20y%20sus%20V_ctimas.%20La%20Habana%2C%20Febrero%20de%202015.pdf [2016, September 1].

Prem, M., Saavedra, S. & Vargas, J.F. 2018, "End-of-Conflict Deforestation: Evidence From Colombia's Peace Agreement", *Available at SSRN 3306715,* .

Restrepo, J.A., Spagat, M. & Vargas, J.F. 2003, "The dynamics of the Colombian civil conflict: A new data set", .

Robalino, J.A. & Pfaff, A. 2012, "Contagious development: Neighbor interactions in deforestation", *Journal of Development Economics,* vol. 97, no. 2, pp. 427-436.

Rodríguez Eraso, N., Armenteras, D. & Alumbreros, J.R. 2013, "Land use and land cover change in the Colombian Andes: dynamics and future scenarios", *Journal of Land Use Science,* vol. 8, no. 2, pp. 154-174.

Rodriguez, J., Del Cairo, C., Ortiz, D., Vergara, T., Velez, J. & Hein, J. 2019, *Forests and peace in Colombia: Challenges in reducing deforestation in the Amazon forest.*

Rodríguez-Piñeros, S., Martínez-Cortés, O., Villarraga-Flórez, L. & Ruíz-Díaz, A. 2018, "Timber market actors' values on forest legislation: A case study from Colombia", *Forest policy and economics,* vol. 88, pp. 1-10.

Rudas, G. 2011, *, Gestión ambiental regional: capacidad financiera y transparencia institucional* [Homepage of DNP], [Online]. Available: https://colaboracion.dnp.gov.co/CDT/Sinergia/Documentos/Boletin_Politica_Publica_Hoy_12.pdf [2019, November 5].

Saab, B.Y. & Taylor, A.W. 2009, "Criminality and armed groups: A comparative study of FARC and paramilitary groups in Colombia", *Studies in Conflict & Terrorism,* vol. 32, no. 6, pp. 455-475.

Sánchez, G., Machado, A., Camacho, Á, Suárez, A., César, C., González, F., Orozco, I., Colorado, J.A., Restrepo, J. & Valencia, L. 2013, "¡ Basta ya! Colombia: Memorias de

guerra y dignidad", *Informe General Grupo de memoria Histórica.Centro Nacional de memoria Histórica.Bogotá, Colombia,* .

Sánchez-Cuervo, A.M. & Aide, T.M. 2013, "Consequences of the armed conflict, forced human displacement, and land abandonment on forest cover change in Colombia: A multi-scaled analysis", *Ecosystems,* vol. 16, no. 6, pp. 1052-1070.

Semana 2015, *, Cronología del proceso de paz entre el Gobierno y las FARC.* [Homepage of Semana], [Online]. Available: https://www.semana.com/nacion/articulo/linea-de-tiempo-del-proceso-de-paz-de-las-farc-gobierno/443570-3 [2019, October 10].

Unfccc, U. 2009, "Kyoto protocol reference manual", *On accounting of emissions and assigned amount,* , pp. 1-130.

Vélez, M.A. 2001, "FARC–ELN: evolución y expansión territorial", *Revista Desarrollo y Sociedad,* , no. 47, pp. 151-225.

World Wildlife Fund (WWF) 2019, *, Deforestation and forest degradation* [Homepage of WWF], [Online]. Available: https://www.worldwildlife.org/threats/deforestation-and-forest-degradation [2019, August 5].