HUNGARIAN UNIVERSITY OF AGRICULTURE AND LIFE SCIENCES

CONSEQUENCES OF ARMED CONFLICTS ON THE LANDSCAPE, SUMAPAZ PARAMO REGION CASE STUDY

THESES OF PhD DISSERTATION

DOI: 10.54598/004890

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Budapest

2024

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1. RESEARCH BACKGROUND

Warfare has transformed landscapes globally by altering lifestyle, economic production, and land use. In Colombia, conflict has directly or indirectly impacted most ecosystems. Paradoxically, military activity during armed conflict sometimes promoted conservation due to strict territorial control, landmines, or disputes over strategic areas. Conversely, after the peace agreement between the Fuerzas Armadas Revolucionarias de Colombia (FARC) and the Colombian Government, new environmental regulations on land use and access led to rapid land cover changes following FARC's withdrawal of the FARC.

In Colombia, research on land cover changes during and after the armed conflict has predominantly focused on extensive forested areas, such as the Amazon and Andean foothills. However, the environmental impact on paramo ecosystems has not yet been studied in detail. From the 1970s to 2016, the Sumapaz Paramo was a crucial corridor for the FARC to access southern Bogotá, the nation’s capital, in an effort to seize control. This territory linked the southern regions of Caquetá and Meta, which are areas of significant FARC influence, with Bogotá. The Sumapaz Paramo has a history of agrarian struggles since the 1920s and is known for its strong support of leftist policies stemming from these historical regional processes and peasant unions.

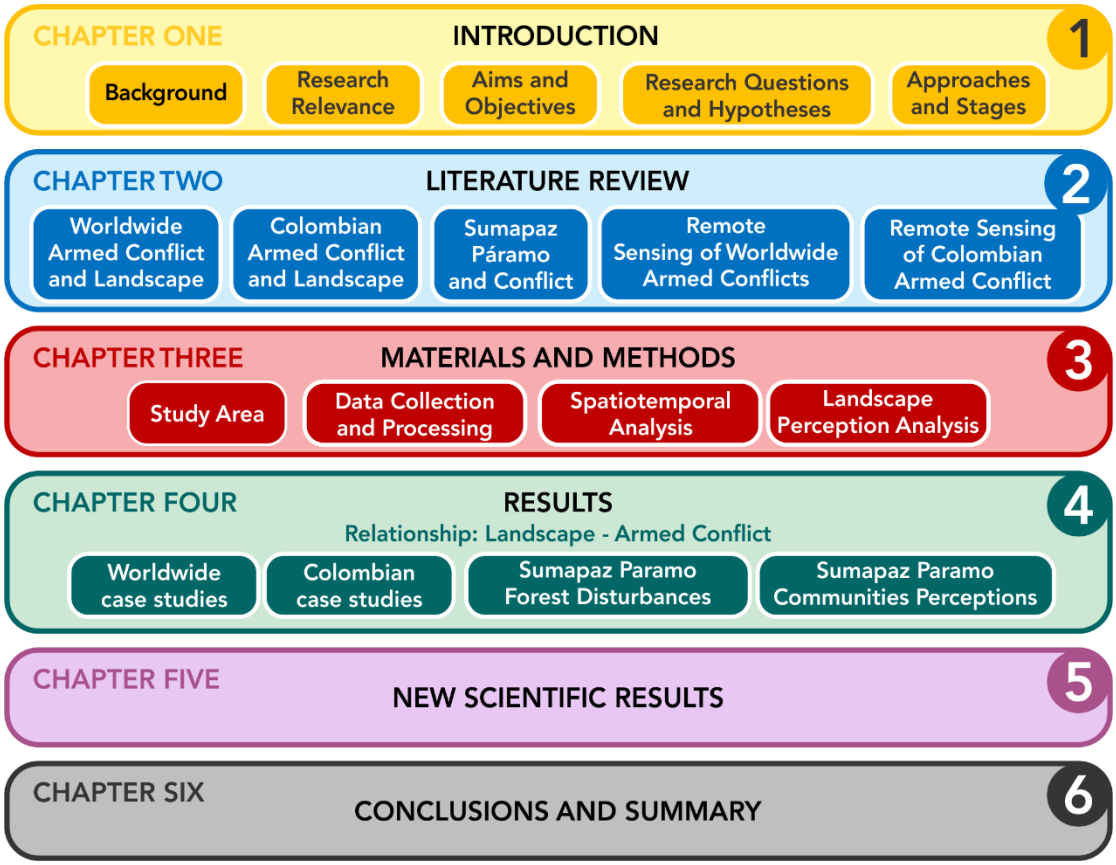
The Sumapaz Paramo is one of the largest paramo in the world, and encompasses alpine tundra ecosystems in the high Andes of Colombia. It is crucial for the nation's environment and socioeconomics, and serves as a strategic military corridor. The Sumapaz Paramo supports ecosystem services for over 15 million people, particularly in Bogotá and nearby regions. Its primary service is the water supply, facilitated by the soil's water retention and regulation capacity. Additionally, it provides food and wood from small trees, shrubs, and frailejones (endemic subshrubs), which benefit local communities. The paramo also contributes to carbon storage, offers significant aesthetic, recreational, and spiritual value, and has been important since pre-Columbian times.

This study aims to investigate the relationship between armed conflict processes, particularly victim numbers and conflict events, and forest disturbances detected via remote sensing. Additionally, I analyzed local communities' perceptions of the conflict-landscape relationship in the Sumapaz Paramo Region. The objectives are to (1) quantify forest disturbance patterns using publicly available remote sensing data; (2) compare forest disturbance rates with victim numbers and conflict events across three periods: armed conflict, negotiations, and post-peace agreement; (3) assess the

influence of the military road network on vegetation disturbance relative to proximity; and (4) measure and analyze local community perceptions through on-site semi-structured surveys.

I provide a critical example of how the intensity of armed conflict over time produces varying impacts on the landscape, highlighting future opportunities at the local, regional, and national levels, applicable to studying other conflict-affected regions.

This study examined the relationship between landscape and armed conflict using three scales. (1) **Worldwide (global case studies)**: The impact of armed conflicts on the environment from 1994 to the present. (2) **National (Colombian case studies)**: Analysis of Colombian armed conflict and its environmental consequences. (3) **Local-regional (Sumapaz Paramo Region case study)**: examination of forest disturbances in the Sumapaz Paramo Region and their connection to Colombian armed conflict over the past 20 years.



Structure of PhD research

2. RESEARCH QUESTIONS AND OBJECTIVES

First Stage. Worldwide case studies.

Research Question 1. ***How has the relationship between armed conflict processes and landscape changes been approached and assessed worldwide?***

Aim 1. Review and assess how the relationship between armed conflicts/warfare and the landscape has been analyzed and studied worldwide.

- Review how, where, and when the link between armed conflict/warfare and landscape has been approached scientifically.
- Identify and link the assessment approaches and methods used to analyze the relationship between armed conflict and the landscape.
- Identify and link armed conflict causes with consequences in the landscape.

Second Stage. Colombian case studies.

Research Question 2. ***How has the relationship between Colombian armed conflict processes and forest disturbances been approached and assessed?***

Aim 2. Review and assess historically how has been analyzed and studied the consequences of the Colombian armed conflict in the landscape to understand, describe, and relate the links between the methods and results.

- Identify when, where, and how (department and ecoregion) the environmental and forest disturbances caused by Colombian armed conflict have occurred.
- Identify and link Colombian armed conflict-derived causes with landscape changes (consequences) and the methods used.

Third Stage. Sumapaz Paramo Region case study; Forest disturbances.

General Research Question 3. ***What has been the relationship between forest disturbances (consequences) and armed conflict processes (causes) during the high-intensity conflict period, negotiation, and post-agreement periods in the Sumapaz Paramo Region?***

Aim 3. Identify and relate forest disturbances with armed conflict causes in the Sumapaz Paramo Region during armed conflict periods.

- Identify, analyze, compare, and assess forest disturbances during armed conflict periods in the Sumapaz Paramo Region (study area) and the Forest-Paramo Transition Zone (buffer area).
- Identify, analyze, compare, and assess the impact levels among various spatial units within the protected and non-protected areas of the Sumapaz Paramo

Region and Sumapaz National Park based on vegetation disturbances during armed conflict periods.

- Determine the landscape impact levels among armed conflict intensity units (causes) and their relationship with vegetation disturbances (consequences) during armed conflict periods in the SPR.
- Identify landscape impact levels in terms of vegetation disturbances (consequences) concerning the proximity to the military road network and military infrastructure (causes) during armed conflict periods in the SPR.

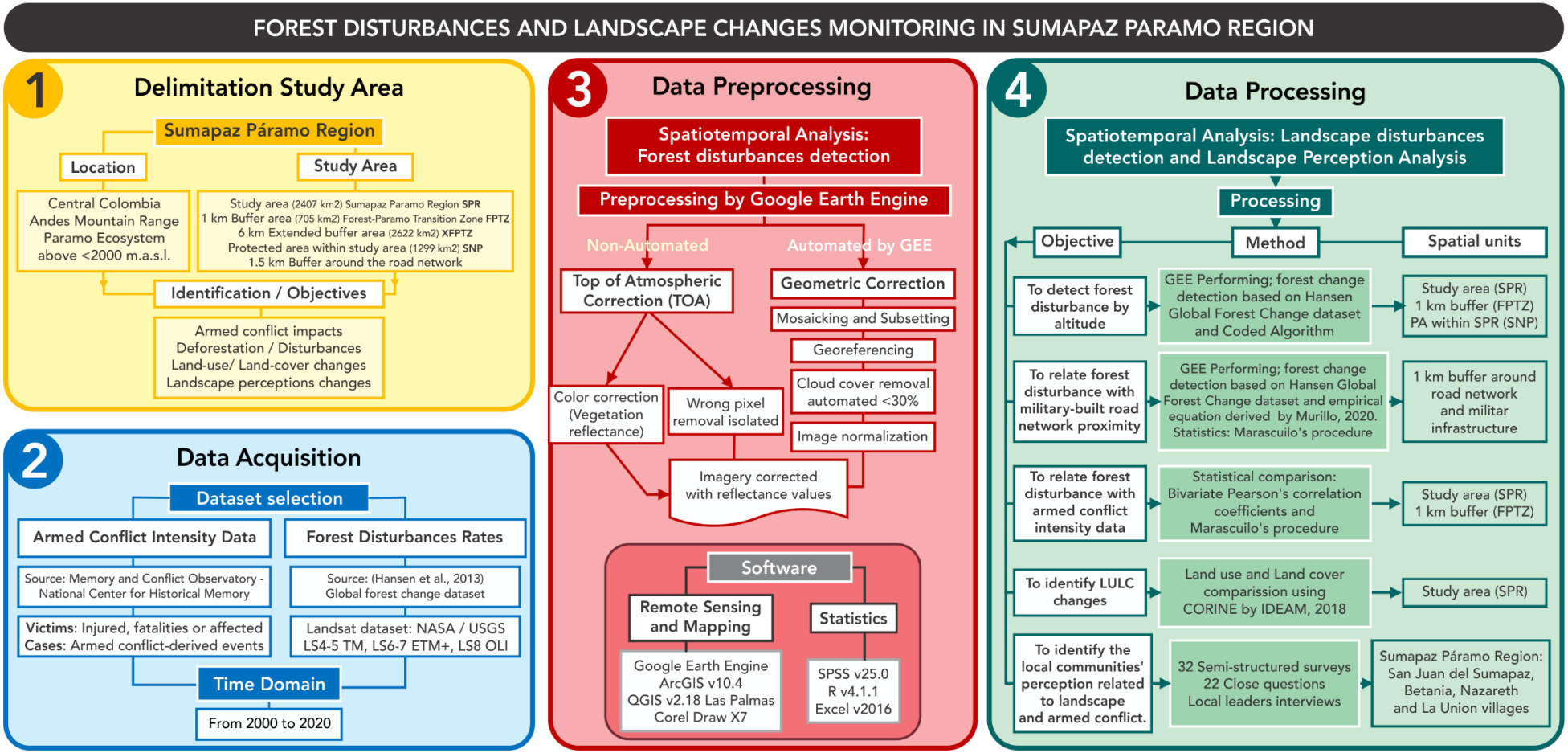
Fourth Stage. Sumapaz Paramo Region case study; Local communities' armed conflict-landscape perception.

Research Question 4. ***What has been the perception of local communities about the relationship between armed conflict and the landscape of the Sumapaz Paramo Region?***

Aim 4. Collect, identify, and assess the perception of local communities about the landscape in the Sumapaz Paramo Region and the influence of armed conflict processes on it.

- Identify and analyze the local community's perceptions of the paramo's landscape values, conservation status, and their relationship to the armed conflict processes in the Sumapaz Paramo.
- Identify and analyze the local communities' perceptions of the relationship between forest disturbances and belligerent forces and the causes derived from the armed conflict processes in the SPR.

3. MATERIALS AND METHODS



General Methodology

4. NEW SCIENTIFIC RESULTS

First Stage. Worldwide case studies.

THESIS 1. Identification of the relationship between armed conflict's consequences assessment, and geographical location.

I have found a direct link between assessing the consequences of armed conflicts and the density of forest cover. In tropical biomes affected by war, where forest density is higher, more significant environmental studies have been conducted on deforestation, land use, and land cover, regardless of the intensity or type of armed conflict in the region. Post-conflict periods have led to an increase in the development of these studies.

I identified that the majority of scientific studies on armed conflicts have focused on medium-scale assessments (covering landscape-scale areas of 1000-9999 km2 and regional-scale areas of 10000-99999 km2. I determined that armed conflict data variables were used in only one-third of the case studies Independent variables used, land-use data have been widely employed, followed by demographic variables.

a) I identified that the post-peace agreement periods prompted the development of studies, which revealed a substantial increase in the number of studies conducted from 2008 to 2019. During the period from 1998 to 2007, the average publication rate was 0.8 articles per year, but this rate increased to 4.92 publications per year from 2008 to 2021.
b) I found that most case studies were conducted in countries near the equator. Countries, such as Colombia, South Sudan, and Sudan, accounted for more than one-third (38.3%) of the studies.
c) From the 77 case studies analyzed, 37 armed conflicts were assessed. Within this group, 22.6% of the cases involved interstate conflicts between two or more states, while 39.3% evaluated internationalized internal armed conflicts. The remaining 37% of the studies analyzed internal armed conflicts between the government of a state and internal opposition groups. I observed that 33.7% of the researchers investigated minor armed conflicts, 30.1% focused on intermediate-intensity conflicts, and 36.2% explored high-intensity conflicts.
d) The data showed that 35% of the researchers analyzed satellite imagery of pre-conflict periods, 87% examined conflict period imagery, and 58.4% assessed post-conflict period imagery.
e) I observed a strong relationship between the consequences of armed conflict and forest cover density. Of the 18 existing biomes worldwide, armed conflict

consequences were identified in 14 (78%). An analysis of 170 biome cases revealed that armed conflicts were more prevalent in torrid zones, with a focus on six tropical biomes (60.5%). Most of these case studies were located near the equatorial line, where there were high biodiversity hotspots and increased forest cover density, including 41.55% in Tropical Rainforest, 31% in Grass Savanna, 27% in Monsoon Forest/Dry Forest, 26% in Montane Forest, and 23% in Semiarid Desert, with Tree Savannah and Grassland accounting for 22%.

f) I found that Landscape-scale studies were the most recurrent, accounting for 36.3% of the total, followed by regional-scale studies at 24.7%, national/global-scale studies at 23.4%, and local-scale studies at 18.2%.
g) Moderate-resolution sensors such as Landsat 4-5 TM, Landsat 7 ETM+, and Landsat 8 OLI were the most commonly used, particularly for studies at medium to large scales such as Landscape, Regional, and National sample sizes. I identified that to analyze small areas at local and landscape scales, fine (1-10m), and very fine resolution (≤1m) satellite imagery sensors such as Quick Bird II, Google Earth VHR, SPOT-5, World View II, and IKONOS are more often used.
h) I found that the majority of studies (80.5%) used multivariate data for their research, with only 62% of them having a unidirectional relationship with independent variable data. However, Armed Conflict data variables were used in only 27% of the studies, while socioeconomic variables and infrastructure were used in approximately 15% of the studies.

THESIS 2. Identification and linking of causes derived from armed conflict with consequences in the landscape.

I identified that in tropical biomes, such as rainforests, monsoon forests, montane forests, and savannas, indirect causes of armed conflict, such as forced and non-forced migration, agriculture, and illegal crops, primarily drive forest disturbances such as deforestation and land-use alterations. These aspects have been extensively studied, whereas short-term impacts, such as military confrontations and bombings, are less explored. Conversely, within the temperate biomes with sparse forest cover, such as broadleaf forests, Mediterranean vegetation, dry steppe, and semiarid desert, experience forest disturbances mainly due to direct causes such as bombings, military confrontations, and landmines. These biomes observe land use changes, agricultural abandonment, craters, and water pollution, with long-term indirect effects such as forced migration, logging, agriculture, and fires being minor. I determined that Landsat satellite imagery sensors were deemed most suitable for assessing the impact of armed conflicts in dense forest areas, such as tropical rainforests, monsoon forests,

and montane forests, because of their effectiveness in detecting changes in forest cover through contrasting bands that capture chlorophyll variances and reflectance.

a) I classified armed conflict-derived consequences in the landscape into two groups: Direct and Indirect. Direct consequences are activities that are physically linked to the direct action of military confrontation such as bombings, direct military confrontations, and landmines. In contrast, the indirect consequences are non-military activities triggered by armed conflict processes such as forced migration, non-forced migration, mining, illegal crops, agriculture, cattle ranching, logging, and fires.
b) I determined that Indirect causes, which accounted for 73.2% of the case studies, were the most common cause. These included forced migration (36.3%), agriculture (26%), illegal crops (13%), nonforced migration (13%), cattle ranching (11.6%), and logging (11.6%).
c) Direct causes, which represented 26.8% of the total case studies, were less common causes. However, the most common direct causes were military confrontation, accounting for 27% of the total, and bombing, accounting for 21%.
d) I identified and categorized the most prevalent and significant consequences of armed conflict on landscapes; they are land-use changes (63.3%), deforestation (61%), abandonment of agricultural lands (15.6%), and forestation (13%).
e) I found that military confrontations have a direct influence with changes in land use (18%) and deforestation (17%). Bombings were found to have a direct impact on changes in land use (13%), the abandonment of land for agriculture (8%), and reforestation (6.5%). Among the causes of changes in land use and deforestation, forced migration had the most significant impact (26%), and by agriculture (19.5%).
f) Research on the impact of bombings as a cause of forest disturbances (21%) was concentrated in countries located primarily in temperate zones. Most studies on military confrontation and/or military infrastructure as a cause of environmental impacts (27.3%) were conducted in Colombia (7) and spread across diverse regions, such as the Middle East and Sub-Saharan Africa.
g) The most commonly studied indirect cause was forced migration (36.3%), which is prevalent in African countries, Colombia, the Middle East, and Southeast Asia.
h) I have determined that for analyzing high-density forest biomes like tropical rainforests, monsoon forests, and montane forests, moderate-resolution sensors such as Landsat 7 ETM+ and Landsat 4-5 TM are most accurate and suitable, used in 66.2% of studies. Conversely, studies on medium- or low-density forest biomes, such as tree savannas, grass savannas, and semiarid deserts, predominantly used very fine

sensors (22%), mainly Quickbird II, IKONOS, and World View II. Aerial photographs were chiefly used for temperate broadleaf forest analyses.

Second Stage. Colombian case studies.

THESIS 3. Identification of the relationship between assessment methods, causes, and consequences generated by Colombian armed conflict.

The 2016 peace agreement between the Colombian government and the FARC Guerrilla spurred increased research into the environmental consequences of armed conflict and forest disturbances. I identified that RS studies primarily focus on national-scale assessments and the general environmental impacts of armed conflict, with study areas chosen based on forest cover density rather than military activity. Few studies have explored conflict-derived causes and consequences locally or regionally. In Colombia, indirect conflict-related causes, such as agriculture, illegal crops, cattle ranching, and non-forced migration, drive the most studied forest disturbances, while short-term consequences of direct conflict activities, such as military confrontations or bombings, though less studied, significantly impact the landscape. I determined that the most significant and recurrent environmental changes identified were deforestation and LULCC, which are closely linked to illegal activities resulting from the conflict.

a) I determined that the 2016 peace agreement had a significant and positive impact on the number of RS studies. From 2001 to 2012, during the intense conflict period, the publication rate averaged 0.16 studies annually. During the 2013-2016 negotiation period, it rose to 1.6, and during the post-conflict period (2016-2021), it reached two studies per year. The end of the Colombian armed conflict has increased interest and investment in understanding the environmental impact of warfare.
b) Indirect causes have been the most studied triggers of environmental impacts. Non-regulated agriculture was the most studied cause (47%), followed by coca crops (42%). In addition, illegal cattle ranching (37%) and forced migration (21%) have been extensively studied as generators of forest disturbances. Similarly, non-forced migration (16%), illegal mining (16%), illegal logging (16%), and fires (11%) have been studied less.
c) I found that Military confrontation (37%) was the most studied direct cause of environmental degradation. Conversely, other events directly related to the Colombian armed conflict, such as air and ground bombings and the location of anti-personnel mines, have scarcely been studied.
d) I determined that Colombian armed conflict significantly increased environmental deterioration and forest cover (deforestation) in 95% of cases, and land cover and

land-use changes in 42% of cases. However, some exceptions are noticeable, where the conflict has unintentionally promoted environmental conservation in the short term, such as forest preservation in 31% of the studies.

e) I found that 42% of the studies were related to the FARC guerrilla, paramilitary groups such as AUC in 31% of the studies, and the ELN guerrilla in 5%. More than 50% of the case studies did not explicitly mention which armed group generated environmental changes, and none of the studies mentioned the National Army as a driver.

f) I found that the Colombian armed conflict have been studied mainly through national-scale case analysis and, to a lesser extent, medium-scale case studies. I determined that the smallest scales, Local and Landscape study areas, were used in only one study each (5%). The regional scale was used in 21% of the studies and the national scale was the most employed in 68% of the studies.

g) I identified the existence of warfare repercussions in all 13 existing types of ecoregions in Colombia. I analyzed 64 different cases of biomes and found that the presence of armed conflicts was higher in high biodiversity spots and high forest cover density, such as Northern Andean (47%), Mag-Urabá Moist (42%), Cordillera Oriental (42%), Caquetá Moist (37%), Northwestern Andean (26%), and Apure-Villavicencio (21%).

h) I found that most studied departments were not necessarily the largest or most populated, except for Antioquia. Northern Antioquia and Caquetá foothills were studied in 42% of the studies, followed by Putumayo, with a recurrence in 37%. Guaviare and Meta were mentioned in 31.5% of studies. Additionally, 26% of the studies were conducted in Cordoba and Nariño. Comes after Amazonas, Guainía, Huila, Santander, and Vaupes were examined in 21% of studies.

Third Stage. Sumapaz Paramo Region case study. Forest disturbances.

THESIS 4. Detection of forest disturbances in the Sumapaz Paramo Region's ecosystems during periods of armed conflict.

Through remote sensing and statistical analysis, I determined that vegetation disturbance was linked to armed conflict periods. A noticeable pattern was observed, revealing a direct connection between higher forest disturbance during high-intensity conflict periods (2001-2003 and 2006-2010) compared to a decrease in deforestation rates during peace talks (2012-2016) and the post-agreement period (2016-2020). Additionally, it was demonstrated that ecosystems with high forest density, such as the high Andean forest or the sub-paramo, suffered more consequences from armed conflict than ecosystems at higher altitudes and low forest density, such as the paramo and the super paramo.

a) I detected the vegetation disturbance in the SPR from 2001–to 2020. I determined that 239,934.172±38.29 ha of the vegetation/land cover remained stable, and 765.82±38.29 ha (95% confidence interval) of forest were disturbed, corresponding to 0.318% of the study area of Sumapaz Paramo. During the high-intensity conflict period (2001–2012) I detected 705.66 ha (0.29% of the study area) of vegetation disturbance. During negotiations (2013–2016), 21.29 ha (0.0089% of the study area), and during the post-peace agreement (2017–2020) 38.66 ha (0.016% of the study area).
b) I detected the vegetation disturbance in the Buffer Area – Forest-Paramo Transition Zone (FPTZ) throughout the entire study period from 2001–to 2020. I determined that 69,970.68±30.66 ha of the vegetation/land cover remained stable, and 613.32±30.66 ha (95% confidence interval) of forest were disturbed, corresponding to 0.87% of the study area of Sumapaz Paramo. During the high-intensity conflict period (2001–2012), I detected 507.51 ha (0.72% of the study area) of vegetation disturbance, and during negotiations and post-peace agreement periods (2013–2020), 105.81 ha (0.15% of the study area).
c) I identified that the forest disturbance detection in the Extended Study Area (XSPR), including the 1 km outer buffer throughout the entire study period of 2001–2020, was 309,904±68.95 ha of the vegetation cover remained stable and 1379.15±68.95 ha (95% confidence interval) of forest were disturbed, corresponding to 0.44% of the study area. During wartime (2001–2012), I detected 1213.18 ha (0.39% of the study area) of vegetation disturbance, during negotiations (2013–2016) 49.81 ha (0.016%), and during the post-peace agreement (2017–2020) 116.15 ha (0.037%).
d) I found that vegetation disturbance was more evident in 2001, 2007, 2009 and 2012.
e) The pattern shows that since 2015, disturbances in the landscape have been higher in FPTZ than in SPR, not only percentage-wise but also in terms of total hectares, with even more significant percentages in 2016 (ha 0 0.27%–ha 1 0.73%) and 2020 (ha 0 0.25%–ha 1 0.75%).
f) Landsat disturbances were primarily concentrated on the periphery of the paramo, encompassing montane forest, subparamo, and paramo ecosystems, particularly in lower altitude areas where they transition into high-Andean, low-Andean, and montane forests between 2100 and 3100 m a.s.l. Significantly higher vegetation disturbance was detected within the 1 km outer buffer zone (forested areas and valleys below 2900 m; these valleys exhibit denser vegetation cover) compared to the study area above 2900 m, where the forest density was lower.
g) I detected that although the study area (SPR) was 3.4 times larger than the buffer area (FPTZ), the distribution of disturbances was significantly higher in the buffer

area during the conflict period (2001–2005, 2007, 2008, 2010–2012), except in 2006 when there was no significant difference, and in 2009, when the difference was slightly significant. Similarly, disturbances were significantly higher in the buffer area during the post-agreement period (2017-2020).

THESIS 5. Detection and comparison of forest disturbances in protected (Sumapaz National Park) and non-protected areas within the Sumapaz Paramo Region during armed conflict periods.

I detected that SNP experienced fewer disturbances than non-protected areas, with significantly lower vegetation disturbance in high-altitude areas (<2900 m.a.s.l.). High Andean forests and sub-paramo were more affected than paramo and super paramo because of higher forest density. However, disturbances in the fragile SNP landscape have substantial environmental impacts and slower recovery. The Remote sensing and statistical analysis revealed a direct correlation between armed conflict intensity and forest disturbances in the Sumapaz Paramo Region protected (SNP) and non-protected (SPR-SNP) areas. Heightened disturbances occurred during intense conflict periods (2001-2003 and 2006-2010), while near-zero deforestation rates were observed during peace talks (2012-2016) and post-agreement (2016-2020).

a) The variation in impact levels between protected and non-protected areas is due to several factors, including altitude, forest density, strategic military location, accessibility, and civilian population. The higher altitudes within the protected area had lower forest density and more exposed rocky soil, reducing disturbances compared to the lower altitude and higher forested non-protected areas. The remote, steep, and inaccessible areas of the national park led guerrillas to prefer lower-altitude areas with greater forest cover for hiding, resulting in most confrontations and bombings occurring outside the protected area.
b) The limited accessibility and lower population within the park limits contributed to fewer disturbances, while the management of national park rangers and peasant associations maintained low disturbances within the paramo compared to non-protected areas, with less environmental control and greater influence of armed actors.
c) I detected vegetation disturbance in the Sumapaz National Park (SNP) within the SPR from 2001 to 2020. I determined that 129,694±9.10 ha of the vegetation/land cover remained stable, and 182.05±9.10 ha (95% confidence interval) of forest were disturbed, corresponding to 0.14% of the national park area within the study area. During the high-intensity conflict period (2001–2012), I detected 178.98 ha (0.14%

of the study area) of vegetation disturbance, and during negotiations and post-peace agreement periods (2013–2020), 3.07 ha (0.002% of the study area).

d) I detected vegetation disturbance in the area of the SPR, excluding the area under the Sumapaz National Park (SNP) limits, from 2001 to 2020. I determined that 110,824±29.19 ha of the vegetation/land cover remained stable, and 583.77±29.19 ha (95% confidence interval) of forest were disturbed, corresponding to 0.53% of the study area excluding SNP. During the high-intensity conflict period (2001–2012), I detected 526.68 ha (0.47% of the study area) of vegetation disturbance, and during negotiations and post-peace agreement periods (2013–2020), 57.09 ha (0.05% of the study area).
e) The area outside SNP had significantly higher disturbance rates during the three periods. During the years of the highest intensity of the conflict (2001-2012), the difference was an average ratio of 4:1, but it was higher in 2006 and 2009, and lower in 2011. I identified significantly lower disturbance rates within the protected area compared to the area outside the SNP, not only percentage-wise but also in terms of total hectares.
f) The spatial distribution of Landsat disturbances within the National Park is concentrated on the northern and eastern periphery of the protected area and some inner valleys, that is, mostly in the lower altitude areas of the paramo where they border the transition zone with the high-Andean forest, low-Andean forest, and montane forest located between altitudes of 2100 and 3100 m.a.s.l.
g) The distribution of disturbances was significantly higher in the study area (excluding the SNP) during the conflict period (2001–2010 and 2012) than within the SNP study area, except in 2011, where the difference was slightly significant.

THESIS 6. The link between armed conflict intensity rates (causes) and forest disturbances (consequences) during armed conflict periods in the Sumapaz Paramo Region.

I observed a significant unidirectional relationship between vegetation disturbance rates and armed conflict intensity rates regardless of the conflict period. I identified that the area was highly sensitive to changes in conflict intensity, as evidenced by the flow between the number of cases, victims, and disturbed hectares. I identified a clear and direct relationship between the two variables, with higher levels of forest disturbance observed during more violent periods (2001-2003 and 2006-2010) and a subsequent decrease in deforestation rates during peace talks (2012-2016) and the post-agreement period (2016-2020). The relationship between forest disturbance and violence rates has gradually declined over time.

a) During the high-intensity conflict period (2001-2003), deforestation rates experienced a rapid decrease from high to medium intensity in the SPR and FPTZ, whereas the conflict intensity rates increased during the same period. The first two years (2001 and 2002) showed high rates of vegetation disturbance and violence. The most violent year was 2003, which coincided when the disturbance rates presented a large drop; in 2004 and 2005, the vegetation disturbance remained relatively steady and lower than in the first years, but the conflict intensity rates decreased significantly. Since 2005, the number of conflict cases and victims has considerably decreased. However, the deforestation rates have increased significantly since 2007. Around 2009, there was an increase in violence, accompanied by an increase in forest disturbance.
b) During the negotiation period (2013–2016), the rates of conflict intensity and disturbance remained very low, almost at zero levels. However, since the peace agreement was signed in 2016, the violence rates remained very low, but the disturbance rates started to increase slowly.
c) In general, during the entire study period (2001-2020) Pearson's correlation coefficient was positive, linking vegetation disturbance rates in the study areas with conflict intensity rates. Pearson's correlation coefficient (r) was used to measure the linear unidirectional relationships.
d) Unidirectional relationships were visible during the war and post-agreement periods; however, they were not significant during the negotiation period.
e) I found a unidirectional relationship between the number of victims and disturbances in the study area ($R2 = 0.61$; $p < 0.001$). Regarding the number of armed conflict events and forest disturbances, $R2 = 0.54$, $p < 0.001$.
f) Armed conflict intensity and forest disturbance pathways showed a positive relationship between forest disturbances and ($\log_e$) the number of victims and forest disturbances and ($\log_e$) conflict events with a positive relationship.

THESIS 7. The link between forest disturbances (consequences) and military road networks during armed conflict periods in the Sumapaz Paramo Region.

The direct influence of armed actors in the area is evident through the construction of military roads such as the* Troncal Bolivariana *by both the army and the FARC, as well as military infrastructure such as military bases, trenches, outposts, camps, and even the reported use of frailejones and other types of vegetation as construction material and fuel.

I identified a significant unidirectional relationship between vegetation disturbance rates near the military-derived road network and conflict intensity rates. The area is sensitive to changes in conflict intensity, and the proximity to road infrastructure

shows a positive association with deforestation. Higher levels of forest disturbance were observed during high-intensity conflict periods (2001, 2002, and 2010) and a substantial decrease in deforestation during less violent years in the negotiation (2012-2016) and post-agreement periods (2016-2020). However, anomalies were detected in 2007, with high disturbance and low conflict intensity rates, and in 2003, with low disturbance and conflict intensity rates. Deforestation directly linked to road construction is relatively low, accounting for 7% to 18% (varying by year) of the total disturbed area in SPR. However, proximity to roads significantly attracts deforestation, especially within the 0.5-1.5 km range, with the most significant impact within the first 500 meters. This indicates that military infrastructure and roads exert pressure on the region's vegetation by providing access to previously untouched areas, notably in the southern SPR, where the guerrilla-built **Troncal Bolivariana** ***facilitated access to formerly inaccessible regions.***

a) I identified two large groups of road networks: the network of civil roads built by the national government, the local government, and/or the community that mainly connects the region with Bogotá to the north. The military road network was built by the FARC guerrilla during the '90s and the early 2000s, beginning in the town of La Unión and heading south, seeking to connect the paramo with the Duda River Canyon and then to the Amazonian foothills.
b) I found that the years with the highest intensity of conflict (2001, 2002, 2003, and 2004) had the highest rate of disturbance near highways, as did 2007, the year in which there was a peak in conflict intensity again. I found that at least 50% of the total disturbance occurred in the first 500m near the road, whereas between 500 and 1000 m, only an average of 20% of the total disturbance occurred, and the remaining 30% occurred between 1000 and 1500 m.
c) I detected that the disturbance in the vicinity of the roads built by the guerrillas was less in its totality concerning civilian highways, which is not the case concerning the proportion since civilian highways are four times more extensive in kilometers compared to roads of military origin.

Fourth Stage. Sumapaz Paramo Region case study. Local communities' perceptions.

THESIS 8. The local community's perception of Sumapaz Paramo landscape during and after the armed conflict.

Based on interviews and surveys of the local community, I determined that during the high-intensity conflict period, there were nearly twice as many landscape impacts as in the post-peace agreement period. According to respondents, these changes were mainly due to the direct consequences of armed conflict, such as military

confrontations, bombings, and construction of military infrastructure. Over half of the respondents also cited indirect causes such as forced migration, antipersonnel mines, and human-origin fires. Deforestation and a decrease in water bodies were the most impactful consequences in the Sumapaz region during both the intense violence and peace periods. The local population predominantly perceives belligerent forces, including the National Army and FARC-Guerrilla, as the main negative influences on the environment during both the conflict and post-agreement periods. According to the respondents, the local communities, peasant unions, and the National Parks' Board were self-perceived as primarily responsible for environmental conservation and restoration. Additionally, local authorities have not been perceived as contributing significantly to landscape conservation, neglecting Paramo for decades. However, the population has recently prioritized Paramo conservation for its survival and well-being, generally holding a positive perception of its preservation.

a) Based on the respondent's perceptions the predominant armed conflict causes that affected the landscape during the conflict period were military confrontations (68.8%), bombing (62.5%), and military infrastructure (62.5%). Other significant factors included manmade fires (56.2%), forced migration (53.1%), agriculture (53.1%), and land mining (50%). The most cited causes in the post-agreement period were cattle ranching (56.2%), military infrastructure (53.1%) and agriculture (50%), manmade fires (37.5%); logging (34.4%); road construction (34.4%); litter, debris, liquid pouring (25%); and forced migration (18.8%).
b) Based on the respondents' perceptions, the primary armed conflict consequences identified during the conflict period were deforestation (75%), pollution, and a reduction in water bodies (50%). Additionally, there was an expansion of farmland (46.9%), changes in land use/cover (40.6%), abandonment of agricultural land (40.6%), and increased land for livestock (40.6%). The most common issues in the post-agreement period were pollution and reduced water bodies (50%), followed by deforestation (46.9%), land use/cover changes (46.9%), and farmland expansion (46.9%). Notably, there was an increase in references of consequences such as land for livestock (34.4%), desertification/land degradation (31.2%), and forestation/vegetation growth (28.1%).
c) There were 190 positive responses for wartime causes compared to 115 for peacetime causes. The most impactful causes in the Sumapaz region were linked to military infrastructure (34.4%) and direct military confrontations (28.1%). The consequences that most affected the people in the Sumapaz region were mostly related to deforestation (43.8%) and a decrease in water bodies (40.6%).

d) The National Army was identified by 81.25% of respondents as the primary driver of forest disturbances. Additionally, 62.5% of respondents attributed significant negative impacts to the FARC guerrilla. Paramilitary groups were held responsible for 15.6% of respondents. Among the non-military actors, 50% blamed national/local authorities, while 31.5% pointed to large landowners as key drivers of change. The NNPB and Local Communities saw themselves as minimally responsible for landscape change drivers. In the post-agreement period, 53% of respondents still viewed the National Army as the main driver of negative changes.
e) Half of the respondents perceived that the environmental paramo's conservation status remained unchanged or showed minor changes between the conflict and post agreement periods. Additionally, 28% thought the environmental status improved after the 2016 peace agreement, while 13% felt it was better preserved during the 2000-2016 conflict period. Furthermore, 44% rated the current ecosystem status as "good," 19%, as "very good," and 25% considered the paramo to be in "acceptable" condition.
f) Seventy-five percent of the local respondents perceived the landscape as a victim of Colombian armed conflict. Additionally, 54% recognized the paramo as a military, and 56% identified it as the warfare's scenario. Paradoxically, 25% of the respondents considered that the ecosystem benefited from the conflict, aiding its conservation.

5. CONCLUSIONS AND CONSIDERATIONS

This study provides the first analysis of the relationship between forest disturbances and the intensity of armed conflict in the paramo of Sumapaz. A unidirectional relationship exists between the number of victims, conflict events, and forest disturbance dynamics. Disturbances expand broadly during intense armed conflict characterized by infrastructure military development and limited environmental regulation, which occurred in the Republic of Congo and Ethiopia. There is an elevation shift in disturbance detection: during the conflict, disturbances reached 4000m; after negotiations, disturbances were not found higher than 3500m. While these documented results seem beneficial for the Sumapaz area, after 2018, forest disturbances — while small, showed a gradual increase. This study highlights the legacy of armed conflict, the fragility of the paramo during times of war and the need to comprehensively address the region's socioeconomic and environmental challenges in the peace era.

Remote sensing of vegetation disturbance rates, compared with local perceptions, showed a correlation between deforestation and the state of Paramo and high Andean forests with armed conflict intensity. High vegetation disturbance during peak conflict

years matched respondents' perceptions of significant deforestation. Post-peace agreements, disturbance rates, and perceived deforestation have decreased, although not equally. Military confrontations between the government and the FARC guerrilla, alongside overall conflict intensity, significantly impacted communities and the environment, influencing deforestation and ecosystem conservation, both directly and indirectly. Conflict should be viewed as a catalyst for other causes of forest disturbances, not the primary cause. This study cannot definitively link specific conflict events (e.g., military clashes or bombings) to land cover changes due to the lack of precise spatiotemporal data. However, these events tangibly alter the landscape, making it impossible to associate directly any disturbance patch with a violent event.

Significant conflict causes, such as forced displacement, military infrastructure construction, illegal agriculture, ranching, and arson, are associated with deforestation drivers. Geospatial analysis of satellite imagery showed disturbance patches mainly in valleys, where subparamo transitions to a high Andean forest. These patches were also near civil and military roads, military infrastructure, and landslide areas, possibly because of bombings, as noted in the community leader interviews.

During high-intensity conflict periods, the relationship between armed conflict and forest disturbances was evident. The absence of government during these times led to weak governance, hindering effective deforestation control and halting paramo restoration and conservation efforts. Conversely, conservation and restoration efforts in the paramo landscape have increased during peaceful periods. Since negotiations began in 2012, forest disturbances and violence rates have decreased, which is attributed to greater government presence and collaboration with local communities on reforestation and conservation programs.

After the peace agreement signing, urbanization and population growth in Sumapaz Paramo, influenced by proximity to Bogotá, have led to socioeconomic and land cover changes, notably urban expansion near the southern area of Usme. Small-scale subsistence farmers and livestock ranchers still affect conservation efforts. Presently, illegal livestock farming, extensive crops, fires (intentional and natural), and military infrastructure significantly shape perceptions of anthropogenic disturbances in the Andean Paramo and Sumapaz forests. Local communities cite unregulated tourism, demographic expansion (including voluntary migration), illegal mining, and the potential resurgence of armed conflict among FARC dissidents, paramilitary groups, and the national government as major threats to paramo conservation.

The paramo's relatively good conservation during and after the conflict was largely due to local communities organized as peasant unions and other groups, as well as the national park board and its rangers. Any development, exploitation, preservation, or conservation plan for the paramo must involve both the local community and National Parks' board. Although the total disturbed area during the conflict and post-agreement period was low (0.44%–1379.15 ha of the total study area = 311,284 ha), especially compared to more heavily affected regions, such as the Amazon foothills, the severity of the conflict's effects lies in the difficulty of restoring disturbed hectares to their original state. The paramo's unique features, such as *frailejón* taking up to a year to grow by one centimeter, highlight that the impact of conflict is more about quality than quantity. Thus, even a small number of deforested paramo and high Andean forest hectares can significantly affect water production and alter landscape conservation perceptions because of paramo's fragility and the high effort needed for recovery.

6. LIST OF PUBLICATIONS

6.1. Journal Articles:

1. **MÉNDEZ-GARZÓN, FERNANDO ARTURO**; MURILLO-SANDOVAL, PAULO J; VALÁNSZKI, ISTVÁN. (2024). "The unidirectional relationship between forest disturbance and armed conflict in the Andean Paramo". *Trees Forests and People. Legacy of Warfare on the World's Forests,* Vol. XVII, Article 100628, 8p.
2. **MÉNDEZ GARZÓN, FERNANDO ARTURO**; VALÁNSZKI, ISTVÁN. (2022). "Landscape disturbances in the Sumapaz páramo area during and after the Colombian armed conflict". *Proceedings book of the Fábos Conference on Landscape and Greenway Planning 7. Moving Towards Health and Resilience in the Public Realm,* Vol. VII; (1), Article 5, 12p.
3. **MENDEZ GARZÓN, FERNANDO ARTURO**; VALÁNSZKI, ISTVÁN. (2020). "Environmental armed conflict assessment using satellite imagery". *Journal of Environmental Geography*, Vol. XIII; (3-4), pp. 1-14, 14p.
4. **MENDEZ GARZÓN, FERNANDO ARTURO**. (2020). "Open spaces and elements adapted to the landscape of Hortobágy National Park". *Journal of Landscape Architecture and Art*, Vol. XVII; (17), pp. 7-12, 6p.
5. **MENDEZ GARZÓN, FERNANDO A**; VALÁNSZKI, ISTVÁN. (2019). "Repercussions in the landscape of Colombian Amazonas (Caquetá and Putumayo Region) caused by deforestation and illicit crops during the internal armed conflict; a review". *Proceedings book of the Fábos Conference on Landscape and Greenway Planning. Adapting to Expanding and Contracting Cities,* Vol. VI; Article 30, 13p.
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6.2. Conference Papers:

7. **MENDEZ GARZÓN, FERNANDO ARTURO**; VALÁNSZKI, ISTVÁN. (2021). "Remote sensing multivariate analysis in areas affected by armed conflicts". *SZIEntific Meeting for Young Researchers – ITT Ifjú Tehetségek Találkozója*, 437p; pp. 149-170, 22p.
8. **FERNANDO ARTURO MENDEZ GARZON** AND ISTVÁN VALÁNSZKI. (2020). "Remote sensing tendencies in the assessment of areas damaged by armed conflicts". *Agriculture for Life, Life for Agriculture. Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering*, Vol. IX; pp. 223-234, 12p.
9. **MENDEZ, FERNANDO**; VALÁNSZKI, ISTVÁN. (2019). "Trends in the use of remote sensing methods for the analysis of areas affected by armed conflicts". *SZIENtific meeting for young researchers - Ifjú Tehetségek Találkozója ITT*, pp. 173-192, 20p.
10. VALÁNSZKI ISTVÁN, JOMBACH SÁNDOR, FILEPNÉ KOVÁCS KRISZTINA, ASMAA ABUALHAGAG AHMED, **MENDEZ GARZÓN, FERNANDO** AND BALHA GABRIELLA. (2019). "Analyzing the relationship between local identity and cultural ecosystem services using participatory mapping (Közösségi térképezés a helyi identitás és a kulturális ökoszisztéma szolgáltatások kapcsolatának értékeléséhez)". *MTA DTB Földtudományi Szakbizottság*, pp. 135-139.
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6.3. Abstracts:

12. **FERNANDO ARTURO MENDEZ GARZÓN** AND ISTVÁN, VALÁNSZKI. (2022). ts in the Sumapaz páramo area during and after the Colombian armed conflict. In: Keszthelyi, Á.B.; Jombach, S.; Valánszki, I.; Filep-Kovács, K.; Kollányi, L.; Ryan, R.L.; Ahern, J.; Eisenman, T.; Lindhult, M.S.; Fábos, J.Gy. (eds.*) Moving Towards Health and Resilience in the Public Realm, 7th Fábos Conference on Landscape and Greenway Planning: Book of Abstracts*, pp.137, 102p.
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    VIII. Magyar Tájökológiai Konferencia Összefoglalók, Kisvárda, Hungary.