

CHAPTER 3

ENVIRONMENTAL PROBLEMS
IN COLOMBIA
AND THEIR RELATIONSHIP
WITH BIOENERGY PRODUCTION

Colombia accounts for a series of complex ecosystems with tremendous wealth in environmental terms. The introduction and use of traditional fuels for transportation, in an agricultural country such as Colombia, has direct or indirect effects on nature, the people and the economy. It is vital to understand the interaction between Colombian natural stock, social and institutional dynamics that emerge from it and the bond that biofuels production can represent.

Biomass has been traditionally used to cover several human needs: food, fodder, energy source, fibre production, forest products and ecosystemic services. Its consumption creates responsibilities regarding use of the resource (and linked resources), and off course downstream it implies waste and residues management. Bioenergy therefore entails competition for resources, and alternatives for various sectors.

The work presented by Perez's team unveiled a set of 8 problems of major scope in terms of environmental development (Perez, Rojas, & Ordoñez, 2010). While all of them have their own importance; a sub-selection of 6 will be the focus, based on the likely impact they might represent as a potential barrier that bioenergy projects have to face in their implementation stage. Furthermore, it will be explained how bioenergy or biofuel countries can improve or worsen the status quo of such problems. The group of problems identified by these researchers from Universidad del Valle is presented as follows:

1. Loss of biodiversity and ecosystem base
2. Land degradation, pollution and inappropriate use
3. Water pollution and inappropriate use
4. Air pollution
5. Climate change
6. Deterioration of the environmental quality of the human habitat

Those problems that have direct linkage with biofuels production and use will be described in detail, however, those that are related to a minor extent will only be approached marginally.

3.1 LOSS OF BIODIVERSITY AND ECOSYSTEM BASE

Biodiversity is defined as the variation of forms of life that is exhibited in different organization levels within nature, from individual, small cells to large communities,

ecosystems and landscapes. During recent years the study of biodiversity has obeyed a system of hierarchic levels, as follows:

- biogeographic diversity,
- diversity of ecosystems,
- diversity of species,
- diversity of populations,
- cultural diversity

For some time, conservation and sustainable use of biodiversity is a top priority at a global level due to the appalling consequences should we suffer its loss, in term of productivity and recovery capacity that are embedded within the ecosystems, in the same way that it represents a serious threat to the survival for the billions of people that depend on them.

It is common to include nature preservation by excluding protected areas in assessments of biomass expansion potential use (just as it is implemented in this study). This implies that forest and already threatened areas are left out of calculations of potential expansion areas, but some other ecosystems also require protection and the current state of it may be insufficient (Chum et al., 2011). Some marginal lands, in spite of having low yields, count on high natural biodiversity; therefore the use of those areas may jeopardize current natural balance. Losses of biodiversity can be consequence of either a) large monoculture settings or b) by establishing croplands for new bioenergy projects or for diverting food crops to low-yield marginal lands. Nonetheless; biodiversity can be enhanced by the introduction of new species in poor or degraded areas, or by the implementation of new agricultural techniques such as agro-forestry systems, that combines food and biomass production for other purposes.

The high rate of destruction and change in natural vegetation, associated with overexploitation of natural habitat, the illegal profiting from them, the destruction of the ozone layer, climate change as a consequence of environmental pollution, the introduction of exotic species, and the raising of illegal crops have led to a big percentage of fauna and flora facing some degree of risk of extinction or a severe reduction of their populations.

3.1.1 Geographic biodiversity

Colombia is a megadiverse country¹ considered as one of the Top 5 countries in the world in terms of biogeographic and ecological biodiversity. Such biodiversity is represented in a great variety of ecosystems and species (of flora and fauna), both terrestrial and marine kind, that as a whole create an impressive genetic richness. Colombia is considered as the second mega-diverse country having within it 10% of the biodiversity of the planet (Romero, Cabrera, & Ortiz, 2008). Colombia contains two hotspots of biodiversity: Choco/Darien and tropical Andes (Brooks, De silva, Foster, Hoffmann, & Knox, 2008).

Within the main policy of biofuels production and use in Colombia (Conpes 3150), there is recognition that bioenergy projects, in particular the establishment, management and processing of energy crops could represent a threat to biodiversity (Castiblanco & Hortúa, 2012). Nevertheless some studies, applied to palm oil sector, refer that effects on biodiversity are linked with particularities of every location regarding climate conditions, production system, chosen feedstock (León, Valbuena, & Borrero, 2006). These impacts could be positive (by widening the knowledge base of related species, habitats recover, and preservation) or negative (like interruption in the biological organization levels, disruption of trophic chains, diminshment of alterations of biota).

In the Colombian Case it is important to bear in mind that most sugarcane plantations have been stablished since colonization times and nowadays they occupy less than 200 thousand ha for sugar and ethanol production and they have not undergone through vast expansions. A similar case is presented for palm oil plantations. The growth rate of production is higher than the plantation area growth during the period 1962-2012, indicating a non-expansive behavior of these two energy crops². Current plantations of sugarcane in the geographic Valley of Cauca River and palm oil in the Northern coast, Nariño and Meta departments do not compromise any biodiversity hotspots and further expansions have been forecasted, taking into account protected areas in such regards.

¹A mega diverse countries are those that shelter most of the living species on Earth, and are therefore considered as extremely biodiverse.

²Based on FAOSTAT database it can be seen that in 1961 sugarcane plantation area was nearly 300 thousand ha, while for palm this area was 800 ha in Colombia. The highest point of expansion in sugarcane was reached in year 2000 with slightly more than 406 thousand ha, but it dropped dramatically in 2009 to nearly 170 thousand ha and it has maintained similar levels ever since. Palm plantations have experienced a fairly continuous but slow growth during the whole period with an average growth rate per annum close to 9.39% and it has been reached an area of 165 thousand ha since 2006 and it has been maintained until today.

3.1.2 Issues related with ecosystem diversity

One of the main threats to ecosystemic diversity is the loss and fragmentation of ecosystems that affect their composition, structure and functionality (Fahrig, 2003). This phenomenon is mainly due to anthropic activities in the way of expanding agricultural frontiers, or by enhancing or augmenting infrastructure projects and mining exploitation, among others. Such problems bring as a consequence:

- reduced functionality of ecosystems, by a reduction of forest areas and their diverse products,
- decline of quality in the remaining areas,
- loss of connectivity between them,
- creation of borders or boundaries over the habitat,
- and geographic isolation due to the fragmentation of these zones.

In terms of species, there is also a notorious reduction in their population size, geographic isolation, reduction in the genetic variability, and increased difficulty for procreation (Fahrig, 2003). The main consequence of fragmentation of the ecologic equilibrium is a continuous change in the landscape, which puts at risk its feasibility and potential use in the long-run (Etter, 1993).

There is one ecosystem in particular that has suffered more than the rest of the Colombian biomes – forests. There is a great loss of forest and woodlands. While it is true that Colombian territory was covered by approximately 49 million hectares of natural forest in 2009, which represents near to 53% of the whole of Colombia, in a little more than 4 decades (1961-2005) there has been a loss of almost 5.3 million hectares. That would imply an average deforestation rate of 120 thousand hectares per annum, which draws a deforestation rate of 0.25%, which is slightly higher than the world average (0.2%). This deforestation has been more concentrated and severe in the Andean and Caribbean zones of Colombia, which are precisely the regions that exhibit higher population densities and more economic development, but with less access to water resources (FAOSTAT, 2009).

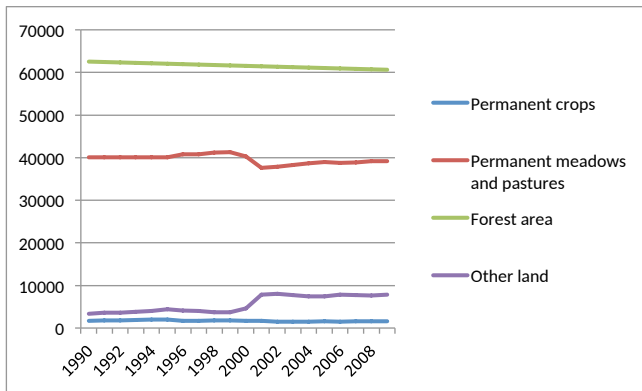
The most preoccupying consequence of the loss in the vegetation is that tropical and subtropical moist broadleaf forests are highly affected, and it clashes directly with the hotspots of biodiversity and the ecological importance that they represent. For instance, 50 of the species of birds of the world are located in the Choco and Amazonia region, and most of them can only survive in the delicate environment that these ecosystems provide. It is a similar situation for some tropical mammals and rare primates. However, probably

the most threatened ecosystems are the mountain and sub-mountain Andean forest, and the tropical dry forests, given these locations are in vastly populated areas.

Also a big concern is the intensive use of agrochemicals, that have had an average increase in usage from 205.36 kg/ha (182.87 for fertilizers and 22.49 for pesticides) in 2002. to 305 kg/ha in 2011 (291.8 for fertilizers and 13.45 for pesticides), which is above the average Latin American levels in the same period, also experiencing a leap from 77 to 109kg/ha (FAOSTAT, 2014)³. Excessive use of these kinds of substances weakens the soil's response capacity in natural ecosystems, resulting in eutrophication processes that inhibit normal development in aquatic fauna.

The loss of forest cover has also been a consequence of wood extraction, firewood consumption (given that just 2.4% of rural families use any other kind of cooking or heating fuel) and forest fires. While at the same time, reforestation efforts are limited to an area of 16,475 replanted hectares per year has to compete against 120,000hectares that are deforested on an annual basis. Finally the construction of road infrastructure and the expansion of urban settlements have contributed to the detrimental transformation of the natural habitat.

Figure 3.I. Evolution of land use in Colombia



³For Colombian and Latin American case the calculations were made by adding the total Nitrogen, Phosphate and Potash consumption of fertilizers assessed in tonnes. Pesticides include the use of insecticides, herbicides and fungicides, also assessed in tonnes. It was taken into the account just the area corresponding to arable land and permanent crops. Part of the huge difference that is presented between the Colombian and the Latin American case can be due to the fact that in FAOSTAT database is missing information for fertilizers in the case of Brazil, Paraguay and Venezuela for the whole period 2002-2011. Some other countries also present blanks in the information collected in such regards.

3.1.3 Diversity of species and their problems

The introduction of exotic species is also a big concern in terms of biodiversity preservation, particularly in the Andean region of Colombia. It has been calculated that nearly 107 out of 117 invasive species (or with invasive potential), are found within the region. Some of these species were incorporated into productive activities, and subsequently they occupied vast monoculture arrays. In the case of bioenergy, initially there was a direct impact by the introduction of African Palm for vegetable oil extraction, and biodiesel production more recently. There have been some introductions of alien species as part of feed and plague control experiments, as is the cases of the bullfrog and the crazy ant (*paratrechina fulvia*). These two species turned into invasive organisms that nowadays have reached high occupation levels in the different biomes in the Andean region.

Thus, the introduction of alien species threatens directly the biological diversity and the landscape composition in the region. For that reason, with the adoption of new species it is possible to displace native incumbent species, creating severe problems for further development. Thus, it is vital to have a clear inventory of those species introduced within a nation, as well as clear identification of those species of invasive flora and fauna (or with invasive potential) in order to establish the proportion of species that embody a threat to native species or ecosystems.

3.2 LAND: DEGRADATION, POLLUTION AND INAPPROPRIATE USE

Soil degradation is clearly and mainly related to human activities, but it can be generated through natural processes, such as geologic erosion, earthquakes, landslides and changes in the climate. Nevertheless, the anthropic factors can be controlled by the action of conscientious authorities, among others, by establishing policies, legislation and other tools.

Land and soil usage change is one of the human activities which most influence the ecosystems' capacity to provide environmental functions. The simplification of ecosystems caused by human activities makes it impossible for modified ecosystems to provide all the regular services that otherwise would be offered in their natural state (Assessment, 2005; Carpenter et al., 2009).

In the biophysics field, land use change (LUC) and change in the soil cover affect those nutrient cycles in the terrestrial and aquatic ecosystems, local and regional climate, water

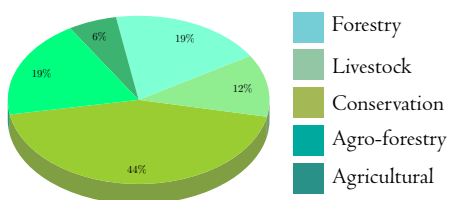
cycle and it might cause decline in biodiversity levels, and erosion and soil loss among other consequences (Metzger, Rounsevell, Acosta-Michlik, Leemans, & Schröter, 2006; Ojima, Galvin, & Turner, 1994).

The main human activities that trigger soil degradation are:

- agriculture,
- livestock farming,
- urban expansion,
- mining,
- road construction
- and wood extraction (WB, 2007).

Regularly these activities take place where potential soil use differs from the one that it is actually used for. In Colombia land use vocation is changing. It was estimated, a decade ago, that approximately 43.5% of the total area is destined for conservationist purposes, followed by agricultural activities, forestry projects, livestock farming practices and agroforestry endeavors.

Figure 3.2. Land use in Colombia 2002 (Total 113'869.035 ha)



(Pérez, Rojas, & Ordoñez, 2010)

3.2.1 Conflict over land use

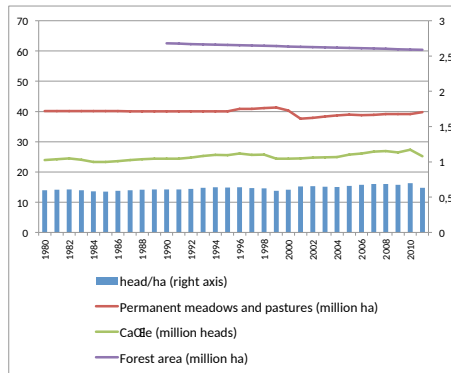
Biomass plantations are usually established in surplus agricultural land; thus intensification in agricultural systems is required given that influences land availability for biomass plantations (by defining land requirements for the food sector) and it may enhance biomass yield levels. (Chum et al., 2011) Therefore within the calculations for the technical potentials of biomass production presented in recent studies, is highlighted the need of taking into the account a combination of high-yielding agricultural systems (in new and existing agricultural land) and international energy trade agreements (Ausubel, 2000; Cassman, Dobermann, Walters, & Yang, 2003; Fischer, Shah, van Velthuizen, & Nachtergaele, 2001; Tilman, Cassman, Matson, Naylor, & Polasky,

2002), as well as the dietary customs of different geographical regions (Gerbens-Leenes & Nonhebel, 2002; Smil, 2002; Stehfest et al., 2009; Wirsenius, 2003).

In Colombia, the conflict over land use is highly correlated to livestock farming practices. An intensive ranching practice induces to forest loss, ecosystemic degradation and changes in the human territory composition (Andrade, 2004). In Colombia, according to assessments and studies, it has been calculated that the suitable area for such purposes approaches 14 million hectares, whereas the area actually being used is more than 38.9 million hectares (FAOSTAT, 2009). In addition, the use of these lands is highly inefficient. Despite the fact that heads of cattle have increased continuously between 1961 and 2005, the increment of the number of heads per hectare has remained practically at the same level (from 0.6 to 0.9), so the level of efficiency has practically not evolved in more than 4 decades. According to statistics from the (Food and Agriculture Organization) FAO, the number of heads of cattle in 1980, including bovine, sheep, goats, and horse cattle (but excluding pigs), reached levels of nearly 30 million, and in 2009 this number grew to over 35 million.

The impact that ranching activities has on employment is not as substantial as the one that can be produced by agriculture (Vergara, 2010), and the impact on the environment is higher with the former (Northoff, 2005; Vergara, 2010). Besides, the influence that cattle farming has on the social structure in terms of violence and land concentration is more accentuated than in some other agricultural activities (Andrade, 2004; Vergara, 2010).

Figure 3.3. Land use in Colombia for Livestock growing purposes



The productivity indicators that reveal ranching sector's performance are not at the cutting-edge compared with some other countries within the LAC region (i.e.

Argentina and Uruguay). For instance every ranch on average counts on 25 heads, where nearly 55% are destined for meat production, 4% for milk production and 45% for double purpose. The level of sacrifice of female animals is 22%, while in US is 77%, Argentina is 54% and Uruguay 44%. The extraction or total sacrifice rate has been stuck in 14% for the last decade, indicating low progress in the productivity in the sector. The production of meat in some countries in the region is over 214 kg per head, but in Colombia such indicator has been reported in 197 kg per head. (Vergara, 2010). Data from FAO indicate a quite stable and low-productivity behavior for the sector, where there is not even one head of cattle per ha (see previous figure).

All these arguments confirm the idea that the use of land for livestock and other cattle farming exhibits a widespread and parasitic pattern, which has a great negative impact on the environment.

Another part of the problem is that not all the territories that have the potential to grow forests and similar ecosystems are doing so. The environmental regulation has "secured" an area of only 11.5 million hectares through the program of national parks. Apart from the problem generated by the fact that some areas are not being used for their natural vocation, there is overexploitation in nearly 17% of the total area in the country. This phenomenon is related to intensive use of the ground, through a model of industrial agriculture, based on a vast use of machinery, modern irrigation methods, and agrichemical boosters. In any case, based on the data exhibited in the previous figure, is not possible to argue that cattle ranching expansion is given at expense of forest area.

Another factor that contributes to a major extent to the deterioration of land and soil is the existence of illegal crops. Agricultural practices that are undertaken to maintain, as well as to eradicate, these sort of crops are extremely aggressive on the environment and they contribute to the change in acidity levels, leading to salinization, resulting in desertification progression. Within the last 20 years, these types of crops have quadrupled, and it is important to bear in mind that they are usually located high up in the mountains, and in forests and jungles where their eradication becomes rather complex. Nevertheless, it is fundamental to remember that these illegal crops have undergone a substantial reduction within recent years, particularly since 1999. For instance, papaver or poppy crops have been reduced by almost 50%, and so have coca plantations (UNODC, 2007).

The Colombian government has tried to re-engage the communities that are involved in cultivating illegal crops, by offering them some alternatives. Perhaps the most influential

scheme that has been employed as policy of State, in coalition with foreign (United States of America) help, was the so-called plan “Plante”. During the period 2000–2004, soft credits were offered (total amount of more than 160 billion COP i.e. more than 55 million USD) to peasants mostly in Putumayo region, as an incentive to abandon coca crops (Vargas, 2010). In this case the product that was employed as an alternative, was the heart of some edible palms. However, a more recent initiative is to employ energy feedstock (DNP Departamento Nacional de Planeación [National Economic Planning Bureau], 2008).

3.2.2 Land degradation

Apart from conflict over the land, given by inadequate vocation allocation or by illegal use, one additional problem is land degradation, which shows symptoms of erosion, salinization and desertification. Erosion covers a considerable area of Colombian territory, it is predicted that near to 50% of it suffers some degree of land degradation, while 23% displays erosion problems that can be classified between moderate and severe. Those lands in severe condition, which occupy near to 7.8% of the total territory, are considered impossible or very expensive to restore. Erosion, as expected, has more presence in those areas densely populated: high and very high levels of erosion are shown in Orinoquia region (20.9% of its area), Caribbean region (14.5%) and the Andean zone (9.9%). Meanwhile, the Amazonia and Pacific regions are the ones that have a minor impact from this variable, which is fortune given their importance in terms of biodiversity (IDEAM, 2004).

The other problem is salinization, which is usually associated with irrigation methods. However, the first difficulty faced by the scholars and technicians that try to study and characterize such problems is the lack of information. The use of extensive monoculture methods and extensive livestock farming practices unleash salinization problems that are evident mainly in the Caribbean zone, affecting 60% of its territory, with levels between high and moderate salinization. Other regions affected by this problem are the Andean region with particular concern in the departments of Cundinamarca, Huila, Tolima and Cauca Valley. These salinization levels are directly linked to an over proportioned growth of irrigated land – it started with 400 thousand hectares in 1981 and ended up with nearly 900 thousand in 2001 (WB, 2007).

The cost of land degradation, due to erosion and salinization processes, assessed through loss in crop productivity, was estimated at US\$ 670 million in 2004 (Larsen, 2004). One of the complications that prevent the land degradation problem from

being solved is the lack of regulation and laws oriented to keep control of them. Neither law 99 of 1993, nor any other dispositions, establish clear mechanisms or responsibilities to mitigate land degradation. In the best scenario, both erosion and salinization are mentioned as problems that require proper attention by the environmental authorities; nevertheless, they do not indicate how these actions must be implemented and controlled.

This fact becomes a difficult barrier to overcome. While there is a desire to assess the relevance of applied policies oriented to preserve land quality, there is a great lack of available data because the authorities that implement them do not use performance indexes and there are no specific targets in terms of erosion and salinization control.

3.2.3 Soil contamination

Land and water are the two abiotic elements of the biosphere that have great interaction thanks to the bio-geochemical cycles of the elements and the hydrologic cycle. In addition, these two elements constitute a fundamental foundation for the development and proper working of several terrestrial and aquatic ecosystems. Having said that, it is clear that those vectors of anthropic contamination that affect water will also compromise land quality, and the difference is marked by the corresponding effects and magnitudes. Land pollution by way of biodegradable organic matter does not constitute a serious problem in most cases, given that the superficial layer on the soil is a very rich bio-reactor. The superficial layer of the ground is also high in biodiversity due to its elevated content of active microbial flora with an extraordinary biodegradation potential. The real problem arises when there is an excessive and uncontrolled use of pesticides, herbicides and in some cases fertilizers, which results in severe contamination of land.

Zúñiga et.al. point out that between the 1950's and 1980's fertilizer applied in cultivated areas was much less (in comparison with product yield) to current methods. Nowadays, it is necessary to apply big quantities of agricultural input to obtain current production, creating a high dependence on fertilizers. Excessive application of nitrogen has contributed to an accelerated deterioration of land quality, therefore, there is an urgent need to promote an agro-sustainable model as the only solution to recover and maintain soil fertility and productive capacity of the Colombian agricultural systems (Zúñiga, Osorio, & Cuero, 2009).

It is clear that these contamination factors are tightly linked to inadequate agricultural practices, both on an industrial scale and on small scale. Among those practices

responsible for hastened soil fertility loss (Zúñiga et al., 2009) is monoculture, which is the main setback, but also:

- the extensive use of fertilizers with synthetic chemical,
- the use of agro-toxins,
- over working the land,
- irregular clearing practices such as burnings,
- soil compaction by excessive mechanization processes
- and irrigation with inadequate waters can be count as.

A perfect illustration of such a situation is given by the case of a variation in the level of organic matter within the soils of the Cauca valley region (Besosa, 2005). In the 1960's this region contained 7% of organic matter within its soil, but every decade it has lost one percent. So by the year 2010 it was assumed to have level of 2% of organic matter. The reader must remember that this particular region in Colombia has been characterized by the cultivation of some fruits, but predominantly it uses sugarcane to support most of the agricultural income in this zone.

Thus, the loss of organic matter in soil leads to a disastrous impoverishment in terms of nutrients, caused by monoculture practices, the lack of crop rotation, and burning methods for clearing purposes. It is also known that continuous and permanent crops of the same species entail a constant extraction of the same nutrients and minerals over and over again.

Alternatives

Intensification and aggressive agricultural management have to be treated carefully because they may imply large input of nutrients, water and pesticides bringing negative consequences to the surrounding environment (like change in species composition, water pollution and eutrophication). However, intensification does not suggest necessarily industrialization of the agriculture, given that yield can also be improved in some regions, via organic farming methods, but with better practices than the ongoing ones (Badgley et al., 2007). Additional techniques of soil and water preservation can also contribute to increase yield in rain-fed regions employed for agriculture having into the account that best agricultural practices are not applied to many world agricultural areas (Godfray et al., 2010), as consequence of poor information, capacity building, access to markets, among others (Neumann, Verburg, Stehfest, & Müller, 2010).

There are some other opportunities to widen expansion areas in sustainable ways if conservation agriculture and mixed production systems are deployed, and water use efficiency and carbon sequestration techniques are developed, and some particular agricultural inputs such as nitrogen are limited in usage. Some other possibilities can emerge in the change of traditional resource-intensive fodder (soy and corn) (Dale, Allen, Laser, & Lynd, 2009), reducing grazing requirements (Chum et al., 2011).

Marginal lands are also an alternative; however there is much uncertainty on how much potential can be used for expansion of bioenergy plantations. Several obstacles need to be tackled in order to take advantage of such lands, among them long periods of time and financial efforts for maintenance and land reclamation task, low yields and involving established populations and their ongoing needs.

3.3 WATER POLLUTION AND INAPPROPRIATE USE

Colombia has a history of generous rain fall over the years, resulting in it recently being catalogued as the fourth country in the world in terms of water availability. However, nowadays it is facing a conflict between socio-economic development and water sources preservation. Current national growth has led to a critical situation where some regions experience regular water shortages, and where population growth also exerts an additional pressure on the resource. Understanding this, it is important to have a general review of this key input to agricultural production, therefore market forces and other implications in terms of pollution are briefly presented below.

3.3.1 Water supply: related issues

Colombia is a country that counts on an immense water supply, which can be broken down into superficial and underground sources. Adding up the national water availability Colombia has a store of 2100 km^3 of fresh water, i.e. $50,000 \text{ m}^3/\text{y}/\text{capita}$, which by far surpasses the supply found in countries like Brazil, Argentina and Mexico. The allocation of underground streams and aquifers are important, given that 30% of fresh water comes from this type of sources, and nearly 40% of municipalities' water supply depend on aquifers for drinkable or potable water provision (IDEAM, 2004).

Notwithstanding, one of the most important features of the water supply in Colombia is its heterogeneity in terms of territorial distribution. It has been established that most of the water resources are concentrated in those unpopulated regions. Thus, the $66,344 \text{ m}^3/\text{sec}$ that belong to Colombian territory are distributed in 5 different hydric basins

that conform to the national continental territory, as defined below:

- Amazonia (22185 m^3/sec)
- Orinoquia (21339 m^3/sec)
- Caribe (15430 m^3/sec)
- Pacific (6903 m^3/sec)
- and Catatumbo (427 m^3/sec).

As it is evident, more than two thirds (76.1%) of the whole water supply is located in the least populated areas (Amazonia, Orinoquia and Pacific). Therefore, only 23.9% of the water is located in those basins that supply high population areas (Caribe and Catatumbo), and subsequently have a greater concentration of economic activity. The Caribe basin itself has Cauca and Magdalena rivers and account for approximately 70% of the Colombian population.

In terms of the hydrographical basins, it is estimated that 40% of the big basins have a degree of vulnerability between moderate and intermediate. This is reflected by the fact that during a dry season 25% of the municipalities face problems with water availability (and that covers 60% of the population). Such shortages fluctuate between medium, medium-high, and high. If such trends continue, as expected in 2015, the affected population could reach 65%. The most vulnerable region is the Andean one, followed by the Caribbean zone (DNP, 2007).

It is vital to have these water availability constraints in mind for further biofuel project implementations, given that the availability of this liquid resource impacts directly not only in its yield, but also in further expansion of such bioenergy feedstock.

In the same way it is expected that global warming exacerbates the impact of such phenomenon. This could result in a total lack, or at least periodical shortages, of water resources in some strategic zones, above all in the high-Andean ecosystems, which are fundamental providers of the liquid.

3.3.2 Water demand: related issues

Water demand for different sectors starts to unveil the roots of conflicts regarding this resource, especially if the uneven geographic distribution is taken into account, as it was

just mentioned. The Instituto de Hidrología, Meteorología y Estudios Ambientales — IDEAM—, (Institute of Hydrology Meteorology and Environmental Studies), presented a study in 2004 where it was indicated that the water demand in 2003 reached 7,435,000 m^3 , where agriculture was the most intensive water user (54.5%).

However, in the cases of agriculture and human consumption, there is a presence of high levels of inequality given that those small-scale and poor users are excluded from having proper access (IDEAM, 2004).

Regarding agricultural sector, the World Bank states that small-scale farmers do not have access to the water rights that they have been allocated, because these usually go to those more powerful and bigger sized users (WB, 2007). Studies on the water footprint of the Colombian agricultural sector establish a clear increment in the water use for this activity. The agricultural water footprint for Colombia includes the total volume for producing food and other raw material from the agricultural sector, however, without including illicit crops and flowers. Pérez calculated this indicator in 2003 to be 42.7 Gm^3 , without including losses by inefficiency in irrigation systems. The volume of water use has undergone a continuous increase since 1961, where it had a level of nearly 13 Gm^3 , and it had an outstanding peak in 1992 exceeding 45 Gm^3 , followed by a gradual decrease that stopped in 1999 (at 32 Gm^3) when it reverted to a growing trend that end up at virtually 43 Gm^3 in 2003. The net effect of the whole period was 29 Gm^3 , which can be translated in an annual growth of nearly 5%. This is slightly above the growth of the GDP of the agricultural sector, which has been reported as 4.5%. The issue that emerges here is that such demand is focused in just these few hydrographical basins with the lowest water availability, adding extra pressure on current water supplies (Perez, 2007).

In the case of human consumption, aqueducts are better equipped in urban areas; where coverage is wider than in rural areas. Nevertheless, even in cities, in those poor neighborhoods and those settlements in urban perimeters water distribution systems are not as good as the ones provided in inner cities.

3.3.3 Water pollution in Colombia

In the case of water pollution, it must be taken into account that this resource is available from three possible sources: superficial water, underground water and sea water. Water quality in Colombia is affected for the most part by organic pollution and sediments (DNP, 2007). The latter are related to soil erosion by agricultural activities and mining.

The main culprit for organic matter disposal, which is assessed in BOD (Biochemical Oxygen Demand), is the agricultural sector, which accounts for 84%, followed by residual households' waters (10%), and residual industrial waters (6%).

Nevertheless, at the present time there is no sure diagnosis for contamination caused by household water management at a national level. Neither is there enough nor reliable information on the current state of water resources, that includes in the analysis elements such as assimilation capacities of the receptor body, impacts of spills on quality of health of exposed populations to water contamination by chemical or microbiological causes. It is important to keep in mind that anthropic contamination that is produced all along the Andean mountains is disposed of in the Caribe basin, and ends up on the North-Western coast of Colombia.

Water scarcity may be a limit for intensification possibilities and possible expansions projects applied to energy crops, or energy plantations in general (Berndes, 2008a, 2008b; de Fraiture & Berndes, 2009; Rost et al., 2009). Nonetheless, this obstacle can be overcome partially by using water management treatments (Rost et al., 2009).

3.4 AIR POLLUTION

3.4.1 Air pollution in the World and in Colombia

Presence of substances in the air, in certain quantities and during long periods of time might alter health and human wellbeing, as well as possibly causing disruption in the normal behavior of ecosystems. Such a situation is known as air pollution, and it manifests through the interaction of different sources and the contaminants or pollutants that they release, as well as the influence of external factors such as the atmospheric conditions in those places where the phenomenon takes place.

Air pollution is produced by those uncontrolled emissions of gases that are freed in to the low atmosphere. Such emissions might be categorized by their incidence or scope on the environment, generally considered as local or global. Some of these substances introduced to given environments by the actions of nature, but there are others that come from man's actions. The origin of these anthropic emissions can be broken down into stationary sources and mobile sources. The former mostly consists of industries and households mostly, while the latter refers to any form of transportation that causes considerable emissions – basically any engine-based terrestrial, aerial, fluvial, or marine means of transport.

The most common pollutants present and which cause more severe reactions for humans and environmental health are:

- Sulphur oxides (SOX),
- Nitrogen oxides (NOX),
- Carbon monoxide (CO),
- Tropospheric ozone (O₃),
- Lead (Pb),
- Particulate matter (soot, ashes and dust),
- Volatile organic compounds (VOC's), among others.

Regarding the sources of emission for those pollutants mentioned above, there are several different systems of classifications. The first way of classifying these sources, involves separating natural from man-made sources. Among the natural sources are volcanic eruptions, sand storms, and organic matter decomposition in natural environments such as swamps or wetlands. While the ones that come from man's actions include, fossil fuels use, industrial processes, waste management and treatment, just to mention a few.

A different approach to sorting, is the use of the spatial reference of the source. As mentioned previously, this is the source of emissions from a stationary or mobile source.

In general, most of the problems that are associated with air pollution have a strong link with anthropic activities, like the use of fossil fuels, either for transportation purposes, or for other common kinds of energy requirements from households and industries. Pollutants have a close connection to the industrial activity that is being performed, so, for instance, transportation contributes vastly to levels of sulphur and nitrogen oxides, and to a minor extent with lead. Energy production (e.g. electricity), on the other hand, accounts for a great deal of nitrogen and lead oxides, and to a lesser extent, sulphur oxides. Carbon dioxide and carbon monoxide, are associated with the use of fossil fuels, but these are also generated by agricultural activities, livestock and cattle farming, and waste disposal (IDEAM, 2001b).

With regard to those gases that create a local effect, the emission core, are more closely associated with the great urban areas, due mainly to a more concentrated and comparably bigger energy demand than in rural spots. This is obviously explained by a higher population density, and those industrial processes of materials transformation that are condensed within cities. Thus, Colombian metropolises like Bogota, Cali,

Medellin, Barranquilla, Cartagena, Barrancabermeja and Sogamoso create most of the emissions of potentially local impact, therefore, making more vulnerable the people that inhabit these urban settlements. Bogota, Cali, and Medellin, are some of the more polluted cities on the American continent (DAMA, 2004; Gurjar, Butler, Lawrence, & Lelieveld, 2008; IDEAM, 2004; REDAIRE, 2003).

Particulate matter represents a serious threat to human health and its level of danger is inversely related to its size. Those particles with 2.5 μm or less are markedly more hazardous to human kind (Franklin, Zeka, & Schwartz, 2006). Indeed, the local pollutant that attracts more attention is particulate matter, because it is responsible for most human health issues (Azizi, Zulkifli, & Kasim, 1995; Calixto & Díaz, 1995; N Lozano, 2003). In the biggest cities, the level of total suspended particles (TSP) and particulate matter with less than 10 μm (PM10), frequently exceeds the guide values established in the standards of the regulation in Colombia (DNP, 2007).

3.4.2 Sources of air pollution and affected sectors in Colombia

According with IDEAM calculations, 41% of total atmospheric emissions, and close to 75% of the national burden of industrial pollutants are focused in the 8 biggest cities and industrial centers in Colombia (IDEAM & MAVDT, 2007). Crossing data with DANE, near to 45% of the urban population in Colombia is located precisely in these places (DANE, 2005). Furthermore, it has been established that mobile sources of pollution, within these 8 cities, are liable for most of the gases emissions in to the atmosphere. A vast proportion of them occur in Bogota, where mobile sources account for nearly 169 thousand tons out of 200 thousand tons. However, the situation is similar in other cities:

- In Medellin mobile sources load the environment with 110 out of 128 thousand tons
- and Cali 99 out of 127 thousand tons.

In the remaining 5 cities, Barranquilla, Sogamoso, Bucaramanga, Cartagena and Pereira, pollution levels do not surpass 50 thousand tons of total emissions each (Brugman, 2004).

In contrast, stationary sources of air pollution are much lower in comparison to mobile ones, in a national perspective. By 2002, the transportation sector was accountable for 85% of the total volume of contaminants (including TSP, PM10, SOX, NOX and CO). In addition, there is a substantial difference between the sulphur content between the fuel that is domestically produced and that which is imported. And consider that gasoline generates 1000/300 ppm, while diesel is 4500/500 ppm. The industrial sector

was culpable for only 9% of the total volume of pollutants, while the thermal energy generation sector (firewood combustion, coal, liquefied petroleum gas, kerosene and natural gas) was accountable for a slight 3.1% (Brugman, 2004).

Therefore, massive transportation systems (like articulated buses) must be encouraged to work efficiently from an environmental perspective and also in terms of energy consumption. An added benefit with massive transport – it reduces the number of cars on the road, thus improving overall travel time for commuters, but it is also a good alternative to protect urban environments. In the same way, a review of less polluting alternatives must be considered as well. Bioenergy for instance can capture carbon dioxide when the chosen feedstock is grown, via the photosynthetic process, although it does have inconveniences associated with the process, as will be explained later. Electric engines could also diminish most gases emissions; however, such technology needs to be proven safe in terms of battery disposal management. Like those examples, there could be other devices and technological advances that help to curve the increase in air pollution, however, at this time most of them are too expensive to be implemented in the short run, or simply too complex to be introduced into the Colombian context.

Picking up the thread on pollutant sources; agricultural practices, such as burning of biological wastes after harvest, have a big role in producing CO and NOX. In Colombia, by 1996, the participation of the agricultural sector in the production of these gases was 47% CO and 19% NOX. Unfortunately, such practice is still widely spread in sugarcane cultivation, greatly affecting those populations close to the plantations. Nevertheless, it is important to acknowledge that there are no epidemiological conclusive local studies that infer a direct association between such practices and the potential hazards on human health by those populations directly exposed to those pollutants that emerge as by-products of burning routines (combustion gases and particulate matter) (Perez et al., 2010).

In regards to greenhouse gas (GHG's) emissions, those activities that implied the use of fossil fuels, industrial processes, inadequate agricultural land management and forest exploitation, jointly released near to 150 thousand Gg of CO₂-Eq in 1994 (IDEAM, 2001a).

Air pollution is definitely a great problem in big urban and industrialized settlements in Colombia. Monitoring plans are still quite precarious and are neither continuous in time nor provide accurate and up-to-date information, that can help to build up a National System of Air quality. There are 19 air quality networks that operate within the national

territory, but management issues, like constant changes in the operating staff, avoid proper delivery on the information (Perez et al., 2010).

3.4.3 Consequences of air pollution in Colombia

Air pollution in urban cores has become in an important problem, in terms of public health, due to the fact that it raises the likelihood of morbidity, and mortality in infants and elderly people, particularly by causing respiratory conditions and cardiovascular diseases (Franklin et al., 2006; Norman, Cairncross, Witi, Bradshaw, & Collaboration, 2007; Slaughter et al., 2004). The CONPES document 3343 shows the annual cost of public health on account of air pollution in urban zones in COP\$1.5 trillion (USD 535 million approx.). Such cost have been assessed based on the treatment of premature mortality as a result of cardiopulmonary problems and lung cancer, and several deaths respiratory type (DNP, 2005). It has been estimated that there are close to 6000 deaths by these causes per annum. The incidence of particulate matter on the health of rural population is also a big concern, due to the use of traditional biomass, i.e. firewood, as fuel for heating and cooking purposes (WB, 2007).

Despite the abovementioned points, there are difficulties to evaluate properly the impacts of air pollution on human health, because analysis has identified deficiencies in data collection and compilation, in conjunction with poor reports of respiratory syndromes associated with air pollutants. If the aforesaid is added to a deficient monitory protocol in the assessment of atmospheric emissions, the whole situation is clouded in uncertainty. This lack of definite correlation between health issues and air quality prevents establishing actual benefits from government interventions in terms of prevention and air quality control. Therefore, large investments in emissions estimations and forecast, monitory programs, and development of control strategies might be lost if it is not clear to what extent these initiatives help to enhance health levels of affected communities (Perez, 2007).

3.4.4 Air management in Colombia and their problems

Air quality management is the process whereby strategies are designed to implement plans and use tools in order to control and monitor sources of pollutant emissions. This management set guidelines and put in motion policies in order to restore air quality and reduce harmful impacts on health and environment. There are 18 air control networks installed in Colombia, but the IDEAM ratifies just 6 of them, who have a record of registers for some pollutants. Consequently there are constraints in the

quality of information and the possibility to aggregate data at a national level (IDEAM, 2004). In summary, with the little information available it has been possible to identify that particulate matter (PM10) is one of the pollutants that supersedes the regulated standard value.

However, there is an urgent need for studies that can precisely determine the magnitude of the effects on human health that is caused by concentration of particles into the air and the incidence of other contaminants, such as that of particulate matter less than 2.5 μm , and tropospheric ozone (DNP, 2007).

Recently, projects around the Sistema Integrado de Transporte Masivo —SITM— (Massive Integrated Transportation Systems) have been introduced as a response to mobility issues in several cities, however, the environmental aspects have not been considered as a relevant factor in any of the current SITM projects. So far, there is no a single SITM project that reports any positive correlation with the SITM implementation.

Biofuels, on the other hand, have received support from the government and have been presented as air cleaning agents (or less polluting agents in comparison with regular fuels), because precisely one of the promotional drivers is their ability to act as catalyzers, improving the combustion effect.

3.5 CLIMATE CHANGE AND CLIMATE VARIABILITY

3.5.1 Climate change and climate variability

Climate change (CC) is the biggest environmental threat in recent times, and despite its vast discussion on the public stage and political arenas, this concept is subjected to different interpretations. Therefore, this concept tends to be mistaken for climate variability, the greenhouse effect and global warming. Climate variability (CV) makes reference to variations in the average climate conditions and other climate statistics (such as standard deviation, extreme phenomena, etc.) in all spatial and temporal scales that go beyond a meteorological event.

On the contrary, CC is defined as the modification of climate over large periods of time, usually decades, and related with comparable historic periods, due to natural causes, internal or external to the Earth, or anthropic but occurring in the geological past. The net effect of CC on agriculture and bioenergy production is highly uncertain, given on

one hand new trends in temperature that have not been recorded before, and on the other the adaptive response of farmers to such phenomenon (Chum et al., 2011).

Climate warming moves along with CO₂ concentrations and corresponding changes in stages in the water cycle (like precipitation patterns and transpiration effects). None of the potential effects from these natural modifications can be currently forecasted with certainty.

3.5.2 Causes and forces of the Climate Change in Colombia and in the World

Climate change (CC) can be unleashed by natural causes but also by the action of man. The most important trigger that has been reported and studied is the Greenhouse effect, which has both natural and human origin.

Most of GHG's emissions are explained by CO₂, in fact they account for 75% of the gross emissions. However, this does not take into account the CO₂ lost from the atmosphere by effect of forest recuperation, or oceanic absorption. Following that line, the remaining elements of methane, carbon oxide, NXOX, O₃ and Chlorofluorocarbon gases (or CFC's), are equally responsible for global warming. The GHG's are predominantly produced by fossil fuel combustion, related with various production sectors around the world.

World levels of CO₂ have reached an atmospheric concentration of 379 ppm in 2005, compared with an approximate concentration of 280 in 1850 (Solomon et al., 2007). Methane concentrations have risen as well over the same period of time (from 0.7 ppm in the industrial era to 1.7ppm in 2005), due, among other factors, to an enormous release of gases by extensive livestock and cattle farming, solid wastes and burning practices. There has been reported an increase in the levels of nitrous oxide (going from levels of 0.27ppm to 0.32 ppm just in 2005) which correlates with the change in agricultural practices and intense use of fertilizers. It is important to point out that the global warming potential of these gases far more powerful than CO₂, (Methane 21 times more than CO₂, and Nitrous Oxide 3100 times!) (Solomon et al., 2007).

The contribution of Colombia to this particular problem is quite low, reaching only 0.4% of the global total in comparison with other nations around the world, and even in the LAC region, being surpassed by countries like Mexico, Brazil, Argentina and Venezuela. In 2001 the IDEAM presented a study which calculated the GHG's

emissions (particularly CO₂-Eq). In that study Colombia was calculated to produce emissions of more than 54 million Gg, and nearly 34.1% of that was the responsibility of the transportation sector.

Therefore, an energy source such as ethanol or biodiesel, which reduces emission levels, might help to alleviate, temporarily, the pressure on the environment, only if the net effect is not affected greatly by LUC and iLUC effects. These effects will be the subject of further discussion later.

3.5.3 Effects and consequences of climate change in the World and Colombia

All these factors in union, or even individually build up climate phenomena (changes in the atmospheric pressure, in the air circulation systems, rain distribution and frequencies), which in turn might result in climate change.

Nevertheless, there is uncertainty as to what extent and how fast the consequences of it take place. This uncertainty is inherent to the weather system, due to its non-linearity and complexity.

Bioenergy takes part in the terrestrial carbon cycle given that resulting emissions from burning processes will be absorbed later during the growing period of the plantations⁴. In accordance with a particular land use terrestrial carbon stocks are released to the atmosphere, therefore the inclusion of LUC effects is crucial for recent LCA studies⁵.

Production and use of bioenergy influences climate change through emissions from the bioenergy chain, changes in the biophysical carbon stocks, alteration of markets (such as the fossil fuel one) by the implementation of bioenergy and changes in established environments (modifications in existing albedo) (Chum et al., 2011).

It is important to point that bioenergy does not necessarily unleash LUC effects. For instance combination of feedstock and some other crops can avoid land displacement. Use of cellulosic material, as well as some wastes and residual oil also provide an alternative in this case. The case of Colombia presents a particularity where it is traded part of

⁴Net carbon balance is not necessarily equal to zero, given that the sequestration process can take longer than the emission one in some cases (Chum et. al., 2011).

⁵These effects can be broken down in direct and indirect LUC. The former have been included in LCAs since the year 2000, while the inclusion of the latter is practically absent in studies of this nature. In this document both effects have been taken into consideration.

the land that was formerly used for exporting sugar and nowadays is utilized to feed the ethanol production process, therefore, there is no need for additional land under the current circumstances, but it could be reconsidered in the near future if ethanol and sugar exports are taken into account.

The use of firewood in a traditional way for heating and cooking task is not efficient, and produce large amount of incomplete combustion products, that impact negatively on CC and the local air quality (K. R. Smith et al., 2000). Consequently its reduction by the implementation of modern biomass products can alleviate those aspects recently mentioned, and the AGB stocks, and forest preservation (with its results on biodiversity) can be done easily (Ravindranath, Balachandra, Dasappa, & Usha Rao, 2006).

3.5.4 Policy actions to tackle CC in the World and Colombia and their main obstacles

According to the latest report of UNFCCC, Colombia was responsible for the emission almost 180 Tg CO₂ Equivalent in GHG during 2004⁶. In fact, in comparison with the previous assessment in 2000, the growth of GHG has raised up to 1.33% over the whole period. The contribution of LUC effect and associated emissions for 2004 was nearly 14.5%. (UNFCCC, 2013) Even though Colombia does not contribute heavily to GHG's (just 0.5% to the world's total emissions, i.e. 30689.5 Tg CO₂ Eq in 2004) (Anderson, Fergusson, & Valsecchi, 2008), it has been active within different agreements and treaties on climate change, like:

- the World Meteorological Organization (WMO) and its World Weather Watch (WWW) program,
- the program of the Inter-American Institute for Global Change Research
- the UNFCCC and its Kyoto protocol,
- through laws 164 of 1994, and 629 of 2000.

Within these agreements Colombia has committed to develop political answers and strategies through mitigation and adaptation, which have been recognized as valid solutions to CC problem.

Since the first official national communication to the UNFCCC (IDEAM, 2001a), Colombian has adopted an active role in implementing mitigation actions, by mean of Clean Development Mechanisms or CDM's as introduced in the Kyoto protocol. These

⁶Including LULUCF/LUCF

projects cover energy production, urban mobility, waste and residual management, among others. So far, these projects represent 0.86% of projects at global level (DNP, 2007).

The quota of responsibility in GHG's emission for Colombia at world level is quite low, for that reason it is difficult to think of a public policy directed at climate control that gives national priority to mitigation of CC. Despite the benefits that are included in the CDM's that have been implemented so far in Colombia, it is important and imperative to highlight the urgent need of setting in motion an adaptation approach, given an enormous vulnerability of strategic sectors such as water resources, agriculture, health and life-supporting ecosystems. It is also crucial to focus political efforts, institutional capacity and knowledge development in this field.

Climate change can be faced with an adaptation strategy, but CC requires a long term strategy as well. So, work must be directed to diminish GHG's emissions and move forward on mitigation actions. This implies the need of restructure the energy matrix towards sustainable alternatives, such as solar, photovoltaic, wind, tide, etc. First generation biofuels in particular can be a transitional option. However, they still represent serious threats to environmental and social equilibriums, if they are not managed properly. Nevertheless, they can provide a low-cost alternative, giving some time to mature other options like cellulosic bioethanol, or algae-based biodiesel, or even some other future options for transportation.

In order to achieve integral management capable of facing the challenge that threatens, it requires an holistic vision or to assume CC as a common factor in the environmental problems that Colombia is confronting, and as an issue that should be managed with a trans-focal and trans-disciplinary approach that covers more areas of expertise that just environmental management, it also needs political, economic and social intervention at a national level, incorporating an adaptation perspective. Alongside this, Colombia must develop an institutional framework that coordinates such management tasks, taking into account those different sectors (DNP, 2007). By doing so it is possible to build a more effective set of policies, create regional coalitions for the inclusion of people, and extend the scope of the local effects to a global level (Bergkamp et al, 2003).

With regard to vulnerability reduction in Colombia, and thinking of the possibility of increasing its adaptive capacity, it must be considered that, albeit adaptive capacity of ecosystems hinges on several biological factors, among them the extension of ecological niches, genetic reserves, etc., human capacity of adaptation goes beyond and does not

only depend on knowledge (technology), but also on the institutions, social, legal and political powers, that rest upon public workers and society in general (Bergkamp, Orlando, & Burton, 2003).

Among the weaknesses for prevention and control regarding CC, at a national level, there is an evident lack of a general action plan, as well as local and regional strategies for mitigation and adaptation to CC. There is no adequate institutional framework either, that coordinates such management: it presents failures in responsibilities allocations and coordination capabilities (DNP, 2007).

Therefore, the next 10 years will be fundamental for Colombia to define its position towards a threat of climatic variability and climate change, given that the adaptation costs from now until 2030 at a global level could increase between 5% and 20% for global GDP (Stern et al., 2007).

3.6 DETERIORATION OF THE ENVIRONMENTAL QUALITY OF THE HUMAN HABITAT

The problems with the human habitat can be described by a lack of environmental rationality expressed in either rural or urban living standards. This can be sensed, described, and assessed by the severe flaws in quality of life for different sectors of the communities. Such problems frequently manifest by the habitation of degraded environments, which are commonly associated with poverty conditions.

A clear manifestation of the aforementioned in urban environments is the accumulation of people in overcrowded cities, which in fact are unable to provide adequate sustenance locally, and are incapable of processing or disposing of waste adequately. The result of the great number of needs, and a shortfall in infrastructure, is that support for an enormous population turns into excessive energy consumption and big environmental impacts.

Urban settlements in developing nations are growing without control in most cases. It is common to find megacities without green zones or basic health infrastructure, along with severe shortages in water and shelter. In such cities, just under 50% of their population have running water, and 25% go to public fountains, or wells, or use manually operated pumps, while the remaining 25% have to use non-drinkable water (Habitat, 2008). In a general sense, cities have been growing in a segregated way, surrounded by slums and precarious public spaces, in strongly degraded social and physical environments. Colombia has not been the exception to such trends.

Urban demographic growth and rural population diminishment

Colombia has experienced a similar urbanization process to the one experienced by several countries in Latin America. In just 40 years the organization of Colombian territory has changed drastically, turning into a more urbanized country. The last census that was carried out in Colombia, took place in 2005. This statistical exercise revealed a population of 41.5 million, of which 76% were living in urban areas as a result of the expected migration from the countryside to cities, but also augmented by the forced displacement phenomenon from internal conflicts. It has been suggested that by the year 2020 populations could reach 43 million people in urban settlements.

The growth of Colombian cities has not followed any sort of formal planning whatsoever, and as a consequence some of the environmental problems mentioned earlier emerge.

The possibility that bioenergy brings to this problem is one of the main drivers associated with an active biofuel implementation policy - to provide different alternatives for rural development. Therefore, if energy crops are established as part of an extensive policy, the migration from rural areas to cities can be reduced. This situation would lead to less crowded spaces and eventually better life conditions.

3.7 CONCLUSIONS

Biomass use is definitely a source of conflict, therefore its employment for energy provision require a balance of advantages and disadvantages. A disruption in the natural equilibrium entails a thread of environmental crisis, which can be summarized in 5 problems. Those problems are closely linked with the implementation of biofuels plans, such as the one that is presented by the Colombian government.

Biofuels production, commercialization and use can help to mitigate some of those issues, but also can trigger or strengthen others.

In particular for Colombia is concluded that current location do not pose threat on biodiversity, and future expansions have only been considered within authorized (non protected) areas. However some other obstacles might emerge as the disruption or fragmentation in natural habitats, and the intensive use of agrochemicals.

LUC and iLUC effects are also foreseen in the implementation of bioenergy projects. Soil can be seriously deteriorated by agricultural practices, therefore R&D and training

to farmers are required to use a soil-friendly techniques, without compromising yields. Bioenergy projects in Colombia can be expended in detriment of livestock farming, which is neither intensive nor technified enough.

Water availability is one of the biggest difficulties to overcome for biofuel expansion projects, due to the heterogenic distribution of the resource. Eventually water management treatments can mitigate this issue.

Biofuels can contribute positively and negatively to air pollution and CC. On the good side, photosynthetic activity removes vast amounts of CO₂, produced by manufacturing and burning processes, but at the same time biofuels itself required to be burned and in the agricultural stage offer a great contribution of NO₂ among other GHG's.

On the social aspect, biofuels might turn into an attractive alternative to bring back confidence in the rural areas. As consequence of this, inverse migration from urban to rural areas could be unleashed with a better distribution of a very uneven demography.

