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Geographic overlaps between priority areas for forest carbon-storage efforts and those for delivering peacebuilding programs: implications for policy design

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Abstract

Of the countries considering national-level policies for incentivizing reductions in forest-based greenhouse gas emissions (REDD+), some 25 are experiencing (or are emerging from) armed-conflicts. It has been hypothesized that the outcomes of the interactions between carbon-storage and peacebuilding efforts could result in either improved or worsened forest conservation and likewise increased or decreased conflict. Hence, for this study we explore potential interactions between forest carbon-storage and peacebuilding efforts, with Colombia as a case study. Spatial associations between biomass carbon and three conflict-related variables suggest that such interactions may exist. Nonetheless, while priority areas for carbon-focused conservation are presumably those at highest risks of deforestation, our research indicates that forests with lower risk of deforestation are typically those affected by armed-conflict. Our findings moreover highlight three possible roles played by Colombian forested municipalities in armed groups' military strategies: venues for battle, hideouts, and sources of natural resources to finance war.

1. Introduction

Within the auspices of multilateral climate change negotiations, global interest has emerged in implementing national-level policies that would simultaneously incentivize forest-based emissions reductions such as REDD+ (Reducing Emissions from Deforestation and Forest Degradation), while producing co-benefits that are now referred to in global climate policy discussions as non-carbon benefits (UNFCCC 2014). These benefits include: biodiversity conservation (Strassburg *et al* 2010), forest governance (Kanowski *et al* 2011), sustainable forest management (Putz and Romero 2012), and community development (Danielsen *et al* 2011).

Although many governments of developing countries have high expectations of the benefits of carbon-focused conservation, REDD+ debates have largely been neglected outside the environmental sector. Contrary to expectations, REDD+ is not yet incentivizing multi-sectoral national-level decision making. Governments' commitments to climate change mitigation action are far from sufficient and, to the degree that they exist, remain limited to the environmental sector (Bliuc *et al* 2015). Given these circumstances, co-benefits of forest-based climate change mitigation need to be better demonstrated as they have the potential to attract funding and increase political and social support (Bain *et al* 2016).

Opportunities to provide evidence of co-benefits may arise outside the environmental sector, for instance, in considering the interactions between priority areas for forest carbon-storage and priority areas for peacebuilding. Such co-benefits would presumably be of interest to the 25 countries that, besides pursuing REDD+, are emerging from (or still struggling with) varying degrees of armed conflict (supplementary table S1, available at stacks.iop.org/ERL/12/054014/mmedia). In fact, since 2009 the Republic of Colombia (Colombia) has advocated in international policy arenas, such as the United Nations Framework Convention on Climate Change (UNFCCC), for the potential for promoting 'beneficial interactions' between forest carbon-storage and peacebuilding efforts (Radio Nacional de Colombia 2014, Presidencia de la Republica 2009, Bates 2016). However, potential interactions between forest carbon-storage and peacebuilding actions have not yet been studied.

Peacebuilding programs are designed to address the structural causes of war and support the capacity of local actors to manage and overcome conflict (Galtung 1985). Such activities range from the support of political processes to the provision of livelihoods (UN 2010), and place particular attention on rural livelihoods, as well as on strengthening governance institutions through policy reforms to ensure rural people's rights and access to land. As such, peacebuilding activities resemble rural development programs (Galtung 1985) and in some cases they incorporate forest conservation strategies (Brottem and Unruh 2009). Like peacebuilding, forest carbon-storage approaches consider general policy reforms and governance (Brockhaus *et al* 2014), as well as the provision of both sustainable livelihoods and land tenure security (Blom *et al* 2010). Thus, given the compatibility of efforts relating to peacebuilding with REDD+, it is reasonable to expect 'beneficial interactions' in locations where these activities overlap. Particularly considering evidence that peacebuilding efforts have created conditions favorable to the implementation of forest carbon-storage programs in conflict-affected areas (Castro-Nunez *et al* 2016), and that forest carbon-storage programs are contributing to post-conflict (Aquino and Guay 2013). This challenges the arguments that highlight the potential threats forest carbon-storage approaches might pose to conflict-affected countries (Karsenty and Ongolo 2012, Saunders *et al* 2002, Unruh 2008, Unruh 2011). A better understanding of potential interactions between priority areas for forest carbon-storage and peacebuilding actions is thus necessary as it may help maximize the benefits and better address the risks of implementing REDD+ in countries experiencing (or emerging from) armed-conflicts.

Similarly, a better understanding of how armed-conflicts and forest-cover influence each other may help to design carbon-based conservation efforts tailored to the specific needs of conflict affected countries. Forest-cover changes are driven by the influence of various complex factors (including social and political unrest) on agricultural expansion, wood extraction, and the extension of infrastructure (Geist and Lambin 2002). Moreover, in the field of 'environmental security', studies on the relationship between forests and war vary greatly as to their findings of the impacts of conflict and post-conflict periods on forest biomass (Sanchez-Cuervo and Aide 2013, Butsic *et al* 2015, Ordway 2015, Burgess *et al* 2015). Under certain circumstances, some studies attribute reduced rates of deforestation to economic disruption (Burgess *et al* 2015) or forced migration (Sanchez-Cuervo and Aide 2013, Ordway 2015), while studies link forest losses to natural resource exploitation (Butsic *et al* 2015, Ordway 2015, Sanchez-Cuervo and Aide 2013). Despite these efforts there is still a lack of both empirical and theoretical understanding of how armed-conflicts influence forest-cover, as well as of how forest-cover in turn influences the dynamics of armed conflicts.

Bearing all aforementioned points in mind, the present study contributes to an improved understanding of how armed-conflict and forest-cover influence each other, while exploring potential interactions between forest carbon-storage and peacebuilding efforts. For this study we assume that interactions would arise if priority areas for forest carbon-storage programs (or those with high forest carbon content) geographically overlap with priority areas for peacebuilding (or those with high values for conflict-related variables). Thus, we investigate spatial associations between carbon in woody biomass and three conflict-related variables: armed actions; conflict victims; and area under coca cultivation. We also investigate spatial associations between forest-cover changes and three conflict-related variables to reflect the common trend that REDD+ is primary focus on areas under high risk of deforestation. We use Colombia as a case because of the country's long history of armed-conflict, its interest in forest for climate change mitigation and its current promising peace process, which makes research into the 'forest carbon-storage –peacebuilding' interactions highly pertinent.

2. Peace-building and forest carbon-storage in Colombia

2.1. Political discourses on interactions between forest carbon-storage and peacebuilding

Colombian President Juan Manuel Santos' intention of 'turning guerrilla members into forest rangers' indicates an approach of simultaneously targeting peace-building and forest carbon-storage (Radio Nacional de Colombia 2014). Underpinning Santos' statement is an assumption that, due to geographic overlap, there is potential for promoting beneficial interactions between forest carbon-storage programs and activities to support victims of violence. This echoes earlier assumptions contained in statements by the previous Colombian President. For instance, at the UNFCCC's 15th Conference of the Parties (COP) in 2009, President Uribe described how the 'forest-ranger families program' contributed to protecting forests and keeping them free of illicit crops (Presidencia de la Republica 2009). He also described scenarios where coca eradication programs are delivered in the same geographic areas as conservation activities, resulting in a doubling of benefits. More recently, high level Colombian officials are supporting the idea that forest carbon-storage efforts can contribute to peacebuilding as much as they can contribute to climate change mitigation and forest conservation (Bates 2016). In addition, Colombia has submitted a Forest Reference Emissions Level (FREL) to the UNFCCC. The FREL argues that in the absence of REDD+ the implementation of the peace agreement signed between the Colombian government and guerrilla groups in 2016 would result in increased forest-based emissions (MADS 2014). This, the Colombian Government argues, will particularly occur in the Colombian Amazon, where armed-conflicts have inadvertently resulted in the protection of forests by rendering their access prohibitively dangerous (MADS 2014).

2.2. Armed-conflict as cause of deforestation

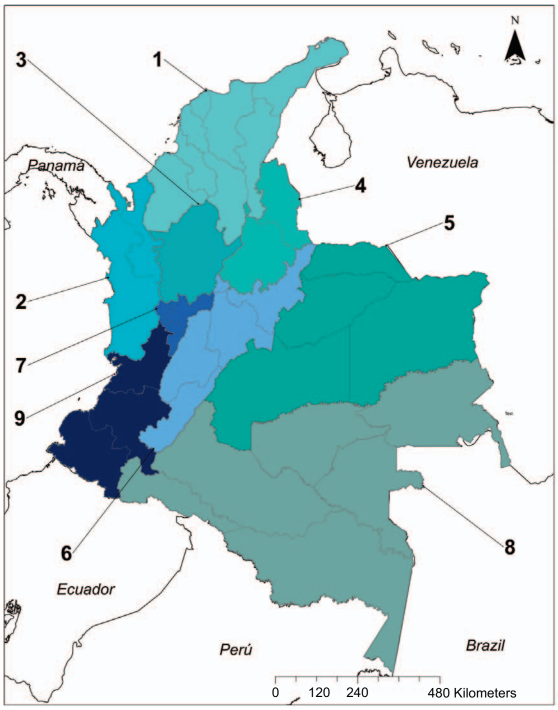
In fact, conflict-affected forests in Colombia have still not been reached by extractive industries and industrial agriculture (Negret *et al* 2017). Nonetheless, in Colombia, agricultural colonization fronts usually start in conflict-affected areas with the production of illicit crops, which are then converted to pasture (Etter *et al* 2005, Chadid *et al* 2015, Van Ausdal 2009, Vina *et al* 2004, Davalos *et al* 2009). The presence of illicit crops and livestock grazing during colonization processes are maybe explained by the significant resources (e.g. labour, financial) required by colonist farmers to fell forests and develop the land for agriculture (Van Ausdal 2009). To obtain short term income, colonists may form 'growth coalitions' with wealthy actors (Rudel and Horowitz 1993) such as drug traffickers and armed-groups to produce coca in remote forested areas. Returns from coca leaf production might then be invested in forest frontiers. This argument is supported by research suggesting that the differentiated spatial and temporal roles played by illicit crops and cattle pasture in the Colombian deforestation process are determined by access (Chadid *et al* 2015). More specifically, forest-cover loss attributed to illicit crops is primarily related to the opening of a new colonization front, while deforestation caused by cattle pastures is related to the expansion of the agricultural frontier and consolidation of urban areas (Chadid *et al* 2015). In addition to low accessibility, regions where coca is cultivated are also characterized by low levels of development and frequently overlap with areas affected by armed-conflict (Rincón-Ruiz *et al* 2013). Thus, while in some contexts access-constraints and violence have shown to be associated with very low deforestation rates, in Colombia these conditions are related to the production of coca and, therefore, with some levels of deforestation (Rincón-Ruiz *et al* 2013). Additionally, government-led coca eradication programs, such as aerial fumigation with glyphosate, have been also linked to deforestation (Rincón-Ruiz and Kallis 2013) and displacement of coca cultivation from the Amazon region to previously unaffected regions in the northern Andes, Caribbean and Pacific (Rincón-Ruiz *et al* 2013, Rincón-Ruiz and Kallis 2013). However, over the years such approaches for reducing the availability of resources used by guerrilla groups to finance combat (e.g. coca production) have been moving toward peacebuilding approaches.

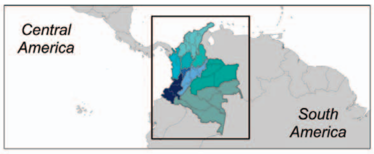
2.3. Peacebuilding, rural development and forest conservation

The objectives of peacebuilding and rural development programs are increasingly compatible. They are even considered 'two faces of the same coin' (Galtung 1985). In Colombia, peacebuilding approaches aim to reduce the causes of conflicts (e.g. land-related grievances), as well as the availability of resources used by guerrilla groups to finance combat (e.g. coca production). These approaches are usually implemented in areas that are emerging from conflict and include: land tenure programs, both individual and collective; land restitution programs; conditional payments for the production of alternative crops and forest conservation; and development and conservation programs. In addition, conservation initiatives, such as the establishment of Natural Protected Areas, often coexist alongside peacebuilding programs. These programs usually seek to improve livelihoods, reduce illegal activities (such as coca leaf production) and contribute toward forest conservation. In summary, peacebuilding efforts in Colombia are increasingly compatible with both 'development' and 'forest conservation' –type programs. This is because development and governance objectives target the re-establishment of territorial control, reduction of conflict over natural resources management among actors, and managing natural resources. This is reflected in the current peace agreement recently signed between the Government of Colombia and the FARC, where land tenure considerations and other development and conservation oriented aspects were an important part of the negotiation agenda (Republica de Colombia and Fuerzas Armadas Revolucionarias de Colombia 2014).

3. Materials and methods

We use Colombian mainland municipal boundaries (1120 municipalities) as the spatial units of analysis. Spearman's rank correlation coefficients (ρ) were calculated at national level for the associations between carbon in woody 'above-ground biomass' (AGB) and three conflict-related variables: (i) armed actions; (ii) conflict victims; and (iii) area under coca cultivation. Variables were defined based on data





Jurisdiction	Region	Departments	# of municipalities
1	Caribe	Atlántico, Bolívar, Cesar, Córdoba, Guajira, Magdalena	195
2	North Pacific	Antioquia and Choco	58
3	Antioquia	Antioquia	111
4	Santander	Norte de Santander and Santander	127
5	Orinoquia	Arauca, Casanare, Meta, Vichada	59
6	Andes	Boyacá Cundinamarca, Huila, Tolima	324
7	Coffee triangle	Caldas, Quindío Risaralda	53
8	Amazon	Amazonas, Caquetá Guainía, Guaviare, Putumayo, Vaupes	59
9	South Pacific	Cauca, Nariño, Valle del Cauca	148

Figure 1. Sub-national areas (or regions) proposed by the Colombian government as jurisdictions for setting emission levels (MADS 2013).

availability and relevance (i.e. capacity to reflect common trends in prioritization of areas for implementing forest-carbon storage and peacebuilding efforts). Carbon is assumed to be equivalent to 50% of AGB and is defined as the average stock of carbon per hectare (t/ha) in municipalities during the year 2010. Armed actions are defined as: the number of attacks, ambushes, harassment and other armed contacts carried out by the Colombian National Army (FF.AA), the Revolutionary Armed Forces of Colombia (FARC) or the National Liberation Army (ELN). The analysis is limited to the FF.AA, FARC and ELN, firstly because these armed groups are involved in ongoing negotiation processes, and secondly because of data constraints. The variable victims is defined as the aggregate number of internally displaced persons (IDPs), kidnapped persons, and persons impacted (civilians and militaries) by landmines, improvised explosives and unexploded munitions (hereafter MAP). Similarly, the variable coca is defined as the average cultivated area (in hectares). Victims and coca are calculated over the period 2001–2010. Sub-national level Spearman's coefficients were also estimated to identify regions where associations took place. For this purpose, nine regions (or jurisdictions) defined by the Colombian government, were investigated at the sub-national level (figure 1) (MADS 2013). In addition, bivariate Moran's Index values were estimated with the software GeoDa v1.6.7.9 to identify local patterns of spatial associations (Anselin 1996) between: (1) carbon and the three selected conflict variables; and (2) forest changes (defined as the percentage of change in forest-cover between 2000 and 2010, with the year 2000 as the reference) and the three conflict variables. Finally, maps indicating the location of municipalities with a significant local Moran's Index were plotted using ArcGIS Desktop v.10.1.

Our analysis is based on four official public datasets. AGB maps were developed by the Colombian Institute of Hydrology, Meteorology and Environmental Studies (IDEAM) using Landsat satellite images (Phillips *et al* 2011, Phillips *et al* 2016) as well as allometric equations to estimate the average AGB in different types of Colombian forests (Alvarez *et al* 2012). Meanwhile, the classification of Colombian forests used is based on Holdridge's 'life-zone legend' (Holdridge *et al* 1971). Similarly, forest cover maps for the year 2000 and 2010 were developed by IDEAM (Cabrera *et al* 2011). Data on armed conflicts actions is compiled by the Observatory for Human Rights and International Humanitarian Law of the Vice Presidency of Colombia (HRO) and is available at municipality level for the years 1998–2014 (Verdadabierta 2015). Data on victims also comes from HRO. Data on illegal cultivation of coca comes from censuses undertaken annually since 2000 by the Integrated Illicit Crops Monitoring System (SIMCI) (UNODC 2015).

Conflict-related variables were not controlled for the size of municipal geometries or for population. We opted not to control conflict variables for two reasons. Firstly, this was to ensure that the article's use of 'armed-conflict' remained consistent. This we defined as 'a 'contested incompatibility which concerns government and/or territory where the use of armed

Table 1. Spearman rank correlation coefficients for associations between carbon biomass and conflict for each of the conflict related variables considered (armed actions, victims and coca) as well as for the armed groups (FARC, ELN, FF.AA) and reported kinds of victims (IDPs, kidnappings and MAP). National ρ is Spearman rank correlation coefficients of all mainland municipalities whereas sub-national ρ is Spearman rank correlation coefficients of all municipalities within defined regions. Values assigned with * are significant correlation coefficients at the 0.05 level or lower.

Conflict indicator	National ρ	Sub-National ρ								
		Caribe	North Pacific	Antioquia	Santander	Orinoquia	Andes	Coffee triangle	Amazon	South Pacific
Armed actions (#)	0.43*	0.57*	0.16	0.57*	0.44*	0.53*	0.34*	0.66*	−0.67*	0.49*
FARC	0.30*	0.39*	0.29	0.44*	0.22*	0.48*	0.24*	0.51*	−0.72*	0.42*
ELN	0.16*	0.35*	0.24	0.19*	0.18*	−0.01	0.08	0.04	.	0.06
FF.AA	0.43*	0.58*	0.05	0.58*	0.46*	0.52*	0.36*	0.68*	−0.65*	0.49*
Victims (#)	0.27*	0.56*	−0.13	0.46*	0.43*	0.31*	0.33*	0.39*	−0.67*	0.51*
IDPs	0.29*	0.57*	−0.13	0.45*	0.47*	0.32*	0.36*	0.48*	−0.67*	0.54*
Kidnaps	0.14*	0.47*	0.21	0.23*	0.14	−0.08	0.04	0.20	−0.71*	0.20*
MAP	0.21*	0.31*	−0.0	0.53*	−0.03	0.20	0.06	0.12	−0.48*	0.13
Coca (ha)	0.28*	0.26*	0.39*	0.47*	0.05	0.32*	0.08	0.12	−0.13	0.12

force between two parties, of which at least one is the government of a state, results in at least 25 battle-related deaths per year' (UCDP 2014). This definition is based on a battle-related deaths threshold, which does not vary according to the size or population of the affected country. Secondly, because governments do not necessarily use standardized variables when identifying priority municipalities for undertaking programs of conflict resolution, victim support or the control of illicit crop cultivation (for an example of how the Colombian government identifies areas affected by illegal crops see UNODC 2015). In addition, this approach is consistent with other studies exploring relations between war and deforestation that do not control conflict variables (Burgess *et al* 2015, Rincón-Ruiz *et al* 2013).

4. Results

At the national-level, we found moderate correlations between carbon and armed actions ($\rho = 0.4263$), as well as low correlations between carbon and victims ($\rho = 0.2733$) and, similarly, low correlations between carbon and coca ($\rho = 0.2757$). At the sub-national level, negative and positive Spearman's coefficients (table 1) provide further explanation of low and moderate national-level correlations. Results demonstrate that correlations between carbon and FF.AA actions are generally higher than similar correlations between carbon and FARC actions, or those between carbon and ELN actions (table 1). Similarly, correlations between carbon and IDPs are generally higher than similar correlations between carbon and other kinds of reported victims. Positive correlations between carbon and armed actions, as well as between carbon and victims were found in seven Colombian regions: Caribe; Antioquia; Santander; Orinoco; Andes; the Coffee Triangle; and the South Pacific. Conversely, high negative correlations were found between carbon and armed actions as well as between carbon and victims in the Amazon region. Similarly, lack of correlation between carbon and coca was found in both the Amazon and the South Pacific coast regions.

Positive low and moderate sub-national correlations are explained by the regional co-existence of both carbon-poor municipalities with low values for conflict-related variables and carbon-rich municipalities with high values for conflict-related variables (online supplementary table S2). As an example, given the relative stability and low-carbon density of the Andean region, we expected high correlations. However, the low correlations observed in the Andean region are explained by the variability of carbon and conflict-levels. For instance, some municipalities have high-carbon density and low values for conflict-related variables, while others feature the inverse. Similarly, negative correlations are explained by carbon-rich municipalities with comparatively low values for conflict-related variables. These findings might be explained by some municipalities being comparatively carbon-poor, yet with very high values for conflict-related variables. Likewise, the absence of correlation between carbon and coca for the Amazon and South Pacific coast regions is explained by the fact that, although some municipalities in these regions are highly affected by illicit crops, they have lower carbon content, when compared to other municipalities in the same regions.

The Global Bivariate Moran's Index values for carbon and armed actions (0.232), victims (0.182), and coca (0.332) confirm national-level correlation coefficients. These values shed light on patterns of spatial associations of municipalities (online supplementary figure S1). Figure 2(*a*) highlights in green the municipalities with high values for carbon surrounded by the municipalities with high values for armed actions. This cluster indicates hot spots for potential co-delivery of carbon-storage and conflict-resolution

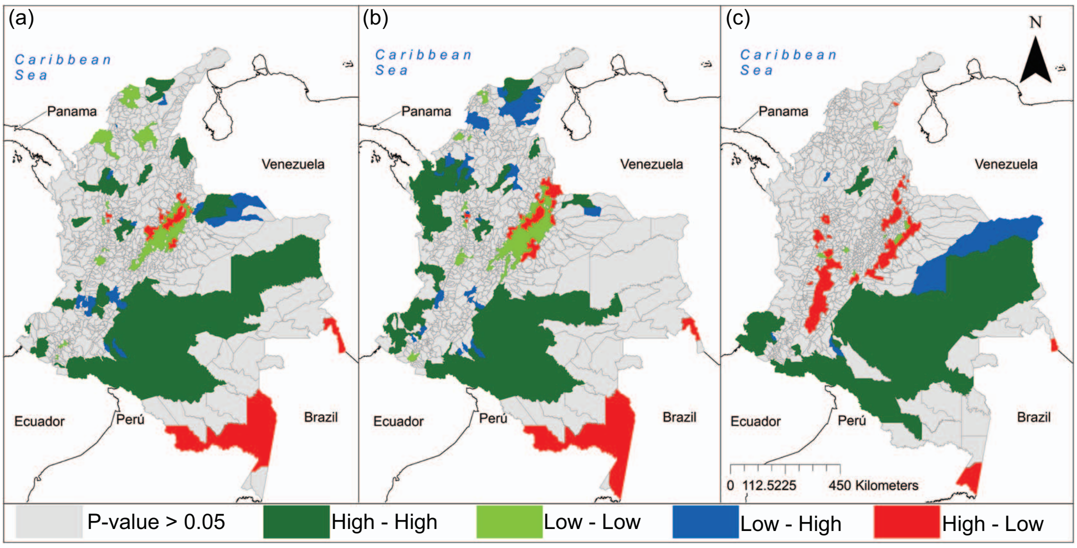


Figure 2. Local Moran maps for carbon and armed actions (a), victims (b), and coca (c). Places with p-values <0.05 are highlighted as follows: municipalities with high values for carbon, surrounded by municipalities with high values for conflict variables, are colored dark green (high-high); municipalities with low values for carbon, surrounded by municipalities with low values for conflict variables, are colored light green (low-low); municipalities with low values for carbon, surrounded by municipalities with high values of conflict variables, are colored blue (low-high); municipalities with high values for carbon, surrounded by municipalities with low values of conflict variables, are colored red (high-low). Locations with non-significant ($P > 0.05$) Local Moran statistics are colored light grey.

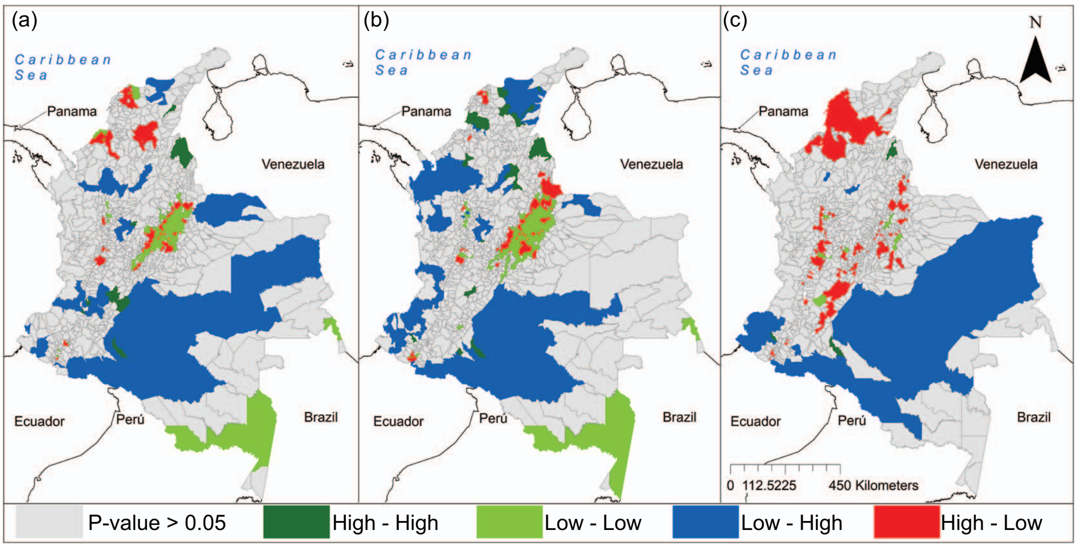


Figure 3. Local Moran maps for changes in forest-cover and armed actions (a), victims (b), and coca (c). Places with p-values <0.05 are highlighted as follows: municipalities with high values for changes in forest-cover, surrounded by municipalities with high values of conflict variables, are colored dark green (high-high); municipalities with low values for changes in forest-cover, surrounded by municipalities with low values for conflict variables, are colored light green (low-low); municipalities with low values for changes in forest-cover, surrounded by municipalities with high values for conflict variables, are colored blue (low-high); municipalities with high values for changes in forest-cover, surrounded by municipalities with low values for conflict variables, are colored red (high-low). Locations with non-significant ($P > 0.05$) local Moran statistics are colored light grey.

and largely matches municipalities clustered as 'low forest changes-high armed actions' (figure 3(a)). This suggests that, due to conflict activity, these municipalities are at low risk of deforestation. The 'high carbon-high armed actions' cluster indicates forested municipalities as preferred battle-sites, while the 'low carbon-high armed actions' cluster reveals non-forested municipalities as the preferred battle-sites.

Municipalities with high values for carbon, surrounded by municipalities with high values for victims, are mainly located in the Pacific Coast (both north and south) and the Amazon River basins (figure 2(b)). Additionally, some 7% of these municipalities are located in northern Colombia (Caribe, Antioquia and Santander). This cluster indicates municipalities where carbon storage efforts and activities to support victims of violence might overlap (figure 2(b)). Nonetheless, as is shown in figure 3(b), most of these municipalities are at low risk of deforestation and probably provide non-state armed groups with hideouts. Alternatively, municipalities clustered as 'low carbon-high victims' might provide non-state armed groups with 'spoils of war' or areas to expand territorial control and accumulate assets. For these municipalities, spearman's coefficients suggest that IDPs are more relevant than the other victimhood variables included in the analyses (table 1).

Similarly, municipalities with high values for carbon, surrounded by municipalities with high values for coca (figure 2(*c*)), are predominantly located in southern Colombia. This cluster shows 'hot spots' where efforts for carbon-storage might be delivered in the same geographic areas as coca eradication programs. Nonetheless, municipalities within this cluster are mostly the same as those defined as 'low forest changes-high coca' (figure 3(*c*)). Hence, these municipalities are at low risk of deforestation. Municipalities within this cluster probably function as sources of high-value natural resources to finance war.

Finally, the Wilcoxon signed-rank test was used to validate that conflict affected municipalities are at low risk of deforestation. We found that the variable of forest change shows a significant difference when medians were compared between municipalities identified as venues for battle (Mdn = 13.612) and municipalities clustered as low armed actions (Mdn = 26.996) ($W = 7375$, $p < 0.000$). Similar differences were found between municipalities identified as hideouts and spoils of war (Mdn = 13.625) and municipalities clustered as low victims (Mdn = 22.833) ($W = 12725$, $p < 0.000$), and between municipalities identified as sources of resources to finance war (Mdn = 8.351) and municipalities clustered as low coca (Mdn = 15.095) ($W = 2280$, $p < 0.001$).

5. Discussion

National and sub-national Spearman's rank correlation coefficients indicate spatial associations between carbon in woody biomass and three conflict-related indicators. However, these are concentrated within specific Colombian regions and do not necessarily constitute positive trends. Meanwhile, bivariate Moran's Index values show local patterns of such spatial associations. Together these results suggest that interactions between forest carbon-storage and peace-building (i.e. conflict resolution, support to the victims of violence, and control of illegal crop cultivation) efforts are possible in Colombia. Particularly in areas where high forest-carbon content geographically overlaps with areas with high values for conflict variables.

Our findings identify, via an empirical and spatially explicit analysis, three possible roles played by Colombian forested municipalities in the military strategies of the armed groups, as: (1) venues for battle; (2) hideouts; and (3) sources of valuable natural resources to finance war. We also found contributions to armed forces from non-forested municipalities. Municipalities clustered as 'low carbon-high victims' are probably preferred as venues of spoils of war, where the civil population has been attacked and displaced by armed groups wanting to accumulate land (Ibáñez and Vélez 2008). Such behavior, however, is aligned with the modus operandi reportedly employed by paramilitary groups that, although not considered in this analysis, are additional actors within the Colombian conflict (Ibáñez and Vélez 2008, Cubides 1999).

Our results suggest that Colombia's conflict-affected municipalities store more carbon and are at lower risk of deforestation than their more peaceful counterparts. Such relationships between conflict affected forests and reduced rates of deforestation have been reported before in other contexts (Ordway 2015, Burgess *et al* 2015). However, our results additionally suggest that the associations between conflicts and forest biomass vary according to the above mentioned roles that forested areas play in armed groups' strategies. This implies that, to further advance our understanding of how armed-conflict influences forest-cover, it is necessary to link the characteristics of local areas of forest with their particular use and governance by armed groups. It also reinforces arguments on the importance of the scale of analysis when linking conflict and other causes of deforestation (Ostrom and Nagendra 2006, Butsic *et al* 2015, Arjona 2014). For instance, patterns of land-use change and armed-conflict are interlinked across Colombia in complex ways, which reflects the country's diverse biophysical, socio-economic, demographic, political (e.g. diverse armed groups), and institutional (e.g. various land use regimes) contexts (Etter *et al* 2006a, Armenteras *et al* 2013, Sanchez-Cuervo and Aide 2013). According to Etter *et al* (2006a), Colombia's deforestation is best predicted by fertility, slopes, precipitation and access. This reflects the condition of agricultural activities (including illicit crop cultivation) and cattle pasture as the main causes of deforestation (Etter *et al* 2006a, Etter *et al* 2006b, Dávalos *et al* 2014). Meanwhile, we argue that alongside these factors, the occurrence and relevance of deforestation activities are also influenced by armed groups' strategies, resulting in land-use competition regarding legal and illegal uses.

Now that the peace agreement has been reached between the Colombian government and the FARC, forests in conflict-affected areas are being exposed to further pressures leading to increases in forest based emissions, as anticipated in the FREL presented by Colombia to the UNFCCC. This is being confirmed by preliminary reports that indicate that deforestation is sharply increasing in areas previously under FARC control (Baena and Correa 2017). Moreover, political stability might attract greater investors and lead to increases in economic activities such as industrial agriculture, logging and mining (MADS 2014, Baptiste *et al* 2017). Therefore, carbon-based conservation efforts should be ready to counteract challenges that may arise once peace is reestablished. Geographical coincidence and compatibilities between peacebuilding, rural development and forest carbon storage initiatives (Galtung 1985, Brottem and Unruh 2009, UN 2010, Blom *et al* 2010) can be exploited for this purpose. Some post-conflict activities proposed in the current peace negotiation process between the government of Colombia and the FARC (Republica de Colombia and Fuerzas Armadas Revolucionarias de Colombia 2014), might contribute simultaneously to peacebuilding and to forest carbon storage, such as those related to protection of areas of environmental interest, land tenure formalization and reinforcement of local institutions. Nonetheless, proposed activities involving credits and subsidies to facilitate land-access arguably have potential to increase forest-based emissions and, therefore, would require careful assessment before and during implementation. Similarly, programs to support victims of violence, such as those aimed at the resettlement of IDPs or the reintegration of former combatants, require careful assessment prior to their implementation (Summers 2012). In such scenarios, conflict would no longer 'prevent' deforestation. Instead, uninhabited forests might provide sites for the relocation of former combatants and victims.

The designation of conservation corridors, as promoted in Colombia (The Brics Post 2015), is an alternative for conserving forests and supporting peacebuilding that also requires careful assessment. The use of conservation areas as part of peacebuilding strategies is an approach that has shown mixed results, mainly because it often restricts rural people's access to forests and land, thus creating conditions for further conflict (Brottem and Unruh 2009). Likewise, forest carbon-storage efforts implemented in situations of unresolved land tenure might exacerbate existing tensions (Saunders *et al* 2002, Unruh 2011, Unruh 2008). Mindful of such potential to inflame tensions, the UNFCCC has adopted safeguards aimed at conflict prevention and securing the rights of indigenous peoples and local communities (UNFCCC 2011). Alternatively, land reforms, including individual or collective land title programs, could be implemented as strategies to reverse and reduce causes of conflicts and forest-loss (Albertus and Kaplan 2012, Ostrom and Nagendra 2006).

Similarly, improved local governance and rural institutions have the potential to co-deliver forest conservation and conflict-resolution (Ostrom and Nagendra 2006). A lack of state presence in combination with weak local institutions are regarded as factors contributing toward deforestation (Geist and Lambin 2002) and armed conflicts (Le Billon 2001). According to Cubides (1999), the FARC enforces rules and community coexistence agreements in areas with low state-presence. These rules sometimes pertain to land-use restrictions and in the event of a peace agreement, state institutions will need to fill the regulatory gaps that military organizations leave behind. However, it is not clear that state intervention is an appropriate solution for areas that have been officially ungoverned for extended periods. In such instances, the state is unlikely to have the capacity to take on such work. Instead it may be more effective for the state to formalize and support the existing community organizations to manage their respective territories (Ostrom and Nagendra 2006).

Some approaches to eradicate illegal crops production have had unintended impacts, including several that targeted FARC-controlled areas containing coca plantations. An example is the 'Program of Eradication of Illicit Crops with Glyphosate', which resulted in the spread of coca plantations to municipalities previously unaffected and, in some instances, led to increased rates of deforestation (Rincón-Ruiz and Kallis 2013, Dávalos *et al* 2011). An alternate approach was the aforementioned program 'forest-ranger families' that provided incentives conditional on adoption of alternative (to illegal crops) production systems and meeting environmental requirements (Carbono Bosques and UNODC 2012). Beneficiary families were encouraged to legally acquire land and the program also implemented actions to promote farmers' associations and community participation. These actions apparently contributed to forest-based climate change mitigation (Carbono Bosques and UNODC 2012).

These experiences from Colombia and the analysis of spatial associations provided in this paper have important implications for countries that are currently emerging from (or experiencing) armed conflicts and that are simultaneously aiming to participate in REDD+. Firstly, we provide empirical evidence supporting political expectations of interactions between carbon-storage and peacebuilding policies. These findings are relevant to national governments supporting integration of carbon-storage with efforts to achieve development priorities. Delivering programs to reduce forest-carbon emissions in conjunction with efforts to achieve peacebuilding could be an important driver for adopting national REDD+ in Colombia and potentially elsewhere, as well as for attracting donor support. Such programs have multi-sectoral impacts and hence are of relevance to actors and institutions working in a range of fields, including governance, peacebuilding and rural development. The Government of Colombia already targets REDD+ funding to priority post-conflict sites (Gobierno de Colombia 2015) and these actions are being supported by donor countries with interests in both the peace negotiation process and financially incentivizing carbon-storage efforts. An example is Norway, which has the dual role of being third party mediator in the Colombian peace talks and a major REDD+ donor to Colombia and other countries.

Secondly, given that conflicts and illegal activities occur, or have recently occurred, in both conserved forests (those with high forest-carbon stocks) and degraded landscapes (those with low forest-carbon stocks), we propose that different REDD+ activities (i.e. forest carbon conservation, enhancements of carbon stocks and sustainable forest management) might be effectively harnessed for peacebuilding, and vice-versa. Carbon payments could be directed to support activities aimed at meeting both sets of objectives, such as land tenure programs, generation of legal alternative livelihoods, and governance and institutional improvements. By adopting this approach, many areas of high-value for peacebuilding could benefit from carbon-based conservation. However, since REDD+ underemphasizes the mitigation potential of forests at low risk of deforestation (Vergara-Asenjo and Potvin 2014) and degraded forests (Mertz *et al* 2012), Colombian forests that host armed actions, victims, and coca production may not benefit as they are typically at reduced risk of deforestation. Thus, beneficial interactions would be enhanced if forests at low risk of deforestation and degraded landscapes were considered in forest carbon-storage approaches, as armed-conflicts are present in such territories. Similar constraints have been reported, for example, for the integration of REDD+ and biodiversity conservation policies (Strassburg *et al* 2010).

Finally, our methodological approach illustrates geographical overlaps between priority areas for peacebuilding and for forest carbon-storage efforts, but does not in itself provide causal explanation of this co-occurrence or whether it is beneficial or not. Thus, additional multidisciplinary research is required to maximize beneficial interactions and better address the risks of implementing actions that simultaneously target peacebuilding and forest carbon-storage. Such a framework can build on REDD+ safeguards adopted by the UNFCCC, which aim at preventing conflict and securing the rights of indigenous peoples and local communities (UNFCCC 2011). Future research into forest carbon-storage and peacebuilding policies in post-conflict settings should ideally also address the conservation and enhancement of ecosystem services provided by forests, as well as the development of the communities that inhabit and depend on them. These constitute essential co-benefits for local communities. Likewise, policies and initiatives of biodiversity conservation and ecosystem services are essential for the adequate implementation of the REDD+. Additionally, in our case study, a significant proportion of the Colombian territory (including the Amazon, Pacific coast and other forested areas) forms part of the National System of Protected Areas or belongs to Afro-Colombian or indigenous communities. The scale at which conflict-data is available impedes us from exploring how the reported correlations work using collective lands and natural protected areas as units of analysis. Such analyses would be useful for understanding how forest carbon-storage and peace-building activities interact within differing land-tenure regimes.

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