Socio-economical and institutional drivers of coca cultivation and associated deforestation in Colombia during the 2000s*

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Abstract

The cultivation of coca (*Erythroxylon coca*) by smallholders represents the first step of the largest illegal agribusiness in the world: cocaine. This paper addresses the regional socio-ecological factors and impacts such as tropical deforestation behind illegal coca expansion in Colombia between 2001-2008. Data on meso-economic, social and institutional factors that characterize coca growing regions in Colombia are disaggregated at the municipality level to identify spatial distributions and clusters of coca cultivation using *exploratory spatial data analysis* (ESDA), in particular *local indicators of spatial association* (LISA). The analysis indicate that the expansion of coca cultivation has produced a process of deforestation mainly affecting humid tropical forested ecosystems and although we found that there are no individual factors exclusively associated with the coca areas, we identified that there are a group of common factors that characterize these areas.

Keywords: Coca crops, socio-environmental conflicts, spatial analysis, tropical deforestation, Colombia

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1. Introduction

Tropical deforestation is complex social-ecological problem and has been explored from many disciplinary perspectives emphasizing economic, social, institutional and environmental factors (Rock, 1996; Angelsen, 1999; Deininger and Minten, 2002; Geist and Lambin, 2002; Culas, 2007; Scrieciu, 2007; Evans *et al.*, 2008; Khan and Khan, 2009). While most research on tropical deforestation has focused on the agricultural frontier and associated activities such as timber extraction, land conversion to cash crop monocultures, little attention has been paid to the deforestation caused by cultivation of illegal crops such as coca for the production of cocaine. This is surprising as the literature has identified this as a driver of deforestation (Farrell and Thorne, 2005; Etter *et al.*, 2006).

Although coca cultivation is not the main cause of deforestation in Colombia, it is affecting ecosystem health through its negative impact on biodiversity especially in forests with suitable environmental conditions for its cultivation (Álvarez, 2007; Dávalos *et al.*, 2009). The displacement of illicit crops to other areas has created a deforestation problem in Colombia as discussed by (Dávalos *et al.*, 2011) using land use coverage maps. There are various factors underlying the location of coca growing areas in Colombia. Some of such factors that have been mentioned in the literature include land tenure ship insecurity (Fajardo, 2002), the existence of political instability and armed conflicts (Díaz, 2004; Garcés, 2005; Vargas, 2005), low levels of social capital (Thoumi, 2005), and high levels of rural poverty (Dion and Russler, 2008).

So far no study has carried out an in-depth analysis using disaggregated spatial level data to better understand the regional characteristics associated with the municipalities with coca crops (Coca Crops Areas - CCAs henceforth). Dion and Russler (2008) have attempted to explain the permanence of coca crops in Colombia, providing evidence that pocerty has a non-linear effect, but were not able to decipher the local particularities of CCAs since their analysis was based on the national and departmental scale rather than a more municipal scale. Díaz (2004) used a lower scale (municipal level) but only analyzed the relationship between land use and armed conflict, which although important only offers a partial view of the illegal coca crop growing problem in Colombia.

This paper applies a spatial analysis at the municipality level based on data spanning 2001-2008 and aims to shed light on the social, economic, environmental and institutional factors that mediate the effects of coca cultivation on deforestation. The main objectives are to identify (i) Regional factors associated with the CCAs, (ii) key characteristics of such CCAs have changed over time (2001-08), and (iii) the enabling factors for the expansion of land cultivated under coca crops at the expense of forest land in the Colombian tropics.

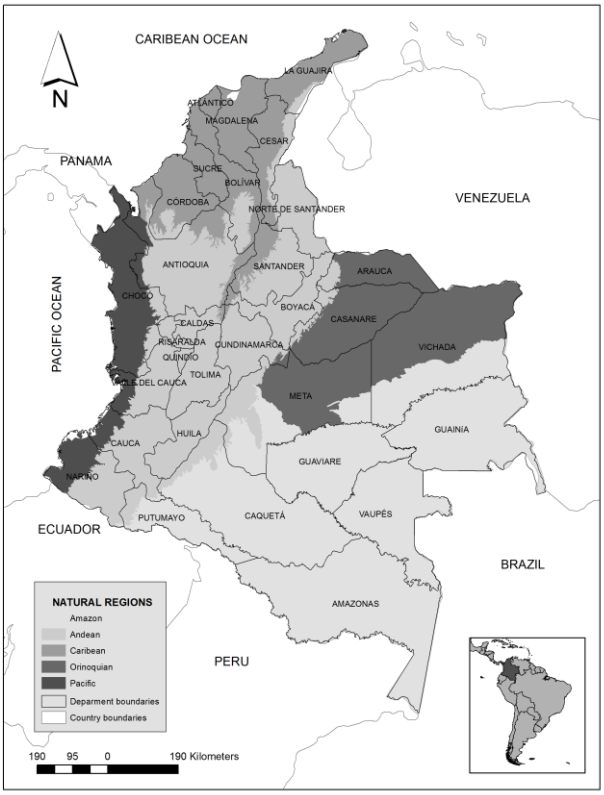
We carry out an *exploratory spatial data analysis* – ESDA, (Anselin *et al.*, 2004; Anselin *et al.*, 2007; Patacchini and Rice, 2007) using information about social, economic, environmental and institutional factors at the municipal level. ESDA allows to visualize and describe spatial distributions, discover patterns of spatial association (spatial clustering) and suggest spatial regimes or other forms of spatial heterogeneity (Anselin, 1994). Here we use both global and local indicators of spatial association which have been used in other applications such as urban crime, economic performance and other social sciences (Murray *et al.*, 2001; Patacchini and Rice, 2007; Sridharan *et al.*, 2007)

Section 2 describes the case study area, Section 3 presents the methodological issues relating to data and methods used during the research, Section 4 shows the results found in global and regional analysis and the deforestation results. Sections 5 refer to the discussion, where we discuss some policy implications regarding the effort to stop the expansion of the cultivations of coca, finally section 6 contains the main conclusions of this research

2. Study area

Colombia is located in the northwestern corner of South America and bordered by the Atlantic and Pacific oceans as well as by six other countries (Venezuela, Brazil, Peru, Ecuador and Panama). The climate is tropical hot and humid with two rainy seasons, March to May and September to December, and a variety of climatic zones ranging from warm to sea level to 5,500 m. Colombia consists of five continental natural regions, i.e., the Andean (AN), Caribbean (CA), Pacific (PA), Orinoquian (OR) and Amazon (AM) regions. These regions are divided into 32 departments and 1101 municipalities (map 1). From these, 23 departments and 274 municipalities have had a presence of coca for at least one year during the period 2001-2008.

Colombia produces more than 50% of coca for cocaine production worldwide, and has an average planting density of 110,000 plants per hectare (UNODC, 2006). The region with the biggest coca yield is the Amazon region, principally in the Meta and Guaviare departments averaging 9,900 kg per ha per year. In 2001 the Amazon region concentrated most of the coca production. The lowest coca yield occurs is the Pacific region (2600 kg per ha per year), but despite its low yield much coca cultivation has been displaced to the Pacific region in recent years, partly due to the government's eradication policies in the Amazon region (UNODC, 2006).



Map 1. Continental Natural Regions of Colombia and Departments

3. Data and methods

3.1 Data for the identification of factors behind coca cultivation

The identification of possible factors associated with the CCAs included in the LISA (Anselin, 1995) was carried out in three ways, (i) a review of the literature, including peer reviewed and policy documents (ii) gathering expert opinion on social, economic, environmental and institutional issues related to illicit crops, meetings were held with researchers from the Integrated Illicit Crops Monitoring System (SIMCI – acronym in spanish), the National Office of Narcotics (DNE – acronym in spanish), the Ministry of Defense, and the NGOs Transnational Institute (TNI), the Arcoiris Foundation and Acción Andina, as well as researchers from Colombian Universities and (iii) fieldwork in two municipalities (Rosario and Leiva) from the department of Nariño, which has experienced the biggest increase in coca cultivation during the 2001-08, in order to gather opinions and information about the regional factors associated to the coca crops, we make interviews with public institutions (Health secretary, local government and national policy), and civil society (local population and indigenous communities such as Awá community[1]).

After identifying the possible factors behind cultivation of coca, spatial and alphanumeric information associated with these factors were collected. Table 1 shows a set of selected variables with information at the municipal level covering the whole country, classified into four categories: social, economic, environmental and institutional factors. The spatial and alphanumeric information on coca crops was obtained from the Integrated System of Monitoring of Illicit crops of the United Nations on Drugs and Crime (SIMCI acronym in Spanish). We selected the percentage of coca area per municipality as a variable (X), on this variable we proceeded to analyze the spatial association with the rest of variables (Y)

The data was collected for the years 2001 and 2008 due to the information availability (of both spatial and alphanumeric information) on coca crops at the municipality level for

[1] The Awá Community is an indigenous community that inhabits the southwest of Colombia, in the Departments of Nariño and Putumayo (also found in Ecuador)

Colombia. In cases when complete information was not available for some of the variables for any year, the existing information for the closest year was used. Additionally, in cases where data was available for one year only, this information was used as reference for both years. Table 1 indicates the year for which information can be accessed regarding each of the variables used in the analysis. The number of violent actions and the murders by illegal armed groups represents the presence of illegal armed groups in the territory and was taken as a proxy of the weakness of the state.

Table 1. Selected variables at municipality level

Tipo de variable	Sigla	Category	Variable name	Year	Source of data
Var X	PCA	Analysis variable	Percentage of the municipal territory in coca area	2001 - 2008	Coca maps (shape) - Integrated Illicit Crops Monitoring System (SIMCI: Spanish acronym for "Sistema Integrado de Cultivos Ilicitos")
Var Y	GDPC	Economic	Growth Domestic Product per capita	2002 - 2007	National Administrative Department of Statistics - DANE, estimation by the authors
	GINILAND	Economic	GINI of land distribution	2002	Offstein 2003
	PRD	Economic	Primary roads density	2005	Road map (shape) - Geographic Institute Agustín Codazzi - Estimation by the authors
	FDP	Social	Forced displacement of population - expulsion	2001 - 2008	Presidency of the Republic of Colombia - Presidential Agency for Social Action and International Cooperation
	UBNI	Social	Unsatisfied Needs Index for rural areas	2005	National Administrative Department of Statistics - (DANE Spanish acronym for "Departamento Administrativo Nacional de Estadística")
	RDP	Social	Rural density population	2005	National Administrative Department of Statistics - (DANE Spanish acronym for "Departamento Administrativo Nacional de Estadística")
	IMD	Institutional	Index of municipal development* (2001 - 2008)	2001 - 2008	National Planning Department of Colombia (DNP - Spanish acronymun for "Departamento Nacional de Planeación") - Dirección de Desarrollo Territorial Sostenible DDTS
	VAIA	Institutional	Number of violent action by Illegal armed groups (used as proxy to presence of illegal armed groups) ,	2001 - 2007	Data Base - Andes University and defense ministery of Colombia
	MR	Institutional	Murder Rate by Illegal armed groups (used as proxy to presence of illegal armed groups),	2001 - 2008	Colombian National Police - Estimation by the Authors
	PPF	Environmental	Percentage of te municipal territory in primary forest area (2000)	2000	Colombia Ecosystem map (shape) - Institute of Hydrology, Meteorology and Environmental Studies of Colombia (IDEAM - Spanish acronymun for "Instituto de Hidrología, Meteorología y Estudios Ambientales de Colombia) - Estimation by the authors

3.2 Deforestation and ecosystem impacts

The analysis on deforestation and ecosystem impact by coca crops was conducted based on information for the year 2000 based on satellite data (IDEAM, 2007). A total of 154 ecosystems were grouped into three principal biomes and 32 sub-biomes. 16 types of land cover types were grouped into eight natural classes and eight semi-natural and transformed

classes.[2] This ecosystem mapping was overlaid by the coca census data for the period 2001-2008 in order to be able to determine the share of cultivation of coca within each of the land cover types. We estimated the share of deforested area and ecosystems affected at the municipality level and the results were complemented with data from the United Nations Office on Drugs and Crime (UNODC, 2006, 2008). Deforestation estimates are made from the natural cover in terms of forest, and other woody formations that existed in 2000 (IDEAM, 2007). With geographical analysis overlapping we estimated how much of these natural ecosystems that existing in the year 2000 has been converted to Coca cultivation in the period between 2001 and 2008 based in the SIMCI information.

3.3 Exploratory spatial analysis of coca cultivation

Two types of exploratory spatial data analysis (ESDA) were carried out to shed light about the key factors associated with coca cultivation in Colombia following the methods in (Anselin, 1994, 1995; Patacchini and Rice, 2007):

First a global multivariate spatial correlation analysis is conducted to calculate a single measure of spatial correlation at the national level between the share of land area under coca cultivation and the selected economic, social, institutional and environmental variables. The estimation is based on the multivariate Moran´s I coefficient (Anselin *et al.*, 2002).

The second ESDA approach involves a local multivariate spatial correlation analysis to identify local patterns of spatial association based on LISA (Anselin, 1995). This approach is used to decompose the Moran's I coefficients by identifying the contribution of each observation. We used a LISA extension for the multivariate case developed by (Anselin *et al.*, 2002). The multivariate LISA offers an indication of the degree of association between the share of coca area in each municipality and the variables of interest in neighbouring municipalities (Anselin, 1995; Anselin *et al.*, 1996; Anselin *et al.*, 2002).

[2] The natural classes are: natural continental waters, shrubs, natural forests, grasslands, grasses and coastal bushes, continental hydrophytes, coastal lakes and estuaries, and secondary vegetation. The semi-natural and transformed land classes are: heterogeneous agricultural areas, largely alternated areas, urban areas, artificial continental water, forest plantation, annual or transitory cultivations, (semi-) permanent crops and grasses

Both global and local multivariate spatial analyses required the creation of a 'weight matrix' (Anselin, 2005; Anselin *et al.*, 2006b; Anselin *et al.*, 2007), to define a local neighbourhood value around each municipality as geographical unit. The weight matrix by contiguity was chosen as the best option due to the heterogeneity of the polygons and the wide range of neighbourhoods per municipality.3

Both multivariate global and local spatial correlation analysis followed the Moran's I statistic visualized in the four quadrants of the generalized Moran scatter plot (Anselin, 1993; Anselin *et al.*, 2002). This plot represents the analyzed variables in a standard form in which the slope of the regression line represents the global Moran's I statistic. In the present analysis it indicates the spatial association at the global (i.e., national) level. The scatter plot also reflects the four types of local spatial correlations between municipalities and their neighbouring areas. The right upper quadrant contains municipalities with high values in the X variable (i.e., percentage of the municipal territory in coca area - PCA) surrounded by municipalities with high values in the Y variable (any of the other key variables selected); we refer to these municipalities having a H-H (High-High) association. The lower quadrant consists of high values of the X variable associated with low or zero values for the Y variable, i.e., High – Low (H-L) association. Low-Low (L-L, lower left) consists of municipalities with low or zero values for the X variable surrounded by municipalities with low or zero values for the Y variable; Lastly, the Low-High (L-H, upper left) quadrant contains low or zero values for the X variable with high neighbour values for the Y variable. High values of the X variable is part of what is denominated "CCAs"

A LISA cluster map (Anselin, 1995; Anselin *et al.*, 2002; Anselin *et al.*, 2006a) maps the location of observations with significant local Moran statistics, highlighting significant spatial clusters and outliers and shows the centres of the clusters. Hence, the spatial range of the clusters should be seen in the broader context of the region, that is, including the neighbouring regions which are not highlighted in the map. We represent the municipalities associated with H-H, H-L, L-H and L-L values in the LISA cluster map. The statistical significance of the correlations was carried out using 10,000 permutations (Anselin *et al.*, 2002; Anselin, 2005)

[3] There are three kinds of weight matrices: contiguity (queen, rook), distance, and k-nearest neighbour.

4. RESULTS

4.1 Deforestation due to coca cultivation (2001-08)

Based on the ecosystems map (IDEAM, 2007), the analysis revealed that in 2001 most coca cultivated areas were mainly found in areas of warm humid to very humid climate (97%)[4], 62% of plots in very humid and warm climate and 35% in humid and warm climate. The remaining 3% are small and isolated, and established in warm dry and mild humid to very humid climates. Regarding the geo-morphological formations, 60% of coca crops are found in foothill areas, 24% in flat plains, 14% in high mountains and 2% in alluvial plains formations. These environmental conditions are typically found in the foothills of the east side of the Eastern Andean mountain range bordering the Amazon region, the west side of the Western Andean mountain range bordering the Pacific region and in the flat and alluvial plains in the Amazon, Caribbean and Pacific regions.

Remarkably, by 2008, a decrease of up to 7% of coca crops found in the warm humid and very humid climates were observed, increasing the presence of the crops in warmer dry, humid to very humid temperate and rainy warm climates by 1.7%, 1.5%, 1.7%, and 1%, respectively. A significant change was also observed in the geo-morphological conditions associated with coca cultivation by 2008. In the foothill formations coca crops fell from 60% to 48% between 2001 and 2008. In contrast, in high mountains coca areas increased from 14% to 24%. The share of coca cultivation areas in alluvial plain and flat plains formations remained stable. This translates into increases of land under coca cultivation in the East side of the Eastern Andean mountain range (the Pacific and Caribbean regions) and the west side of the Western Andean mountain range (the Amazon and North of the Andean region).

The shift in the geographical distribution of coca cultivation in Colombia during 2001-2008 period is remarkable. As can be seen from map 2 coca cultivation has decreased in the Amazon and the Orinoquia regions and it has increased in the Pacific, Caribbean and the north of the Andean Region.

[4] The precipitation ranges in Colombia are: Arid (0-500 mm/year); very dry (501 – 1000 mm/year); dry (1001-2000 mm/year); warm humid (2001-3000 mm/year); very humid (3001- 7000) and pluvial (> 700 mm/years) (Holdrige, 1978).

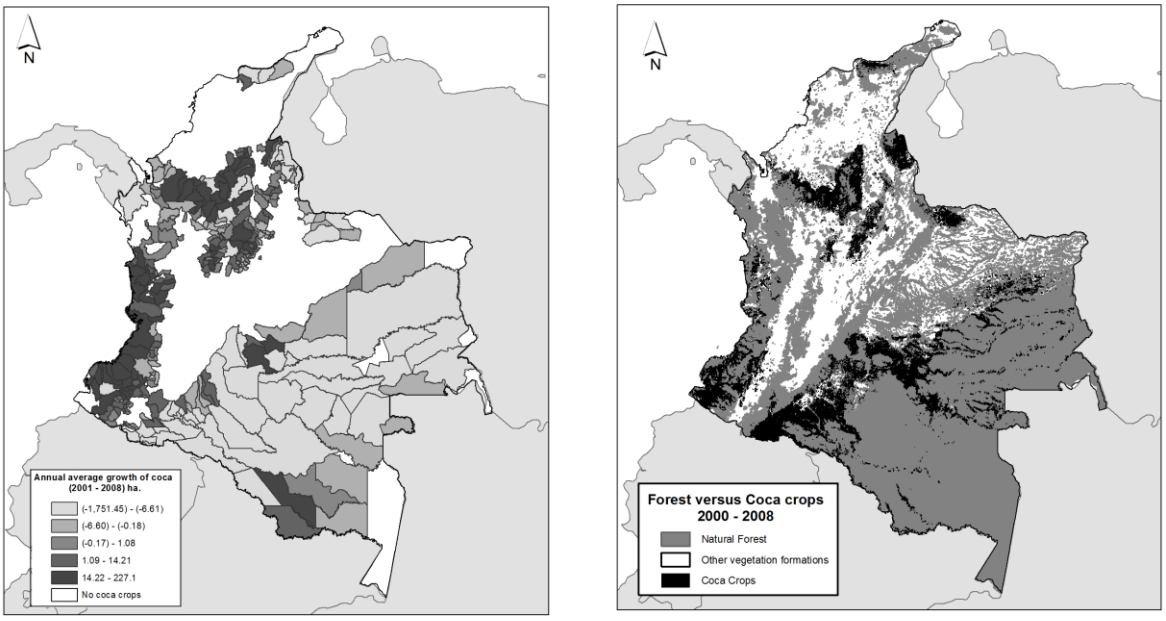
During the study period (2001 -2008) the expansion of illicit crops in Colombia produced a process of deforestation which affected mainly humid tropical forest land. Illicit crops have now moved to the Pacific, Caribbean and northern Andean regions. Based on the natural cover and ecosystems existent in the year 2000, it was found that in 2001 the most affected ecosystems by such expansion of Coca cultivation were the humid tropical forests of Orinoco and Amazon. A total of 67700 has (40%) of the coca area in 2001 were located in the humid tropical forest. This percentage decreased in this ecosystem to 20555 ha (33%) for 2008. In addition, during the 2000s, Coca cultivation had expanded to other region mainly the humid tropical forests of the Pacific region. , For 2001, 1982 ha (2%) of the coca area was located in humid tropical forest of the Pacific region; this value increased to 8166 ha (11%) on this ecosystem for 2008. Finally, we found for 2001, that 3442 ha (2%) of the coca area was located on humid tropical forests of foothills of the Amazon and Pacific, this value increase to 7% (5155 ha) for 2008(table 2).

Table 2. Natural cover in 2000 that has been converted to coca in 2001 and 2008

Forest	Area (Ha)	
	2001	2008
Tropical humid forest of the Orinoco and Amazon	67.600	20.555
tropical rainforest in the Pacific	1.982	8.166
Foothills of the Amazon and Pacific	3.442	5.155
Forest in Catatumbo, Caribiam and Andes regions	17.181	9.043

Although in absolute terms the coca area have declined between 2001 and 2008, principally due to the sharp decrease in the Amazon region, the displacement of the coca crops between 2001 and 2008 to new areas in Colombia have negatively impacted on primary forest ecosystems, with a total of 110.026 hectares of primary forest having been transformed into coca (UNODC, 2008, 2009, 2009a).

This has caused several important and in many ways irreversible impacts on forested and woody ecosystems, including those that had not been associated with the coca, such as the ecosystems of the Pacific region. We estimate that 58% of the total area cleared for coca cultivation in 2008 (44,635 ha) was previously under natural forests in 2000 (c.f. map 2).



Map 2. Annual average growth of coca and Forest area vs coca area (2000 -2008)

4.2 Factors associated to the coca cultivation (2001-08)

The existence of coca crops in certain areas of Colombia is not only due to favourable environmental conditions for cultivation but it also depends on social, economic and institutional factors. Here we explain the results of the local and global spatial multivariate analysis where these factors are spatially analyzed at the local scale.

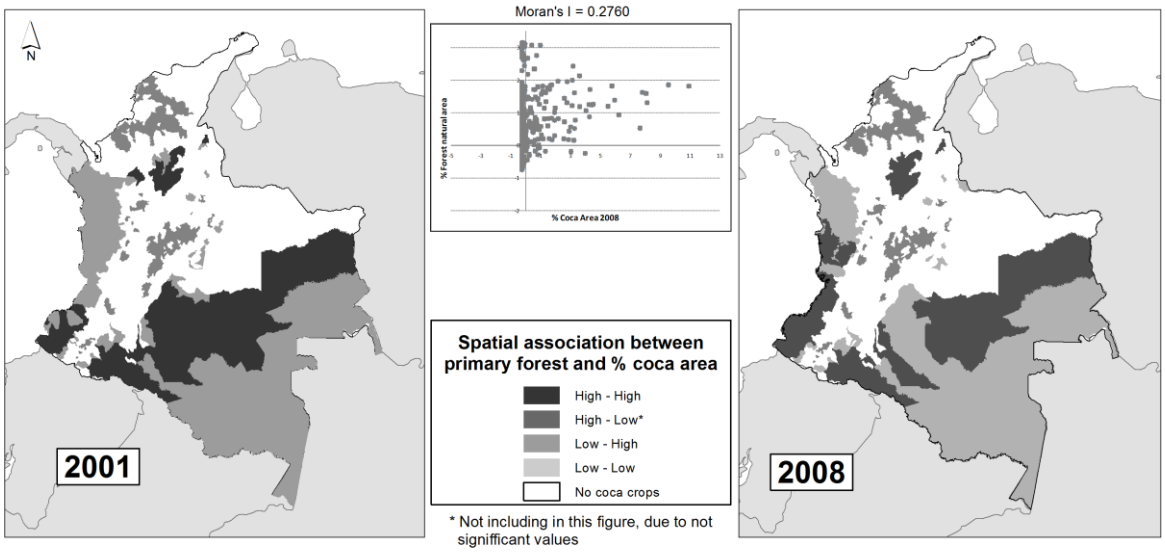
Based on the multivariate global spatial analysis, a significant global spatial association was identified (for the two years 2001 and 2008) between the share of area under coca cultivation at the municipality level and each one of the variables selected in the analysis that appear in Table 3. An inverse relationship was found between coca area and the following variables: rural population density (RPD), Growth Domestic Product per capita (GDPC), primary road density (PRD) and the Index of Municipal Development (IMD). By contrast a positive relationship was found between coca area and the rural unsatisfied basic needs index (RUBN), Murder Rate by Illegal armed groups (MR), forced displacement of population (FDP), violent acts committed by illegal armed groups (VAIA) and share of primary forest area (PPF)

Table 3. Multivariate Global Spatial Analysis (significant associations with Percentage of coca area 2001 and 2008).

Category	Variable	Sig. association (5%)	
		2001*	2008*
Social	Unsatisfied Needs Index for rural areas	0.035	0.179
Social	Rural Density population	-0.008	-0.018
Social	Forced displacement of population - expulsion	0.125	0.206
Economic	Growth Domestic Product per capita	-0.044	-0.073
Economic	Primary Road Density	-0.086	-0.238
Institutional	Index of Municipal development	- 0.099	- 0.253
Institutional	Murder Rate by Illegal armed groups (Proxy for illegal groups presence)	0.017	0.147
Institutional	Number of Violent action 2001 – 2007 (Proxy for illegal groups presence)	0.170	0.180
Environmental	Percentage of primary forest	0.125	0.276

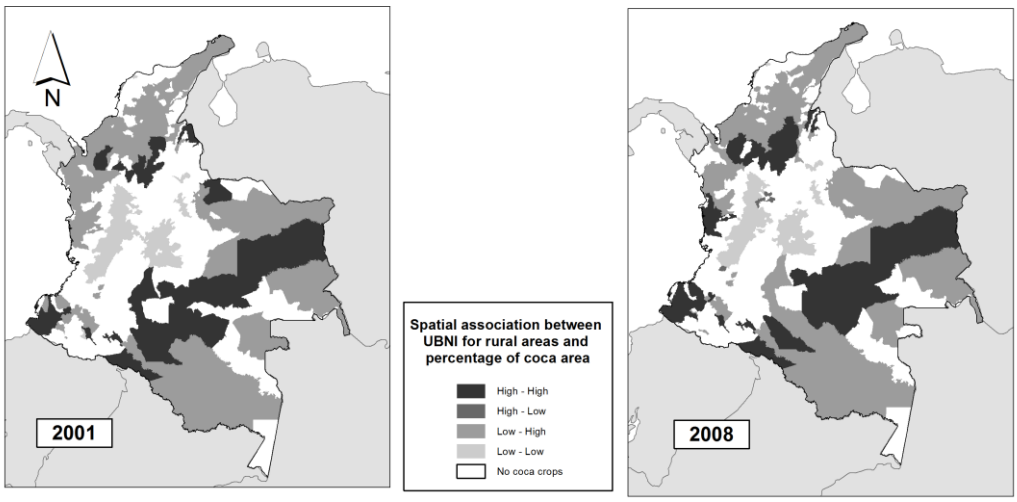
The multivariate local Spatial Analysis uncovered the following findings. First, in 2001 the municipalities where coca was being cultivated had a significant spatial correlation with the variables analyzed before (in the global analysis), obtaining similar results to the global analysis (similar signs and significance of the correlations), except for GDP which was not significant. Second, none of the analyzed variables can be considered to be exclusively associated with the CCAs, significative associations were indentified as well in regions without coca. Third, by 2008 a clear displacement of the coca crops towards the Pacific, the Caribbean and northern area of the Andean region can be found. In the new coca growing areas a similar significant spatial correlation can be found with respect to the variables analysed in 2001, thereby implies that between 2001 and 2008 the coca crops were displaced to areas with similar social, economic, institutional and environmental characteristics. Fourth, although there are no individual factors exclusively associated with CCAs, a distinct set of common factors between them can be identified, including low levels of municipal development, low road density, high proportion of primary forest, high level of forced displacement, significant presence of illegal armed groups and a high RUBN. The results of the LISA analysis are presented below with accompanying maps:

Environmental factors: A positive association between CCAs and areas with a large share of primary forest (H-H clusters) was found for the year 2001. However, also in 2001 areas with a high share of primary forest were also associated with municipalities that had a low presence of coca crops (L-H cluster). In 2008, an expansion of the H-H cluster was found towards the pacific and the Caribbean region, implying that coca crops were displaced to areas with a high share of primary forest (map 3).



Map 3. LISA map for primary forest (2001 – 200) and % coca area (2001 - 2008) by municipality (significant clusters at 0.05 sig. level)

Social Factors: In 2001 the coca growing municipalities were associated with high levels of RUBN (H-H cluster). This cluster was mainly found in the Amazon and Orinoquian regions, where the coca crops were concentrated (c.f. map 4). Nevertheless L-H cluster could also be identified, which indicates municipalities with low or null coca levels associated with zones of high RUBN levels (in the Pacific and the Caribbean region). In 2008 an expansion of the H-H cluster could be in the Pacific, Caribbean and northern areas of the Andean region, while a decrease of the H-H cluster could be observed in the Amazon region. As expected in the Andean region L-L cluster was identified (Andean region gathered the municipalities with the best social conditions in Colombia and don't have the appropriate physical conditions for coca cultivation in most of its territory.

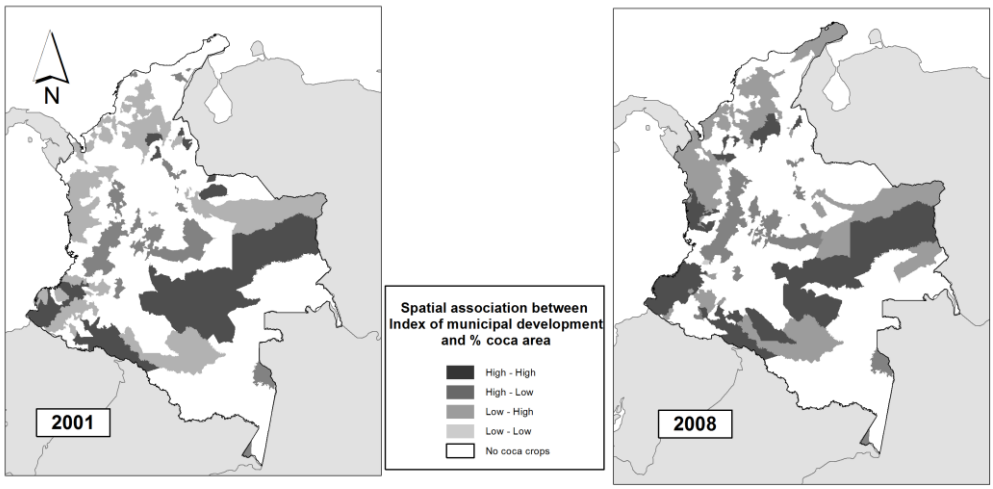


Map 4. LISA map for UBNI for rural areas (2005) and percentage of coca area (2001-2008) by municipality (significant clusters at 0.05 sig. level)

In 2001 there is a significant spatial association between coca growing municipalities and low rural population density (H-L cluster), however significant clusters proving spatial relationship between areas without coca (or with low coca levels) and low rural population density areas (L-L cluster) in other regions was found as well. For the year 2008 an expansion of the CCAs associated significantly with low rural population density (H-L clusters) was found towards the Pacific and the north of the Andean region.

Economic factors: Compared to the global multivariate analysis (table 3), different results were found in the local level spatial analysis regarding the association between levels of GDP per capita level and coca cultivation. While there was an inverse significant association at the global level in 2001 and 2008, there was no association between them at the local level. In addition, "road density" which is a factor that facilitates market development shows a significant negative spatial association with the coca municipalities (H-L cluster), implying that CCAs that are isolated by road transport have a higher presence of coca cultivation. The H-L cluster in the traditional coca regions in 2001 and the expansion of the H-L cluster in 2008 towards the Pacific, Caribbean and the northern region of the Andes confirms this finding.

Institutional factors: Using the index of municipal development (IMD), the local spatial association analysis showed the presence of H-L cluster in the coca growing areas (map 5), implying that coca growing municipalities are associated with municipalities which have low levels of development In 2001. However, areas with low levels of IMD were found as well associated to municipalities with low (or null) coca area. In 2008 the H-L clusters shifted towards the Pacific and Caribbean regions from the Amazon region. On the other hand, variables linked with violent acts and murders by illegal armed groups (proxy of weakness state) show the following results: in 2001 H-H clusters were identified in the CCAs (municipalities with high levels of percentage of coca area associated with zones with high levels of violent acts and murders by illegal armed groups). Nevertheless also L-H clusters were found, showing that in areas with a low to null presence of coca, illegal armed groups are also present (map 4). In 2008 similar results was obtained in relation with the significative variables than in 2001, the only difference was that the H-H significative were displaced to the southwest and the north of the country



Map 5. LISA map for Index of municipal development (2001 – 2008) and % coca area (2001 - 2008) by municipality (significant clusters at 0.05 sig. level)

5. Discussion

We thus share Thoumi's (Thoumi, 2005, 2005a) point that particular variables such as the economic incentive (profitability) generated by the illegality and the high global demand for cocaine cannot in its own explain why coca cultivation and cocaine production is concentrated in countries like Colombia, from our analysis what explain that behaviour is related with the regional characteristics associated to the CCAs.. We show that there is no single regional factor associated exclusively with coca growing areas in Colombia. For example that factors such as armed violence and conflict and the high levels of unsatisfied basic need and poverty often cited as a variables associated with the expansion of the cultivation of coca (DNP, 2003; Angrist and Kugler, 2008; Dion and Russler, 2008) are not exclusive associated to the coca growing areas. This finding also concurs with the view that illegal groups have existed and developed in Colombia independently from coca cultivation (Rangel, 2000; Díaz, 2004) and with that illicit crops do not seem to be linked directly to the initiation of armed conflicts and hence the presence of illegal armed groups, but they do seem to elongate pre-existing wars (Ross, 2004).

To the best of our knowledge this is the first study carried out with spatial explicit data at the municipal scale covering the whole of Colombia and different variables, using Local Indicator of Spatial Analysis (LISA). This kind of analysis has been helpful in identifying the regional characteristics of the CCAs and without use causal analysis.

This study has focused on a set of key ecological, institutional, economic and social factors, here we show that what makes particular areas in Colombia become coca growing areas are not individual or particular variables but a set of specific regional conditions that make possible its existence and expansion (low levels of municipal development, low road density, high presence of primary forest, forced displacement, presence of illegal armed groups and a high index of unsatisfied basic needs).

In relation to the deforestation analysis, given that our analysis of deforestation are based on data of natural forest existent in 2000, is possible the existence of an over – estimation, because part of the natural forest in 2000 could be transformed first to agriculture or other activity and after in coca, and not to be a direct process of transformation of natural forest to coca. Since this research is advancing, it will continue the work to refine and improve this

information. However, the estimates are significant because show how the deforestation by coca has change geographically to the Pacific region, where one of the two World Biodiversity hotspots Most Important in exist (Myers *et al.*, 2000).

Regarding the discussion of specific results we found that literature confirms a positive relationship between road density and deforestation (Vance and Geoghegan, 2002; Ali *et al.*, 2005; Perez-Verdin *et al.*, 2009). However in the case of coca crops, a low road density being associated with low accessibility is associated with the maintenance of coca cultivation hence allowing coca cultivation to remain in the area and refrain from expanding to other areas causing further deforestation. Additionally, forest cover in isolated areas provides suitable conditions for concealing coca cultivation. Nevertheless, once land under coca cultivation expands, it is a major driver of deforestation due to the establishment of roads and trots that serve for the transport of chemical supplies for the processing of the cocaine (Rincon *et al.*, 2006), despite much coca transport being conducted by rivers.

On the other hand the global spatial analysis indicates that there is an inverse correlation between GDP per capita and areas where coca cultivation can be found. Nevertheless the association is not statistically significant when the analysis is carried out taking into account local level factors. Using the local level analysis, we can see that coca crops can be found in both high and low GDP areas, this is explained because some coca municipalities are also important in terms of extractive natural resources such as gold mining, oil and palm oil plantations, which implies high level of GDP percapita, nevertheless have high levels of inequality. In future research its necessary analyze the relationship between coca municipalities and the distribution of wealth, since no data were available at the municipal level. In the research an exercise was done using the land distribution index, taken as a source work (Offstein, 2003; Offstein *et al.*, 2003), however this indicator did not reflect adequately the land concentration by illegal armed groups and drug dealers during the past

decades (Posada, 2009). Not having a reliable source of information can explain the why the local association analysis were not significant, however, is a variable that must be taken into account in future studies, when better information be available.

One of the most frequently approach mentioned by society and government to solve the expansion of illicit coca is transform the coca region in productive zone of legal good, through planting and alternative product market as for example the palm oil plantation (Fedepalma, 2006; DNP, 2007; Fedepalma, 2007). We posit here based on the data analysed that this is a simplification of the problem because coca crops expansion is not a exclusively associated with poverty and low levels of GDP, even if the alternative product generate economical benefits, if the regions continue to exhibit characteristics such as low state presence and low levels of municipal development, the most probable is that even with crops as palm oil may remain deforestation and the social conflict (Comision intereclesial de justicia y paz, 2007; Goebertus Estrada, 2008; Grupo Semillas, 2008). Because of that the discourse against the illicit crops supported in its social and environmental impacts (which are true), don't have sense if the proposed solutions do not take into account regional characteristics and can generate worst social and environmental impacts. New productive projects such as oil palm and other crops can replace illicit crops (or possibly move them to other locations) but can continue generating new socio-environmental conflicts (Snyder, 2006) if institutional problems are not resolve in these regions.

Moreover, some current policies such as aerial aspersion of illicit crops might just create a temporary effect (Walsh *et al.*, 2008) , since as we have seen, there would remain favourable characteristics for the expansion of its cultivation into other regions of Colombia and even outside Colombia, where there is also some evidence of the growth of coca for illicit use in Peru, Bolivia and Ecuador in recent years (UNODC, 2009b, 2009c). It is thus important to investigate which are the regional characteristics associated with these new areas of expansion of coca crops outside Colombia too.

6. Conclusion

We identified that during the study period (2001 -2008) the expansion of illicit crops in Colombia produced a process of deforestation, which affected mainly humid tropical forest. We found that in 2001 the most affected ecosystems by such expansion of coca cultivation have been the humid tropical forests of the Orinoco and Amazon regions, with 67600 ha of coca. This value decline in 2008, were an estimated 20,555 hectares of coca had been established in this ecosystem. However, this decrease was partially offset by an expansion of crops to other humid tropical region mainly the forests of the Pacific region. It was estimated that in 2001, 1982 ha of coca had been located in humid tropical forests of the Pacific region, this percentage increased in 2008 to 8166 ha, (11%) in this ecosystem.. In general it was estimated that 58% of the total area under cocaine in 2008, had been natural forest in 2000.

A multivariate global spatial analysis has shown that the coca growing municipalities are not unexpectedly associated significantly to areas with low levels of road density, GDP per capita, rural population density, municipal development and a high level of unsatisfied basic needs in rural areas, forced displacement, presence of illegal armed groups and high percentage of forest land cover. The analysis at a local level (LISA analysis) has further allowed to show that (1) none of the analyzed regional variables can be considered as associated exclusively with the CCAs as these factors were also found associated to municipalities without coca crops; (2) Although there are no individual regional factors exclusively associated with the CCAs, there is a group of common factors in these areas, including low levels of municipal development, low road density, high presence of primary forest, forced displacement, presence of illegal armed groups and a high index of unsatisfied basic needs; (3) In 2008 there was a displacement of the coca crops (to the Pacific, the Caribbean and northern area of the Andean region), in the new areas similar significant spatial correlation was found with the variables analysed. This means that between 2001 and 2008 the coca crops were displaced to areas with similar regional characteristics.

The CCAs have particular regional characteristics that create enabling conditions for deforestation. Despite remaining in areas with high percentage of primary forests, as they coincide with favourable environment conditions for coca production, these zones remain not only physically isolated (low road density), but also socially deprived as reflected by their high index of unsatisfied basic needs index, as well institutionally impaired as reflected by

their low indices of municipal development. These characteristics create an enabling environment for the existence of illegal armed groups to enforce control over the territory and its population through violence and forced displacement. Under these circumstances the forests and the local population become easily exploitable for illegal activities. Through violence, a new structure of rules are created in these regions, in which the forest is considered as an easily and freely utilizable resource, this in combination with a population in low social conditions create a favourable scenery for the deforestation by coca crops for illegal use.

This context leads to re-evaluate drug policy that has been implemented in Colombia during the past 10 years, specifically relating to aerial spraying and manual eradication. While continues existing regions that have the common characteristics identified in the analysis, illegal activities such as coca cultivation for the cocaine production and even other activities such as mining (Coltan, Gold) or palm cultivation that have been produced in an illegal way in other regions (Ballvé, 2009) will continue to expand.

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