

# Project report: Links between carbon, deforestation and conflict in Colombia



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# Project report: Links between carbon, deforestation and conflict in Colombia

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The project “Implementing sustainable agricultural and livestock systems for simultaneous targeting of forest conservation for climate change mitigation (REDD+) and peace-building in Colombia” aims to contribute towards the reduction of land-based GHG emissions, conserving forest, restoration of degraded landscapes and improving rural livelihoods, while stimulating peace-building in rural Colombia. This report adds to Activity 1.2 of the project by providing a data driven analysis of geographical overlaps between priority areas for peace-building and land-based climate change mitigation.

## 1 Introduction

In 2016, the Colombian Government and the Revolutionary Armed Forces of Colombia (FARC) signed a peace agreement, which includes important goals relating to sustainable rural development of conflict-affected areas. Meanwhile, the Colombian Government expressed its commitment to the Paris agreement (emission reductions), the Aichi Targets (biodiversity conservation) and the Bonn Challenge (landscape restoration). Recent research suggests the existence of associations between conflict-related variables on the one hand and biomass carbon and deforestation hot-spots on the other (Castro-Nunez et al. 2017). Thus, combined policies for peace-building and forest carbon storage promise effective synergies. Particularly, agricultural and cattle ranching activities practiced in conflict-affected areas are important drivers of GHG emissions and landscape degradation. This highlights the urgent need for developing sustainable land use systems that simultaneously contribute to land-based climate change mitigation and peace-building.

The project “Implementing sustainable agricultural and livestock systems for simultaneous targeting of forest conservation for climate change mitigation (REDD+) and peace-building in Colombia” lead by the International Center for Tropical Agriculture (CIAT), Colombia and financed through the International Climate Initiative 2018 (IKI) of the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB), Germany supports the Colombian government to develop and strengthen the synergies arising from combined policies for forest conservation and peace-building. The analysis in this report was conducted within Activity 1.2 of the project. The goal of the report is to support the prioritization process of relevant intervention areas by (a) providing an overview of the current state of carbon stored in above ground biomass (in the following AGB carbon), deforestation and three selected conflict indicators; (b) determining correlations between AGB carbon, deforestation and the conflict indicators; and (c) identifying areas and municipalities characterized by high rates of AGB carbon and deforestation and high values of the conflict indicators.

For the analysis of this report we use data on AGB carbon from IDEAM (n.d. (a)), on forest areas from IDEAM (n.d. (b), 2018), armed actions from Anden University (2018), victims of armed actions from Red Nacional de Informacion Colombia (2019), and coca cultivation areas from Observatorio de Drogas Colombia (2019). The analysis covers 1121 municipalities in Colombia. We use visualization techniques and methods of descriptive statistics. The Local Indicators of Spatial Association (LISA) analysis was carried out using the GeoDa software (University of Chicago 2018), all other computation was done

with ArcGIS (ESRI 2016) and R (R Core Team 2018).

The outline of this report is as follows. After this introductory chapter (chapter 1), the applied methods are briefly described (chapter 2). Subsequently, an overview on AGB carbon, deforestation and the three conflict indicators is given (chapter 3). In Chapter 4 the results of the correlation analysis on national and department level are presented. This is followed by a presentation of the Local Indicators of Spatial Association (LISA) analysis in chapter 5 and the conclusion in chapter 6.

## 2 Methods

For the analysis, data from IDEAM (n.d. (a)), IDEAM (n.d. (b), 2018), Anden University (2018), actions from Red Nacional de Informacion Colombia (2019), and Observatorio de Drogas Colombia (2019) is used. Methods of descriptive statistics are applied to draw links between AGB carbon, deforestation and conflict indicators, as well as to identify geographical areas of interest for the project.

### 2.1 Correlation analysis

We conduct a correlation analysis to gain insights about associations of AGB carbon respectively deforestation and conflict indicators. In correlation analysis the association between two variables is expressed in form of a correlation coefficient. The values of correlation coefficients range between -1 (perfect negative correlation) and 1 (perfect positive correlation). A correlation coefficient of 0 indicates that no correlation between the two variables exist. Correlation coefficients larger than  $\pm 0.5$  can be considered as indicators for a strong association. In addition, the significance of the correlation coefficient needs to be accessed to make sure the target significance level (p-value) is met (Mayers 2013).

Different types of correlation coefficients exist. We apply Spearman's rank correlation for an analysis on national (Table 1) and department level (Table 2). As its name suggests, Spearman's rank correlation is calculated based on a ranking of the actual values. This type of correlation analysis is suitable for non-normal distributed data containing outliers or extreme values (Gauthier 2001; Mayers 2013).

Computation of the correlation analysis was done in R (R Core Team 2018) using the "Hmisc" package (Harrell Jr et al. 2018).

### 2.2 Local Indicators of Spatial Association (LISA)

In addition to the correlation analysis, a Local Indicators of Spatial Association (LISA) analysis was conducted by calculating the bivariate Local Moran's Index (Anselin 1995; Anselin et al. 2006). Local Moran's Index was first introduced by Anselin (1995) and is now widely used in spatial data analysis. The basic idea of the analysis using the Local Moran's Index is the identification of areas (in this case municipalities), which are characterized by high values of one variable (AGB carbon or deforestation rate) and high values of another variable (armed actions, victims of armed actions or coca cultivation area) in neighbouring areas. These areas are determined through a so called Moran scatterplot (Anselin 1995).

The result of the LISA analysis is a clustering of the districts in four different classes:

1. High-High: Areas with high values of the first variable in the actual area and high values of the second variable in neighbouring areas.
2. High-Low: Areas with high values of the first variable in the actual area and low values of the second variable in neighbouring areas.
3. Low-High: Areas with low values of the first variable in the actual area and high values of the second variable in neighbouring areas.
4. Low-low: Areas with low values of the first variable in the actual area and low values of the second variable in neighbouring areas.

The High-High areas are of special interest in this study as these depict the municipalities with high AGB carbon respectively deforestation rates being located in an region with high values of the respective conflict indicator.

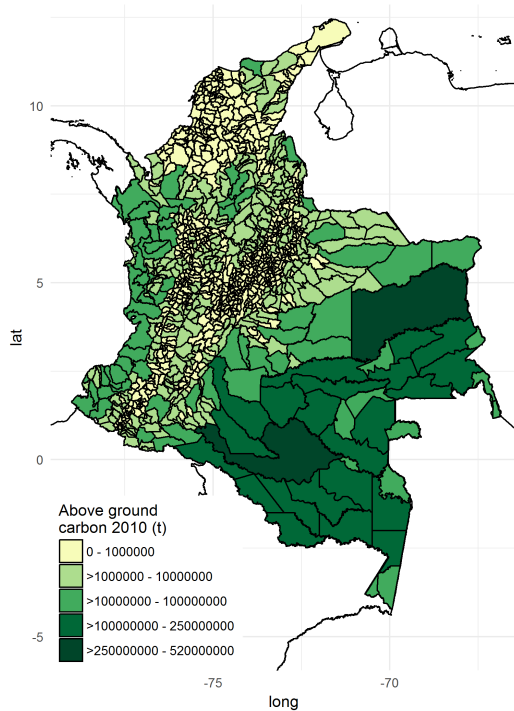
Local Indicators of Spatial Association Analysis (LISA) analysis was carried out using the GeoDa software (University of Chicago 2018), all other computation was done with ArcGIS (ESRI 2016) and R (R Core Team 2018).

## 3 Overview

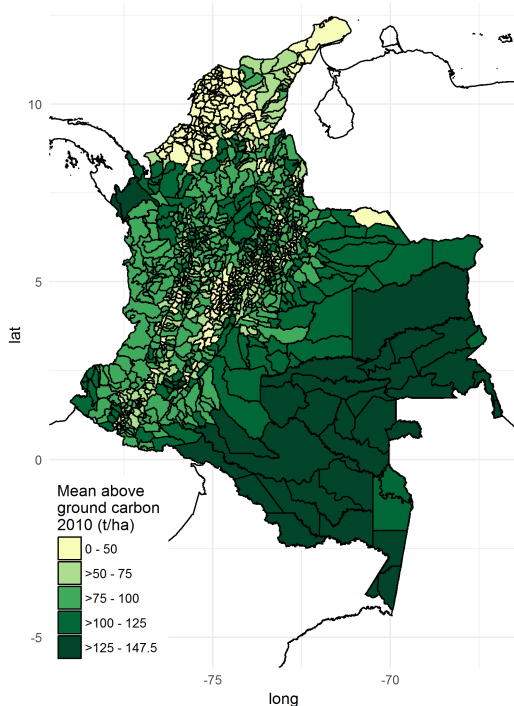
### 3.1 Carbon

Carbon stored in woody 'above-ground biomass' (AGB) for the year 2010 is derived from a raster data file provided by IDEAM (n.d. (a)). Total AGB carbon (Figure 1) and mean AGB carbon (Figure 2) was calculated on municipality level.

Highest total AGB carbon values are found in municipalities in South and South-Eastern Colombia (Figure 1). Most of these municipalities in the Amazon



**Figure 1:** Carbon in woody ‘above-ground biomass’ (AGB) in 2010 (t). Highest total AGB carbon values are found in municipalities in the Amazon basin in South and South-Eastern Colombia.



**Figure 2:** Mean carbon in woody ‘above-ground biomass’ in 2010 (t/ha). Similar to the total amount of AGB carbon, municipalities in the Amazon basin in South and South-Eastern Colombia show the highest amounts of mean AGB carbon. However, a few municipalities in the North-West on the border to Panama fall in the same category.

basin store more than 100 Million tones of AGB carbon. Contrary, municipalities in central Colombia and on the Caribbean coast depict the lowest levels of total AGB carbon. Municipalities with the highest amounts of AGB carbon in 2010 are:

1. Solano (Caqueta; 5.10 mio t)
2. Vichada (Cumaribo; 5.05 mio t)
3. Miriti-Parana (Amazonas; 2.16 mio t)
4. Mitu (Vaupes; 2.07 mio t)
5. Puerto Colombia (Guainia; 1.99 mio t)

Considering the varying sizes of the municipalities, the mean AGB carbon allows a different comparison of the municipalities. Similar to the total amount of AGB carbon, municipalities in the Amazon basin in South and South-Eastern Colombia show, with values larger than 125 tones per hectare, the highest amounts of mean AGB carbon. However, a few municipalities in the North-West on the border to Panama fall in the same category. In total, 35 municipalities store in average more than 125 tones AGB carbon per hectare.

### 3.2 Deforestation

Mean yearly deforestation rates for the time period 2005 to 2017 on municipality level are calculated based on two raster data files provided by IDEAM (n.d. (b), 2018). Results are shown in figure 3.

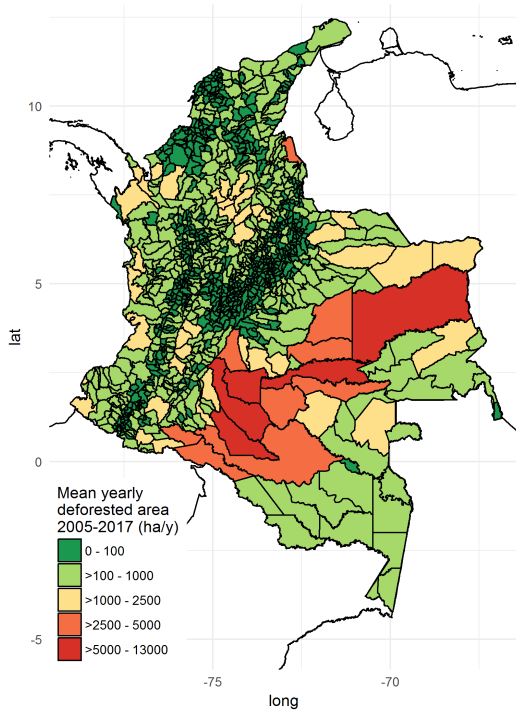
Highest mean deforestation rates for the covered time period are found in form of a band reaching from the East to the South-West. The municipalities are located in the northern part of the group of municipalities with highest average AGB carbon in the Amazon basin. The deforestation rates of these municipalities range between 2 500 and about 12 800 hectares per year. The only municipality with a yearly deforestation rate larger than 2 500 hectares outside this area is the municipality of Tibu (Norte de Santander). Municipalities with an average deforestation rate (2001-2017) larger than 2 500 hectares per year are

1. San Vicente del Caguan (Caqueta; 12 867 ha/y)
2. Cartagena del Chaira (Caqueta; 10 422 ha/y)
3. La Macarena (Meta; 9 533 ha/y)
4. Cumaribo (Vichada; 8 959 ha/y)
5. San Jose del Guaviare (Guaviare; 7 444 ha/y)
6. Solano (Caqueta; 4 902 ha/y)
7. Puerto Guzman (Putumayo; 4 077 ha/y)
8. Mampiripan (Meta; 3 937 ha/y)
9. Puerto Gaitan (Meta; 3 212 ha/y)
10. Calamar (Guaviare; 3 155 ha/y)
11. Puerto Leguizamo (Putumayo; 3 097 ha/y)
12. El Retorno (Guaviare (3 027 ha/y)
13. Uribe (Meta; 2 715 ha/y)
14. Tibu (Norte de Santander; 2 569 ha/y)

Most other municipalities experienced a yearly deforestation rate between 100 and 2 500 hectares. 688



municipalities had a yearly deforestation rate of less than 100 hectares.



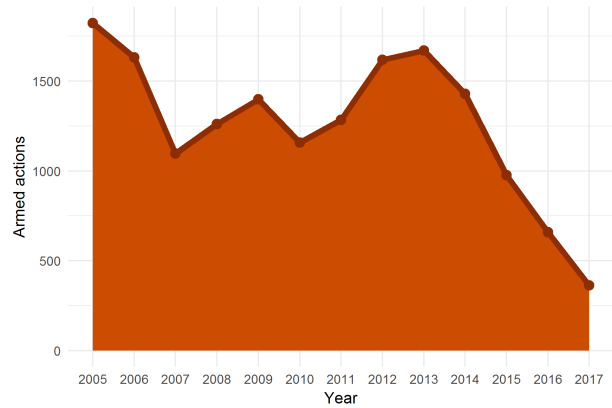
**Figure 3:** Mean yearly deforestation 2005-2017 (t/ha). Highest mean deforestation rates are found in form of a band reaching from the East to the South. Outside this area, only Tibu (Norte de Santander) has similar deforestation rates.

### 3.3 Conflict

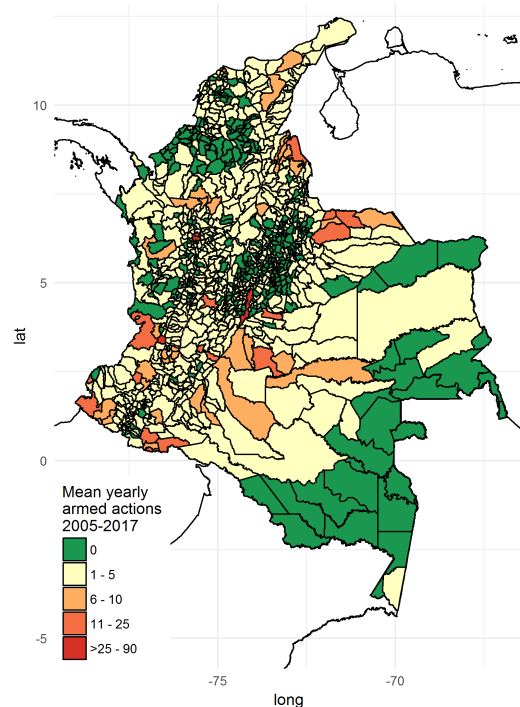
Three indicators are chosen as proxies for the conflict in Colombia. We define armed actions as the sum of assaults on people, terrorist actions, acts of piracy on land, illegal roadblocks, harassment, attacks on police facilities, attacks on aircrafts, subversive actions, and ambushes. Data on armed actions is derived from Anden University (2018) and the single variables are summed up. Data on victims of armed actions is derived from Red Nacional de Informacion Colombia (2019). Data on coca cultivation area is derived from Observatorio de Drogas Colombia (2019).

#### 3.3.1 Armed actions

The number of armed actions dropped significantly from 1823 actions in 2005 to 363 actions in 2017 (Figure 4). However, this was not a linear trend. While two local minimums are identified for the years 2007 (1097 actions) and 2010 (1158 actions), armed actions in 2013 (1670 actions) were only slightly below the 2005 level. After 2013, the number of armed actions declined dramatically.



**Figure 4:** Armed actions 2005-2017. While the number of armed actions fluctuated at high levels until 2013, it dropped significantly in the years afterwards.



**Figure 5:** Mean yearly number of armed actions 2005-2017. Bogotá, Medellín, and Cali have the highest numbers of armed actions. Overall, in 11 municipalities 15 or more armed actions were recorded on average per year.

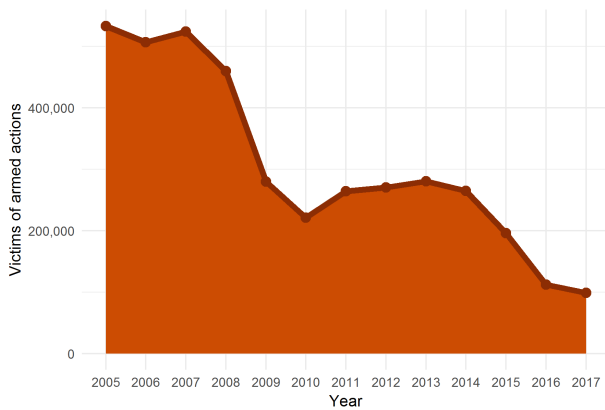
Large differences exist between municipalities, where the actions took place (Figure 5). For large parts of the country no or a relatively low number of armed actions is recorded. Bogotá, Medellín, and Cali have the highest numbers of armed actions. Municipalities with 15 or more armed actions on a yearly average in the time period 2005 to 2017 are:

1. Bogotá D.C. (Bogotá; 89 actions per year)
2. Medellín (Antioquia; 54)
3. Cali (Valle del Cauca; 32)
4. Tumaco (Nariño; 23)
5. Saravena (Aruaca; 21)

6. Neiva (Huila; 18)
7. Tame (Arauca; 18)
8. Tibu (Norte de Santander; 17)
9. Barranquilla (Atlantico; 17)
10. Arauquita (Arauca; 16)
11. Villavicencio (Meta; 15)

### 3.3.2 Victims of armed actions

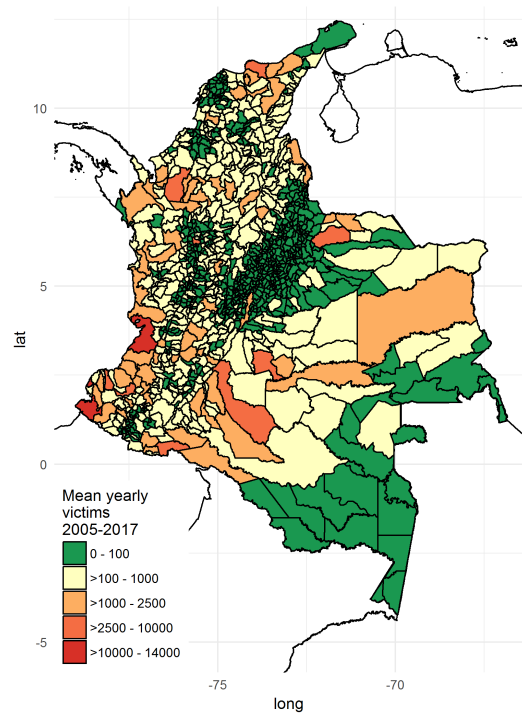
The number of victims from armed actions fell from 533 048 victims in the year 2005 to 98 829 in the year 2017 (Figure 6). While the number of victims remained at high level until 2007, it dropped by more than half between 2008 and 2010. In the time period 2011 to 2014 the number of victims remained constant around 270 000 victims per year. In the years after 2014, it again decreased significantly.



**Figure 6:** Victims of armed actions 2005-2017. The number of victims from armed actions declined dramatically in the time period 2005 to 2017. Especially, between 2008 and 2010 and 2014 to 2016 a steep drop is recorded.

Similarly to the number of armed actions, the number of victims is very high in only a few municipalities, while for many other municipalities relatively low numbers of victims are reported (Figure 7). In 645 municipalities less than 100 victims of armed actions per year are recorded for the covered years. Municipalities with the highest average number of victims for the time period 2005 to 2017 are:

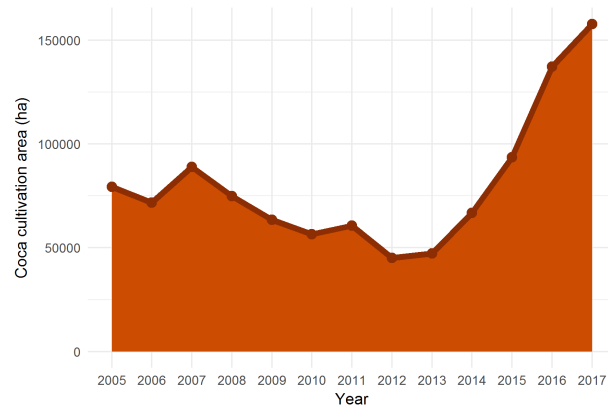
1. Buenaventura (Valle del Cauca; 13 052 victims)
2. Tumaco (Narino; 11 064)
3. Medellin (Antioquia; 6 673)
4. Santa Marta (Magdalena; 3 397)
5. San Vicente del Caguan (Caqueta; 3 056)
6. El Charco (Narino; 3 046)
7. Tame (Arauca; 3 024)
8. Tierralta (Cordoba; 2 792)
9. Vistahermosa (Meta; 2 517)
10. Puerto Asis (Putumayo; 2 502)



**Figure 7:** Mean yearly number of victims of armed actions 2005-2017. The number of victims of armed actions is very high in especially a few municipalities. Municipalities with the most victims of armed actions are Buenaventura (Valle del Cauca) and Tumaco (Narino).

### 3.3.3 Coca cultivation

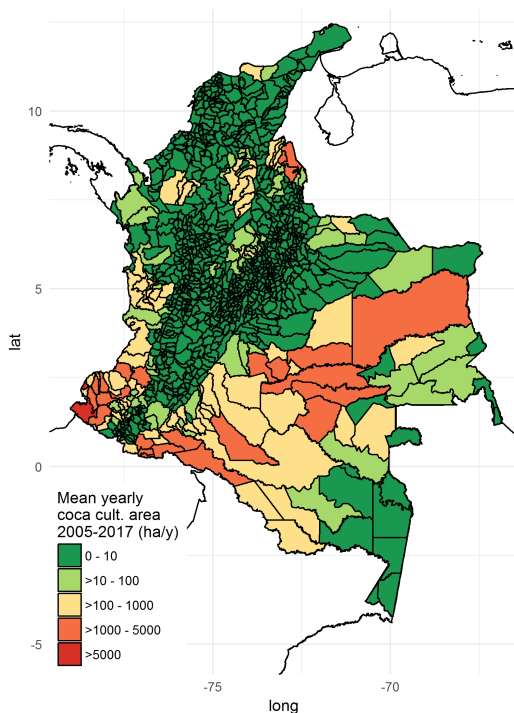
The area used for coca cultivation decreased in the first half of the covered time period but increased dramatically in more recent years (Figure 8). Between 2005 and 2012 coca cultivation area declined from 79 336 hectares to 45 063 hectares. Within this trend, a slight increase is recorded for the year 2007 (88 973 hectares). In the four years after 2013, coca cultivation area more than tripled to 157 814 hectares in 2017.



**Figure 8:** Coca cultivation area (ha). Coca cultivation area decreased in the first half of the covered time period but increased dramatically in more recent years

While 875 municipalities were coca free over the whole time period, four coca cultivation hot-spots can be highlighted. One hot-spot is located in South-Western Colombia, close to the Pacific and the Ecuadorian border. Another conglomerate of municipalities with high coca cultivation areas is situated on the border triangle Colombia-Ecuador-Peru. Relatively large municipalities with high coca cultivation rates are in Eastern Colombia. The smallest hot-spot of coca cultivation is found in Northern Santander on the Venezuelan border. Municipalities with an average yearly coca cultivation area larger than 2 000 hectares are:

1. Tumaco (Narino; 9120 ha)
2. Puerto Asis (Putumayo; 3578 ha)
3. Tibu (Norte de Santander (3272 ha)
4. Cumaribo (Vichada; 2756 ha)
5. Barbaças (Narino; 2512 ha)
6. El Tambo (Cauca; 2189 ha)
7. San Jose del Guaviare (Guaviare; 2076 ha)
8. El Retorno (Guaviare; 2007 ha)



**Figure 9:** Mean yearly coca cultivation area (ha). While many municipalities were coca free in the time frame 2005 to 2017, four coca cultivation hot-spots can be located at different parts of the country.

## 4 Correlations

The correlation analysis at national and department level gives valuable information about potential links between AGB carbon, deforestation and the conflict indicators.

### 4.1 Correlations at national level

The correlation analysis on national level has been carried out using mean AGB carbon (2010) and the mean yearly deforested area (2005-2017) as first variable with the three conflict indicators mean yearly armed actions, mean yearly victims of armed actions, and mean yearly coca cultivation area (all 2005-2017) as second variable. The results of the Spearman correlation are listed in Table 1.

On national level, the highest correlation is found for deforestation and victims of armed actions (0.59). Coca has a moderate correlation with both AGB carbon (0.38) and deforestation (0.49). Lowest correlation values are determined for armed actions.

### 4.2 Correlations at department level

Large difference in terms of correlations exist on department level. For most departments the correlation between AGB carbon and armed actions is not significant (sig. level 0.5). Only for Cordoba and Magdalena a moderate positive correlation is determined, while Sucre has a moderate negative correlation. More correlations using AGB carbon as first variable could be found with victims and coca cultivation area. 13 departments have a mostly strong correlation of AGB carbon and victims. 11 departments have a correlation of AGB carbon and coca cultivation area ranging from weak correlations (Boyaca: 0.19) to quite strong correlations (Bolívar: 0.71; Meta: 0.75). Compared to the low occurrence of correlations between AGB carbon and armed actions, the frequency of departments showing a correlation between deforestation and armed actions is much higher. For 14 departments a correlation between deforestation and armed actions is determined. Here the correlation coefficients range from -0.44 (Sucre) to 0.66 (Norte de Santander). Most departments show a correlation between deforestation and victims (21 departments) respectively coca cultivation area (16 departments). The departments with the highest correlation coefficients between deforestation and victims are Bolívar (0.81), Caquetá (0.82), and Putumayo (0.80). Regarding the correlation between deforestation and coca cultivation area, Putumayo (0.81), Meta (0.8) and Norte de Santander (0.72) are the departments with highest correlation coefficients.

Certain departments stand out in terms of correlations. Córdoba and Magdalena are the only departments, having correlations between all six indicator pairs. In addition, most of the correlations of these two departments are quite strong (ranging from 0.42 to 0.81). Moreover, six departments show correlations in all but the "Carbon – Armed action" correlation pair: Bolívar, Boyaca, Meta, Narino, Santander, and Valle del

**Table 1:** Spearman correlation of mean AGB carbon (2010) and the mean yearly deforestation rate (2005-2017) with the three conflict indicators mean yearly armed actions, mean yearly victims of armed actions, and mean yearly coca cultivation area (all 2005-2017). The highest correlation is found for deforestation and victims. Coca has a quite strong correlation with both AGB carbon and deforestation. Lowest correlation values are determined for armed actions.

Variable 1	Variable 2	cor.-coef.	p-value
Mean AGB carbon (t/ha)	Armed actions (total/y)	0.13	0.00
Mean AGB carbon (t/ha)	Victims (total/y)	0.24	0.00
Mean AGB carbon (t/ha)	Coca cult. area (ha/y)	0.38	0.00
Deforestation rate (ha/y)	Armed actions (total/year)	0.31	0.00
Deforestation rate (ha/y)	Victims (total/year)	0.59	0.00
Deforestation rate (ha/y)	Coca cult. area (ha/y)	0.49	0.00

**Table 2:** Spearman correlation between AGB carbon, deforestation, and the three conflict indicators. Explanation: Carbon is mean AGB carbon per area in 2010 (t/ha), deforestation is the mean yearly deforestation rate between 2005 and 2017 (ha/y), armed actions is the mean yearly number of armed actions between 2005 and 2017 (total/y), victims is the mean yearly number of victims of armed actions between 2005 and 2017 (total/y), coca is the mean yearly coca cultivation area between 2005 and 2017 (ha/y). The departments Arauca, Bogota, Guaviare, Vaupes, and Vichada consist of not enough municipalities to be able to conduct a meaningful correlation analysis. The departments of Cordoba and Magdalena are the only ones having correlations between all six indicator pairs. Six departments show correlations in all but the "Carbon – Armed action" correlation pair: Bolivar, Boyaca, Meta, Narino, Santander, and Valle del Cauca. Highest correlation coefficients are determined for Bolivar (Deforestation – Victims), Caqueta (Deforestation – Victims), Cordoba (Carbon – Victims), Meta (Deforestation – Coca), and Putumayo (Deforestation – Victims, Deforestation – Coca).

Department	Carbon – Armed act.	Carbon – Victims	Carbon – Coca	Deforest. – Armed act.	Deforest. – Victims	Deforest. – Coca
AMAZONAS	not sig.	not sig.	not sig.	not sig.	not sig.	not sig.
ANTIOQUIA	not sig.	not sig.	NA	<b>0.21</b>	<b>0.66</b>	NA
ATLANTICO	not sig.	not sig.	NA	not sig.	not sig.	NA
BOLIVAR	not sig.	<b>0.59</b>	<b>0.71</b>	<b>0.62</b>	<b>0.81</b>	<b>0.62</b>
BOYACA	not sig.	<b>0.54</b>	<b>0.19</b>	<b>0.21</b>	<b>0.69</b>	<b>0.42</b>
ALDAS	not sig.	<b>0.58</b>	not sig.	not sig.	<b>0.63</b>	<b>0.56</b>
CAQUETA	not sig.	not sig.	<b>0.58</b>	not sig.	<b>0.82</b>	<b>0.69</b>
CASANARE	not sig.	not sig.	NA	not sig.	<b>0.53</b>	NA
CAUCA	not sig.	<b>0.61</b>	<b>0.62</b>	not sig.	<b>0.44</b>	<b>0.31</b>
CESAR	not sig.	not sig.	not sig.	not sig.	<b>0.55</b>	not sig.
CHOCO	not sig.	not sig.	not sig.	not sig.	<b>0.7</b>	<b>0.53</b>
CORDOBA	<b>0.42</b>	<b>0.81</b>	<b>0.62</b>	<b>0.52</b>	<b>0.72</b>	<b>0.61</b>
CUNDINAMARCA	not sig.	not sig.	not sig.	<b>-0.26</b>	<b>0.39</b>	<b>0.29</b>
GUAINIA	not sig.	not sig.	not sig.	not sig.	not sig.	not sig.
HUILA	not sig.	<b>0.51</b>	NA	not sig.	<b>0.6</b>	NA
LA GUAJIRA	not sig.	not sig.	not sig.	<b>0.57</b>	<b>0.59</b>	<b>0.59</b>
MAGDALENA	<b>0.47</b>	<b>0.62</b>	<b>0.58</b>	<b>0.49</b>	<b>0.58</b>	<b>0.56</b>
META	not sig.	<b>0.59</b>	<b>0.75</b>	<b>0.49</b>	<b>0.71</b>	<b>0.8</b>
NARINO	not sig.	<b>0.46</b>	<b>0.38</b>	<b>0.41</b>	<b>0.69</b>	<b>0.57</b>
NORTE DE SANTANDER	not sig.	not sig.	not sig.	<b>0.67</b>	<b>0.67</b>	<b>0.72</b>
PUTUMAYO	not sig.	<b>0.57</b>	<b>0.6</b>	not sig.	<b>0.8</b>	<b>0.81</b>
QUINDIO	not sig.	not sig.	NA	not sig.	not sig.	NA
RISARALDA	not sig.	not sig.	NA	not sig.	not sig.	NA
SANTANDER	not sig.	<b>0.54</b>	<b>0.45</b>	<b>0.37</b>	<b>0.74</b>	<b>0.65</b>
SUCRE	<b>-0.47</b>	not sig.	NA	<b>-0.44</b>	not sig.	NA
TOLIMA	not sig.	<b>0.64</b>	NA	<b>0.34</b>	<b>0.69</b>	NA
VALLE DEL CAUCA	not sig.	<b>0.59</b>	<b>0.47</b>	<b>0.31</b>	<b>0.69</b>	<b>0.54</b>

Cauca. Highest correlation coefficients are determined for Bolivar (Deforestation – Victims: 0.81), Caqueta (Deforestation – Victims: 0.82), Cordoba (Carbon – Victims: 0.81), Meta (Deforestation – Coca: 0.80), and

Putumayo (Deforestation – Victims: 0.80; Deforestation – Coca: 0.81).



## 5 Local Indicators of Spatial Association (LISA)

In the following, the spatial distribution of the High-High areas of AGB carbon, deforestation rate, and the three conflict indicators is described. Subsequently, the overlap of High-High areas is specified.

### 5.1 High-High areas

High-High municipalities are municipalities with high values of either AGB carbon or deforestation rates, surrounded by municipalities with high values of one of the conflict indicators. Overview maps with all six combinations of AGB carbon and the conflict indicators, respectively deforestation and the conflict indicators are displayed in Figure 11.

Despite the differences in AGB carbon and deforestation rates, High-High areas with mean yearly armed actions appear to be quite similar. Accordingly, High-High areas with these combinations are found in North-East, Central and South-West Colombia. Slight differences exist between the two combinations, e.g. Fortul (Arauca), Sitionuevo (Magdalena), Suarez (Cauca).

More High-High municipalities are identified for the combinations with mean yearly victims of armed actions. Besides certain similar areas as shown for the combinations with armed actions, most municipalities on the pacific coast and a number of municipalities in the North-East are marked as High-High. Again, only slight differences exist between AGB carbon and deforestation. Most remarkable in the North in the departments Magdalena, La Guajira, and Cesar.

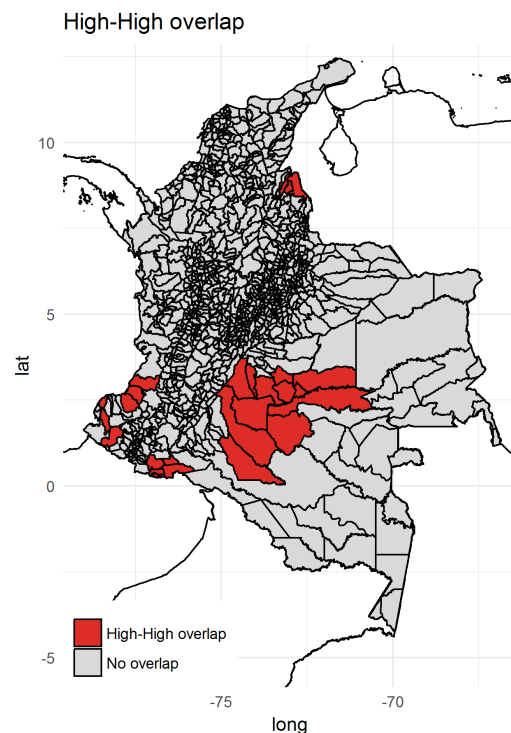
The largest area of High-High municipalities are determined for the combinations with coca cultivation area. A band of High-High municipalities is reaching from the East side to the South-Western part of the country. In addition, an area close to the border to Ecuador and the Pacific and certain municipalities in the department of Norte de Santander are marked as High-High in terms of AGB carbon respectively deforestation and coca cultivation area.

### 5.2 Overlap

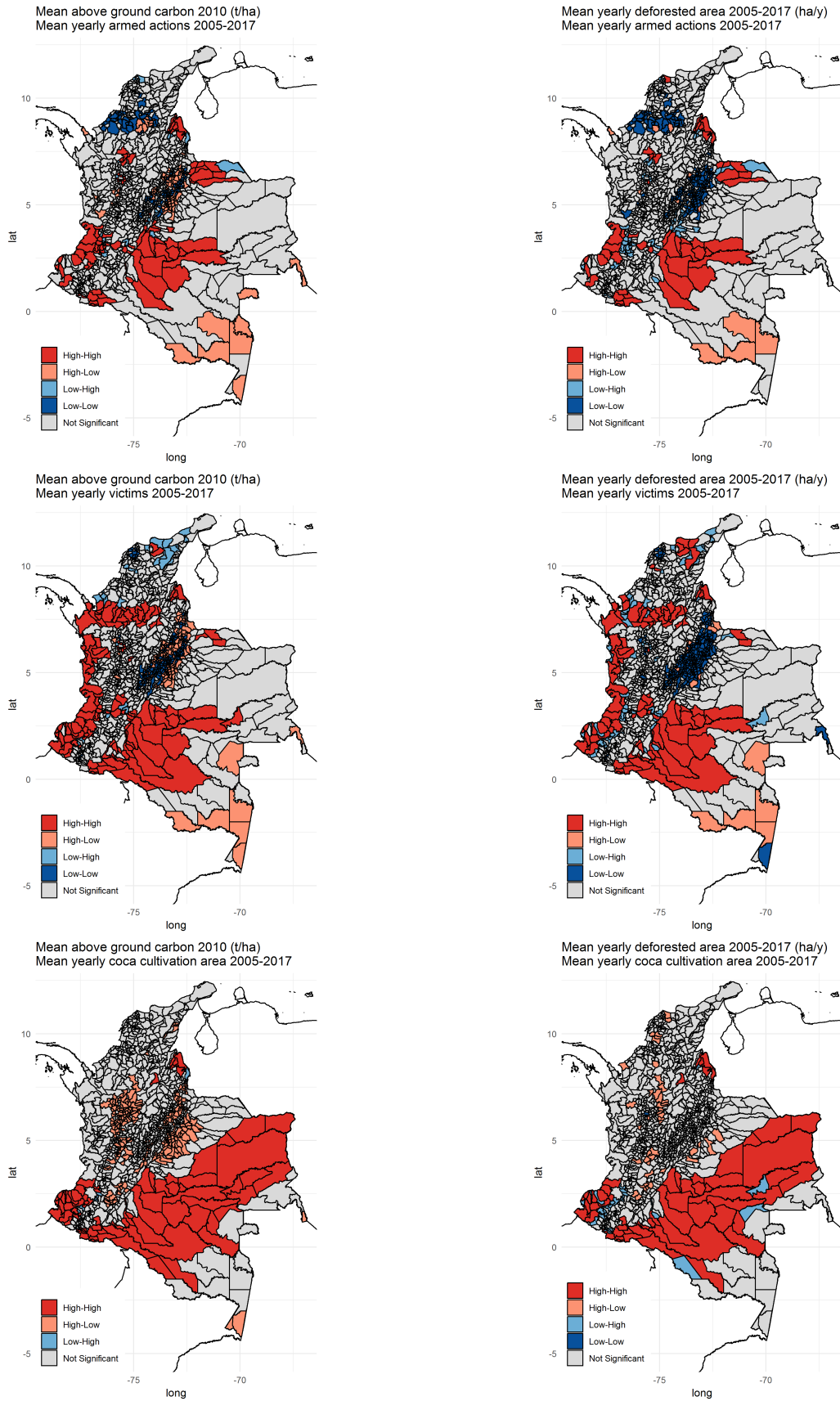
Through an overlap of all High-High areas described above, municipalities with an high content of AGB carbon, high rates of deforestation and high conflict values are identified (Figure 10). Namely, these municipalities are:

1. Cartagena Del Chaira (Caqueta)
2. San Vicente Del Caguan (Caqueta)
3. Guapi (Cauca)

4. Lopez (Cauca)
5. Timbiqui (Cauca)
6. Mapiripán (Meta)
7. Mesetas (Meta)
8. La Macarena (Meta)
9. Uribe (Meta)
10. Puerto Concordia (Meta)
11. Puerto Lleras (Meta)
12. Puerto Rico (Meta)
13. Vistahermosa (Meta)
14. Barbacoas (Narino)
15. Mosquera (Narino)
16. Roberto Payan (San Jose) (Narino)
17. El Tarra (Norte De Santander)
18. Teorama (Norte De Santander)
19. Tibu (Norte De Santander)
20. Orito (Putumayo)
21. Puerto Asis (Putumayo)
22. Puerto Caicedo (Putumayo)
23. San Miguel (La Dorada) (Putumayo)
24. Valle Del Guamuez (La Hormiga) (Putumayo)
25. San Jose Del Guaviare (Guaviare)
26. Calamar (Guaviare)
27. El Paujil (Caqueta)
28. Balboa (Cauca)
29. Morales (Cauca)
30. Patia (El Bordo) (Cauca)
31. Francisco Pizarro (Salahonda) (Narino)
32. San Calixto (Norte De Santander)



**Figure 10:** Coca cultivation area (ha). Coca cultivation area decreased in the first half of the covered time period but increased dramatically in more recent years



**Figure 11:** High-High municipalities according to the Local Indicators of Spatial Association (LISA) analysis.

## 6 Conclusion

The challenges of simultaneous improving forest conservation and peace-building in Colombia are manifold. In this report we shed light on certain related aspects.

Carbon stored in woody 'above-ground biomass' plays an important role for climate change mitigation. Municipalities in the Amazon basin store the most AGB carbon. Strikingly, the municipalities in the Northern parts of this area are the municipalities with the highest deforestation rates in the time period 2005 to 2017. These municipalities build kind of a deforestation frontier from the East to the South-West. Only one municipality outside this belt has comparable deforestation rates (Tibu, Norte de Santander).

The conflict variables covered in this report are (a) armed actions, (b) victims of armed actions, and (c) coca cultivation area. With constantly more than 1000, in four years more than 1500 armed actions, the time between 2005 and 2013 can be described as very violent. In more recent years this number dropped significantly. In general, most armed actions were executed in the three biggest Colombian cities Bogota, Medellin and Cali. However, also for other, more rural municipalities a high number of armed actions was recorded. Similarly, the number of victims of armed actions declined in the covered time frame. Interestingly, municipalities with the highest number of victims are not necessarily the municipalities with most armed actions. The area used for coca cultivation declined until 2012 to then more than threefold until 2017. Certain areas in North-East, East and South-West depict hot-spots of coca cultivation.

On national level, moderate to strong correlations are determined for deforestation and victims as well as deforestation and coca cultivation area. On department level the picture is diverse. For many departments, we do not find a correlation between AGB carbon, deforestation, and the three conflict indicators. Contrary, in certain municipalities correlations are moderate, in some strong. Departments, for which most correlations are found, are Cordoba, Magdalena, Bolivar, Boyaca, Meta, Narino, Santander and Valle del Cauca.

The Local Indicators of Spatial Association (LISA) analysis is to identify special areas of interest. Through an overlay of areas with high values of two indicators, 32 municipalities are identified. These municipalities are characterized by a high content of AGB carbon, high deforestation rates, and high values of the conflict indicators.

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