Coca (Erythroxylon coca) crops and social-environmental conflicts: a spatial analysis

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Abstract

The cultivation of coca (*Erythroxylon coca*) in Colombia represents the first step of the largest illegal agribusiness that exists in the world, namely Cocaine. In this production chain, the small local cultivators consists of the first step, followed by the step, where most of the money profit is made. This sphase correspond to the elaboration of cocaine and its commercialization at a global scale which is in the hands of illegal armed groups and drug dealers. Most of the literature related to illicit crops considers the national and global factors that influence the expansion of these products. However, only little is written in the scientific literature concerning the local conditions where the social-environmental impacts due to these activities are concentrated. This study analyses for the first time the local factors (social, economic, environmental and institutional) associated to the expansion of cocaine during the last decade and how these activities have provided the favourable settings for the increase of deforestation in zones of high environmental importance. For the proposed analysis a social-ecological conceptual framework was made, based on literature reviews which were confirmed by statistical analysis of data at a municipal level and the use of bivariate Local Indicators of Spatial Association (LISA) during the two year period of this study. This has allowed an improved comprehension of the complexity between the coca cultivations and its association with the emergence of social-environmental conflicts. It is shown that an relationship exists between deforestation of primary forest in low-laying areas and the increase of cultivated areas of coca with an intensification of land-use conflicts. This study demonstrates the environmental, institutional and social-economical resemblances that determine the establishment of coca cultivations at a local level and its relationship with increase of coca cultivations towards the north and southwest of Colombia and as such the expansion of the social-environmental conflicts.

Keywords: Coca crops, socio-environmental conflicts, spatial analysis

INTRODUCTION

Deforestation is an increasing and complex problem mainly in tropical countries, and has been explored from a variety of disciplinary perspectives: Economically, environmentally and socially (Rock 1996; Angelsen and Kaimowitz 1999; Deininger and Minten 2002; Scrieciu 2007; Khan and Khan 2009) and in more recent years from the point of view of institutions (Culas 2007; Evans *et al*. 2008). Most research about deforestation is focused on the deforestation caused by activities such as wood, palm oil, and agriculture expansion; however there is a lack of studies on deforestation caused by illegal cultivations such as the coca crops. Most often it is addressed as just an additional driver of deforestation (Armenteras *et al*. 2009) without going into details of the particular local characteristics. Generally these studies do not differentiate between the associated factors of the deforestation by the cultivation of coca and other causes of deforestation (legal crops, oil exploitation, etc). The deforestation by coca crops for the cocaine production exists only in three countries, namely Colombia, Peru and Bolivia. While the cultivation of coca is of traditional use in Peru and Bolivia and a few regions of Colombia, the manufacture of cocaine is the main purpose of the coca production in Colombia.

The studies about deforestation by coca crops in Colombia have been realized principally by the Integrated System of Monitoring of Illicit Crops ("Sistema Integrado de Monitoreo de Cultivos Ilícitos") of the United Nations on Drugs and Crime – UNODC - (UNODC 2006; 2008; 2009), and have been focused on estimating deforestation by coca at a national and departmental level.

The producing countries of coca for cocaine are under influence of pressures within an external international framework, consisting of two fundamental components: i) The existence of a continuous demand for cocaine. The annual prevalence of cocaine use at a global scale was assessed to range from 15,6 to 20,8 million people, equivalent to 0,4% to 0,5% of the population aged between 15 and 64 years (UNODC, 2008); and ii) Coca and cocaine are considered illegal. In a global agreement the coca leaf has been considered a drug in accordance to the 1961-Single Convention and is therefore only permitted for medical, scientific or traditional use according to the 1988-Convention against Illicit Traffic in Narcotic Drugs and Psychotropic Substances (UNODC, 2008). In this international context a monetary incentive has been generated for the cultivation

of coca and created a market that could only be satisfied by specific countries and particularly by zones within countries which present the particular internal conditions for the production of the basic input, namely “la coca”, or “the coke”. These conditions are more complex than just a particular zone that exploits the economic benefits of coca. Even more, until now it has not been explained why the production has been concentrated in only three countries, when many more other countries could obtain benefits from its production (Thoumi 2005a; Thoumi 2005b; Thoumi 2005c).

In the last decade, authors have identified different factors associated to the coca crops, such as economical factors (Rocha 1997; 2000; Thoumi 2002; Becker *et al*. 2004; Ibanez and Carlsson 2009), environmental factors (Álvarez 2001; Álvarez 2007) and factors related to institutional and social topics such as forced displacement (UNDP - United Nations Development Programme. 2003; Ibáñez and Vélez 2008), the concentration of land (Fajardo 2002; Posada 2009), the violence and the armed conflict (Díaz 2004; Garcés 2005; Vargas 2005) and the existence of low levels of social capital (Thoumi 2005).

The diversity of factors associated with coca production shows the complexity of the topic. The main objective of this study is to define the local conditions that characterize the areas associated to the coca municipalities in Colombia and how these conditions create a favourable environment for deforestation by coca crops. Furthermore, to be able to characterize the complexity of the factors that shape these particular circumstances for coca production, the social, economic, environmental and institutional dimensions associated with the coca crops are included as part of the analysis.

This research shows how neither of the factors studied can be considered associate exclusively to the coca regions, because these factors were found in other no coca regions of Colombia as well. However, we found that the coca regions have common social, economic, environmental and institutional characteristics, this means that although there are no individual factors associated exclusively to the coca regions, there are a group of common factors that exist only in the coca regions and that as a whole create a suitable environment to the deforestation by coca crops.

1. METHODOLOGY

The developed methodology in this study was implemented in five steps and are demonstrated in Figure 1.

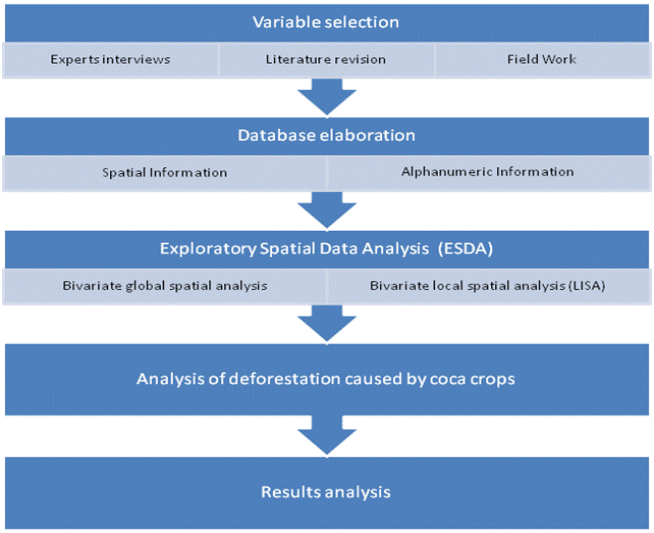

Figure 1. Methodological framework

1.1 Study area

Colombia has 5 continental natural regions which are shown in Figure 2., namely Andean (AN), Caribbean (CA), Pacific (PA), Orinoquian (OR), Amazon (AM) and one insular natural region. The country is divided into 32 departments and 1101 municipalities, of which 23 departments and 274 municipalities have shown presence of coca for at least one year during the period 2001-2008. Coca crops are mainly found in the Amazon and the pacific region and in less proportion in the other continental natural regions.

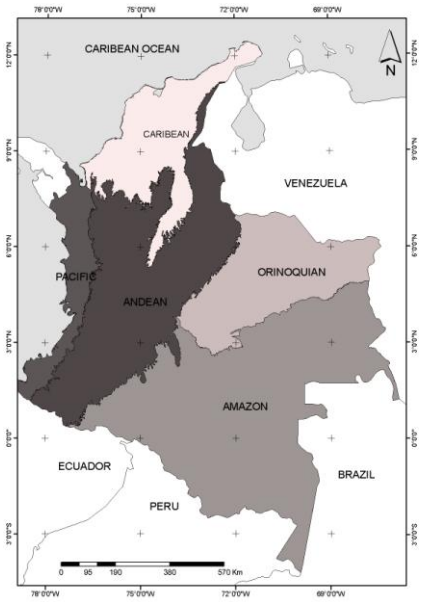

Figure 2. Natural continental regions of Colombia

1.2 Variables selection

With the purpose of applying an appropriate selection of the variables to use, interviews to experts were done, combined with an extensive revision of associated literature that included gray literature. A fieldwork in two municipalities, namely Rosario and Leiva, of the department of Nariño was undertaken, in which interviews to representatives of the public sector (education, health and local government) and local population was done with the objective to identify new possible variables.

1.3 Database design

The Database was constructed using different sources of information of public and private institutions, NGOs and research institutions. Table 1 shows the selected variables at municipal level, which were classified into four categories: social, economic, environmental and institutional. Information on coca crops has been made available by the Integrated System of Monitoring of Illicit Crops ("Sistema Integrado de Monitoreo de Cultivos Ilícitos" in Spanish) of the United Nations on Drugs and Crime, who use teledetection of satellite images to obtain information on the location and extension of the crops.

To acquire data on coca crops at municipal level, information from the year 2001 and 2008 were used for analysis. If information of these years would not be available, data of the closest date to the studied years was used. When variables only presented data of

one of the selected years, this information was used as substitute for the lacking year. Table 1 presents the list of variables used for analysis. To obtain estimations on the weakness of the State at a municipal level, it was decided to use as a proxy the "presence of illegal armed groups" which was estimated through the number of violent actions afflicted by these groups.

Table 1 Selected variables

Variable by municipality		
Category	**Name**	**Source**
Economical	GDP per capita (2002 - 2007)	National Administrative Department of Statistics - DANE, estimation by the authors
Economical	GINI of land distribution (2002)	Offstein 2003
Economical	Primary roads density (2005)	Instituto Geografico Agustin Codazzi - IGAC
Social	Forced displacement (expulsion and reception) (2001 – 2008)	Accion Social - Presidency of the Republic (Colombia)
Social	Rural Basic unsatisfied Needs Index (2005)	National Administrative Department of Statistics - DANE
Social	Rural density population (2005)	National Administrative Department of Statistics - DANE, estimation by the authors
Institutional	Index of municipal development (2006)	National Planning Department of Colombia
Institutional	Number of violent action (2001 – 2007)	Colombia's Ministry of Defence
Institutional	Homicide Rate (2001 - 2008)	Colombian National Police
Environmental	Percentage of primary forest area (2001 - 2008)	Institute of Hydrology, Meteorology and Environmental Studies of Colombia -IDEAM
Analysis variable	Percentage of coca area (2001-2008)	Integrated Illicit Crops Monitoring System – SIMCI (Spanish acronym for "Sistema Integrado de Monitoreo de Cultivos Ilícitos")

1.4 Exploratory Spatial Data Analysis

Exploratory Spatial Data Analysis (ESDA) is an assemblage of techniques that allows visualizing and describing spatial distributions, clusters or hot spots, suggesting spatial regimes or other forms of spatial heterogeneity (Anselin 1994; 1995; Patacchini and Rice 2007). In this study two types of analysis were carried out using ESDA: 1) Global bivariate spatial correlation: This provides a single measure of spatial correlation between the percentage of coca area and the variables selected (violence, population, economical activity, etc.) at the national level and; 2) Local bivariate spatial correlation: This gives an indication of the degree of association (positive or negative) between the

percentage of coca area at a given municipality and the average of any another variable at neighbouring locations (Anselin 1995; Anselin *et al*. 1996; Anselin *et al*. 2002).

To carry out the global and local estimations it was necessary to create a "weight matrix" (Anselin 2005; Anselin *et al*. 2006; Anselin, *et al*. 2007), which defines a local neighbourhood value around each geographic unit. There are three kinds of weight matrices: contiguity (queen, rook), distance, and k-nearest neighbour, which can be used depending on the research aim and data. In this study a weight matrix by ´contiguity´ was chosen as the best option due to the heterogeneity of the municipalities and the wide range of number of neighbourhoods for each municipality.

The Bivariate global and local spatial correlation analysis was based on the ´Moran's I statistic´ which is visualized in the four quadrants of the generalized Moran scatter plot (Anselin 1996; Anselin *et al*. 2002). This plot represents the analyzed variables in a standard form in which the regression line slope is the global Moran's I statistic indicating the spatial association at a national level. Figure 3 shows such a scatter plot, in which the Global Moran´s I is presented between percentage of coca area (2008) and percentage of primary forest (2005). The scatter plot reflects the four types of local spatial correlations between a municipality and its neighbouring zones: High-High (H-H, upper right) contains municipalities with high values in X variable (in our case coca area percentage – "PORCOC8") surrounded by municipalities with high values in the Y variable (Percentage of primary forest for Figura 3.). High-Low (H-L, lower right) consists of high values of X variable associated with low values in Y variable in neighbouring areas (low or null values in Y variable). Low-Low (L-L, lower left) consists of municipalities with low or null value in X variable surrounded by municipalities with low or null values in Y variable; and Low-High (L-H, upper left) contains low or null values in X variable with high neighbour values in Y variable.

The significance analysis of the correlations was based on the permutation approach with 10,000 permutations (Anselin, *et al*. 2002; Anselin, 2005). A map showing the where significant local Moran statistics is found, is referred to as a LISA (Local Indicators of Spatial Analysis) Cluster Map. Figure 4 shows such a map: dark black indicates H-H values, grey shows H-L values, black clear L-H values and white for L-L values. This map highlights the significant spatial clusters, showing specifically the centres of the clusters. It should be taken into account that although neighbouring

regions are not highlighted, the spatial range of the clusters should be considered in the broader context of the region.

The main contribution of the ESDA is to highlight potentially interesting features in the data and to facilitate the exploration process. The bivariate analysis of spatial correlation between the percentage of area in coca crops and each one of the social, environmental, and economical variables was implemented for the two study years, 2001 and 2008. The bivariate analyses do not constitute of an analysis of causality, nor can they be considered deterministic: They only show how the coca municipals are associated spatially with areas of social, economic and environmental similarities.

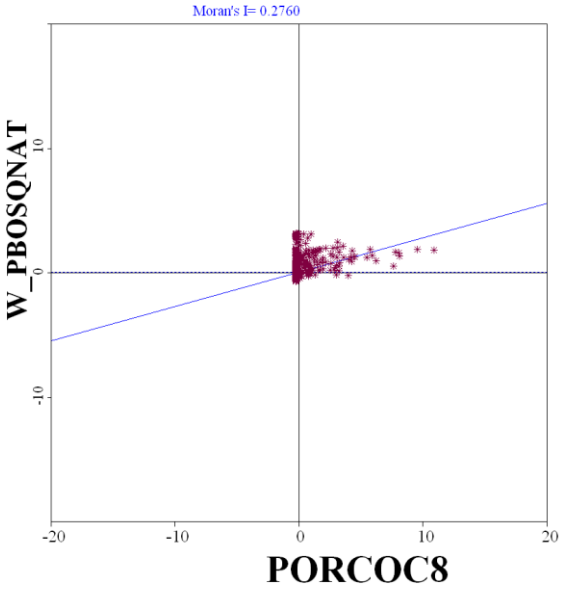

Figure 3. Scatter plot, Global Moran´s *I* between percentage of coca area in 2008 (W_PBOSQNAT) and percentage of primary forest in 2005 (PORCOC8).

1.5 Analysis of deforestation

The analysis of deforestation was conducted based on information on the ecosystems of Colombia for the year 2000 (IDEAM *et al*. 2007). A total of 154 ecosystems were grouped into 3 principal and 32 sub-biomes. Sixteen types of land cover were grouped into 8 natural classes (natural continental waters, shrubs, natural forests, grasslands, grasses and coastal bushes, continental hydrophytes, coastal lakes and estuaries, and secondary vegetation) and 8 transformed classes (heterogeneous agricultural areas, largely alternated areas, urban areas, artificial continental water, forest plantation, annual or transitory cultivations, (semi-) permanent crops and grasses). This land cover map was overlaid by the coca census data for the study period 2001-2008, to be able to

determine the percentage of cultivations in each of the identified land cover types of the country. Based on estimations on deforestation realized by SIMCI on municipal level (UNODC - United Nations Office on Drugs and Crime. 2006; UNODC - United Nations Office on Drugs and Crime. 2008) and the environmental characteristics of the municipals other possible areas of coca cultivations were identified.

2. RESULTS

2.1 Bivariate global spatial analysis

A significant global spatial association was identified between the percentage of coca area per municipality and for each of the used variables in the analysis (See Table 2). It is seen that the value of the correlation increases in the year 2008. The variables that show mayor coefficients of correlation were primary forest percentage, presence of illegal armed groups (Number of violent actions), road density, municipal development index and the index of rural unsatisfied basic needs index (RUBN). PIB per capita and the rural population density obtained inferior values.

Table 2. Bivariate Global Spatial Analysis (significant associations with Percentage of coca area). 2001: Initial year; 2008 Final year.

Category	Variable	Relation	Significant association	
			2001	2008
Social	Rural Unsatisfied Basic Needs Index - RUBN	Positive	0,035	0,179
Social	Rural Density population	Negative	-0,008	-0,018
Social	Forced Displacement	Positive	0,1247	0,2063
Economical	GDP per capita	Negative	-0,0442	-0,073
Economical	Primary Road Density	Negative	-0,086	-0,2377
Institutional	Index of Municipal development	Negative	- 0,099	- 0,253
Institutional	Homicides rate (Proxy for illegal groups presence)	Positive	0,017	0,1475
Institutional	Number of Violent action 2001 – 2007 (Proxy for illegal groups presence)	Positive	0,17	0,18
Environmental	Percentage of primary forest	Positive	0,1251	0,276

In the correlation analysis an inverse relationship was shown in the case of rural population density, PIB per capita, primary road density and the municipal development index. Direct (positive) relationships were found with the RUBN index, homicide occurrence, forced displacement, violent acts committed by illegal armed groups and percentage of primary forest.

2.2 Bivariate Local Spatial Analysis (Local Indicators of Spatial Association – LISA)

Environmental factors: Bivariate local spatial analysis for the year 2001 shows a positive association between the coca municipals and the zones of high primary forest percentages (H-H clusters). Nevertheless for the mentioned year it was also found that zones with high percentages of primary forest were associated with municipals with low to null presence of coca crops (L-H). When analysis was performed for the year 2008, an expansion of the H-H cluster was found towards the Pacific and the Caribbean region. This illustrates how the coca crops are sustained and are displaced to zones with high percentages of primary forest. In the analysis a geographical change in the conformation of the H-H clusters was shown: While in the year 2001 coca crops were concentrated in the Amazon and Orinoquian region, by 2008 they were displaced to the Pacific and Caribbean region.

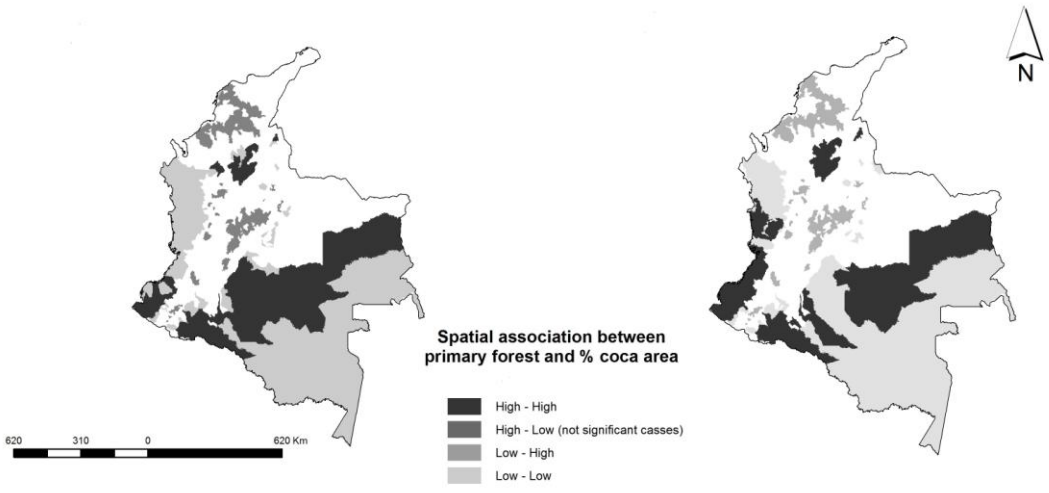

Figure 4. LISA map for percentage of coca area (2001-2008) and percentage of primary forest (2001 - 2008) by municipality. Significant at 0.05 level.

Social Factors: Results shows that for the year 2001 the coca municipalities are significantly associated to zones of high levels of the RUBN index (H-H cluster relation – Figure 5). This cluster is mainly found in the Amazon and Orinoquian. Nevertheless L-H cluster was also identified in the Pacific and the Caribbean region, which indicates the existence of zones with high RUBN levels associated to municipalities with low or null coca levels. In the analysis of 2008 an increase of the H-H cluster was found mainly in the Pacific, Caribbean and northern areas of the Andean region, while a decrease of the H-H cluster was observed in the Amazon region. As expected in the Andean region the L-L cluster was identified as the municipalities located in the Andean region generally do not present the appropriate environmental conditions to cultivate coca and additionally have always presented the highest levels of wellbeing of the country.

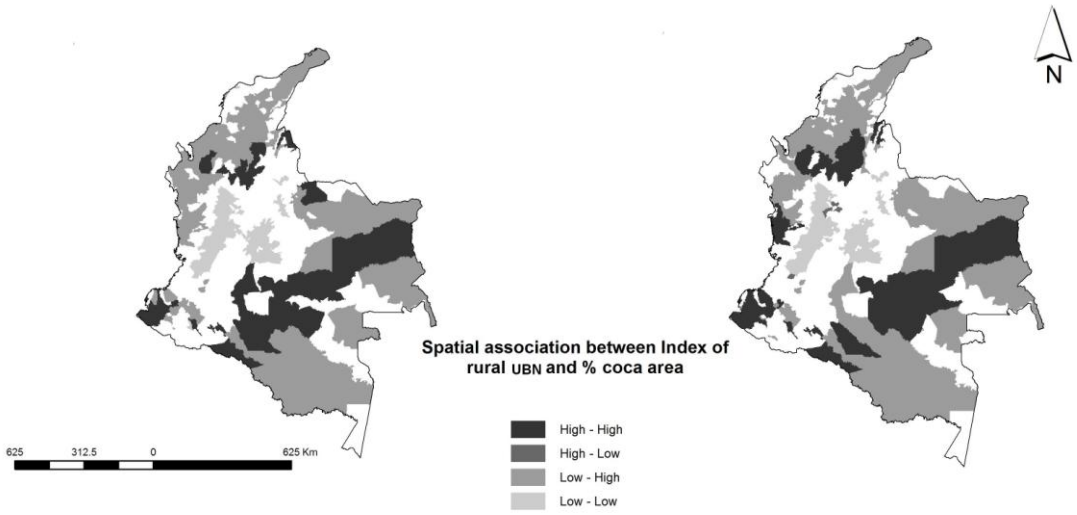

Figure 5. LISA map for percentage of coca area (2001-2008) and Index of Rural Unsatisfied Basic Needs (2005) by municipality. Significant cluster at 0.05 level.

The bivariate analysis of spatial association in case of rural density showed a significant spatial association between the coca municipalities and the zones with low rural density (H-L cluster). However significant clusters proving spatial relationship between area of low rural density and low coca levels were also found (L-L cluster). For the year 2008 the same patterns with the mentioned variables were found, in an expansion of these H-L clusters towards the Pacific and the north of the Andean, while a decrease was seen in the clusters that were present in the Amazon region.

Economic factors: Compared with the global analysis, different results were found in the local analysis of the GDP per capita indicator. H-L cluster (High levels of percentage of coca area and low levels of GDB per capita) was found only in the south of the Pacific region, which extended in 2008 to the entire Pacific region. No H-L cluster was found in the Amazon and Orinoquian region.

One of the analyzed variables, which is included as an economic component (although it could be included in another category) is the principal road density which can be considered as a factor of accessibility to the territories. A significant spatial association was found between the coca municipalities and zones of low road density (H-L cluster), as large areas of the country are isolated, coca crops seem to have a tendency to move to these areas. In the year 2001 the presence of a H-L cluster in the traditional coca regions and the expansion of the H-L cluster in 2008 towards the Pacific, Caribbean and the northern region of the Andes confirms this association. Clusters of spatial association between municipalities with low and null coca levels and zones with low road density were also found in 2001. However it is to these zones where the H-H cluster extended during the study period.

Institutional factors: Analysis of local spatial association using the Index of Municipal Development (DNP 2002) showed the presence of H-L cluster in the coca regions (figure 6), which means that coca municipalities are associated with zones of low levels of municipal development. Nevertheless, L-L clusters were also identified, showing the presence of low levels of municipal development in zones where also low levels of coca crops are found. In the Andean region the L-H cluster was found as was expected, as the region presents the best levels of municipal development and additionally present no coca crops. For the year 2008 the H-L clusters spread out to the Pacific and Caribbean regions, and decreased in the Amazon region. Similarly for the other analyzed variables, the zones of low levels of municipal development are not exclusively associated to coca municipals, but indeed zones to which the coca crops have extended.

On the other hand, results using the variable violent acts afflicted by illegal armed groups (variable used as proxy to assess the presence of illegal armed groups) were similar to the other variables analysed. For the year 2001 H-H clusters were identified in the coca municipalities (municipalities with high levels of percentage of coca area associated with zones where there is a presence of 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.

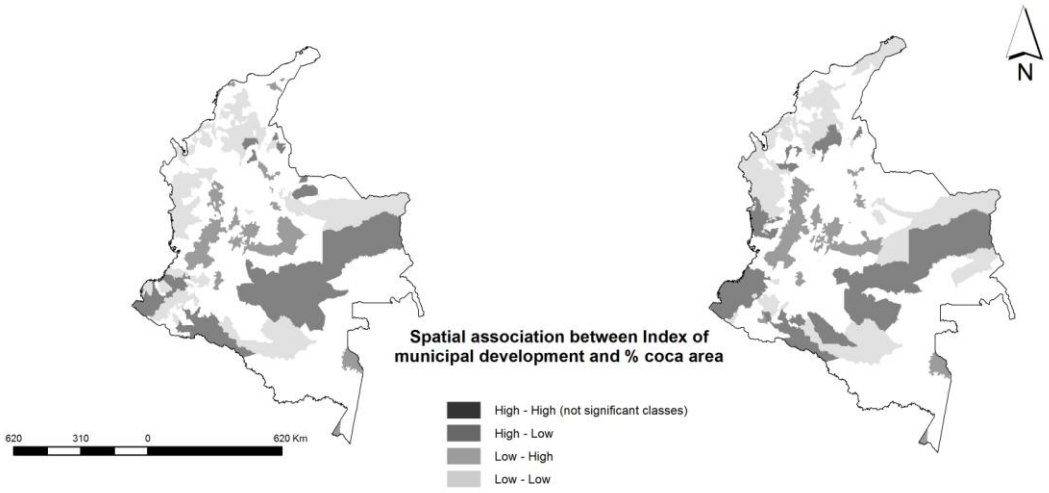

Figure 6. LISA map for percentage of coca area (2001-2008) and Index of municipal development (2001 – 2008) by municipality. Significant cluster at the 0.05 level.

The results of the bivariate analysis showed that none of the analyzed factors in the study can be considered as exclusively associated to the coca zones, as they were also found in other regions were no coca is present. However, it was shown that these factors are present in the coca municipals and furthermore that coca crops are expanding to zones where all of the analyzed factors are present (low road density, rural unsatisfied basic needs, low rural density, high percentage of primary forest percentage, low level of municipal development, presence of armed groups). So, as none of the individual factors exclude the others, there is a group of factors that are commonly found in coca zones. This assemblage of factors is thought to make up the favourable conditions for the coca cultivations to expand.

In Colombia, the illicit crops are located and extend to zones where highest percentages of primary forest is found, which can be explained by the fact that in these regions more easily available area is found for the illegal cultivation of coca. Additionally these zones remain not only physically isolated as is shown by the low road density, but also socially (high rural unsatisfied basic needs) and institutionally (low indices of municipal development). These characteristics allow a favourable environment for the illegal armed groups to enforce control over the territory and the population by using violence and forced displacement (the other two factors associated to coca zones). Under these

circumstances the forests and the local population become easily exploitable for illegal activities.

Large part of the zones with highest percentage of primary forest in Colombia are associated to zones with high levels of rural unsatisfied basic needs, low road density and low presence of the state, conditions that have been exploited by the illegal armed groups. Through violence, a new structure of rules was created in these regions, in which the forest is considered as an easily and freely utilizable resource. In combination with a population in low social conditions (for whom the forest is an easy economic resource) the favourable circumstances for the deforestation are generated.

In Figure 7 a brief resume is presented of these results, in relationship to the external context. It can be observed from the figure that the external demand for an illegal good (cocaine in this case, needing as a supply the coca) encounters in the local conditions in some zones of Colombia, the appropriate place to expand. Furthermore it can be seen that the existing local conditions (social, economic, environmental and institutional) create the circumstances that make the existence of coca cultivations and the expansion of deforestation possible.

The coca cultivations have expanded in territories with a combination of certain common social, economic, environmental and institutional characteristics. One of these characteristics is the richness in primary forest, which unfortunately concurs with low levels of RUBN of the population, the presence of illegal armed groups, the low road density and the inaccessible conditions. Due to these characteristics deforestation is made feasible and has expanded to territories of high importance as is shown in the following section.

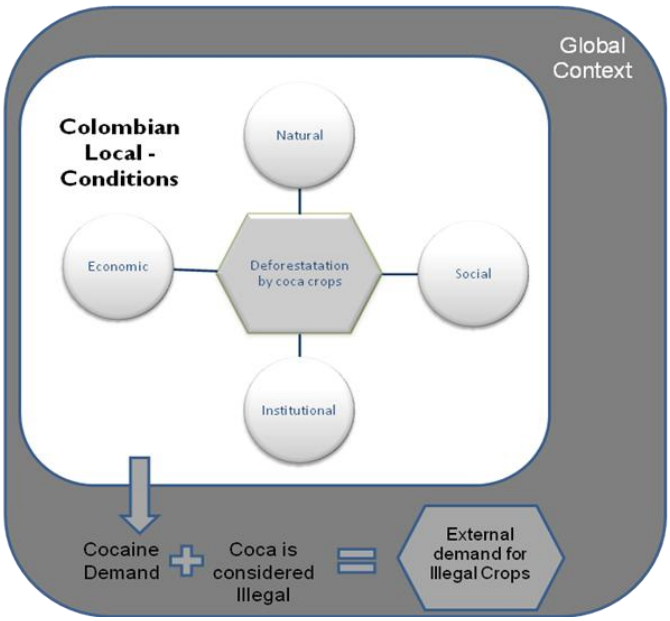

Figure 7. Colombian local conditions vs global context

2.3 Deforestation in the coca regions

Although the coca cultivations were traditionally concentrated in the Amazon and Orinoquia region in Colombia, during the last decade a change has occurred: The region of the Amazon and the Orinoquia decreased while the Pacific, Caribbean and the north of the Andean Region presented an increase in crop cultivations (See Figure 8).

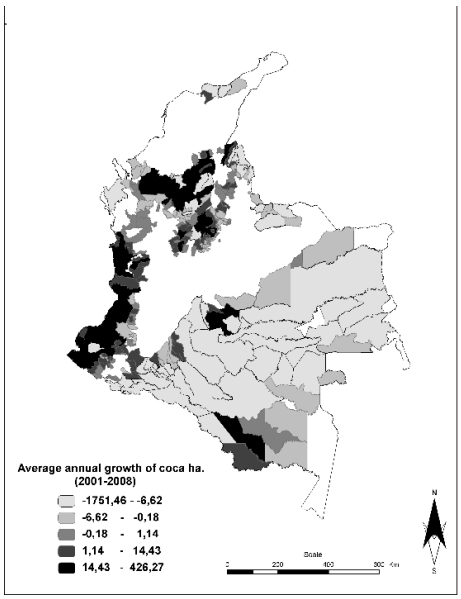

Figure 8. Average annual growth of the coca cultivations (2001-2008)

This has had as a consequence that the extensive and continuous areas of native forest, mainly the humid tropical forest (46%), humid tropical riverine forest (10%) and the savannahs of the Amazon and Orinoquia region are nowadays the target of illicit cultivations as almost 57% is found in these areas. Currently and thanks to the conditions of these regions, this situation is expanding to other zones of the country mainly the tropical humid forest (10%) and the riverine forest in the Pacific, forest of low sub-Andean (8.8%) such as the regions of the tropical humid forest of the Catatumbo (4.7%) and the humid tropical forest of the Magdalena-Caribbean (3.5%).

Between 2001 and 2008 a total of 110,026 ha of primary forest has been transformed due to the expansion of coca cultivations (through an increase of cultivated area). The irregular pattern of displacement characterized by its surprising advance, affected new areas principally of forest where soils are ecologically fragile.

In 2001 it was found that the cultivations are mainly realized in areas that present a warm humid to very humid climate, namely 97% (62% in warm very humid climate and 35% in warm humid climate). The remaining 3% of the crops are small and isolated, and established in warm dry, and mild humid to very humid climates. Likewise (concerning geopedological formations) 49% of these cultivations are found in areas of structural high plains, with slopes less than 50%. Almost 21% of these coca cultivations are found in alluvial plains with slopes less than 7%. The fluvial-coluvial foothills with slopes less than 12% and an imperfect to excessive drainage constitute of the third type of geopedological formation where 8% of the cultivations is found. Mountains with slopes steeper than 50% and structural-erosion hills of slopes of less than 25% form the fourth and fifth place of cultivation presence, with 6% and 5% respectively. These environmental conditions are typical of the Amazon, Caribbean and Pacific region, such as the foothills of the east side of the Eastern Andean Mountain Range and the west side of the Western Andean Mountain Range.

For the year 2008, although the observed tendency continued, a slight decrease of 7% of crops in the warm humid and very humid climates is observed, increasing the presence of the crops in warm dry, humid to very humid temperate and rainy warm climates with 1.7, 1.5, 1.7, and 1% respectively. An important change was observed in the geomorphological conditions of the crops: a significant decrease of 20% was seen in the fluvial-gravitational low hills with slopes less than 50%; it dropped from 44% in 2001

to 24% in 2008. Equally a slight decrease of 3% was observed in the areas of alluvial plains with slopes less than 7%. In contrast, a large increase of 14% was found for areas of fluvial-gravitational mountains with slopes over 50% and in structural-erosion low hills with slopes less than 25%. The presence of coca crops in alluvial-colluvial foothills of slopes less than 12% remained stable through time. These environmental conditions (where an increase of crops was observed) is characteristic of the Pacific region, such as the foothills of the east side of the Eastern Andean Mountain Range and the west side of the Western Andean Mountain Range.

3. DISCUSSION

The discussion is focused on two general aspects. First of all the discussion on some of the results in the study in comparison to the existing literature. This is the case of the results on road density, the presence of armed groups and rural density. On the other side several variables of high importance are discussed but which were not included due to lack of information at a municipal level but that are important to mention, such as the property of land, social welfare, and the weakness and absence of the state. Although the latter factor was included as a proxi, it was not studied completely as a municipal level. Literature has confirmed a positive relationship between roads and deforestation (Vance and Geoghegan 2002; Ali et al. 2005; Perez-Verdin et al. 2009). However in the case of coca crops, the low density of roads and low accessibility provides a way to maintain in clandestine the illegal activities and as such its inverse relationship. Their location in areas with limited accessibility and limited control by the state (where any other illicit crop would have difficulty to compete), creates an economy which is virtually only sustained by illicit money. Additionally, the richness of the forest provides the available area for the coca cultivations and as such a cover to maintain concealed. However, once the coca crops expand, they cause a multiplying effect on deforestation due to the establishment of roads and trots that serve for the transport of chemical supplies for the processing of the cocaine. It can be stated that the expansion of roads and trots is a logic consequence of the expansion of the coca crops, but it must be taking into account that large part of the illegal transport is by river (Vance and Geoghegan 2002; Ali *et al*. 2005; Perez-Verdin *et al*. 2009). Although low density of principal roads is typical of coca areas (being meant to be hidden) coca cultivations demand a minimal grade of contact with the market by rivers, forest pathways and trots. Coca cultivations are still not located in the most inaccessible zones of the country,

where several of the identified factors found in this study are present. In other words, it is possible that in the future the coca advances towards these zones. There has been some evidence of cultivations in the most unreachable departments, such as Vaupés located in the south of the Amazon region.

With respect to presence of illegal armed groups, Ross (2004) states that illicit crops such as opium, coca and cannabis do not seem to be linked directly to the initiation of the conflict and the presence of illegal armed groups, but they do seem to elongate pre-existing wars. In most of the opium and coca exporting states (Afghanistan, Burma, Colombia and Peru) it has been shown that the drug dealers had little to do with the initiation of the existing conflicts but they did extend its presence. In the case of Colombia the illegal groups already existed and developed independently from the coca cultivations. Nevertheless, in the last decades their relationships with this cultivation changed (Rangel 2000; Díaz 2004): In the 2000s decade, these groups converted themselves into traders dealing in cocaine as it was adapted as a new strategy to get economic resources. Actually only 40% of the municipals with presence of illegal groups show coca cultivation and 78% of the coca municipals present illegal groups (UNODC 2009b). The illicit crops seem to have a system of their own that provided the conditions in which illegal armed groups could maintain themselves in the last decade. Nevertheless, historic evidence seems to show that the agribusiness of coca is adaptable, whenever there exists a set of minimum of regional characteristics to develop. Previously the cultivations were controlled by large drug-cartels but after their collapse, they were rapidly replaced by smaller illegal armed groups.

On the other hand, the results showed that the coca municipals were associated with zones with low rural density. However, in a large part of the literature, population is associated with deforestation in a direct way (Angelsen 1999; Pahari and Murai 1999; Dolisca, McDaniel *et al*. 2007; Entwisle *et al*. 2008). These results can be explained by the fact that by being an illegal activity, the coca crops expand to remote territories where population is living that has been excluded socially (high levels of unsatisfied basic needs) and geographically (low road density and the contact with the principal markets). These are furthermore zones with low economic opportunities, presence of illegal armed groups and violence that constantly causes forced displacement. Although these zones present a high percentage of rural population, they are not the most densely populated. As a fact, most coca regions are the ones that have had the most recent

colonization and population increase. Furthermore, these are the areas with a fast exchange of people, some on the run and displaced by violence caused by the appropriation of territories for the cultivation of coca, while others come and go looking for an economic opportunity in the coca production, many without any permanent residence.

4. CONCLUSION

The analysis at a national level (bivariate global spatial analysis) showed that the coca municipals are related significantly to zones with high levels of Rural Unsatisfied Basic Needs, low levels of GDP per capita, rural population and limited municipal development and high levels of forced displacement and homicides, low road density, presence of illegal armed groups and high percentage of forest. These results were expected and are coherent with the literature considering coca crops in Colombia. Nevertheless the analysis at a local level (bivariate global spatial analysis) allowed to determine that none of these factors can be considered as related exclusively to coca zones, as they are also found in regions not considered as coca areas. We found that a group of common factors is present in various regions in Colombia that creates as an assemblage the favourable circumstances for the expansion of coca crops and deforestation.

Based on the bivariate local spatial analysis, it was shown that the coca regions have similar social, economic, environmental and institutional characteristics. Furthermore these crops are located and displaced towards zones with similar characteristics. In 2001 the coca municipals were related significantly with zones of low levels of rural density, municipal development and road density, and high percentages of primary forest, forced displacement and the presence of illegal armed groups. In 2008 the coca crops were displaced to zones with similar characteristics in the Pacific, Caribbean and north of the Andean region.

One of the characteristics of the coca regions has been the high percentage in primary forest. In the deforestation analyses we evidence that the expansion of the coca crops has begun to affect new areas of primary forest in the Pacific region.

Several of the mentioned characteristics are also present in an individual way in other areas, but in the coca regions of Colombia these characteristics exist in a combined way. The richness in forests, the low road density and its inaccessibility, the low conditions of life quality, the weakness and absence of the State and the low levels of social prosperity makes that the illegal armed groups can exercise control over a territory, and as such where expansion of coca is facilitated and therefore the expansion of the deforestation.

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