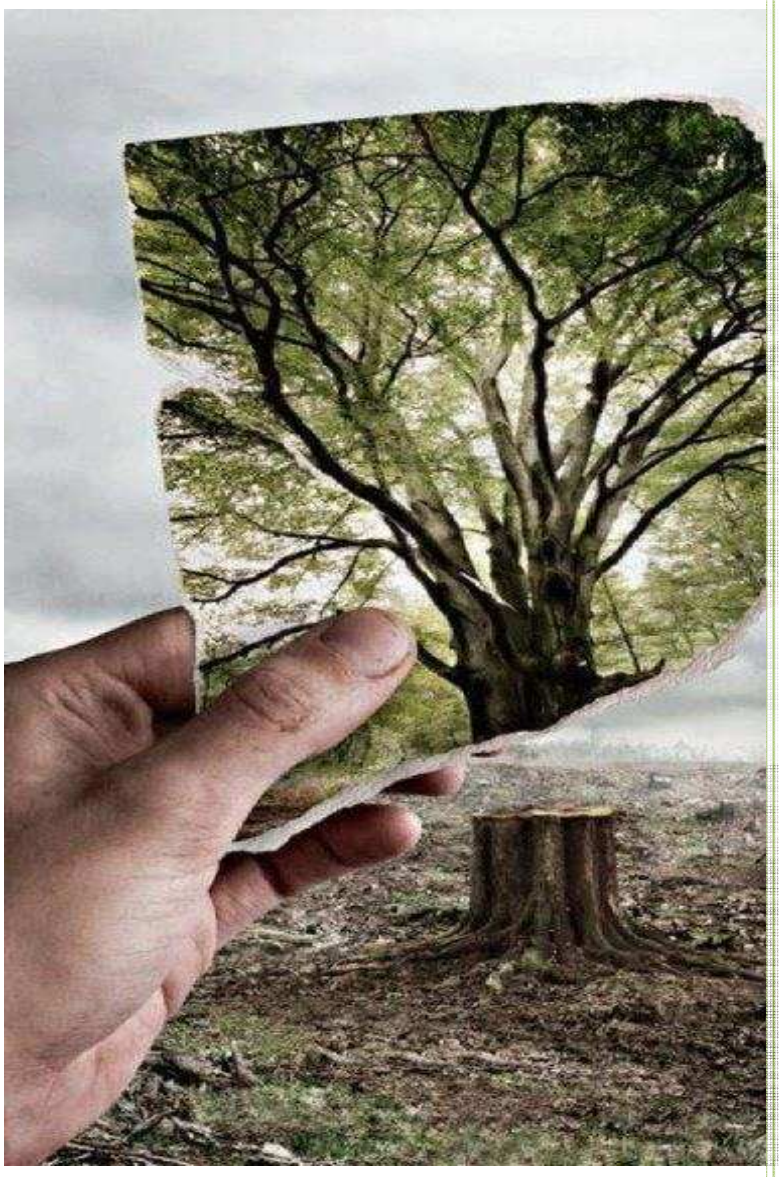
2012

Assessing the ground truth drivers of land cover and land use changes at a local scale in Cundinamarca and Tolima Departments in Colombia



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Abstract

The land use and land cover change is a problem which affects mostly tropical developing countries such as Colombia. Drivers of these changes are both direct and indirect, and exogenous or endogenous and include agricultural expansion, deforestation, climate change, and national and international policies. Drivers are divided according to the grade of expansion and the level of influence on the land. This project proposal evaluated the uses of the land in Colombia, the constraints, land cover, farming distribution, and permanent crops and arable land, by percentage of intensity. Two specific sites were chosen in the departments of Cundinamarca and Tolima by using Terra-i software which identified the land cover and habitat change in real time every sixteen days from 2004 to 2011. The cover and uses of the land for each site are described along with the conflicts in the uses of land. In order to fully understand the issue, both the drivers and the causes of land use and land cover are given, in addition to case studies and photographs. The data was analysed in the field qualitatively through direct interviews to communities in both sites to verify information given by Terra-i. The results focus on the changes in the land use produced by increasing industrialization and overexploitation of the land. Drivers in the land use change are divided into demographic, institutional and technological development, and global environmental change conditions.

1. Introduction

Changes in the coverage and the land use are the most visible signals of the impact of humanity on ecosystems change (Petschel and Lasco, 2005a). These changes have a background of regional, local, national and international scale drivers which are mainly influenced by economic, socio-political and demographic factors (Petschel and Lasco, 2005b).

Increasing population in developing countries is a driving force which demands more land (Jepma, 1995a). According to Harvard University in a presentation "Land Use Change in Developing Countries", 2002, countries in a development process increase population much faster than developed countries at a rate of 2.3% compared with 0.4% for industrialized nations. Due to the rapidly increasing population, the extension of cropland and areas for agricultural services has become a necessity (Etter, et al, 2006).

According to Millennium Ecosystem Assessment 2005, the classification of drivers is expressed as exogenous and endogenous, and direct and indirect drivers. Exogenous and endogenous drivers are defined in terms of decision makers. If decision makers cannot alter but can influence the drivers they are called exogenous. In contrast, if decision makers in a particular scale have influence on the drivers, they are called endogenous. On the other hand, direct and indirect drivers act according to the influence on ecosystem processes.

On a global scale, drivers of ecosystem change are represented by activities where humans have a direct relation. These include population growth, proposal of new technologies, and changes in the behaviour of the environment (Houghton et al. 2001). The land use is determined by agricultural intensification, agricultural development and the extraction of natural resources which produces the conversion, fragmentation and degradation of habitats,

which are key factors in determining the effects on biodiversity by changes in the land cover (Srinivasan and Rogers, 2000).

The lack of land for agricultural purposes has increased deforestation processes mainly in Asia, Africa and Latin America, in countries such as Brazil, Bolivia, Ecuador and Colombia (Achard et al, 2002). For land use planning it is important to consider and understand land cover changes, predictions for future changes in land cover and possible drivers which cause the problem.

In Colombia, there is some evidence from studies focused on the landscape level; however, limited information is available about the drivers which produce the land cover change at local and national levels (Etter et al, 2008a). The landscape represents the interaction between human activities and land transformation produced from natural drivers (Jepson et al, 2008).

During the last decade, these changes in Colombia have increased dramatically due to direct and indirect changes in ecosystem services (Etter et al, 2008b). Direct changes are influenced by local, regional or national decision makers who have the choice and power over changes in technology development or prices in the market. Indirect changes are mainly demographic, economic, socio-political, technological, and cultural (Mai, 2003a). These changes could lead to human conflicts over land, scarcity of agricultural products and serious environmental damage.

The primary reason for this research is to analyse two municipalities in Colombia ("Cota" and "El Espinal") , identifying areas of rapid deforestation or land use change and to ground-truth the data from Terra-i by field visits; establish local drivers of land use change and

explore the impact of change. Directly interviews to the population were done to verify information given by Terra-i about habitat change in those areas.

The sites have been characterized as having highly fertile soils but also industrial activities (DP “Cota and “El Espinal” 2012-1015). Factors affecting these mediums, among others, are: climate change, industrialization, overexploitation, and internal and external policy drivers. Some questions that introduce issues described in this research which are fundamental to determining current and future investigations on changes in the land use are as follows:

What are the processes of land use change identified by Terra-I (e.g. forest to agriculture, agriculture to industry)

Has Terra-i software correctly identified areas with high rates of deforestation during the last eight years?

What are the external drivers in the land use change?

2. Materials and Methods

2.1 Materials

Colombia is a South American country located in the northwest of the continent with an area of 1.13 million km^2. The country is divided into 32 departments and one capital district (Bogota), (figure 1).

Figure 1: Political map of Colombia. Source: Colombia Virtual, 2012

Each department is divided into municipalities and each municipality is divided into veredas (villages). There are seven bio-geographic regions which contrast in biophysical and land use characteristics: The Colombian Amazon, the Andes, the Caribbean, the Orinoco plains, and the Pacific Coast (figure 2).

Figure 2: Colombian Biogeographic regions. Source: Skyscrapers, 2012

2.1.1 Land use in Colombia

According to the world development indicators from the World Bank 2010, the land use in Colombia is divided in four categories: Forestry, pasture, arable and other uses (see figure 3).

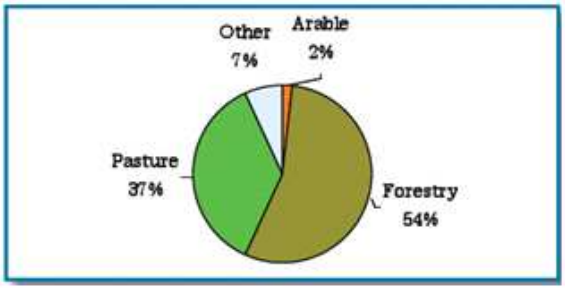

Figure3: Land use in Colombia (2005). Source: World Development Indicators World Bank, 2009

Most of the national territory has undetermined percentage of intensity in permanent crops and arable land, and only the Andean region has departments such as Cundinamarca, Tolima Huila and Cauca with more than 60% of arable land (see figure 4).

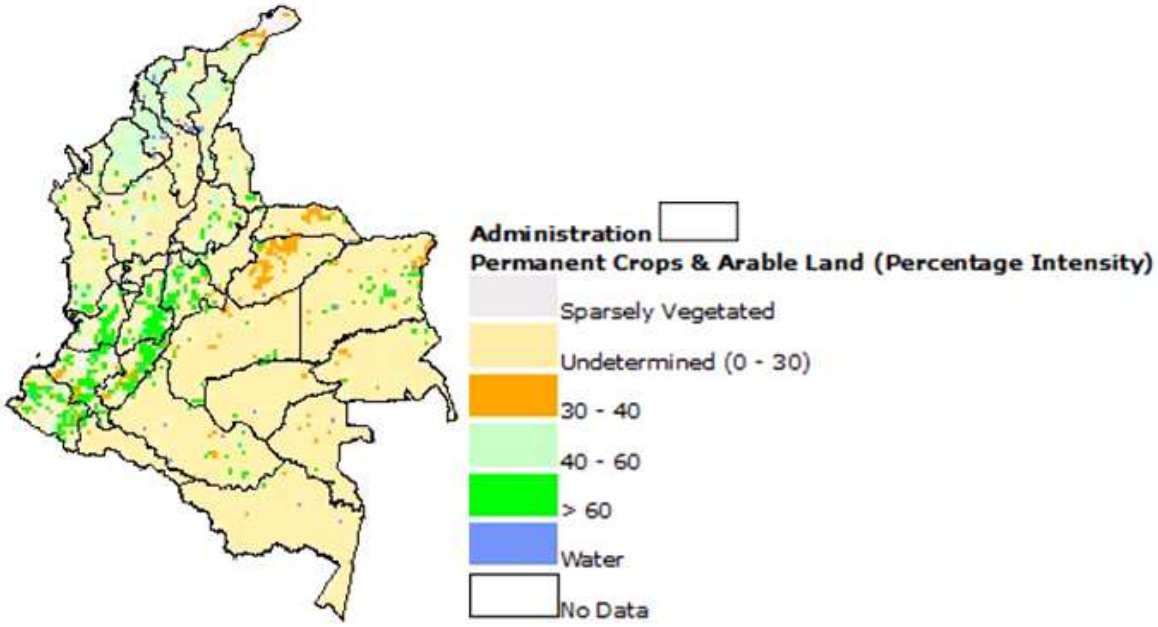

Figure 4: Permanent crops and arable land: Source: Food and Agriculture Organization (FAO), 2012

The proportion of agricultural land in Colombia (which mix pasture and cultivation or arable land) for 2009 was estimated to be around 39%, of which 37% was for pasture and 2% for cultivation (arable land), which supports crops such as rice, corn, sorghum and cotton (figure 3), being in the 103rd position in the world of the 205 countries ranked by the World Bank (table 2). The land covered by forest in 2005 was 54% of the land use in the country (see figure 3 above) (Edmeades, 2009).

	1960-1961	1982-1986	1987-1991	1992-1996	1997-2001	2002-2006	2007-2011	
	Country name				2007	2008	2009	
205	Singapore				0.0	0.0	0.0	
204	Bermuda				20.0	0.0	0.0	
203	Suriname				0.4	0.5	0.5	
202	Greenland				0.6	0.6	0.6	
201	Turks and Caicos Islands				1.1	1.1	1.1	
106	Switzerland				38.1	38.1	38.1	
105	Montenegro				38.2	38.1	38.2	
104	Andorra				38.3	38.3	38.3	
103	Colombia				38.2	38.4	38.3	
102	Austria				39.3	38.5	38.4	
101	Mauritania				38.5	38.5	38.5	
100	Thailand				38.5	38.6	38.7	
5	South Africa				81.8	81.8	81.7	
4	Nigeria				85.6	85.1	81.8	
3	Comoros				80.6	80.6	83.3	
2	Burundi				85.3	85.3	83.7	
1	Uruguay				83.5	85.1	84.6	

Table 2: Agricultural land (% of land area). Ascendant scale. World Bank 2010

The arable land in hectares per person following World Bank 2009 (published in 2010) was on average 0.04 hectares per person being in 163th place in the world among a register of 203 countries and below other countries like Argentina, Paraguay and Uruguay who occupied the 6th, 9th and 11th positions respectively (The World Bank, 2012) (see table 1). Arable land (hectares per person) includes land defined by the FAO as land under temporary crops (double-cropped areas are counted once), temporary meadows for mowing or for pasture, land under market or kitchen gardens, and land left temporarily fallow. Land abandoned as a result of shifting cultivation is excluded.

	1980-1981	1982-1986	1987-1991	1992-1996	1997-2001	2002-2006	2007-2011
	Country name				2007	2008	2009
203	Singapore				0.00	0.00	0.00
202	Bermuda				0.02	0.00	0.00
201	Cayman Islands				0.00	0.00	0.00
200	Bahrain				0.00	0.00	0.00
199	Djibouti				0.00	0.00	0.00
165	Marshall Islands				0.04	0.04	0.04
164	Papua New Guinea				0.04	0.05	0.04
163	Colombia				0.05	0.04	0.04
162	Israel				0.04	0.04	0.04
161	Costa Rica				0.04	0.04	0.04
11	Uruguay				0.40	0.50	0.56
10	Belarus				0.57	0.57	0.58
9	Paraguay				0.59	0.60	0.60
8	Lithuania				0.54	0.55	0.61
7	Ukraine				0.70	0.70	0.71
6	Argentina				0.84	0.81	0.77
5	Russian Federation				0.86	0.86	0.86
4	Niger				1.07	1.03	1.00
3	Canada				1.37	1.35	1.34
2	Kazakhstan				1.47	1.45	1.45
1	Australia				2.10	2.05	2.15

Table 1: Arable land (hectares per person). Ascendant scale. World Bank, 2010.

Colombia is a free market economy with major commercial and investment ties to the United States. The transition from being a highly regulated economy has been underway for more than fifteen years. The country had an average annual economic growth rate of over 5% from 2002 to 2007 which can be attributed to an increase in domestic security, resulting in greater foreign investment; prudent monetary policy; and an increase in exports.

Access to the land in tropical countries is considered an important issue which hugely impacts agricultural services. According to the Colombian newspaper “El Tiempo” in an article published on December 2011, a study conducted by the United Nations Organization for Food and Agriculture (FAO) and global anti-corruption organization “Transparency International” (TI, Spanish acronym), found serious corruption problems in access to land in 61 countries, including Colombia. The Study translated into English reports: “There has been unprecedented pressure on the land, cultivated new areas occupied by expanding urban centres or abandoned due to degradation, climate change and conflict" (El Tiempo newspaper, 2011). This is one of the issues which will be analyzed in this study together with the importance of the extension of services, rural infrastructure and economic incentives.

2.2 Methods

The procedure consisted of a prospective study by the researcher of satellite imagery from Terra i online software created in collaboration with the International Centre for Tropical Agriculture (CIMAT), DAPA (Decision and Policy Analysis), based in Colombia, the Nature Conservancy (TNC), the School of Business and Engineering (HEIG-VD) based in Switzerland), and King’s College London (KCL). The system is based on a “MODIS sensor on NASA’s terra and aqua platforms” to identify in real time the land cover, habitat change and changes in greenness every sixteen days from 2004 to 2011. The programme is trained to understand the normal pattern of changes in vegetation greenness in relation to the terrain and rainfall for a site, and then to mark areas as changed where the greenness suddenly changes well beyond these normal limits.

Terra i manage images following pixels of different colour. Each colour has a pixel number, Julian days, year and date in which the habitat change was presented. Figures above will show in detail the selected areas.

Field visits to each municipality will be developed over two weeks (one week per site). Information were collected and recorded per location, the potential ground truth drivers are analysed through interviews, photographs and visual observations. Visits are registered, recorded and analysed through interviews with residents. This project is a pilot test to verify information given by Terra-i about habitat changes.

2.3 Specific study sites

The sites were selected according to exploration of Terra-i software. The software identified areas with land change mainly by identifying deforestation. Two of the areas near Bogota (the capital of Colombia), display numerous number points represented by red to yellow pixels (figure 5). The points are located in two municipalities: “Cota” in Cundinamarca and “El Espinal”, in Tolima.

Figure 5: Departments of Cundinamarca and Tolima, Colombia

2.3.1 Characteristics of each Municipality

2.3.1.1 Cota-Cundinamarca.

Figure 6: Location of Cota in Cundinamarca. Source: Wikimedia Commons, 2007

Location (Decimal)	4.816667°, -74.1°
Altitude (MASL)	2,566
Area (hectares)	Urban: 141.56 Rural: 5,202
Average temperature (° C)	13.5
Population (inhabitants)	Urban 13,315 Rural: 10,070

Table 3: General Characteristics Cota. Source: Official Cota site, 2012

The municipality is composed of the main town and its eight villages (figure 7).

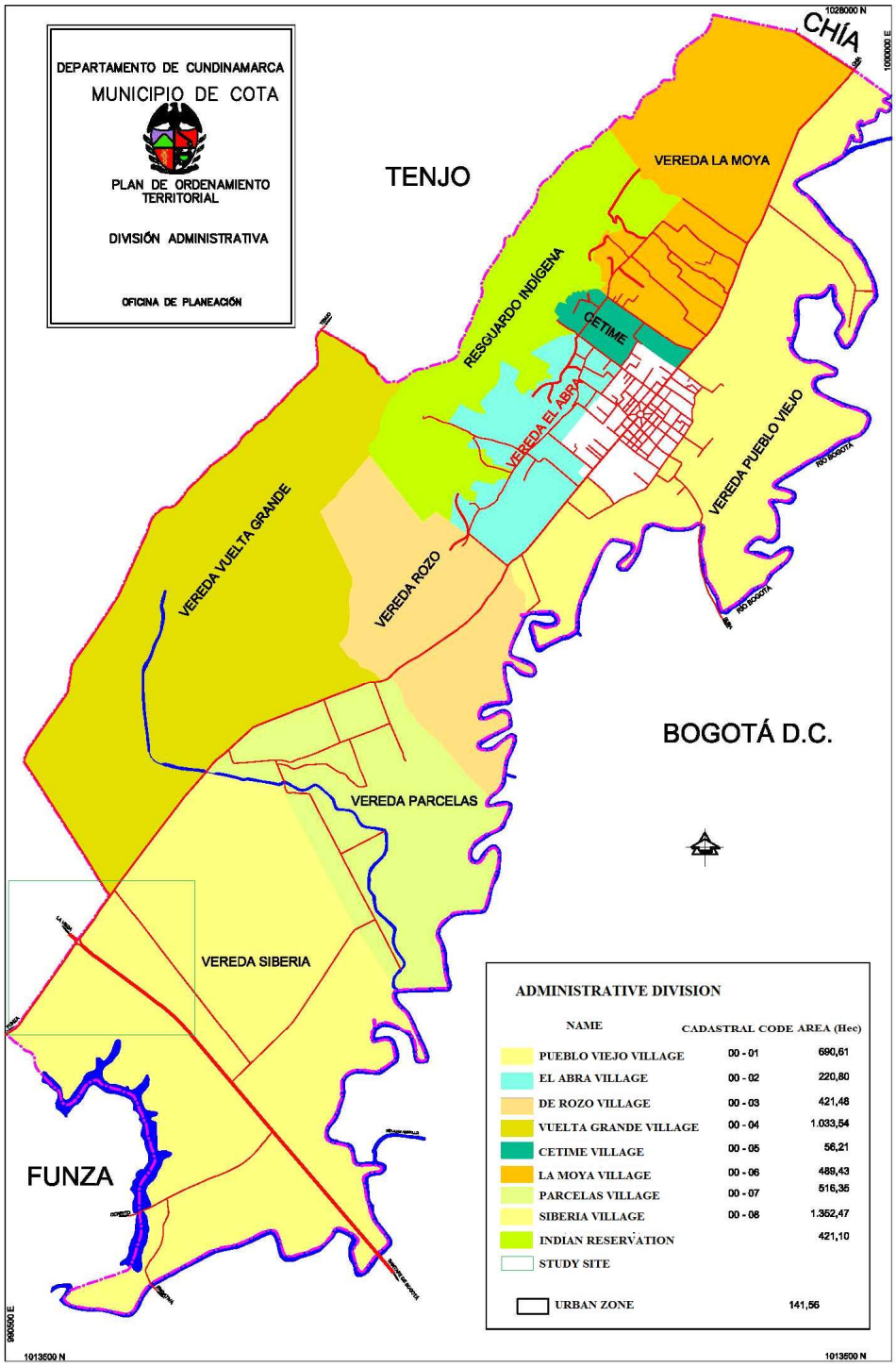

Figure 7: Villages in municipality of Cota (legend translated into English) Scale 1:60000.

Source: Official site Cota, 2012

2.3.1.1.1 Land uses

Land uses in Cota are divided into protective land, productive activity land, and suburban land (see Figure 8).

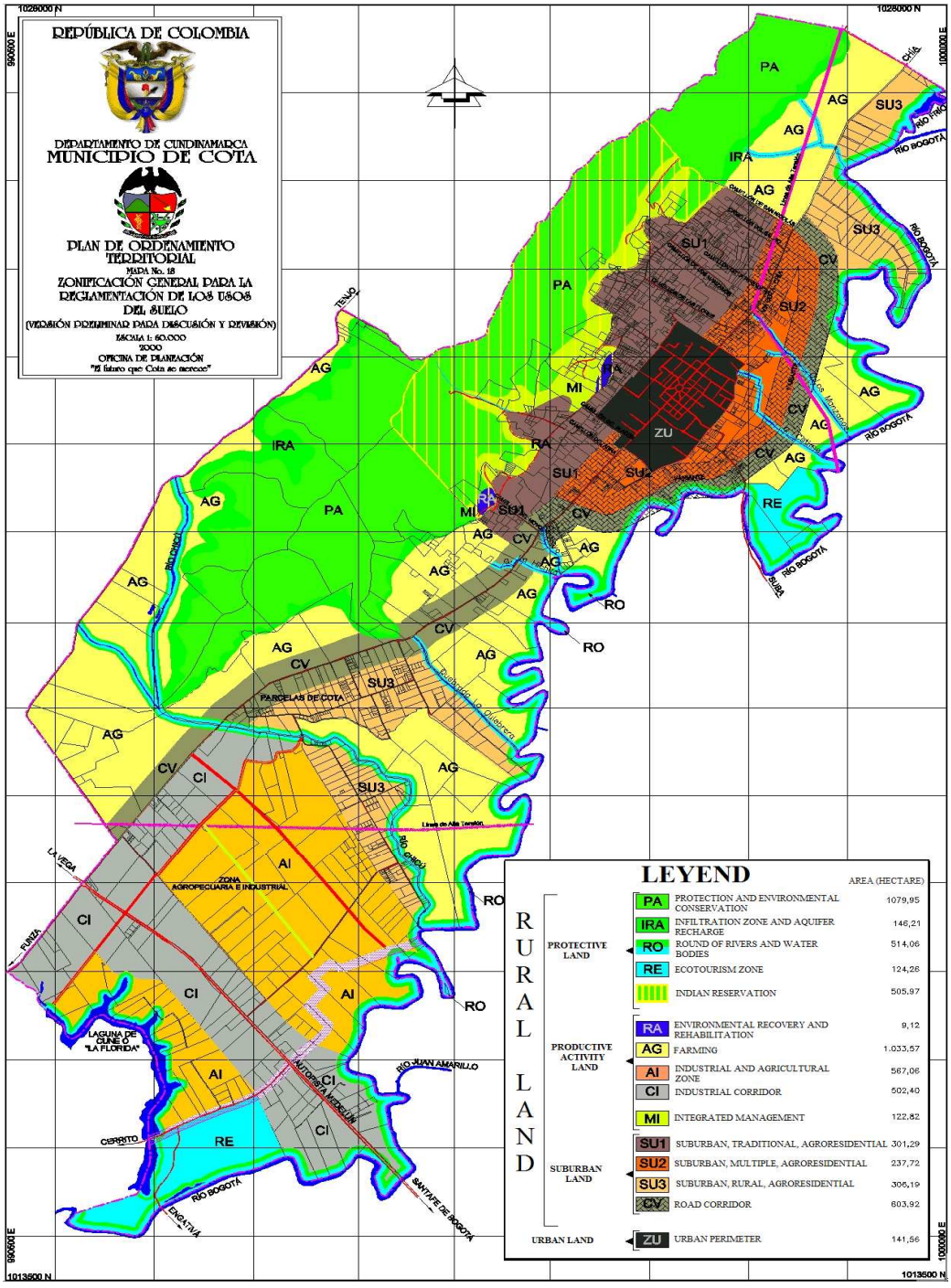

Figure 8: Land uses municipality of Cota scale 1:60,000 (Legend translated into English).

Source: Official site Cota, 2012

2.3.1.1.2 Study Area in Cota

The study area has been located according to the pixel points from Terra-i in the village of Siberia (see Figure 9). The scale of the map is the perfect image to analyse in detail the land use. However, unfortunately using the same scale from the second study site, the image is cloudy and not possible to read.

Figure 9: Deforestation in Siberia (Cota), scale 700:2000ft. Source: Terra-i software, 2012

The area has sloping land with inclinations of up to 25% with mild to moderate limitations related to inadequate annual rainfall distribution. It does not have restrictions on the establishment of crops with long permanence, pastures and forests. The primary use is semi-intensive transient crops. The use of the land around this municipality is mainly for agricultural purposes (IGAC, 2012a).

2.3.1.2 “El Espinal”-Tolima

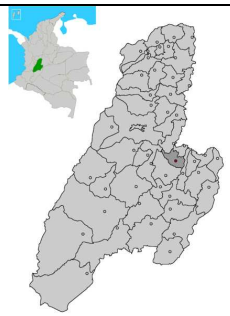

Figure10: Location “El Espinal” in Colombia

Location (Decimal)	4.15°, -74.883333°
Altitude (MASL)	323
Area ($km^{2)}$	Urban: 4. Rural: 212.74
Average temperature (° C)	29
Population (inhabitants)	Urban 55,787 Rural: 20439

Table 4: General characteristics “El Espinal” municipality. Source: Official “El Espinal” site, 2012

The site is composed of the main town and its twenty seven villages (figure 11).

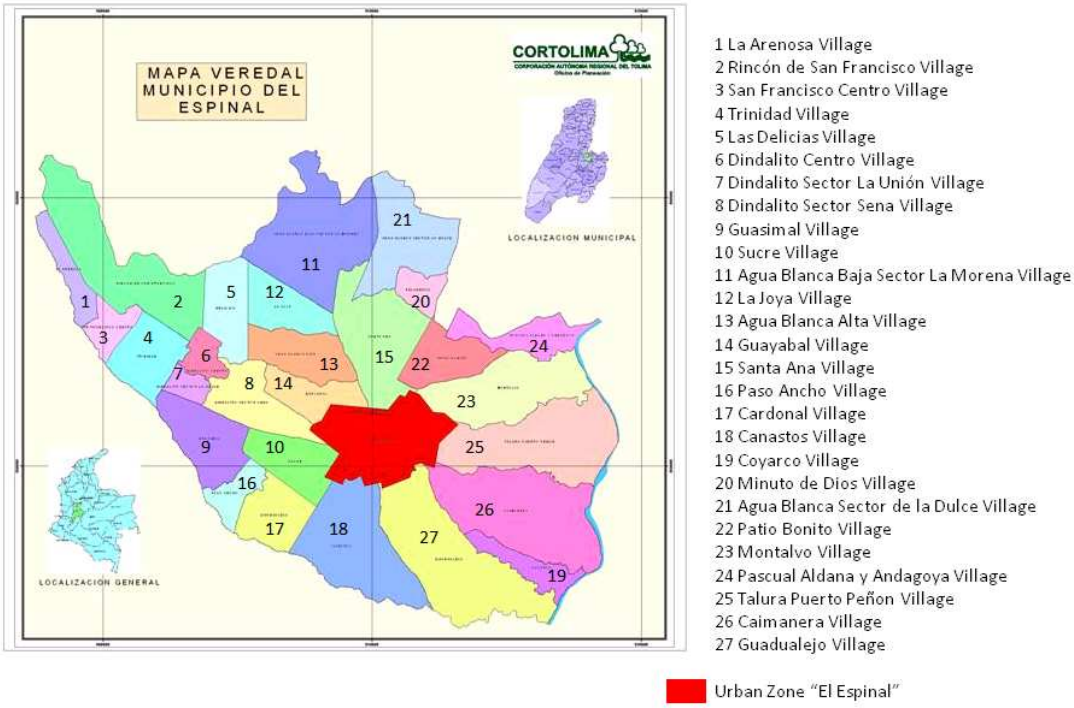

Figure 11: Villages Municipality of "El Espinal" (Legend translated into English). Adapted from CORTOLIMA, 2010.

2.3.1.2.1 Land uses

According to the Geographic Institute Agustin Codazzy (IGAC), in "El Espinal" the predominant use of the land is intensive agriculture with annual species such as rice, cotton, sorghum, corn, beans, and potatoes, which cover the whole area. Land uses for housing are: commercial, industrial, agricultural, institutional, recreational, mining and extraction of materials and transport (PBOT Espinal, 2001). The type of coverage is transitory with some rotational crops (IGAC, 2012c) (see Figure 12).

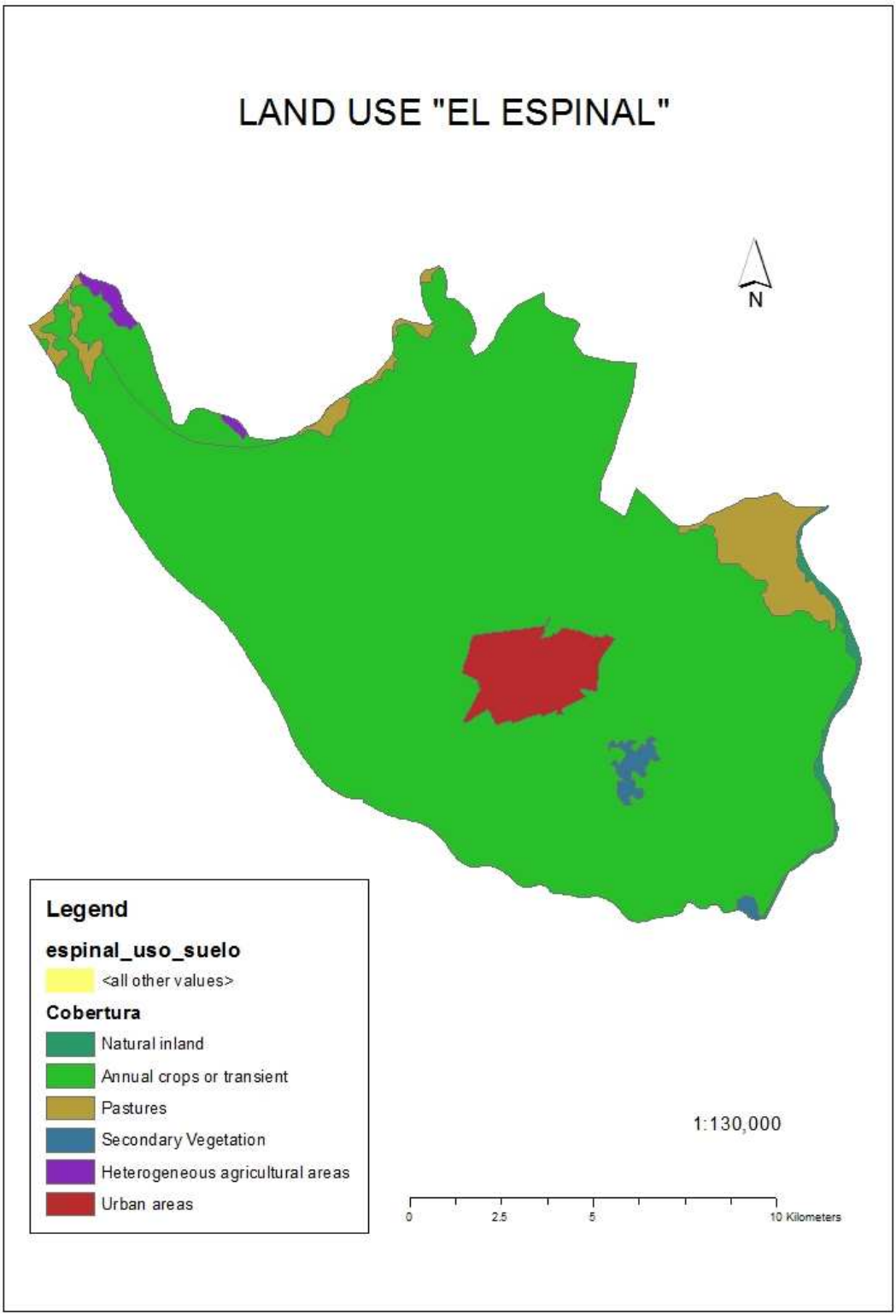

Figure 12: Land uses in “El Espinal” (legend translated into English). Adapted from IDEAM, IGAC, IAvH, Invemar, I. Sinchi e IIAP Colombia. 2007

2.3.1.2.2 Study area in “El Espinal”

The study area has been located according to the pixel points from Terra-i in villages around the municipality (see figure 11). The scale of the map is different than municipality of “Cota”, because this is the minimum scale available by the software (figure 13).

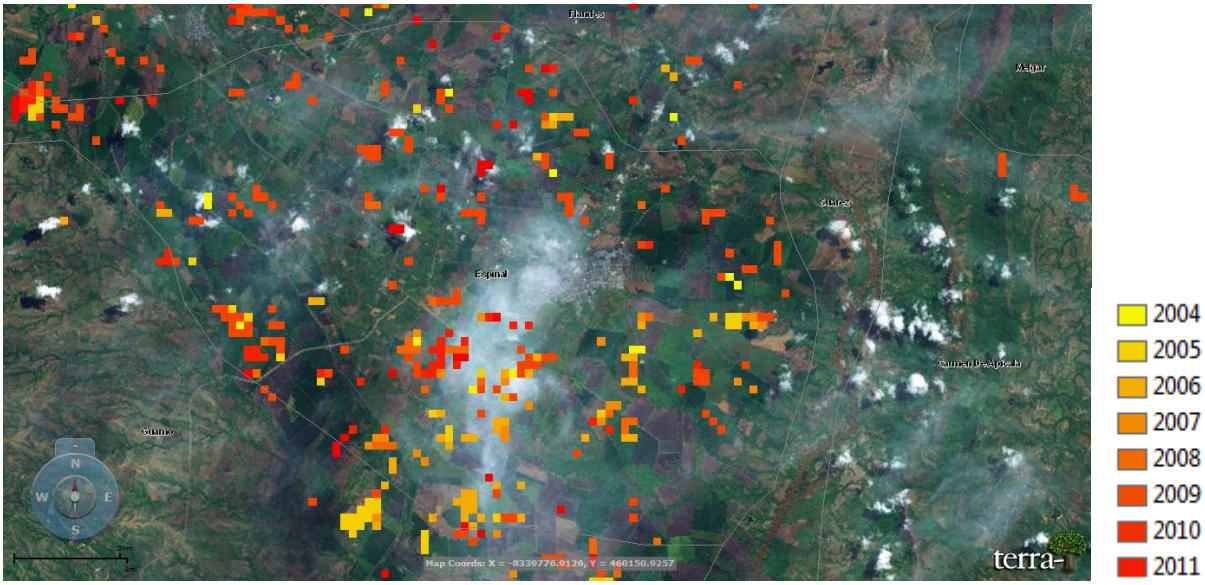

Figure 13: Deforestation around “El Espinal” scale: 3 km: 2 mi. Source: Terra-i software

The type of coverage in the site is determined by annual crops with natural vegetable cover with crops as subclass of coverage (IGAC, 2012e).

3 Data Collection

From the study areas presented in the sections above, ten points were selected according to the colour pixels from Terra-i images (Figure 9 and 13). The characterization of each point is presented in Table 5 following by its satellite location. The points were located in Google Earth 2012 and are shown in figures 14 to 37.

Area 1: COTA				
Point	Pixel Number	Land use type	Date of change by Terra-i	Coordinates (decimal N/W)
1	136	Industrial	03/12/2009	4.737767,-74.155483
2	139	Industrial	17/01/2010	4.747689,-74.161577
3	135	Industrial	17/11/2009	4.764198,-74.160547
4	137	Industrial	19/12/2009	4.765737,-74.156427
5	51	Agroindustrial	22/03/2006	4.759921,-74.148531
6	135	Agroindustrial	17/11/2009	4.763471,-74.149132
7	136	Agroindustrial	03/12/2009	4.766764,-74.145098
8	140	Agroindustrial	02/02/2010	4.761546,-74.140892
9	72	Agroindustrial	18/02/2007	4.754105,-74.134626
10	183	Industrial	19/12/2011	4.750341,-74.149218

Table 5: Characterization of each located point in village Siberia, Cota

Figure14: Study area Siberia village, Cota. Source: Google Earth 2010

Figure15: Point 1

Figure16: Point 2

Figure17: Point 3

Figure18: Point 4

Figure19: Point 5

Figure20: Point 6

Figure21: Point 7

Figure22: Point 8

Figure23: Point 9

Figure24: Point 10

Area 2: EL ESPINAL				
Point	Pixel Number	Land use type	Date of change by Terra-i	Coordinates (decimal N/W)
1	72	Annual crops or trancient	18/02/2007	4.136959,-74.922209
2	37	Annual crops or trancient	13/08/2005	4.133107,-74.923239
3	137	Annual crops	19/12/2009	4.128655,-74.890537

		or trancient		
4	107	Annual crops or trancient	28/08/2008	4.128826,-74.898434
5	127	Annual crops or trancient	12/07/2009	4.123176,-74.856892
6	47	Annual crops or trancient	17/01/2006	4.165466,-74.844704
7	131	Annual crops or trancient	14/09/2009	4.165466,-74.883842
8	110	Annual crops or trancient	15/10/2008	4.17317,-74.94195
9	161	Annual crops or trancient	01/01/2011	4.158446,-74.911995
10	183	Annual crops or trancient	19/12/2011	4.14552,-74.917231

Table 6: Characterization of each located point in “El Espinal”

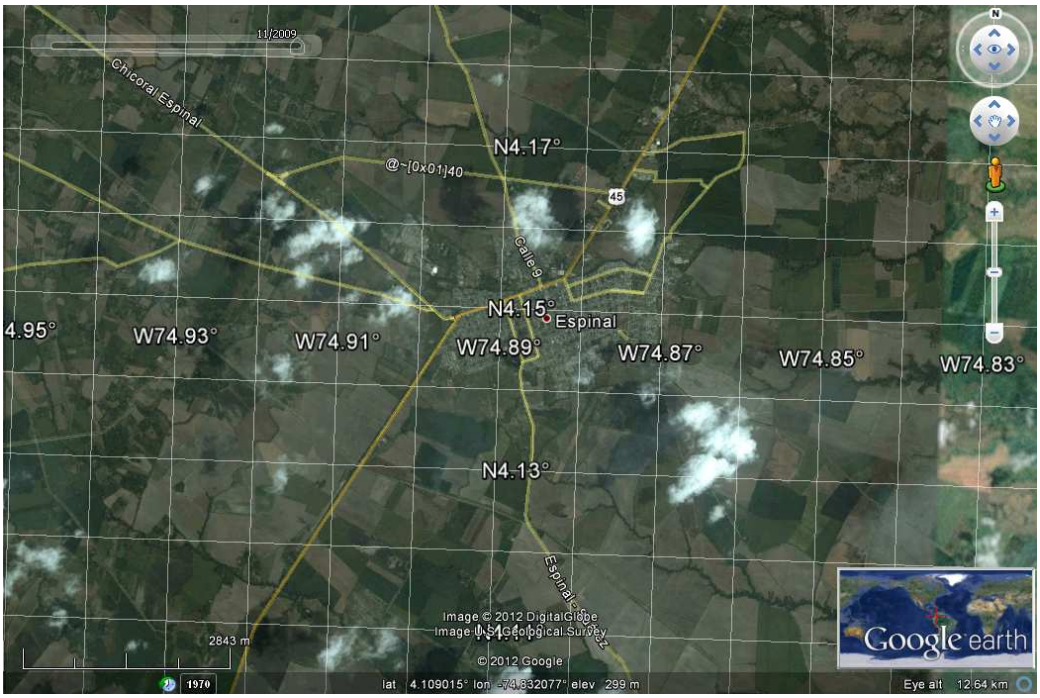

Figure25: Study area “El Espinal”. Source: Google Earth 2010

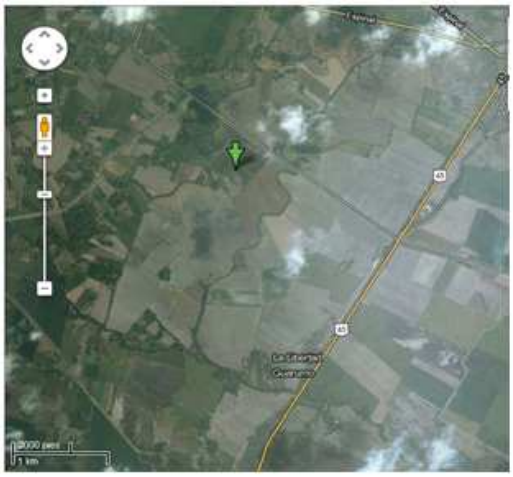

Figure26: Point 1

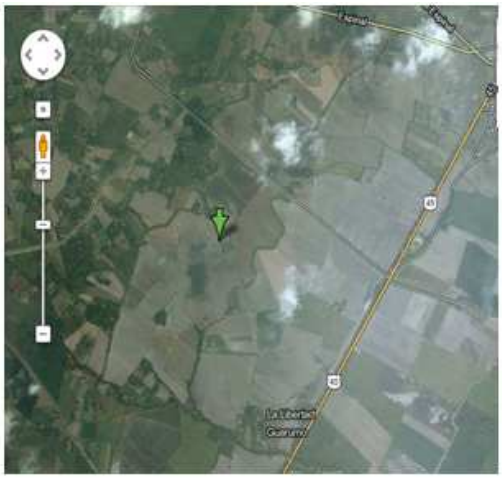

Figure27: Point 2

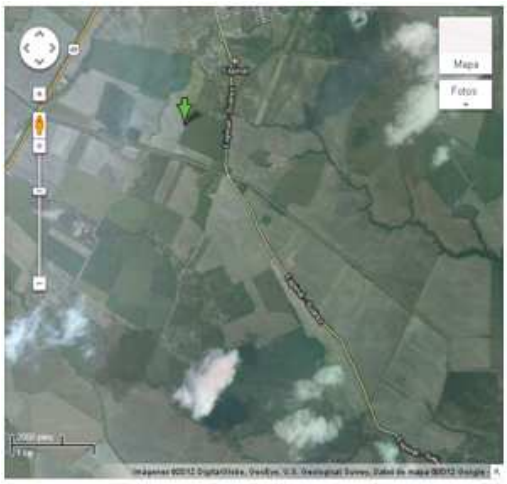

Figure28: Point 3

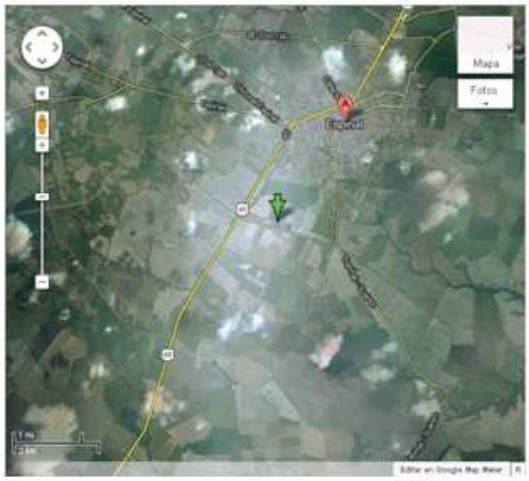

Figure29: Point 4

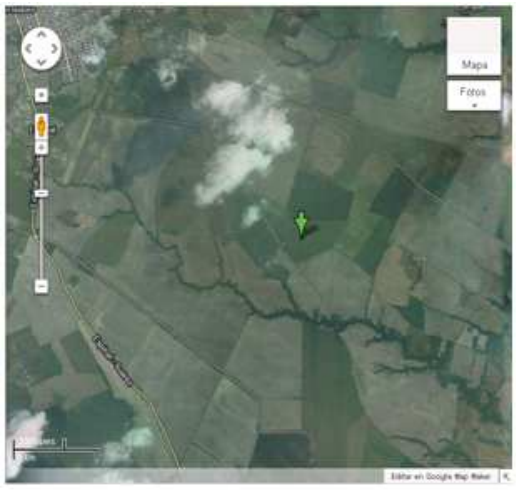

Figure30: Point 5

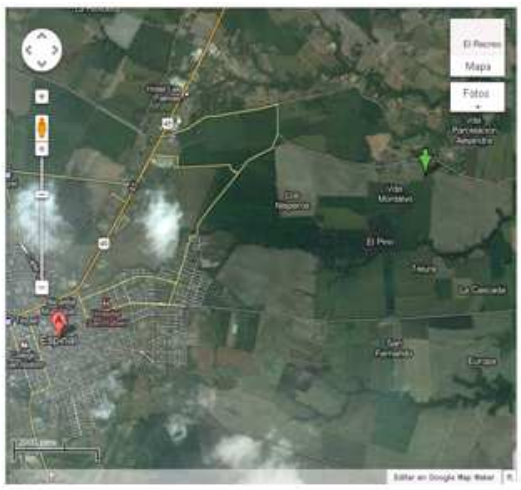

Figure31: Point 6

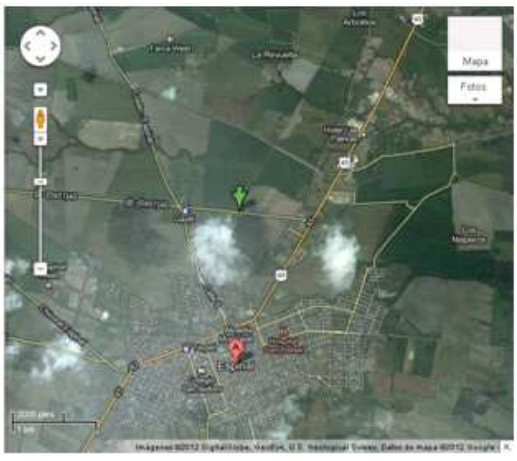

Figure32: Point 7

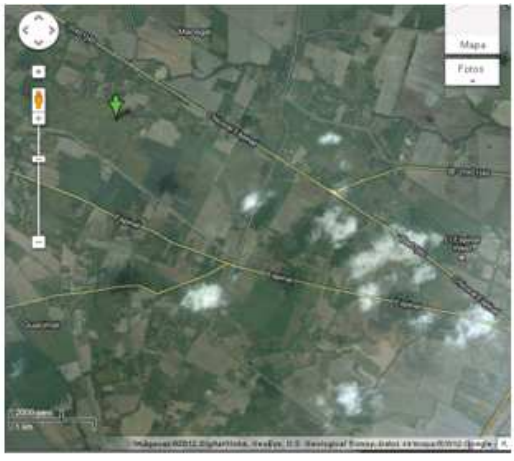

Figure33: Point 8

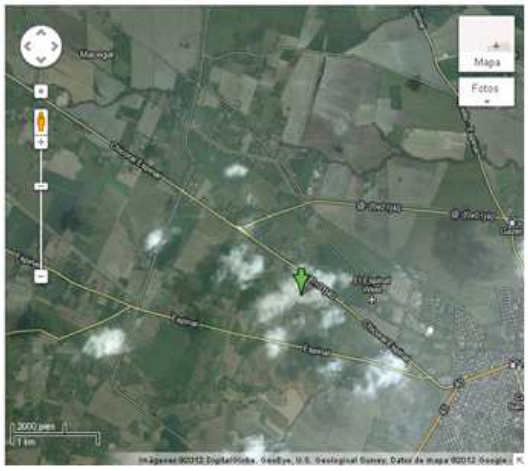

Figure34: Point 9

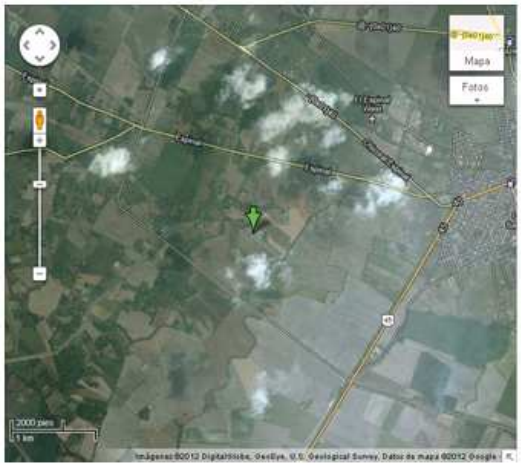

Figure35: Point 10

Following the selection of points, field visits were conducted over two weeks. Interviews regarding current land conditions, problems and causes of land use change were made selecting random people around the selected points. The structure of the interview is shown in the Appendix I. The interviews have been conducted once due to limitations of time from surveyed population.

All results have been analysed in a conceptual system which is divided into two sections: a) The current situation of land use change found in the field; b) The current situation of land use change described by residents of the area (Interviews). The discussion section focuses on the identification of the drivers of land use and land cover change, similar case studies, and the differences between the sites.

4 Results

Terra i software mainly identifies forest and non forest areas in Latin-America. However, the images used from the software to identify the potential disturbed sites, have indicated a change from agriculture to industry in one site, and intensification of agriculture in the other. The date of change of some changes were the same day due to probable intervention and alteration of habitats for the establishment of new buildings or the expansion of agriculture.

Aerial photographs from 1994 and satellite images have been given in the project to identify those changes in the land use of each municipality.

COTA

Visits to the municipality of Cota have been to the village of Siberia. The area is called "Agricultural and Industrial Zone" according to the 'Basic Land Use Plan' of Cota (PBOT Spanish acronym). It features extensive industrial parks with prestigious organizations such as LG, Copidrogas, Spring, Chevrolet, Cinecolor, as well as business centres (see Appendix II-Cota photos 4, 7, 8, 9, 15, 16). Figures 14 to 24 from Google Earth 2010 shows significant expansion of industry compared with the image from Terra-i (figure 9) and an aerial photograph from 2007 shown in the Appendix III.

Interviews in this site were conducted with 7 random people around selected points in the site. The questions have been analysed and are summarized in the following table including the most relevant responses.

Question	Response
1) Are you the owner of this land or other specific territory in the area?	In the municipality, 5 of the 7 people surveyed are land owners. Two of the respondents are employees of their organizations. The industries in the area are the landowners having direct authority and privacy of use.
2) Which are the current land uses and classification of land use management in the site?	The land is classified as conservation and protection, agricultural, housing, services, recreational, institutional, industrial,

	microenterprise and commercial. Crops usually found around the municipality are: spinach, carrots, coriander, potatoes, corn, lettuce, celery, cauliflower, and broccoli.
3) Is there significant background of other land uses?	There is a Background of wetland territory with flood risks. Prior to industrialization, Most of the spaces were used as greenhouses, especially for flower and vegetable crops.
4) Are your crops used as a source of survival or for export?	There were only potato and flower crops in the visited area (see photos 13, 17, 18 on Appendix II-Cota). However, respondents believe that most of the crops were used as source to survive, trade and for exportation.
5) What you know about deforestation in the area? Do you have any idea if this has affected the land use?	All respondents believe that deforestation and the replacement of agriculture by industry have produced environmental emergencies such as flooding in areas around the municipality.
6) Do you think current land fertility is high, medium or low? Is the agricultural land declining in quality of productivity?	The land fertility has been medium-low due to its background of being wetland. The Quality is decreasing due to increasing industrialization.

7) How important are the agricultural development policies in the access of land, extension of services in agriculture, rural infrastructure and economic incentives in countries with low agricultural productivity in the rural sector such as Colombia?	Among the 10 locations selected, all the 7 respondents believe that land access is very important because there are problems with land possession by foreign companies. The Extension of services focuses on the demand for assistance in agricultural production. Financial Investment is important for 4 of the 7 respondents as it affects the country's economy. The rest have a neutral opinion because they do not know if the government will invest the money properly or if it will produce more corruption problems. Rural infrastructure is important for 5 of the respondents; however, farmers believe that most of the money from governments is invested in urban development at the expense of rural communities who survive and work with agricultural services. Economic incentives are important for all the respondents, provided in the agricultural sector. Incentives for industrialization will produce more employment but affect in the environment for future generations.

8) Is the Colombian government doing enough to promote techniques to improve and avoid significant changes in land uses?	According to two responses, the government has policies on proper land use such as discharges and environmental policies for organizations. Nevertheless, 5 of the respondents believe that the government, represented by the municipal mayor, supports industry and has to improve technologies for agricultural services and eliminate corruption from money management.
9) Have you ever been affected by any drastic change in the land use?	All the respondents have been affected by drastic changes relating to the degradation of the land by pollution from sewage. The actual drastic change has been produced by overflow and flooding of the Bogota river (see photos 1 and 2 Appendix II-Cota). Also according to all respondents the industry in the area is also a change which everybody has to adapt to or get involved in.
10) Do you pay any tax for land use?	According to the interviews all respondents pay taxes according to the activity developed. People pay the “Property Tax” which depends of the land uses mentioned in the Township tax statute of the municipality

	2010. Taxes are mainly for agricultural and industrial use, farming, and residential or other uses. Also, industries have to pay the "Industry and Trade Tax" for directly or indirectly carrying out those activities within the municipality.
11) Which potential drivers do you consider are causing deforestation in your working area?	According to all respondents the drivers of deforestation are: Economic with International trade and the increasing of new technologies. Socio-political with the role of the public in decision making. Natural drivers that include climate variability and extreme weather events such as drought, flooding and forest fires. Demographic with increasing population from urban to rural areas.

Table 7: Summary of interviews municipality of Cota

EL ESPINAL

In the study area, extensive agriculture mainly of rice, sorghum, corn and cotton in low quantities was found. The identification by Terra-i software was based on the identification of areas that present significant changes of land use, particularly overexploitation of the land. Agriculture has been always on the site and is shown in Terra-i image (figure 13), and in an Aerial photograph (Appendix III).

Interviews on this site were conducted with 10 people around all selected points. The questions have been analysed and are summarized in the following table including the respondents' most relevant responses.

Question	Response
1) Are you the owner of this land or other specific territory in the area?	In the municipality, 6 of 10 people surveyed are not land owners, which imply poor economic conditions. Land has been rented and used for agriculture and livestock activities.
2) What are the current land uses and classification of land use management on the site?	All of the population surveyed confirmed that most of the area is used for farming, stubble (see photos 30 and 31 on Appendix) and livestock (photo 34); however, fisheries, aquaculture, mining and pastures are also presented in other areas around the municipality. The area of the district where "El Espinal" is located has 65,000 hectares of agriculture of which 40,000 are rice and 25,000 is dry land which includes: rice, cotton, corn, sorghum, fruit trees and alternative crops such as soybeans and peanuts (see photos 24 to 42 Appendix II-"El Espinal"). Other products such as pineapple, passion fruit, tangerine,

	lemon, basil, mint are projected to grow in the area over a period of 5-6 years depending on demand.
3) Is there a significant background of other land uses? Which ones?	According to all the respondents, the land has a background of historical economy based on agriculture. Basically, the use of the land depends on changes introduced by the same population. They may choose rice or prefer another crop, but always for agricultural purposes.
4) Are your crops used as a source of survival or for export?	Most of the crops are a source of survival according to 7 of 10 respondents; however the major rice producers grow crops to export.
5) What you know about deforestation in the area? Do you have any idea if this has affected the land use?	Rates of deforestation have increased in the area due to the intensification of crops replacing forest with agricultural land (see photos 29 and 39 Appendix II-El Espinal).
6) Do you think current land fertility is high, medium or low? Is the agricultural land declining in quality of productivity?	According to 9 of the 10 respondents, the land fertility has decreased considerably within the scale of high-medium; however, one person believes that fertility always has been high because new type of crops with good adaptability have been introduced in

	the area to generate more income and reduce reliance on rice.
7) How important are the agricultural development policies in the access of land, extension of services in agriculture, rural infrastructure and economic incentives in countries with low agricultural productivity in the rural sector such as Colombia?	All respondents believe that the development of policies in the land access is very important because currently there is not clear legislation to regulate and guarantee land access for everybody in the country. They recognize the existence of policies in the access and distribution of land but people believe that those are not sufficiently stringent. An armed conflict is happening in the country displacing people to other lands, but fortunately this is not happening to population interviewed. The extension of services in agriculture is very important because it will guarantee efficiency in procedures becoming more competitive in the market. Rural infrastructure is mainly limited to access roads, public services including water supply which is an issue nowadays in the whole department of Tolima as there is not enough liquid to supply all the area. All the respondents suggest more economic

	incentives in the agricultural sector to make imports and exports more significant in the finance sector and also create programmes focus in Agro-Efficiency.
8) Is the Colombian government doing enough in techniques to improve and prevent significant changes in land uses?	In terms of government actions, all respondents believe that the municipal government is working through environmental and agricultural programmes to combat changes in the land use, but that there is not enough legislation to regulate the land use. In the study area there are no people displaced by violence which is a clear consequence of land use change, however, this is a very sensitive subject that covers other areas of the country. Also everybody recognizes that the national government is working to have an effective land use management with alternative agreements that supply benefits to the whole country in agriculture, but also expects disadvantages for small farmers.
9) Have you been affected by any drastic change in the land use?	Everybody (100% of questioned) has been affected by drastic changes in the land use in economical, political, demographic and

	environmental terms. Unfortunately, those changes have produced demand for specific products, particularly rice, and have saturated the land with other crops never before seen in the area.
10) Do you pay any tax for land use?	The compulsory tax, according to all respondents, is the Property Tax which includes all relevant information of the property according to the land use, including irrigation, road access and use of fertilizers. Taxes are paid for by each land owner and depend on the services required by the property. There are other sectors that require tax to be paid including: postharvest, soil fertilization, and irrigation among others (see photo 68 to 70 on Appendix II-El Espinal).
11) Which potential drivers do you consider are causing deforestation in your working area?	Drivers of deforestation, according to all the population surveyed, are mainly increasing population because it will change patterns of agricultural land uses; establishment of new land use policies, especially free trade agreements that could have negative effects on the agriculture; social conflicts with displacement of people from their land (not

	the situation in the visited sites but it happens in other areas of the country) and economic crisis that involves survival crops and the removal of natural vegetation to increase the agricultural space.

Table 3: Summary of interviews municipality of “El Espinal”

5 Discussion

The aim of this study was to analyse local patterns of deforestation for agricultural land uses in two locations which are typical for agriculture and arable land in Colombia, and to understand fundamental drivers and restrictions.

Terra-i application works detecting land-cover changes resulting from human activities in near real-time and habitat change rate mainly by deforestation. Also identifies changes in the context of predict the evolution of green vegetation intensity, based on previous green measures and current climate measures to detect significant changes in habitats. Therefore, the software has performed a suitable work on identifying those areas which have presented transformations of the territory the last years. The software has been used for detections in Caquetá (Colombia), Argentina, Paraguay and the entire Amazon, trying to set the deforestation resulting from human activity (Pollock, 2012a). The outputs not always guarantee that every pixel detected is from human activities or Terra-i events are deforestation occurred since 2004 (Pollock, 2012b).

Similar studies about land cover and land use change have been done in other countries like Mexico and Britain. A research in the state of Michoacan (Mexico) in 2002, showed similar

changes registered in this project (Acosta, 2002). The study made a photo-interpretation of aerial photographs between 1974 and 1999 and finally made tables of changes in land cover and land use for the study site. Most of the changes were made in terrestrial ecosystems due to conversion in land cover, land degradation and intensification in land use. On the other hand a study of land use change in Britain registered the nature of change focused on built uses and extensive uses such as agriculture (Bibby, 2009). The study registered changes in agricultural products, with areas of basic crops which are stable and others with unpredictable change. The study found implications of policy-driven pressures to produce new type of crops unlikely to increase the agriculture.

Ecosystems change and drivers of land use change are mainly produced by decision makers (farmers or local production communities who have direct interaction with the land). According to the interviews of seventeen people in "Cota" and "El Espinal", drivers are divided into endogenous and exogenous with direct or indirect effects as follows:

Exogenous local drivers in "Cota":

Indirect drivers that influence the decision making process:

- Institutional: Marketing regulations. Approbation of policies to establish the area as industrial, removing all agriculture from the area.
- Technological development: with increasing industrialization
- Demographic with increasing population from Bogota to rural areas influencing the use of food and public services.

Direct drivers that directly affect ecosystem condition and services

- Natural - Global environmental change: "La Niña" phenomenon in Colombia and Latin America resulted in heavy rain and flooding between 2011 and 2012 (Escandón, 2011).

Endogenous local drivers in "Cota":

Indirect drivers that influence the decision making process:

- Technological adaptation: Technology necessary in case of maintenance Colombian Free Trade Agreements with other nations (USTR, 2012a).

Direct drivers that directly affect ecosystem condition and services

- Changes in land use and land cover: Including removal of vegetation and establishment of industry for commercial purposes.

Exogenous local drivers in "El Espinal":

Indirect drivers that influence the decisions making process:

- Institutional: Marketing regulations. Approbation of Free Trade Agreements (FTAs) specially the last one with USA on April 2012 with influence in agricultural services (USTR, 2012b).
- Prices in the market of products which are into the FTAs
- Technological development: use of new technologies to avoid land use change and properties of the land. Also, implementation of new technologies to be more competitive with other markets.

Direct drivers that directly affect ecosystem condition and services:

- Global environmental change: Transition from dry season to rainy season. The land have changed due to intensive drought and long rainfall season, burning and destroying crops because of high temperatures and flooding (El Colombiano, 2012).

Endogenous local drivers in "El Espinal"

Indirect drivers that influence the decision making process:

- Technological adaptation in importations and exportations because the quality of products has to be comparable to developed countries.

Direct drivers that directly affect ecosystem condition and services

- Changes in land use and land cover: Including the removal of vegetation and the establishment of industry for commercial purposes.

- External inputs: Impact in the use of fertilizers that puts public health at risk, water for irrigation and collapse of product prices in the market (Mai, 2003b).

As previously mentioned, the U.S-Colombia free trade agreement, signed in October 2011, will have advantages and disadvantages in business, economy and agriculture of the country in general. The FTA will enter into force at the end of 2012, or in the first half of 2013.

The pact includes a variety of goods, including machinery, raw materials and agricultural products which can be traded without import tariffs needing to be paid.

The advantages of the agreement are:

- Elimination of duties on wheat, barley, soybeans, soybean meal and flour, high-quality beef, bacon, almost all fruit and vegetable products, wheat, peanuts, whey, cotton, and the vast majority of processed products.
- Provision of duty free tariff in rate quotas (TRQ) on standard beef, chicken leg quarters, dairy products, corn, sorghum, animal feeds, rice, and soybean oil.
- Tariffs on agricultural products will be phased out over a period of time, ranging from three to 19 years. Colombia will eliminate quotas and over-quota tariffs in 12 years for corn and other feed grains, 15 years for dairy products, 18 years for chicken leg quarters, and 19 years for rice.

Disadvantages:

- Unsustainable competition in domestic industries. International markets are not on the same level as the domestic industry. Low labour costs in countries like Colombia mean that goods such as rice are produced at a much lower cost and therefore, able to be sold at a much lower price than rice made in the U.S.

The information above is proving to determine the significance of policy drivers as indirect influence in land cover and land use change. If the agricultural sector is threatened with those

policy drivers, decision makers will focus on the expansion and creation of new alternatives to combat the disadvantages of those policies.

In the whole country, there are compulsory taxes in land use for all citizens who make use of it. Taxes depend on the activity carried out, the space it occupies and the impact it has. Taxes were made to regulate, punish and update all the information of land by municipality, city or province. However, the value of these tax increases uncontrollably, causing corruption problems.

To conclude, the information collected on each site, based on sites located by Terra-i software that present changes in habitat change and deforestation, is summarized:

Cota is already an area for economical and business purposes in which agriculture has been reduced drastically due to the declaration of the area as Industrial by the local government, (Basic Land Use Plan "Cota", 2000). The aerial photograph 1 from 1994 (Appendix III), shows the agriculture and small industries in that year , however the Terra-i image (Figure 9) from 2007, figures 14 to 24 from Google earth 2012 and photographs in Appendix II-Cota, show the increase of industry, pasture, paddocks, livestock and areas with filler around the study site .

"El Espinal" has all its territory dedicated to agriculture, being one of the main producers of rice in the country. However, problems with viruses and land renting have decreased the productivity of the area. Also, sensitive crops such as cotton tend to disappear from the area due to expensive management requirements.

Colombia suffers armed conflict in some areas of the country with displacement of land, and illegal crops (Rodriguez, 2005). However, none of the respondents have been involved in this

conflict. The problems mentioned before are also drivers in the land use change but are not considered into this project.

The conservation of the environment cannot be given without an environmental awareness of citizens of “Cota” and “El Espinal”. The advancement of agriculture and increase of industry are a major cause of deforestation. There are clear programs but is a process and takes time.

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Appendix

Appendix I: Structure of Interviews

University of Southampton

1) Are you the owner of this land or other specific territory in the area?
2) Which are the current land uses and classification of land use management in the site?
3) Is there significant background of other land uses?
4) Are your crops used as a source of survival or for export?
5) What you know about deforestation in the area?
6) Do you think current land fertility is high, medium or low? Is the agricultural land declining in quality of productivity?
7) How important are the agricultural development policies in the access of land, extension of services in agriculture, rural infrastructure and economic incentives in countries with low agricultural productivity in the rural sector such as Colombia?
8) Is the Colombian government doing enough to promote techniques to improve and avoid significant changes in land uses?
9) Have you ever been affected by any drastic change in the land use?
10) Do you pay any tax for land use?
11) Which potential drivers do you consider are causing deforestation in your working area?

Appendix II: Photographs

COTA

1-Flooding

2-Flooding

3-Paddocks

4-Industry-LG

5-Pasture

6-IndustrialPark

7-Industry-Copidrogas

8-Industry-Spring

9-Industry-Chevrolet

10-Pasture

11-Livestock

12-Filler

13-Potatoe-crop

14-Pasture

15-Industry-Cinecolor

16-Canine-School

17-Greenhouse

18-Potatoe-Crop

19-Flooding

20-Industry-Colombina

21-Pasture

22-Paddock

EL ESPINAL

23-Rice

24-Rice

25-Rice

26-Rice

27-Fruit

28-Fruit-Rice

29-Cotton-Corn-Rice

30-Paddock

31-Paddock

32-Cotton

33-Corn

34-Livestock

35-Rice-Mills

36-Corn

37-Rice

38-Irrigation

39-Irrigation

40-Cotton

41-Crop-residues

42-Sorghum-Corn

43-Corn

44-Plowing

45-Plowing

46-Plowing

Appendix III: Aerial Photographs