Scenarios of the future expansion of Oil Palm in Colombia: impacts generated by the biofuels sector

Carmenza Castiblanco Rozo

Pontificia Universidad Javeriana
Facultad de Estudios Ambientales y Rurales
Bogotá, D.C., Colombia
2014

Scenarios of the future expansion of Oil Palm in Colombia: impacts generated by the biofuels sector

Carmenza Castiblanco Rozo

Thesis submitted as a requirement for the degree of:

Ph D. in Environmental and Rural Studies

Director:

Andrés Etter (PhD)

Research program:

Ecología y Territorio

Pontificia Universidad Javeriana

Facultad de Estudios Ambientales y Rurales

Departamento de Ecología y Territorio

Programa de Doctorado en Estudios Ambientales y Rurales

Bogotá, D.C., Colombia

2014

"Pero cuanto más difícil es una tarea, tanto más educadora es. Cuanto más especial es una ciencia, mayor es la concentración espiritual que exige; más grande ha de ser el desinterés que la anima. Es al científico moderno más que a ningún otro, a quien conviene el austero consejo de Kipling: " Si puedes ver de pronto hundirse la labor de tu vida, y recomenzar la tarea, si puedes sufrir, luchar, morir sin murmurar, tú serás un hombre, hijo mío".

Gaston Bachelard

Dedication

A María, mi **madre**.

“El viaje no termina jamás. Solo los viajeros terminan. Y también ellos pueden subsistir en memoria, en recuerdo, en narración... El objetivo de un viaje es solo el inicio de otro viaje”.

José Saramago.

Acknowledgements

I would like to express my gratitude to all the people who gave me their support and companion during the development of my doctoral thesis. I want to thank particularly:

Professor Andrés Etter, my thesis advisor, who guided me through this research process by providing me with his knowledge, experience and time.

Professor Álvaro Moreno, director of the Economics School of Universidad Nacional de Colombia, for his support, guidance and contributions to the economic analyses, especially the development of the fourth chapter.

Professor Mitch Aide from the Biology Department of the University of Puerto Rico, for his accompaniment as member of the Doctoral Committee and his collaboration in the development of the second chapter.

Jeiner Buitrago, Agronomist and expert in Geomatics, for his permanent presence and help in the spatial modeling analyses.

Professor Alberto Ramírez from the Environmental and Rural Studies Faculty of Pontificia Universidad Javeriana, for his advice regarding statistics and his contributions in the development of the third chapter.

Professor Lesley Potter from Australia National University for her invitation and presence in the tour we took around several oil palm zones in Colombia, during the first semester of 2011.

Professors Nohra León and Tomás León Sicard from the Environmental Studies Institute in the Universidad Nacional de Colombia, who as directors of this Institute gave me their support by authorizing my studies commission and by providing financial resources to fund my PhD thesis.

Professor Beatriz Alzate and student Carolina Gutiérrez from the Environmental Studies Institute in the Universidad Nacional de Colombia, for their collaboration in the analyses related to Geographic Information Systems.

Professor Jairo Sánchez from the Environmental Studies Institute in the Universidad Nacional de Colombia. He took the time to read and make comments on some of the texts included in this thesis.

Students of the Environment and Development Master Program of the Environmental Studies Institute (Universidad Nacional de Colombia): Alba Ruth Olmos, Carolina Gutiérrez and Sonia Hortúa; and students of the Environmental Management and Rural Studies Master Program (Pontificia Universidad Javeriana): Guillermo Fernández, Ángela Romero and Luis González. Doubtlessly, the reading of your texts and the discussions we held were significant for clearing up diverse topics of my own work.

The directive board of the Investigation Institute of Biological Resources Alexander von Humboldt, for the information they provided regarding Colombian Orinoquia region.

Sofía Rincón, Sector Policy Officer of WWF Colombia and the Direction of Ecosystems and Environmental Information of IDEAM by supply me information about the Colombian land covers map for the period 2002-2008.

Sonia Hortúa, student of the Environment and Development Master Program for her collaboration in simultaneous translation, style correction and translation of some of the texts that compose the final document.

Ángela López and Norma Sabogal, for their contributions in the edition process.

My dear classmates and friends from this PhD program, especially Aída, Gloria and Olga Lucia, for their permanent support and solidarity.

And finally, I want to thank my beloved family, particularly Julian, my son, for his love and unconditional support.

Abstract

Biofuels are promoted worldwide as an alternative for the replacement of fossil fuels, especially in the transportation sector. Currently, oil palm is the most important crop used for biodiesel production in the world. Colombia is the fifth largest oil palm grower worldwide, and policies that provide subsidies have been enacted to ensure that Colombia plays an important role in future biodiesel markets. At that same time, many sectors of society are concerned that the negative effects of biofuels may be worse than the benefits. Important questions have been raised concerning: i) impacts generated by land use and land cover change; ii) impacts on prices and food production, iii) impacts on water and related ecosystem services, and iv) socioeconomic impacts of oil palm production in rural areas.

This research is to examine and explain some impacts deriving from oil palm crop extension and increase, for biodiesel production in Colombia, specifically in regard to land use changes in the main oil palm producing areas; the effects a state policy of biofuel support and promotion has had over different agents integrating the productive chain, and over the well-being of those communities located in oil palm producing areas.

In order to identify associated factors and key impacts of the expansion of oil palm plantations, different theoretical and methodological approaches are applied. A spatial regression analysis and an econometric model were used to identify the land use transitions generated by oil palm crops for the period 2002-2008. In order to analyze the contributions of this crop to social and economic well-being of the producing municipalities, a conceptual framework was proposed, based on the hypothesis of the main primary exportation product (staple thesis). Descriptive statistics methods and multivariate analyses are applied. Finally, the economic impacts of policies supporting biodiesel production in Colombia, such as subsidies and mandatory mixtures were evaluated by applying a partial equilibrium model of two sectors: markets of crude palm oil biodiesel industrial production, and demand for land to produce palm oil.

The results show that between 2002 and 2008, more than 50,000 ha of new oil palm plantations were established in Colombia were established in areas previously used as pastures, 20% of new plantations has replaced agricultural lands, particularly areas that

were previously used for the production of rice, banana and mixed agriculture. Less than 15% of the new oil palm plantations impacted natural vegetation (e.g. forest, savannas). However our study possibly underestimated the impacts of palm plantations on natural areas because we did not quantify the effects of indirect land use transitions. Indirect land use transitions could be important when oil palm plantations are displacing previous landowners (e.g. subsistence farmers, cattle ranchers), who then colonize new areas by clearing forest to continue their farming and cattle activities.

Our results also suggest that the oil palm municipalities present lower levels of unmet basic needs and bigger fiscal incomes in comparison to municipalities where this crop is not cultivated. While the averages for the indexes GINI_T , GINI_P and the violence index (IV), at the national level, are higher in oil palm municipalities during the period of analysis, although these differences only for some years and in some regions are statistically significant.

Finally, the simulation results of the partial equilibrium model for the period 2010-2020 reveal that the subsidies themselves alone are not effective tools for achieving the objectives defined in the Biofuels Program in Colombia. Subsidies must be complemented with mandatory biofuel blend regulations to guarantee that oil palm growing and biodiesel production are profitable enough investments, so that producers can place their bets on such business.

In conclusion, although oil palm is an important component of the Colombian agro-export and energy strategies, the government's future expectations do not match reality. It is highly unlikely that the government's expectations of an increase of 3 million hectares of oil palm plantations will be achieved. Even with strong government support the projected oil palm plantations in Colombia will not reach more than one million hectares by the year 2020. Moreover, the indicator analysis leads us to realize that when conditions such as land concentration, violence and inequality in income distribution are given, oil palm cultivation may represent in the long term a trap for rural development (staple trap).

Finally, the analysis of policies in support of the biodiesel industry leads us to conclude that the subsidies should not be regarded as an effective tool for achieving the goals of blending defined in the Biofuels Program in the country. The effects on the production of CPO and

biodiesel are not very important. Nonetheless, subsidies increase the producer price of CPO and biodiesel in the short and long term. The producers of the palm industry benefit to a large degree from the effects of subsidies in the short term, but in the long term biodiesel producers will get a much larger share of the income growth of the entire production chain.

Key Words

Oil palm, spatial modelling, land use change, rural development, social welfare, staple thesis, staple trap, biodiesel subsidies.

TABLE OF CONTENTS

CHAPTER 1

1. Introduction

The program of biofuels in Colombia is based on biodiesel production from sugar cane and oil palm, and this latter constitutes the focus of attention of this dissertation. This introduction presents background information about the impacts derived from the support program for oil palm biofuel production, as well as the pertinence of the analysis and evaluation of such impacts. This section also points out the research questions, objectives, conceptual framework and methodological approach followed by this investigation in order to evaluate the next main topics: land use and cover changes derived from oil palm crops expansion; contribution of this energy crops in the welfare of rural populations; income distribution among several agents of the value chain; effects and efficiency costs of tax exemption and subsidy policies, as well as their impact on production, exports and supply of Crude Palm Oil (CPO) for other uses. The structure of the dissertation is presented at the end of this section.

1.1. Background and problem identification

The rapid growth of human population and its demand for goods and services represent every day a bigger pressure on natural resources and ecological systems (MEA, 2005). Currently, the nations around the world face the challenge of managing soil and water resources in a more efficient way in order to provide food to a growing population; guaranteeing low cost and environmentally sustainable energy sources; and planning land uses that allow adaptation and mitigation regarding the effects of climate change (Foley, et al., 2005; Lotze - Campen, et al., 2009; MEA, 2005).

The global productive infrastructure based on fossil fuels (oil in particular) and the new demands by emerging economies such as China and India generate scarcity scenarios and high volatility of oil prices (IEA, 2012; FAO, 2008). The energy policies around the world are focused on reducing Greenhouse Gas (GHG) emissions, removing subsidies for fossil energy, and promoting energy saving and the change to other sources that present low carbon emissions (IEA, 2010). These facts have pushed the nations to find a sustainable energy model, where the production and use of biofuels have a promising forecast (IEA, 2006; IEA, 2010).

Policies and programs oriented to promote biofuels use and production have gained increasing importance because they are advertised as a renewable and clean energetic option that allows countries (especially developed countries) to comply with their compromise of reducing GHG emissions in the short and medium term. Additionally, first generation biofuels are seen as an opportunity to promote economic growth in rural areas, particularly in developing countries (FAO, 2008).

The production of raw materials for biofuels currently occupies 16 million hectares (ha), which is nearly 1.7% of the global agricultural land (OFID-IIASA, 2009). A demand increase for these lands is forecasted in 3% and 4% for 2020 (Gallagher, 2008). Possible options are identified in order to keep up with that growing demand: i) crop intensification; ii) land use change in agricultural lands; iii) expansion of the agricultural frontier towards natural covers and countries with land availability; and iv) conversion of marginal lands which are degraded or abandoned (Lotze- Campen et al., 2009).

The expansion potential of arable lands is mainly located in South America and Sub-saharan Africa, and it is more limited in Asia, where the demand will be concentrated on food production (OFID-IIASA, 2009).

Like other energy sources, the development of biofuels represents opportunities: strengthening of national energy baskets; mitigation of GHG emissions; enhancement of Gross Domestic Product (GDP) due to exports; and increase of income and employment in rural areas. But biofuels may also originate significant risks: expansion of agricultural frontier towards zones which have ecological importance; direct and indirect land use changes and its consequences in terms of GHG emissions; concentration of land and production means; and price increase of land, food and supplies for agricultural production. The risks vary according to the kind of raw material, the production location, the transformation process and the economic and political context (Duffey, 2011).

In the face of these risks and uncertainties, producer and consumer countries have modified their support policies and have established various certification schemes oriented to guaranteeing biofuel sustainability. These initiatives (led mainly by the European Union, the Netherlands, the United Kingdom and Non-Governmental Organizations) cover several aspects, such as: i) mitigation of impacts due to GHG emissions derived from direct and indirect land use changes; ii) regulation of impacts on food supply and price; iii) control of local environmental impacts on soil and water; iv) mitigation of social conflicts related to land and labor rights; and v) development of second and third generation technologies (Sorda et al., 2010; Koh and Ghazoul, 2010; Miyake et al., 2012).

Currently, the European Union employs the Guideline 28/2009/CE/RED, which establishes restrictions regarding the origin of raw materials and regulations on land use (among other requests). The challenge is maintaining this sector’s growth with governmental support and mandatory blends, and simultaneously complying with ecological sustainability requirements.

- **Biodiesel production from oil palm plantation in Colombia**

Biofuel production in Colombia started in 2001 with the Law 693 of 2001, which established deadlines and requirements of oxygenated blends in cities with more than 500.000 inhabitants. In 2004, the Law 939 defined the general guidelines for blends of diesel with vegetable fuels (especially for those derived from oil palm). Finally, the CONPES 3510 (DNP, 2008) outlined the foundations and orientation of the national policy concerning the sustainable production of vegetable fuels in Colombia.

The biofuel sector fits well in the Colombian economic model that relies mainly on the primary sector and the agroindustrial production for exports (as revealed in the National Development Plans from 2002 to 2014). This country has high expectations on the consolidation of biodiesel (oil palm) and ethanol (sugar cane) industries, not only to supply the domestic demand, but to export as well (DNP, 2008). In order to achieve those objectives, the national government has given a strong support to this sector, which includes mandatory blends and economic incentives. There is currently an ambitious goal of a 20% mandatory biodiesel blend for 2020 (Law 693 of 2001, Law 939 of 2004).

Colombia is the first CPO producer in America and the fifth in the world. Oil palm is the main raw material used to produce biodiesel. This crop has existed in this country for more than fifty years and is currently established in 108 municipalities of 17 departments (or provinces). While, oil palm agroindustry is one of the most promising Colombian agricultural sectors. Although it has a huge development potential, it also faces several challenges. One of them is overcoming the phytosanitary issues that have led to the loss of nearly 70.000 oil palm ha in the last seven years. This a possible threat to this sector’s sustainability (FEDEPALMA, 2013). In addition to that, the high production costs (in comparison to the main producer countries) also impact the economic sustainability and competitiveness of this sector internationally.

Given the rise of biofuels in the last decade, the national government has an ambitious goal of a 3 million ha oil palm crop expansion, out of which 1.9 million would be located in the Eastern zone of the country (Bochno, 2009).

Nevertheless, the expansion of oil palm crops in Indonesia and Malaysia at the expense of natural tropical forests, intervened forests and agroforestry systems (documented by Koh and Ghazoul, 2008; Hansen et al., 2012; Miyake et al., 2012) is a precedent that has led to a strong debate in Colombia regarding the real contribution of energy crops and biofuel production in social welfare, ecosystems conservation and the development of rural areas.

On one hand, the State and enterprises argue that energy crops (particularly those related to biofuels) may be important drivers of economic growth and a source of exports, because they generate employment, circulation of foreign currency and life quality improvement for rural population (DNP, 2008; FEDEPALMA, 2013).

On the other hand, several groups of civil society (NGO, farming and ethnical communities) point out that energy crops incite competition for natural resources (water and soil) and other agricultural production supplies (CINEP, 2009; Fajardo and Salinas, 2010); they also concentrate assets (such as land) and increase inflationary pressures on food (FAO, 2008). Additionally, there is evidence suggesting that biofuels tend to monopolize state subsidies and that they have also contributed to displacement and conflict in rural zones (CGR, 2008; Seeboldt and Salinas, 2010, Molano, 2012).

There is uncertainty regarding the effects of a large-scale expansion of oil palm crops to produce biodiesel. The following are concerns from an environmental perspective: i) expansion of the agricultural frontier towards vulnerable and strategic areas; ii) increase of GHG emissions due to direct and indirect land use changes; iii) deterioration and pollution of soil and water bodies; and iv) biodiversity loss derived from crop expansion. From an economic perspective, it is uncertain if these products, which are export-oriented and cultivated at a large scale, are able to become drivers of rural development (Fajardo and Salinas, 2010; Molano, 2010). From a social approach, in some of the oil palm productive areas there is evidence of the role played by this activity in violent land dispossession and violation of labor rights (Seeboldt and Salinas, 2010).

In order to gather documented information around this debate, four research questions are formulated. They are approached in the development of this dissertation.

- Which are the variables that explain the recent expansion processes of oil palm crops in Colombia?
- Which zones in Colombia may present a bigger expansion of oil palm crops?
- How have oil palm crops contributed to the development and social welfare of communities and regions where this activity takes place?
- Which are the economic effects of the biofuels promotion policy in Colombia?

1.2. Objectives

General objective

The general objective of this investigation is analyzing some of the impacts derived from the intensification and expansion of oil palm crops to produce biodiesel in Colombia.

Each of the aforementioned questions is linked to a specific objective.

Specific objectives

- Quantifying and analyzing the factors associated to the current and future expansion of oil palm crops in Colombia.
- Modeling and quantifying recent and future expansion areas of this crop and determining land use and cover transitions.
- Evaluating socioeconomic impacts derived from oil palm production in rural zones through the analysis of some available indicators, in order to establish if these crops have a differential effect in comparison to other municipalities where oil palm is not produced.
- Evaluating economic impacts of policies related to tax subsidies and mandatory biodiesel blends.

1.3. Conceptual framework

“Strong sustainability” is the key concept that integrates the chapters of this dissertation and it emerges from ecological economics (Daly, 1992; Martinez Alier and Roca, 2013; Riechmann, 2014), an academic approach that establishes the interface between economy and ecology by proposing that natural capital (ecosystems’ structure and functions) is limited by environmental features such as irreversibility, uncertainty and the critical components of these ecosystems, which make a unique contribution to human welfare (De Groot et al., 2002).

In order to understand the concept of “strong sustainability”, it is necessary to explain the meaning of sustainability beforehand: it is defined in terms of the required conditions to guarantee an equal distribution of welfare among several generations. The rule is simple: current generations must satisfy their needs without compromising the ability of future generations to meet their own needs (Brundtland Report, 1987). In order to achieve a sustainable development, the decisions made in the present regarding accumulation of physical capital, human capital and natural capital (land, water, soil, biodiversity) must be consistent with a sustained and equitable growth of intra- and intergenerational welfare.

In this sense, the notion of “weak sustainability” assumes that all kinds of capital are replaceable; in other words, the accumulation of physical and human capitals is able to compensate the deterioration of natural capital (land, ecosystems, natural landscape and others). When this substitution is not possible, one is referring to a “strong sustainability”, which means that the precaution and conservation principles (if there is uncertainty about the effects of any activity, if changes are irreversible or if the exhaustion of some resource jeopardizes life) are included in the decision-making processes (Daly, 1997; Turner and Pearce, 1994).

The concept of “strong sustainability” understands sustainability in terms of scale and temporality, and also advocates for the conservation of the ecosystems’ qualities and natural features, which allow them to perform a wide range of functions, including the conservation of biodiversity (Ekins et al., 2003). Martinez Alier and Roca (2013) points out that, in a strict sense, only a human economy based on renewable energy sources and closed matter cycles has the potential of being indefinitely sustainable.

Two hypotheses about growth based on natural resources or products from large-scale plantations are also important for this dissertation: the Staple Thesis and the Natural Resource Curse. It can be affirmed that the Staple Thesis concurs with sustainable development, whereas the Natural Resource Curse of may conduct nations or regions towards unsustainable paths.

The Staple Thesis was one of the first models to support the position that rural development, both regional and national, was feasible if based on a main primary product such as oil palm. This theory claims that if important links are found between crop production and the rest of the economy, bonds will be generated both in the front and in the back of the chain which will stimulate investment in the supply, transportation and infrastructure sectors, and activities will turn up to use crops as an input, thus unleashing a dynamic process of productive diversification and a virtuous circle. Although, if links are fragile and the new sectors are distant from national businessmen in terms of technology and innovation, income deriving from crops will eventually increase imports and displace both national and regional production, thus aborting structural development and deepening monoculture specialization, that is, ending up in a “staple trap” (Watkins, 1963; Findlay, 1995, Barbier, 2005, Willebald, 2011).

The Natural Resource Curse model (Sachs and Warner, 1999, 2001), on the contrary, claims that specialization in natural resource intensive products (soil, minerals, water) unleashes vicious circles which shall eventually deepen rural poverty and inequity both at national and regional levels. A hypothesis related to this model is that of the so-called Dutch Disease, triggered by an exchange rate revaluation and a lower participation of the tradable good sector in the economy (Corden and Neary, 1982). In general, these sectors create positive externalities, technological innovation and social capital. If they disappear, the economy will go into a low balance supported by the non-tradable good and monoculture sectors, which reduces growth rates in the long term (Leite and Weidmann, 1999; Sachs and Warner, 1999, 2001; Doppelhofer et al., 2000).

This pattern sharpens in productive models organized as a large plantation and capital-intensive. A larger income and land property concentration is negatively correlated to the internal market expansion and long term economic growth (Persson and Tabellini, 1994; Leamer et al., 1999; Cimoli and Rovira 2008). As manifest by Auty (2001): “The deterioration among the resource-abundant countries is more severe where the natural resource rents emanate from “point” resources, such as mining, rather than from “diffuse” source resources like land under peasant farms. Points rents are associated with staples that are relatively capital-intensive and concentrate ownership. They include not only mines but also plantations where the crop requires immediate processing as the case sugarcane (oil palm)”.

In this respect, even though regions may go through an economic boom, what happens next is that the area will experiment a growth rate below the one before the natural resource boom (Barbier, 2005). Recently, the Product Space model has been developed, which is a representation of all the products produced and exported by a country or a region shaping an interconnection network. This literature claims that economic development is a process of learning and accumulating capabilities to produce increasingly complex and sophisticated goods. The secret to economic success lies essentially in the capability to produce new goods or to develop activities with the highest productivity and efficiency levels. It was found, in a classification by complexity of about 5,132 products, in 176 countries, that oil palm is number 5,044, from highest to lowest level of sophistication, that is, if one area or country specializes in crude palm oil, it will have little possibility to develop high productivity and complexity projects, thus restricting growth and long term development rates (Hidalgo et al., 2007).

Figure 1.1 presents the conceptual framework of "sustainable development" adapted to the case of oil palm and biodiesel production. Initially, society has three kinds of capital: physical (KF0), human (KH0), and natural (land and natural resources) (KN0). These three are required in the value chain. However, in order to start biodiesel production, it is necessary to include governmental support policies such as subsidies, tax exemptions, allowances for rural capitalization, price regulation and mandatory blends. The net impacts on welfare are not direct, because results depend on the development of the Staple Thesis or the Natural Resource Curse.

If the region or country has the conditions to generate a virtuous cycle derived from the Staple Thesis, then it is possible that the welfare of present and future generations improves because there are conditions for a strong sustainability. Regarding oil palm industry, this means that most of the income is reinvested in human and physical capital, as well as in the protection of the natural capital that supports the development of this productive activity. The existence of well-defined land property rights and strong institutions reduce the over exploitation of natural resources, and thus allow its conservation for future generations (strong sustainability).

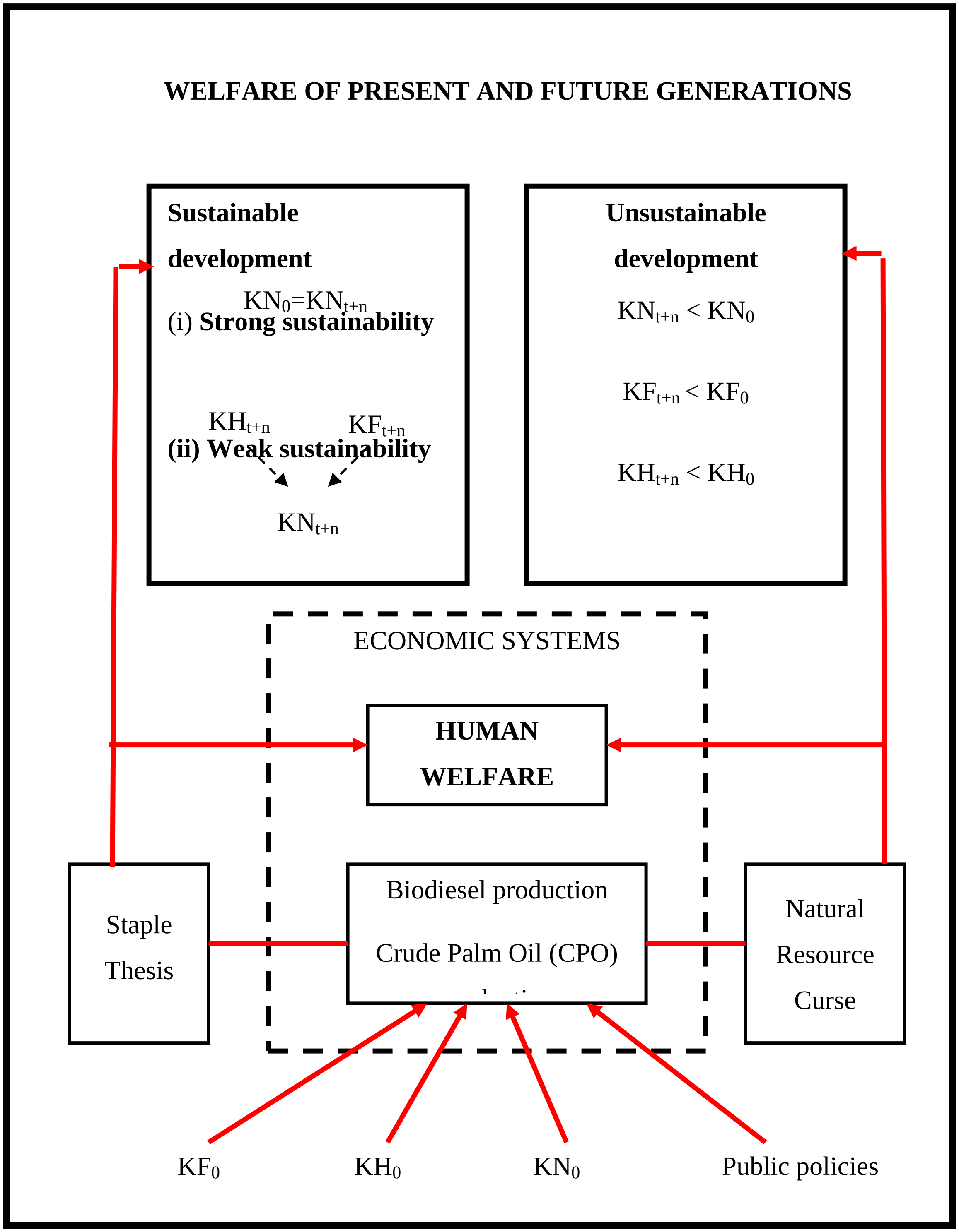


Figure 1.1. Analysis of biofuel policy from a sustainable development approach.

Source: adapted from Barbier (2005)

On the contrary, if these conditions contribute to a Natural Resource Curse, the development is no longer sustainable. In the above example, this means that the three kinds of capital decrease in the long term, as well as the welfare of present and future generations. The surplus is lost in unproductive activities (like rent seeking and corruption), income distribution worsens, and the incentives for accumulating human capital are reduced. If land property rights are not well defined, then this resource may be over exploited. This way, there are no conditions supporting a strong sustainability (Barbier, 2005).

1.4. Methodological approaches

This investigation employed several methodological approaches to analyze the impacts of the promotion policy of oil palm biodiesel. Land use transitions generated by the expansion of these crops were analyzed with a spatial modeling of the land use and cover change (LUCC) drivers. The economic analysis of the impacts derived from subsidies and mandatory blends were carried out by using partial equilibrium models and time series econometric models.

1.4.1. Spatial modeling of the land use and cover change (LUCC) drivers

As of the 1990s, a large international research program has been developing; it is aimed at advancing in the theoretical understanding of the causes of land use and cover changes, by means of a revision of generic causal mechanisms and their relationship to global change (Lambin and Meyfroid, 2010). In this respect, the International Geosphere Biosphere Program (IGBP) was launched in 1993, and later, in 2005, the Global Land Project (GLP) initiative appeared, both aiming at studying landscape transformations and their relations to human activity. The goal of these programs was to model landscape transformation dynamics and to study the impact of such changes in the supply of environmental services, global change and the resilience of the ecologic and social systems involved (Guhl, 2009).

Policies and changes in land use, can produce either direct land use changes (DLUC) or indirect land use changes (ILUC). DLUC is produced when new agricultural activity is developed in a specific area, thus creating a transition in land cover and land use, which may be directly observed and measured by using mapping techniques. An indirect land use change (ILUC) is produced as an unintended consequence of decisions regarding land use in other places far away. Un like DLUCs, an ILUC is not easy to observe or measure, nor can be isolated from other factor with an incidence on land use changes, such as a decrease in crop profitability, or changes in support policies (Young, 2011). The reason why ILUCs are a relevant concern is the risk that other animal and crop farming activities may be displaced by crops intended for biofuel production, on to lands whose vegetable cover represents carbon reserves. A large amount of GHG emissions come from land conversion, and could offset any reduction achieved by biofuel implementation (Croezen, 2010). On the other hand, there is a chance that new crops and agricultural supplies to produce biofuel may have undesirable consequences, such as environmental damage due to agricultural expansion, and risks for food security (Croezen, 2010).

In general, different research methods on land use and cover change (LUCC) share the following features: i) they are based on the study of the complex interactions between social and bio physical processes, ii) they integrate methods both from social and natural sciences, in order to study the effects of land cover and use changes in the global environment, together with the ways global changes feed back into the landscape, iii) they incorporate space and time as essential categories in order to analyze LUCCs, iv) they model the interaction of biophysical, social, political and economic driving forces, and examine how such forces generate specific environmental use and degradation patterns, v) they consider spatial patterns linked to the historical landscape usage, vi) they emphasize spatial modeling of local, regional or global transformations that may allow the prediction of future changes (Veldkamp and Lambin, 2001).

Figure 1.2 depicts how the LUCC that contribute to ecosystem transformation demand an adequate understanding of the interactions between ecological and socioeconomic systems. LUCC are highly contingent, nonlinear processes that do not follow particular patterns, they are not deterministic, and present variability in their specific trajectories (Lambin and Meyfroidt, 2010).

The proposed methodological approach includes the main drivers of LUCC and describes the causal links between indirect and direct change factors. Indirect factors (such as variations in the national and international policies, or demographic, economic, technological or cultural changes, at a global or national scale) have an important incidence in land use transitions. Direct factors, on the other hand, occur at a local scale (agricultural expansion, exploitation of timber or minerals, and in general, environmental factors) (Lambin et al., 2003).

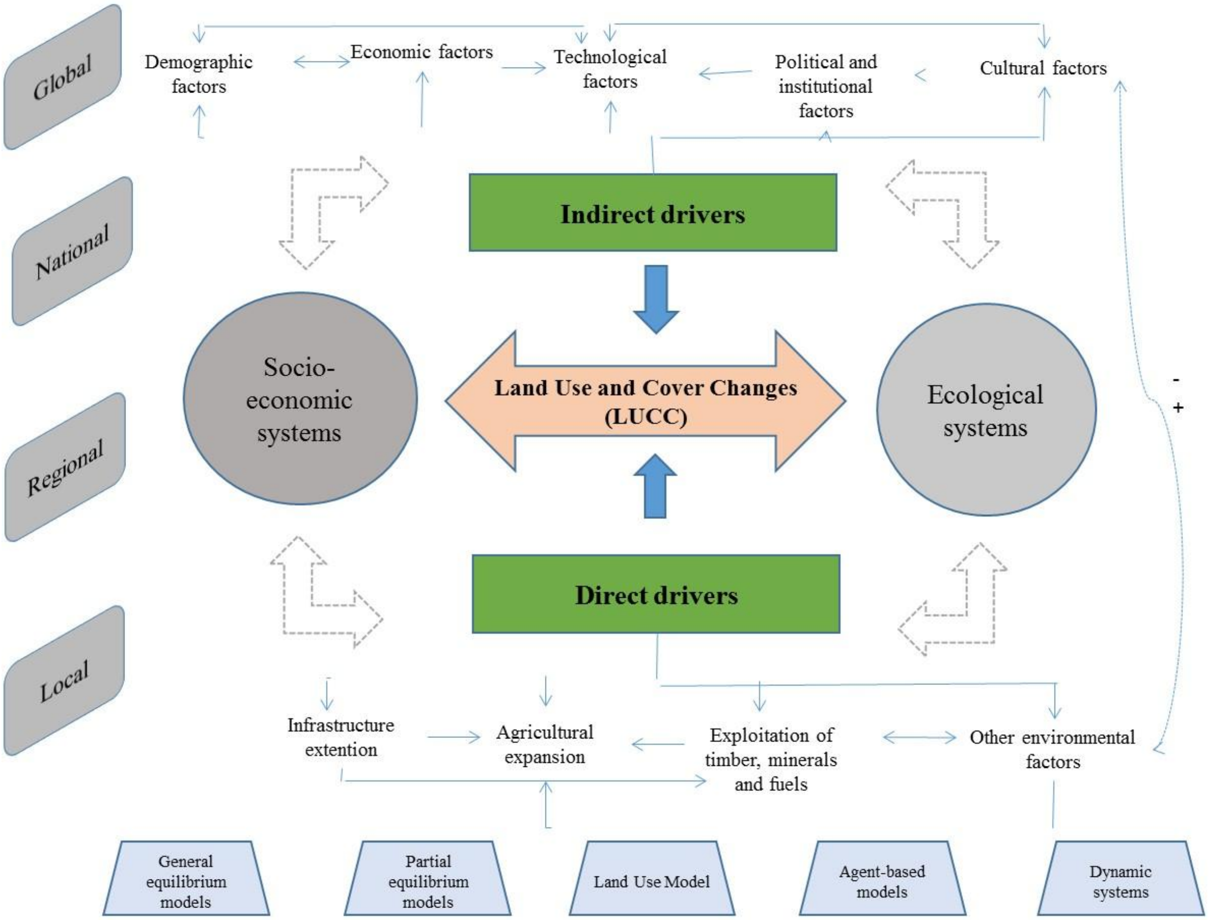


Figure 1.2. Land use and cover change (LUCC) drivers

Source: own elaboration

LUCCs derived from non-linear relations between endogenous socio-ecological forces and external shocks to the system coming from socioeconomic changes (Lambin and Meyfroidt, 2010). Separating and identifying the rate of different factors requires consistent formal models and simulation methodologies, which allow the combination of different scales of biophysical, ecologic and socioeconomic aspects. Spatially modeling socioeconomic factors poses a great challenge, given that most economic models either do not include spatial analysis, or do not offer enough spatial details to establish and describe the effects of such variables on LUCCs. All this due to the fact that data corresponding to socioeconomic variables are usually aggregated (Lambin and Meyfroidt, 2010). Additionally, when spatial heterogeneity is introduced, the results of the aggregation of individual decisions on land use in the market becomes rather complex (Lotze- Campen et al., 2009).

Recently, a series of methodologies and models has been developed to study LUCCs created by biofuel use expansion with different reaches, ranging from the study of the emission of GHGs produced by direct and indirect land changes in different countries and regions (Searchinger et al., 2008; Achten and Verchot, 2011; Overmars et al., 2011), to works aiming at developing bio-economic models to assess the main routes to make a more productive global agricultural system, so that the global biofuel demand can be met (Irwin and Geoghegan, 2001; Lotze-Campen et al., 2009).

Additionally, other methodologies grounded on optimization, partial equilibrium and general equilibrium models, as well as agent-based models, have also been used in order to model land use changes due to biodiesel demand and its relationship with other markets and macroeconomic policies.

1.4.2. General and partial equilibrium models applied to the evaluation of biofuel policies

In the last years there have been significant improvements regarding the tools for analyzing impacts of biofuel promotion policies. The economic analysis of the effects derived from subsidies and mandatory blends has been carried out through computable general equilibrium models (designed by the Global Trade Analysis Project, GTAP) and partial equilibrium models (Kretschneer and Peterson, 2008). The GTAP models allow examining the impacts of policies and exogenous shocks at a global level and including all the interactions among several markets and agents. These models demand a large amount of disaggregated information and sophisticated calculation methods (Woltjer et al., 2007).

Partial equilibrium models allow modeling specific markets and excluding relationships with other economic sectors. They require less information and their calculation methods are simpler. These models are used often to evaluate and restructure agricultural policies in the USA and Europe (Garder, 2007; Gorter and Just, 2009a).

Some theoretical and empirical studies have been developed in recent years by using partial equilibrium models in order to analyze the impacts of biofuel promotion policies on several variables (economic, environmental, and related to climate change). These studies have been focused on ethanol (USA) and biodiesel (Europe). For instance, Gardner (2007) examines the advantages of using direct subsidies to corn production or subsidies to ethanol production in order to maintain the income of agricultural producers. In this investigation, a partial equilibrium model is employed to evaluate those support policies for biodiesel in Colombia.

1.4.3. Approach

This research incorporates three kinds of complementary analyses: the first one, related to LUCC analysis and modeling; the second, analysis of descriptive statistics and multivariate statistics to assess some socioeconomic indicators available, in order to establish differential welfare impacts between municipalities were oil palm is produced and other municipalities; and the third, a partial equilibrium economic analysis aimed at assessing the impact of subsidies, tax exemptions and regulations on biofuel blends upon the whole chain.

The following analyses were made to determine LUCCs: (i) A map overlay to determine the existing kinds of land cover and the areas replaced with oil palm crops between 2002 and 2008, using for this purpose the oil palm plantations map of 2007, which was updated in 2008 with Landsat images, and the 2002 land cover map, which was reclassified; (ii) A projection of the future expansion of the farming area in different scenarios: a) assuming a simple linear trend of the historical data about oil palm growing, b) Estimating an econometric model of time series intervention which incorporates the historical trend of oil palm growing and the impact at the moment of incorporating support policies, c) Projecting the cultivated area demands required to meet the biofuel blend regulations projected for 2020; (iii) A spatial logistic regression model incorporating biophysical and socioeconomic variables to determine the land areas most likely for oil palm crops to expand into; (iv) Future land use transitions were analyzed from the overlay of the estimated expansion probability map and the land cover map reclassified for 2002.

In order to establish if oil palm crops have a differential impact on social well-being in relation to municipalities without oil palm production, descriptive statistics and multivariate method analyses were applied, at regional and national levels, by using socioeconomic databases from the available Colombian municipalities for the 1993-2007 period.

Finally, to improve the economic analysis, a bi-sectorial partial equilibrium supply and demand model integrating oil palm production and biodiesel markets. Subsidies and tax exemptions have been explicitly incorporated, as well as the national biodiesel blend regulations. The model was calibrated for 2009 and the free parameters were adjusted to replicate the equilibrium values of the base year. Then, the model was used to evaluate the impacts of subsidies and tax exemptions, and of biofuel blend regulations on the fundamental variables of the model, such as crude palm oil production, the need for land, and the prices paid by oil palm and biodiesel producers.

1.4.4. Structure of the dissertation.

This thesis is divided into seven chapters. Introduction is presented in the first chapter. In chapter two, is presented the dynamics of palm oil market and production in the international and local context, oil palm is analyzed as a multipurpose crop but the emphasis is centered on biodiesel production, the main aspects of this market are described, such as international prices and economic incentives. The trade-offs resulting from this crop's expansion regarding environment, society and economy are discussed. In the third chapter a revision of literature on biofuels is presented. In the four chapter, spatial land use and cover change analyses as a result of oil palm crop expansion in Colombia are presented. Spatial analyses and models merge with econometric analyses to determine the impact of state policies on crop land expansion and show that according to projections from the model, the optimistic expectations of the state are not realistic (specific objectives 1 and 2).

Chapter five is aimed at developing an analysis of the impacts of oil palm production on social well-being at a municipal level, some quality of life indicators are contrasted between municipalities with and without oil palm production (located below 1000m above sea level), and a conceptual framework is presented to assess risks and uncertainties of regional specialization in low complexity natural resource (water, land) intensive products such as oil palm growing (specific objective 3).

Chapter six presents the aggregated partial equilibrium supply and demand model for the biofuel and the oil palm production sectors in Colombia. The model has been calibrated for 2009 and applied to improve simulation exercises and scenarios to evaluate the impacts of government policies on oil palm and biodiesel production, on oil palm and biodiesel prices, on the distribution of sectorial income among agricultural producers and biodiesel brokers, on exports and on an estimate of "deadweight expenses" or of inefficiencies in government intervention policies (specific objective 4). Finally, chapter seven presents a general synthesis of the main contributions of this thesis to the discussion on the impacts of biofuel and oil palm promotion in Colombia in its 3 dimensions: land use and cover changes, economic and distributive impacts on the diverse actors in the productive chain and aspects related to social well-being in growing areas. The limitations of the data and of the different methodologies employed are also presented, and new research lines are suggested for the future as well.

Chapters 3, 4 and 5 have been published in indexed publications and chapter 6 was accepted with corrections and is being published.

CHAPTER 2.

2. Dynamics of palm oil market and production: international and local context

2.1. Introduction

Palm oil is currently one of the most profitable agricultural products worldwide. Oil palm crops naturally adapt to humid tropical zones and have a big expansion potential. Main producer countries are Indonesia, Malaysia and Thailand (Southeast Asia); Colombia and Ecuador (Latin America); and Nigeria (Africa). Recent oil palm crop expansion is the result of a high demand of edible oil (due to the increasing growth of China and India) and regular oil as raw material to produce biodiesel (Sayer et al., 2012).

Producer countries have taken this crop as an opportunity to enhance national markets, diversify their energy baskets and enter international markets by offering Crude Palm Oil (CPO) and its byproducts to produce food and/or biodiesel, depending on international oil (petroleum) prices and supply costs (OCDE and FAO, 2011). These governments have designed support policies that include new legislation, biodiesel mandatory blends, and economic incentives for oil palm cultivation and biodiesel production (Sorda et al., 2010).

Colombia is the first CPO producer in America and the fifth in the world. Oil palm plantation has been developed in this country for more than fifty years; it is distributed in sixteen departments and 118 municipalities in four production zones (Northern, Center, Eastern and Southwestern). During the last decade the cultivated area has significantly increased (at a 9% annual rate) from 156,000 hectares (ha) in 2000 to 476,782 ha in 2013, which makes oil palm the fourth most important crop in the country. There are fifty-eight extraction and refinery plants whose production reached a million tons of palm oil in 2013, out of which 46% (approximately) is used for biofuel production (FEDEPALMA, 2013).

Oil palm agroindustry is one of the most promising Colombian agricultural sectors. Although it has a huge development potential, it also faces several challenges. One of them is overcoming the phytosanitary issues that have led to the loss of nearly 70,000 oil palm ha in the last seven years. This a possible threat to this sector's sustainability (FEDEPALMA, 2013). In addition to that, the high production costs (in comparison to the main producer countries) also impact the economic sustainability and competitiveness of this sector internationally. The principal dilemma of Colombian oil palm agroindustry is how to guarantee this economic sustainability without the strong state support (laws and economic incentives), which is currently assuring its profitability.

Colombian oil palm regions also present high rates of land and wealth concentration, as well as increasing violence and poverty. These factors generate social and environmental conflicts that hinder the possibilities for this agroindustry to become a source of development and wellbeing for rural productive regions (Fajardo, 2009; Seeboldt and Salinas, 2010).

This chapter describes the dynamics of oil palm crops in Colombia. It highlights the conditions that account for the distinguishing factors of its expansion and growth in the different producing regions. Oil palm is analyzed as a multipurpose crop but the emphasis is centered on biodiesel production: the main aspects of this market are described, such as international prices and economic incentives. The chapter is divided into three sections: the first one analyzes the main variables and structure of the global oil palm and CPO market. The main producer countries are identified, as well as the Colombian perspectives in an international context. The second one presents an evaluation of oil palm value chain in Colombia, production costs and support policies for this sector. The third section points out the main challenges of oil palm agroindustry. The trade-offs resulting from this crop's expansion regarding environment, society and economy are discussed as a conclusion.

2.2. International context

2.2.1. Oil palm crop around the world

Oil palm (Elaeis guineensis) is a tropical crop from western and central Africa. It was cultivated for the first time in Asia in 1917 and since 1966 it is commercially produced in Indonesia and Malaysia. Indonesia has been the main oil palm producer in the world since 2005 due to its climate conditions and low production costs (Sheil et al., 2009). Oil palm production starts in Latin America in the sixties and the leading countries are Colombia, Ecuador and Brazil. Oil palm plantations have also existed in Central America (Honduras, Costa Rica and Guatemala) at a smaller scale (Pacheco, 2012). The expansion of this crop is the consequence of several facts: increasing global demand for vegetable oil due to population and income growth, and recently, the boost of biofuel market (Sayer et al., 2012).

In 2013 oil palm cultivated area was 16.4 million ha. Growth annual rate was 3% in the last fifty years and it reached 4.8% in the last twenty years (Oil World Annual, 2014). This growth can be explained by the increase of cultivated area and yield improvements (Kongsager and Reenberg, 2012). In Indonesia, this area was 1.3 million ha in 1990 and it reached 7.7 million ha in 2010 (51% of the global cultivated area); whereas Malaysia went from 2.1 million ha in 1990 to 5.2 million ha in 2010 (34% of the global cultivated area) (Gurnaso et al., 2013).

The restricted land availability in Indonesia and Malaysia has forced the companies to search other regions with open agricultural frontiers and options to enhance oil palm production. This is the case of African countries (Liberia, Cameroon and the Democratic Republic of the Congo) and Latin American countries (Colombia, Ecuador and some countries in Central America) (GIP Report, 2012). Africa has presented a modest growth in its cultivated area in the last two decades (1.8% annual rate) when compared to Latin America (5.5%), Oceania (5.4%) and Asia (7.2%). The main African producer is Nigeria, which in 2010 contained 71% of oil palm crops in that region. For the same year, Africa had 21% of the global oil palm cultivated area (FAOSTAT, 2012; Oil World Annual, 2012). Figure 2.1 shows the evolution of oil palm areas in the main producer countries for the period 2002-2011.

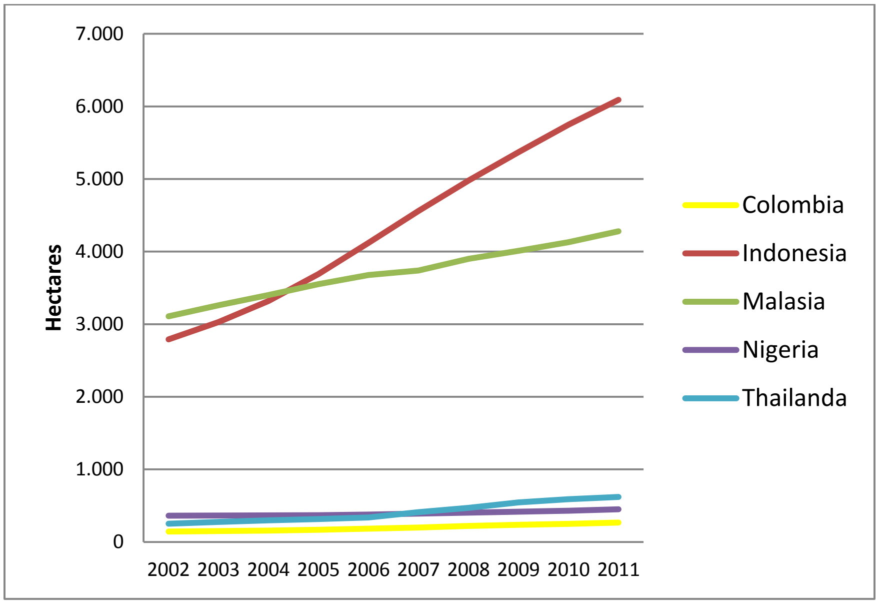


Figure 2.1. Evolution of oil palm production areas in the main producer countries
Source: FAOSTAT, 2012.

A significant aspect of oil palm production is the cost. Indonesia and Malaysia present the lowest production costs and higher yields per hectare. These costs are higher in Colombia; however, the strong state support increases the profitability of this crop.

The expansion of oil palm raises some concerns around the impacts in natural forests and other strategic ecosystems that regulate water production and biodiversity, due to land use change. This matter is even more concerning because decisions regarding the location of new oil palm plantations are made according to economic instead of social or ecological sustainability criteria (Sayer et al., 2012).

2.2.2. Expansion of oil palm crops to produce biodiesel and land use change

Oil palm cultivated area has increased in all producer countries during the last years, except for the Democratic Republic of the Congo (which presented a slight decrease) and Papua New Guinea (which presented no changes) (Kongsager and Reenberg, 2012).

Oil palm expansion in Indonesia and Malaysia has occurred due to the direct conversion of tropical and peat forests (Abdullah and Nakagoshi, 2007; Koh and Wilcove, 2008; Yusoff and Hansen, 2007). Koh and Wilcove (2008) point out that between 1990 and 2005, 50% of oil palm crop expansion has been possible at the expense of natural rain forests. In a subsequent study, Koh et al. (2011) demonstrated that 888,000 ha of Malaysian tropical peats had been converted to oil palm plantations.

A recent study by Gurnaso et al. (2013) estimated land use change associated to oil palm expansion at industrial scale in Indonesia (Sumatra, Kalimantan and Papua), Malaysia and Papua New Guinea. They obtained the following results: i) between 1990 and 2010 in the three studied countries, the amount of cultivated oil palm went from approximately 3.5 million ha to 13.1 million ha; ii) this growth presented a constant speed of 7% per year during more than twenty years; iii) for all the analyzed cases, an average of 4.1% (397,000 ha) of oil palm plantations were established on non-intervened forests (0.2% highlands and 4.0% swamps), whereas 32.4% (3.1 million ha) were established on intervened forests (25.6% highlands and 6.8% swamps). Conversion of bush prairies with low biomass corresponded to 17.8% (1.7 million ha) with a 13.5% of highland soils and 4.4% of swamps. The substitution of other plantations and agroforestry systems reached 33.9% (3.3 million ha).

Additionally, this research by Gurnaso et al. (2013) performed a detailed analysis of disturbances on peat soils: in the studied countries, oil palm plantations established on this kind of soils increased from 418,000 ha (12% of the total oil palm cultivated area) in 1990 to 2.43 million ha (18%) in 2010. Sumatra has the higher absolute measurement of oil palm plantations on peats (1.4 million ha: 11%), followed by Sarawak (476,000 ha: 46%), Kalimantan (307,515 ha: 11%) and Peninsular Malaysia (215,984 ha: 8%). Only 2% of oil palm plantations are established on peat soils in Sabah (29,000 ha) and Guinea (1,727 ha). In Papua New Guinea there was no peat soil conversion.

The analysis was also performed by countries. The conversion of forests to oil palm (including non-intervened and intervened forests, both highlands and swamps) during the analyzed period was proportionally bigger in Guinea (61%: 33,600 ha), Sabah (62%: 714,000 ha) and Papua New Guinea (54%: 41,700 ha), followed by Kalimantan (44%: 1.23 million ha), Sarawak (48%: 471,000 ha), Sumatra (25%: 883,000 ha) and Peninsular Malaysia (28%: 318,000 ha). In Kalimantan, the main land sources for new plantations were bushes and pastures (48%: 1.3 million ha), whereas other kind of plantations were more important in Sumatra (59%: 2.1 million ha) and Peninsular Malaysia (44%: 487,000 ha).

Pacheco (2012), described as the traditional agriculture in South America has been held back in the last years. On the contrary, commercial agriculture has presented a significant growth, particularly new crops of oily seeds (soy and oil palm) and sugar cane. This growth is associated, firstly, to an increasing demand by food markets and fodders for agricultural production (particularly in Asia); and secondly, to a growing demand of raw materials for biofuel production oriented to national and international markets (Pacheco, 2012). Between 2000 and 2010, there was a net increase of 24 million ha of cultivated land in South America, out of which 20 million ha correspond to new soy crops. Between 1990 and 2010, soy production grew from 33.1 million tons to 132.3 million tons and the cultivated area went from 17.7 million ha to 46.2 million ha. This occurred at the expense of lands previously used for profitable activities, such as cattle and also at the expense de native vegetation (Pacheco, 2012).

In Latin America, the expansion of crops used as raw material (sugar cane, oil palm and soya) for biofuel production have expanded around other bigger production zones which are already deforested and have replaced other cultivations. This is the case of Brazil (São Paulo, Goiás and Mato Grosso do Sul), Colombia (Valle del Cauca) and Bolivia (north of Santa Cruz) (Pacheco, 2012). The author also points out the intense debate around direct and indirect effects of biofuel development in Brazil Amazonian deforestation. Some opinions note that ethanol production has a relatively small direct effect on deforestation (this is the case of most sugar cane plantations located in center-southern and northwestern Brazil). However, the real problem is the indirect effect of these plantation´s expansion on land use. Nepstad et al. (2006) argue that sugar cane cultivated in the south tends to displace soy crops in the center-southern zone, which in turn compels cattle to move towards the Amazonian periphery.

Lapola et al. (2010), based on some simulations, affirm that land use change will have a small impact on carbon emissions because most of biofuel plantations could replace pasture zones. Nevertheless, the indirect use of these lands changes, particularly when cattle lands move towards Amazonian forests. In this sense, these authors estimate that sugar cane ethanol and soy biodiesel contribute to nearly half of the indirect deforestation of 121,970 square kilometers forecasted for 2020. Indirect land use change can also be influenced by other factors such as the increase of food price or specific incentives that promote food production (Pacheco, 2012).

2.2.3. Main CPO producer countries and production evolution.

Global palm oil production has considerably increased in the last years, from 22.2 million tons in 2000 to 55.8 million tons in 2013 with an average annual growth rate of 6.7% (FAOSTAT, 2013). In 2012, palm oil represented approximately 32% of the global production of vegetable oils; soy represented 22%; and colza oil, 13% (Kongsager and Reenberg, 2012; FAOSTAT, 2013).

Asian countries are the biggest CPO producers. In 2013, Indonesia produced 28.4 million tons; Malaysia, 19.2 million tons; and Thailand, 1.97 million tons. This represents 92% of the global production. In Africa, Nigeria produced 0.96 million tons (2%). In Latin America, Colombia generated 0.94 million tons (2%). Other small producers contributed with the remaining 6% (see Figure 2.2), (FAOSTAT, 2013).

Asian countries also present the highest average CPO yields per hectare (Malaysia, 4.2 ton/ha and Indonesia, 4.0 ton/ha). However, this performance has been stuck in recent years and it has only increased in 1%. Two Latin American countries present high yields: Costa Rica (4.9 ton/ha) and Colombia (3.5 ton/ha). In Africa, these numbers remain low when compared to global rates (Kongsager and Reenberg, 2012).

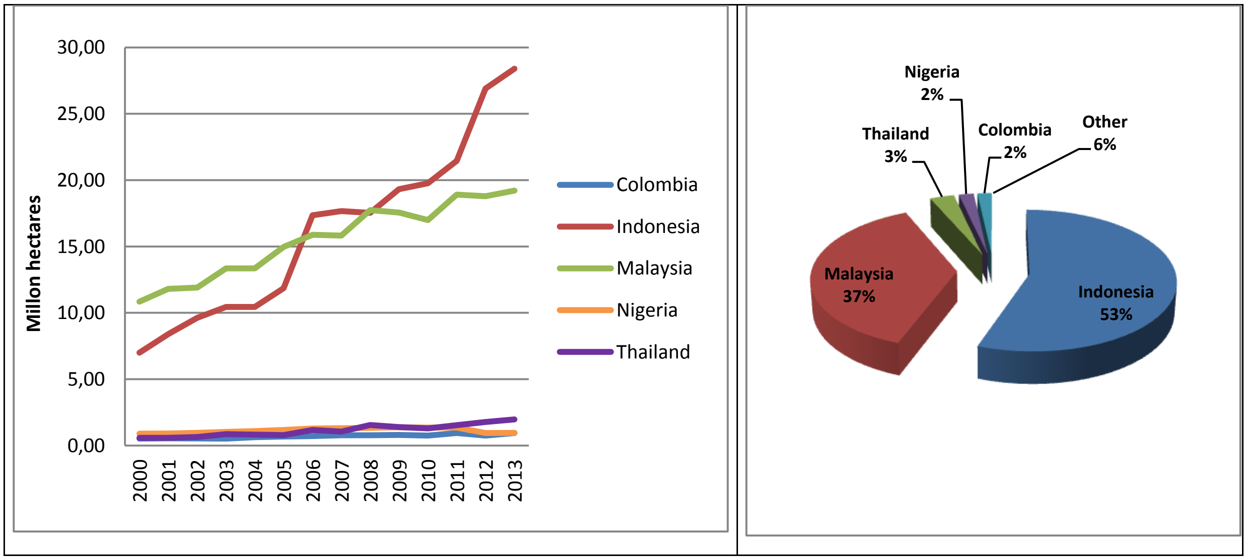


Figure 2.2. Evolution of CPO production and participation of main producer countries.

Source: FAOSTAT

Although CPO production in Latin America barely reached 1.97 million tons in 2013 (6% of global production), Colombia shows the best perspectives because it contributed with 31% of the production in the American continent. This country is followed by Ecuador (17%), Guatemala (9.9%) and Brazil (9.9%).

2.2.4. Main CPO exporters and producers

From 2000 to 2012, 60.45 million tons (approximately) of vegetable oils were exported, out of which 36.45 million tons corresponded to palm oil, equivalent to 60% of global vegetable oil exports (Kongsager and Reenberg, 2012).

The countries who have the control over this external market are Malaysia and Indonesia: both exported 36.6 million tons in 2012, which corresponded to 90% of global exports. The biggest importers are: India (18.9%), China (15.6%), the European Union (15.3%), African countries (11%), Pakistan (5%), Bangladesh (3%) and the United States of America (3%) (FEDEPALMA, 2013).

Until 2007 Malaysia was the biggest palm oil exporter in the world, but after that year its participation diminished because of land availability issues. Since then, Indonesia has taken the leadership with 49% of global palm oil exports, due mostly to the strong state support. Nearly 80% of palm oil production in Indonesia is oriented to global market (USDA, 2012).

The growing palm oil supply in this global market is followed by an important growth of its demand in some importer countries. India, China and some countries of the European Union are the main palm oil importers. The significant economic boost in China and India in the past years has generated an increase in food and energy demand. Table 2.1 shows that India, China and the European Union had the largest proportion of global palm oil imports between 2008 and 2012. China and India use this product as a source of vegetable and food oils, whereas the European Union uses it for food purposes and biodiesel production.

Table 2.1. Production, exports and imports of palm oil (millions of tons) (2008-2012)

Country	2008	2009	2010	2011	2012	Growth rate
Production	**43,551**	**45,478**	**46,040**	**50,792**	**53,665**	**5,7**
Indonesia	19,400	21,200	22,300	24,300	26,900	10.7
Malaysia	17,735	17,.566	16,.993	18,.912	18,785	-0.7
Thailand	1,300	1,310	1,.380	1,530	1,600	4.6
Nigeria	840	870	885	930	940	1.1
Colombia	778	805	753	945	974	3
Ecuador	418	429	380	495	540	9.1
Others	3,080	3,298	3,349	3,680	3,926	6.7
Exports	**33,605**	**36,100**	**36,444**	**39,057**	**40,741**	**4.3**
Indonesia	14,612	16,938	16,450	17,070		11.9
Malaysia	15,413	15,881	16,664	17,993		-2.3
Papua New Guinea	446	470	486	572	540	-5.6
United Arab Emirates	361	250	350	340	330	-2.9
Colombia	237	181	59	126	141	11.5
Others	2,536	2,380	2,435	2,956	3,060	3.5
Imports	**33,830**	**36,174**	**37,145**	**38,658**	**41,364**	**7.0**
India	5,753	6,828	6,649	6,745	7,809	15.8
China	5,593	6,558	5,804	6,173	6,447	4.4
European Union	5,289	5,854	5,868	5,405	6,311	16.7
Pakistan	1,847	1,925	2,010	2,014	2,036	1.1
USA	997	979	948	1,088	991	-8.9
Iran	665	561	615	719	740	2.9
Egypt	630	710	800	720	691	-4.1
Japan	546	551	569	588	577	-1.8
Others	12,510	12,208	13,882	15,206	15,762	3.7

Source: Statistical Yearbook FEDEPALMA (2013)

2.2.5. Decisive aspects of market and price evolution

Oil palm sector is perceived as a high profitable industry with a strong position in the market. Palm oil is the vegetable oil with a consistent presence in China and India. This is so because of palm oil prices: they tend to be lower in comparison to other alternative vegetable oils. In the last seven years, energy markets have impacted the markets of basic agricultural products.

Vegetable oils prices are influenced by high fossil fuel costs and energy costs, as well as by biofuel demand. Palm oil prices are expected to increase in the following years. Several authors consider that this future price will depend on: i) the capacity to mechanize workforce and reduce its price; ii) the potential to improve yields; iii) the possibilities of widening cultivation areas in the two main producer countries: Malaysia and Indonesia (Carter et al., 2007).

Between 2001 and 2013, international CPO price has shown a growing tendency; however, it has also presented significant fluctuations due to speculation regarding food prices, natural disasters and biofuel promotion (fig. 2.3). Additionally, the scarcity of soybean oil in 2008, the growing demand by China and India, the financial crisis, and the increasing biofuel demand also explain the erratic behavior of the prices between 2008 and 2013 (FAOSTAT, 2013).

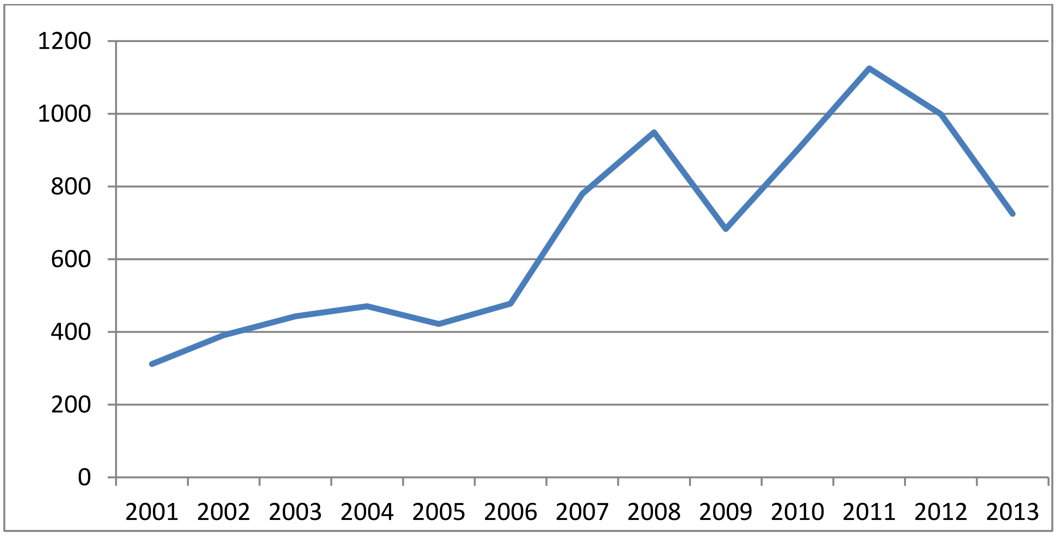


Figure 2.3. Evolution of international palm oil price (US/t)

Source: FAOSTAT.

2.2.6. Implications of biodiesel market. How many CPO is used for biofuel production worldwide?

Palm oil plays a minor role in the global business of vegetable oils for biofuel production. Koh (2007), Thoenes (2007) and Rupilius and Ahmad (2007) estimated that this product stood for less than 5% of the total biofuel market in 2006; whereas colza and sunflower represented 84% and 13%, respectively (Koh, 2007; Thoenes, 2007). The leading role of colza oil is explained by the strong state support in EU countries, where it is the main raw material for biofuel production (Thoenes, 2007). Nonetheless, this scenario may change in the future because oil palm crops have one of the highest yields; this means that they present the largest carbon compensation (Gibbs et al., 2008). There is a general consensus around the fact that palm oil would be by far the most competitive raw material for biodiesel production, if there were no subventions for other oils (Thoenes, 2007).

In the last years the import of palm oil in the EU has doubled in order to replace colza oil for food production, because more than a half of European colza crops are used to produce biofuels (Persson and Azar, 2010). Between 2006 and 2012, the 27 EU countries increased their total palm oil consumption in 40%: from 4.5 million tons to 6.4 million tons, out of which 1.9 million were used for biofuel production.

Additionally, Thailand, Malaysia and Indonesia used 1,153 million tons of palm oil for biofuel production in 2010. In Colombia, 385,100 tons were employed to produce the B10 mixture. This means that the total amount of palm oil used as raw material for biofuel production reached nearly 3.5 million tons (Table 2.2), which correspond to 5.4% of the total global production. Assuming an average global yield of 3 ton/ha, it can be said that oil palm crops employed in biofuel production occupy a rough area of 1,100,000 ha in tropical lands (Kongsager and Reenberg, 2012).

Table 2.2. Palm oil used for biofuel production in 2011

Region/country	**Palm oil to produce biodiesel (tons)**	**Source**
EU/27 countries	1,900,000	USDA, 2011
Thailand	500,000	Salvatore and Damen, 2011
Malaysia	53,000	FAPRI, 2011
Indonesia	600,000	FAPRI, 2011
Colombia	385,100	FEDEPALMA, 2012
Total	**3,438,100**	

Source: adapted from Kongsager and Reenberg, 2012.

2.2.7. International policy trends related to the regulation of CPO and biofuel production

Employing palm oil as raw material to obtain biodiesel has contributed to increase its demand in the global market. Therefore, the governments of producer countries have designed policies, regulations and economic incentives that allow enhancing the production in order to satisfy domestic and global demand for palm oil. Several countries (including the EU) established mandatory blends and subsidy policies for biofuels with the objective of facilitating the transition from fossil fuels to ecologically sustainable fuels in the transportation sector (see Table 2.3).

Table 2.3. Incentives and mandatory blends for biodiesel

Country	Incentives for biodiesel	Biofuel targets
European Union		Biofuels will be 10% of transportation fuels by 2020
Germany	E0.09/liter tax relief on pure biodiesel 4.4% mandatory blending	8% blend in 2015
France	E0.33/liter tax relief on biodiesel	Biodiesel quota increases to 3.2 million tons by 2010
United Kingdom	E0.20 liter tax relief on biodiesel, 2.5% mandatory blends from April 2008	
USA	US$1.00/gallon excise tax rebate on biodiesel	350m liters of biofuel by 2010
Indonesia	Government invests US$22 billion over 5 years to promote biofuels from CPO, cassava, jatropha and sugar cane	15,000 tons of jatropha biofuel by the end of 2007 and 1.5 million tons of biodiesel by 2008
Malaysia	Proposed 5% mandatory blend of refined palm oil with fossil diesel	1 million tons of biodiesel in 2007 and 5% blend by 2007-2008
Thailand	Ministry is considering adjusting the price of diesel (Bt100) to reflect prices of raw palm oil, ethanol and production costs	1.5bn liters of biodiesel by the end of 2011.
Argentina	Accelerated repayment; early tax devolution; exemption of hydric infrastructure tax. This does not apply for exports.	Current B7 blend
Brazil	Differential tax exemptions; “social fuel” stamp, exemption of industrial products tax.	Current B75 blend
Colombia	Exemption from VAT and global tax for biodiesel, financial incentives for the expansion of oil palm plantations.	B7, current B10 blend, B20 for 2015

Source: Abdullah, 2012; REN 21, Renewable Energy, Policy Network for the 21st Century, 2011.

In some countries, support policies have proved to be expensive and have generated adverse effects, such as: i) increase of price volatility of agricultural raw materials (FAO, 2011; Banco Mundial et al., 2011); ii) rise of carbon dioxide emissions derived from indirect land use changes due to crop expansion (Achten and Verchot, 2011); iii) violation of labor and land rights in producer countries (Marti, 2008, McCarthy, 2010).

Currently, there is no clarity regarding the real impact of biofuel promotion policies on palm oil consumption patterns in producer and consumer countries. There is also a great concern when it comes to the sustainability of oil palm crop expansion, particularly in Indonesia, Malaysia and other tropical countries.

Under these uncertain circumstances, producer and consumer countries have modified biofuel policies and they currently focus on the following aspects (Sorda et al., 2010; Koh and Ghazoul, 2010; Miyake et al., 2012):

- Maintaining state support with mandatory blends and economic incentives to guarantee the sector´s sustainability.
- Controlling impacts on prices and on food production.
- Mitigating impacts of Greenhouse Gas (GHG) emissions derived from direct and indirect land use changes.
- Establishing new rules that guide the support given to this sector.
- Developing new second and third generation technologies.

The last points demand certifications in relation to the origin of raw materials, as well as regulations on land use (EU, Guideline 28/2009/CE/RED; USA, RFS2; Brazil, Indonesia). The challenge is maintaining the sector´s growth and at the same time, fulfilling all the requirements regarding ecological sustainability.

In this context, the EU formulated the Guideline 2009/28/CE of the European Parliament and the Council of April 23rd 2009, about the promotion of energy derived from renewable sources. This Guideline modifies and derogates the Guideline 2001/77/CE and 2003/30/CE, and presents the following objectives: i) member countries must reach a quota of 20% of renewable energies in 2020 in their final energy consumption (the current quota is 8.5%); ii) the transportation sector must reach a renewable energy quota of 10% in 2020, and the production of this energy must be sustainable. Article 17 establishes sustainability criteria for biofuels related to GHG emissions reduction of 50% for 2017 and the verification of the origin of raw materials. Those that come from lands where biodiversity or carbon reserves are affected must be rejected.

This measures show that sustainability is turning to be an important requisite for biofuel commercialization in the European market, and this is becoming a global trend.

2.3. National context

2.3.1. Oil palm crop in Colombia

The agricultural area in Colombia reaches nearly 4.9 million ha (excluding forest products). Permanent crops occupy 65.1% of the cultivated area (3.2 million ha), and particularly, oil palm crops are established in 476,782 ha (2013), out of which 334,493 are productive (see Fig.2.4). This crop represents 14.7% of Colombian permanent crops and 9.6% of the total agricultural area (FEDEPALMA, 2013).

Oil palm crops are located in 16 departments and 118 municipalities, gathered in four main productive zones: Northern, Center, Eastern and Southwestern (see Figure 2.5).

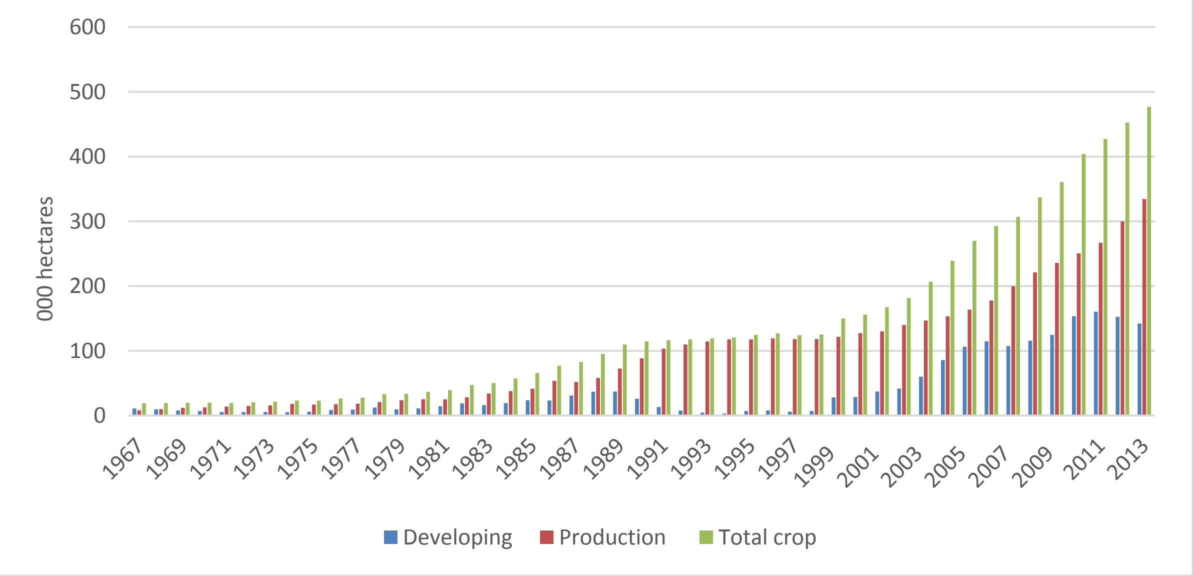


Figure 2.4. Oil palm crop evolution in Colombia

Source: Statistical Yearbook FEDEPALMA (2013)

Each one of these productive nuclei has particular features such as geographical proximity among plantations; soil conditions; and homogeneity regarding climate, rainfall regime and accessibility. These factors constitute special strengths for each zone but also reflect different necessities when developing oil palm plantations. In 2012, oil palm represented 9.2% of the national permanent crops; 5.8% of the national agricultural production; and 3.6% of the national farming production (FEDEPALMA, 2013).

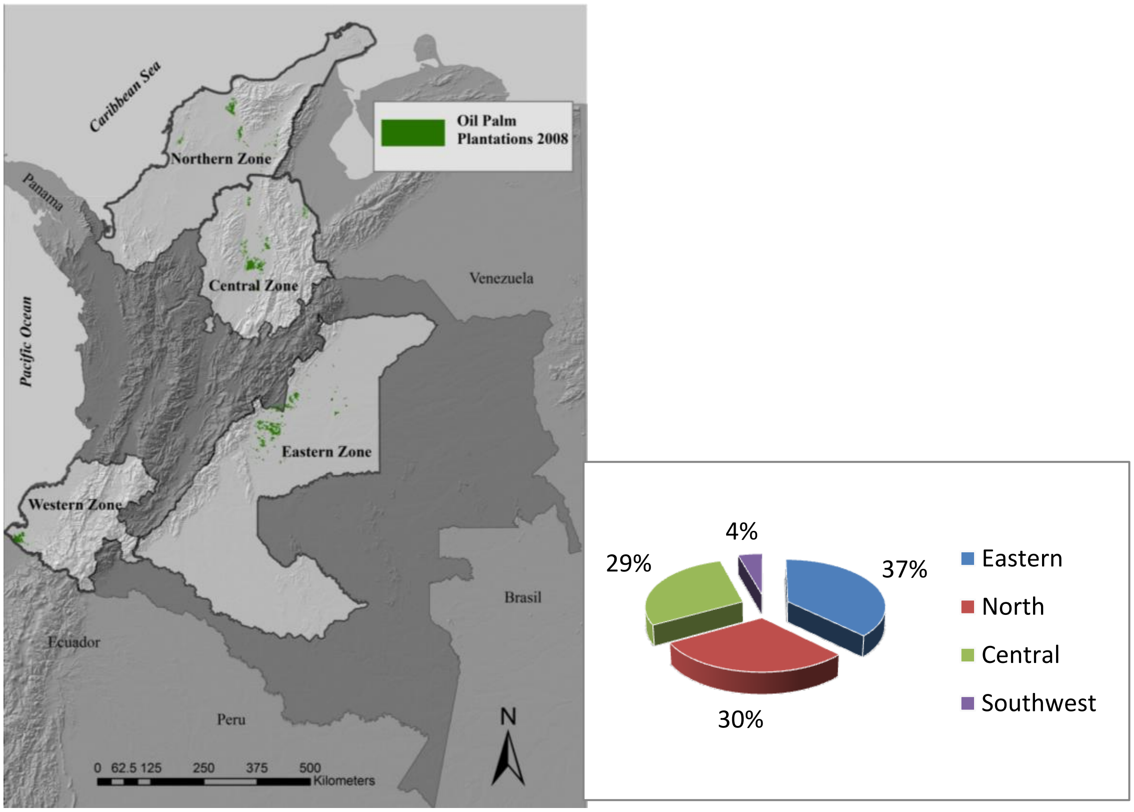
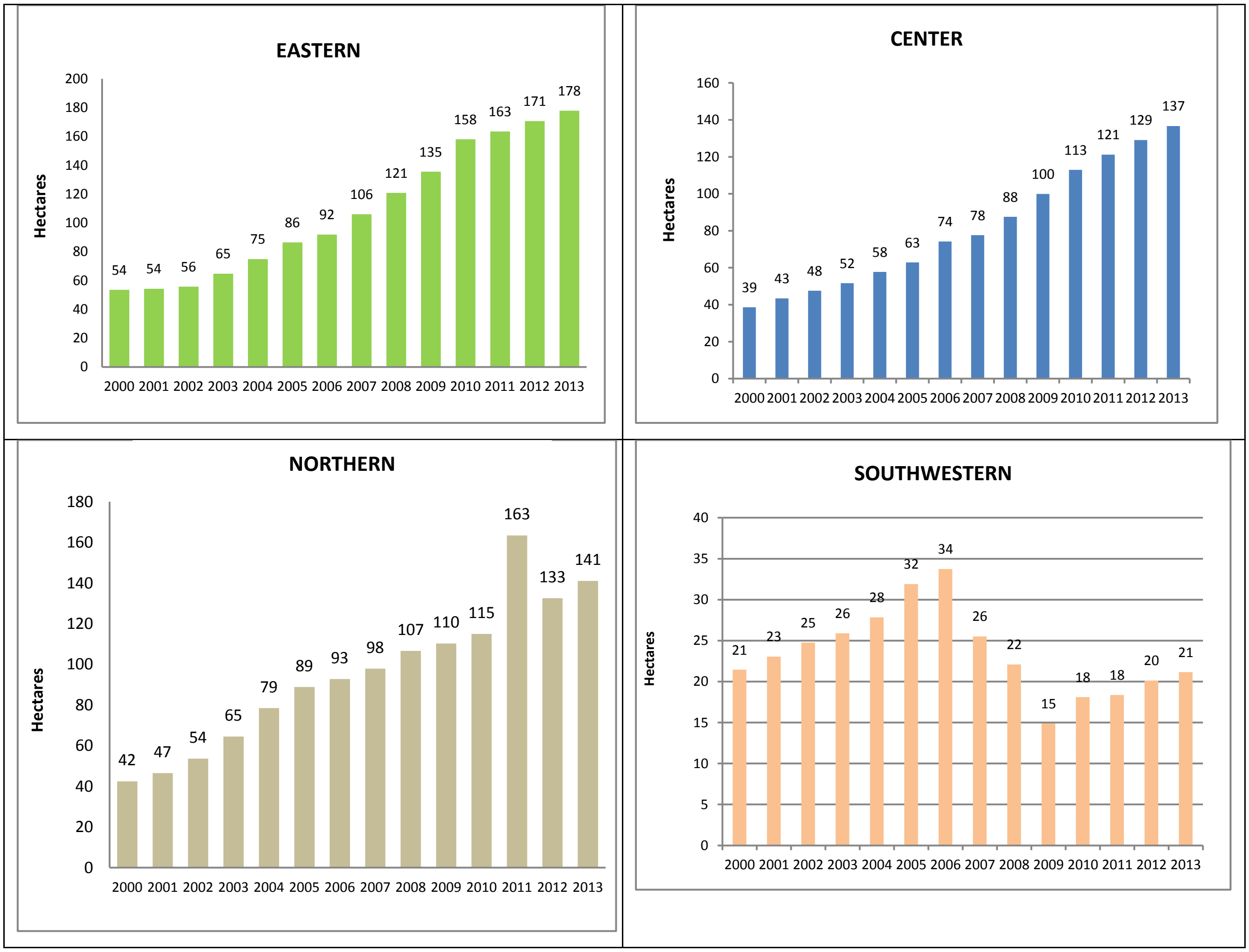


Figure 2.5. Oil palm productive zones and proportion of cultivated area

Source: FEDEPALMA, 2013

The Eastern zone presents the highest annual average contribution with respect to the national cultivated area in the last ten years. In 2013, this zone had plantations in 177,849 ha and its participation reached 37%. The Northern zone takes the second place with 141,099 ha and 30%, followed by the Center zone with 136,685 ha (29%), and in the last place comes the Southwestern zone with 21,149 ha (4%), (figure 2.6), (FEDEPALMA, 2013).

The dynamics regarding the growth of cultivated areas follows a similar pattern: the Eastern zone presents the highest growth (11.5%), followed by the Center zone (9.9%) and the Northern zone (9%). In Figure 6, the growth of planted areas shown. The Southwestern zone, on the contrary, presents a decrease (-1.5%) due to the consequences of bud rot (Pudrición de Cogollo or PC in Spanish), which had a strong incidence in the municipality of Tumaco. This disease is associated to the region´s high humidity and cloudiness, but also, to the fact that oil palm expansion has been developed there over forests. Other additional factors have also limited the growth of oil palm agroindustry in this zone: deficient infrastructure, armed conflict and the existence of collective afro-Colombian territories (Seeboldt y Salinas, 2010; BID, MME, 2012).



EASTERN

CENTER

NORTHERN

SOUTHWESTERN

Figure 2.6. Evolution of cultivated areas in the main oil palm productive zones

Source: Statistical Yearbook FEDEPALMA (2013)

Bud rot (PC) remains the most important sanitary limitation of oil palm cultivation in Colombia. It has affected yields in three of the four productive zones: Northern, Center and Southwestern. In the Eastern zone there is other disease called fatal yellowing (Marchitez Letal or ML in Spanish), which appeared in 1994 and since then, there have been at least 214,000 affected palms. In the last year, this number reached 40,000 in that zone (FEDEPALMA, 2013).

Despite this phytosanitary crisis, in 2013 there were some new productive projects in some of these zones, particularly in the municipalities of Maní, Orocué and Puerto Gaitán (Eastern zone); and Puerto Parra, Yarima and Catatumbo region (Center zone). The success of these new projects would significantly increase the oil palm cultivated area in Colombia (FEDEPALMA, 2013).

2.3.2 Oil palm value chain in Colombia

The value chain of oil palm agroindustry integrates several markets and agents who interact in different phases of the productive and business processes. This value chain is divided into three stages: agricultural, industrial and services (Figure 2.7), (MADR, 2005).

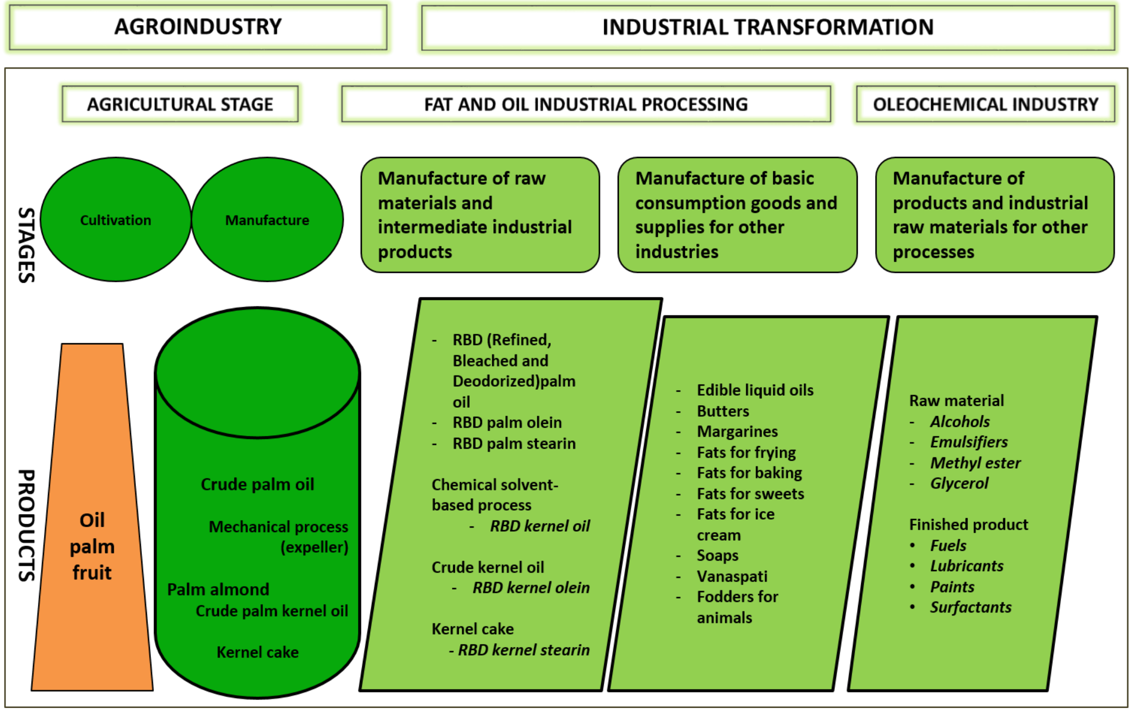


Figure 2.7. Stages and products in oil palm productive chain

Source: Martinez, 2013

The first stage includes oil palm growers (from small producers to large estates or plantations with advanced technology). They are associated to suppliers who provide them with seeds, seedlings, fertilizers and agrochemicals (MADR, 2005). The crop presents a good development under special conditions such as high temperatures, sun radiation, rainfall and relative humidity. However, it adapts well to several conditions, which explain its success in four different Colombian zones. When oil palms are grown with commercial purposes, they have a life expectancy of 24 to 28 years, according to the kind of palm. During its productive life, each tree is able to produce up to 4,2 tons of fruit, depending on the crop´s technical management (MADR, 2005). A palm starts producing at 24 months and it will continue providing fruits the rest of its productive life (FAO, 2010; MADR, 2005).

The yield may present significant variations, even inside the same plantation where there are palms with similar age and same genetic material. This can be explained by the differences in the soil´s physical-chemical features, weed control, sanitary measures and other activities related to the management of this crop. This is why there are visible discrepancies in Colombian yields regardless of their size or origin.

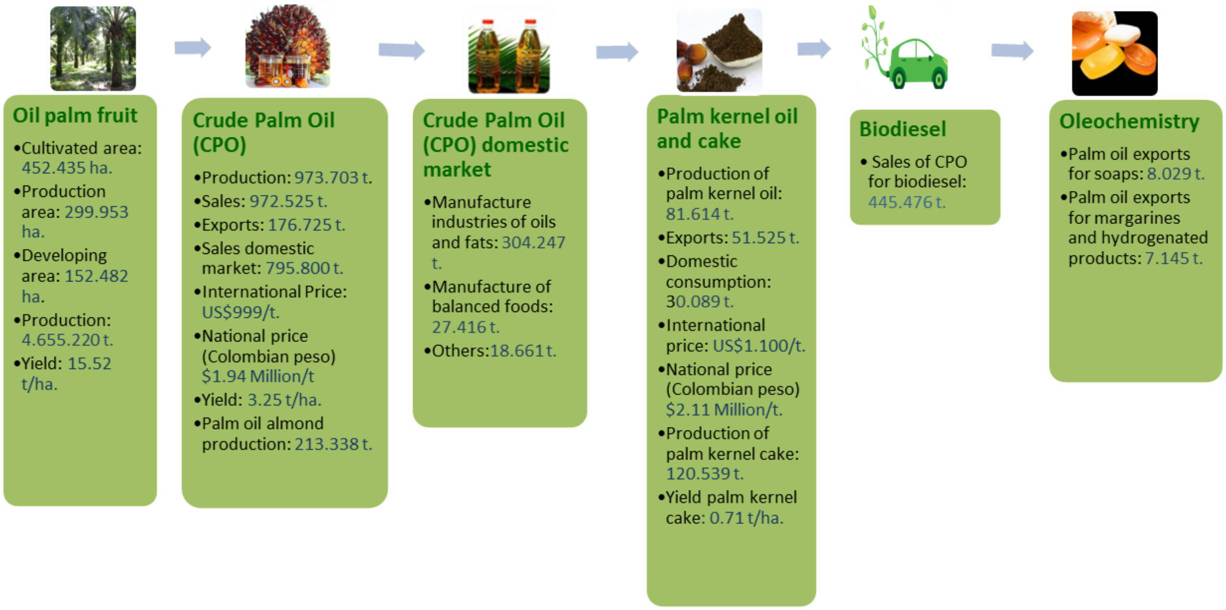
FAO (2010) points out that in Colombia there is a mixture of several productive schemes: from a small property to a large plantation with a complex and modern layout, and there are collective associative mechanisms between small, medium and large producers.

The industrial sector is composed of two links. The first one focuses on CPO extraction, an activity that usually takes place in collection centers near the plantations. CPO is then used in the traditional food industry, and for producing cosmetics, fodders or biodiesel. The second link corresponds to industrial plants in charge of producing biodiesel through transesterification processes (FAO, 2010).

Oil extraction plants must be located near the crops because fruits must be processed as fast as possible in order to avoid acidification. In 2012, 58 plants were active: 25 in the Eastern zone; 13 in the Northern zone; 13 in the Center zone, and 5 in the Southwestern zone. The national average capacity is 24 tons RFF/hour (Martinez, 2013).

Palm oil is extracted from the fruit, and the palm kernel oil is obtained from the almond. Another byproduct from this extraction process is the cake. A bunch offers 65% fruits and 35% husks. The fruit´s weight is split up in 62% pulp and 38% nuts. The pulp is 45% crude oil and 55% waste, which has some protein content but is not commercially used. The nuts, on the other hand, contain 30% almond and 70% of non-useful peel; the almond is 43% crude oil, 50% cake and 7% waste material (MADR, 2005). Crude oil provides the most important byproducts (edible oils and biodiesel) that have an influence in the economic results of this business. Other important byproducts are the cake (used to manufacture fodder due to its protein content) and the soap stock. The seeds provide palm kernel oil and kernel cake, which is used to produce balanced foods (MADR, 2005). Figure 2.8 shows production data, prices and profits from several byproducts of oil palm industry in Colombia in 2012.

Finally, the services sector is composed of enterprises or companies who participate in the distribution and sale of several products, including biofuel. This includes storage plants, collection centers and service stations, where the final consumer purchases the product.



Oil palm fruit
- Cultivated area: 452.435 ha.
- Production area: 299.953 ha.
- Developing area: 152.482 ha.
- Production: 4.655.220 t.
- Yield: 15.52 t/ha.

Crude Palm Oil (CPO)
- Production: 973.703 t.
- Sales: 972.525 t.
- Exports: 176.725 t.
- Sales domestic market: 795.800 t.
- International Price: US$999/t.
- National price (Colombian peso) $1.94 Million/t
- Yield: 3.25 t/ha.
- Palm oil almond production: 213.338 t.

Crude Palm Oil (CPO) domestic market
- Manufacture industries of oils and fats: 304.247 t.
- Manufacture of balanced foods: 27.416 t.
- Others:18.661 t.

Palm kernel oil and cake
- Production of palm kernel oil: 81.614 t.
- Exports: 51.525 t.
- Domestic consumption: 30.089 t.
- International price: US$1.100/t.
- National price (Colombian peso) $2.11 Million/t.
- Production of palm kernel cake: 120.539 t.
- Yield palm kernel cake: 0.71 t/ha.

Biodiesel
- Sales of CPO for biodiesel: 445.476 t.

Oleochemistry
- Palm oil exports for soaps: 8.029 t.
- Palm oil exports for margarines and hydrogenated products: 7.145 t.

Figure 2.8. Value chain of oil palm agroindustry in Colombia

Source: Statistical Yearbook FEDEPALMA (2013)

- **CPO transformation into biodiesel**

CPO is sold as the main supply for biodiesel producers. CPO is then negotiated with blenders who combine it with fossil diesel, and it is subsequently distributed to wholesalers and service stations where the final consumer purchases fuel (FEDESARROLLO, 2010). The national government participates by managing financial tools, tax exemptions and by directly regulating prices in order to maintain profitability and guarantee the sustainability of the business in the long term.

In Colombia, biodiesel production started at an experimental level in the first semester of 2008. In that same year it began to be combined with diesel at a commercial scale with a B5 blend. Even though there were intentions to include other raw materials, palm oil is the only one used in biodiesel production. The biodiesel-diesel blends in the national territory are currently the following: B10 in the Atlantic coast, Pacific coast and in southern Colombia; B8 in the Center zone, Meta and Casanare departments; and B2 in the rest of the country.

In 2012, 973,000 t of CPO were produced, out of which 439,000 were used for biodiesel production and 333,700 in the traditional market (foods and cosmetics). 489,991 t of biodiesel were produced in the country in that year (Figure 2.9).

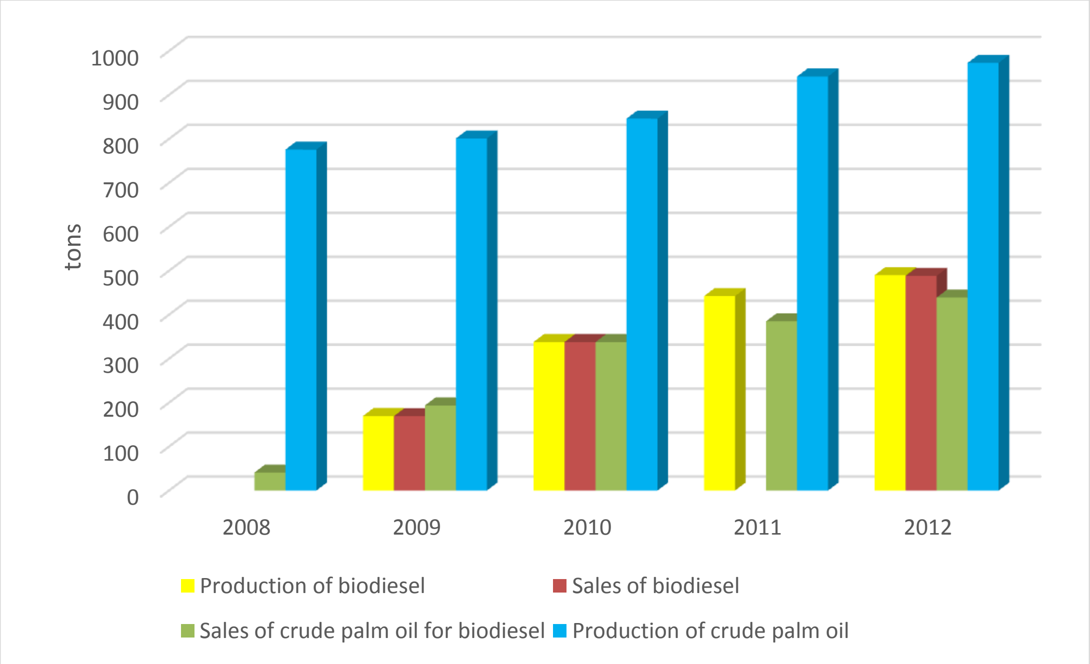


Figure 2.9. Oil palm biodiesel in Colombia

Source: Federación Nacional de Biocombustibles de Colombia, 2013

There are currently seven plants producing biodiesel in Colombia: two are located in the Magdalena and Cesar departments; two in Santander; one in Cundinamarca; and three in Meta. Table 2.4 describes the main features of these plants. Together, they have an installed capacity to produce 591 thousand tons per year.

Table 2.4. Active plants producing biodiesel

Región	Empresa	Capacidad (T/año)	Área Sembrada (Ha) **	Empleos Directos	Empleos Indirectos	Fecha entrada en Operación
Norte, Santa Marta	Biocombustibles Sostenibles del Caribe	100,000	29,240	4,177	8,354	01/03/2009
Norte, Codazzi	Oleoflores	60,000	17,544	2,506	5,013	01/01/2008
Norte, Barranquilla	Romil de la Costa	10,000	0	0	0	
Norte, Gálapa	Biodiésel de la Costa	10,000	0	0	0	
Norte, Santa Marta	Odín Energy	36,000	10,526	1,504	3,008	
Oriental, Facatativá	BioD	120,000	36,810	5,259	10,517	01/02/2009
Central, Barrancabermeja	Ecodiesel de Colombia	120,000	36,810	5,259	10,517	01/06/2008
Oriental, San Carlos de Guaroa	Aceites Manuelita	120,000	36,810	5,259	10,517	01/07/2009
Oriental, Castilla la Grande	Biocastilla	15,000	4,601	657	1,315	
Total		**591,000**	**172,341**	**24,621**	**49,241**	

Source: Federación Nacional de Biocombustibles de Colombia, 2010.

2.3.3. CPO market in Colombia

CPO market in Colombia is relatively small compared to the Southeast Asian countries, particularly when it comes to production amounts and cultivated area. Currently, Colombia represents 2% of global production; however, CPO market is expanding and showing an increasing trend. As a result, this country is the largest Latin American producer and the fifth in the world (FEDEPALMA, 2012). This can be explained by the favorable agricultural and climatic conditions for this crop in several regions, and also, by the strong state support, which includes regulation policies and economic incentives that have a direct incidence in the progressive consolidation and continuous growth of the Colombian oil palm industry in the last years.

During the last decade, CPO production has grown 6.6% in average. Since 2008 most of the production has been oriented to domestic market at the expense of possible exports, which showed a significant decrease of 51% in 2010 in comparison to previous years due to the rise of biodiesel sales in country, to the effects of the winter season, and the persistence of diseases in the crops. These factors contributed in 2010 to reducing production rates and exports.

In 2011 Colombian oil palm sector reached a record production of 940,838 palm oil tons with a growth rate of 24.9% (FEDEPALMA, 2012). These numbers were possible because of the important increase of domestic consumption (16%) oriented to compelling a B10 mandatory blend. This has contributed to the consolidation of biodiesel industry. The rising trend regarding the internal CPO demand for biodiesel production is confirmed with the following numbers: in 2007, the biodiesel sector demanded 8,600 tons and five years later (2012) 439,000 tons were requested; whereas the demand for the traditional industry of edible oils and cosmetics has decreased from 422,000 tons in 2007 to 333,700 tons in 2012 (see figure 2.10), (FEDEPALMA, 2012).

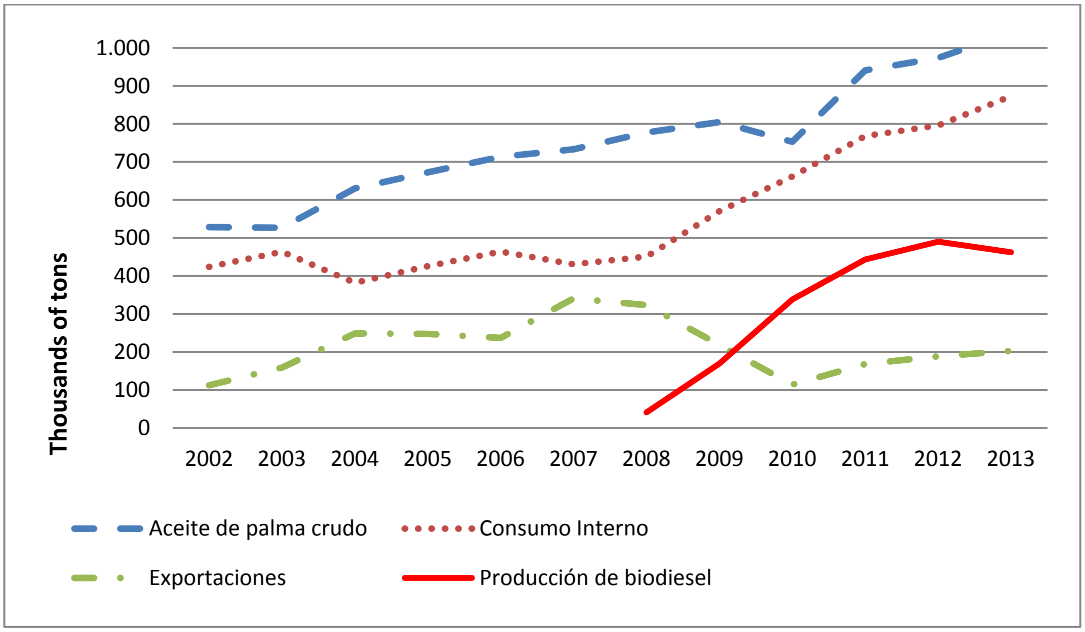


Figure 2.10. Evolution of the production and uses of CPO in Colombia (2002-2013)

Source: FEDEPALMA, 2013.

In 2013, 1,039,800 tons of CPO were produced in the country, out of which 873,300 (84%) were consumed in the internal market. Nearly 500,000 tons were destined to biodiesel production. In that year, the levels of CPO oriented to traditional markets (edible oils, balanced foods and soaps) were acceptable. Biodiesel market only grew 3% because the government refused to increase the mandatory blend from 8% to 10% in Bogotá and the llanos Orientales region (eastern flatlands) (FEDEPALMA, 2013).

The Eastern zone was the most dynamic regarding CPO production in 2013: 398,000 tons (38.8% of the total production), followed by the Northern zone, where 332,760 ton were produced (32%). The Center zone manufactured 294,745 tons (28%), and the Southwestern zone, 14,280 tons (1.4%).

The average yield of CPO production (2002-2012) was 3.7 tons/ha. During 2013 there was a decrease of 4.3% with respect to the previous year, due mainly to the effects of bud rot, which has affected the crops in the Center and Southwestern zone.

- **Production costs**

Colombia has high production costs when compared to other oil palm producers. This country registered the highest production cost in 2012 (US$ 747/t), 67% above the global average (US$449/t) and 81% above Indonesia, the most competitive country (US$413).

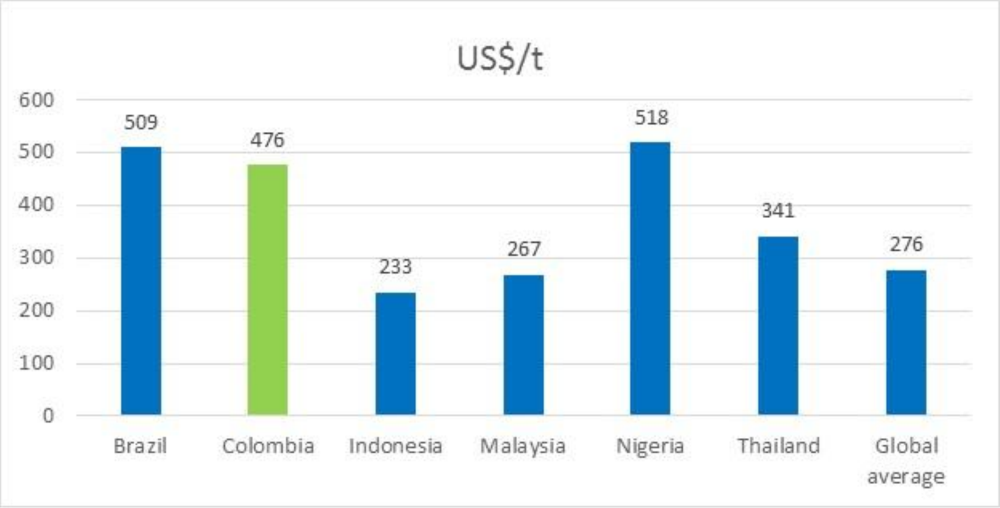


Figure 2.11. Average total costs of CPO production (1984-2012)

Source: L. Guterman. FEDEPALMA, XLII General Convention, june 3rd 2014.

The highest percentage regarding the total costs corresponds to fixed capital (30.2%), followed by workforce (25.8%), administrative costs (24.7%), fertilizers (14.9%) and others (4.4%). Putting aside the land and administrative costs, the most significant factors are workforce (40.8%) and fixed capital (23.9%), (Guterman, 2014).

The main differences in comparison to Indonesia and Malaysia are related to workforce cost structures which impact the social sustainability and competitiveness of the country. In Colombia, the average daily wage reaches $24, whereas in Malaysia is US$ 11.4, and in Indonesia it barely approaches US$4.7 (Martinez, 2013). In 86% of the cases, the remuneration system functions by paying per unit (this means, to pay for a particular task and not according to a daily wage). Guterman (2014) argues that although this system may generate an increase in the physical productivity; it may not impact production costs because any increase in the number of produced units per day may cause a proportional rise in the work cost. This author suggests complementing this system with incentives to labor or work productivity per production weight (differential remuneration rates for determined productivity standards).

Production costs can also be analyzed by region. In 2012, the Center zone presented the highest numbers ($2.2 million/t) and the Northern zone showed the lowest ($1.6 million/t). In the Eastern zone, the costs reached 1.9 million/t. These results point out the necessity of increasing yields with the objective of closing the gaps with the two biggest oil palm producers in the world (Guterman, 2014).

2.3.4. Association schemes for production and labor rights

There are difficulties when it comes to finding information about quantity and quality of job positions, labor rights, and the results of the association schemes for production. These data are limited and there are contradictory positions, because they depend on who sponsors the studies or researches. Additionally, the entities in charge of supervising and controlling labor issues (Ministry of Social Protection and the Superintendency of Solidary Economy) do not have unified information regarding the total number of Associated Work Cooperatives (*Cooperativas de Trabajo Asociado* in Spanish) and Productive Alliances (*Alianzas Productivas* in Spanish) linked to the oil palm agroindustry (Seedboldt and Salinas, 2010; Garcia and Calderon, 2012).

There are two studies sponsored by the oil palm entrepreneurial association (FEDEPALMA). One is called “Evaluation of the oil palm Productive Alliances model”, it was published in 2011 and other institutions (besides FEDEPALMA) also participated: USAID/MIDAS and the Colombian Entrepreneurial Council for Sustainable Development. 23 Productive Alliances from the four oil palm regions were analyzed in order to identify strengths, weaknesses, threats and opportunities of this model, and also, proposing changes in public policies or entrepreneurial actions that would allow improving the conditions of these Alliances.

The second study, “Characterization of the labor in the Colombian palm sector” was also supported by FEDESARROLLO and IQuartil. 1,200 surveys were carried out in the four oil palm regions. Semi-structured interviews were also held with several actors connected to this economic sector.

The results revealed that one worker is employed per 3.2 ha of cultivated oil palm. This number is lower than other permanent crops such as cocoa tree or plantain, but this percentage is acceptable when compared to the cattle industry that previously occupied oil palm lands: this activity had a low intensity regarding labor force because it employed one person per 200 ha.

In 2011, 267,000 ha cultivated with oil palm generated 64,000 direct jobs. On the other hand, biodiesel production offered 21,800 direct jobs and 43,000 indirect jobs (Garcia and Calderon, 2012). The study estimated that 59% of the workforce is directly hired by the plantation or transformation plant; 34.1% is employed in an Associated Work Cooperative; and the rest is contracted under other schemes. In the case of other activities (not related to oil palm), 46.2% of the workforce is directly hired by the plantations or plants; 2.8% is employed in an Associated Work Cooperative; and the rest is hired under other schemes (Garcia and Calderon, 2012).

After analyzing these employment conditions (wages and social security), the studies conclude that oil palm industry offers better options for workers. The research by Garcia and Calderon (2012) indicates that a position in this sector increases in 60% the possibilities to have access to social security and labor risk protection.

- **Associated Work Cooperatives (AWC)**

In 2010, there were 83,636 workers (in average) in the oil palm industry. Most of them belonged to an AWC and other small enterprises that offer services for the plantations. This means that 83.6% of this sector´s employment has been outsourced (Seeboldt and Salinas, 2010). The changes in Colombian labor regulations in the nineties approved the relaxation of labor relationships, and this affected labor rights. These reforms contributed to the creation of AWC, whose members are considered entrepreneurs (they are not catalogued as workers).

AWC have leaders who negotiate with large oil palm companies the kind of service, fees and other conditions. AWC are responsible of guaranteeing social security to their members. They also manage their own budgets and acquire the tools and equipment required to develop their services. AWC must cover extra pays (bonuses) and sanctions imposed by the companies when the activities are delayed, among other expenses. On the other hand, given their entrepreneurial label, the workers are not able to form labor unions or develop a strike (in 2008, only 1.8% of oil palm workers belonged to a labor union); additionally, there is no general association that gathers all AWC or represents their rights and interests (Seeboldt and Salinas, 2010). All these factors are criticized by some sectors that point out the job insecurity and the unequal conditions in the workers-companies relationships. This situation is worsened when considering low education levels of AWC members and their limited access to information and legal advisory.

The Ministry of Work forbid the use of AWC in 2012, given the lack of job stability they offered. However, some of them continued functioning and they received a sanction in January 2013 of $7,700 million Colombian pesos. This sanction included nine AWC and one oil palm company. The Supervision and Control Direction of this Ministry found out that there were irregular outsourcing practices that violated labor rights. For example, social security was not completely covered, and the company was involved in the management of the AWC by influencing decisions related to human resource selection. This kind of practices distortion the real purpose of cooperatives and contribute to violating labor rights (Ministerio de Trabajo, 2013).

- **Productive Alliances (PA)**

PA are formal relationships between agricultural producers with commercial and agroindustrial entities and public or private support organisms. The objective of this scheme is expanding oil palm permanent crops and updating the technology of productive units owned by small producers (FEDEPALMA, 2010).

From 2001 to 2009, FINAGRO (Fund for Financing the Agricultural and Livestock Sector) supported the creation of 66 PA with $37,436 million Colombian pesos through credits, the Incentive to Rural Capitalization (IRC), and other guarantees offered by the Agriculture and Livestock Guarantee Fund. Likewise, the Peace Investment Fund subsidized PA with $21,395 million Colombian pesos; MIDAS program by USAID contributed with USD$19.7 million; and the Ministry of Agriculture and Rural Development promoted an incentive that reached $2,597 million Colombian pesos (FINAGRO, 2011).

Most of these PA have been led by oil palm entrepreneurs and regional political leaders who understood that the real value of this business is not related to controlling land property; the key is controlling its use. There are different kinds of AP: some are organizations of producers (or even individual producers) who maintain direct commercialization bonds with the extractive company, whereas others have indirect relationships. Currently, there are about 105 industrial strategic alliances and producers with 70,000 hectares in which 6,500 families are involved (García and Calderon, 2012).

The general scheme of a PA is the following: the producer or group of producers (small or medium) provide the land and workforce. They receive a loan from the Agrarian Bank with resources from FINAGRO, which in 2009 oscillated between 4,000 and 5,000 million Colombian pesos with a twelve year term. The National Guarantee Fund supports the loan and the Incentive to Rural Capitalization leads the operation of these incentives, which are managed through a fiduciary. Credits are solidary, this means that the association as a whole takes the responsibility of compelling with credit obligations; but if the associate is not able to pay, the association keeps the land, because it is the real pledge or guarantee of the business (FINAGRO, 2012).

The commercial ally –the company or enterprise- provides the PA with seeds, fertilizers (a fertilization plan for ten hectares costs 12 million Colombian pesos per year), fungicides and technical assistance. The company manages the credits, so it deducts the associations´ debts with the banks and the producers receive the remaining quantity. They are compelled to sell their fruit to the associated company for 25 years. The fruit bunches are delivered and weighted in collection areas, and then transported to a refinery or a biodiesel extraction plant (FINAGRO, 2012).

In some cases these companies become monopolies, which in spite of not having property over the land, are able to manage the business with the state support. This is the case of Promotora Hacienda Las Flores S.A., whose owner and main stockholder is the former Agriculture Minister Carlos Murgas. He controls the PA business in the Magdalena Medio region, Montes de María and Cesar, and supervises the whole steps of the process. Moreover, this company manages the credits with the Agrarian Bank; sells the seeds; gives technical assistance; buys the production; and in 2005 it began to build a biodiesel extraction plant as a mixed enterprise, where 49% of the capital belongs to the associates and 51% to the company. For this purpose, a percentage of the profit is withheld from these associates (Molano, 2012).

In 2010, nearly 64,000 ha were cultivated under the PA model (16% of the total cultivated area). The enterprises that have promoted these alliances with small producers are located in the Center and Northern zone. The Eastern zone is characterized by enterprises who own large land extensions and have disperse extraction plants that normally manufacture their own fruit. However, biodiesel companies use raw material produced by third parties (García and Calderon, 2012).

The study that assessed the Alliances (sponsored by FEDEPALMA) identifies the strengths of this scheme: market security, access to financing, and assistance from an experienced company. The main threats are related to the difficult sanitary situation of the crops, the unstable public order in the main oil palm producer zones, the high costs of fertilizers, delays regarding credit payments, and the volatility of international palm oil prices (FEDEPALMA, 2010).

2.3.5. Incentives received by the oil palm sector in Colombia (2000-2011)

The national government has promoted the development of permanent crops through a sectorial policy. In the particular case of oil palm, Colombian state has provided strong support in the last decade, in terms of: resources for research and development; technological transfer; strengthening of phytosanitary measures; infrastructure improvement; a funding policy with special credit lines; financial support to associative schemes; and tax and economic incentives (DNP, 2007, CONPES 3477).

The Incentive to Rural Capitalization (IRC) is an economic benefit provided by the Ministry of Agriculture and Rural Development, with the objective of executing new investments in the agricultural sector that improve its competitiveness. Through this Incentive, the oil palm sector has managed an important amount of resources. This sector captured (between 2001 and 2007) almost the entire governmental support through credits, in comparison to other permanent crops like rubber or cocoa tree (see figure 2.12).

	IRC for permanent crops	IRC for oil palm	Percentage (%)
2001	10,229	8,846	86.5
2002	12,926	12,243	94.7
2003	13,293	11,828	88.9
2004	17,467	13,995	80.1
2005	15,715	11,268	71.7
2006	23,713	15,082	63.6
2007	22,861	13,392	58.6
2008	29,009	13,753	47.4
2009	77,922	38,167	48.9
2010	111,796	36,445	32.6
2011	126,036	14,959	11.9
TOTAL	460,967	189,978	41.2

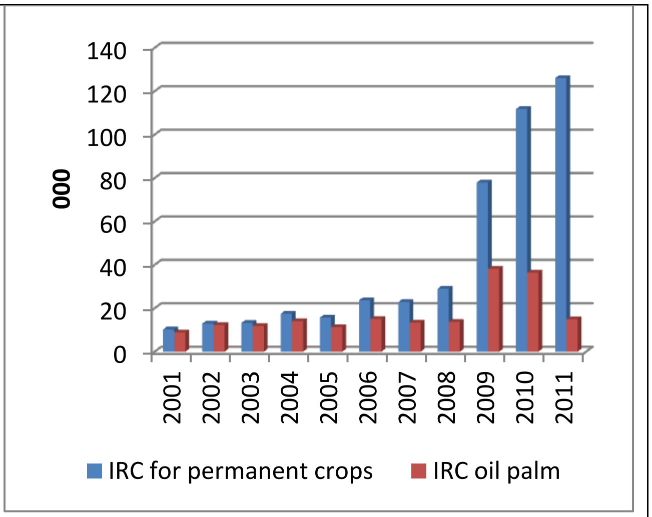


Figure 2.12. Amounts given by the Incentive to Rural Capitalization (millions of Colombian *pesos*)

Source: Ministerio de Agricultura y Desarrollo Rural, 2012.

Oil palm producers have also received additional income through the Forest Incentive Certifications (FIC)[1]. In 2008, a notable proportion of this incentive was directed to oil palm sector (65.6%). According to the Ministry of Agriculture and Rural Development, out of $32,825 million Colombian *pesos* that constituted the FIC, $21,532 million were concentrated in this sector. It is important to point out that this occurred even though there was a strong debate in that time around the Rural Development Statue (Law 1152 de 2007), which was then declared as unconstitutional.

There is a disparity in the numbers provided by FINAGRO and the Ministry of Agriculture and Rural Development, regarding the FIC. For example, for 2009, the Ministry reserved $15,000 million Colombian *pesos* for the FIC´s investment and operational expenses. This number exceeds in 38.5% the amount paid by FINAGRO to the oil palm sector ($20,772 million). Other example is the following: the Ministry balance in 2005 indicates that $34,363 million were destined to cover the FIC, whereas the CONPES 3509 of 2008 points

---

[1] The Forest Incentive Certifications (FIC) were created by Law 139 of 1994. Through the FIC, the state acknowledges the positive externalities of reforestation regarding social and environmental issues. This Incentive is applied in the execution of projects and direct investments in commercial plantations or those oriented to nature protection. Currently, there is an emphasis in the commercial plantations, as mentioned in the National Development Plan 2010-2014 (FINAGRO, 2012).

out that only $6,500 million constituted this investment line. A third example: the Ministry reported an amount of $11,611 million for the FIC in 2006 (which according to FINAGRO, were received by the oil palm sector); but this information does not correspond to the data given by the CONPES 3509 of 2008 and 3576 of 2009, documents that report an investment of $19,600 million Colombian pesos (figure 2.13).

The lack of clarity with respect to the balances and numbers given by diverse state institutions makes it complex to perform an adequate follow-up to the resources destined to specific economic sectors. This has evident impacts on the efficiency of promotion public policies, among other interventions measures.

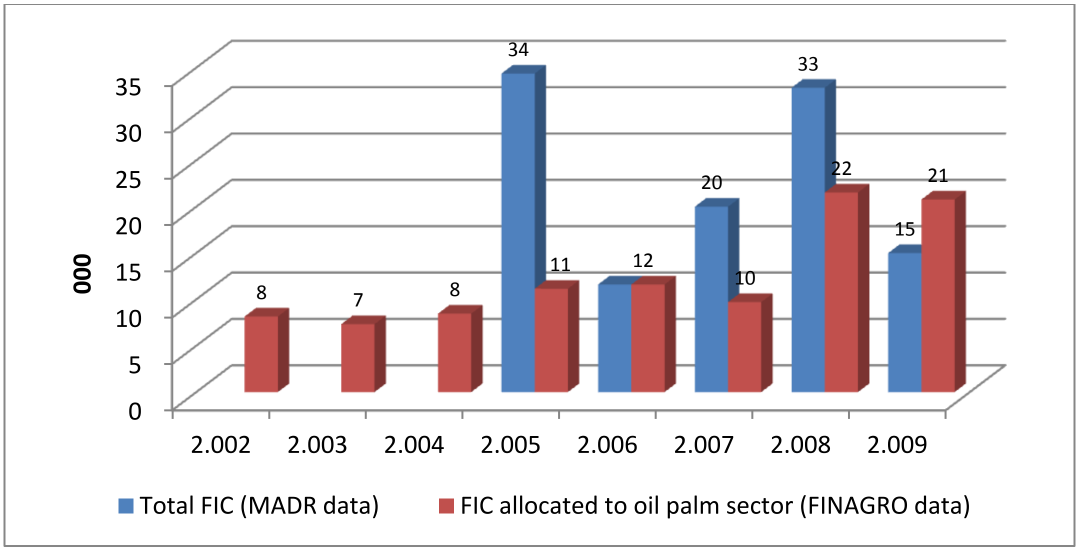


Figure 2.13. Forest Incentive Certifications (FIC), 2002-2009 (million Colombian *pesos*).

Source: FINAGRO, 2012; MADR Report, 2006-2009.

There are additional public incentives for the oil palm sector. One of them is the Program of income protection for producers of exportable agricultural goods, which has been implemented since 2006. This program aims at providing supplies that strengthen economic activities related to agricultural tradable products. Oil palm sector was highly benefited from this program since the beginning (in the first year it captured almost all the resources). The following years, the amount of this incentive increased not only for this sector, but for other agricultural tradable goods (plantain, flowers, sugar cane, cattle meat, fruit trees, among others).

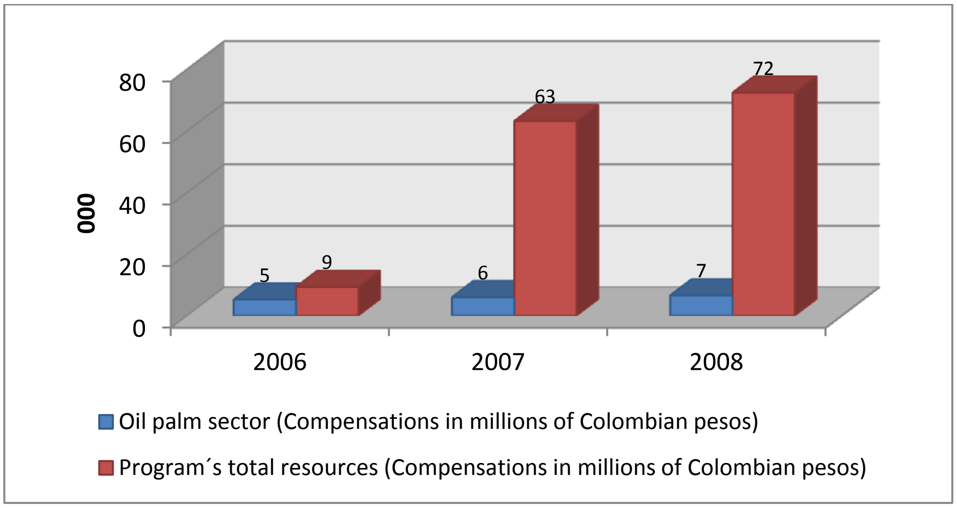


Figure 2.14. Allocation of resources from the Program of income protection for producers of exportable agricultural goods (2006-2008)

Source: MADR Report, 2006-2009.

The oil palm sector has certainly a huge growth potential at a national level, as shown by the mentioned numbers regarding cultivated area, production volumes and state support. Nevertheless, there have been changes in the proportion of incentives oriented to this sector: they have slightly decreased in comparison to the support allocated to other sectors. This could be the result of changes in the governmental approaches (which have been more evident since 2010 with the new administration) that tend to a more balanced distribution of resources in the agricultural sector. It is important to highlight the fact that the lack of coordination among institutions (which is evident in the disparity of balances and numbers) makes it difficult to evaluate and monitor resource allocation.

2.4. Challenges and initiatives for a sustainable and inclusive oil palm production

The main tropical producer countries face some challenges when developing oil palm agroindustry: minimizing impacts on biodiversity; reducing carbon emissions derived from land use change; improving local wellbeing; and compensating the effects on food production and prices (Sayer, et al., 2012; Miyake, 2013). Two options are establishing oil palm crops on degraded lands, so that its productivity improves; and also, offering incentives to small producers. However, oil palm expansion is reaching regions whose local governance is weak, where there is no adequate land planning and there are uncertainty and conflicts regarding land property rights (Feintrennie et al., 2010).

According to several authors (McCarthy, 2010; German et al., 2011), these institutional failures may be the main obstacle for environmental protection and for a fairer oil palm expansion. Sayer et al. (2012) propose three recommendations that may contribute to a more sustainable oil palm development in the producer regions: i) promoting crop intensification and reducing requirements related to expansion areas; ii) improving governance regarding land property rights of small producers and guaranteeing the conservation and protection of strategic ecosystems; and iii) promoting small producers associativity in order to balance the power in negotiation processes with the State and big companies.

The analysis of the Colombian oil palm sector is more complex due to several circumstances: in the last fifty years there has been a persistent armed conflict which particularly affects rural zones and whose main structural factor is the concentration of land property; the agriculture and livestock sector faces a deep crisis, which is confronted by the government with the design of a new policy of Land and Rural Development, where oil palm agroindustry plays a main role as driver of rural development; the role of this economic activity in environmental pollution and the effects of its expansion in strategic ecosystems; and lastly, the social conflicts regarding the violation of labor and land property rights. These challenges tend to be more complex when analyzing the particularities of rural zones where the crop is expanding. Some of these challenges are presented below and they are also approached in other chapters of this investigation.

2.4.1. Preventing and controlling environmental problems generated by the expansion and intensification of oil palm crops.

The growth of oil palm agroindustry demands soil and water and this may end up in an unequal distribution of the benefits provided by the ecosystems (water, fertile soil, and biodiversity), favoring palm companies over the population who live in producer zones (Olmos, 2014). The latter are able to perceive how this economic activity puts pressure on ecosystems and other environmental components; therefore, they are often against the expansion of oil palm crops and they are open about the divergence of interests and objectives related to the use of the land (Olmos, 2014). From an environmental perspective, the main concerns arise due to the alterations of regional hydrological systems and a growing rise in the demand for water. The academia, on the other hand, points out the uncertainties regarding the true dimension of the increase of GHG emissions generated by the expansion and intensification of energy crops. These concerns are described below.

- **Changes in water use and alterations in the hydrological structure in producer zones.**

Water constitutes an important productive supply in agriculture. Although it is used intensively, users generally pay a relative low price for it. The world is currently facing the dilemma of producing food or creating energy, and in this context water is a strategic and limiting resource (Berndes, 2002). Energy crops, such as oil palm and sugar cane, put high pressure on water resources because they demand a large amount of this liquid in the cultivation stages. The conflict around water is more serious in potential expansion zones with a current or potential water deficit (Olmos, 2014).

Research carried out by Berndes (2002), Varis (2007) and De Fraiture et al., (2008) indicate that water demand for irrigating energy crops may vary according to the cultivated species, geographic location and production techniques. For instance, in order to obtain the amount of corn required to produce a liter of ethanol in China, 2,400 liters of irrigation water are needed; whereas the amount to grow enough sugar cane to generate a liter of bioethanol is calculated in 3,500 liters.

A recent study by Olmos (2014) around the environmental conflicts associated to water provision and regulation due to the expansion of oil palm crops in eastern Colombia reveals that the main causes of these conflicts are derived from a high water demand in cultivation zones and its consequences regarding scarcity (drought), and also, the monopolization of this resource in the stages of planning, land adaptation and configuration of drainage and irritation systems. These activities affect some of the critical variables inside strategic ecosystems (such as savannahs) which allow generating services of water provision and regulation: hydrological regimes that depend on seasonal variation; soil structure and composition (including sub-superficial flows); and hydraulic connection among different ecosystem elements (creeks, wetlands, vegetation, recharge and discharge areas).

Land adaptation (including land use change and plot extension) is the activity that generates the highest pressure and changes on water regulation because it requires draining low and wet zones, as well as intervening different strategic ecosystems and environmental elements that play an important role in the water regime: creeks, gallery forests, wetlands and recharge areas. It is important to highlight that the alterations may be caused not only by the disappearing of these elements and ecosystems: their reduction, fragmentation, isolation and appropriation may contribute as well. Another critical stage for water provision is the crop production, because the plantation needs different works and practices for irrigation (dams, canals, lock-gates) (Olmos, 2014).

- **Increase of GHG emissions due to an intensive use of fertilizers, and direct and indirect land use changes.**

The agricultural sector is the highest emitter of nitrous oxide in Colombia (72.4% in 1990). The fertilizers employed in agricultural soils are the main source of N2O in this economic sector, which accounted for 91% of N2O emissions in 1991 (UNFCCC, 2001). The commercial and intensive production of agroindustrial crops oriented to national and international markets uses significant amounts of inorganic fertilizers, and it also causes the highest degradation of organic matter in the soils, thus contributing to release carbon.

The expansion of energy crops to produce biodiesel (oil palm and sugar cane) may also generate direct and indirect land use changes, which have important consequences in terms of GHG emissions and affectations in biodiversity, depending on the converted natural cover.

The experience of the countries in Southeast Asia has been widely documented by Koh and Wilcove, (2008), Koh et al. (2011) and Gunarso et al. (2013). These authors have analyzed and estimated land use changes related to oil palm expansion at an industrial scale in Indonesia (Sumatra, Kalimantan and Papua), Malaysia and Papua New Guinea. They point out that oil palm plantations have substituted mainly natural forests, secondary forests and peats in Malaysia and Papua New Guinea; whereas in Indonesia they have replaced agroforestry systems, shrubs and pastures. In Colombia, it is necessary to carry out rigorous investigations at an appropriate analysis scale in order to calculate the magnitude of direct and indirect land use changes and their implications in terms of GHG emissions.

2.4.2. Breaking the bond between oil palm industry and land conflicts

Most of the 108 municipalities where oil palm is cultivated have been zones characterized by social conflict and violence due to illegal armed groups. There are at least five emblematic cases of forced displacement and land dispossession linked to oil palm implementation: i) Alto Mira and Frontera (Tumaco, department of Nariño); ii) Hacienda Bella Cruz (La Gloria, department of Cesar); iii) Hacienda las Pavas (El Peñon, department of Bolívar); iv) Macondo 1,2,3 (Mapiripán, department of Meta); and v) Jiguamiandó and Curvaradó (Sucio river in Carmen de Darién, department of Chocó) (FEDEPALMA, 2013).

According to a studied carried out by Sánchez et al. (2010), several modalities of illegal land appropriation were detected: forced land transfer with ridiculous payments; forced sale without the owner´s consent; false sales (land transfer by using false data in public and private documents); and administrative caducity (when a land granted by the State is abandoned, after some time it is re-allocated to new owners).

In addition to violent and forced displacement, there are also migration phenomena due to economic issues caused in part by oil palm agroindustry. The Colombian government promotes these permanent crops to produce biodiesel and restricts its investments in small producers, except for the cases in which they are associated to large plantations. Only under these conditions, these small producers are able to receive subsidies and credits. Migration is also a symptom of changes in the rural infrastructure that prioritizes oil palm production. This way, it is very difficult for rural population to maintain their autonomy and their traditional crops (Seeboldt and Salinas, 2010).

2.4.3. Overcoming sanitary problems

This is one of the main challenges for Colombian oil palm agroindustry. Approximately 100,000 ha have been lost due to bud rot in the last five decades. Currently, the most affected area is the Center zone (municipalities of Puerto Wilches in the department of Santander, and Cantagallo in Bolívar), where 37,000 ha are infected with this disease. The Southwestern zone has been continuously impacted by bud rot; for this reason, other oil palm varieties with more resistance to the disease have been cultivated since 2007. In the Eastern zone, the fatal yellowing is expanding.

CENIPALMA (the research division of FEDEPALMA) has identified the causal agent of bud rot. This is a huge step in the prevention and cure of this disease. Additionally, FEDEPALMA has a Sectorial Program for Sanitary Management, which develops strategies at a regional and national level, and processes public policies related to these phytosanitary issues.

2.4.4. Achieving oil palm certification by the Roundtable on Sustainable Palm Oil (RSPO)

The Roundtable on Sustainable Palm Oil (RSPO) is a global initiative created in 2004 to promote sustainable growth and use of palm oil through the cooperation inside the supply chain and the open dialogue among stakeholders. RSPO is a voluntary association composed of palm oil producers and traders, suppliers, distributors, banks and investors, and some environmental and social Non-Governmental Organizations (NGO). Currently, RSPO members account for nearly 40% of global palm oil production (RSPO, 2014).

RSPO published the Principles and Criteria (P&C) for sustainable palm oil production (including guidelines and indicators) for the first time in November 2005. The principles promoted by RSPO are: i) commitment to transparency; ii) compliance of regulations; iii) commitment to a long-term economic and financial viability; iv) use of better practices by growers; v) responsibility towards the environment and conservation of natural resources and biodiversity; vi) responsibility of growers and processing plants towards employees, individuals and the community; vii) responsible development of new plantations; and viii) commitment to a continuous improvement in different key areas of this activity (RSPO, 2014).

The principle regarding continuous improvement also establishes an adjustment of the P&C every five years. The first update was made in 2007, after a period of implementation and adjustments. The last version was released and approved in November 2013. Some of the changes of this version are four new criteria: ethical behavior; avoiding forced labors and traffic of workforce; respect for human rights; and reducing GHG in new plantations. All member countries must adjust their P&C according to these novelties and the RSPO established the deadline for this task until April 2014 (RSPO, 2014).

One of the most important criteria for obtaining the RSPO certification is the protection of natural forests in oil palm producer regions. However, in the last revision of the P&C document, the RSPO received critics regarding its ineffectiveness when it comes to approach crucial issues as deforestation and emission of GHG, particularly in Indonesia.

Colombia made a national interpretation of the P&C standards and it was approved by the RSPO in November 2010. Currently, the recent P&C version of 2013 is being adjusted by a technical group composed of producers, traders, environmental NGO, governmental institutions and experts. This group is in charge of proposing changes regarding the scope of the P&C; including associated Colombian regulations; and suggesting recommendations and specific guidelines that facilitate the implementation of these measures in Colombia.

The RSPO process in Colombia has been developed in a closed space by the technical group in charge. There is no participation of key actors that have suffered displacement, and dispossession such as ethnical groups (afro-Colombian and Indigenous). There is no presence of organizations that stand for labor rights; farmer organizations; or regional environmental authorities whose task is managing and controlling the use of natural resources.

Currently, the draft of this document (version 2013) is uploaded on the Internet. When analyzing new and eliminated elements, one can observe that, despite of the international effort of including new principles regarding ethics and respect for human rights, the obligations related to participative mechanisms and land property rights are omitted in the Colombian interpretation.

2.4.5. Adjusting oil palm agroindustry to a more inclusive and equitable rural development model

In Colombia, rural development is approached in terms of economic growth. The current agrarian model has a series of strategies for the agricultural and livestock sector, which aim at: enhancing productivity; promoting production linkages; increasing value addition; strengthening domestic and international markets; managing risks; improving income generation for rural population; achieving equity in the regional rural development; and upgrading institutional structures in order to achieve these goals (PND, 2010-2014).

According to Fajardo (2011), those strategies do not take into account the economic, social and political conditions around agricultural production; for example, issues related to land property and power relationships, which control the access to basic resources such as land, water, technology and markets.

In this agricultural model, the entrepreneur is prioritized as the main actor that enables achieving economic growth. Farmers and rural population in general are perceived as subjects that may contribute with land and workforce in entrepreneurial projects, managed by large investors (Salgado, 2011). Oil palm production is the best example that illustrates how this model works.

Oil palm production model fits perfectly in the current rural development model, which is designed for actors that have large scale productions and mobilize institutional resources such as contracts, credits, markets and cooperation. An evidence of this fact is a law project (that would modify Law 160 of 194) designed to regulate the access to vacant lands in order to establish rural zones for economic and social development. This would allow creating associative projects between farmers and enterprises in remote rural areas where production is highly expensive. This way, vacant lands owned by the State which should be allocated to rural population, are granted to agrarian entrepreneurs. This decision is justified by the argument that farmers do not have financial possibilities to make these lands productive, because the costs are elevated (Molano, 2014).

It is important to point out that the entrepreneurial sectors and export markets are indeed important and their potentialities are huge. However, some questions need to be raised: what is the place of small and medium producers inside this model, as they are citizens and significant actors in the national food supply (they produce 45% of commercial food)? In this agrarian institutional crisis, is there a way to actually guarantee their rights? (Salgado, 2011).

2.5. Conclusions

When social and institutional actors choose a particular policy or development model to manage the territory, the asymmetries regarding benefits and costs of this choice may arise.

This happens due to the existence of two or more options or models of economic growth that have opposite, contradictory of incompatible interests and features, generally known as trade-offs (Kosmus et al., 2013). In the Colombian case, the national government supports the promotion of an agro-export model based on the cultivation of permanent crops used to produce food and biofuels. This decision benefits a sector of the population but at the same time, it generates costs and uncertainties for other groups, mainly rural actors.

From an environmental perspective, although energy crops (and derived biofuels) may be a sustainable energy alternative that responds to a global environmental problem such as climate change, the expansion of large scale crops in tropical producer countries may become a driver of direct and indirect land use changes. Additionally, crop intensification may increase N2O emissions of the agricultural sector due to a higher use of inorganic fertilizers. This contributes to the degradation of organic matter in the soils, and therefore, to the liberation of carbon, thus contradicting the supposed sustainability of energy crops. These impacts, as well as others related to water pollution, alteration in hydrological structures in producer zones and loss of biodiversity must be analyzed from a rigorous, objective and independent viewpoint.

From a social perspective, it is important that the oil palm sector clears up its responsibility in cases that involve forced displacement and land dispossession caused by paramilitary groups. A recent study carried out by Colombian Vice-presidency evidences that a constant factor in the four oil palm producer regions in the country is armed conflict. This can be explained by the fact that these zones have abundant natural resources and many armed actors (legal and illegal) have had an historical confrontation over their control (Sánchez, et al, 2010).

As far as the living conditions improvement of rural populations, some studies in other countries have revealed that the income for small producers and plantation workers has increased (Bunyamin, 2008; Sheil et al., 2009), but this is not entirely true for the Colombian case. Although an investigation by FEDESARROLLO (2009) indicates that in the producer regions the welfare index is higher in households enrolled in oil palm activities (in comparison to control groups that participate in other agricultural sectors), the analysis of some socioeconomic indicators in those oil palm producer nuclei register elevated levels of rural poverty (Northern zone: 42%; Southwestern zone, 32%; Eastern zone, 35.6%; and Center zone 30.1%) in comparison to the national average in 2009 (29.4%) (DANE, 2012). The oil palm producer departments in 2009 also presented one of the highest land concentration rates: 0.80 (in average) (PNUD, 2012).

These indicators suggest that income increase for oil palm producers does not necessarily contribute to a more equitable distribution of regional rents, nor a reduction of rural poverty. It is probable that the high levels of violence and land concentration hinder the achievement of an equitable development in the producer zones.

In relation to the sustainability of the oil palm sector, it is important to acknowledge the variety of products generated in its value chain (agricultural and industrial), whose production and performance standards are high. Therefore, oil palm agroindustry is one of the most important sectors in Colombian agriculture and has significant development potential. However, it also faces several critical challenges. One of them is overcoming the phytosanitary issues that have caused meaningful losses and is one threat for this activity’s sustainability (FEDEPALMA, 2013). Other challenge is related to the high production costs in Colombia, when compared to other main producer countries. This factor has an impact on the economic sustainability and competitiveness of this agroindustry at an international level.

The strong state support to oil palm production is materialized in economic incentives (such as the Incentive for Rural Capitalization); in the creation of parafiscal and stabilization funds; in tributary exemptions; and in credit granting. These benefits doubtlessly guarantee this sector’s profitability. The Fund for Price Stabilization has been the main mechanism supporting the presence of Colombian oil palm sector in the international market. According to some estimations, eliminating this fund would reduce oil palm exports in 28% (FEDEPALMA, 2013). The strong dependence to this fund generates serious concerns regarding oil palm future in Colombia because such protection mechanisms will tend to disappear in the medium and long term due to free trade agreements.

CHAPTER 3

3. Biofuels as a new energy paradigm: main debate points after a decade[2]

3.1. Introduction

Energetic security constitutes a major strategic issue for all countries worldwide. Geopolitical tensions around the territorial control of oil and global climate change issues represent some of the reasons that have led to search for sustainable energy alternatives. Biofuels are a renewable option to substitute part of the fossil fuels used in the transportation sector, and have been growing very fast during the last decade (FAO, 2008; Mandil and Shihab-eldin, 2010; OECD-FAO, 2011). Liquid biofuels can be manufactured from several agricultural and forest products. On that account, ambitious programs and policies have been implemented during the last decade in order to promote its manufacturing and use in center and periphery countries. The production and consumption of biofuels also aims to: i) mitigate Greenhouse Gas (GHG) emissions; ii) encourage investment and promote development in rural areas; iii) diminish poverty; and iv) increase exports (Ahmed et al., 2011; OECD-FAO, 2011).

Public policies have played a significant role in the exponential growth of biofuels (ethanol and biodiesel), which has increased during the last decade from 18,000 million liters in 2000, to 129,000 million liters in 2011 (FAPRI, 2011). Nevertheless, biofuels still represent a limited contribution in the world energy matrix. In 2009, renewable energies constituted

---

[2] Castiblanco, C., Etter, A., 2013. Biofuels as a new energy paradigm: main debate points after a decade. Cuadernos de Desarrollo Rural 10, 70, 69-92.

only 16% of the global energy offer; of these, 60% come from fuelwood primarily used for cooking and heating in rural areas of developing countries, while only about 5% corresponds to biofuels (Ahmed et al., 2011).

As with other energy sources biofuels present risks and opportunities which depend on the type of feedstock used, the transformation process, and the social and economic contexts (Dufey and Stange, 2011). After more than a decade of biofuels promotion and development worldwide, the current debates focus on four major topics: i) the impacts generated from land-use and land cover change (biodiversity, GHG emissions, soil degradation); ii) the implications on the access, ownership and distribution of land; iii) the fluctuations of food prices; iv) the impacts on water use and ecosystem services related to water resources.

The aim of this article is to present an overview of the current status of biofuels in relation to the above mentioned topics with emphasis in tropical countries. This is attained in three parts: i) a general overview of global biofuel market evolution in the last decade; ii) a review of the academic debate in relation to land cover change, access to land, food prices and ecosystem services related to water regulation and greenhouse gas reduction; iii) a discussion of the main points from the perspective of the rural communities.

3.2. Global biofuel market evolution for the period 2000-2010.

To discuss how biofuel market has evolved in this ten year period, we will present some aspects of its growth dynamics, how it behaves currently, and the overall demands relating to crops, land and environmental issues. We will also mention the role that new technologies play in the biofuel market and the particular challenges they establish in developing countries.

During the last decade the growth of biofuels increased responding to demands, crops, land, environmental issues and technological innovations. Between 2000 and 2010, the production of biofuels increased at an average annual rate of 12% for ethanol and 27% for biodiesel, with a partial slowing during the global financial crisis of 2008 and 2009. The collapse of capital markets and productive activities impacted biofuel production due to restrictions to credit access, the decrease of the price of oil and the consequent fall of the demand for biofuels (Dufey and Stange, 2011). However, the global production of biofuels grew again 13.8% in 2010, accounting for 86,870 million liters of ethanol and 19,800 million liters of biodiesel. This was one of the most significant increases in the supply of liquid fuels within the decade (Figure 3.1). In 2010 liquid biofuels contributed to a record 2.7% of the energy used in the transportation sector worldwide (Ahmed et al., 2011). However, at least three factors can be identified as restrictive for the biofuel market growth: national protection policies for biofuel production; the focus on few agricultural products as main inputs; and the new environmental requirements imposed to the industry.

First, the international biofuel market is rather limited because a major part of the production is used as domestic consumption. In general governments protect local production, and the trade is therefore highly affected by commercial preferences and barriers, particularly in countries where biofuels are part of strategies oriented to support rural producers (Dufey and Stange, 2011). Some countries in the European Union and USA have trade agreements that grant a preferential access to certain countries. On the other hand, the financial assistance for production is also a significant trade barrier. For instance, USA supports ethanol industry with US$5,500 to US$7,300 million annually (Koplow and Track, 2006), while the European Union grants a financial support of 0.52 Euros per liter (Steenblik, 2007).

Second, the type of crop, its productivity and the potential expansion of croplands for biofuels are also issues that affect the market. Between 2000 and 2010, the most used energy crops for ethanol production were sugarcane and corn. For biodiesel production the main feedstock were oil plants such as rapeseed, soy and palm oil (Dufey and Stange, 2011). It is estimated that croplands currently used as feedstock for biofuels occupy an average of 14 million hectares, which is about 1.6% of the global agricultural land (OFID-IIASA, 2009). The potential for cropland expansion is mainly located in South America and Sub-Saharan Africa. The global growth of land used to cultivate food and feed is expected to add an additional area of around 98 million ha by 2020 and 147 million ha by 2030 in comparison to 2000. The expansion of biofuel production will be reflected in an additional use of agricultural lands and it has been estimated to reach 35 million ha by 2020, of which 13 million ha would be located in developed countries, and 22 million ha in developing countries (Mandil, and Shihab-eldin, 2010; OFID-IIASA, 2009).

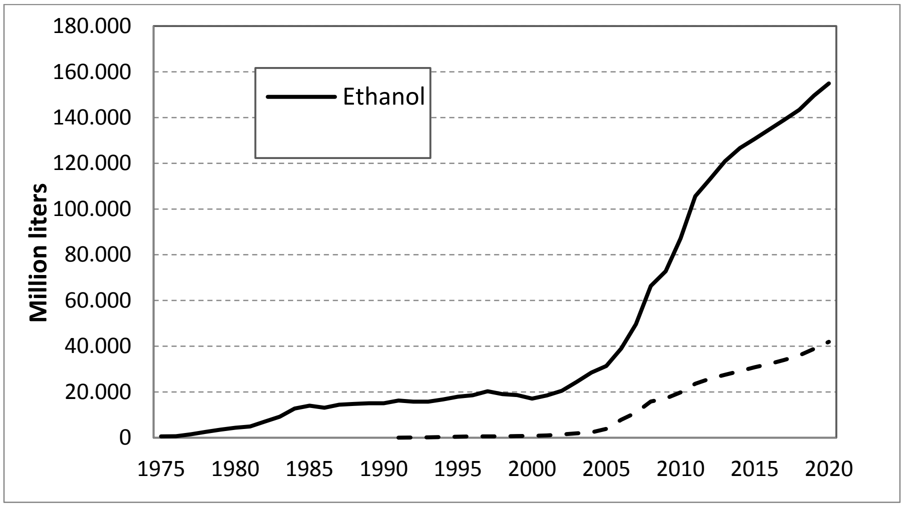


Figure 3.1: Evolution of global ethanol and biodiesel production

Source: OECD-FAO, 2011; EPI 2010; FAPRI, 2011

Thirdly, in relation to environmental issues, it can be said that sustainability concerns are becoming increasingly important and constitute a requirement in order to have access to the main markets (Dufey and Stange, 2011). As a response to potential environmental impacts of large-scale biofuel expansion, the main importing countries (particularly the EU) have implemented certification schemes oriented at guaranteeing biofuels sustainability. These initiatives are pioneered by the Netherlands, the United Kingdom and Non-profit Organizations, and cover aspects such as mitigation of GHG emissions, local environmental impacts on soil and water, and impacts on social aspects and food production (Scarlat and Dallemand, 2011).

The discussion of the biofuels market also needs to take into account the development of new technologies that would make the industry of "first generation biofuels" more sustainable, by achieving increased reductions of GHG emissions, land and water use, and social costs (IEA, 2010). However, against this there still are serious restrictions relating financing and profitability which limit the development of new technologies and the possibility to replace first generation biofuels production.

Developed countries (OECD) and other countries with emergent economies have been carrying out important research and investments in advanced biofuels. Additionally, a set of voluntary and mandatory norms and practices have been implemented. For instance, United States Congress established a mandate to promote the production of cellulosic ethanol, in order to achieve 950 million liters in 2011, which the Environmental Protection Agency (EPA) reduced to only 30 million liters for 2012 due to environmental concerns (Fairley, 2011). On the other hand, the European Commission (EC) included indirect land-use changes in the Renewable Energy Directive 2009 which only accepts biofuels whose carbon footprint is at least 35% lower than gasoline, a threshold that will be increased to 60% in 2018 (IEA, 2010).

In the future, a large portion of biofuel production must be achieved by shifting to a wide variety of non-food materials (seeds, and wastes of leaf, stem, weed and oil) or wild crops that grow in marginal lands, known as “second generation” biofuels (Fairley, 2011). However, “second generation biofuels” (non edible sources) present higher production costs compared to first generation biofuels and fuels derived from oil. Production and selling costs of cellulose ethanol are US$1.10 per liter of oil equivalent (about US$4 per gallon), whereas the equivalent production and selling costs of a corn ethanol liter oil is US$0.75, cane ethanol US$0.62, and conventional gasoline US$0.54 (Fairley, 2011).

On the other hand, the establishment of extraction and processing plants require a higher capital investment because the operation scales will also be larger. The IEA (2006) indicates that in the USA an investment of US$375 million is needed to install a cellulosic ethanol plant with a capacity of 50 million gallons per year (2005 US dollar price). At present the USA focuses on research and development of new technologies with the objective of reducing the costs of cellulosic ethanol to half (Timilsina and Shrestha, 2011).

In general, developing countries must face additional difficulties when it comes to developing second generation technologies, such as: improving road and agricultural infrastructure; qualifying labor force; enhancing financing possibilities; implementing and integrating into sustainability evaluations aspects related to land-use, land access and rural development strategies; and creating the conditions for improved cooperation and technological transfer with industrialized countries. Investment will also be required to promote research for the: identification and availability of suitable land; technological development; assessment of impacts derived from production and commercialization of second generation technologies; study of the local agricultural markets; materials flow; and finally, the analysis of the social, economic and environmental benefits and risks (EIA, 2010).

3.3. Risks related to large scale production and use of biofuels: main aspects of this debate

Although biofuels are an interesting alternative from the perspective of energy crisis and global warming, its large scale production implies significant risks, particularly for tropical countries, with effects of production and use going beyond the production chain (ABN, 2007; De la Torre Ugarte, 2006; Fajardo, 2009a). The process of land acquisition and plantation development in biophysically and socially heterogeneous regions can cause negative collateral ecological effects, reflected on indicators such as biodiversity, food security, inflation, and land and wealth distribution in developing countries, because institutions are often weak and there is a lack of mechanisms to strengthen property rights (Fajardo, 2009a).

Figure 3.2 shows the four main topics of concern in the current producer countries, which we discuss in the following sections, addressing the main debate points and their interrelations.

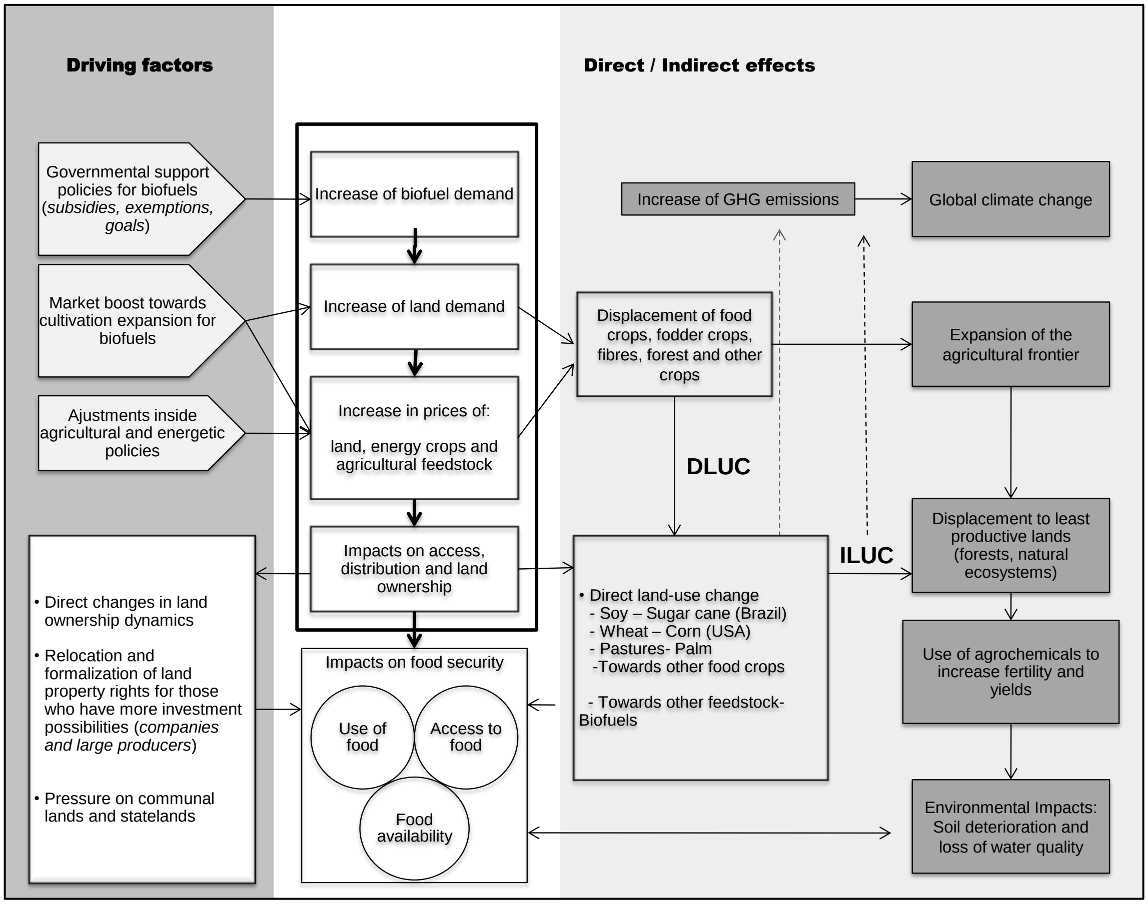


Figure 3.2: Links between biofuel production; land-use change and land access; GHG emissions; and food security

Source: Based in Ericksen, 2008

3.3.1. Direct and indirect land-use changes generated from the expansion of biofuel production.

A direct land-use change (DLUC) is produced when a new agricultural activity is developed in a particular area, creating land cover/use transitions which can be directly observed and measured using mapping techniques. An indirect land-use change (ILUC) reflects an unwanted consequence of land-use decisions in other neighboring or far away places. Unlike DLUC, an indirect change is often very difficult to observe or measure, or be isolated from other factors which are also contributing to those land-use changes, for example profitability decreases or modifications in support policies (Young, 2011).

ILUC is a matter of concern because areas oriented to biofuel production can displace other agricultural activities towards lands whose land cover are important carbon reservoirs, or food production. A large amount of GHG emissions is generated from land conversions that counteract any reduction obtained from the implementation of biofuels (Croezen, 2010).

Moreover, it is also possible that the new use of croplands and agricultural outputs to obtain biofuels does not satisfy other human needs generating unwanted consequences such as environment damage due to deforestation from agricultural expansion and threats to food security (Croezen, 2010). Examples of DLUC and ILUC generated by biofuels in the countries where its production is promoted include the following:

- **Land-use changes due to sugarcane expansion in Brazil**

In Brazil 90% of the sugarcane is cultivated in the south-western region (Sao Paulo, Goiás, Mato Grosso and Paraná). In these areas, the expansion of sugarcane crops has occurred at the expense of soy crops, pastures and formerly forested or reforested zones (Schlesinger, 2010). Cattle ranching also expanded towards North and center-western Brazil, into the Amazon rainforests and the Cerrado savannas. The current expansion of cattle ranching is considered a main factor of deforestation in the Amazon jungle. The ILUC of sugarcane expansion by the contribution to these deforestation trends in south-western states of the Brazilian Amazon has been documented by Goldemberg and Guardabassi (2009) and Gao et al. (2010). In the period 1997-2007, the cattle heads in the Amazon region showed a 78% increase, and currently this region hosts 35% of the cattle in the country. Precise figures for GHG emissions from such indirect land-use changes are still missing, but it is estimated that they could exceed carbon savings resulting from biofuel use (Schlesinger, 2010).

- **Land-use changes generated by the expansion of oil palm cultivation in Asia and Colombia**

Griffiths (2010) discusses the case of the oil palm company Sime Darby in Malaysia, which sells both, certified and non-certified palm oil. From 65 production units only 5 are certified by the Roundtable on Sustainable Palm Oil (RSPO) which provides palm oil to produce biofuels. The remaining 60 units depend on non-certified plantations located in tropical forest ecosystems in Liberia (Africa) and new plantations in Western Kalimantan (Indonesia) mostly producing edible and cosmetic oils.

Although the RSPO promotes the sustainable growth and use of oil palm products through global standards and investors commitment, it does not approach the issue of land-use change (Scarlat and Dallemand, 2011). As a result, several RSPO certified companies such as IOI and Cargill have expanded their plantations in forestlands. These companies fulfill the EU sustainability criteria for biofuels, and they will continue expanding to other zones in order to satisfy the additional oil palm demand for other uses, generating indirect GHG emissions. This means that RSPO certification does not warrant sustainability and it will not prevent deforestation because the RSPO does not deal with the issue of land-use change (Griffiths, 2010).

The case of DLUC in Indonesia is alarming: having the largest tropical forest cover of tropical Asia, this country has also had one of the highest deforestation worldwide: 5.39 million ha of forests disappeared between 2000 and 2008 (9.2% of Indonesia remaining original forest in 2000). More than 2 million ha of forests (including protected and conservation areas) have illegally become oil palm plantations (Koh and Ghazoul, 2010). Similar cases in Malaysia and Thailand have been documented by Wilcove and Koh (2010) and Dillon and Laan, (2008).

Nevertheless, the DLUC patterns are highly variable. In Colombia for example, changes resulting from the expansion of oil palm plantations have been different in spite of their environmental concerns: most new plantations in the 2002-2008 period in at least 50% of the cases replaced former pasture areas mostly of low productivity cattle grazing (Castiblanco et al., 2013). The replacement of natural vegetation such as tropical forests and savannas only occurred in 7.7% and 5% respectively; but it has also impacted agricultural areas in 30% of the cases. In this case the knowledge about the ILUC is still missing and needs additional research.

However, in relation to ILUC it is important to mention that not all biofuels generate negative impacts. For instance, in some cases the use of feedstock for biofuels can be compensated by biofuel co-products that are generated during the manufacturing process. These co-products can be used directly to substitute food for animals or for energy generation, which leads to a limited and even a negative demand of additional land (Young, 2011). Finally, ILUC are not an exclusive phenomenon of biofuels. Any additional demands in the global agriculture system have a potential to generate ILUC. Currently biofuels represent a small amount of the global agricultural production (approximately 2%). Also non-agricultural activities can result in ILUC impacts, such as oil exploration and exploitation, mining activities, urban expansion or establishment of new infrastructure (Young, 2011).

3.3.2. Impacts on land access and land prices.

The implications of biofuels on land access vary depending on the type of feedstock, land ownership systems and biofuel production models (from local self-sufficient energy models to large scale plantations for export). Implications also depend on the role agriculture plays in a national economy. In general, countries with a high rate of rural population, a high contribution from agricultural GDP in their economy and high availability of natural resources, will experiment a greater impact from land-use and cover changes (Cotula et al., 2008).

Cotula et al. (2008) show how government policies direct sector support changes in land prices and determine the forms of access and distribution. The support policies to the biofuel sector tend to be broadly reflected in an increase of the price of land and the cost of agricultural inputs. When the land demand grows and the market is limited an informal, the opportunity cost increases and the most profitable uses are selected. Profitability in agriculture strengthens the tendency towards higher land prices, particularly in the more fertile areas, circumstances under which the less profitable crops are displaced to least productive zones, such as pastures, forests or abandoned lands. Increases in land prices contribute to land concentration in fewer owners who have access to capital and infrastructure resources, especially in regions where there are strong power assymetries, lack of transparency and weak support from legal frameworks that establish property rights, agricultural and environmental policies, and create questionable incentives for land use and access (Cotula et al., 2008).

This said, in the long term the growing biofuel production will cause changes in land property, making the access to land for marginal groups more difficult (Cotula and Neves, 2007). Specific groups such as itinerant farmers, women and small producers will tend to experience land exclusion because of land price increases (Cotula and Toulmin, 2007). This can also be seen in developed countries, where only 5% of women farmers own their lands (IFPRI, 2011). This fact is even more relevant in cases where a considerable number of women are widows and single mothers due to the armed conflict, which makes them more vulnerable to displacement towards marginal lands when land prices increase (Cotula et al., 2008).

3.3.3. Impact on production and food prices.

A potentially important impact of first generation biofuels is the impact on production costs and food prices. Ewing and Msangi (2009) for example, show that the corn production for ethanol in the period 2002-2007 in the USA was responsible for the 30% price increase of wheat and secondary cereals. These authors also indicate that in the same period, 93 million tons of wheat and secondary cereals, and 81 million tons of corn (a quarter of the entire corn production in USA) were used for ethanol production. According to the International Monetary Fund (IMF), the global growth of biofuel production explains the average 12% increase of food prices between 2006 and 2008. In addition to that, the International Food Policy Research Institute (IFPRI) also estimates that the growing demand for bioenergy represented 30% weighted price increase of grains between 2000 and 2007 (Tirado et al., 2010).

On the other hand, there is evidence that the higher the oil prices, the stronger the bond between biofuels, land-use changes and food security (Dufey and Stange, 2011). The more expensive oil becomes, the more profitable biofuel production will be, causing pressure on land and increasing land rent. This means that significant and continuous changes in fossil fuel prices, as well as sectorial support and promotion policies, will be reflected on the reduction of land availability for food, and this can cause a regular increase of household goods prices (Kretschmer and Peterson, 2008; Msangi et al., 2010).

Figure 3.3 shows the impacts of the changes in the prices of labor and land rent resulting from the implementation of biofuels. It adapts a conceptual framework from bi-sectorial models with fixed production factors in order to analyze the effects of changes in oil prices and the demand for energy sources derived from agricultural outputs (Corden and Neary, 1982). If the prices of fossil fuels have a significant increase, then the demand for biofuels rises. As a result, the curve of land demand is displaced from Lb to L’b. The new global equilibrium is located at point B. This implies that land rents rise from R0 to R1. At the same time, the land used for food production experiences a reduction from Lf to L’f. Assuming that the number of workers inside the sector is constant, and then a smaller amount of land is reflected on a lower food production, which goes from qA to qB. Finally, in the global market the reduction of food supply leads to a price increase, from PfA to PfB.

Biofuels expansion can also generate additional income for agricultural producers, and exportations can contribute to economy growth by generating currency and new job opportunities. However, the results of the partial equilibrium analysis indicate that countries whose population is vulnerable and present malnutrition would not be able to acquire food in spite of their productive capacity or the food availability (Ewing and Msangi, 2009). What is at stake here is the problem of agricultural income distribution between large and small producers and consumers, and in the end this is the issue that defines the impact of biofuels on human wellbeing (Ewing and Msangi, 2009).

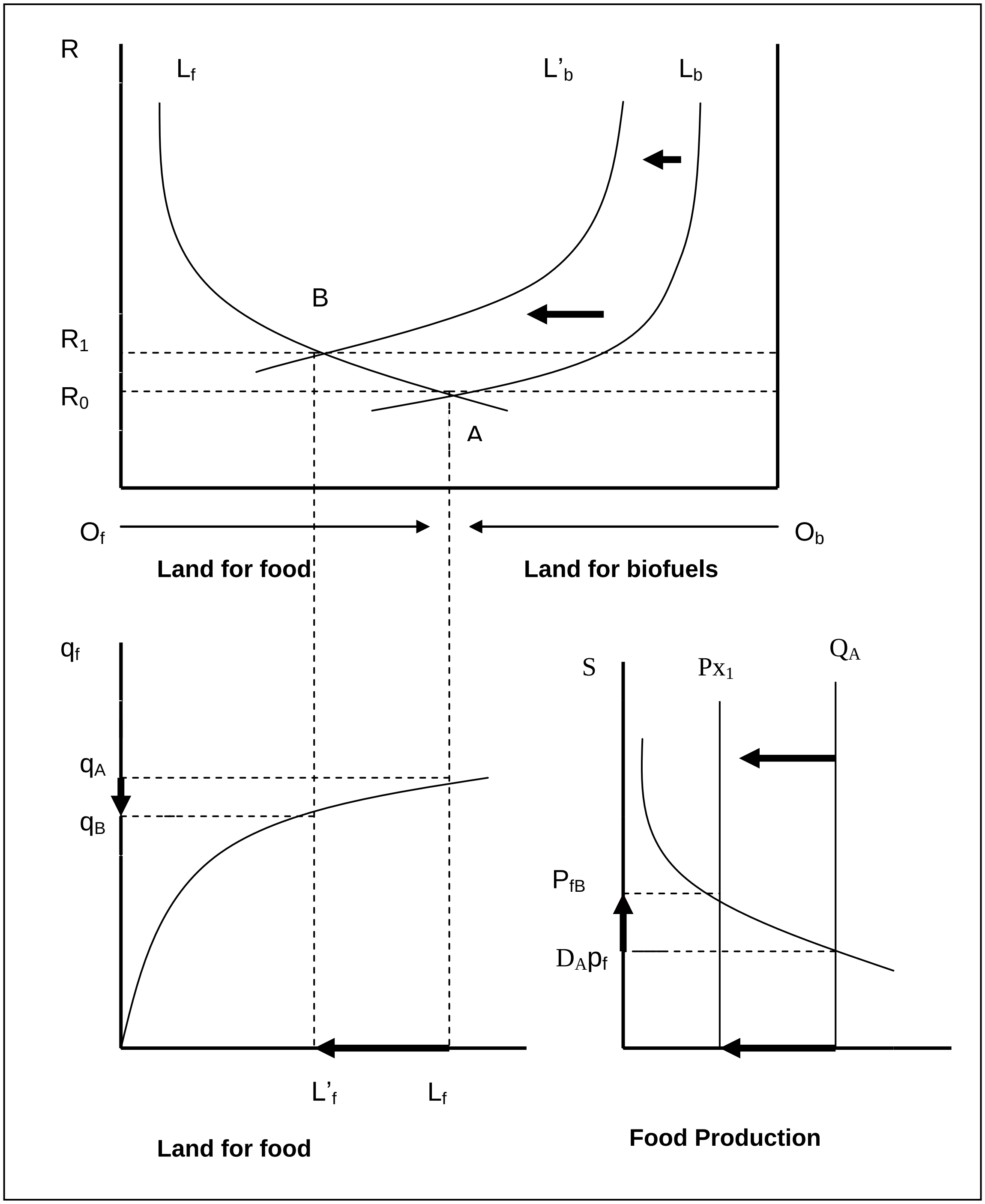


Figure 3.3. Effects of biofuel production on land supply and food prices

Source: Adapted from Corden and Neary, 1982.

3.3.4. Impacts on ecosystem services derived from water.

Biofuels are an additional factor that increases competition for water and land in the agricultural sector. Even though the contribution of energy crops to global water demand in agriculture is rather modest. In 2008 it was estimated that only around 1% of the whole amount of extracted water for agricultural purposes is used to irrigate biofuel feedstock (IWMI, 2008). However, this varies locally and depends on factors such as cultivation type, soil type, weather, agronomic practices and efficiency of production technologies (De Fraiture, 2009).

There still remains a lot to be studied about the impacts of biofuel production cycle on water resources. Berndes (2002) evaluated water consumption of different stages of biofuel production, indicating that the phase of feedstock cultivation consumes around 90% of the water needs, whereas the phase of industrial transformation uses 10%. Rosegrant et al. (2002) analyzed the role of water in agriculture, arguing that biofuel production affects water resources most directly when used for irrigation and in industrial processes transformation, and also indirectly by increasing water loss due to evapotranspiration, which otherwise would be available as runoff and underground water. However, De Fraiture and Berndes (2009) mention that 20% of water requirements for energy crops comes from irrigation, mostly in northern Africa, southern Asia and the northern plains of China, while 80% is met by rainfall, mostly in Latin America and Europe.

Other studies have focused on the concept of the “water footprint”, proposed by Hoekstra (2003). This concept relates to the direct and indirect uses of water through the production chain. Hoekstra et al. (2009) demonstrated that depending on the kind of feedstock and climate conditions of the geographic region where the fuel is produced, the water footprint from energy biomass can be 70 to 700 times larger than the water footprint from fossil fuels. Recently, Lienden et al., (2010) estimated the future water footprint of biofuel production indicating that it could grow to up to 5.5% of the available “blue water” (liquid water) by 2030, and that the water footprint of the transportation sector would increase approximately 10 times due to the use of biofuels.

A most obvious and visible effect is related with irrigation agriculture because the use of water from rivers, lakes, lagoons and swamps reduces the volume of the flow. This can dry up water bodies especially in dry seasons. River deviations, construction of dams and other infrastructures designed to retain and obtain water for agricultural purposes can cause important alterations in the hydrological structure, which in turn affects sedimentation and flooding patterns (Falkenmark and Rockstrom, 2006). On the other hand, draining peat lands and wetlands with agricultural purposes is one of the main causes of the loss of these ecosystems around the world (Finlayson and D' Cruz, 2005). There are several examples of the damages caused in wetlands due to biofuel expansion. In south-eastern Asia large areas of tropical peat lands have been degraded because of wood cutting and conversion from forests to oil palm plantations (De Fraiture et al., 2008).

In Colombia diverse conflicts generated by water use in municipalities of the Orinoco region where oil palm plantations occur have been documented (Olmos, 2012). The most frequent conflicts are related to land reclamation to introduce new oil palm plantations or to expand current plantations. Most complaints relate to the alteration of gallery forests and wetlands, as well as excavation of drainage ditches or construction of irrigation channels. Communities have expressed their concern about the irreversible alteration of flows, superficial and underground water currents in those areas, leading to flooding phenomena from bursting of small rivers and channels that receive water flows above their capacity.

Additionally, biofuel production and industrial transformation also impacts water quality of groundwater and water bodies because of contaminated runoff water with fertilizers, pesticides and herbicides, particularly on large scale agriculture. In general, nutrient contamination turns into eutrophication processes. Moreover, when the underground water resources are used for biofuel production, there are changes in underground reservoir levels that may generate collateral damage such as soil salinization, such as observed in India, China, Mexico, USA and Australia (Siebert et al., 2010).

However, the impacts derived from producing feedstock for biofuels on ecosystem services related to water resources are not particularly different from those observed in agricultural crops. In general, agriculture tends to increase the provision of some services (food, fuels, wood, and water), at the expense of other ecosystem services such as regulation services (underground water recharge, flooding control, and sediment control, among others), protection services, and supporting services (habitat, primary production, nutrient cycle) (MEA, 2005).

3.3.5. Greenhouse Gas (GHG) emissions: uncertainties and assumptions in modeling and quantification of impacts derived from ILUC.

A strong argument for promoting biofuel production and use has been its contribution to the reduction of GHG emissions. In this respect, authors such as Fargione et al., (2008) and Searchinger et al., (2008) initiated the debate around the impacts, importance and implications of policies with respect to ILUC generated by first generation biofuels production. The study by Fargione et al., (2008) of peat drainage and forest clearing in Indonesia found that only the carbon emissions from peat decomposition is 420 times larger than the carbon savings from using oil palm biodiesel during one year. Searchinger et al., (2008) found that corn-based ethanol nearly doubles GHG emissions over 30 years.

Achten and Verchot, (2011) evaluated the consequences of GHG emissions from land-use change in 12 case studies from 6 countries. The life cycles of different biofuel production systems were analyzed, including oil palm, jatropha and soy. Their results show that carbon debts range from 39 to 1,743.7 Ton CO2/ha. Oil palm presents the highest carbon debt (472-1,743 Ton CO2/ha) because its expansion mostly took place at the expense of tropical forests and peat lands.

Overmars et al. (2011) estimated GHG emissions generated by ILUC from biofuel production in the EU using historical data. They found emissions to be substantial compared to those of traditional fossil fuels (84 g CO2 equiv/MJ): for ethanol ILUC emissions are 26–154 g CO2/MJ and for biodiesel 30– 204 g CO2/MJ, when the conversion emissions are spread over 20 years.

However, there are critics to these studies, such as the lack of historical data that allow discerning the use trajectories that precede agro industry development and the lack of regional evaluations of land cover change at high spatial and temporal resolutions that imped to identify dynamic changes (Carlson et al., 2012; Ellis and Ramankutty, 2008). There are no unified criteria to model land-use change impacts, and the models have gaps or assumptions that increase uncertainty with respect to the nature and magnitude of the calculated impacts (Young, 2011).

Under these circumstances, policy makers are regulating ILUC without conclusive scientific proof related to their scale and intensity. In this respect Di Lucia, Ahlgren, and

Ericsson, (2012) recommend that policy makers assume a preventive approach: although it does not assure that negative impacts from ILUC disappear, it does allow lowering the probability of negative impacts, by taking into account more adequate sustainability requirements and critical thresholds of GHG emissions.

3.4. Biofuel policy parallel agenda: the point of view of the rural communities

State policies that promote biofuel production create tensions and conflicts inside communities and organizations which are part of civil society. This is not a well-studied topic in the general literature, but has been addressed by several authors in Colombia, which we use as a case to explore the issue. In Colombia, indigenous groups, afro-american and peasant communities often constitute a resistance front against the promotion and expansion of agroindustrial energyc crops in their territories (Roa and Toloza, 2008). They argue that the growth of these plantations disrupts their culture, ecosystems and community life. On the other hand, there are also conflicts between capital and work which reflect in union manifestations that stand for the defense of labor rights and are opposed to the cooperative model of Associated Workers (Roa and Toloza, 2008; CINEP, 2009). The main debate points relating biofuel policy and social conflict in Colombia are discussed below.

- **Biofuels and threats for food security**

Both edible (first generation) and non-edible (second generation) crops used for energy production may generate competition for agricultural lands, water, labor force and other agricultural production inputs (Friends of the Earth, 2008). The large scale of industrial biofuel production often expands the agricultural frontier with important repercussions on price, land concentration and access to production inputs. In some cases this has been reflected in violent processes of land invasion where indigenous and afro-descendant groups are settled, and also in expropriation of land from small and medium farmers impacting food production (Pérez, 2011). Because the purchase and leasing of lands by foreigners for biofuel production are mortgaged over long time periods, the opportunity costs can be significant in terms of food production (OXFAM, 2012).Therefore, one of the challenges faced by rural communities is to make their social welfare, economy and culture visible through the preservation of their food security and autonomy (Salgado, 2010).

- **Work outsourcing and labor rights violation**

A practice that is becoming common in tropical lands that produce commodities for biofuels, is the subcontracting of workers and activities by enterprises through the cooperative model of Associated Workers and Strategic Productive Alliances (Dufey and Stange, 2011). These models of outsourcing hiring procedures are aimed at reducing costs of labor force, and land rent tend to impose asymmetrical conditions when it comes to the relations with workers. This allows the enterprises to access a low-cost labor force, bypassing legal protections implied in regular labor relationships (Seeboldt and Salinas, 2010).

- **Biofuels and the agrarian conflict in poor countries**

The biofuels business model tends to contribute to the consolidation of an entrepreneurial agriculture which in tropical countries strengthens the land concentration, characterized by the participation of landowner and investors who emphasize the land as a production factor, a source of income and an axis of local political power (Salgado, 2010). Under this model, rural communities such as indigenous, afro-american and peasants where property rights over their lands are not clearly established tend to become secondary value as laborers or rural salary earners. This generates particular forms of integration and expulsion of rural population, resulting in an undervaluation of these communities as cultural subjects of the development processes. From this perspective land property and socio-political recognition are important tools for these communities to build their life projects, maintain their identities and their sense of social belonging (Salgado, 2010).

- **Biofuels and issues of security and violation of human rights in countries and regions with internal conflicts**

In countries facing internal conflict such as Colombia, the expansion of energy crops has in cases been associated with forced displacement, illegitimate and violent land appropriation and violation of human rights (Seeboldt and Salinas, 2010). In these cases, enterprises related with biofuels industry have been accomplices by action or by omission, by allowing the entrance of armed groups and illicit cash flow in the entrepreneurial and politic ambits of the regions.

The absence of a clear policy to repair for violence victims that would prioritize the return to land and property restitution limits the possibilities for enterprises to establish projects with the legal land owners (Seeboldt and Salinas, 2010). The characteristic lack of censuses of property rights and ownership generates resettlement processes and legitimizes expropriation. This means that communities disintegrate, and it is therefore often not possible to identify the head representatives of local communities who could be helpful in the mitigation and fair compensation of active losses generated by voluntary resettlements.

3.5. Conclusions

The development and implementation of biofuels in many countries around the world during the last decade has raised serious questions against the optimistic promotion of biofuels as a solution to the energy crisis. One of the main arguments for development of biofuels as substitutes for fossil fuels in the transport sector was its contribution to GHG mitigation: the impacts generated by direct land-use change (LUC) and indirect land-use change (ILUC) are often larger than the expected benefits. Although conclusive scientific proofs with respect to scale and intensity of the impacts are still needed, the state of the art recommends that policy makers assume a preventive approach, particularly in tropical countries characterized by high social and ecological vulnerabilities. It is necessary to refine methodologies, standardize criteria and models, and unify measurement languages and techniques, with the objective of achieving key consensus.

Recent literature warns about the negative collateral damages from the expansion of energy crops on land prices and food production. It is demonstrated that the higher the oil prices, the stronger the bond between biofuels, changes in land prices and food security are. Significant and constant changes in support policies and promotion of this sector will be reflected on a reduction of land availability for food production, and on a constant price increase, which will have important consequences particularly in developing countries.

Biofuels also intensify the competition for water. Impacts derived from production and expansion of biofuels on water resources has not been profusely studied. The more visible effects are related to river deviation and draining, construction of dams and infrastructures that cause serious alterations in hydrological structures. Moreover, the main reasons that explain the loss of water ecosystems in the world are the drainage of wetlands, swamps and peat lands to cultivate raw materials, as well as the dumping of water polluted with fertilizers, pesticides and herbicides.

Energy crops expansion can also have an influence in conflicts of agricultural production and rural land property, especially in developing countries that lack modern institutional infrastructures or unclear assignation of property rights. Organizations that are part of civil society have expressed concerns about the negative effects of large-scale plantation models that supports biofuel production on rural populations, leading to the concentration of wealth and rural income, and rural displacement and land dispossession. There is great uncertainty about the magnitude of the impacts and risks that biofuels may have on human welfare, especially in developing countries. Before promoting ambitious biofuels production, detailed diagnoses of the potential production that include the assessment of their ecological and social impacts are required.

CHAPTER 4

4. Oil palm plantations in Colombia: a model of future expansion[3]

4.1. Introduction

The growth of biofuels production is associated with the rapid increase in the global demand for primary energy. It is estimated that global demand for energy will increase by 36% between 2008 and 2035, and that fossil fuels will remain the primary energy source until 2035. However, the development of new energy alternatives is being driven by the need to avoid emissions from fossil fuels and identify sources of sustainable, low-cost energy able to guarantee the energetic security of all countries (BP, 2011; IEA, 2010).

Biofuels are promoted worldwide as an alternative to replace fossil fuels used in the transportation sector, although the extent to which biofuels could meet this need is unclear (Gallagher, 2008). In 2007, about 13 million hectares or 1% of the arable land in the world was used for biofuel crops. It has been estimated that by 2030 these crops could represent 4% of arable land, but biofuel production would still account for only a small fraction of the total fuel requirements for transportation (Sheil et al., 2009).

Although biofuels are often seen as environmentally friendly, many concerns have been raised about the possible environmental impacts of the expansion and intensification of biofuel production (Ewing and Msangi, 2009; Gallagher, 2008; Gasparatos et al., 2011; Searchinger et al., 2008). These impacts include: i) competition for lands that are used to produce food; ii) increase pressure on water resources; iii) the expansion of plantations into

---

[3] Castiblanco, C., Etter, A., Aide, T.M., 2013. Oil palm plantations in Colombia: a model of future expansion. Environmental Science & Policy 27, 172–183.

natural ecosystem areas; and iv) increasing greenhouse gas emissions due to land use changes.

The relation between the expansion of crops to produce biodiesel and forest loss in tropical countries has been well documented in Malaysia and Indonesia (Dillon and Laan, 2008; Wilcove and Koh, 2010). Between 1990 and 2005, approximately 59% of oil palm expansion in Malaysia (FAO, 2005) and 56% of palm plantations in Indonesia occurred at the expense of natural forests. In contrast, in Brazil the expansion of sugar cane crops for ethanol production has not been a direct cause of deforestation in the Amazon region, because expansion has occurred mainly on pastures lands (Goldemberg and Guardabassi, 2009). Nevertheless, the expansion of sugarcane has contributed indirectly to deforestation by displacing pastures used for grazing towards the south-eastern states of the Amazon (Gao et al., 2010). A large component of the impact of biofuel production also depends on the type of land use or land cover that it replaces (Achten and Verchot, 2011). Most studies have focused on how biofuels help to avoided emissions from fossil fuels or on life cycle analyses (e.g. emissions associated with production, processing and transport) of biofuels, but emissions from land use change have been largely ignored. For example, conversion of tropical forest will result in large losses of carbon to the atmosphere, and the benefits of biofuels can take hundreds of years to replace the original carbon debt (Lapola et al., 2010; Achten and Verchot, 2011). It is also critical to understand what happens to land use activities, such as food production, when they are displaced by biofuel production (Hellmann and Verburg, 2011).

Colombia is the main oil palm producer in America. Commercial production began fifty years ago, and is currently consolidated in four geographic regions (Ospina, 2007). In 2010, oil palm plantations covered 404,104 ha, and approximately 160,000 ha were used for biodiesel production (FEDEPALMA, 2011). The expanding national and international biofuel market has stimulated much interest in biodiesel production in Colombia, especially given that the government has the ambitious goal of producing biodiesel, by replacing 20% of diesel with biofuel by 2020. By 2010, most regions of the country had implemented the mandatory 7% volume blend, lower than the initially planned goal of 10%; this increase in the domestic consumption oil palm biodiesel has reduced oil palm exports (FEDEPALMA

2011). To meet the 20% national goal an additional 600,000 ha of oil palm are needed, for which the government has implemented a subsidy program designed to promote the expansion of oil palm plantations in several areas of the country (Consulting Biofuel, 2007). In another document the Ministry of Agriculture has even set a target of 3 million hectares for the oil palm industry (Bochno, 2009). To achieve these goals a set of normative tools, such as statutory mandates for mixtures and economic incentives that include price supports, subsidies, tax exemptions or preferential taxes were designed (DNP, 2008). These policy tools reduce the risk and uncertainty from the prices of both raw materials and energy inputs. In response to these expectations, two studies were done to identify suitable areas to grow oil palm (CENIPALMA-CORPOICA, 1999; IDEAM-IGAC, 2009). But these had serious limitations as areas of current productive plantations appear as non-suitable in their analysis.

The purpose of this paper is to examine the impacts and the factors associated with recent and future projected expansion of oil palm plantations in Colombia. First, we analyze the impact of new oil palm plantations during the period 2002-2008 by determining the land use transitions of these plantations. Second, we apply an econometric model time series to forecast the area of oil palm plantations in 2020; this model incorporates the impact of governmental policies (normative and economic that support the biofuel sector) through an "intervention analysis". Third, we construct a probability map of future oil palm plantation expansion based on a logistic regression model that incorporates biophysical and socioeconomic variables to spatially project the estimates of cultivated areas for 2020. Finally, we analyze the probable future land cover/use transitions associated with the 2008-2020 projected expansion of plantations.

4.2. Materials and methods

4.2.1. Study area

Colombia is located in northeast South America, in the inter-tropical zone. The total area is approximately 1.14 million km^2, of which approximately 50% is covered with forest. The country is geographically heterogeneous due to high variation in climate, physiography, vegetation, soils, and biota. A major feature is the Andean region which runs across the central portion separating the Eastern and Western lowlands where most forests still occur. With about 45 million inhabitants, Colombia is the fourth most populated country in America. The population is concentrated in the Andean and Caribbean regions; approximately 76% of the inhabitants live in urban areas (Etter et al., 2006).

As a result of the high ecological variability between regions, Colombia has one of the highest levels of species diversity per unit of area worldwide: in only 0.77% of the world's land area it contains 10% of its known species (IDEAM, 2004). In spite of its natural richness, Colombia has experienced rapid transformation processes by which natural ecosystems have been replaced or fragmented. Currently deforestation rates are approximately 238,000 hectares (Cabrera et al., 2011). The causes of deforestation are diverse and depend on the specific conditions of each region, but they are usually related to the expansion of the agricultural frontier for cattle grazing, forest fires, wood extraction and the growth of illicit crops (Cabrera et al., 2011).

The most extensive land use is cattle grazing which spans over more than 70% of the agricultural land, usually exhibiting low productivity levels (McAlpine et al., 2009). Only 9.6% of agricultural land is used for crops (4.1 million ha in 2011). Annual crops represented 33% of the cultivated area, whereas permanent crops and plantations represented 59%, the remaining 8% was classified as fallow land. During the period 2002-2008 annual crops increased by 1.7%, while the area of permanent crops and plantations increased 25.6% (MADR, 2011).

Oil palm plantations account for less than 1% of the total agricultural lands and 0.3% of the country area (FEDEPALMA, 2011). In 2010 oil palm made up 2.6% of the agricultural GDP and 0.22% of total GDP (MADR, 2011). Oil palm plantations are located in four zones: north, central, eastern and the western zones (Figure 4.1). The Eastern Zone has the most plantations and contributes 39.1% of the area planted with oil palm. The oldest plantations are located in the north (28.5%) and central zones (28%). The Western Zone contributes only 4.5% of the cultivated area in the country (FEDEPALMA, 2011).

Although limited in area, the expansion of oil palm in the Western Zone mainly occurred in areas that were previously forested (Seeboldt and Salinas, 2010). However, due to the high humidity and cloudiness, the bud rotting disease reduced plantations from 33,700 in 2006 to 18,000 ha in 2010 (FEDEPALMA, 2010b). In addition, poor infrastructure, armed conflicts, and the existence of Collective Territories of Afro-Colombian communities have limited the development of the oil palm industry in this region (Seeboldt and Salinas, 2010; BID, MME, 2012).

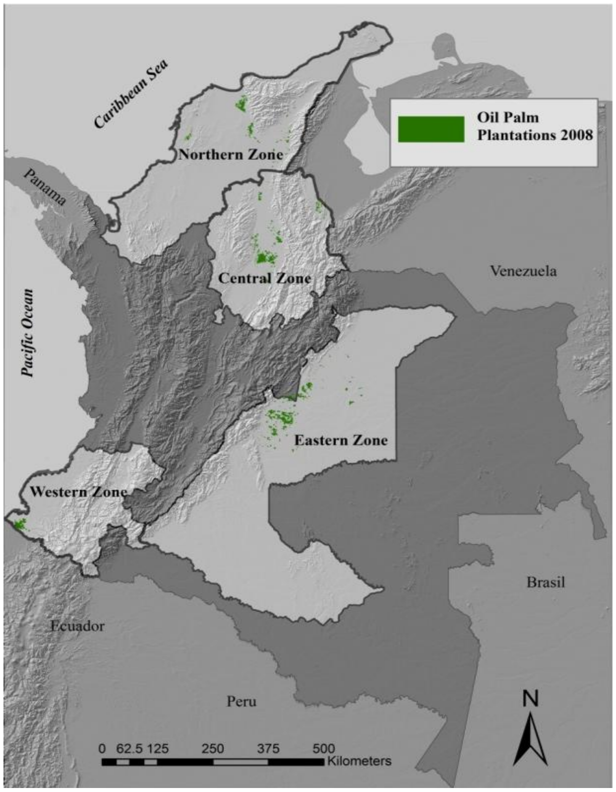


Figure 4.1: Location of oil palm plantation areas in 2008, and plantation zones in Colombia as defined by FEDEPALMA

Source: FEDEPALMA, 2008

4.2.2. Data

The type of data, units, and sources of the information used in the analysis and modelling are presented in Table 4.1.

To identify the previous land use in areas that have been transformed into oil palm plantations during the period 2002-2008, we used a national land cover map (IDEAM, 2002) and updated a plantation growth map for 2002-2008. This plantation map was constructed using information on the establishment date of plantations from the 2007 oil palm plantations map based on satellite and field data (FEDEPALMA 2007), updated by us to 2008 using Landsat-ETM imagery (http://glovis.usgs.gov/) and expert knowledge. The 2002 land cover classes were reclassified it into 11 classes, as follows: 1) heterogeneous agricultural areas (including crops mosaic, mosaics of crops and natural areas, and mosaics of crops, pastures and natural areas), 2) undifferentiated annual crops (cereals, vegetables, tubers and other seasonal crops), 3) undifferentiated permanent crops (, sugar cane, coffee, cocoa), 4) rice crops, 5) banana, 6) pastures, 7) savannas (open grassland, dense grassland), 8) secondary regrowth (includes fragmented forests), 9) plantation forests, 10) natural forests (dense forests, open woodlands), and 11) other coverage (swamps, water, bare soil, areas where mining extraction takes place, and urban areas).

To create the Time Series Intervention Model, we used the statistics of oil palm plantation areas for the period 1967-2009 (FEDEPALMA, 2001, updated to 2009 with annual statistics). To account for the intervention policies to promote the biofuel sector introduced in 2002 (DNP, 2008), a dummy variable was added to the model. The dummy variable was assigned a 0 value for all years before the intervention policy and a value of 1 after the intervention.

To calculate the plantation area required to provide the oil needed to comply with the mandates of biofuel blends, we used the data on domestic diesel demand projected for 2020 (UPME, 2008). We assumed a gradual increase in crop productivity from the current 3.5 Mg/ha to 4.1 Mg/ha in 2020 (FEDEPALMA, 2011), and the gradual increase of blends from 5% in 2008, 7% in 2010, 10% in 2014, and 20% in 2020 (UPME, 2008).

To perform the spatial analyses of oil palm expansion, the 2008 oil palm map and a set of map grids of biophysical and socioeconomic variables representing the suitability factors of plantation expansion in the country were constructed. An exploratory analysis to verify possible correlations between independent variables was performed. The eighteen variables finally included in the model are presented in Table 4.1. All maps were projected to the same coordinate system, with a spatial resolution of 500 meters. The ArcGis.v10 and Idrisi15.ANDES-version software were used for the spatial analyses.

Table 4.1 Data sources used in the different modeling and analysis procedures.

Analysis	Variable Group	Variable	Source	Type of data	Units
Logistic Regression	Dependent	Oil palm presence	Map oil palm plantations in Colombia (FEDEPALMA 2007) and Landsat imagery.	dichotomic	--
	Explanatory variables	Mean annual temperature	World Clim (Hijmans, et al., 2005)	continuous	°C
		Annual rainfall of driest month	World Clim (Hijmans, et al., 2005)	continuous	mm
		Relative humidity	Climatological maps (IDEAM, 2007)	categorical	--
		Solar radiation	Solar radiation map (IDEAM, 2007)	categorical	--
		Effective depth	Soil map of Colombia (IGAC, 2003)	categorical	--
		Altitude	90m DEM (IGAC 2009)	continuous	m
		Slope	90m DEM (IGAC 2009)	continuous	%
		Distance to oil palm extraction plants	Oil palm map (FEDEPALMA, 2007)	continuous	km
		Distance to road	Distance map to nearest road network.(IGAC, 2007)	continuous	km
		Distance to populated centers	Base map (IGAC, 2009)	continuous	km
		Distance to main cities	Base map (IGAC, 2009)	continuous	km
		Population density	National municipality statistics (DANE 2010)	continuous	pers/km^2
		Natural protected areas	National Natural Parks map (IDEAM-IGAC, 2009)	dichotomic	--
		Indigenous reserves	Indigenous reserve map (DANE-IGAC, 2005)	dichotomic	--
		Afro-descendant communities	Afro-descendant communities map (DANE, IGAC, 2009)	dichotomic	--
Land Use Transitions		Land cover type	Ecosystem map of Colombia (IDEAM, 2007)	categorical	ha
		Oil palm plantation growth area 2002-2008	Oil palm plantations maps 2002 and 2008 (FEDEPALMA 2007) and Landsat imagery	dichotomic	ha
Econometric Analysis	Dependent	Oil palm areas (1967-2009 series)	Statistics (FEDEPALMA 2001, 2010)	continuous	ha

4.2.3. Modeling and analysis.

The study included four independent types of analysis : 1) a map overlay to analyze the transitions of land use, to determine which land cover classes and areas were replaced by oil palm plantations during the period 2002-2008; 2) a Time Series Intervention Model Analysis to project the cultivated area for the year 2020, which incorporated the impact of government policies (normative and economic policies that support the biofuel sector); 3) a logistic regression model that incorporated biophysical and socioeconomic explanatory variables, to produce a probability map of oil palm presence to be used to project for the future expansion of oil palm plantations and 4) a map overlay to analyze the transitions of land use using the probability map to project the likely land cover/use classes that would be impacted by the future expansion of oil palm plantations. The methodological procedure used to integrate econometric analysis with the spatial modeling analysis is presented in Figure 4.2.

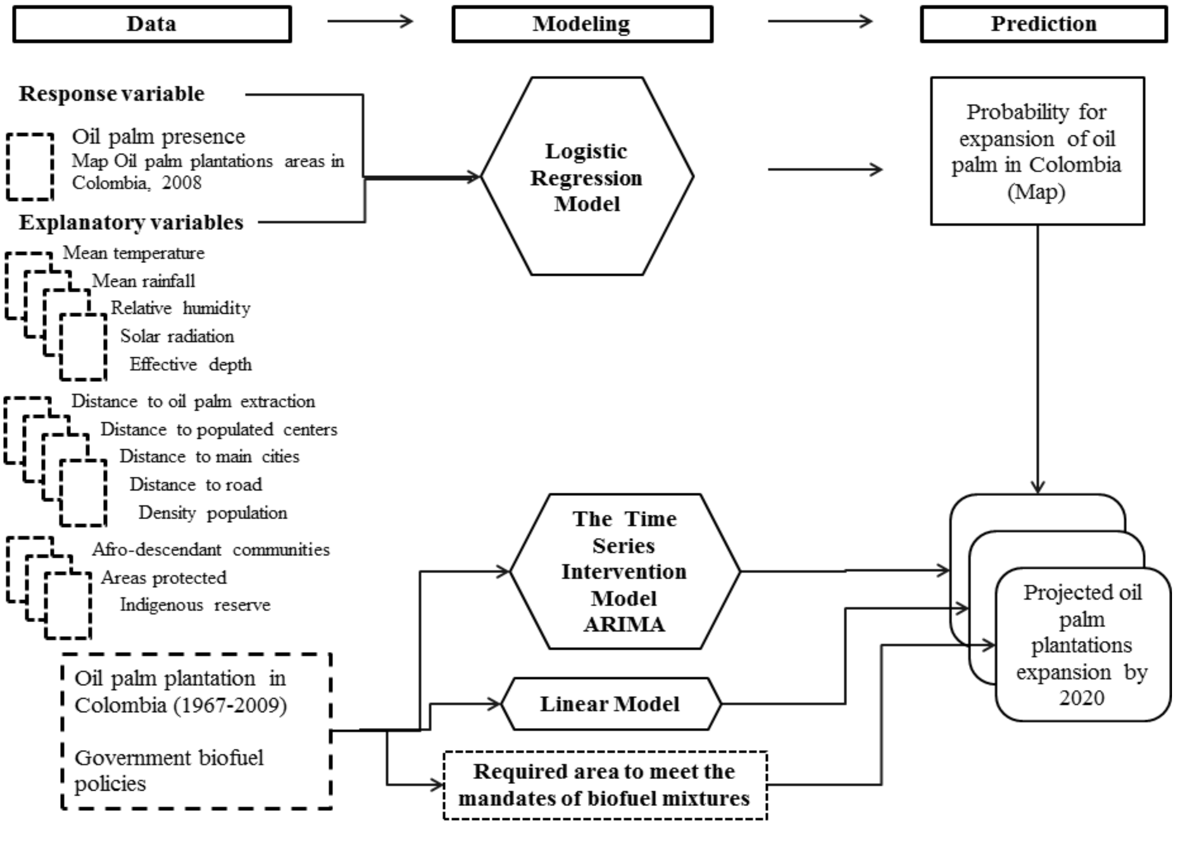


Figure 4.2. Methodological diagram showing data inputs, modeling sequences and outputs.

Source: Own elaboration.

- **Analysis of land use transitions for the 2002-2008 period**

To quantify the land use transitions we performed a GIS map overlap procedure of the 2002-2008 plantation growth area with the reclassified 2002 land cover/use map. This provided the information on the spatial location and the quantity of land cover/use classes transformed into oil palm plantations. The statistics were calculated for each of the four geographic palm plantation zones.

Projections of the future expansion area in different scenarios

To estimate the increase of oil palm plantations by 2020, we performed four calculations: i) a simple linear trend based on the historic data; ii) an econometric model that incorporated the historic trend and the policy interventions and subsidies; iii) the projected demands that follow from the planned increases in the biofuel mixtures (7% in 2010, 10% in 2014, and 20% in 2020); and iv) the trend that incorporated the expected national goal of 3 million hectares (Bochno, 2009).

Econometric Intervention Analysis model

The Intervention Analysis is an econometric method that examines the impact of external events such as public policies on the historical trend of a time series. According to Vallejo (1996), quantifying the impact of an intervention variable helps explain the behavior of the time series and enhance the parameter estimations and model results. The Time Series Intervention model is an extension of the ARIMA (p,d,q) method, in which an additional explanatory variable that accounts for changes in policies affecting the process is included (Enders, 1995). The model is formally expressed as follows:

$$y_t = a_0 + \sum_{i=1}^{p} a_i y_{t-i} + \sum_{i=0}^{q} \beta_i \varepsilon_{t-i} + \theta X_t + u_t \text{ (Equation 1)}$$

Where yt is the dependent variable, which in this case is defined as the absolute variation the area of oil palm plantations in hectares at each time step; εt is the error; ai,, βi, and θ are parameters to be estimated; p is the lag order of the dependent variable; q is the order of the moving mean component; d the differentiation degree of the series; X is the dummy variable representing the policy intervention and ut is the estimated error.

Spatial modeling to identify the most probable areas of future oil palm plantation expansion

The suitability for a particular land use can be explained by a wide range of factors such as biophysical and climatic conditions of the site, as well as economic and political factors, such as taxes, subsidies, access to credit, technology production and transportation costs, and land use planning policies that restrict or encourage certain land uses (Koomen et al., 2007). The logistic regression model is appropriate when used to predict the probability of a particular event occurring or not occurring (binary dependent variable) (Aldrich and Forest, 1984). These models are characterized by binary dependent variables, while explanatory variables can be continuous, categorical or dichotomous. In our case we are interested in assessing the likelihood of the presence (1) or absence (0) of oil palm cultivation in a particular area, given certain biophysical (climate and soils) and infrastructure for production conditions. The general specification of the model is based on studies of land use and cover change by Etter et al. (2006) and Lambin and Meyfroidt (2010). For our study, the logistic regression model is represented by the following equation:

$$Log\left(\frac{Y}{1-Y}\right) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_{16} X_{16} + \varepsilon \qquad \text{(Equation 2)}$$

Where, Y is the binary dependent variable, which takes the value of one (1) in the presence of oil palm plantations or zero (0) in the absence of oil palm plantations in each analyzed cell; X1,X2, X3….X16, are the explanatory variables that include that biophysical and socio-economic factors used to explain the presence/absence of the crop; β_0, β_1, β_2,…,β_{16} are the parameters to be estimated and ε is the regression error. The explanatory variables included in our model were: slope, altitude, relative humidity, rainfall of driest quarter, mean annual temperature, solar radiation, effective soil depth, distance to roads, population density, distance to major cities, distance to extraction plants, distance to population centres, presence of Afro-colombian territories, presence of indigenous reserves and presence of national parks (Table 4.1).

The output of this model was a probability map of the presence of oil palm plantations. The probability map was then used to show where future oil palm plantations are expected to expand based on the amount of change by 2020 for each scenario.

Analysis of probable future land use transitions (2008-2020)

To assess future land use transitions, we overlapped the predicted distribution of new oil palm plantations for the period 2008-2020 with the reclassified 2002 land cover/use map. Because we do not have future land use maps, by using the 2002 map this analysis we are assuming that the areas outside the oil palm plantations will remain unchanged; therefore, this analysis ignores other possible land use transitions (e.g. pastures to crops, crops to pastures). Although this is a limitation, the analyses are meant to provide an indication of the regional differences of the most probable transitions. The statistics were calculated for the four zones of oil palm production in the country.

4.3. Results

4.3.1. Land use transitions in the oil palm producer zones for the period 2002-2008

Although transitions varied slightly from region to region, in general the main transition to oil palm plantations was from pastures (Table 2-2). Of the 155,100 ha of new oil palm plantations between 2002 and 2008, 79,000 ha (51%) occurred in pastures, 29.1 % in croplands, and 16.1% in natural vegetation (forest and savannas) and regrowth forests. The transition from pastures was more dominant in the East and Central Zones, while the transitions from heterogeneous agricultural areas were highest in the North Zone. In the Western Zone there were no changes in the area of palm oil plantations during the period analyzed.

In the Eastern and Central zones oil palm plantations showed the largest expansion with 68,600 and 68,500 hectares respectively. In the Eastern Zone 58% occurred at the expense of pastures, 11% of savannas, and 12% of irrigated rice crops (Table 4.2). In the Central Zone 51% originated from areas that were in pastures in 2002, and approximately 20% and 11% of the transformation occurred in heterogeneous agricultural areas and natural forests, respectively; while 4.3% of the change took place in secondary vegetation. In the Northern Zone, 18,000 ha of new plantations occurred between 2002 and 2008, mostly from pastures (26%), followed by heterogeneous agricultural areas (24%).

Table 4.2 Land cover transitions towards oil palm in the producer zones for the period 2002-2008 (000s).

	NORTHERN ZONE			CENTRAL ZONE			WESTERN ZONE			EASTERN ZONE			TOTAL	
COVER TYPE	Area in 2002 (ha)	Change to oil palm (ha)	%	Area in 2002 (ha)	Change to oil palm (ha)	%	Area in 2002 (ha)	Change to oil palm (ha)	%	Area in 2002 (ha)	Change to oil palm (ha)	%	Change to oil palm (ha)	%
Heterogeneous agricultural areas	2,821.30	4.2	23.6	3403.1	13.7	20.0	1666.3	0	0.0	1462.2	3.8	5.5	21.8	14.0
Undifferentiated Annual crops	70.956	0.7	4.1	42.6	0.1	0.2	10.5	0	0.0	2.2	0.0	0.0	0.9	0.6
Undifferentiated Permanent crops	125,706	7.2	39.8	88.3	4.2	6.2	143.8	0	0.0	93.6	2.9	4.3	14.3	9.2
Banana	59,422	0.1	0.8	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.1	0.1
Rice	52,852	0.0	0.0	0.1	0.0	0.0	0.0	0	0.0	141.0	8.0	11.7	8.0	5.2
Pastures	6,286.76	4.7	26.0	2598.4	34.7	50.7	703.9	0	0.0	3865.8	39.6	57.7	79.0	50.9
Forest plantations	31,098	0.0	0.0	2.0	0.1	0.2	19.9	0	0.0	3.7	0.0	0.0	0.1	0.1
Natural Forests	3,758.62	0.6	3.3	3753.1	7.4	10.9	4377.7	0	0.0	16031.4	3.9	5.7	12.0	7.7
Savannas	458.732	0.0	0.0	603.0	1.5	2.1	0.0	0	0.0	7010.6	7.6	11.1	9.1	5.8
Secondary vegetation	874.978	0.4	2.4	996.0	2.9	4.3	1217.2	0	0.0	1618.8	0.7	1.1	4.1	2.6
Other covers	2651.068	0.0	0.0	1191.1	3.7	5.3	863.9	0	0.0	1862.4	2.0	3.0	5.7	3.7
TOTAL	17,191.5	18.0	100	12,677.8	68.5	100	9,003.4	0	100	32,091.7	68.6	100	155.1	100

4.3.2. Projections of oil palm plantations area growth under different scenarios

The four projected growth trend scenarios of oil palm plantations for 2010-2020 are very different (Figure 4.3). The extrapolation of the linear trend based on data from 1967-2002 predicts 330,982 ha of oil palm plantations by 2020. The econometric time intervention model, which includes the effect of the subsidy policies after 2002, predicts 647,687 ha by 2020. The third projection is based on the additional production requirements needed to meet the increasing biodiesel mixture targets established by the government, and this predicts approximately 930,000 ha. None of these models are close to the expectations of the government to reach 3 million hectares by 2020 (Bochno, 2009).

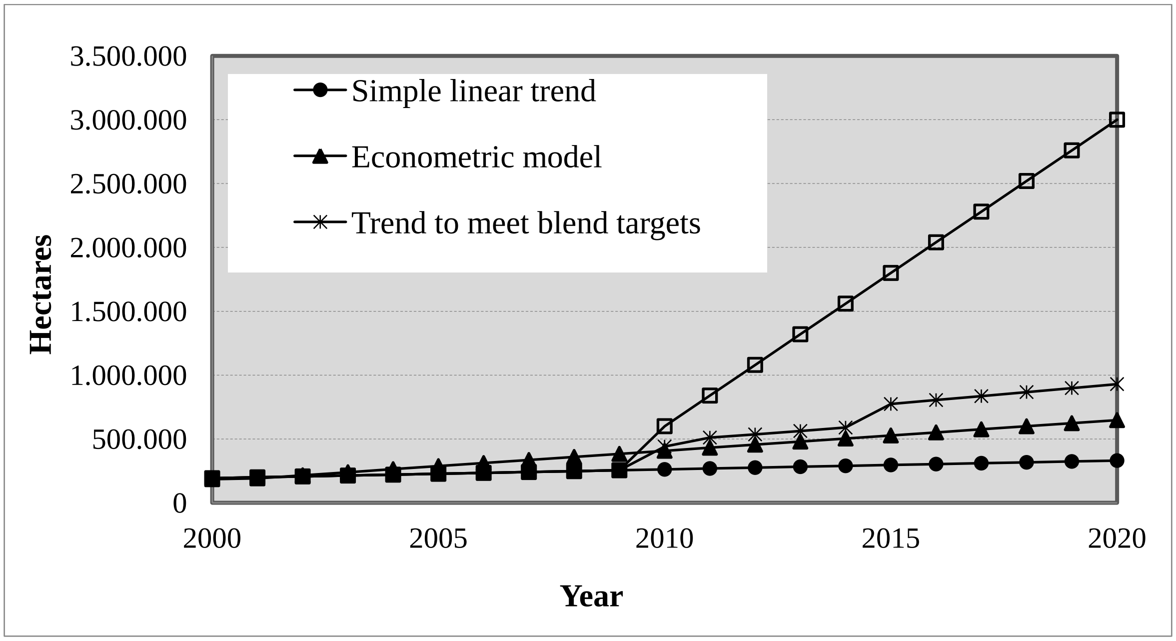


Figure 4.3: Four comparative projections for the expansion of oil palm plantations for 2000-2020 according to the different scenarios considered: simple linear trend based on the pre-intervention 1967-2002; econometric model including policy intervention effects; government biodiesel blending targets; and Ministry of Agriculture expectations.

The econometric time intervention model explained 70% of the variance of the dependent variable, i.e. increase in the area of oil palm plantations (Supplementary Table S1). The dummy intervention variable that captures the effect of policies to promote biofuels since 2002 was statistically significant ($p < 0.01$), which indicates that the policies implemented for the sector in 2002 had a significant positive effect, generating important changes in entrepreneurial decisions, which resulted in a 50% increase in the area oil palm plantations between 2002 and 2008.

4.3.3. Projected spatial oil palm expansion scenarios

The variables that best explained the presence of oil palm plantations in Colombia included: altitude, rainfall of driest quarter, distance to roads and distance to extraction plants (Supplementary Table S3). Other significant variables included slope, distance to populated centres and solar radiation. The low significance of national parks and indigenous reserves is explained by the fact that the extent of these protected areas is very small compared to the total national area; even though some of these areas have suitable climatic and soil characteristics their national conservation status restricts certain type of land use activities.

The spatial expression of the logistic model (Figure 4.4a), shows that although large areas of suitable land for oil palm are located in the vicinity of existing plantations, large areas can also be found in other locations. Figure 4.4b shows the spatial distribution of oil palm plantations for the three different scenarios of the projected expansion area of plantations constructed from the probability map. The models suggest that under current conditions much of the oil palm expansion is likely to occur in the Central Zone and in the Northern Zones in areas of Tolima, Cundinamarca, Antioquia, Bolivar and Córdoba. All these areas are also characterized by important food production (e.g. rice, banana and livestock) which could generate substitution risks, threatening the food security of these regions. Another new expansion zone is predicted to the south of the Eastern zone in the colonization front of the Northern Amazon region.

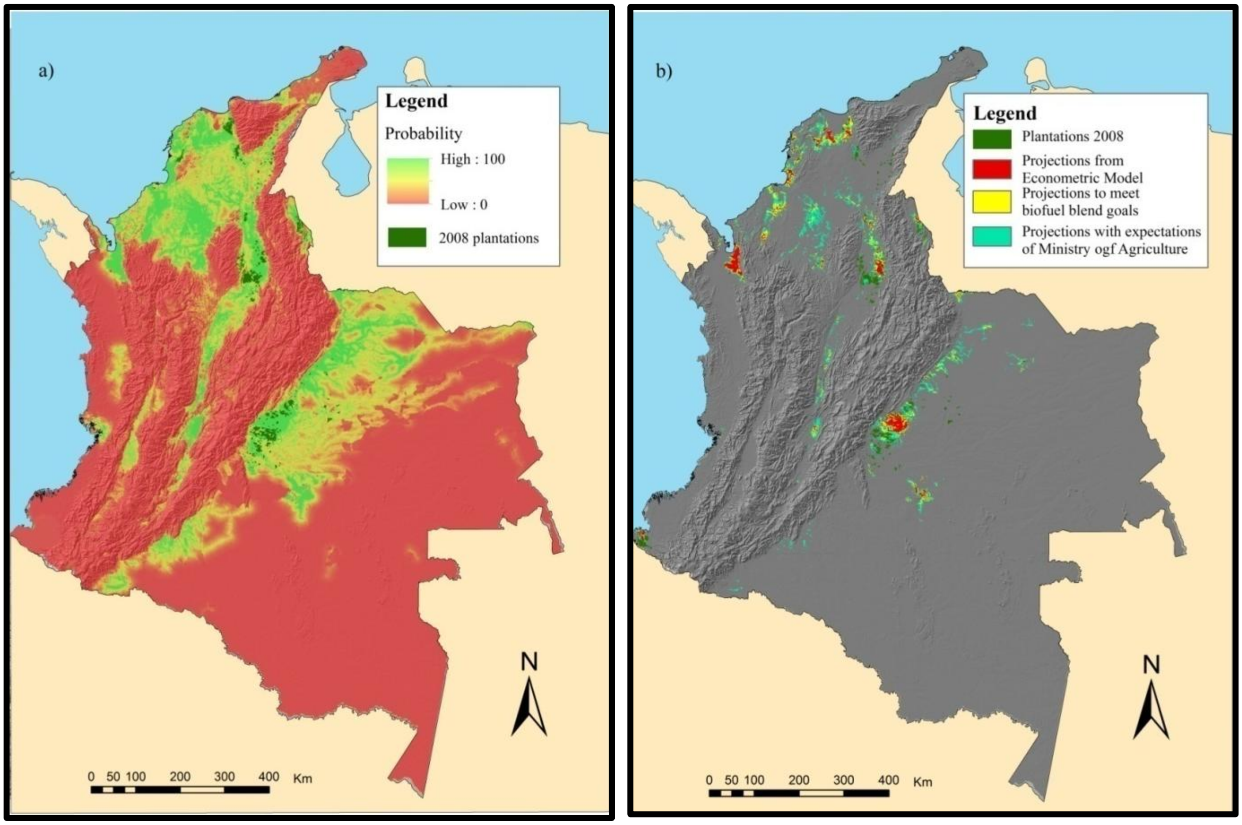


Figure 4.4. Spatial model of future oil palm plantations expansion in Colombia: a) expansion probabilities according to the logistic model; b) most probable spatial expansion of oil palm in 2020 according to the total projected area from the econometric model (647,687 ha), the calculated biofuel blending goals (930,000 ha), and the Ministry of Agriculture expectations (3,000,000 ha).

4.3.4. Analysis of future oil palm land use transitions

If the future expansion of oil palm, as predicted by our model, is approximately 361,000 ha (Figure 4.4b), 49.4% will replace current pasture areas while 19% will replace heterogeneous agricultural areas (i.e. a combination of crops, fallows, secondary vegetation and pastures). Approximately 12.7% (40,000-50,000 ha) of new plantations are expected to replace natural vegetation areas (i.e. forests, shrublands and savannas), the majority savannas and forests of the Eastern zone. The analyses also showed that approximately 6,750 ha of rice in the Eastern zone, and 22,200 ha of banana in the Northern zone could be replaced by oil palm plantations by 2020. In the Western zone, future oil palm expansion (13,000 ha by 2020) are expected to replace agricultural areas (4,200 ha), natural forests (3,500 ha) and secondary vegetation (4,000 ha) (Table 4.3). Two large areas (23,750 ha) in important agriculture areas which have no plantations at present were assigned high probabilities for future plantations: 1) Tolima, an area important for rice production, and 2) Urabá a region with extensive banana plantation, mainly for export.

Table 4.3 Predicted future land use transitions to oil palm plantations (2008-2020) according to the spatial projection of the area from the econometric model

Cover type	NORTHERN ZONE		CENTRAL ZONE		EASTERN ZONE		WESTERN ZONE		REST OF COUNTRY		TOTAL	
	Change to oil palm (ha)	%	Change to oil palm (ha)	%	Change to oil palm (ha)	%	Change to oil palm (ha)	%	Change to oil palm (ha)	%	Change to oil palm (ha)	%
Heterogeneous agricultural areas	45,375	27.6	7,350	13.1	6,400	6.2	4,175	32.3	4,775	20.1	68,076	18.9
Undifferentiated Annual crops	300	0.2	625	1.1	50	0.0	0	0.0	50	0.2	1,025	0.3
Undifferentiated Permanent crops	4,675	2.8	0	0.0	0	0.0	0	0.0	0	0.0	4,675	1.3
Banana	22,200	13.5	0	0.0	0	0.0	0	0.0	0	0.0	22,200	6.1
Rice	1,575	1.0	0	0.0	6,750	6.5	0	0.0	1,550	6.5	9,875	2.7
Pastures	64,275	39.0	39,150	69.6	65,475	63.3	100	0.8	9,475	39.9	178,477	49.4
Forest plantations	25	0.0	0	0.0	0	0.0	0	0.0	0	0.0	25	0.0
Natural Forests	5,450	3.3	2,825	5.0	8,100	7.8	3,500	27.1	3,650	15.4	23,525	6.5
Savannas	1,375	0.8	0	0.0	6,500	6.3	0	0.0	975	4.1	8,850	2.5
Secondary vegetation	5,300	3.2	825	1.5	1,625	1.6	4,025	31.1	1,700	7.2	13,475	3.7
Other covers	14,150	7.9	5,475	8.9	8,600	7.7	1,125	8.0	1,575	6.2	30,925	7.9
Total	164,700		56,250		103,500		12,925		23,750		361,125	

4.4. Discussion

This study is the first comprehensive nationwide assessment of the past and future expansion of oil palm and the relation with land cover changes in Colombia. Our results contradict the existing literature and projections oil palm plantations in Colombia in two important aspects. First, the historical impacts and most likely future impacts of oil palm plantations occurred or will occur primarily in areas that have already been cleared (e.g. cattle pastures, agricultural lands), and not in areas of natural vegetation (e.g. forest, savannas). Second, our analyses suggest that the total area of oil palm plantations in 2020 will be much lower than current estimates.

4.4.1. The conversion of other land cover land use classes to oil palm plantations

Between 2002 and 2008, more than 100,000 ha of new oil palm plantations were established in Colombia (Table 3.2), more than 50% of which were established in areas previously used as pastures. This transition could be interpreted as positive given that oil palm plantations are more productive than most pasture lands (McAlpine et al., 2009), they provide more jobs (Barrientos and Castrillón, 2007) and they can contribute to climate mitigation by the uptake of carbon (Germer and Sauerbrn, 2008; Etter et al. 2011). New oil palm plantations (20%) also replaced agricultural lands, particularly areas that were previously used for the production of rice, banana and mixed agriculture. The social, economic, and environmental impacts of these transitions are less obvious, and will depend on the local context and need more detailed studies. Pérez (2011) and Infante and Tobón (2010) for example, point to the likely increases in land, labor wages and agricultural input prices, which displace subsistence crops to more marginal lands and impact on local food prices and food security.

Less than 15% of the new oil palm plantations impacted natural vegetation (e.g. forest, savannas). A possible explanation for the low level of forest clearing is that it will add to the costs of establishing plantations. Furthermore, these areas are unlikely to have the infrastructure (e.g. roads, electricity) that an agricultural region would have. Most of the forest loss has occurred in transformed landscapes with highly fragmented forest remnants, not in continuous forests of the agricultural frontier. However our study possibly underestimated the impacts of palm plantations on natural areas because we did not quantify the effects of indirect land use transitions (Croezen, 2010). Indirect land use transitions could be important when oil palm plantations are displacing previous landowners (e.g. subsistence farmers, cattle ranchers), who then colonize new areas by clearing forest to continue their farming and cattle activities. However, the recent main cause of deforestation in Colombia has been the land clearing for the production of illicit coca crops (Dávalos et al., 2011), mostly beyond the agricultural frontier (Cabrera et al., 2011).

Even though we have emphasized the low impact of new plantations on natural areas in the past, our models suggest that by 2020 approximately 37,000 ha of forest and woody vegetation could be cleared for plantations (10% of all transitions). If the current estimates of deforestation are correct (238,000 ha per year), (Cabrera et al., 2011), this would only account for 1-2% of the total area deforested in Colombia in the coming 8-10 years. Another important area of future expansion is the in the Casanare and Arauca Departments of the Eastern Zone. These areas still has extensive areas of diverse natural savannas, but the transformation of this region has already been predicted independent of oil palm expansion (Etter et al. 2011). But, in the regions where these changes are to occur, there will also be impacts on water quality and quantity and the price of land (De Fraiture et al., 2008; Pérez, 2011). This is where our spatial analyses of future transformation can assist in identifying high probability of change areas. In these areas, monitoring, policy, or preventive actions could be taken to prevent or reduce the rates of transformation and other negative impacts. For example, although the Western Zone is not experiencing expansion at present, if in the future the problems caused by diseases and poor infrastructure are overcome, our model suggests that a significant proportion of oil palm expansion in this area would occur in forested areas. Actions taken now (e.g. regional zoning plan) could help to reduce future negative impacts.

4.4.2. The future distribution of oil palm plantations: how much and where?

Two important aspects of projecting future changes of oil palm plantations are to estimate how much new area will be established and where these changes will occur.

First, our econometric model, which incorporated government policies and subsidies, estimated a growth of approximately 650,000 ha of oil palm plantations by 2020, that is close to the estimate of 743,000 ha of the palm growers association (FEDEPALMA 2010), but much lower than the 930,000 ha estimate needed to meet the demand of a 20% blend in biodiesel and the Ministry of Agriculture goal of 3 million hectares (Figure 3.3). To achieve the goal of 20% diesel-biofuel mixture, we believe that a major policy change (e.g. large incentives) or an external shock (e.g. dramatic increase in the price of oil, technological changes) will be necessary. The 3 million hectares goal of the government is highly unlikely because to add an additional 2.5 million hectares of oil palm plantations in the next 8 years, would require an investment of at least 37.5 billion USD (assuming total establishment costs USD 15,000/ha), equivalent to approximately 1% of the annual GDP spread over the next 8 years 2012-2020. An investment of this magnitude would require a significant increase in subsidies and capital from the government or from the foreign investors. Our model assumes that the present levels of subsidies, the production technologies, and infrastructure cannot deliver the needed increases in palm oil area. A change in these factors will alter the estimates of the model. For example, the recent free trade agreements with the United States and the European Union could alter our estimates. Given that the production costs of biofuels is currently higher in Colombia than in United States and the European Union (Infante and Tobón, 2010; USDA, 2008), it is even possible that these agreements could have the indirect effect of reducing future oil palm plantations in Colombia.

Second, regarding where oil palm expansions would take place in the future, our model predicted a very different spatial scenario compared with two previous studies CENIPALMA-CORPOICA (1999) and IDEAM-IGAC (2009) that assessed suitable areas for oil palm cultivation in Colombia. We attribute these differences to the modelling approaches and the data used in the models. CENIPALMA-CORPOICA (1999) used a general suitability approach based on a few soil and climate variables (rainfall, drainage, slope and effective depth), but they did not include economic or infrastructure variables. IDEAM-IGAC (2009) applied the FAO Land Evaluation framework (FAO, 1976) that included biophysical, ecological and socio-economic characteristics weighed against the crop requirements, to produce four suitability classes.

We question the maps of these studies because large areas of highly productive active oil palm plantations in Meta, Casanare and Santander Departments were classified as moderate to severe crop limitations. We also found strong discrepancies of our results with those of the mentioned studies in the location and extent of the “higher suitability” areas, especially in the Eastern zone (Arauca, Casanare and Vichada Departments), Central zone (Santander and Cundinamarca Departments) and Northern zone (Atlántico and Bolivar Departments). Possible reasons for these differences are besides the methodological, probably the result of the difficulty to match the coarse databases of the available variable maps to the finer scale crop requirement data. Another aspect is that these two models identify coarse suitability areas, not permitting to identify temporally framed hotspots of change, which our study does. Our model although based on current plantation areas, projects important potential crop expansion areas outside of traditional oil palm growing regions, such as in areas of Tolima, Antioquia, Cundinamarca and Urabá (Figure 4.4).

Finally, our results should be put in context of a national scale analysis, the available data, and the assumptions based on the currently used technologies, market trends, oil prices, prices of raw materials, low supply of biodiesel to the foreign market, subsidies context. Any modifications to these factors will have an impact in the future of the industry. The future developments of the oil palm industry will certainly have impacts on the prices of land, labor supply and food price and supply (Hellmann and Verburg, 2011). To address this, a careful analysis of the macroeconomic effects of the changes in variables associated with oil palm expansion and the likely impacts on the food sector and food security are needed. They should incorporate data and criteria to locate and exclude restriction in areas with high social, conservation or ecological services values (MEA, 2005). Approaches that include a combination of general equilibrium models and multi-criteria analysis, such as those developed by Irwin and Geoghegan (2001) and Lotze-Campen et al. (2009) could be well suited to this end. These analyses would be particularly relevant to analyze the impacts in areas that have been predicted by our models to have high chances of being converted in the future.

4.5. Conclusions

Our study suggests that although oil palm is an important component of the Colombian agro-export and energy strategies, the government's future expectations do not match reality. It is highly unlikely that the government's expectations of an increase of 3 million hectares of oil palm plantations will be achieved. Even with strong government support the projected oil palm plantations in Colombia will not reach more than one million hectares by the year 2020. Therefore, the expected biodiesel blends (20%) do not appear to be feasible. However, the accelerated processes of transformation and the fragmentation of ecosystems that Colombia is experiencing are likely to be increased by the central government's decision to grow its internal consumption and encourage the country to become a strong competitor in the international market for biofuels. The spatial modelling exercises and econometric analyses developed for this study demonstrate that in the three main producing areas of palm oil in the country, the crop has mainly expanded into areas previously used as pastures. A lower proportion of the land use change has been from heterogeneous agricultural areas and natural forest to palm oil crops. It is necessary to refine the spatial scale of analysis and incorporate detailed regional information to determine local impacts on strategic regional ecosystems, food systems and water resources. This analysis should focus on areas that are most likely to be involved in expansion of palm crops, such as the eastern and central areas.

CHAPTER 5

5. Impacts of oil palm crop expansion in Colombia: what do socioeconomic indicators show?[4]

5.1. Introduction

The contribution made by energy crops and biofuel production to development, social welfare and conservation of ecosystems and ecological services has constituted a controversial debate. On one hand, governments and enterprises in producer countries argue that the biofuels area may become a significant driving force for economic growth and a source of exports for tropical countries because it generates employment, foreign currency and improves the life quality of poor farmers (Dufey, 2006; Feintrenie et al., 2010; Garcia - Ulloa, J. et al., 2012; World Bank, 2010; Obidzinski et al., 2012).

On the other hand, many civil society organizations (NGOs, farmer and ethnic communities) criticize the expansion of energy crops by indicating that they promote competition around natural resources (like water and soil) and other agricultural production supplies (De Fraiture, 2009; Sheil et al., 2009; Croezen, 2010). It is also affirmed that production of raw materials for biofuels concentrate assets such as land, and they increase food inflationary pressures (FAO, 2008; Ewing and Msangi, 2009; Tilman et al., 2009). In addition to this, there is evidence that points to the tendency of biofuels to concentrate subsidies given by the governments, contributing in some countries to population

---

[4] Castiblanco, C., Etter, A., Ramírez, A., 2014. Impacts of oil palm crop expansion in Colombia: what do socioeconomic indicators tell? accepted for publication in Land Use Policy

displacement and conflict in rural areas (Hickey and DuToit, 2007; Marti, 2008; Colchester, 2010; Friends of the Earth, 2010; Seeboldt and Salinas, 2010).

Establishing a thorough review of this controversy is not an easy endeavor. Specialized literature shows that an evaluation of biofuel impacts must explicitly state every aspect related to the production system, forms of land tenure, labor regimes, the business model and the role of the State (McCarthy, 2010; German et al., 2011). The accumulated social and economic benefits generated by the biofuels sector mostly depend on several aspects such as the established policies, the power positions of diverse agents participating in the productive chain, and the patterns of land and income distribution (Dauvergne and Neville, 2010; McCarthy, 2010).

Studies from Indonesia reveal an improvement in economic indicators for small farmers: there is a constant increase in the contribution made by the biofuels sector to provincial GDP and to producer's incomes. On these cases, small farmers received technical assistance and were included in commercialization chains, which allowed them to enlarge their productivity and benefits (Bunyamin, 2008; Rist et al., 2010a; Obidzinski et al., 2012).

Many authors emphasize the importance of the State in the development of agro-industrial projects at a small scale, particularly its role in the direct intervention of economic and legal instruments to warrant land property rights and environmental laws (Hickey and DuToit, 2007; German et al., 2011). However, McCarthy (2010) notices that even when there is political will to include small farmers, it remains a difficult and contradictory process because the State is usually attracted by powerful economic sectors that jeopardize its capacity of acting as a neutral mediator.

In general terms, social and environmental conflicts derived from the development and expansion of energy crops in tropical producer countries are related to three main topics:

i) *Local conflicts around land property rights*: the main issue in developing countries is the lack of clear legal regulations and the lack of strong institutional frameworks that allow managing the requirements regarding land use and tenure (McCarthy, 2010; Sorda et al., 2010; Timilsina et al., 2010; Vermeulen and Cotula, 2010).

In Indonesia, the NGO "Sawit Watch" identified 630 land conflicts between enterprises that produced oil palm and local communities (Marti, 2008) and the National Land Office also determined 3,500 "feuds" between 2005 and 2010 (Colchester, 2010). The majority of these conflicts are a consequence of a missing clear assignation of land rights (or there is no recognition of these rights at all), the lack of transparency in purchase and renting contracts, and the lack of previous information and consultation to the community who inhabits these areas (Marti, 2008; Rist et al., 2010b).

Colombia lacks a reliable judicial framework regarding land property rights, and this has enabled displacement and land abandonment due to violence in various regions of the country (Fajardo, 2012). In the last decade, a number of cases of usurpation have been reported, and they were performed by illegal groups in order to occupy lands owned by Afro-Colombian communities and cultivate oil palm in the Colombian Pacific region (Mingorance et al., 2004).

(ii) *Conflicts relating to labor rights and contractual conditions between small farmers, enterprises and the State*: the problems in Indonesia and Malaysia are created by shared risk contracts between farmers and enterprises (McCarthy, 2010). Often the price of the product depends on the fluctuations of the products' international prices (crude oil palm, soy or sugar cane), which leads to uncertainty regarding possible future benefits for the small producers (Garcez and Vianna., 2009; World Bank, 2010; German et al., 2011; Hospes and Clancy, 2011).

In Latin-American producer countries, the subcontracting of workers and activities by enterprises is a general practice. This is achieved through schemes such as the Cooperative model of Associated Workers and the Strategic Productive Alliances (Dufey and Stange, 2011). These two models are frequent in the oil palm agroindustry in Colombia, and they have been an object of criticism because of labor rights issues (Seeboldt and Salinas, 2010).

(iii) Environmental conflicts due to contamination and agricultural frontier expansion in strategic ecosystems: approximately 4.1% of the recent expansion of oil palm in Indonesia, Malaysia and Papua New Guinea has occurred at the expense of natural forest and 32.4% of secondary forest expanded (Gunarso et al., 2013).

Gutierrez Velez et al. (2011) assessed the area deforested by industrial-scale high-yield oil palm expansion in the Peruvian Amazon from 2000 to 2010, finding that 72% of new plantations expanded into forested areas. However, studies made in Brazil on sugar cane (Goldemberg and Guardabassi, 2009; Martinelli et al., 2010) and Colombia on oil palm expansion (Castiblanco et al., 2013) show that direct land use changes (LUC) had minor impacts on forests since most of plantations used for biofuels have mainly replaced pasturelands. Nevertheless, in terms of indirect land use changes (ILUC) produced by crop expansion could have an important impact on areas of natural and semi-natural ecosystems in tropical countries (Searchinger et al., 2008; Croezen, 2010; Achten and Verchot, 2011).

In countries such as Colombia, the effects are confused by socioeconomic particularities that make the separation of their origins difficult, because: i) oil palm areas may be highly dynamic due to their overlap with oil and mining zones, where important energy and infrastructure projects are take place (Galán, 2012; Tenthoff, 2012); ii) there is often the presence of illegal armed actors (paramilitary, guerrilla and narcotraffickers) who increase social tensions, and fights over land tenure (Posada, 2009; González et al., 2012); iii) oil palm growing areas are adjacent to territories of indigenous communities, or lands owned by Afro-Colombian communities.

Under such conditions, the varied optimistic and pessimistic versions must be contrasted. The former ones affirm that the oil palm plantation model contributes to solve many conflicts and fulfills many interests through a virtuous circle that allows farmers, indigenous, laborers, municipal authorities and entrepreneurs to benefit according to their own marginal contribution to social welfare (World Bank, 2010; Willebald, 2011). The pessimistic visions in turn, consider that the intensive production of goods coming from natural resources and land inevitably leads to the social involution, poverty, and concentration of income and power in few hands reflected in the environmental deterioration and distributive conflicts that will create more violence in such areas (Cimoli and Rovira, 2008).

Amid this controversy, worth asking how energy crops contribute to improving the living conditions of rural people?

Globally, there are significant growth expectations of the global biofuels market (Sorda et al., 2010; OECD-FAO, 2011). In the Colombian case, there are important financial investments and expansive scale of the large land property required by the oil palm cultivation (Dufey and Stange, 2011; Castiblanco et al., 2013). These facts need an evaluation of the socioeconomic impacts of oil palm production in rural zones characterized by significant expansion probabilities.

The purpose of this research is evidencing the possible socioeconomic effects of oil palm production in rural areas through the analysis of available socioeconomic indicators, with the objective of establishing whether oil palm crops have a distinguishing effect in comparison to non-producer municipalities. First, we present a conceptual framework under which we examine the effects of rural production models based on the main primary exportation product (staple thesis) on the social and economic conditions of the main productive zones. Second, we use the available multi-temporal socioeconomic indicators to analyze the observed changes within palm cultivation areas and comparable areas outside the palm growing areas, using descriptive statistics and multivariate analysis. On basis of the results, we draw conclusions about the observable impacts.

5.2. Conceptual framework: oil palm agribusiness, “staple thesis” or “staple trap”?

After bananas and sugar and molasses, palm oil is the third agricultural export in Colombia (Proexport Colombia , 2014), for this reason and given the ambitious expansion goals, of oil palm fits the hypothesis of the major primary exportation product (staple thesis) which proposes that the exploitation of abundant natural resources based on an open agricultural frontier allows generating “virtuous circles” in regions suitable for large plantation crops (Barbier, 2005; Findlay, 1995; Willebald, 2011; Watkins, 1963). However, as shown by Findlay and Lundahl (1999), the success conditions of a development model based on the main primary product (staple thesis) are unique. An example of this was the so called “golden age” of growth led by natural resources (1870-1914) where only countries such as Canada, the United States of America and Australia achieved high growth levels and productive transformation, whereas other economies that based their growth on plantations (Brazil) or mineral extraction (Bolivia, Chile, South Africa) did not succeed in the promotion of a structural change and a productive diversification, predicted by the staple thesis model.

Research carried out by Watkins, 1963; Auty, 2001; Auty and Alan, 2002; and Birdsall et al., 2002 show that several countries that have followed this model by producing a main primary product (related to agriculture or mining) have fallen in a trap known as the "staple trap". This means that specializing on a single product under the design of a large plantation may not produce the economic linkages which are necessary to stimulate other complementary productive sectors (industry, technology or innovation) demanded by the productive transformation process in a region or a country (Findlay and Lundahl, 1999).

There is also empirical evidence that points out negative relationships between economic performance and the specialization in primary products which are intensive in natural resources (Leite and Weidmann., 1999; Sachs and Warner, 1999, 2001; Doppelhofer et al., 2000; Thorvaldour, 2001; Lederman and Maloney, 2007). An initial hypothesis to explain these results makes reference to the Dutch disease: the dependence on primary agricultural or mining products may trigger a reversion in the development process and deindustrialization as a consequence of an increase in the prices of primary products (staple) in international markets, which end up revaluing the real exchange rate and reducing the profitability of the tradable sector. As a result, the production, exportation and employment in the modern sectors are diminished (Corden and Neary, 1982; Puyana, 2013).

Other mechanisms are associated to the growing inequality expressed in concentration of income and property rights of the abundant natural resource (land). The major concentration of income and land property is negatively related to the expansion of the domestic market and the long term economic growth (Persson and Tabellini, 1994; Leamer et al., 1999; Cimoli and Rovira, 2008). In this sense, though regions may initially experience an economic boom, it is not sustainable. The area or the country will present later a slower growth when compared to the original scenario, before the natural resource boom.

Some authors have associated this negative relationship between the abundance of natural resources and economic performance with the quality of the organizations (political risk, respect for the law, quality of bureaucracy, corruption levels, expropriation risk, reputation of the government and contract strengthening). According to this hypothesis, developing regions with abundant natural resources tend to have weak institutions that promote rent seeking and displace undertaking and innovation (Mehlum et al., 2006).

Figure 5.1 presents a graphic application of the "staple trap" model for the case of oil palm plantations. In it we identify the mechanisms and sequences of economic and political processes related to this crop expansion as a result of biofuel promotion, and also, determining impacts in the dynamics of socioeconomic indicators such as poverty, fiscal income, and concentration of income and wealth.

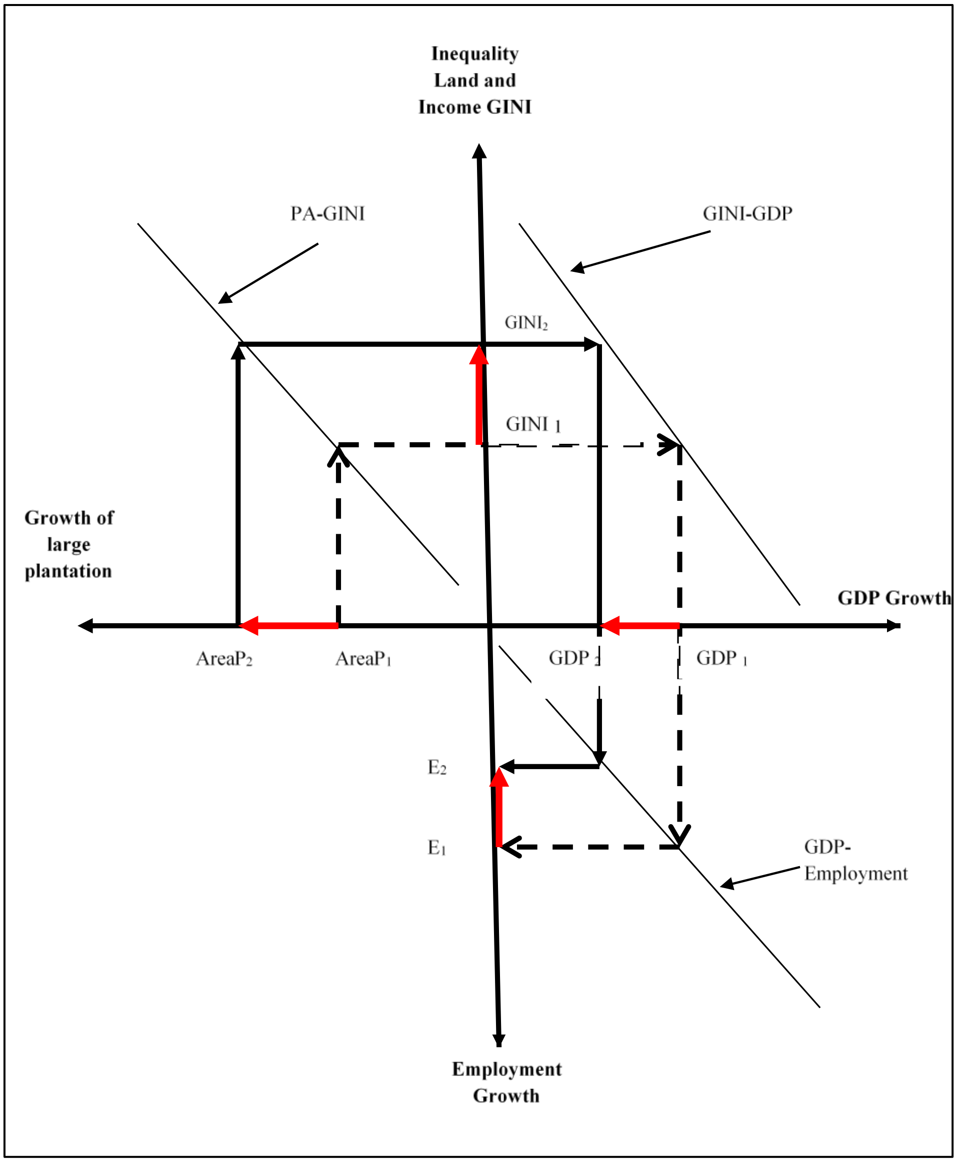


Figure 5.1. Model of long term relationships between the growth of agribusiness large plantations, inequality in the distribution of land and income, economic growth and employment growth (Relations do not imply linearity).

Source: Based on the theoretical relationships identified in: Persson and Tabellini, 1994; Leamer et al., 1999; Cimoli and Rovira, 2008 and Galor et al., 2009.

The model integrates the relationships between four components (plantation areas -PA-, GINI index, GDP and employment) through three sequential processes resulting from the cultivation expansion (from AreaP1 to AreaP2): i) the positive relationship between PA-GINI relates the oil palm cultivation expansion and inequality in land distribution and income; ii) the negative relationship between GINI-GDP shows how inequality in land distribution and income are related to the growth rate of the economy on the long term; iii) the positive relationship between economic growth and employment (GDP-employment).

Initially, support policies such as tax exemptions, mandatory blends and direct subsidies to biofuel production and commodities evidently increase the profitability of such projects (Khanna et al., 2008; Taheripour and Tyner, 2010). This allows starting important investment projects that demand large agriculture units, which can be complemented by alliances with medium and small producers (Sheil et al., 2009). As a result, the conditions of some farmers and laborers improve because their income and land increases and their poverty levels are reduced (Sheil et al., 2009; Dayang et al., 2010; Chile, 2013).

However, the bigger land concentration allows the owners of large properties to acquire a significant part of these business rents, which inhibits growth possibilities for the rest of the population that does not participate in these activities. In fact, as shown by (Galor et al., 2009), there is a negative relationship between the concentration degree of land property and investment in education, and at the same time, a smaller accumulation of human capital and a smaller efficiency in land assignation reduce the rate of long term growth and employment (Galor et al., 2009). Additionally, when income and wealth distribution worsens, social conflicts may arise (Hirschman and Rorhschild, 1973; Wiesner, 2008). This way, the resources of the State are used for maintaining patronage that restricts initiatives regarding infrastructure investment and productive development. All this leads to a “staple trap” (Birdsall et al., 2002).

5.3. Materials and methods

5.3.1. Study area

Colombia has an approximate area of 1.14 million Km^2 (Figure 2). This country has a geographic heterogeneity, confirmed by five biogeographic regions which present high variations in altitude (0- 5800 m), medium annual precipitation (300-1000 mm) and geological substratum (Etter et al., 2006). Colombia´s significant environmental variability in relation to its geographic size determines its high endemism rates and richness related to species, which makes Colombia a mega-diverse country (Etter et al., 2011). Its population reaches approximately 45 million inhabitants, located mainly in urban zones (76%). Indigenous settlements occupy 31 million ha (29% of the national territory) with 1.4 million inhabitants. Collective territories owned by Afro-Colombian communities reach 5.5 million ha and around 3 million inhabitants (GEF, 2010).

Poverty, land concentration and inequality have increased in rural areas in Colombia in the last decade (MADR, 2010). The rural GINI index went from 0.74 to 0.88. Currently, poverty in the countryside reaches 54.3% and indigence 22%, whereas, in urban areas, these numbers are 35.8% and 7% respectively (World Bank, 2012).

In 2012, the agricultural area was approximately 5.2 million ha, out of which 3.1 million have permanent cultivations; 1.6 million have annual cultivations, and 0.5 million are forestry plantations (FEDEPALMA, 2013). The commercial oil palm crop has been developed in Colombia for more than fifty years and in the last decade it has grown at an annual rate of 8.9%, reaching in 2012 a cultivated area of 452,435 ha, which represent 8.75% of the national agricultural production and 14.5% of the permanent cultivation for the same year (FEDEPALMA, 2013).

Since 2008, with the implementation of a mandatory blend of 10% biodiesel, the domestic market of crude oil palm increased. Currently, 445,999 ton of crude oil palm (56% of domestic market sales) are designated to biodiesel production (FEDEPALMA, 2013).

Presently, this cultivation is located in 108 municipalities of 17 departments (Figure 5.2), and they constitute four productive nuclei in the following regions: Northern, Center, Eastern and South-Western. Each one has varied characteristics related to climate, soils, infrastructure and socioeconomic conditions. The region with bigger projections for this cultivation expansion is the Eastern zone, and it occupies the first place in terms of the share in the production of crude oil palm with 36, 5% in 2012. The Northern zone follows with 35.3% and the Center and South-Western zones occupy the third and fourth place with a share of 27.3% and 1.1% respectively (FEDEPALMA, 2013). Some of the main characteristics of these palm regions are described below:

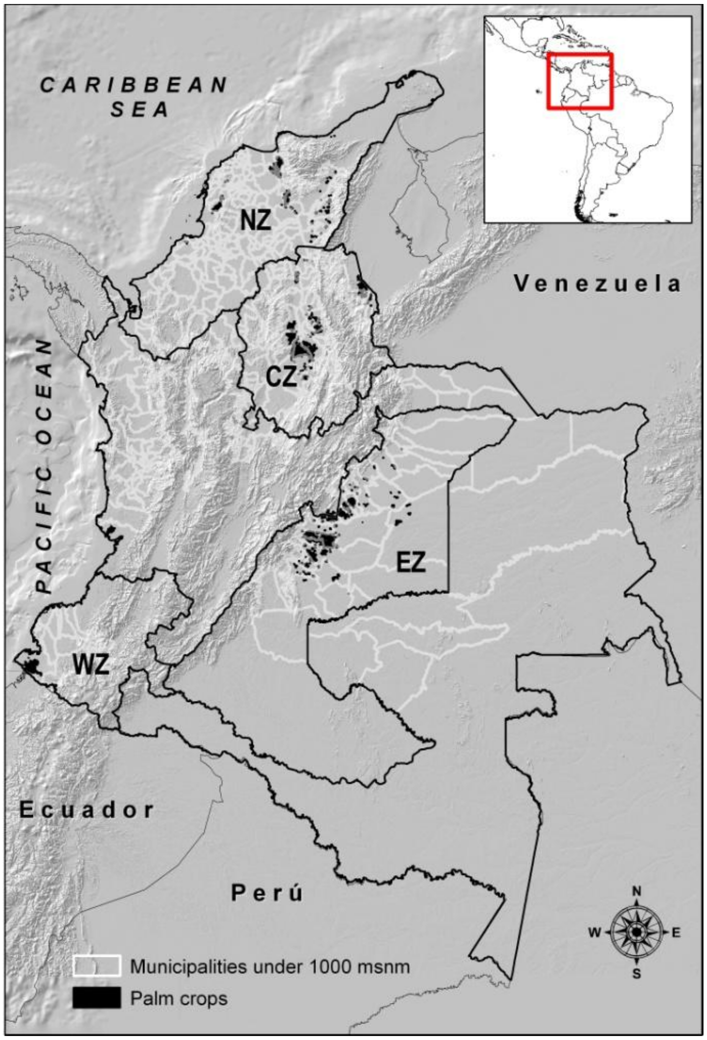


Figure 5.2. Map of Colombia showing the municipalities below 1000m, where oil palm plantations existed in 2007. (NZ: North Zone; CZ: Central Zone; EZ: Eastern Zone; WZ: Western Zone)

Source: drawn from map oil palm plantations in Colombia FEDEPALMA, 2007.

Northern zone: corresponds to the tropical dry forest biome that presents fertile, flat and deep soils with high luminosity, favorable conditions for oil palm crops (Aguilera, 2002). Historically, this has been an area oriented to cattle production but in the last decades the violence dynamics have caused population displacement and land abandonment, increasing poverty levels and land concentration (Sánchez et al., 2010). In 2012, the poverty rate in this area reached 42% and the land concentration index GINI_L was 0.81 (Sánchez et al., 2010). Currently, this oil palm nucleus is composed of 42 municipalities which belong to 9 departments, and includes 29% of the national oil palm cultivated area corresponding to 132,530 ha, out of which 81,600 ha were productive in 2012 (FEDEPALMA, 2012).

Center zone: corresponds to the tropical rainforest biome, therefore, is the habitat of numerous terrestrial and aquatic species (IDEAM, 2001). This area presents an active economic dynamism: there is gold exploration and the biggest oil refinery in Colombia is located there. There is also cattle production and oil palm has been cultivated for more than forty years. Nevertheless, in spite of its economic importance, the inhabitants of this zone present the most significant poverty rates. Except for Barrancabermeja, all the municipalities of this area present unmet basic needs indexes above 60% (PDPMM-CINEP, 2007). In 2012, there were 129,112 ha cultivated with oil palm, out of which 81,000 are currently productive (FEDEPALMA, 2013).

Eastern zone: this oil palm nucleus is located in the Orinoco region and corresponds to the tropical savannah biome and tropical rainforest biome, with a high ecosystem diversity that includes 32 types of savannas, gallery forests, Andean forest and tropical forest. Up to 40% of the hydric richness of Colombia is located here: it contains more than 55% of wetlands, and 40% of underground water (IDEAM, 2001; Romero-Ruiz et al., 2004). This is a strategic area for the economic growth of Colombia because the most lucrative activities (which are also the ones with better projection in global markets) take place there: hydrocarbon exploitation, road infrastructure, forestry projects and large-scale agricultural production. Oil palm agroindustry has been present in this area for more than thirty years, and its relationship with biofuel production makes it a promising sector for the region´s development (DNP, 2013). In the Eastern zone, oil palm crops are located mainly in Meta and Casanare departments. In 2012, the cultivated area reached 170,662 ha with a total production of 354,199 tons of crude oil palm, corresponding to 35.3% of the national production, locating the Eastern zone in the first place in terms of production and cultivated area (FEDEPALMA, 2013).

South-Western zone: it makes part of the Colombian Pacific also known as biogeographic Chocó. This is one of the wettest and most biodiverse regions in the country, three quarters of its total area correspond to tropical rainforest of approximately 5.4 million ha, out of which 47% is not yet exploited (Díaz and Gast, 2009). 90% of the population is Afro-Colombian, and 4% is indigenous (CIJP, 2007). In spite of its richness, and cultural and ecological diversity, this zone has the highest of unmet basic needs index (65%), the infant mortality rate is 91 out of 1000 births, and the illiteracy rate is over 30% (PDD, 2012). In the last seven years, the cultivated area has drastically diminished from 33,743 ha in 2006 to 20,000 ha in 2012 (FEDEPALMA, 2012) due to a permanent attack of bud rot (PC, pudrición de cogollo in Spanish) and unfavorable climatic conditions for the growth and development of this crop like excessive humidity, soil compaction and low sun luminosity (CORPOICA, 2007).

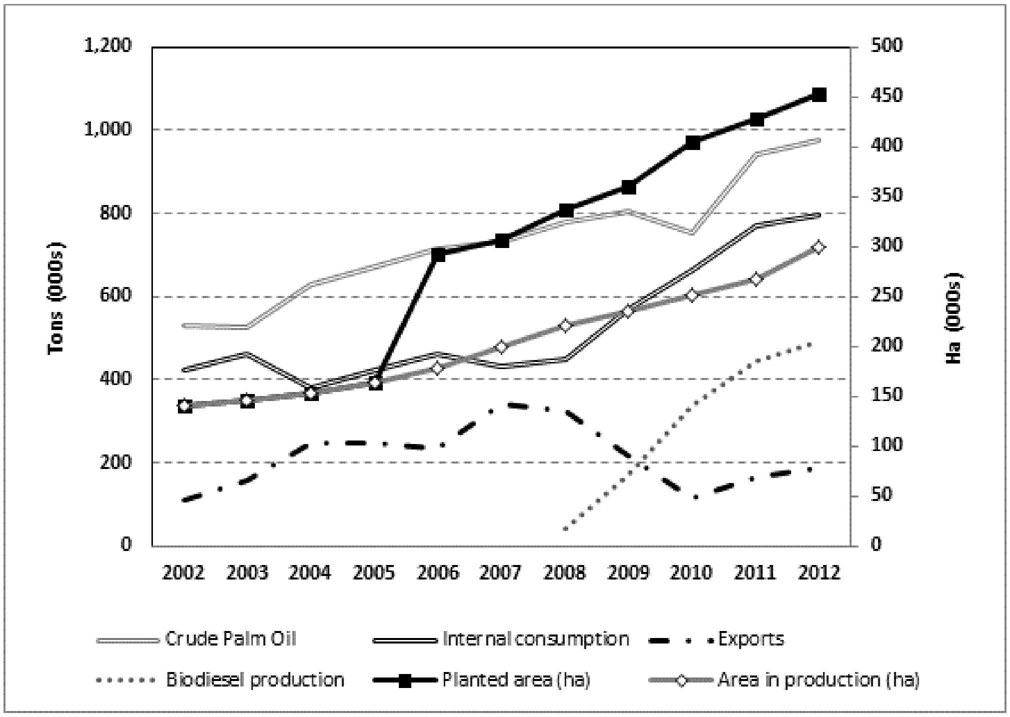


Figure 5.3. Evolution of plantation area, production and uses of crude palm oil in Colombia (2002-2012).

Source: statistical yearbooks of FEDEPALMA.

5.3.2. Information sources

The municipal indicators given by the National Statistics Department (DANE) constitute the available socioeconomic information for assessing the effects of oil palm crops. In order to analyze the possible impact of oil palm agroindustry on life quality indicators, the municipalities located under 1000 m were selected by using a digital elevation model (DEM). The cases in which most of the area is placed above 1000 m were not included because altitude, and climatic conditions do not allow oil palm to be grown there. The South-Western zone was excluded because it only has one municipality where oil palm is cultivated, and this impedes the performance of statistical procedures.

Municipalities included in the study show an oil palm cultivated area of more than 50 ha according to an official map by FEDEPALMA (2007) that registers every sowing year between 1992 and 2007. This map was updated by Castiblanco et al. (2013) including information until 2009. In the analyzed sample oil palm municipalities and those where this crop is not present were included, according to the geographic regions defined by FEDEPALMA (2012) (Figure 5.2).

The number of municipalities for every period of analysis changed because plantations have been expanding. By 1993 there were 15 oil palm municipalities, in 2000 this number increased to 49, in 2005 there were 72 municipalities and in 2009 approximately 100.

In order to perform the study, some life quality indicators were selected: unmet basic needs, infant mortality, land concentration, economic performance and fiscal income. This data was available at the municipal level for the analyzed period 1993-2009 (Table 5.1).

Table 5.1.Description of the analyzed socioeconomic indicators and data sources.

Indicator	Description	Source and analyzed period
General Unmet Basic Needs Index (UBNI_G)	Percentage of households that present at least one scarcity situation expressed by the simple indicators defined by DANE.	DANE 1993, 2005, updated 2009 http://www.dane.gov.co/index.php/estadisticas-sociales/necesidades-basicas-insatisfechas-nbi
Rural Unmet Basic Needs Index (UBNI_R)	Percentage of rural households that present at least one of the scarcity situations expressed by the simple indicators defined by DANE.	DANE 1993, 2005, updated 2009 http://www.dane.gov.co/index.php/estadisticas-sociales/necesidades-basicas-insatisfechas-nbi
Infant Mortality Rate (IMR)	Number of children who pass away before their first year per 1000 live births.	DANE, 2005 updated 2009 http://www.dane.gov.co/files/investigaciones/poblacion/proyepobla06_20/8Tablasvida1985_2020.pdf
GINI_L	Used as an indicator to measure the degree of land concentration in rural properties. The closer to 1, the more concentration.	PNUD (2012). Analyzed period: 2000, 2005, 2009
GINI_O	It is estimated with the land area possessed by every owner. The closer to 1, the more concentration.	Analyzed period: 2000, 2005, 2009 (UNIANDES, 2012)
Violence Index (VI)	It is composed by two indicators: displacement intensity and homicide intensity: **VI = 1 - (ID+IH)/2**. The closer to 1, the less violence intensity.	PNUD (2012) Analyzed period: 1993, 2000, 2005, 2009
Municipal Income Index (MII)	Composite index obtained from the municipal fiscal income (income tax, industry and commerce tax) and the municipal current income: **MII=fiscal income/current income.** The closer to 1, the more municipal fiscal incomes.	PNUD (2012) Analyzed period: 1993, 2000, 2005, 2009

5.3.3. Statistical analysis

The first step was performing a linear correlation analysis between variables with the purpose of checking statistically significant relationships. We also verified that the available data for every variable had a normal distribution (Johnson and Bhattacharyya, 1996). Variance and mean of the socioeconomic indicators was calculated for the selected municipalities at national and also regional level according to the oil palm zones defined by (FEDEPALMA, 2010). In order to determine the differences between the two data groups (municipalities with and without oil palm), statistical F and t tests were applied (Johnson and Bhattacharyya, 1996).For the cases where the variances of the sample were not equal a Welch test was performed, a type of t-test for unequal variances (Johnson and Bhattacharyya, 1996).

Multivariate statistics were also applied with the purpose of determining the significance of oil palm presence in the changes of socioeconomic indicators. First, a regression model with DUMMY variables was estimated, where the independent variable takes a value of one (1) if oil palm is present in the municipality and zero (0) when this is not the case; and the dependent variables correspond to the analyzed socioeconomic indicators. Additionally, analyses of univariate and multivariate regression were performed by using as independent variables the proportion of oil palm area per municipality for the years 2000 and 2009, and the proportion change for the period 2000-2009 respectively, and they were contrasted with the change in the socioeconomic variables for the analyzed period. Finally, an analysis of principal components (PCA) was made, and the two principal axes were used in a regression analysis against socioeconomic indicators. These analyses and their variables are depicted in Table 5.2.

Table 5.2. Statistical analysis performed

Analysis	***X Variables***	***Y Variables***
Multivariate regression	Change in area planted with oil palm by municipality (2000-2009)	Relative change indicators: UBNI_R, UBNI_G, IMR, VI, MII (1993-2009)
	Proportion of oil palm area by municipality (2000)	
	Proportion oil palm area by municipality (2009)	Relative change indicators: GINI_L, GINI_O (2000, 2009)
PCA	Axis I (90%) Axis II (6%)	Relative change in socio-economic variables for the analyzed period.
DUMMY Regression	1) with oil palm (0) no oil palm	Change in socio-economic variables for the analyzed period.

Source: Own elaboration

5.4. Results

5.4.1. Effects of oil palm presence on socioeconomic indicators.

- **Differences at the national level**

Differences between municipalities with and without oil palm are not consistent nor are they statistically significant for all indicators in all the analyzed periods. The indicators showing bigger statistical differences between oil palm municipalities and other municipalities are: General Unmet Basic Needs Index (UBNI-G) (Fig.5.4 a) and the Municipal Income Index (MII) (Fig. 5.4 d). The UBNI-G is significantly lower for oil palm municipalities during the three analyzed periods, and the MII is significantly higher in those places since the year 2000 (Table 5.3). At the national level, it can be seen that UBNI-G has diminished whereas MII has increased for both groups in the three analyzed periods. The differences between those two indexes are inclined in favor of oil palm municipalities (Table 5.3).

In relation to rural unmet basic needs (UBNI_R) (Fig 5.4 b) and the Infant Mortality Rate (IMR) (Fig. 5.4 c), these variables present statistically significant differences since 2005, and the averages of these indexes for oil palm municipalities are smaller.

Unlike the above mentioned indicators, averages for the indexes GINI_L at the national level are smaller in oil palm municipalities for the three analyzed years (2000, 2005, 2009) though the differences are not statistically significant (Table 5.3).

The violence index (VI) only shows statistically significant differences at the national level for 2005. It is important to point out that during the four analyzed years (1993, 2000, 2005, 2009) this index was worse for oil palm municipalities, although the differences are not statistically meaningful.

Table 5.3. Comparative mean values of selected socioeconomic indicators between municipalities with and without oil palm plantations in Colombia. (* p<0.1; ** p<0.05).

a. **Better socioeconomic conditions in areas with palm**

General Unmet Basic Needs Index

		National	North Zone	Central Zone	Eastern Zone
1993	PALM	**61.1****	65.6	62,0	**54.1****
	NO PALM	**67.1****	66.8	62.4	**66.9****
2000	PALM	Nd	nd	nd	nd
	NO PALM	Nd	nd	nd	nd
2005	PALM	**49.7 ****	**54.7****	49.9	**41.8***
	NO PALM	**58.6****	**59.9****	50.7	**54.8***
2009	PALM	**49.6****	**55****	49.8	**41.9***
	NO PALM	**58.5****	**59.6****	50.7	**54.9***

Rural Unmet Basic Needs Index

		National	North Zone	Central Zone	Eastern Zone
1993	PALM	68.0	72.4	70.9	60.7
	NO PALM	69.6	71.1	65.1	64.5
2000	PALM	nd	nd	nd	nd
	NO PALM	nd	nd	nd	nd
2005	PALM	**59.6****	64.7	61.7	**50.3****
	NO PALM	**65.7****	65.9	59.6	**65.0****
2009	PALM	**59.0****	63.6	61.9	**50.2****
	NO PALM	**65.6****	65.6	59.6	**65.0****

Infant Mortality Rate

		National	North Zone	Central Zone	Eastern Zone
1993	PALM	50.2	41.1	60.8	nd
	NO PALM	46.6	43.2	48.9	nd
2000	PALM	Nd	nd	nd	nd
	NO PALM	Nd	nd	nd	nd
2005	PALM	**38.5****	41.9	33.8	36.3
	NO PALM	**43.0****	38.2	35.6	36.7
2009	PALM	**35.7****	40.2	30.8	33.3
	NO PALM	**39.6****	36.2	32.7	34.3

Municipal Income Index

		National	North Zone	Central Zone	Eastern Zone
1993	PALM	0.35	**0.18****	0.18	**0.61****
	NO PALM	0.38	**0.36****	0.31	**0.12****
2000	PALM	**0.43****	0.40	0.39	**0.49****
	NO PALM	**0.29****	0.31	0.28	**0.26****
2005	PALM	**0.54****	**0.52****	0.49	**0.61****
	NO PALM	**0.41****	**0.42****	0.42	**0.41****
2009	PALM	**0.62****	**0.58****	**0.58****	**0.71****
	NO PALM	**0.43****	**0.45****	**0.44****	**0.48****

b. No better socioeconomic conditions in areas with palm

Violence Index

		National	North Zone	Central Zone	Eastern Zone
1993	PALM	0.90	0.89	0.90	0.90
	NO PALM	0.92	0.92	0.88	0.92
2000	PALM	0.69	**0.62****	0.65	0.81
	NO PALM	0.76	**0.77****	0.75	0.86
2005	PALM	**0.61****	**0.59****	**0.62****	0.65
	NO PALM	**0.76****	**0.78****	**0.77****	0.64
2009	PALM	0.83	0.91	0.78	0.82
	NO PALM	0.85	0.90	0.84	0.81

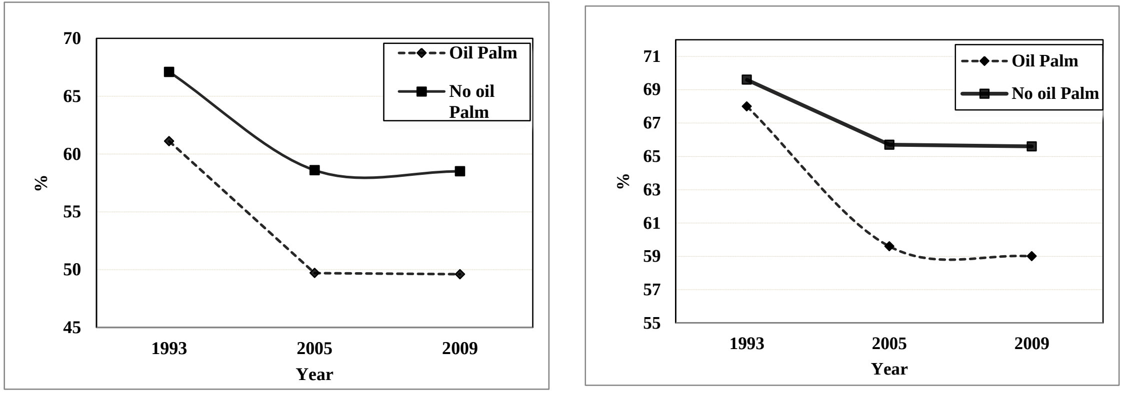
c. Ambiguous socioeconomic conditions in areas with palm

GINI Land

		National	North Zone	Central Zone	Eastern Zone
1993	PALM	nd	nd	nd	nd
	NO PALM	nd	nd	nd	nd
2000	PALM	0.67	0.67	**0.62****	**0.70****
	NO PALM	0.68	0.67	**0.69****	**0.60****
2005	PALM	0.66	0.66	**0.63****	**0.71****
	NO PALM	0.67	0.68	**0.69****	**0.59****
2009	PALM	0.66	**0.65****	**0.63****	**0.71****
	NO PALM	0.67	**0.68****	**0.68****	**0.61****

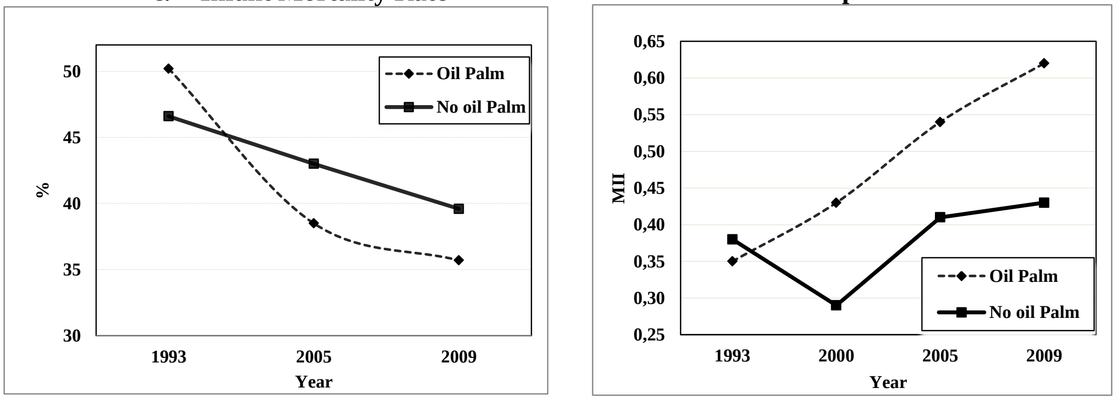
GINI Owner

		National	North Zone	Central Zone	Eastern Zone
1993	PALM	nd	nd	nd	nd
	NO PALM	nd	nd	nd	nd
2000	PALM	0.69	0.70	**0.65****	**0.70****
	NO PALM	0.70	0.68	**0.71****	**0.60****
2005	PALM	0.69	0.69	**0.66****	**0.72****
	NO PALM	0.69	0.69	**0.72****	**0.60****
2009	PALM	0.70	0.69	**0.67****	**0.71****
	NO PALM	0.69	0.70	**0.72****	**0.61****



a. General Unmet Basic Needs Index

b. Rural Unmet Basic Needs Index



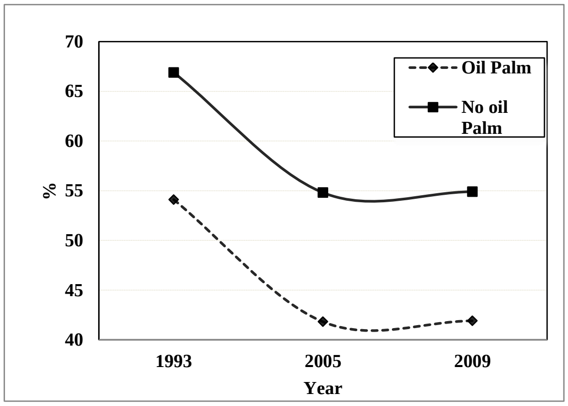
c. Infant Mortality Rate

d. Municipal Income Index

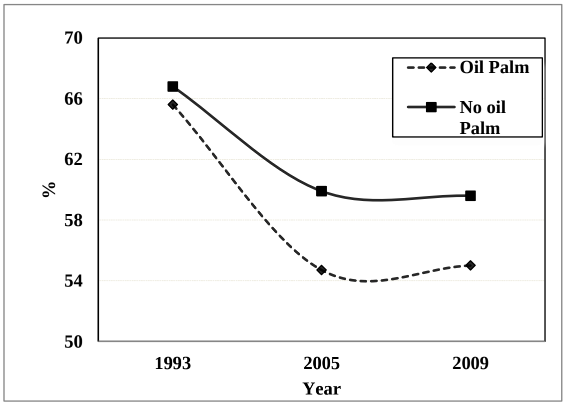
Figure 5.4. Trends of change of the indicators with statistically significant differences at the national level.

- ### Differences between indicators at the regional level

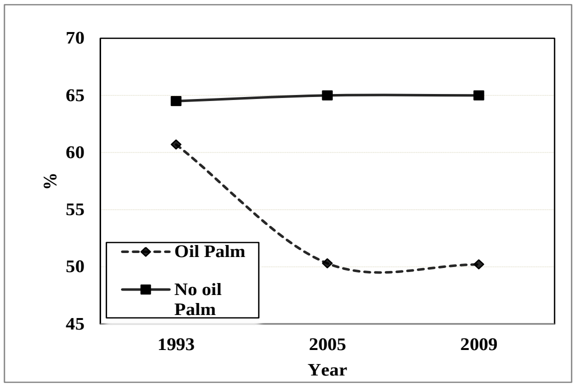
At the regional level, the bigger contrast was given for the indicators UBNI_R and GINI_L of the Eastern and Center zones.



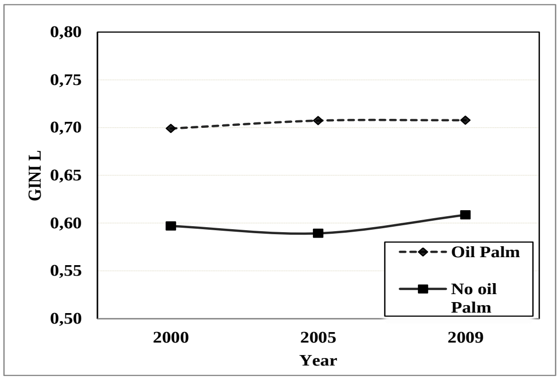
a1. General Unmet Basic Needs Index (Eastern zone)



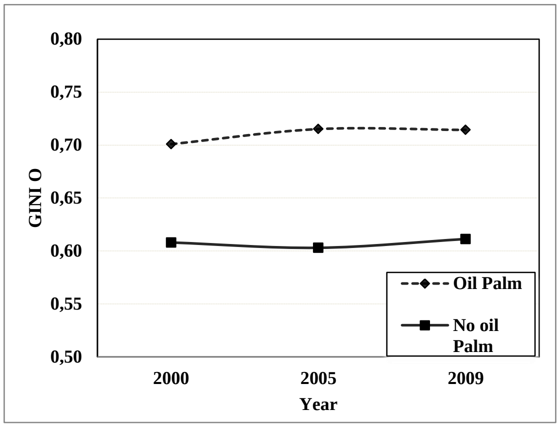
a2. General Unmet Basic Needs Index (North zone)



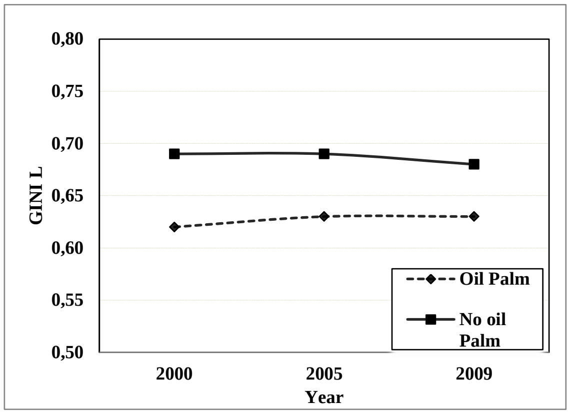
a3. Rural Unmet Basic Needs Index (Eastern zone)



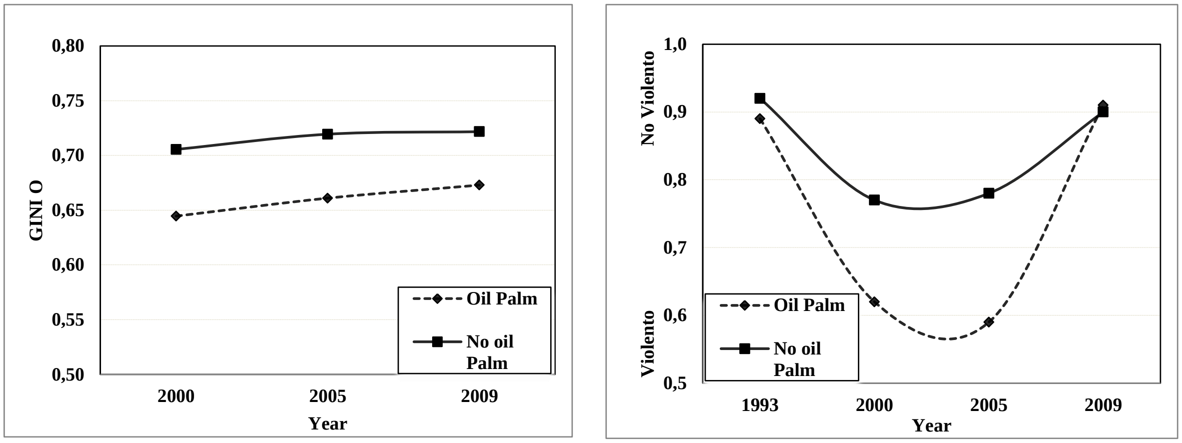
b1. GINI Land (Eastern zone)



b2. GINI Owner (Eastern zone)

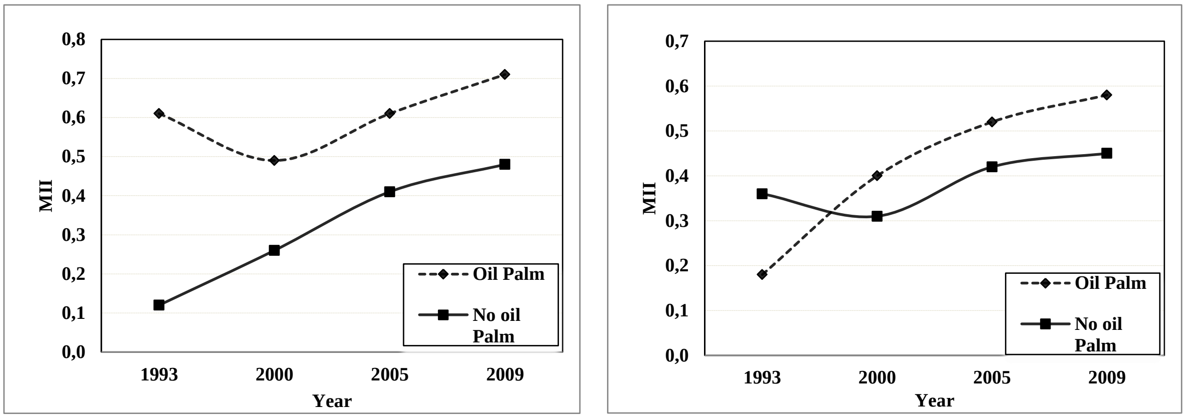


b3. GINI Land (Central zone)



b4. GINI Owner
(Central zone)

c. Violence Index
(North zone)



d1. Municipal Income Index
(Eastern zone)

d2. Municipal Income Index
(North zone)

Figure 5.5. Trends of change of the indicators with statistically significant differences at the regional level.

General unmet basic needs (UBNI-G) and rural unmet basic needs (UBNI_R)

The differences in the UBNI-G between municipalities with and without oil palm turned out to be statistically significant in the Eastern zone during the three analyzed years and in the Northern zone for the years 2005 and 2009. This means that, in these zones and during that time, UBNI-G was lower in oil palm municipalities (Fig. 5.5, a1 and a2). UBNI_R is smaller for oil palm municipalities located in the Eastern zone during the years 2005 and

2009. In the other zones, there are no statistically significant differences for this index between municipalities with and without oil palm.

Infant mortality rate (IMR)

This indicator didn´t show any statistically significant differences between producer and non-producer zones. This means that the average rate of infant mortality is equal in both groups of municipalities for all zones and during all analyzed periods.

Land concentration index (GINI_L) and GINI owners (GINI_O)

These indicators showed statistically significant differences for the Center and Eastern zones. For the Eastern zone the average of GINI_L and GINI_O indicators is bigger in oil palm municipalities during the three analyzed years, and the differences with municipalities without oil palm for every year turns out to be statistically significant (Fig.5.5.b1 and b2; Table 5.3). On the contrary, in the Center zone the averages of GINI_L and GINI_O are smaller for oil palm municipalities (Fig. 5.5, b3 and b4), (Table 5.3).

Violence index (VI)

The violence index is significantly bigger in oil palm municipalities located in the Northern zone during the years 2000 and 2005 (Fig. 5.5c) and in the Center zone in 2005 (Table 5.3). For the rest of the zones and years, the differences of the violence index between the two groups of municipalities are not statistically significant.

Municipal income index (MII)

The average of the municipal income index is bigger in oil palm municipalities in the last decade for the three studied zones (Table 5.3). In the Eastern zone during the four analyzed years, this index was bigger in oil palm municipalities and the differences with the other type of municipalities (without oil palm) are statistically significant (Figure 5.5 d1). In 1993, this indicator was minor in oil palm municipalities located in the Northern zone but since 2000, this index was bigger for oil palm municipalities. The differences with the other group are statistically significant for the years 2005 and 2009 in the Northern zone (Fig. 5.5 d2) and for the year 2009 in the Center zone (Table 5.3).

5.4.2. Effects of the increase of oil palm cultivated areas on the change in socioeconomic indicators

The above mentioned results are supported by other results obtained when analyzing the effects of the increase of cultivated areas on socioeconomic indicators.

The regression analysis with DUMMY variables shows that the oil palm is significantly related to many socioeconomic variables, though with low r2 (1 to 5%). Results show that in general, the greater the expansion of oil palm crops, the better the performance of the UBNI-G and UBNI_R, and the lower infant mortality rate for 2009. With more palm, there is a greater GINI_L in 2000, and GINI_O in 2000 and 2009, and the higher the municipality income (MII) (Table 5.4).

There is a significant relation between the proportion of oil palm areas for the years 2000 and 2009 per municipality and the GINI_L and GINI_O for 2009 (the r2 explains between 9 and 20% respectively). Out of the bivariate regression analyses performed, only one relationship turned out to be statistically significant: the regression between the municipal income index (MII) and the change in proportion of oil palm areas for the years 2000 and 2009 per municipality, though the r2 is low and only explains between 8 and 10%. The Principal Components Analysis (PCA) shows that the first component explains 90% of the information of oil palm variables and the second explains 6% (a total of 96%). Regression analysis between the axis of the components I and II was performed against socioeconomic variables and some significant relationships were found for the GINI_L and GINI_O 2009, and for the violence index (VI) for 2009 (Table 5.4).

Table 5.4. Summary results of the multivariate statistical analysis.

Y Variable	*X Variable*	*n*	*R²*	*p value*
Dummy Regression				
Change in UBNI_R 1993-2009	(1) With oil palm	306	0.017	0.023
Change in UBNI_G 1993-2009	(0) no oil palm	353	0.051	1 E-05
Infant Mortality Rate 2009		354	0.020	0.008
GINI_L 2000		356	0.014	0.024
GINI_O 2000		356	0.015	0.022
GINI_O 2009		356	0.014	0.028
Municipal Income Index (MII) 2000		356	0.036	0.0003
Municipal Income Index (MII) 2009		356	0.115	5 E-11
Univariate Regression				
GINI_L 2009	Proportion of oil palm area by municipality (2000)	63	0.123	0.063
GINI_O 2009	Proportion of oil palm area by municipality (2009)	63	0.108	0.080
GINI_O 2009	Proportion of oil palm area by municipality (2000)	63	0.117	0.006
GINI_O 2009	Proportion of oil palm area by municipality (2009)	63	0.088	0.018
Bivariate Regression				
Change of MII 1993-2009	Proportion of oil palm area by municipality (2000)	39	0.104	0.069
Change of MII 1993-2010	Change in proportion of the intervention area oil palm (2000-2009)	39	0.859	0.090
PCA				
GINI_L 2009	Axis I (90%)	87	0.191	2 E-05
GINI_O 2009	Axis I (90%)	87	0.135	0.0004
Violence Index 2009	Axis I (90%)	87	0.051	0.036

5.5. Discussion

In general, the regions palm production are zones of great economic dynamism (mining, oil exploitation, agribusinesses), where it has historically existed presence of illegal armed groups. There is also great demographic dynamism by migration of population that contributes to the labor supply of the regions. These conditions difficult to identify the impacts caused solely by oil palm industry on the economic and social transformations of these territories.

Based on the available statistical information, the presented results show that in Colombia oil palm municipalities have lower unmet basic needs indicators and have bigger fiscal income when compared to other municipalities where oil palm is not produced. For these indicators, the differences are more apparent since 2005 because support policies such as tax exemptions, mandatory blends and direct subsidies to biofuel production and commodities began to be implemented in that year. These results coincide with those obtained by FEDESARROLLO (2009), who found that, in Colombia, the welfare index increases for households linked with oil palm production compared with those that do not participate in this activity. This study was sponsored by the oil palm association.

Nevertheless, when it comes to land and owner concentration indexes (GINI_L and GINI_O) some contrasts between regions can be seen: in the Eastern zone land concentration is significantly greater in oil palm municipalities in the analyzed period, whereas, in the Center zone, this indicator is significantly minor. This result can be explained by two facts occurring in the Center zone: the strong implementation of the Strategic Productive Alliances design with small farmers and the farmer oil palm project promoted by the Programa de Desarrollo y Paz del Magdalena Medio (PDPMM_CINEP, 2007).

In relation to the violence index, its average was in general higher in oil palm producing municipalities, although the differences are only statistically significant for 2000 y 2005. This result is coherent with the research recently made by the “Historic Memory group of the Colombian Vice-presidency” (GMH, 2013) who indicates that the armed conflict in this country reached its peak (in terms of quantity and extension) in the period 1996-2005, and the main driving forces were land appropriation, use and tenure especially in the strategic corridors where oil palm is cultivated: Magdalena, Norte de Santander, middle Magdalena, southern Bolívar, southern Cesar, Montes de Maria, lower Atrato river, Eastern plains, Casanare foothills and the Pacific, where paramilitary groups have been present (GMH, 2013).

This violence environment is summed to a significant land and wealth concentration, which is reflected in high levels of rural poverty in regions where oil palm is produced. Oil palm departments presented an average index of land concentration of 0.80 in 2009 (PNUD, 2011). The results of this study show that, except for the Center zone, land concentration is bigger in oil palm municipalities when compared to municipalities where this crop is not present, and this is particularly significant in the Eastern zone. Likewise, in the regions where oil palm production nuclei have been existing since more than thirty years, poverty rates were higher in relation to the national average (29.4%): the average of the municipalities that are part of the Northern Zone (42%), Southwest Zone (32%), Eastern Zone (35%) and Central Zone (30.7%) (DANE, 2012).

It can be seen that a better income for oil palm producers does not guarantee a better equity in the distribution of regional incomes, and it does not help to diminish rural and regional poverty. It seems that high levels of land concentration and violence obstruct the possibility of an equitable development in oil palm producer regions.

5.5.1. ¿Has the implementation of energy crops at a large scale contributed to the improvement of life conditions of rural populations in producer countries?

Investigations made in other tropical countries reveal that the income for small producers and plantation workers improved with the implementation of energy crops.

Brazil, the incomes in the sugar cane sector may be from 30% to 80% higher, in comparison to other rural regions (Novo et al., 2010). In Western Kalimantan, Bunyamin (2008) found that oil palm crops have contributed to an increase in the provincial GDP and farmer´s incomes. The average salary for a small producer in Indonesia is seven times bigger than the salary of a subsistence farmer (Sheil et al., 2009). In Papua New Guinea, a small producer with 2 hectares obtained an annual income equivalent to two minimum wages, whereas the return rates of large-scale plantation exceeded in a factor of 12 the ones obtained by a subsistence farm (GLOBAL, 2011).

In Colombia, the results of this research confirm the improvement in municipal incomes and unmet basic needs indexes in oil palm producer municipalities. These results could support the affirmation that energy crops agroindustry is an efficient alternative to prevent poverty in rural households. But there is a paradox: at an aggregate or macro level, the results tend to change. An example is the case of Brazil, a country that for the last forty years has been developing a system of commercial agriculture at a large scale around sugar cane and ethanol production, but presents a historical inequity in land and income distribution. In the last decades, Brazil has figured as one of the most unequal countries around the world. In 2009, GINI_L was 0.85 and GINI income reached 55%. In spite of having improved its poverty indicators, Brazilian rural zones presented a poverty rate of 51%, significantly better to the urban zones (35%) and the national average (22.6%) (Buainain and Dantas, 2009; Martinelli et al., 2010). This scenario is similar in oil palm producer countries from Southeast Asia, where the average of rural people under poverty line in 2010 was larger than the urban or national average: Indonesia (rural poverty 17%, urban poverty 9.9%); Malaysia (rural poverty 7.1%, urban poverty 2%); Thailand (rural poverty 11.5%, urban poverty 3%) (World Bank, 2012).

This pattern is also apparent in Colombia, who is currently the sixth most unequal country in income distribution around the world (Ortiz and Cummins, 2011) with a 58% GINI, and the poverty is significantly high in rural zones (54.3%) in comparison to urban poverty (35.8%) (World Bank, 2012). Per capita income in rural areas corresponds to 34% of the per capita income of urban areas (DANE, 2012).

In this sense, the macro analyses made by some investigators in Africa (Cotula et al., 2007; Vermeulen and Cotula, 2010b), Indonesia and Malaysia (Colchester, 2010; McCarthy, 2010), in Brazil (Martinelli et al., 2010), and in Colombia (Molano, 2009; Fajardo and Salinas, 2010) about impacts of large crude oil plantation on rural development follow the proposals made by the staple trap model. This means that, at an aggregate level, a high land and income concentration generates more social conflicts, smaller accumulation of human capital, less efficiency in land use and a smaller rate of long term growth and employment, under which circumstances, institutions may tend to be inclined towards patronage and corruption.

5.5.2. Limitations of the study and the data collection methodologies

A general methodological problem is that most research evaluating the impact of energy crops is based on perception surveys (subjective indicators) that do not avoid the bias of the sample selection and do not allow assessing impacts at a municipal or regional scale. For instance, some studies that evaluate perceptions about oil palm impacts on the environment show that most of the workers and small producers consider that the effects are minimum, whereas independent farmers and community who live near a plantation point out that water and the air deterioration is significant (Andriani et al., 2010). For example, a study by FEDESARROLLO (2009) does not include in the oil palm farmers perception survey crucial aspects that influence regional development, such as changes generated on land purchase prices and renting, costs of production supplies, and impacts on prices of essential foods.

A possible alternative for evaluating impacts of energy crops on household welfare is using aggregate socioeconomic indicators; a proposal followed by our study. Several indicators were analyzed for the case of municipalities with and without oil palm in Colombia: poverty, violence, fiscal income, infant mortality and land concentration (objective indicators). Because indexes were constructed for many years, we could capture their dynamics, an aspect that is usually overlooked by the investigations that use surveys for a transversal study.

Other important aspect is that, although oil palm cultivations have existed in Colombia since more than thirty years, the biofuel boom and support policies started ten years ago, and this could be a limitation because development theories or hypothesis are analyzed on a long term basis. Another limitation is related to information availability: there are no data for GDP per capita, education and employment at the municipal level. Infant mortality data are limited. Even when this investigative exercise is useful to verify some hypothesis and trends, the results are limited because of the impossibility of quantifying other important social variables such as quality of institutions, cultural level of citizens, violence driving forces, etc.

5.6. Conclusions

The results of this study confirm several issues found in the international literature: oil palm municipalities present lower levels of unmet basic needs and bigger fiscal incomes in comparison to municipalities where this crop is not cultivated. However, in Colombia depending on the region and time period, violence and land tenure concentration are higher in oil palm municipalities, which may help to explain the persistence of inequity and poverty in some areas.

Oil palm production may be associated to the so called “staple thesis”, where regions present an initial period of sustainable and fair development with farmers, ethnical communities, enterprises and States coordinating efforts to remove these regions out of the vicious circle of violence and economic failure. However, for oil palm production to become a “blessing”, it is important that the agroindustry generates sustained positive economic linkages with other land uses and economic activities, in order to contribute to a regional productive transformation and diversification. The main paradox of oil palm production is that farmers involved in the production chain have often better income in comparison to those who do not participate in this activity, but this income is concentrated in the higher levels of the value chain, such as industrial transformation and commercialization.

Theories like the “natural resources curse” and recent developments of the “product space” model warn about the risks of concentrating all the efforts in such type of agribusiness. In Colombia, the institutional conditions (high levels of corruption and bureaucracy, weakness in the definition of land property rights) and social conditions (significant distribution inequalities and high violence levels) inhibit long term growth and rural development in oil palm producer zones.

CHAPTER 6

6. Impact of policies and subsidies in biofuels: the case of oil palm and biodiesel in Colombia [5]

6.1. Introduction

Public policies for biofuel promotion aim at developing strategies that allow reaching several goals: expanding the energy matrix of regions and countries; reducing the dependency on fossil fuels; lessening greenhouse gas emissions and its impacts on global warming; diminishing health costs of respiratory diseases associated to environmental pollution; promoting employment and rural development; reducing tax cost of agricultural subsidies; and increasing exports (Garcia y Calderon, 2012; FAO, 2010; De Gorter, 2007). However, there is a current debate around the net effects of biofuel use regarding the following topics: negative impacts on food prices; biofuels´ ecological and environmental net balance; low generation of rural employment; higher income and wealth concentration derived from large-scale plantations; negative impacts on fuel prices for final consumers; and tax and deadweight losses generated by tax exemptions and other subsidies inside the productive chain (Babcock, 2008; Khanna et al, 2008; Rosegrant et al, 2008; Taheripour and Tyner, 2007; FAO, 2010; Gardner, 2007).

In this context, an analysis of the economic impacts of biodiesel promotion policies is a topic that has been addressed in various countries and for different raw materials (Gardner, 2007; De Gorter and Just, 2007; Arndt et al., 2009). Generally these studies seek to make

---

[5] Castiblanco, C., Moreno, A., Etter, A., 2014. Impact of policies and subsidies in agribusiness: the case of oil palm and biofuels in Colombia. Accepted for publication in Energy Economics, is being corrected.

the relationships between business decisions of feedstock cultivation and industrial production of biofuels and fuel consumption explicit, with the aim of determining the effects of the various direct support instruments on the links in the production chain, as well as in other markets for agricultural inputs, food, land or fuels (Latruffe and Mouel, 2009). For example, the way in which the establishment of mandatory blending not only increases the demand for biodiesel, but also reflects in the agricultural markets, food, land and fuel. Similarly, direct subsidies or tax exemption for biodiesel can generate the conditions for biofuel production to be profitable, but may create inefficiencies and welfare costs for society, more commonly known as "deadweight losses" (Tirole, 1988). All these policy decisions have impacts on the use and conversion of land, CO2 emissions and on the income of the different players in the sector (Latruffe and Mouel, 2009). Such aspects need to be estimated in order to assess the benefits and costs of public policies.

In recent years, significant progress has been made in refining the tools to analyze the impacts of policies promoting biofuels. Kretschmer and Peterson (2008) conducted a detailed review of the various options for economic modelling of biofuels. Among these tools, the computable general equilibrium models have been used intensively, because these models can examine the impacts of policies and exogenous shocks globally, taking into consideration all the interactions between the various markets and agents (Hosoe et al., 2010).

The general equilibrium model of the GTAP-E version, Woltjer et al. (2007) explicitly represents the use of cereals, vegetable oils and sugar cane as raw materials for the production of biofuels in a multi-level structure of the oil industry. This allows analyzing the policies of tax exemption and obligatory blending mandates as exogenous increases of the share of biofuels (Woltjer et al., 2007). Reilly and Paltsev (2008) used a computable general equilibrium model to estimate the global land area needed to produce the biofuels required to attain the stabilization policies and mitigation of atmospheric gases proposed by the U.S. Congress for the period 2010-2100. The simulated scenarios indicate that by 2100 an additional area of between 700 million and 1 billion ha would be required globally.

Hertel et al., (2008) studied the effects of mandates of ethanol and biodiesel blends with fossil fuels in the US, EU and Brazil on land use and land cover changes in the 2005-2015 period. Results show that the effects are substantial: grain production would increase by 6.2% and vegetable oil by 7.7% in the US; cultivation of vegetable oils would grow by 48% in Europe; while in Brazil, sugarcane and soya should increase by 23% and 6.4% respectively. Hertel and Beckman (2010) argue that promoting biofuels increases price volatility of agricultural products, which creates problems for macroeconomic management and significant challenges in food security issues of poor countries.

In a study carried out for the World Bank, Timilsina et al., (2010) examined the long-term impact of large-scale expansion of biofuels on land use change, food supplies and prices globally. The study found that the impact on agricultural prices was moderate with the exception of sugar prices that grew between 7% and 10%. However, there were significant impacts in terms of changes in land use, with a reduction of pasture and forest areas alongside the increase in biofuel crops. They estimated that the expansion of biofuels in the world can lead to the loss of about 26 million ha of forest by 2020. Another study using a general equilibrium model for Mozambique to evaluate the results of large-scale investments in the biofuels sector in economic growth, income distribution and poverty in the country, Arndt et al. (2009) found that the investment policies in the biofuel sector should have positive effects on growth and poverty reduction.

Although general equilibrium models are a powerful tool to simulate the impacts of biofuels promotion policies on changes in land use, changes in welfare and potential climate impacts, and the existence of information gaps and data quality problems, often limit the scope of calibration and simulation exercises (Feng and Babcock, 2008). Tyner and Taheripour (2008) show that many conventional general equilibrium models tend to overestimate the effects of biofuels on agricultural markets. One possible reason is that most of these exercises ignore the role of by-products in the production of ethanol and biodiesel, which can mitigate the effects on raw material prices for animals and the food industry.

An important conceptual alternative that requires less information and less computational complexity are partial equilibrium models. These models have been used for the evaluation and restructuring of agricultural policies in the U.S. and Europe (Floyd, 1965; Dewbre et al., 2001; Guyomard et al., 2004). In recent years, there has been theoretical and empirical research using partial equilibrium models applied to examine the impacts of biofuel promotion policies on different economic variables, climate change and the environment. Studies have mostly focused on ethanol in the U.S. and biodiesel in Europe (Gardner, 2007; De Gorter and Just, 2007, 2009a, 2009b; Hochman et al., 2008; Khanna et al., 2008).

In Colombia the promotion of a "new energy paradigm" began in 2001, when the national government issued Law 693 of 2001 which establishes deadlines and requirements for mixtures of oxygenated fuels consumed in cities of over 500,000 inhabitants. In 2004, the Law 939 defined the general guidelines for mixtures of diesel fuel with vegetable fuels, especially palm oil. Finally, CONPES 3510 of 2008 defined the ground rules and direction of national policy to promote "sustainable production" of fuels of vegetable origin in Colombia (Fajardo, 2009a; FAO, 2010). The Ministry of Mines and Energy and the Ministry of Agriculture and Rural Development undertook the task of designing a specific support model (Bochno, 2011). It introduced various incentives and schemes of direct and indirect subsidies targeted at different stages of the business chain. For example, tax benefits were granted to consumption, such as exemption from value added tax (VAT), the overall tax and surcharge for ethanol and VAT and global tax for biodiesel (articles 8 and 9 of Act 939 of 2004). To increase the production capacity of biofuels, tax free zones with benefits to investments in ethanol and biodiesel production plants were established and blending mandates were introduced for the period 2008-2020. Additionally, significant resources were allocated to finance the cultivation of sugarcane and oil palm for biofuels production, channeled through instruments such as the "rural capitalization incentive" (ICR), the Agricultural Income Insurance Program, the Price Stabilization Fund for Oil Palm Production (FEP) and the development of programs of partnerships and the "Social Financial Model" (MF-S) adapted from Malaysia (FAO, 2010). Law 939 of 2004 exonerated oil palm producers income from taxes for ten years. Law 1111 of 2006 allowed them to deduct up to 40% of the value they had invested on fixed actives from their income tax payment (Garcia y Calderon, 2012).

However, in Colombia there have been many questionings as whether all these promotional and subsidy policies are really targeting all actors in the production chain (Fajardo, 2009a). Apparently, the studies on the assistance and subsidies to rural capitalization tend to show that the main beneficiaries are mostly the landlords and not necessarily the direct producers, who initially sought help (Latruffe and Mouel, 2009).

The aim of this paper is to quantify the possible future economic impacts of biodiesel promotion policies in Colombia associated to tax exemptions (tax credits) and blending mandates, by applying a partial equilibrium sector model based on the model by Gardner (2007). The Gardner model was adapted to the palm oil and the biofuel sector, to simulate quantitative scenarios of the costs and benefits of government programs aimed to support and promote the production and consumption of biodiesel. The exercise is also aimed at establishing the differential benefits and costs of the subsidies to the different actors in the production chain. Since the Gardner model (2007) only integrates crude oil palm and biodiesel markets, it is necessary to build a new model for diesel and biodiesel markets. To do so, the De Gorter (2007) model was adapted according to institutional features and regulations inside those markets.

6.2. Materials and methods

6.2.1. Study area

Colombia is located in northwestern South America on the equator with a land area of 1.14 million Km^2. By location in the equatorial zone and large mountain ranges, the country has a large variety of climates, ecosystems and cultures differentiated into five geographic regions: Caribbean, Pacifica, Andina, Orinoco and Amazon regions (Etter et al., 2006). Current population is around 45 million inhabitants, located mainly in urban zones (76%). Large tracts of land especially in the Amazon and pacific are very sparsely populated. Indigenous territories span 31 million ha (one third of the country) but only with 1.4 million inhabitants (3%) living there. Collective territories owned by Afro-Colombian communities reach 5.5 million ha and around 3 million inhabitants (GEF, 2010).

The most extended land use is cattle grazing which spans over more than 70% of the agricultural land, usually exhibiting low productivity levels (McAlpine et al., 2009). In 2012, the agricultural area was approximately 5.2 million ha, out of which 3.1 million have permanent crops, 1.6 million correspond to annual crops, and 0.5 million are forestry plantations (FEDEPALMA, 2013).

The added value of the agricultural sector accounts for 7% of GDP and employs 18% of the working population (World Bank, 2012). Colombia has one of the highest indices of land concentration in the world (Land Gini 0.86) (PNUD, 2011), and high rates of rural poverty, reaching 54.3% of the population (DANE, 2012).

With the implementation of the "free market" treaties and policies in the 1990s, the Colombian economy showed a progressive reduction in the share of modern sectors such as industry in GDP, strengthening its specializing in the export of primary goods, mining and agricultural goods. The pressures of exchange rate appreciation generated symptoms of "Dutch disease", where non-tradable activities such as financial services and construction gain importance with respect to non-traditional and industrial exports (Sarmiento, 2011).

The commercial oil palm plantations have been developed in Colombia since more than fifty years, but in the last decade the area has increased at an annual rate of more than 8%, reaching an area of 452,435 ha in 2012, which represents 14.5% of the area of permanent crops and 8.75% of the national agricultural production (FEDEPALMA, 2013).

Currently oil palm is cultivated in 108 municipalities of 17 departments (Figure 6.1), forming four productive zones: Northern, Center, Eastern and South-Western. Each one has varied characteristics relating climate, soils, infrastructure and socioeconomic conditions. The region with highest projections of plantations expansion is the Eastern zone, which currently occupies the first place in terms of participation in the production of crude oil palm (CPO) with 36.5% in 2012. The Northern zone follows with 35.3% and the Center and South-Western zones occupy the third and fourth place with 27.3% and 1.1% of the respectively (FEDEPALMA, 2013).

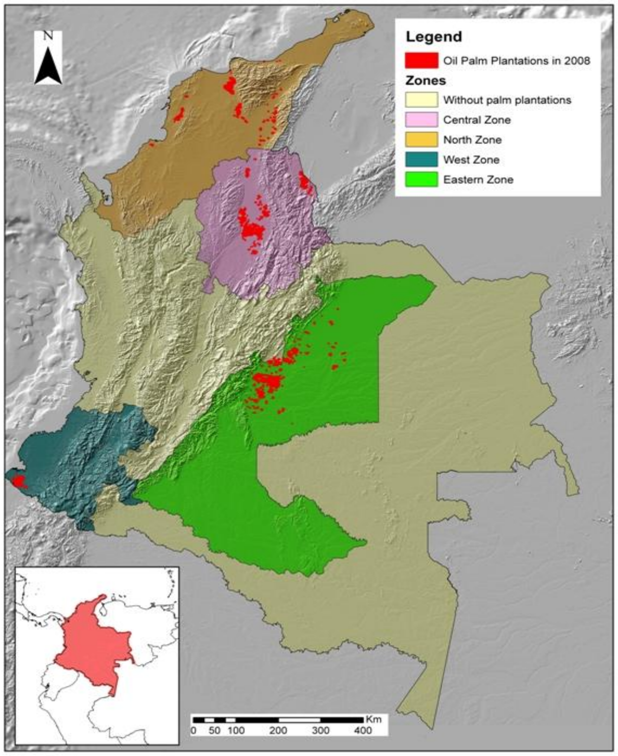


Figure 6.1: Production areas of oil palm in Colombia

Source: FEDEPALMA, 2008.

6.2.2. Analytical framework

Biodiesel and diesel value chain integrates several markets and agents acting in different phases of the productive process. Crude palm oil is sold as the main input for biofuel producers, who negotiate its sell with mixers. Subsequently, it is combined with fossil fuels and distributed to wholesalers and service stations, where the final consumer has access to it (Garcia y Calderon, 2012). The national government intervenes in all the stages of this productive chain by using financial tools, tributary exemptions, and by directly regulating prices in order to maintain profitability and guaranteeing this business' sustainability in the long term.

Figure 6.2 depicts the market structure of the value chain of mixed diesel and biodiesel. Crude palm oil (CPO) market is composed of fruit producers, extraction plants, biodiesel producers and agents that use crude palm oil for exports. Regarding the biodiesel market, the main agents are biodiesel producers and mixers who combine it with fossil fuel. The mixture market is composed of wholesalers and station services who sell biodiesel to the final consumer.

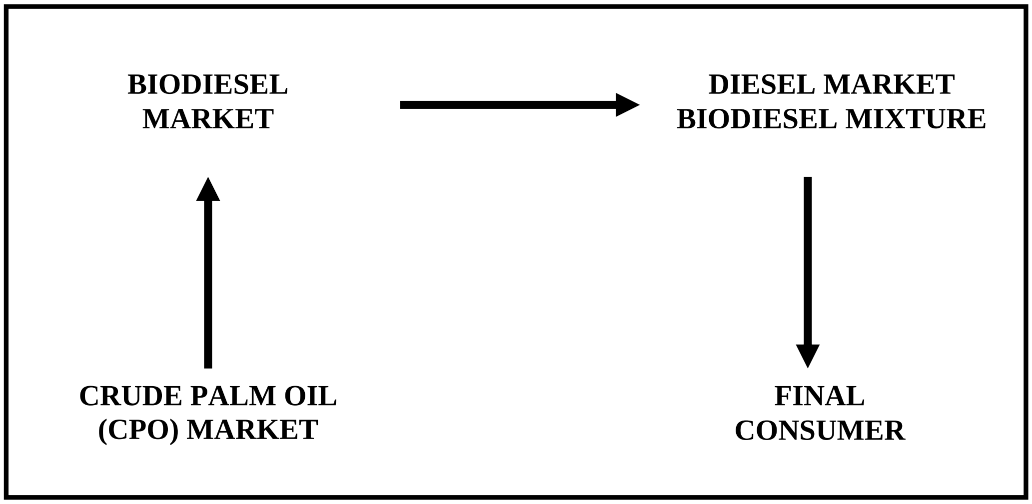


Figure 6.2 Market structure of the value chain of biodiesel-diesel fuel

Source: Own elaboration

The analysis of the impacts of some of the oil palm production promotion policies is carried out in two stages. The first one develops a partial equilibrium model that allows examining the impacts of mandatory blends and tax exemptions of CPO and biodiesel markets. The second one presents the modelling of the mixed fuel market (mixture of diesel and biodiesel) in order to assess the impacts of biodiesel and diesel price regulation policies on the consumer´s wellbeing. This constitutes an important exercise, because even when tributary exemptions reduce biodiesel price for mixers, it is the consumer who is compelled to pay a higher price due to tributary distortions and mandatory blends.

6.2.2.1 Model crude palm oil (CPO), and biodiesel markets

A formal model for the market of biodiesel and oil palm presented below follows the scheme proposed by Gardner (2007). In Colombia crude palm oil (CPO) has different uses in the domestic market either as a source for the production of biodiesel or food, and the rest is exported. In the model the production of fruit and the processing of CPO are integrated into a single market. The biodiesel industry faces a technology of fixed coefficients, where the biofuels are produced using CPO and other materials (plant and equipment) in predefined proportions. It is assumed that the plant and equipment are specific to the biodiesel industry.

We modified the model of Gardner (2007), to introduce the by-products of the production of biodiesel, the land requirements of production and the blending mandates, which are ignored in the original model. The model is built of six equations and their respective endogenous variables (Table 6.1): the bid price of biodiesel (Py), the price of CPO (Px), the price of raw materials for the production of biodiesel (Pw), the production of biodiesel (X1), the demand for CPO for other uses and exports (X2) and the requirement of land to produce CPO (T).

Table 6.1 Equations for the proposed partial equilibrium model

Equations	Description
1. Demand for biodiesel (D_{bd}) $P_y - S = a_0 - a_1 M + a_1 y$	Where: Py: is the Price of demand of biodiesel per tonne y: is the demand for biodiesel S: is the subsidy given to the demand for biodiesel M: is the mandate of blending. a_0 y a_1: are the parameters
2. Supply of other raw materials for the production of biodiesel different to crude palm oil (Sw) $P_w = c_0 + c_1 w$	Where: Pw: is the price of the raw materials per tonne of biodiesel w: is the demand of other raw materials expressed in units of crude palm oil. c_0 y c_1: are parameters
3. Demand for crude palm for other uses different to the production of biodiesel ($D_{ACP\ others}$) $P_x = d_0 + d_1 x_2$	Where: Px: is the price of the tonne of crude palm oil. $X_{2:}$ is the demand for crude palm oil different from the biodiesel sector. d_0 and d_1: are parameters
4. Total offer of crude palm oil (S_{bd}) $P_x = h_0 + h_1(x_1 + x_2)$	Where: $X_{1:}$ is the quantity of crude palm oil destined for the production of biodiesel. $X_{2:}$ is the quantity of crude palm oil destined for other uses. h_0 y $h_{1:}$ are parameters.
5. Demand for crude palm oil to produce biodiesel (D_{ACPbd}) $P_x = (a_0 - a_1 M - c_0) + (a_1 - c_1)x_1 + S$	Where: $X_{1:}$ is the quantity of crude palm oil destined for the production of biodiesel. . M: is the blending mandate. S: is the subsidy for the demand for biodiesel
6. Demand or land required to produce biodiesel (D_T) $T = k_0 + k_1 P_x$	T: land destined for the cultivation of African palm Px: is the price of a tonne of crude palm oil k_0 y $k_{1:}$ are parameters

Figure 6.3 shows a schematic representation modified from the original model by Gardner (2007), which integrates both, the biodiesel and CPO markets, and includes the demand for

land to complement the analysis. The labor market is left implicit, assuming that in the Colombian countryside the labor supply is unlimited (Lewis, 1954). It is important to point out that all physical quantities are measured in equivalent units of tons of CPO. Prices were obtained by applying the conversion rates of one ton of CPO to gallons of biodiesel.

The upper panel (a) of Figure 6.3 shows the biofuels market. The equilibrium is reached when the supply of biodiesel (Sbd) intersects the demand (Dbd). The supply of biodiesel is derived from adding the oversupply function crude palm oil (SCPO)[6] and the supply of industrial materials for the industrial processing of biofuels (SW). The market clearing price of biodiesel is Pyo. The lower panel (b) shows the market equilibrium of CPO. The total supply of crude palm oil total SCPOT, and the demand total is DCPOT. Demand for crude palm oil is obtained by adding the biodiesel sector purchases (DCPObd) and other sectors that use the material for food production, various products or exportation (DCPOothers), ie DCPOt =DCPObd+DCPOothers. The equilibrium is found when the price of CPO is PX and the total quantities traded are X.

As demonstrated by Gorter and Just (2007; 2009), tax exemptions or "tax credits" on the demand of biodiesel, act as a subsidy towards consumption. The grant provides a wedge between the price received by the industrial biodiesel producer and the price paid by consumers (mixers and producers of diesel). Figure 6.3 shows this effect in panel (a), where "S" is the subsidy. As noted, the price received by industrials - Pyo passes the equilibrium price before the implementation of policy measures to PY1> Pyo, while the price paid by consumers of biodiesel is Py2 <Py1 <Pyo. Indeed, the consumer price of biodiesel (Py) is reduced as shown by the red arrow. Higher prices motivate biodiesel producers to increase production, X1 to X1'. Increased production of biodiesel requires a greater amount of CPO and raw materials different from the crop. This is reflected in an increase in input prices and incomes processing plant (Pw) as shown by the red arrows in the diagram in panel (a).

---

[6] The SCPO is the function curve oversupply of crude palm oil for industrial uses, which is derived from subtracting the total supply (SCPOt) demand for uses other than the production of biodiesel, ie DCPO other. If we add to this curve the supply curve for diesel production inputs (SW), is obtained Sbd industrial supply sector Sbd.

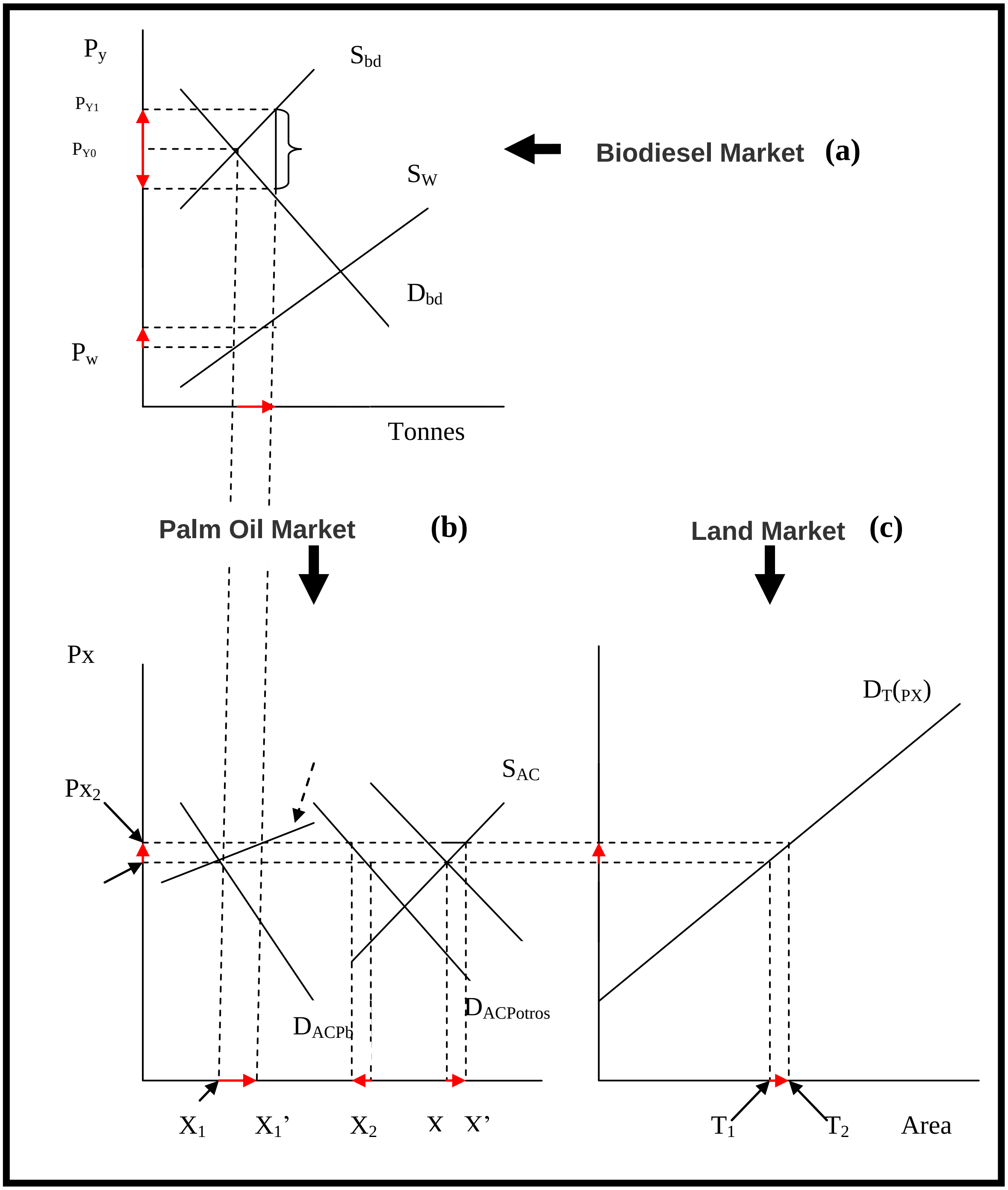


Figure 6.3: Effects of policies and support to biofuels sector

Source: Adapted from Gardner, 2007

The effects of the "tax credit" on biodiesel consumption are evident in the CPO market, through price increases (the red arrow) (Gardner, 2007; Gorter and Just, 2009a). The palm oil that is destined for the production of biodiesel goes from X1 to X1' while demand for other uses (DCPOothers), such as food and exports reduces, as noted by the red arrow. Similarly, the increase in prices creates incentives for producers of CPO to increase production, what effectively happens is that the total supply of CPO goes from X to X ' as shown in panel (b). The higher production of CPO requires producers to increase their demands for land and work.

As seen in panel (c), the land demand changes from T1 to T2 in units of cultivated area (hectares). Net losses of efficiency to society in the biodiesel market can be determined as the area of the triangle in panel (a) of figure 6.2. It is calculated as ½*(X1’-X1)*S (Tirole, 1988).

A blending mandate shifts the demand for biodiesel and industrial products to the right, which will be reflected in higher prices for biodiesel and increased production of biofuels and CPO. Therefore, a "tax credit" and a blending mandate always increase the price of the biodiesel for the producer. The mixed fuel price is reduced with subsidy of biodiesel, but may increase or decrease with the blending mandate, everything depends on the relative elasticity of supply of diesel and biodiesel (De Gorter and Just, 2009b). Figure 6.4 shows the causal relationships between exogenous variables (policy instruments) and endogenous in the model.

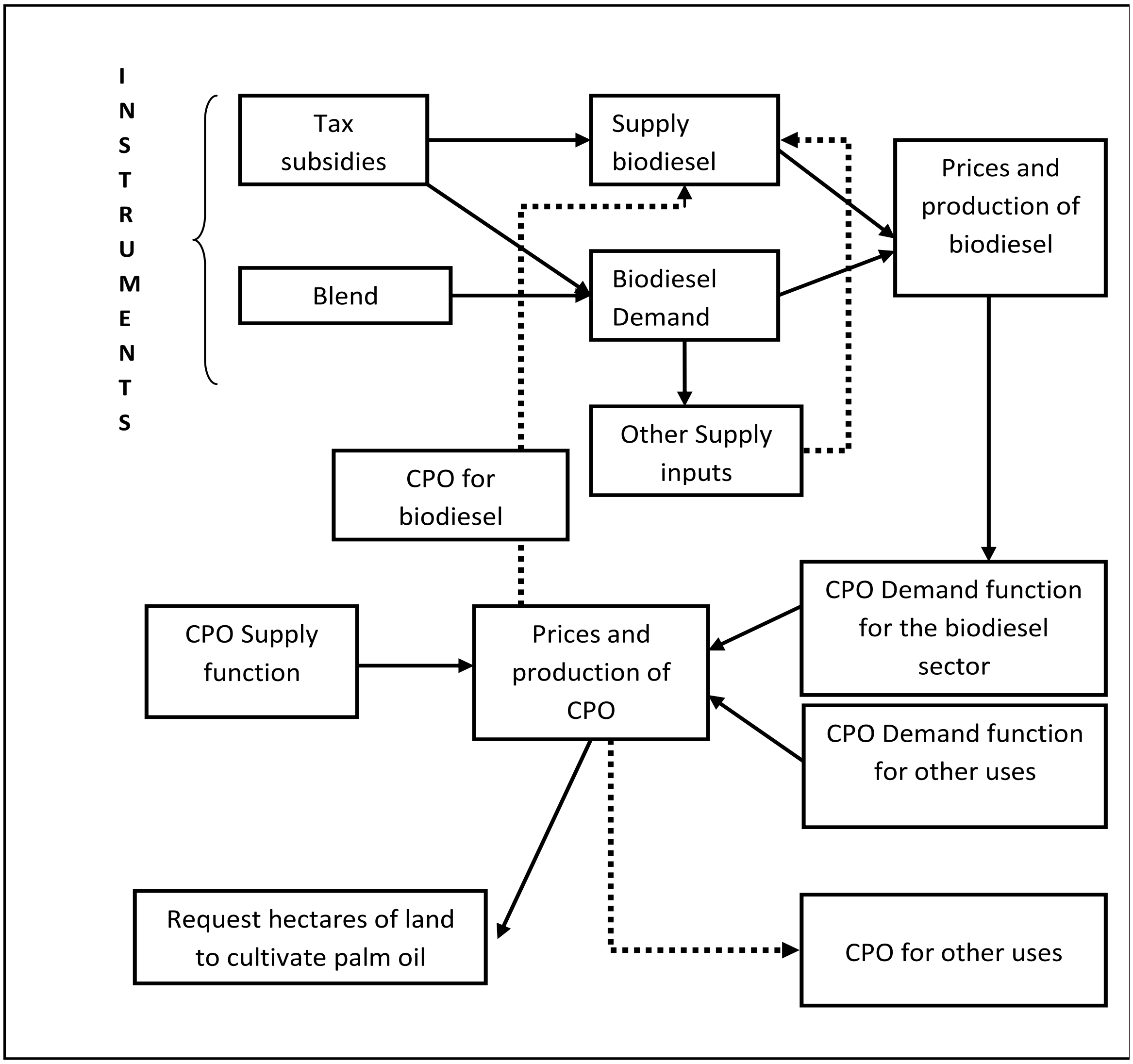


Figure 6.4: Causal relationships between endogenous and exogenous variables that make up the system of equations

Source: Own elaboration

6.2.2.2. Calibration of model parameters and data

The model was parameterized and calibrated to a base year 2009, and al monetary figures are in USD. Basic parameters used correspond to the coefficients in the six equations of the system, that refer to: i) the inverse function for the demand of biodiesel (Dbd); ii) the inverse function of CPO demand for uses other than the production of biodiesel exports more (DCPOothers); iii) the supply function of industrial inputs and plants biofuel processing (SW); iv) the total supply of crude palm oil (SCPOT); and v) the demand for land (DT)7. For the parameters of the system of equations, , estimates of the price elasticity, supply functions, market demand and the observed prices are needed, measured in units homogeneous.

To do this, we proceeded to search for econometric and empirical studies that have made estimates of these parameters for Colombia. As the production and sale of biodiesel started in 2008 is not possible to have robust estimates of the price elasticity of demand. However, assuming that biofuel is regarded as a close substitute for diesel, you can take the elasticity of demand for diesel as a good proxy for the price elasticity of demand for biodiesel. Dahl (2012) shows that the price elasticity of demand estimated for Colombian diesel is -0.22. Estimates of the price elasticity of supply of CPO were taken from a study of Ramirez et al., (2004). The authors show that the price elasticity of SCPO in the short term is 0.26 and for the long term is 1.21. Similarly, they made estimates for the price elasticity of the cultivated area at 0.29 in the short term. Meanwhile, Tudela et al., (2004), made estimates of the price elasticity of supply and demand for CPO and national price elasticity of exports for the period 1994-2003. The results obtained are as follows: the price elasticity of demand for CPO is -0.20; the price elasticity of supply of crude oil palm is 0.65 and the price elasticity of exports is -0.88.

The price elasticity of other raw materials for biodiesel production has not yet been estimated in the country; therefore, this parameter is used as a free variable to adjust the model solution and replicate the base year. The result of this process yielded a value of price elasticity of supply of raw materials different to palm oil at 3.3. As we have two estimates of the price elasticity of supply of CPO, the geometric mean value was taken as a reference, (0.26 * 0.65) ^ 0.5 = 0.41. Similarly, the price elasticity of demand for CPO for other uses and exports, - (0.55 * 0.2 +0.23 * 0.88) = -0.31 was calculated. The weights were obtained to calculate the shares of CPO used in other industries and for those aimed at foreign markets. The used values for price elasticity are presented in Table 6.2.

Table 6.2 Estimated price elasticities of supply and demand functions of crude palm oil and biodiesel in Colombia.

Description	Value
ε_{PDACP} : Price elasticity for the demand for crude palm oil	ε_{PDACP} = -0.2042
ε_{PSACP} : Price elasticity for the supply for crude palm oil	ε_{PSACP} = 0.41
ε_{PExACP}: Price elasticity for the exportation of crude palm oil	ε_{PExACP} = -0.8820
ε_{PSw} : Price elasticity for the supply of raw materials different to crude palm oil to produce biodeisel	ε_{PSw} = 3.3
$\varepsilon_{PDACP\ others\ usos}$: Price elasticity for the demand for crude palm oil for exportation and other uses	$\varepsilon_{PDACP\ other\ uses}$ = -0.31
ε_{PDT}: Elasticity of the demand or requirements of land to the Price of crude African palm oil	ε_{PDT}=-0.29

The procedure to obtain the parameters of the model equations follows to Gardner (2007). First, we used the physical conversion factors for all variables expressed in units of metric ton of CPO, where one ton of biodiesel equals 308.7 gallons of biofuel. One ton of CPO translates to 0.95 ton of biodiesel. In the year 2009, 53.95 million gallons of biodiesel were sold on the market (Ministry of Mines and Energy, 2009), which amounts to 174,761 ton of biodiesel, corresponding to 183,959 ton of CPO.

The average price/gallon of biodiesel in 2009 was $ 5,872 (US$ 2.72) was deflated by the CPI (Consumer Price Index) as published by DANE (National Administrative Department of Statistics). If we multiply the price/gallon by 308.7, we obtain the average price of a ton of biodiesel, ie, $ 1,812,605 (US$ 840.72). To get the price of a ton of biodiesel in terms of CPO, we multiply this figure by 0.95 to obtain $ 1,721,975 (US$ 798.68). The other figures necessary to calibrate the model parameters were obtained from the statistical yearbooks FEDEPALMA (FEDEPALMA, 2010). Total production of palm in 2009 was 804,838 tons. 183,959 ton were used as raw materials in the biodiesel industry and for other uses and exports 620,879 ton were used.

The price of a ton of CPO, deflated by the CPI was $ 1,633,333 (US$ 757.57) in 2009. The prices of raw material different from CPO for biodiesel production is obtained from the difference between the price of a ton of biodiesel and the price of a ton of CPO, $88,642 (US$ 41.11). The number of these raw materials/ton of CPO was obtained from the information of the structure cost. Technical studies of UPME of the Ministry of Mines and Energy (2009) show that CPO accounts for between 70% and 90% of the total production costs of biodiesel, so if one takes 70% as the point of reference, the cost of the other raw materials, other than CPO, they are equivalent to 78,839 ton of palm for the year 2009.

The inverse demand price elasticity of biodiesel is obtained as – (1/0.22) = -4.54545 [7]. With this value, the coefficients of biodiesel demand function are obtained as:

$$a_1 = \frac{-4.54545 * P_{y2009}}{y_{2009}} = \frac{-4.54545 * 1{,}721{,}975}{183.959} .$$

The other function coefficient is,

$$a_0 = P_{y2009} - 4.54545 * \mathrm{y}_{2009} = 1{,}721{,}975 - (4.54545 * 183{,}959)$$

All other coefficients are obtained by following the same procedure. Table 6.3 all calibrated parameters are presented.

Table 6.3 **Model parameters**

Function	Parameter estimates
Biodiesel demand function $P_y - S = a_0 - a_1 M + a_1 y$	a_0 =9549134 a_1 =- 42.5484
Supply function input different from palm $P_w = c_0 + c_1 w$	c_0 =62049.4 c_1 =0.337303
Demand function of crude palm oil different from biodiesel $P_x = d_0 + d_1 x_2$	d_0 =6902149 d_1 =-8.48606
Supply function of crude palm oil $P_x = h_0 + h_1(x_1 + x_2)$	h_0 =-2350406 h_1 =4.94974
Demand or requirement of land to produce crude palm oil $T = k_0 + k_1 P_x$	k_0 =255981.27 k_1 =0.0640

---

[7] Supply price elasticity is defined as: $\sigma = \frac{\partial Y}{\partial P} * \frac{P}{Y}$, thus the inverse elasticity of supply price is: $\frac{1}{\sigma} = \frac{\partial P}{\partial Q} * \frac{Q}{P}$

To perform a comparative static exercise, the model was calibrated and resolved for the base year 2009. The exogenous variables of the model are the blending mandates (M) and tax exemptions or subsidies to biodiesel demand (S). In the scenarios described below it is assumed that M = 0. Not initially considering blending mandates allows a rigorous examination of the effects of biofuel tax exemptions on the endogenous variables of the model. In Colombia, biodiesel consumption is promoted through tax exemptions of VAT and the global tax one has to pay for fuel for diesel motors of fossil origin. The VAT rate is 16% which is taxable to the income of the producer. The global tax is a lump sum tax which is updated every year in line with inflation as determined by the State Bank (Banco de la República).

To determine the subsidy intended for the production of biodiesel one follows the methodology proposed by Rudas (2008). The exercise takes into account the detailed discrimination of the price of a gallon of diesel, and diesel-biodiesel mixture published by the Ministry of Mines and Energy for the relevant year. The idea consists of calculating the subsidy/gallon of biodiesel. This is obtained by taking into account the exemptions and the percentage of biofuel mixture (B10, B20 and B25) set out in the FAO (2010) for different periods. The subsidy calculation is based on the analysis of the structure of the reference price for biodiesel and diesel, published by the Ministry of Mines and Energy for each effect. The idea is to work out the taxes paid by the biodiesel-diesel blend and pure diesel, thereby establishing the tax differential in favor of biodiesel.

To estimate the subsidy, we projected the prices of biodiesel and diesel for the period 2011-2020, using the actual average growth rate between 2008 and 2011. The years used as a reference to estimate the subsidy were 2010, 2014 and 2015. Correspondingly the subsidies are: 2010 - US$15.7/ton, 2014 - US$40.13/ton, and 2015 - US$53.59/ton.

The effects of the subsidy are obtained by resolving the model for the three levels of subsidy and comparing the initial equilibrium (base year 2009) with the final balance including the subsidy. As suggested by Gardner (2007), it is important to compare the results for the short and long term. The difference between the exercises of short-term and long-term resides in the value of the parameters of the elasticities of the model. It is assumed that these values increase in all cases in the long term. Hence the calibration exercise and solution model replicated parameters by taking as reference the parameters of functions of the long-term. These are assumed coefficients. The elasticities that were changed are: the price elasticity of demand for long-term biodiesel was assumed to equal -5; the elasticity of demand for crude oil and other export use was assumed to equal -1, the price elasticity of supply of CPO was estimated at 1.21 by Ramirez et al., (2004). The values of the other elasticities were equal to those reported in Table 6.2.

Table 6.4 Absolute change in the effects of tax exemptions for biodiesel in Colombia for base year 2009.

	Grant Short Term Effect			**Grant Long Term Effect**	
	B10	**B20**	**B25**	**B20**	**B25**
Subsidy (US$)	15.7	40.13	53.59	40.13	53.59
Crude palm oil (tons)	465	1,188	1,586	10,131	15,611
Crude palm oil for biodiesel (Ton)	736	1,881	2,511	16,564	25,537
Crude palm oil for other uses and Exports (Ton)	-271	-693	-925	-6,433	-9,926
Price per ton of Palm (US$)	1,068	2,727	3,641	8,620	12,883
Price per ton of Biodiesel (US$)	-14,530	-37,113	-49,557	-28,.922	-36,713
Price of a ton of other raw materials for biodiesel (US$)	0.115	0.294	0.393	2.591	3.995
Incomes of the Palm Producers (millions US$)	1.211	3.095	4.134	14.685	22.372
Incomes of the Biodiesel Producers (millions US$)	0.817	2.090	2.793	15.721	24.307
Income from the plants and other materials of Biodiesel (millions US$)	0.063	0.162	0.217	1.469	2.301
Consumer spending on Biodiesel (millions US$)	-2.073	-5.338	-7.159	7.704	13.121
Crude Oil Expenditure on other Uses and Exports (millions US$)	0.458	1.168	1.559	0.433	0.366
Tax Expenditure (millions US$)	2.89	7.42	9.95	8.02	11.19
Deadweight losses (US$)	6, 000	38, 000	67 ,000	332, 000	684,000
Deadweight losses as % of Tax Expenditure	**0.2**	**0.5**	**0.7**	**4.1**	**6.1**

6.3. Results

6.3.1 Analysis of the impact of tax exemptions for biodiesel

The simulations generally confirm the assumptions of the model, in that subsidies increase the production of CPO, both in the short and long term (Table 6.4). However, the effects are not significant. With the largest grant of US$53.59/ton of biodiesel, the production increases only by 1,586 ton in the short term and 15,611 ton in the long run. On the other hand, oil palm used in biodiesel production would increase from 736 to 2,511 ton in the short term, and 25,327 ton the long term.

Production of CPO destined to other uses and to exports would drop in the short term to between 271 and 925 ton and the long term by up to 9,926 ton, which means that subsidies allow the production of biodiesel to increase in the short and long term. However, there are no effective mechanisms for achieving the objectives defined in the Government Plan for biofuels. The above results are derived from the changes in the relative prices that result from government intervention. Indeed, biodiesel price paid by consumers is reduced in the short and long term, allowing agents replace diesel with biodiesel.

Similarly, of biodiesel and CPO the price to the producer increased in the short and long term, this not only makes such activities more profitable, but it also means that the income of the producer and agro-industrialist increase substantially. The income of the producers of CPO in the short term increases between US$1.2 million and US$4.1 million, while the producers of biodiesel make between US$0.8 million and US$2.7 million. That is, the producers of the agroindustry of the palm earn higher returns from the subsidy policy on the biodiesel demand in the short term.

This result is not maintained in the long term. In fact, the income of producers of biodiesel increased from between US$15.7 million and US$ 24.3 million, while that of the agricultural producers makes between US$14.6 million and US$ 22.3 million.

The State subsidy is significant. In the short term, biodiesel entrepreneurs and consumers benefit from a reduction of tax between US$2.8 million and US$9.9 million. In the long term, the amount ranges from between US$ 8.0 million and US$11.1million. Deadweight losses are small in the short term, representing only between 0.2% and 0.7% of tax expenditures (state subsidies for biodiesel). However, in the long term they become significant rising to between 4.1% and 6.1% of the tax payer's expense account for the promotion of biodiesel.

Figures 6.5 and 6.6 show the distribution of subsidy benefits between CPO producers, biodiesel entrepreneurs and suppliers of other the raw materials for biodiesel production. What we see is that, in the short term the subsidies benefit more the farmers and agricultural producers, while in the long term the winners are the entrepreneurs of the biofuels industry. Increases in the value of the subsidy associated with the blends B10, B20 and B25 does not affect significantly the distribution of income between the different actors in the productive chain. This result holds in the short and long term.

However, the model does not allow examining the distribution of benefits in greater detail, for example, between landowners, direct producers and salaried labor in rural areas, which would require more complex and disaggregated models. Additionally, this would also require including into the analysis, the subsidies and direct support that the government grants producers of late yield crops such as oil palm. These general equilibrium models would require specifications, calibration and resolution that are beyond the scope of this paper.

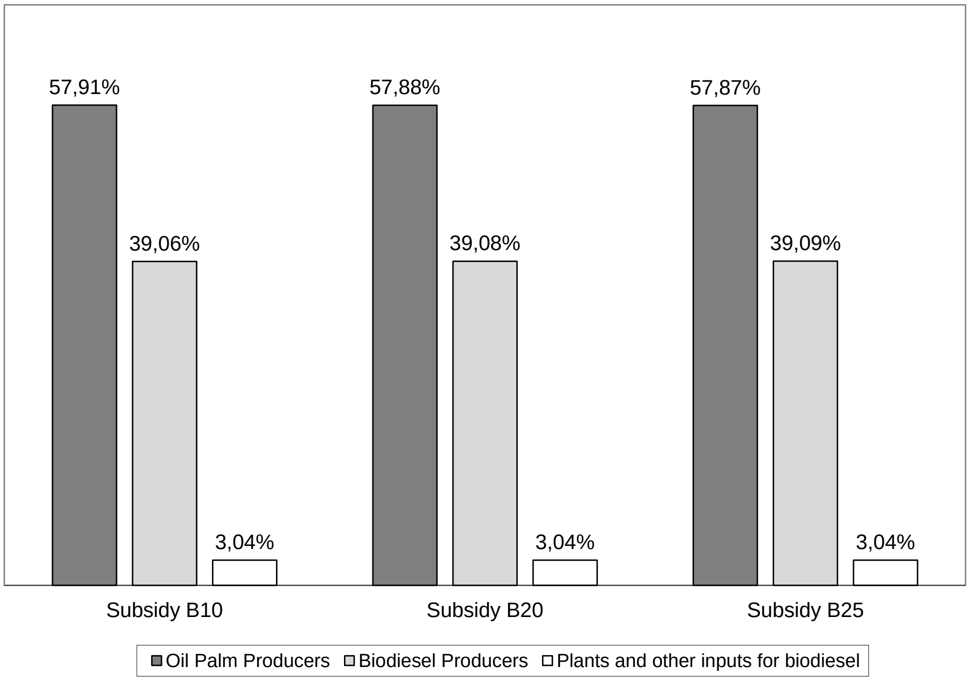


Figure 6.5: Distribution of income growth in the short term

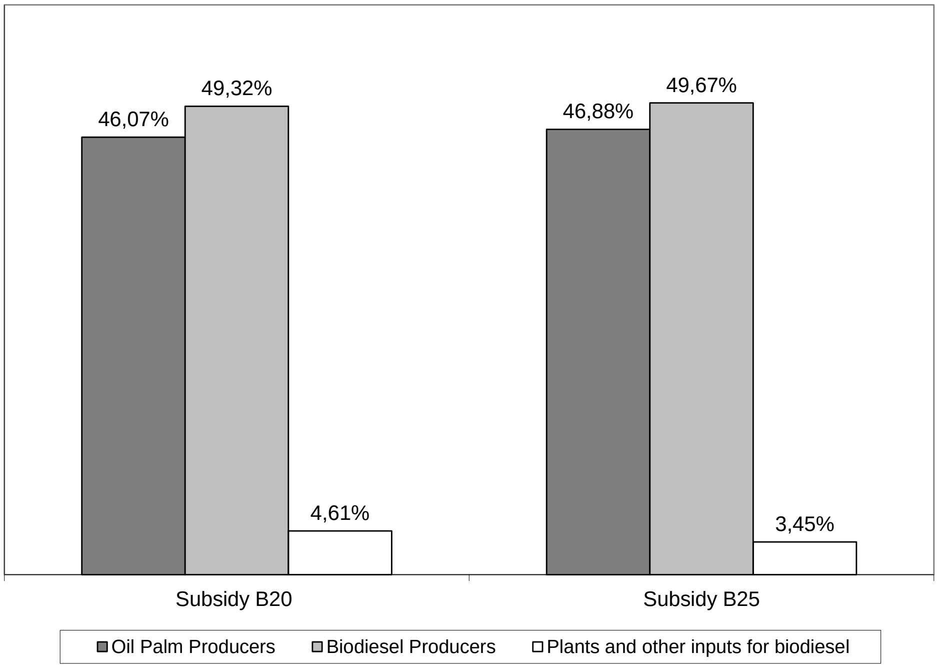


Figure 6.6: Distribution of income growth in the long term

6.3.2 Analysis of the impact of tax exemptions for biodiesel

The proposed model for analyzing biodiesel and CPO markets allows a simultaneous examination of the effects of subsidies and blending mandates on the endogenous variables of the system of equations. For the construction of scenarios, estimates of subsidies and mixtures for the study period are needed. Table 6.5 shows the values for both variables between 2010 and 2020.

Table 6.5 Analysis scenarios for the planned mixture blends

	2010 B7	**2011 B10**	**2012 B10**	**2013 B10**	**2014 B10**	**2015 B20**	**2016 B20**	**2017 B20**	**2018 B20**	**2019 B20**	**2020 B25**
Subsidy (US$/Ton)	10.7	16.7	17,6	18.6	19.0	41.7	43.6	45.5	47.8	49.6	66.3
CPO production (000 Ton)	399	590	611	632	653	1,346	1,385	1,422	1,463	1,503	1,928

It should be stressed that, in most studies on biodiesel and palm oil, researchers refer to the estimates of the blending mandates regardless of the interrelationships of the various markets and the implications for relative prices and production decisions. In the exercises discussed below, subsidies and mandates are raw materials of the model, therefore, the analysis is performed on the equilibrium solutions of the model calibration.

Table 6.6 Simulation results on the production and use of crude palm oil

Year	Crude palm oil (000Tons)	Crude palm oil for Biodiesel (000 Tons)	Crude palm oil for other uses and Export (000Tons)
2010	1,037.6	552.5	485.1
2011	1,149.2	729.2	420.0
2012	1,161.8	749.2	412.6
2013	1,174.2	768.8	405.4
2014	1,186.2	787.8	398.4
2015	1,591.7	1,429.7	161.9
2016	1,614.6	1,466.0	148.6
2017	1,636.1	1,500.1	136.0
2018	1,660.2	1,538.2	122.0
2019	1,683.8	1,575.6	108.2
2020	1,932.2	1,968.9	-36.7

The combined policy of subsidies and "statutory mandates" for blending and mixtures is effective to achieve the objectives of the "National Biofuels Program". Table 6.6 shows the results for the production and use of CPO. The production of CPO passes from 1,037 thousand ton in 2010 to 1,932 thousand ton in 2020. CPO used in biodiesel production rises from 552.3 thousand ton in 2010 to 1,968 thousand ton in 2020. This model of raw material usage results in practice in the virtual disappearance of exports and other uses of CPO throughout the analysis period. In fact, in 2020 the B25 blend or mixture means in effect the importation of CPO to meet the demands of the biofuel sector.

Undoubtedly, the patterns of production and use of CPO are subject to changes in relative prices and investment returns. As shown in Figure 6.2 the biodiesel consumption subsidies (tax breaks) and statutory blending mandates increase the prices of the CPO and biodiesel, improving profitability, which implies a significant reallocation of resources and factors of production to the production of CPO and biodiesel for transport usage.

In effect, the simulations clearly show that prices of CPO and biodiesel tend to increase through time. In fact, periods of mixtures and blending changes show a differential impact on the upward trend in prices. It is clear that, under these conditions, the use of CPO in other productive activities or exports cannot be maintained. Table 6.7 shows the real prices of CPO, biodiesel and the raw material for biodiesel production.

The change of gross income of producers of CPO, producers of biodiesel, and suppliers of raw materials for biodiesel production is shown in Table 6.7. The revenue streams from three central agents of the market, increases in real terms over the period. However, it is important to highlight that while the income of agricultural producers remains above that of the biodiesel producers between 2010-2018, this trend is reversed from 2017 onwards, which shows that the income of producers of biodiesel increases above that of the of rural producers, ie subsidy policies and mixtures in the long run favor more the agents of the biofuels sector. The functional income distribution pattern of the model in question does not allow for detailed analysis. Even so, it can be assumed that most of the benefits of the subsidy policy and mixtures go to compensate landowners.

Table 6.7 Projected Incomes of producer and Prices of crude palm oil, biodiesel and raw materials to produce biodiesel

Year	Prices of crude palm oil (US$/ton)	Prices of biodiesel (US$/ton)	Prices of raw materials to produce biodiesel (US$/ton)	Incomes crude palm oil producers (millions US$)	Incomes Biodiesel producers (millions US$)	Incomes from plants and other inputs of Biodiesel (millions US$)
2010	1,291.9	1,396.3	115.2	1,340.4	777.4	63.6
2011	1,548.2	1,674.3	142.9	1,779.2	1,233.1	104.2
2012	1,577.2	1,705.5	146.0	1,832.5	1,291.0	109.4
2013	1,605.6	1,736.4	149.1	1,885.4	1,349.1	114.6
2014	1,633.1	1,766.0	152.0	1,937.2	1,406.3	119.8
2015	2,564.0	2,774.6	252.5	4,080.9	4,026.7	360.9
2016	2,616.6	2,831.1	258.1	4,224.7	4,214.3	378.4
2017	2,666.1	2,884.0	263.5	4,362.0	4,394.6	395.2
2018	2,721.3	2,943.1	269.4	4,517.9	4,600.4	414.4
2019	2,775.5	3,001.0	275.3	4,673.5	4,807.0	433.7
2020	3,345.8	3,616.1	336.8	6,464.8	7,250.8	663.2

Finally, we present the results of the model on the demand for land to produce palm oil. Figure 6.7 shows the demand for land for palm oil cultivation.

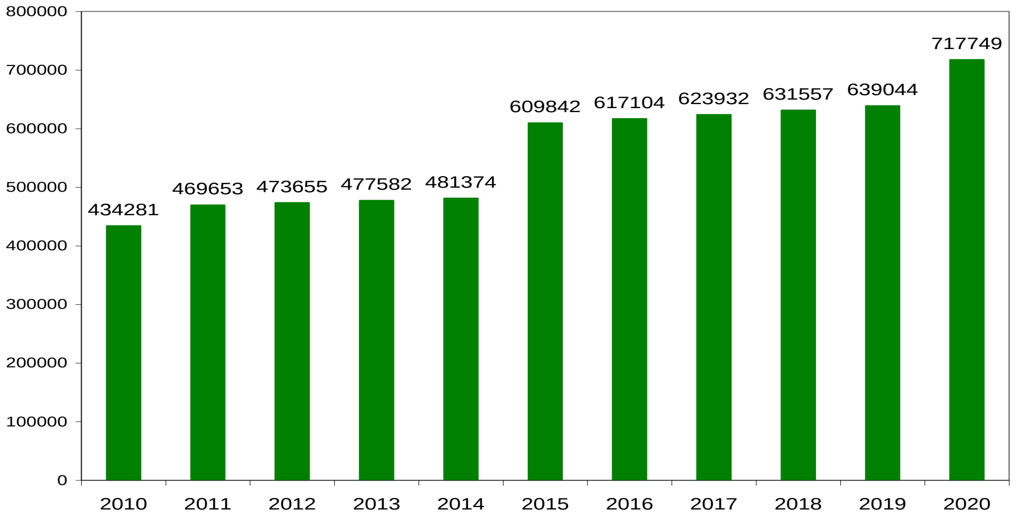


Figure 6.7: Estimated area for palm oil cultivation (Hectares).

Policies promoting biofuels in general and biodiesel in particular will have significant impacts on land use in Colombia. The cultivated area of oil palm increase from 434,281 ha in 2010 to 717,749 ha in 2020, which corresponds to 65% increase in the area devoted to the crop. This results essentially from the future demand of the raw material for the production of biodiesel.

6.4 Partial equilibrium model of the diesel-biodiesel mixture

The national consumption patterns of liquid fuels have presented significant changes during the last years. Since the end of the 90s the gasoline demands have systematically decreased, whereas diesel consumption maintained its growing rate. Since 2006, the national sales of diesel-biodiesel overcame the sales of gasoline and ethanol (Figure 6.8). This substitution process was the result of: changes in the people´s preferences for load and passenger vehicles equipped with diesel engines; the implementation of massive transportation systems in Bogotá and other cities; the growing gasoline smuggling; and the governmental policies of price setting and regulation (ELRC, 2013; FAO, 2010).

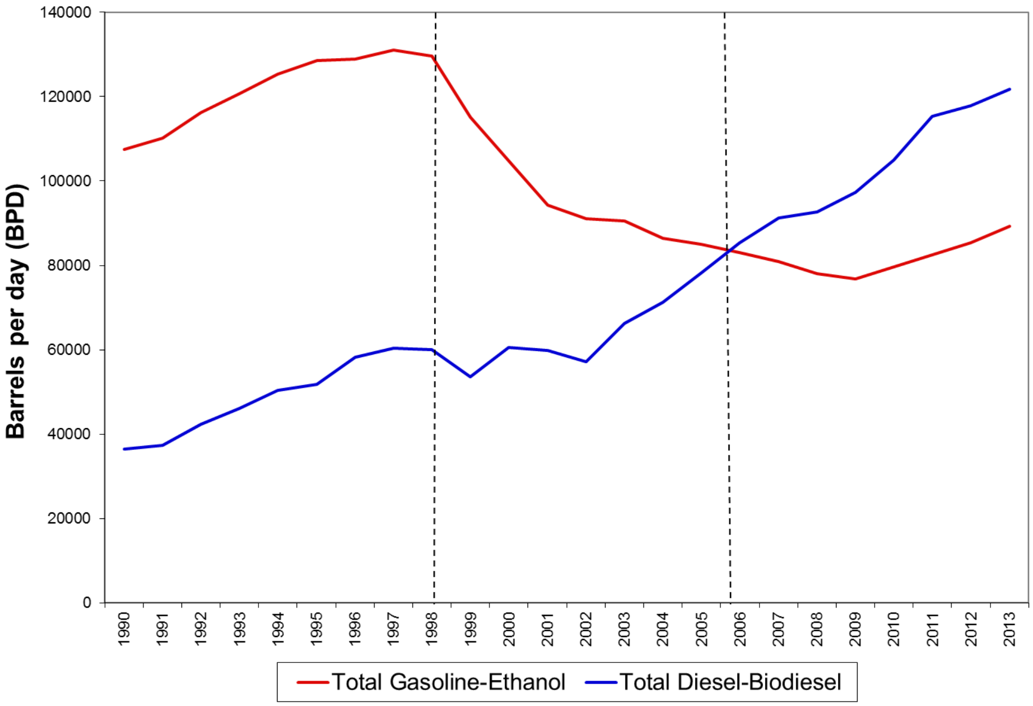


Figure 6.8 Consumption of Gasoline-Ethanol and Diesel-Biodiesel (ElRC, 2013)

The growing demand for diesel and the quality requirements for this fuel (Law 1205 of 2008) required the import by ECOPETROL of nearly 53.000 low-sulfur barrels per day between 2010 and 2012. There is expectation around the investments in the improvement of refineries in Cartagena and Barrancabermeja, because they will allow Colombia to become a net exporter for the period 2015-2020 (ELRC, 2013). The mentioned growing demand for diesel favored the biodiesel promotion program in Colombia, because its market demand substantially grew, and also, the quality standards improved its features: it is a clean and polyaromatic fuel (ELRC, 2013). Figure 6.9 shows the evolution in the consumption of fossil fuels and biofuels in Colombia.

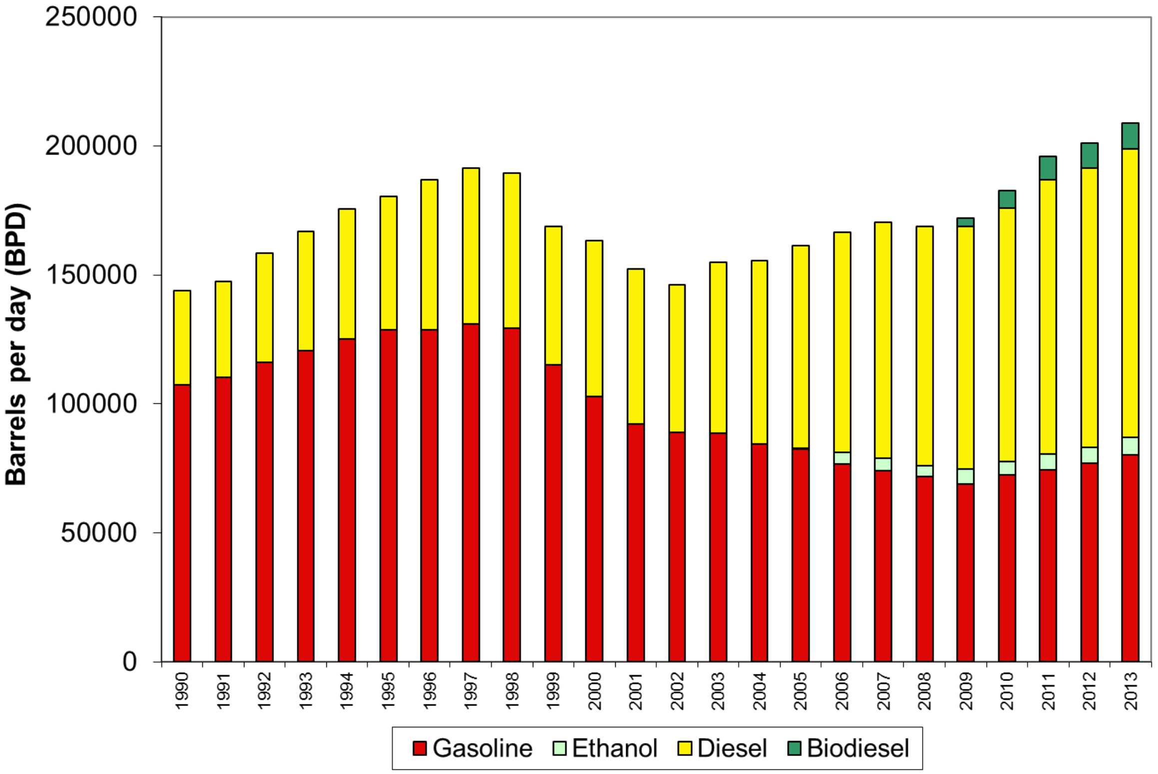


Figure 6.9 Fossil fuel and biofuel consumption (ELRC, 2013)

Fuel market in Colombia is regulated by the government, and fossil diesel and diesel prices are set by the Ministry of Mining and Energy (MME). The methodologies to do so have change during time (Rincón & Aaron, 2004; MME, 2011; Rincón, 2009). In the last years, the policies have intended to reduce subsidies and opportunity costs of fuel sales under their export (or import) parity. At the same time, the national government has tried to reduce the effects of the highly volatile international prices of oil and its byproducts on the domestic market prices (Rincón, 2009). The Stabilization Fund of fuel prices was one of the government´s initiatives, and it was created in 2007 with $90,000 million Colombian pesos. High oil prices in 2010 and the growing diesel import reduced the efficiency of this stabilization mechanism because the Fund was almost extinguished (FAO, 2010). “MME was forced to constantly adjust producers’ incomes during 2010, which increased their volatility. This fact and the decline of the WTI price led to almost losing all the profit due to the relative variability of the internal price (as opposed to the scenario where this price depended directly on the international prices)” (Suescun et al., 2011).

Regardless of that, MME continues issuing on a monthly basis the resolutions that define diesel and Biodiesel prices. The diesel Fob price in the Gulf coast (USA) is taken as a reference to determine the diesel producer price, deducting transportation costs from Barrancabermeja to the Gulf coast (export parity) (Rincón, 2009; ELRC, 2013). Then, taxes and other costs (wholesalers and retailer margins) are added until the final consumer price is set. The biodiesel producer price is defined as the maximum between "Diesel 2" import parity price and oil palm import parity price (Rotterdam), and in both cases the biodiesel "Efficient Production Factor" is added (FAO, 2010). Figure 6.10 depicts the price evolution of diesel, biodiesel and the mixture of both in Colombia between 2010 and 2013.

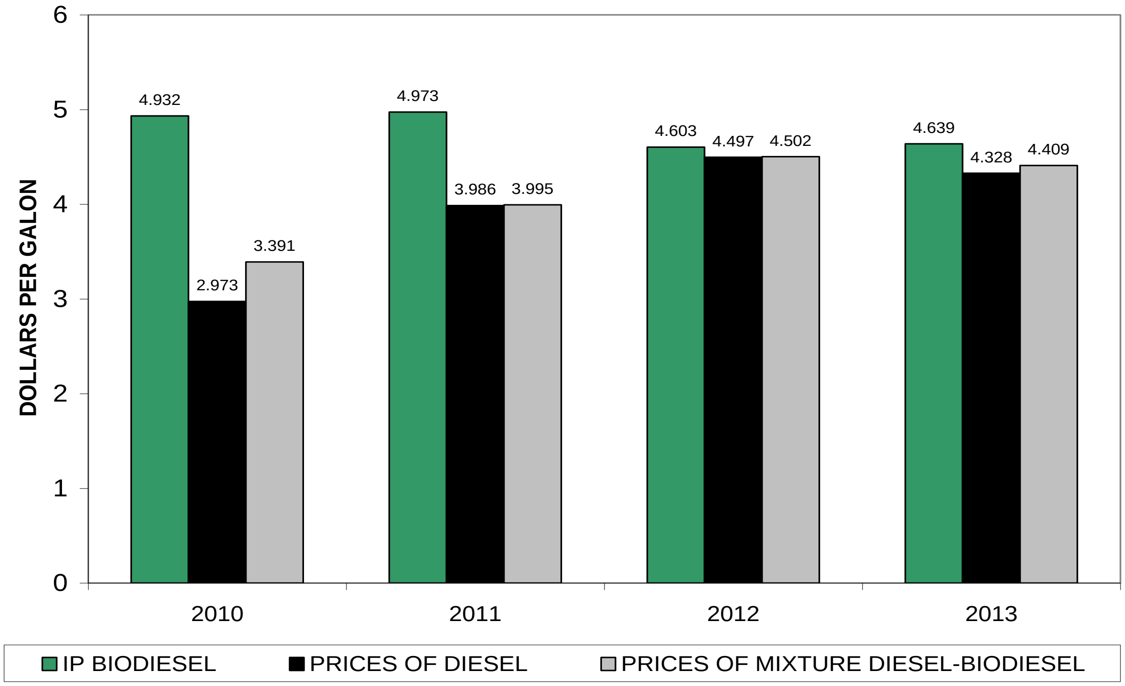


Figure 6.10 Biodiesel, diesel and mixture prices

It can be noted that during the analyzed period (2010-2013) MME has maintained the prices in favor of biodiesel producers. In spite of the tributary exemptions of biodiesel, the price paid by the consumer for the diesel-biodiesel mixture at service stations has always been above the diesel price.

The partial equilibrium model for the diesel-biodiesel market is presented below. The De Gorter and Just model (2007) was adapted in order to incorporate the institutional features and particularities regarding price regulations in Colombia. The objective is examining and determining efficiency costs (deadweight costs); costs faced by the consumers when paying higher prices for fuel; and the quasi-rents transferred to biodiesel producers through this schema of mandatory blends and discretional set of maximum prices for consumers.

Biodiesel prices (PB), diesel prices (PD) and mixture prices (PM) are determined by the government. Biodiesel supply functions S(PB), diesel supply functions S(PD), and mixture supply functions S(PM) are horizontal in the space of prices and quantities. Diesel supply contains the quantities produced in the country and the amounts imported by ECOPETROL. Total fuel demand in the market is DF(PM). Biodiesel demand corresponds to α D(PM), where α is the percentage of the mandatory blend with the green fuel. The equations of this model are described in Table 6.8.

Table 6.8 Equations for the proposed partial equilibrium model

Equations	Description
$P_B = Max\left[P_{D2}, P_{CPO}\right] + FC$	P_{D2}= import parity price of "Diesel 2" $P_{CPO=}$ import parity price of palm oil (Rotterdam) FC= Efficient Production Factor
$P_D = IP + IMP + TPol + MMay + MMin + CT + O$	IP= Producer or imporer Income IMP=Taxes (IVA, Global Tax and Surcharge) TPol=Transportation cost – oil pipelines MMay=Wholesaler Margin MMin=Retailer Margin CT=Transportation cost – service station O=Other costs
$P_M = \alpha P_B + (1-\alpha)IP + (1-\alpha)IMP + TPol + MMay + MMin + CT + O$	IMP= Taxes (IVA, Global Tax and Surcharge) for diesel only TPol= Transportation cost – oil pipelines MMay=Wholesaler Margin MMin=Retailer Margin CT= Transportation cost – service station O=Other costs α=Mixture percentage
$S_D + S_B = D_F(P_M)$	Market equilibrium
$S_B = \alpha D_F(P_M)$	Required biodiesel mixture

Figure 6.11 presents a graphic solution of the partial equilibrium model for the diesel-biodiesel market. It is assumed that these functions are lineal. Given the absence of a biofuel policy, the fuel price is PD and the amounts of diesel compromised in the market are QF*. When the mixture mandates are introduced and the tributary exemptions to biodiesel are established, the market solutions change. The price faced by the consumer increases to PM and the amount of mixed fuel is reduced to QF. The biodiesel sale for mixers increases to QB and its price is set by the government in PB. The amount of diesel is reduced to QF-QB and is sold at PM. It can be observed that biodiesel price is higher than the mixture price, which in turn is higher than diesel price; in other words, PB>PM>PD. Costs for consumers correspond to the yellow rectangle, whereas deadweight losses, for smaller consumed amounts are represented in the blue triangle. The quasi-rents obtained by biodiesel producers due to regulations and mandatory blends correspond to (PB-PD)*QE.

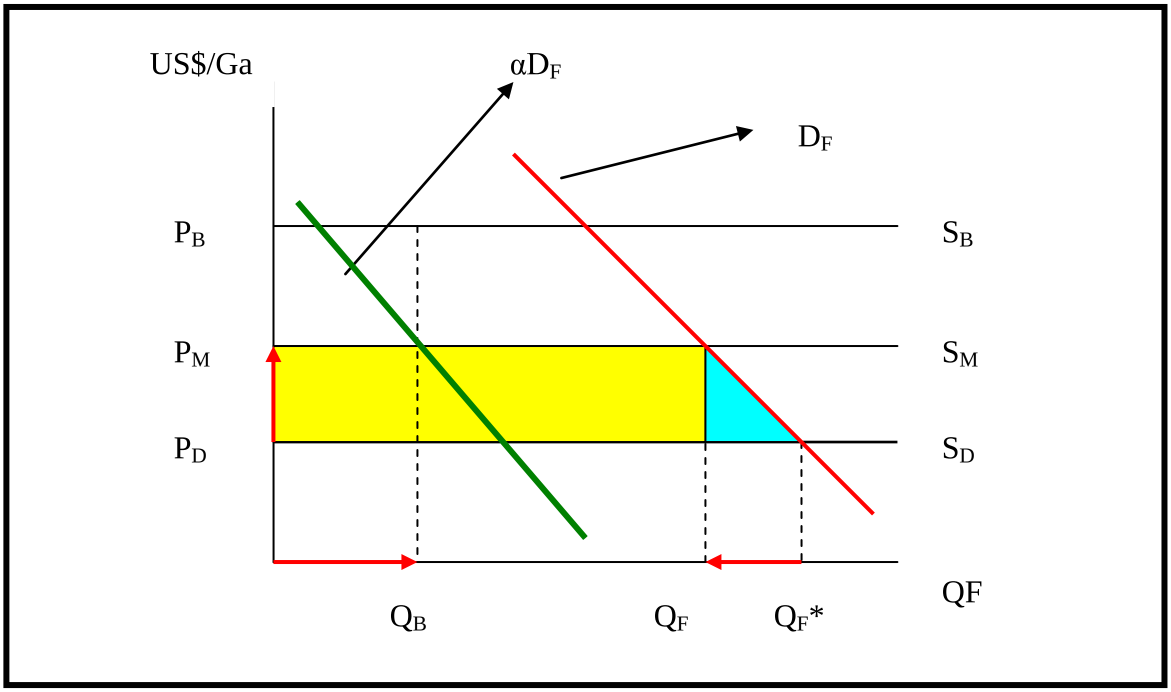


Figure 6.11 Diesel market and the biodiesel mandatory blend (adapted from De Gorter and Just, 2007)

Table 6.9 shows the results for the years 2010, 2011, 2012 and 2013. Information regarding prices was obtained from the database of Fedecombustibles. Information related to the sale of barrels was consulted in the ELRC study (2013). The equation of the mixture demand was calibrated for four years, and the price elasticity of -0.22 of the diesel demand for Colombia (reported by Dhal, 2012) was used.

Table 6.9 Results of the 2010-2013 model (millions of dollars)

	2010	**2011**	**2012**	**2013**
Income of biodiesel producers	480	611	610	619
Income of diesel producers	4705	5858	6662	6687
Quasi-rents for biodiesel producers	191	121	14	41
Consumer losses due to higher biodiesel prices	639	13	9	221
Consumer deadweight losses due to a lower fuel consumption	69	1	1	24
Total expense of final consumers	5185	6469	7272	7306

The total consumer expense regarding diesel and biodiesel went from US$ 5,185 million in 2010 to US$ 7,306 million in 2013. The income of biodiesel producers increased from US$ 480 million in 2010 to US$ 619 million in 2013; and for diesel producers the income increased from US$ 4,705 in 2010 to US$ 6,687 in 2013. This means that their real income raised 29% and 42% respectively. Doubtlessly, the patterns will change once the mandates of bigger blends come into force in the following years (for 2010 the mixture was 6.4% national average, and in 2013 it barely reached 8.1%).

Consumer losses have been significant. Between 2010 and 2013, the sum of the areas of the yellow rectangle and blue triangle reached US$ 977 million. The losses have been reduced because the prices present a convergence tendency (Figure 6.12). Finally, the quasi-rents received by biodiesel producers during the analyzed period reached US$ 367 million.

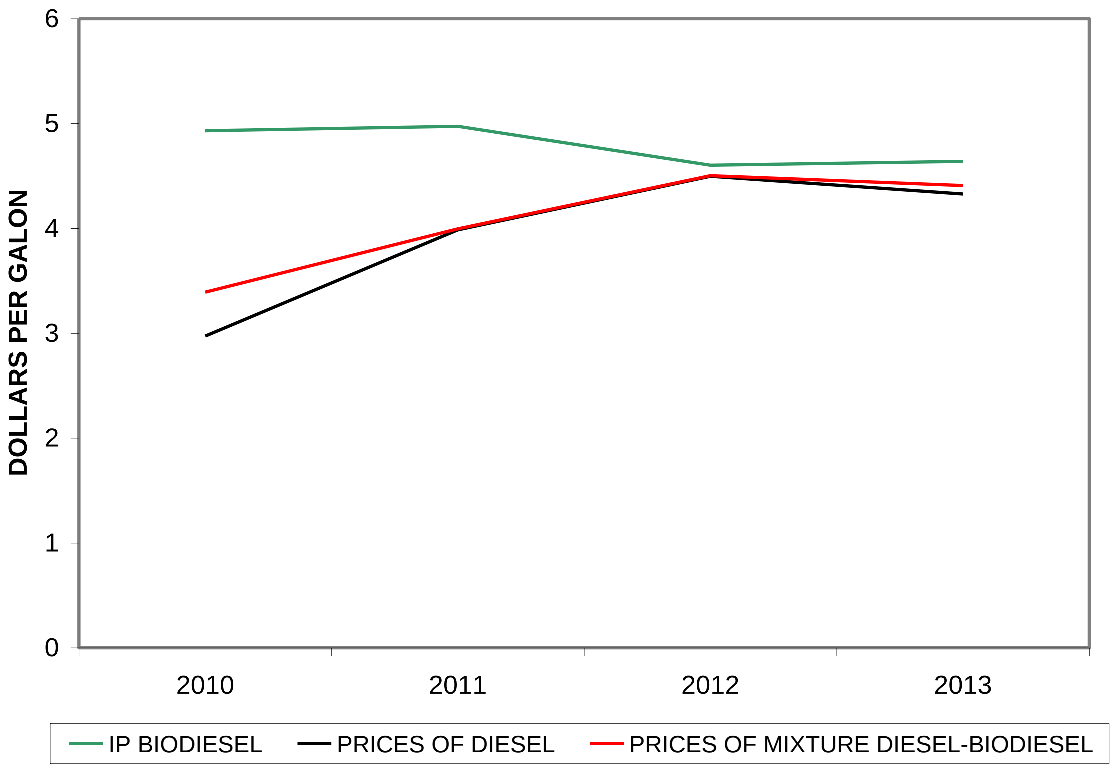


Figure 6.12 Convergence of biodiesel, diesel and mixture prices

The implementation of the biofuel policy has generated high costs for consumers in Colombia. A cost-benefit evaluation demands a detailed analysis regarding the productive chain and the positive externalities of biofuel use, which is beyond the scope of this investigation. However, a partial study was recently carried out by ELRC (2013) and its results show a positive balance, but it only analyzes the costs associated to the higher prices paid for biodiesel and excludes other costs that emerge in the model proposed by this work. In fact, "deadweight losses" due to lower amounts of fuel consumption have to be included in this kind of analysis when it comes to establishing the convenience of using green fuels in the country.

6.5 Discussion

Public support policies to biofuels aim at two objectives: (i) improving the income of producers and (ii) reducing CO2 emissions, derived from fossil fuel consumption. Nevertheless, in order to determine the most adequate policy tools, it is necessary to take into consideration the country´s institutional characteristics, as well as specific market parameters (Dewbre and Short, 2002; Guyomard et al., 2004). In Colombia as in other countries, these tools include the exemption of tax payments for biofuel producers (tax credits) and establishing blend mandates. The combination of these regulations results in a direct subsidy to biodiesel or ethanol consumption, which only benefits agricultural producers indirectly (De Gorter and Just, 2007).

Recent evaluations made for ethanol in USA reveal that the combination of tax credits and blend mandates generate significant net losses of social welfare (De Gorter and Just, 2009a; Gardner, 2007). Likewise, it is demonstrated that not only small producers are able to access the benefits of biofuel subsidies, because an important part of these advantages is transferred to landowners through bigger land rents (Taheripour and Tyner, 2007). Additionally, when reducing fuel prices, CO2 emissions increase, and there is also a rise of negative externalities produced by traffic congestions that result from a more frequent use of vehicles (Khanna et al., 2008). In fact, the recommendations suggest eliminating tax credits and maintaining blend mandates since their allow reducing gasoline consumption (fuel prices are higher) and they do not generate tributary costs for the government (De Gorter and Just, 2009b).

ELRC (2013) has recently developed a study regarding a cost-benefit evaluation of biofuel policy in Colombia for the period 2007-2025. Results reveal a net benefit of US$ 3,000 million. Nevertheless, the analysis excludes tributary costs due to exemptions to income tax and other subsidies for the productive chain. It did include the cost derived from the differential price assumed by biodiesel consumers, but deadweight costs of the lower consumption were not taken into account.

This study shows that such costs may be important because deadweight costs of lower consumption amounts reached US$ 95 million between 2010 and 2013. In sum, total costs for the consumer were $US 977 million.

6.5.1 Is subsidizing biodiesel production good for the country?

The simulations in our study, made through the model of partial static equilibrium regarding biodiesel and CPO market, show that subsidies and mandatory blends policies are effective when it comes to achieve the objectives of the Biofuels Program in Colombia. The model estimated by this study reveals that public policies in favor of the biofuel sector allow a significant increase of biofuel production profitability in general, which is reflected on larger prices and income for the agents inside the productive chain (crude oil palm producers, biodiesel producers and plant owners).

Crude oil palm producers are benefited in the short term, but biofuel entrepreneurs have access to a greater part of the income in the long term. The model simulated by Gardner (2008) points out that direct support to conventional agricultural producers are better than indirect support to the producers through ethanol subsidies. According to this author, the final impact on welfare depends on the price elasticity of the demand.

In addition, when analyzing the repercussions on land demand, our study estimated that areas cultivated with palm may increase in 65% for the period 2010-2010. The demand for additional land may magnify the existing tension in expansion zones because of land control and labor. It can be said that there are no possibilities for biodiesel exportation. The simulations show that palm production will be used to supply domestic biodiesel market. This can be pointed out as one of the weaknesses of the biodiesel production and promotion model in Colombia, because the industry needs first to improve its production efficiency so that it can compete with biofuel imports from other countries.

Nonetheless, the evaluation of welfare and efficiency costs of tax credits for biodiesel reveals that the net effect is negative. The costs of social efficiency derived from tax subsidies are small in the short term: up to US $67,000. However, this number increases in the long term to US $684,000. This result is similar to the one obtained for ethanol in the USA by Gardner (2007), who also concluded that efficiency costs are minimum in the short term but meaningful in the long term.

It is important to point out that these results do not take into consideration the combined effects of tax credits and blend mandates. In that case, efficiency and welfare costs would meaningfully increase (De Gorter and Just, 2009a). Under these conditions, the benefit-cost analysis indicates that biodiesel subsidies are unlikely to generate net social gains. In other words, subsidies or tax credits for biodiesel are not efficient for the country.

6.5.2 Alternative subsidizing scenarios

In order to achieve the objectives made by the biofuel promotion program in Colombia, it is important to acknowledge that the effects of support policies depend on the next fact: are rural producers able to own land and other supplies required for oil palm cultivation? (Latruffe and Mouel, 2009). In Colombia, the land concentration index is one of the highest around the world (0.86) and this indicates that income increases for producers –derived from state support policies for the biofuel sector- will be owned mostly by landowners through bigger land prices and rent. The state must design an assignation scheme of uncultivated lands and land distribution for small producers and farmers in suitable zones for oil palm (Fajardo, 2009b). On the other hand, it is also possible to combine blend mandates with subsidies to agricultural supplies and alternative energies (Gorter and Just, 2009b), as well as introducing direct transfers for farmers and small producers who improve their income, without imposing production and cultivation requirements for crude palm oil cultivation (Guyomard et al., 2004).

6.5.3 Limitations and possible shortcomings of the study

The partial equilibrium model solved and calibrated in this study assumed functional relations to be linear. Although this is a good approximation close to the model's equilibrium, it is important to accept that relations may not be linear, which restricts the validity of general conclusions at points close to equilibrium. On the other hand, the model does not allow the disaggregation of the different kinds of oil palm producers in order to examine the impact on large, medium and small ones. Likewise, it isn't possible to analyze functional distribution of the chain's income into wages, interests, income and profits, essential variables to determine distributive impact. Finally, given that it is a partial equilibrium model, it doesn't allow an analysis of the interrelations with the rest of sectors of the economy.

6.6 Conclusions

The main conclusion of this research is that the subsidies should not be regarded as an effective tool for achieving the goals of blending and mixtures defined in the Biofuels Program in the country. The effects on the production of CPO and biodiesel are not very important. Nonetheless, subsidies increase the producer price of CPO and biodiesel in the short and long term. The producers of the palm industry benefit to a large degree from the effects of subsidies in the short term, but in the long term biodiesel producers will get a much larger share of the income growth of the entire production chain. The efficiency loss and deadweight losses that result from the subsidy in the short term are small, but they become significant in the long term, accounting for 6.2% of the total subsidy of biodiesel associated with a grant US$53.59/ton of biodiesel.

When the subsidy and the mandatory blending levels are combined, the effects of the policy become significant. The production of CPO moves from 1,037 thousand ton in 2010 to 1,932 thousand ton in 2020. CPO used in the production of biodiesel goes from 552.3 thousand ton in 2010 to 1,968 thousand ton in 2020. Prices and incomes of producers of CPO and biodiesel increase throughout the period 2010-2020. Biodiesel prices are always above that of CPO. The income of the agricultural producers exceeds that of the businessmen involved with biodiesel between 2010 and 2017, however, following that the pattern reverses. Hence, we can say that subsidy policies and mandatory blending in the long term benefit most biodiesel producers. Finally, the planted area of palm oil increases significantly between 2010 and 2020, from 434,281 ha in 2010 to 717,749 ha in 2020, an increase of 65%. The major part of this increase will be devoted to the production of biodiesel which would maintain the incentives as proposed and analyzed in this paper and would result in the disappearance of the other uses of CPO over time.

Biofuel market in Colombia is regulated by the national government. Fuel prices are set by the Ministry of Mining and Energy (MME) through monthly resolutions. Although the guidelines issued during the last years have aimed at reducing tax costs and subsidies for fuel sale, as well as diminishing price distortion, there are still important differences between the prices paid by consumers and the fuels’ parity or competition prices. Between

2010 and 2013, biodiesel price was above diesel and mixture prices, which implied significant quasi-rents for biodiesel producers: US$ 367 million.

It is important that a cost-benefit analysis of this biofuel program explicitly includes deadweight costs from the reduction of fuel consumption, as well as the efficiency costs of the higher biodiesel production. This work shows that deadweight losses for consumers are meaningful because they reached US$ 95 million between 2010 and 2013. Costs for consumers have been reduced during time, but they may increase as a consequence of price regulation and new blend mandates. The estimations made by this study reveal that final consumers had to pay nearly US $882 million due to higher prices as a result of biofuel promotion policies.

CHAPTER 7

7. Final Conclusions

This thesis analyzes and describes some of the impacts deriving from the expansion of oil palm crops for biodiesel production in Colombia, specifically in relation to land use changes in the main areas of oil palm production; the results of the State policy of support and promotion of biofuels on the different agents integrating the productive chain, and the effects on the communities located in oil palm producing areas.

A synthesis of the results of the research is presented next, a discussion on the main limitations of this document is developed, and some ideas on future research are proposed.

7.1. General conclusions

Oil palm has been harvested in Colombia for more than fifty years. Between 1967 and 1989, cultivated areas have continuously increased at an average annual rate of 8%. Between 1990 and 1998 there was a standstill reflected in reduction of this rate in 1%. Thanks to the new orientation of Colombian development models and the implementation of the National Biofuel Policy in 2001 there has been a notable recovery of this sector: the new cultivated areas have expanded and the annual growth rate between 1999 and 2013 reached 9%. Doubtlessly, the reason behind this “new expansion” of oil palm crops in Colombia is the support to the biofuel industry. This investigation shows (through a model of intervention time series) how the support policies account for the dynamics of the new oil palm crops in this country.

The model of the oil palm-biodiesel chain value corresponds to what Albert Hirschman (1958) described as “backward linkage”: a non-primary industry (such as biodiesel production) induces oil palm producers to increase crops in order to obtain more CPO, the main raw material in biodiesel production. In fact, the partial equilibrium model (calibrated according to the Colombian case) that integrates oil palm and biodiesel markets also leads to that conclusion. It also evidenced that tax exemptions and mandatory blends significantly increase oil palm and biodiesel prices, thus improving the profitability of this value chain and minimizing other alternative CPO uses. The results of the simulations developed in this investigation show that by 2020 almost all CPO production will be used to generate biodiesel.

The benefits of the Colombian biodiesel model must be evaluated under three perspectives: i) cost-benefit analysis; ii) contribution in the economic and social development; and iii) environmental impacts. The analysis carried out in this work evidences that there are negative effects in terms of the economic efficiency of the support policies. The deadweight prices of subsidies and tax exemptions may represent 6% of this sector’s tax expenses in the long term. On the other hand, there are also negative effects related to the final consumer's wellbeing. In fact, the losses due to high prices and the reduction of the productive efficiency of these blends in the market reached US$ 907 million in the analyzed period (2010-2013).

As far as the impact of oil palm expansion on social welfare, the preliminary analysis of this dissertation indicates that there are high probabilities for a Natural Resource Curse scenario to be configured. Even though some socioeconomic indicators show that oil palm municipalities have a better performance and positive indexes in some cases, this does not guarantee the generation of a growth virtuous cycle and productive diversification. Facts such as the absence of strong institutions, corruption, and lack of clarity regarding land property rights may also contribute to inhibiting social development and growth. Additionally, although the income concentration generated by this great plantation model (which is typical in new expansion areas, such as the Eastern zone) allows to take advantage of economies of scale, it ends up increasing inequality and social conflict.

Lastly, this investigations shows that the future oil palm expansion will occur in the current oil palm nuclei, and this crop will mainly replace pastures (in the Northern, Center and Eastern zone), rice crops (Eastern zone) and banana crops (Northern zone). Some natural forest, as well as agricultural areas, will be replaced in the Southwestern zone. The forecasts indicate that oil palm will also expand to regions where there are currently no plantations: Tolima, Cundinamarca and Urabá Chocoano. These regions present weak governance, failures in land management planning and absence of environmental authorities which are independent from economic and political groups. All these factors are obstacles to the protection and conservation of natural resources and ecosystems.

As Babbier (2005): points out:

“Policy and market failures, such as rent-seeking behavior and corruption or open access resource exploitation, are prevalent in the resource sectors of many developing economies. Frontier land expansion and resources exploitation is especially associated with open access. In addition, many large-scale resources-extractive activities, such as timber harvesting, mining, ranching and commercial plantations, are often responsible for initially opening up previously inaccessible frontier areas. Investor un these activities are attracted to frontier areas because of the lack of government controls and property rights in these remote areas mean that resource rents are easily captured, and thus frontier resources-extractive activities are particularly prone to rent-seeking behavior. All of these factors combine to ensure that frontier-based economic development is unlikely to lead to high rates sustained economic growth”

7.2 Main contributions

This study offers analytical and empirical elements, by means of spatial analysis and modeling, estimates of econometric models of time series interventions, and a calibration of partial equilibrium economic models, as well as the application of multivariate statistical analysis of indicators, aimed at broadening the information and substantively contributing to the debate on the impacts of the promotion and development of biofuels in Colombia, specifically in relation to the production of biodiesel from oil palm in the following three aspects

i) Impacts of the expansion of oil palm plantations on land use and cover.

The spatial modeling analyses performed show that, in spite of the variability in land use transitions for the different areas of Colombia, the main land use transition occurred from pastures to oil palm crops. Out of the 155,100 ha of new oil palm plantations sown between 2002 and 2008, approximately 79,000 (51%) were over pastures. About 29% of the oil palm plantations replaced heterogeneous agricultural areas, while 16% replaced natural vegetation, specifically forests and savannahs. An econometric intervention model that included the effects of subsidy policies after 2002 allows predicting a maximum area sown with oil palm of approximately 650,000 ha by 2020. Additionally, projections based on production required to meet a mandatory biodiesel blend of 20% in 2020, show that approximately 930,000 ha are required to meet this fuel blend regulation. The model suggests that, under the current conditions, the future expansion of crops will especially take place towards the Center and Eastern zones. In the Central zone, expansion would occur towards Tolima, Cundinamarca and Antioquia departments, some of which feature important food production (rice and banana); this could generate future usage tensions and conflicts regarding food production.

The preoccupation over indirect land use changes (ILUC) still persists; nevertheless, the limited reach of this study does not allow the study of such changes, whose repercussions may be very important in terms of the GHG emission balance, and additionally, by loss of vegetation cover contributing to the service of water regulation and impacts on biodiversity.

This study proves that, in spite the oil palm producing sector being an important component in the agricultural export strategy, and for the biodiesel industry in Colombia, the expectations of future expansion raised by the central government do not correspond to reality. It is very unlikely for the state’s expectations of reaching 3 million ha sown with oil palm by 2020 to be met. Even with the firm government’s support, the projected oil palm plantations will not even reach a million ha by 2020. Therefore, the envisaged 20% biodiesel blend for 2020 seems unlikely.

ii) Contribution of oil palm to social welfare in the producing regions

The evaluation of the possible relationships between the oil palm industry and socioeconomic indicators in Colombia permits to highlight different conclusions. The results of this analysis reveal that the indicators that best show a difference between oil palm producing and non-producing municipalities are those of rural unsatisfied basic needs (NBI_R) and total unsatisfied basic needs (NBI_T). The national average of the NBI_R and NBI_T is considerably lower for oil palm producing municipalities. NBI_T in 2009 was 50.1 and 56.5 for oil palm producing and non-producing municipalities respectively, while NBI_R was 58.4 and 62.7 the same year. There are substantial differences by production area in the eastern zone for the three analyzed years. The municipal income index is higher for oil palm producing municipalities than for the non-producing ones, and this difference is statistically significant at a national level in 2000, 2005 and 2009, for the Northern zone in 1993, 2005, and 2009, and for the Eastern zone in all the analyzed years. These results show that in general, oil palm producing municipalities have lower levels of unsatisfied basic needs and higher Tax Revenue than the non-producing ones. Nevertheless, other very important indicators, such as the Land Concentration Index GINI_T, and the Land Owner Concentration Index GINI_P are appreciably higher for the oil palm producing municipalities in the Eastern zone. In the Central zone, the results are appreciably lower for oil palm producing municipalities. At the national level, there are not significant differences between oil palm producing and non-producing municipalities. The Violence Index is substantially higher for oil palm producing municipalities in the Northern zone in 2000 and 2005 than in the non-producing ones. In the Central zone, the Violence Index is substantially higher for oil palm producing municipalities in 2005. Significant differences were not noticed in the Eastern zone. At the national level, the Violence Index is substantially higher for oil palm producing municipalities in the Northern zone in 2000 and 2005 than in the non-producing ones. Claim can be made in general that oil palm producing municipalities show higher land concentration and intensity of violence. Seemingly, oil palm producing municipalities configure an accumulation pattern in agreement with the

Staple Trap and the Natural Resource Curse models. Major investments in oil palm producing projects linked to the large plantation spurred the economic activity, this implied higher incomes for producers and municipal governments which in turn allowed the reduction of the levels of unsatisfied basic needs, and although, this is based on a higher inequity in the distribution of the assets and income generated by the business, which intensifies the distributive conflict between legal and illegal agents present in the area.

Therefore, it is possible that oil palm production is not able to generate the virtuous cycle mentioned by the Staple Thesis. In oil palm producing zones there are continuous conflicts around land property rights and land concentration, the violence indexes are higher, and local institutions are weak. These conditions may constitute traps for the development processes of these regions (Staple Trap and Natural Resources Curse). In any case, the convergence of several legal and illegal productive activities and the presence of legal and illegal actors in these zones make it difficult to identify the impacts caused solely by oil palm industry on the economic and social transformations of these territories.

Lastly, many international analysts point out that the high-price cycle of fossil fuels has come to an end. Clearly, a fall in oil prices and raw materials threatens the sustainability of the productive model of oil palm and biofuels. Under these circumstances, this industry could be sustained only by subsidies and governmental support. However, the requirements regarding tax austerity and budget restructuring limit these state allowances. Therefore, the future of oil palm agroindustry and its growth in producing regions may not be as promising as expected.

iii) Distributive and Economic Impact Assessment of the Government's Policy of Subsidies and Mandatory Fuel Blends.

In order to analyze these impacts, a partial equilibrium model of two sectors was built in which, by means of an equation system, the crude palm oil and the industrial biodiesel production markets are interrelated. The results obtained in the simulations for the 2010-2020 time period allow to see that subsidies are not efficient instruments on their own, to achieve the expected biofuel blends defined by the Biofuel Program in Colombia. Subsidies must be complemented with mandatory biofuel blend regulations to guarantee that oil palm growing and biodiesel production be profitable enough investments, so that producers can place their bets on such business. Additionally, it has been found that, in the short term, oil palm producers profit more from the effects of subventions; although, in the long term, it is biodiesel dealers who capture most of the income growth in the whole production chain. The model’s simulations show that, under the mixed subsidies and mandatory biofuel blend policies, oil palm and biodiesel prices rise continuously during the analyzed period. Given this scenario, oil palm production will be completely intended for biodiesel production in 2020, stepping from 552,300 tons in 2010 to 1,968,000 tons in 2020, and all the other uses and exports will practically disappear. Finally, according to this model the area planted with oil palm will increase significantly between 2010 and 2020, from 434,281 ha in 2010 to 717,749 ha in 2020 that is an increase of 65%. The State subsidy is significant. In the short term, tax payers paid to entrepreneurs and consumers of biodiesel between US$2.8 million and US$9.9 million. In the long term, the amount ranges from between US$8.0 million and US$11.1million. Deadweight losses are small in the short term represent between 0.2% and 0.7% of tax expenditures (state subsidies for biodiesel). Nevertheless, in the long term are significant and rise to between 4.1% and 6.1% of the tax payer's expense account for the promotion of biodiesel.

Biofuel market in Colombia is regulated by the national government. Fuel prices are set by the Ministry of Mining and Energy (MME) through monthly resolutions. Although the guidelines issued during the last years have aimed at reducing tax costs and subsidies for fuel sale, as well as diminishing price distortion, there are still important differences between the prices paid by consumers and the fuels’ parity or competition prices. Between 2010 and 2013, biodiesel price was above diesel and mixture prices, which implied significant quasi-rents for biodiesel producers: US$ 367 million.

It is important that a cost-benefit analysis of this biofuel program explicitly includes deadweight costs from the reduction of fuel consumption, as well as the efficiency costs of the higher biodiesel production. This work shows that deadweight losses for consumers are meaningful because they reached US$ 95 million between 2010 and 2013. The estimations made by this study reveal that the final consumer’s losses (due to the high prices of the diesel-biodiesel blend) reached US $882 million between 2010 and 2013. In other words, the total losses for these consumers in the analyzed period added up to US$ 977 million.

7.3 Limitations of this study

- The availability of spatial and temporal data

The performance of spatial and temporal analyses depends on the data availability and quality. The cartographic information available in Colombia to carry out these analyses is rather limited. Including biophysical, economic and social features in spatial models is enormously difficult, since detailed spatial data at regional and local levels are not available.

The spatial analyses carried out in this research were developed at a national scale, it is necessary to refine the spatial analysis scale, so that detailed regional information may be incorporated which allows the determination of the local impacts of oil palm expansion on regional strategic ecosystems, food systems and water resources. This study should focus on areas that are more likely to be involved in oil palm crop expansion, such as the eastern and central areas.

The information related to socioeconomic variables and quality of life indicators is incomplete, heterogeneous and restricted; no per capita GDP or employment data are available at the municipal level. Data on poverty, quality of life and economic development are aggregated at departmental and national scale, which prevents the performance of local analyses at municipal level.

Even though the exercises done with the available information allow the verification of some hypothesis and trends, they will always be insufficient, given the difficulty or impossibility to quantify some rather meaningful social variables such as institution quality, citizen’s cultural level, violence generating factors, etc.

- The scope of the used economic model

The partial equilibrium model solved and calibrated in this study assumed functional relations to be linear. Although this is a good approximation close to the model’s equilibrium, it is important to accept that relations may not be linear, which restricts the validity of general conclusions at points close to equilibrium. On the other hand, the model does not allow the disaggregation of the different kinds of oil palm producers in order to examine the impact on large, medium and small ones. Likewise, it isn't possible to analyze functional distribution of the chain's income into wages, interests, income and profits, essential variables to determine distributive impact. Finally, given that it is a partial equilibrium model, it doesn't allow an analysis of the interrelations with the rest of sectors of the economy.

- The temporal period of study

Notwithstanding the fact that the commercial cultivation of oil palm in Colombia dates back more than 50 years, the growth and large scale expansion boom is very recent and can be directly linked to the promotion of the biofuel sector at a global level, and in this country it only dates back 10 years. So, the analyses performed are short termed, and it is necessary to keep monitoring the sector's development in order to verify the hypothesis and to contrast results with other producing countries.

- The weak institutional infrastructure to develop interdisciplinary research.

Research integrating environmental, economic and social analyses requires the support of research lines in the different disciplinary areas that may contribute to strengthen both the methodological and the conceptual aspects, and to both clarify and incorporate, in models and analyses, the critical interactions given between biophysical and socioeconomic aspects, assessed at different spatial and temporal scales. This interdisciplinary research infrastructure is still precarious in our universities, which amplifies the level of difficulty and effort needed approach the complexity of the areas of study specific to environmental sciences.

7.4 Future research subjects

- It is evident that macroeconomic and ecologic assessments on the impacts on human well-being deriving from the expansion of biofuels are not well represented for most countries, let alone for developing countries such as Colombia. It is necessary to refine methodologies, to standardize criteria and models, and to unify languages and measuring techniques; all this aiming at advancing in the research for the key features of the subject of this thesis.

- It is required to create a research line aimed at assessing the impacts generated by direct and indirect land use changes (DLUC – ILUC), deriving from the expansion of crops used as raw materials to produce biofuels in Colombia. There is clear evidence in other producing countries of the transformation of large extensions of wetlands, forests and natural savannahs, in order to give way to energy crops, generating noteworthy GHG emissions coming from land conversion, which could override any reduction that might have been achieved by implementing biofuels.
- Recent literature bluntly warns of the negative collateral effects of the expansion of energy crops on food production and prices. It is necessary to develop conclusive studies regarding the scale and severity of such impacts in Colombia.
- To get a complete understanding of the impact of the biofuel industry, it is urgent to advance in the research on second generation technologies to produce biofuels. It has become evident in developed countries that, in spite of the large investments in research and the ambitious production goals established in those countries, it can be predicted that advanced biofuels will only be commercially available as of the next decade, that is, first generation biofuels will still be the better part of biofuel supply in this decade, and will coexist with second generation biofuels after 2020.

An interesting interdisciplinary research line opens that integrates spatial biophysical and ecological analyses with economic analyses. From economics, it is necessary to advance in the building and calibration of computable general equilibrium models, which allow more structure and the incorporation of the interrelations between the oil palm and biofuel sectors and the rest of the economy. These models allow the performance of comparative static analyses and dynamic analyses. From the Land Use Change (LUCC) research approach, a variety of spatial analysis and modeling methods, which allow to carry out a spatially explicit analysis of the driving factors in land use change, and the socio-environmental relations and their dynamics, in order to simulate future land use patterns and to formulate analysis scenarios at the national, regional or local scale. This kind of interdisciplinary and ecologically/economically integrated research would allow the more thorough examination of the quantitative impacts of public policies, and of the expansion of oil palm cultivation on ecosystems and their services, economic growth, rural production, and income and employment distribution.

- It is important to mention that the estimations and correlations obtained by this study (thanks to the analyzed social and economic indicators) must be examined and assessed by taking into account other variables that allow determining the role of oil palm in Colombian municipalities. Microdata statistical information (such as the total area cultivated with oil palm at municipal levels) is not available. This exercise is feasible only when the oil palm census and the agricultural census are developed; this is also a topic for future investigations.

References

ABN. 2007. Agrofuels in Africa. The impacts on land, food and forest. African Biodiversity Network. Available at: http://www.biofuelwatch.org.uk/docs/ABN_Agro.pdf. (accessed 20 .03.2012).

Abdullah, S., Nakagoshi, N., 2007. Forest fragmentation and its correlation to human land use change in the state of Selangor, peninsular Malaysia. Forest Ecology and Management, 241, 1-3, 39-48

Achten, W., Verchot, L., 2011. Implications of biodiesel-induced land-use changes for CO2 emissions: case studies in tropical America, Africa, and Southeast Asia. Ecology and Society, 16, 4, 3-14.

Aguilera, M., 2002. Economía Regional. La palma africana en la Costa Caribe. Banco de la República, Cartagena.

Ahmed, S., Jaber, A., Dixon, R., Eckhart, M., Hales, D., Radka, M., Mubiru, P., et al. 2010. Renewables 2010 Global Status Report. Renewable Energy Policy Network for the 21st Century. Available at: www.ren21.net/.../REN21_GSR_2010_full_revis (accessed 20 .03.2012).

Ahmed, S., Jaber, A., Konukiewitz, M., Dixon, R., Eckhart, M., Hales, D., and Thompson, G., 2011. Renewables 2011 Global Status Report. Renewable Energy Policy Network for the 21st Century. Available at:www.ren21.net/Portals/97/documents/GSR/GSR2011_Master18.pdf, (accessed 20 .03.2012).

Aldrich, J., Forrest, D., 1984. Linear probability logit, and probit models. Series L Quantitative Applications in the Social Sciences. Newbury Park: Sage University Publication.

Andriani, R., Andrianto, A., Komarudin, H., Obidzinski, K., 2010. Environmental and Social Impacts from Palm based Biofuel Development in Indonesia. Ecology and Society, 17, 1, 25.

Arndt, C., Benfica, R., Tarp, F., Thurlow, J., Uaiene, R., 2009. Biofuels, poverty and growth: a computable general equilibrium analysis of Mozambique. Environment and Development Economics. 15, 81–105.

Auty, R., 2001. The political economy of resource-driven growth. European Economic Review 45, 839–846.

Auty, R., Alan, G., 2002. Political Economy of Resource-Abundant States. Oxford University, ed, Resources Abundance and Economic Development. Oxford University Press.

Barbier, E., 1994. Economics and Ecology. New Frontiers and Sustainable Development, Springer-Science + Business Media, B.V.

Barbier, E., 2005. Natural Resource and Economic Development. Cambridge University Press.

Barrientos, J., Castrillon, G., 2007. Generación de empleo en el sector agrario colombiano. Agronomía Colombiana 25, 2, 383-395.

Berndes, G., 2002. Bioenergy and water: the implications of large- scale bioenergy production for water use and supply. Global Environmental Change, 12,4, 253-271.

BID-MME, 2012. Evaluación del ciclo de vida de la cadena de producción de biocombustibles en Colombia. Resumen Ejecutivo. Available at: www.fedebiocombustibles.com (accessed 20 .03.2012)

Birdsall, N., Pinckney, T., Sabot, R., 2002. Natural Resources, Human Capital, and Growth. In: Resources Abundance and Economic Development. Oxford University Press.

Bochno, E., 2009. Biocombustibles visión del sector agropecuario. Ministerio de Agricultura y Desarrollo Rural (MADR). Available at: http://www.sigp.minagricultura.gov.co. (accessed 11.06.2011)

Bochno, E., 2011. El estado del arte y novedades de la bioenergía en Colombia. Organización de las Naciones Unidas para la Alimentación y la Agricultura FAO. Oficina Regional para América Latina y el Caribe.

BP, 2011. British Petroleum, Statistical Review of World Energy. Available at: http:// www.bp.com/statisticalreview. (accessed 13.01.2012)

Brundtland Report, 1987. Our Common Future. Commission on Environment and Development.

Buainain, A., Dantas, H., 2009. Crisis y pobreza rural en América Latina: el caso de Brasil. IE/UNICAMP.

Budidarsono, S., Susanti, A., Zoomers, A., 2013. Oil palm plantations in Indonesia: the implications for migration, settlement/resettlement and local economic development, in: Zhen Fang (Ed.), Biofuels Economy, Environment and Sustainability. Bogor Indonesia, pp. 1–20.

Buhaug, H., Gates, S., 2002. The Geography of Civil War. Journal of Peace Research 39, 417–433.

Bunyamin, B., 2008. Impacts of oil palm plantations on the regional economy of West Kalimantan region. Untan Press, Pontianak. Indonesia.

Cabrera, E., Vargas, D., Galindo, G., García, M., Ordoñez, M., 2011. Memoria técnica de la cuantificación de la deforestación histórica nacional – escalas gruesa y fina. Instituto de Hidrología, Meteorología, y Estudios Ambientales-IDEAM. Bogotá.

Carlson, K., Curran, L., Ratnasari, D., Pittman, A., Soares-Filho, B., Asner, G., Trigg, S., et al. 2012. Committed carbon emissions, deforestation, and community land conversion from oil palm plantation expansion in West Kalimantan, Indonesia. Proceedings of the National Academy of Sciences (USA), 109, 19, 7559–7564.

Carlton, D., Perloff, J., 1994. Modern Industrial Organization. 4Th Ed. International publishers. pp 822.

Carter, C., Finley, W., Fry, J., Jackson, D., Willis, L., 2007. Palm oil markets and future supply. Eur. J. Lipid Sci. Technol. 109, 307–314.

Castiblanco, C., Etter, A., Aide, T.M., 2013. Oil palm plantations in Colombia: a model of future expansion. Environmental Science and Policy 27, 172–183.

CENIPALMA-CORPOICA, 1999. Evaluación edafoclimática de las tierras bajo el trópico colombiano para el cultivo de la palma de aceite. Centro de Investigación e Innovación en Palma de Aceite y Corporación Colombiana de Investigación Agropecuaria, Bogotá.

CGR, 2008. Concentración en la distribución de los apoyos económicos sectoriales agropecuarios. Documento de Trabajo. Contraloría Delegada para el Sector Agropecuario. Dirección de Estudios Sectoriales.

Chile, M., 2013. Influencia socioeconómica de la producción de palma en el Recinto Valle del Sade Quinindé, Esmeraldas. Tesis de grado, Facultad de Ciencias Agrícolas, Universidad Central del Ecuador.

Chocó, PDD, 2012. Bases para el Plan de Desarrollo Departamental 2012-2015. Gobernación del Chocó.

CIJP, 2007. La memoria, presente y perspectivas de Curvaradó y Jiguamiandó (Chocó). Comisión Intereclesial de Justicia y Paz. Revista Semillas 34, 20-35.

Cimoli, M., Rovira, S., 2008. Elites and Structural Inertia in Latin America an Introductory note on the political Economy of Development. Journal of Economic Issues XLII, 327–347.

CINEP, 2009. Monocultivo y megaproyectos de la agroindustria para combustibles en Barrancabermeja; Los agrocombustibles una amenaza al derecho de la tierra en el Choco. En Pinilla, M. (Ed.), Seminario Nacional Agrocombustibles y Derecho al Territorio. Centro de Investigaciones y Educación Popular, Bogotá.

Colchester, M., 2010. Oil palm expansion in South East Asia: trends and implications for local communities and indigenous peoples. Available at: http://www.forestpeoples.org/topics/palm-oil-rspo/publication/2011/oil-palm-expansion-south-east-asia-trends-and-implications-loc. (accessed 28.06.2012).

Consulting Biofuel, 2007. Desarrollo y consolidación del mercado de biocombustibles en Colombia. Unidad de Planeación Minero Energética (UPME), Ministerio de Minas y Energía, Bogotá.

Corden, W., Neary, J., 1982. Booming sector and de-industrialization in a small open economy. The Economic Journal, 92, 368, 825-842.

CORPOICA, 2007. Presente y Futuro de la Palma de Aceite en la Zona Occidental Colombiana. Corporación Colombiana de Investigación Agropecuaria. Bogotá.

Cotula, L., Chauveau, J., Cissé, S., Colin, J., Delville, P., Neves, B., Quan, J., Toulmin, C., 2007. Changes in “customary” land tenure systems in Africa, Changes. London: IIED.

Cotula, L., Toulmin, C., 2007. Conclusion. In L. Cotula (Ed.), Changes in “customary” land tenure systems in Africa. London: IIED.

Cotula, L., Dyer, N., Vermeulen, S., 2008. Fuelling exclusion? The biofuels boom and poor people’s access to land. Order a Journal on the Theory of Ordered Sets And Applications. IIED, London.

Croezen, H., 2010. Aceite de soja y el cambio indirecto del uso de la tierra. Cultivo de agrocombustibles, el cambio indirecto del uso de la tierra y las emisiones. Brussels, Belgium: Friends of the Earth Europe.

Dahl, C., 2012. Measuring global gasoline and diesel price and income elasticities. Energy Policy. 41, 2–13.

Dale V., Efroymson, R., Kline, K., Langholtz, M., Leiby, P., Oladosu, G., Davis, M., Downing, M., Hilliard, M., 2013. Indicators for assessing socioeconomic sustainability of bioenergy systems: A short list of practical measures. Ecological Indicators 26, 87-102.

Daly, H. 1992. De la economía del mundo lleno a la economía del mundo vacío en Goodland R. et al (eds) Medio Ambiente y Desarrollo. Trotta, Madrid (1996).

DANE, 2012. Pobreza en Colombia. Comunicado de prensa. Departamento Nacional de Estadística de Colombia, Bogotá.

DANE-IGAC, 2005. Mapa de resguardos indígenas de Colombia (1:200,000). Departamento Administrativo Nacional de Estadística, Instituto Geográfico Agustín Codazzi, Bogotá.

Dauvergne, P., Neville, K., 2010. Forests, food, and fuel in the tropics: the uneven social and ecological consequences of the emerging political economy of biofuels. The Journal of peasant studies 37, 631–60.

Dávalos, L., Bejarano, A., Hall, M., Correa, H., Corthals, A., Espejo, O., 2011. Forest and Drugs: coca-driven deforestation in tropical biodiversity hotspots. Environmental Science and Technology 45, 4, 1219-1227.

Dayang, N., Kunjappn, M., Chin, G., Schoneveld, L., Potter Andriani, R., 2010. The local impacts of oil palm in Sabah, Malaysia: Lessons for an incipient biofuel sector. Available at: www.cifor.org/publications/pdf_files/WPapers/WP-78Andriani.pdf. (accessed 12.09.2012).

De Fraiture, C., Berndes, G., 2009. Biofuels and Water. In R. W. H., Cap. 8, Bringezu (Ed.), Biofuels: environmental consequences and interactions with changing land use, pp. 139-153.Gummersbach, Germany: Proceedings of the Scientific Committee on Problems of the Environment (SCOPE) International Biofuels. Available at: http://cip.cornell.edu/biofuels/. (accessed 15.09.2011).

De Fraiture, Giordano, M., Liao, Y., 2008. Biofuels and implications for agricultural water uses: blue impacts of green energy. Water Policy, 10, 51, 67-81.

De Groot, R., Wilson, MA., Boumans, R., 2002. A typology for the classification, description and valuation of ecosystem functions, goods and services. Ecological Economics 41, 393-408.

De la Torre Ugarte, D., 2006. Opportunities and challenges of biofuels for the agricultural sector and food security of developing countries. Paper presented at the expert meeting on participation of developing countries in New Dynamic Sectors World Trade, Geneva.

Dewbre, J., Antón, J., Thompson, W., 2001. The transfer efficiency and trade effects of direct payments. American Journal Agriculture Economics. 83, 1204–1214.

Dewbre, J., Short, C., 2002. Alternative Policy Instruments for Agriculture Support: Consequences for Trade, Farm Income and Competitiveness. Canadian Journal of Agricultural Economics. 50, 443–464.

DFID. (2007). Land: better access and secure rights for poor people. London. Available at: http://www.dfid.gov.uk/pubs/files/LandPaper2007.pdf.(accessed21.06.2011).

Di Lucia, L., Ahlgren, S., Ericsson, K., 2012. The dilemma of indirect land-use changes in EU biofuel policy – An empirical study of policy-making in the context of scientific uncertainty. Environmental Science and Policy, 16, 9-19.

Díaz, J., Gast, F., 2009. El Chocó Biogeográfico de Colombia, Primera. Ed. Banco de Occidente, Bogotá.

Dillon, H., Laan, T., 2008. Biofuels at What Cost? Government support for ethanol and biodiesel in Indonesia. Geneva: The Global Studies Initiative of the International Institute for Sustainable Development.

DNP. 2007. Documento CONPES 3477. Estrategia para el desarrollo competitivo del sector palmero colombiano. Consejo Nacional de Política Económica y Social, Departamento Nacional de Planeación.

DNP, 2008. Lineamientos de política para promover la producción sostenible de biocombustibles en Colombia (CONPES 3510). Departamento Nacional de Planeación, Bogotá.

DNP, 2010. Plan Nacional de Desarrollo 2010-2014. Available at:http://www.dnp.gov.co/PND/PND20102014.aspx. (accessed 02.09.2011)

DNP, 2013. CONPES Altillanura Documento Borrador. Departamento Nacional de Planeación, Bogotá.

Doppelhofer, G., Miller, R., Sala-i-Martin, X., 2000. Determinants of Long-Term Growth: A Bayesian Averaging of Classical Estimates (BACE) Approach. Available at:http://www.nber.org/paper/w7750.pdf. (accessed 12.07.2012).

Dufey, A., 2006. Biofuels production, trade and sustainable development, Group. International Institute for Environment and Development (IIED). London.

Dufey, A., Stange, D., 2011. Estudio regional sobre economía de los biocombustibles 2010: temas clave para los países de América Latina y el Caribe. CEPAL. Santiago de Chile. Available at: www.cepal.org/cgi-bin/getProd.asp?xml=/.../xml/4/. (accessed 21.10.2012).

Earth, Friends of the, 2008. Declaración final del seminario internacional; Agrocombustibles como obstáculo a la construcción de soberanía alimentaria y energética. Amigos de la Tierra, Gobierno federal de Brasil. Sao Pablo. Available at: http://www.tierra.org/spip/spip.php?article678. (accessed4.10.2012).

Earth, Friends of the, 2010. Africa: up for grabs – the scale and impact of land grabbing for agrofuels. Friends of the Earth. Brussels.

Ekins, P., Folke, C., De Groot, R., 2003. Identifying critical natural capital. Ecological Economics 44, (2-3), 159–163.

Ellis, E., Ramankutty, N., 2008. Putting people in the map: anthropogenic biomes of the world. Frontiers in Ecology and the Environment, 6, 8, 439-447.

Enders, W., 1995. Applied econometric time series, second ed. Wiley, New York.

EPI, 2010. Data center, climate, energy and transportation. Earth Policy Institute. Available at: www.earth-policy.org/data_center/C23.(accessed3.12.2012).

Ericksen, P., 2008. Conceptualizing food systems for global environmental change research. Global Environmental Change, 18, 234-245.

Etter, A., McAlpine, C., Wilson, K., Phinn, S., Possingham, H., 2006. Regional patterns of agricultural land use and deforestation in Colombia. Agriculture, Ecosystems and Environment 114, 369–386.

Etter, A., McAlpine, C., Seabrook, L., Wilson, K., 2011. Incorporating temporality and biophysical vulnerability to quantify the human spatial footprint on ecosystems. Biological Conservation 144, 1585–1594.

Etter, A., Sarmiento A., and Romero-Ruiz, M., 2011. Land use changes (1970-2020) and the carbon emissions in the Colombian Llanos. In Hill, M. J. and N. P. Hanan (Eds). Ecosystem Function in Savannas: Measurement and Modeling at Landscape to Global Scales. Taylor and Francis, New York, pp 383-402

Ewing, M., Msangi, S., 2009. Biofuels production in developing countries: assessing tradeoffs in welfare and food security. Environmental Science and Policy, 12, 4, 520-528.

Fairley, P., 2011. Next generation biofuels. Nature, 474, 2-5

Fajardo, D., 2009a. Los biocombustibles: otro capítulo dudoso de la estrategia agro exportadora. Available at: http://www.razonpublica.com.(accessed6.12.2011)

Fajardo, D., 2009b. Territorios de la agricultura colombiana. Colombia, Universidad Externado de Colombia, Primera Ed. Bogotá, pp. 1–280.

Fajardo, D., Salinas, Y., 2010. La Colombia de los agrocombustibles. Publicación Semillas, Bogotá.

Fajardo, D., 2011. Los componentes agrarios del Plan Nacional de Desarrollo. Política Tierras y Desarrollo Rural. ¿Cuál futuro para el campo colombiano? Revista Semillas, 44-45

Fajardo, D., 2012. Transformaciones recientes de la agricultura colombiana. El caso del Piedemonte de la Orinoquia. Semillas 48, 54–59.

Falkenmark, M., Rockstrom, J., 2006. The New Blue and Green Water Paradigm: Breaking New Ground for Water Resources Planning and Management. Journal of Water Resources Planning and Management 132, 3, 129-132.

FAO, 1976. A Framework for Land Evaluation. Soils Bulletin 32, FAO, Rome.

FAO, 2005. Global Forest Resources Assessment. Available at: http://www.fao.org/forestry/fra2005. (accessed 12.02.2010).

FAO, 2008. The state of food and agriculture, 2008. Lancet. 2, 1-116. Rome. Available at: http://www.ncbi.nlm.nih.gov/pubmed/12340867 (accessed 12.15.2010).

FAO, 2008. El Estado Mundial de la Agricultura y la Alimentación. Biocombustibles: perspectivas, riesgos y oportunidades Available at: http://www.fao.org/docrep/011/i00e00.htm.(accessed 12.10.2012).

FAO, 2010. Bioenergía para el desarrollo sostenible. Bogotá, pp. 1–113. Available at: www.rlc.fao.org/.../politicas_publicas_sobe_biocombustibles_colombia.pdf. (accesed 25.07.2012).

FAO Statistical Yearbook, 2011, 2012, 2013. World food and agriculture. Organization of the United Nations. Rome. Available at: http://www.fao.org/docrep/018/i3107e/i3107e00.htm (accesed 25.07.2012; 12.10.2014).

FAPRI, 2011. Food and Agricultural Policy Research. Available at: www.fapri.iastate.edu/tools/outlook.aspx. (accessed 18.05.2012).

Fargione, J., Hill, J., Tilman, D., Polasky, S., Hawthorne, P., 2008. Land clearing and the biofuel carbon debt. Science 319, 5867, 1235-1238.

Finlayson, C., D'Cruz, R., 2005. In land water systems. In R. Hassan, R. Scholes, N. Ash (Eds.), Ecosystems and human well-being: current state and trend. Washington, D.C.: Island Press.

FEDEBIOCOMBUSTIBLES, 2013. Estadísticas de Biodiesel. Available at: http://www.fedebiocombustibles.com/v3/. (accessed 18.02.2014).

FEDEPALMA, 2001. La palma africana en Colombia, apuntes y memorias 1. Federación Nacional de Cultivadores de Palma de Aceite, Bogotá.

FEDEPALMA, 2007. Mapa de ubicación de los cultivos de palma de aceite en Colombia (1: 25,000). Federación Nacional de Cultivadores de Palma de Aceite, Bogotá.

FEDEPALMA, 2010. Anuario Estadístico 2010, Federación Nacional de Cultivadores de Palma de Aceite, Bogotá.

FEDEPALMA, 2010a. La agroindustria de la palma de aceite en Colombia y en el mundo, Anuario Estadístico 2010. Federación Nacional de Cultivadores de Palma de Aceite, Bogotá.

FEDEPALMA, 2010b. Campaña de divulgación y sensibilización sobre la problemática de PC. Federación Nacional de Cultivadores de Palma de Aceite, El Palmicultor 461, 37-40.

FEDEPALMA, 2011. La agroindustria de la palma de aceite en Colombia y en el mundo, Anuario Estadístico 2011. Federación Nacional de Cultivadores de Palma de Aceite, Bogotá.

FEDEPALMA, 2012. Anuario Estadístico. Federación Nacional de Cultivadores de Palma de Aceite, Bogotá.

FEDEPALMA, 2013a. Informe de Gestión. Federación Nacional de Cultivadores de Palma de Aceite. Bogotá.

FEDEPALMA, 2013b. Anuario Estadístico. Federación Nacional de Cultivadores de Palma de Aceite, Bogotá.

FEDESARROLLO-QUARTIL, 2009. Estudio de caracterización del empleo en el sector palmero colombiano. Bogotá, Colombia.

Feintrenie, L., Chong, W., Levang, P., 2010. Why do farmers prefer oil palm? Lessons learnt from Bungo District, Indonesia. Small-Scale Forestry 9, 379–396.

Felipe, J., Kumar U., Abdon A., 2010, As you sow so shall you reap: from capabilities to opportunities, Asian Development Bank mimeograph. Forth coming as working paper of the Levy Economics Institute of Bard College.

Feng, H., Babcock, B., 2008. Impacts of ethanol on planted Acreage in market equilibrium. Iowa. Available at: www.oxfordjournals.org/content/92/3/789. (accessed 23.04.2011).

FINAGRO, 2012. Información estadística. Entrevista personal con Julio Enrique Corzo Ortega Vicepresidente de Operaciones, en marzo de 2012.

Findlay, R., 1995. Factor, Proportions, Trade, and Growth. The Ohlin Lectures, MIT Press, Cambridge, Massachusetts.

Findlay, R., Lundahl, M., 1999. The Relevance of the 1870-1914 Experience for today's Developing Economies. The United Nations University, Working Paper 162.

Floyd, J., 1965. The Effects of farm price supports on the returns to land and labor in agriculture. Journal of Political Economy 73, 148–158.

Foley, J., DeFries, R., Asner, G., Barford, C., Bonan, G., Carpenter, R. Chapin, F., Coe, M., Daily, G., Gibbs, H., Helkowski, J., Holloway, T., Homard, E., Kucharik. C., Monfreda, Ch., Patz, J., Prentice, C., Ramankutty, N., Snyder, P., 2005. Global Consequences of Land Use. SCIENCE 309, 570-574.

Friends of the Earth, 2010. Africa: up for grabs – the scale and impact of land grabbing for agrofuels. Friends of the Earth. Brussels.

Galán, E., 2012. Apuntes al eje multimodal del Río Meta. Revista Semillas 48, 84–88.

Gallagher, E., 2008. The Gallagher Review of the indirect effects of biofuels production. Renewable Fuels Agency, London.

Galor, O.,Moav, O., Vollrath, D., 2009. The Great Divergence Inequality the Emergence in Landownership, of Human-Capital Institutions, Promoting and the Great Divergence. Review of Economic Studies 76, 143–179.

Gao, Y., Skutsch, M., Drigo, R., Pacheco, P., Masera, O., 2010. Assessing deforestation from biofuels: methodological challenges. Applied Geography 31, 508-518.

Garcez, C., Vianna, D., 2009. Brazilian biodiesel policy: social and environmental considerations of sustainability. Energy 34, 645–654.

Garcia-Ulloa, J., Sloan, S., Pacheco, P., Ghazoul, J., Koh, L.P., 2012. Lovering environmental costs of oil-palm expansion in Colombia. Conservation Letters 5, 366–375.

Garcia, H., Calderon, L., 2012. Evaluación de la Política de Biocombustibles en Colombia. FEDESARROLLO, Bogotá

Gardner, B., 2007. Fuel ethanol subsidies and farm price support. Journal of Agricultural and Food Industrial Organization. 5, 1–20.

Gasparatos, A., Stromberg, P., Takeuchi, K., 2011. Biofuels, ecosystem services and human wellbeing: Putting biofuels in the ecosystem services narrative. Agriculture, Ecosystems and Environment 142, 111-128

GEF, 2010. Fortaleciendo las áreas protegidas de afuera hacia adentro en Colombia, Global Environment Facility. Available at: http://www.thegef.org/gef/node/2609 (accessed 12.10.2013).

Gerbens-Leenes, P., Hoekstra, A., Van der Meer, Th., 2008. The water footprint of bio-energy: global water use for bio-ethanol, biodiesel, heat and electricity. Value of Water Research Report Series No. 34. UNESCO-IHE.

German, L., Schoneveld, G., Pacheco, P., 2011. The Social and Environmental Impacts of Biofuel Feedstock Cultivation: Evidence from Multi-Site Research in the Forest Frontier Ecological and Society 16, 3 - 24.

Germer, J., Sauerborn, J., 2008. Estimation of the impact of oil palm plantation establishment on greenhouse gas balance. Environment Development and Sustainability 10, 697–716.

GLOBAL, ITS, 2011. The Economic Benefits of Palm Oil in Papua New Guinea. International Trade Strategies, Melbourne.

GMH, 2013. ¡Basta Ya! Colombia: memorias de guerra y dignidad. Informe General Grupo de Memoria Histórica. Imprenta Nacional, Bogotá.

Goldemberg, J., Guardabassi, P., 2009. Are biofuels a feasible option? Energy Policy 37, 10-14.

González, F., Gutiérrez, O., Nieto, C., Aponte, A., Rodríguez, J., 2012. Conflicto y Territorio en el Oriente Colombiano, Primera. ed. CINEP, COLCIENCIAS, Bogotá.

Gorter, H. De, Just, D., 2007. The Economics of U.S. Ethanol Import Tariffs with a Consumption Blend Mandate and Tax Credit. Working Paper 21. Department of Applied Economics and Management. Cornell University, Ithaca, New York.

Gorter, H., De Just, D., 2009a. The Welfare Economics of a Biofuel Tax Credit and the Interaction Effects with Price Contingent Farm Subsidies. American Journal Agriculture Economics. 91, 477–488.

Gorter, H. De, .Just, D., 2009b. The Economics of a Blend Mandate for Biofuels. American Journal Agriculture Economics. 91, 738–750.

Griffiths, H., 2010. El aceite de palma “sostenible” impulsa la deforestación. Cultivo de agrocombustibles, el cambio indirecto del uso de la tierra y las emisiones. Brussels, Belgium: Friends of the Earth Europe.

Gudynas, E., 2007. La soja en el 2008, Perspectivas bajo nuevos contextos. Observatorio en agropecuaria y sustentabilidad. OAS-CLAES-D3E.

Gudynas, E., Pardo, M., 2006. Los claroscuros de la soja en el Cono Sur. Enfoques, El País Agropecuario, Buenos Aires.

Guhl, A., 2009. Café cambios del paisaje en Colombia. Primera Edición Universidad Eafit, Medellín, Colombia.

Gunarso, P., Hartoyo, M., Agus, F., Killeen, T., 2013. Oil palm and land use change in Indonesia, Malaysia and Papua New Guinea. Report from the technical Panels of the 2° Greenhouse Gas Working Group of Roundtable on sustainable Palm oil (RSPO).

Guterman, L., 2014. Medición de costos de producción e indicadores de productividad laboral en la agroindustria de la palma de aceite en Colombia 2011-2012. XLII Asamblea General de FEDEPALMA, junio de 2014.

Gutiérrez-Vélez, V.H., DeFries, R., Pinedo-Vásquez, M., Uriarte, M., Padoch, C., Baethgen, W., Fernandes, K., Lim, Y., 2011. High-yield oil palm expansion spares land at the expense of forests in the Peruvian Amazon. Environmental Research Letters 6, 044-029.

Guyomard, H., Mouel, C., Gohin, A., 2004. Impacts of alternative agricultural income support schemes on multiple policy goals. European Review of Agricultural Economics. 31, 125–148.

Hansen, S., Olsen, S., Ujang, Z., 2012. Greenhouse gas reductions through enhanced use of residues in the life cycle of Malaysian palm oil derived biodiesel. Bio resource Technology 104, 358–66.

Hellmann, F., Verburg, P., 2011. Spatially explicit modelling of biofuel crops in Europe. Biomass and Bioenergy 35, 2411-2424.

Hertel, T., Tyner, W., Birur, D., Lafayette, W., 2008. Biofuels for all? Understanding the Global Impacts of Multinational Mandates. GTAP Working Paper No. 51.

Hertel, T., Beckman, J., 2010. Commodity Price Volatility in the Biofuel Era: An Examination of the Linkage between Energy and Agricultural Markets. GTAP Working Paper No. 60.

Hickey, S., DuToit, A., 2007. Adverse incorporation, social exclusion and chronic poverty. Chronic Poverty Research Center, University of Manchester. Manchester.

Hidalgo, A., Klinger, B., Barabasi, A., Hausmann, R., 2007. The Product space conditions the development of nations. Science 27, 317, 5837, 482-487.

Hijmans, R., Cameron, S., Parra, J., Jones, P., Jarvis, A., 2005. Very high resolution interpolated climate surfaces for global land areas. World Clim. International Journal of Climatology 25, 1965-1978.

Hirschman, A., 1958. La estrategia del desarrollo económico, Fondo de Cultura Económica, México, 1970.

Hirschman, A., Rorhschild, M., 1973. The Changing Tolerance for Income Inequality. Quarterly Journal of Economics 87, 544–566.

Hochman, G., Sexton, S., Zilberman, D., 2008. The economics of biofuel policy and biotechnology. Journal of Agricultural and Food Industrial Organization. 6, 1–22.

Hoekstra, A., 2003. Virtual water trade: Proceedings of the International Expert Meeting on Virtual Water Trade, Delft, The Netherlands, 12-13 December 2002, Value of Water Research Report Series No.12. The Netherlands: IHE Delft.

Hoekstra, A., Chapagain, A., Aldaya, M., Mekonnen, M., 2009. Water footprint manual – State of the art 2009. November 2009. Enschede, The Netherlands: Water Footprint Network.

Hosoe, N., Gasaza, K., Hashimoto, H., 2010. Text book of computable General Equilibrium modeling. Macmillan, First Edition. Great Britain.

Hospes, O., Clancy, J., 2011. Unpacking the discourse on social inclusion in value chains, in: Value Chains, Social Inclusion and Economic Development: Constrasting Theories and Realities. Routledge, London, pp. 23–41.

IDEAM, 2001. Ecosistemas de Colombia, in: IDEAM (Ed.), El medio ambiente en Colombia. Instituto de Hidrología, Meteorología y Estudios Ambientales, Bogotá, pp. 278–346.

IDEAM, 2002. Mapa de coberturas de la tierra de Colombia (1:100,000). Instituto de Hidrología y Meteorología y Estudios Ambientales, Bogotá.

IDEAM, 2004. Informe anual sobre el estado del medio ambiente y los recursos naturales renovables en Colombia. Instituto de Hidrología, Meteorología y Estudios Ambientales, Bogotá.

IDEAM-IGAC, 2009. Incorporación de criterios ambientales para la identificación de zonas aptas para el cultivo de palma de aceite en Colombia. Componente Agronómico. Instituto de Hidrología, Meteorología y Estudios Ambientales; Ministerio de Ambiente, Vivienda y Desarrollo Territorial, Bogotá. (Unpublished report and maps).

IEA, 2006. Key World Energy Statistics. Available at:www.iea.org/textbase/nppdf/.../2006/key2006. (accessed 28.04.2009).

IEA, 2010. Sustainable production of second -generation biofuels. Renewable Energy. Available at: www.oecd.org/dataoecd/17/12/44567743.pdfnp (accessed 28.03.2011).

IEA, 2010. Key World Energy Statistics. International Energy Agency. Available at: htttp:www.iea.org/textbase/np (accessed 28.03.2011).

IEA, 2012. Annual Report. International Energy Agency. Available at: http://www.iea.org/publications/freepublications/publication/IEA_Annual_Report_publicversion.pdf. (accessed 12.03.2013).

IFPRI, 2011. Las implicaciones de género en las transacciones de tierra a gran escala. International Food Policy Research Institute. Available at: www.ifpri.org/es (accessed 6.05.2011).

IGAC, 2003. Estudio General de Suelos de Colombia (1:500,000). Instituto Geográfico Agustín Codazzi, Bogotá.

IGAC, 2007. Mapa de vías de Colombia Bogotá (1:500,000). Cartografía temática. Instituto Geográfico Agustín Codazzi, Bogotá.

IGAC, 2009. Mapa de Parques Nacionales Naturales de Colombia (1:500,000). Instituto Geográfico Agustín Codazzi, Bogotá.

IGAC, UNIANDES, 2012. Atlas de la distribución de la propiedad rural en Colombia. Instituto Geográfico Agustín Codazzi, Universidad de los Andes, Bogotá.

Infante, A., Tobón, S., 2010. Bioenergía para el desarrollo sostenible. Políticas públicas sobre biocombustibles y su relación con la seguridad alimentaria en Colombia. Ministerio de Asuntos Exteriores y de Cooperación. FAO. Bogotá.

IPPC, 2007. Climate Change 2007. Mitigation of climate change. Available http://www.ipcc.ch/publications_and_data/ar4/wg3/en/contents.html. (accessed 25.07.2010).

Irwin, E., Geoghegan, J., 2001. Theory, data and methods: developing spatially explicit economic models of land use change. Agriculture, Ecosystems and Environment 85, 7-23.

IWMI, 2008. Agua para la alimentación, agua para la vida. In David Molden (Ed.), Water Management, England. Available at: www.fao.org/nr/water/docs/CA_SUMMARY_ES.pdf. (accessed 25.07.2010).

Johnson, R., Bhattacharyya, G., 1996. Estatistics, Principles and Methods, 3rd Ed. New York.

Jussi, L., Markku, O., 2009. Biofuel policies and the environment: the effects of biofuel feedstock production on climate, water quality and biodiversity, Paper Prepared for International Association of Agricultural Economics Conference. Beijing China.

Khanna, M., Ando, A., Taheripour, F., 2008. Welfare effects and unintended consequences of ethanol subsidies. Review of Agricultural Economics. 30, 411–421.

Kline, S., Dale, V., 2008. Biofuels: Effects on Land and Fire, edited by Jennifer Sills. Science, 321, 199-200.

Koh, LP., 2007. Potential habitat and biodiversity losses from intensified biodiesel feedstock production. Conserv Biol 21:1373-1375.

Koh, LP., Ghazoul, J., 2008. Biofuels, biodiversity, and people: Understanding the conflicts and finding opportunities. Biological Conservation 141, 2450–2460.

Koh, LP., Ghazoul, J., 2010. Spatially explicit scenario analysis for reconciling agricultural expansion forest protection and carbon conservation in Indonesia. Proceedings of the National Academy of Sciences (USA), 107, 24, 11140-11144.

Koh, LP., Miettinen, J., Liew, S., Ghazoul, J., 2011. Remotely sensed evidence of tropical peatland conversion to oil palm. PNAS, 108,12, 5127-5132.

Kongsager, R. and Reenberg, A., 2012. Contemporary land-use transitions: The global oil palm expansion. GLP Report No. 4. GLP-IPO, Copenhagen.

Koomen, E., Stillwell, J., Bakema, A., Scholten, H., 2007. Modelling Land-Use Change Progress and Application. Springer (eds). The Netherlands.

Koplow, D., Track, E., 2006. Biofuels at what cost? Government support for ethanol and biodiesel in the United States. Geneva, Switzerland. Available at: www.iisd.org/gsi/sites/default/files/brochure_us_update.pdf. (accessed 25.07.2010).

Kosmus, M., Renner, I., Ulrich, S., 2013. Integración de los servicios eco sistémicos en la planificación del desarrollo: un enfoque sistemático en pasos para profesionales en TEEB. Quito, Ecuador. GIZ.

Kretschmer, B., Peterson, S., 2008. Integrating Bioenery in to Computable General Equilibrium Models-A Survey. Working Paper N°1473. Kiel Institute for the World Economy.Germany.

Lambin, E., Meyfroidt, P., 2010. Land use transitions: Socio-ecological feedback versus socio-economic change. Land Use Policy 27, 108-118.

Lapan, H., Moschini, G., 2012. Second-best biofuel policies and the welfare effects of quantity mandates and subsidies. Environmental Economics and Management. 63, 224–241.

Lapola, D., Schaldach, R., Alcamo, J., Bondeau, A., Kock, J., Koelking, C., Priess, J., 2010. Indirect land-use changes can overcome carbon savings from biofuels in Brazil. Proceedings of the National Academy of Sciences 107:3388–3393.

Latruffe, L., Mouel, C., 2009. Capitalization of government support in agricultural land prices: what do we know? Journal of Economic Surveys. 23, 659–691.

Leamer, E., Maul, H., Rodriguez, S., Schott. P., 1999. Does natural resource abundance increase Latin American income inequality? Journal of Development Economics 59, 3–42.

Lederman, D., Maloney, W., 2007. Natural Resources. Neither Curse nor Destiny. Available at: https://openknowledge.worldbank.org/.../378930LAC0Natu101OFFICIAL. (accessed 25.07.2012).

Leite, C., Weidmann., J., 1999. Does Mother Nature Corrupt? Natural Resources, Corruption, and Economic Growth. Available at: www.imf.org/external/pubs/ft/wp/1999/wp9985.pdf. (accessed 23.06.2012).

Lewis Arthur, 1954. Economic Development with Unlimited Supplies of Labour. Manchester School of Economic and Social Studies. 22, 139–191.

Ley 693 de 2001, por la cual se dictan normas sobre el uso de alcoholes carburantes, y se crean estímulos para su producción, comercialización y consumo. Available at: http://www.secretariasenado.gov.co/leyes/ L0693001.HTM. (accessed 01.09.2009).

Ley 939 de 2004, por la cual se estimula la producción y comercialización de biocombustibles de origen vegetal o animal para uso de motores diesel. Available at: http: //www.secretariasenado.gov.co/leyes/L0939004.HTM.(accessed 01.09.2009).

Lienden, A., Gerbens - Leenes, P., Hoekstra, A., Meer, T. van D., 2010. Biofuel scenarios in a water perspective: The global blue and green water footprint of road Transport in 2030. Netherlands. Available at: www.waterfootprint.org/.../GerbensLeenes-Hoek.(accessed 02.04.2011)

Lotze- Campen, H., Popp, A., Beringer, T., Muller, C., Bondeau, A., Rost, S., Lucht. W., 2009. Scenarios of global bioenergy production: the trade-off between agricultural expansion, intensification and trade. Ecological Modelling 221(18), 2188-2196 .(accessed12.06.2010).

MADR, 2005. La cadena de las oleaginosas en Colombia. Una mirada global de su estructura y dinámica 1991-2005. Documento de trabajo Nº 62. Available at: http:/www.agrocadenas.gov.co

agrocadenas@iica.int (accessed 02.07.2014).

MADR, 2010. Una Política Integral de Tierras para Colombia, in: Ministerio de Agricultura y Desarrollo Rural, Bogotá.

MADR, 2011. Estadísticas del sector agropecuario. Available at:www.minagricultura.gov.co/Estadisticas/tabid/75/Default.aspx (accessed 02.04.2012).

Mandil, C., Shihab-eldin, A., 2010. Assessment of biofuels potential and limitations. Available at: www.ief.org/_.../biofuels-assessment.../ief-biofuel(accessed 02.04.2012).

Marti, S., 2008. Losing ground: the human rights impacts of oil palm plantation expansion in Indonesia. Friends of the Earth, Life Mosaic and Sawit Watch. Available at: http://www.foe.co.uk/ resource/reports/losingground-summary.pdf. (accessed 23.08.2012).

Martinelli, L., Naylor, R., Vitousek, P., Moutinho, P., 2010. Agriculture in Brazil: impacts, costs, and opportunities for a sustainable future. Current Opinion in Environmental Sustainability 2, 431–438.

Martinez Alier, J. and Roca, J., 2013. Economía Ecológica y Política Ambiental. Tercera edición. Fondo de Cultura Económica México.

Martínez, G., 2013. Panorama de la agroindustria palmera, retos y oportunidades. Presentación Seminario “La agroindustria de la palma de aceite: un negocio sostenible e inclusivo, FEDEPALMA, Universidad de la Sabana. Octubre 2013.

McAlpine, C., Etter, A., Fearnside, P., Seabrook, L., Laurance, W., 2009. Increasing world consumption of beef as a driver of regional and global change: A call for policy action based on evidence from Queensland (Australia), Colombia and Brazil. Global Environmental Change 19, 21-33.

McCarthy, J., 2010. Processes of inclusion and adverse incorporation: oil palm and agrarian change in Sumatra, Indonesia. The Journal of peasant studies 37, 821–50.

McCarthy, J., Cramb, R., 2009. Policy narratives, landholder engagement, and oil palm expansion on the Malaysian and Indonesian frontiers. The Geographical Journal 175, 112–23.

MEA. (2005). La evaluación de los ecosistemas del milenio. Millennium Ecosystem Assessment. Available at: www.maweb.org. (accessed 23.08.2012).

Mehlum, H., Moeme, K., Torvik, R., 2006. Institutions and the resource curse. The Economic Journal 116, 1–20.

Mingorance, F., Minelli, F., Du, H. Le, 2004. El cultivo de la palma africana en el chocó. Human Rights Everywhere (HREV), Diócesis de Quibdó, Bogotá Colombia.

Ministerio de Minas y Energía, MME., 2008. Precios de Referencia de Gasolina y ACPM - Precios de Referencia Gasolina Motor Corriente, 2008. República de Colombia. Available at: www.minminas.gov.co. (accessed 01.09.2009).

Ministerio de Minas y Energía, MME., 2009. Precios de Referencia de Gasolina y ACPM - Precios de Referencia Gasolina Motor Corriente, 2009. República de Colombia, Available at: www.minminas.gov.co. (accessed 01.09.2009).

Ministerio de Minas y Energía, MME. 2011. Documento de política - precios de los combustibles. Availaible at: http://www.minminas.gov.co/minminas/downloads/UserFiles/File/hidrocarburos/Capitulo_0_Resumen_ejecutivo_final.pdf. (accessed 01.06.2014).

Ministerio de Trabajo, 2013, multas por incumplimiento a normas laborales. Available at: http://www.mintrabajo.gov.co/medios-enero-2014.html?start=30 (accessed 01.06.2014).

Miyake, S., Renouf, M., Peterson, A., McAlpine, C., Smith, C., 2012. Land-use and environmental pressures resulting from current and future bioenergy crop expansion: A review. Journal of Rural Studies 28, 650–658.

Molano, A., 2008. Parar la Guerra. El Espectador. Available at: www.elespectador.com/...molano.../columna-parar-guerra. (accessed 23.04.2013).

Molano, A., 2009. En medio del Magdalena Medio, Primera Ed. CINEP, Bogotá.

Molano, A., 2012. Paramilitarismo y palma en el Catatumbo. El Espectador. Available at: http://www.elespectador.com/impreso/judicial/articulo-330074-paramilitarismo-y-palma-el-catatumbo. (accessed 23.04.2013).

Molano, A., 2014. Ley VIP. Artículo publicado en el Espectador, 18 de octubre de 2014. Available at: http://www.elespectador.com/opinion/ley-vip-columna-522853. (accessed 18.10.2014).

Msangi, S., Mandy, E.,Rosegrant, M., 2010. Biofuels and Agricultural Growth: Challenges for Developing Agricultural Economics and Opportunities for Investment. In K. Madhu, J. Scheffran, D. Zilberban (Eds.), Handbook of Bioenergy Economics and Policy. New York: Springer.

Nepstad, D., Schwartzman, S., Bamberger, B., Santilli, M., Ray, D., Schlesinger, P., Lefebvre, P., Alencar, A., Prinz, E., Fiske, G., Rolla, A., 2006. Inhibition of Amazon Deforestation and Fire by Parks and Indigenous Lands. Conservation Biology, 20, 1, 65–73

Novo, A., Jansen, K., Slingerland, M., Giller, K., 2010. Biofuel, dairy production and beef in Brazil: competing claims on land use in São Paulo state. The Journal of peasant studies 37, 769–92.

Obidzinski, K., Andriani, R., Komarudin, H., Andrianto, A., 2012. Environmental and Social Impacts of Oil Palm Plantations and their Implications for Biofuel Production in Indonesia Ecological and Society 17, 1 - 25.

OECD-FAO, 2011. Agricultural Outlook 2011-2020. Available at:www.oecd.org/.../0,3746,en_36774715_367756. (accessed 23.04.2013).

OFID-IIASA, 2009. Biofuels and food security. Vienna, Austria. Available at: www.iiasa.ac.at/.../OFID_IIASAPam_38_bio. pdf . (accessed 23.04.2013).

Oil World Annual, 2014. Statistics oilseeds. Available at: http://www.oilworld.biz/app.php?fid=1061&fpar=YToyOntzOjEzOiJQdWJsaWNhdGlvbklkIjtzOjQ6Ijc1MjMiO3M6NDoiVHlwZSI7aTowO30%3D&isSSL=0&aps=0&blub=36af38ba9e66bf787c604e91ed496413&ista=fvtztrmsb(accessed 23.10.2014).

Olmos, A., 2014. Conflictos ambientales asociados al aprovisionamiento y regulación hídrica, generados por la expansión de cultivos de palma africana. Zona oriental colombiana. Tesis de maestría, Instituto de Estudios Ambientales, Universidad Nacional de Colombia, Bogotá.

Ortiz, I., Cummins, M., 2011. Global inequality: beyond the bottom billion: A Rapid Review of Income Distribution in 141 Countries, Social and Economic Policy Working Paper. Available at: http://www.unicef.org/socialpolicy/files/Global_Inequality.pdf. (accessed 23.11.2013).

Ospina, M., 2007. Los rostros de la palma. Primera edición. FEDEPALMA, Bogotá.

Overmars, K., Stehfest, E., Ros, J., Prins, A., 2011. Indirect land use change emissions related to EU biofuel consumption: an analysis based on historical data. Environmental Science and Policy, 14, 248-257.

OXFAM, 2012. La peligrosa carrera mundial por la tierra. Available at: http://www.corporacionpba.org/portal/novevades/la-peligrosa-carrera-mundial-por-la-tierra.(accessed 23.11.2013).

Pacheco, P., 2012. Soybean and oil palm expansion in South America. A review of main trends and implications. Working Paper 90. Center for International Forestry Research (CIFOR). Bogor, Indonesia.

PDD, 2012. Bases para el Plan de Desarrollo Departamental del Choco 2012-2015, Gobernación del Chocó.

PDPMM-CINEP, 2007. Lecturas del Magdalena Medio: Región, Desarrollo y Paz. Programa de Desarrollo y Paz del Magdalena Medio, Centro de Investigación y Educación Popular (CINEP). Bogotá.

Pérez, M., 2011. Dinámica del sector palmero en Colombia y la región del Sur de Bolívar, análisis de sus conflictos ambientales. Available at: Seminarioambienteycultura.bligoo.com.co/.../Perez_Mario_2010_b. (accessed 28.06.2012)

Persson, T., Tabellini, G., 1994. Growth, Distribution, and Politics, in: Perssson, T and Tabellini, G.E. (Ed.), Monetary and Fiscal Policy, Vol 2. The MIT Press, Cambridge, Massachusetts.

PNUD, 2012. Colombia Rural- Razones para la esperanza. Informe Nacional de Desarrollo Humano 2011. Programa de las Naciones Unidas para el Desarrollo.

Posada, A., 2009. Guerreros y Campesinos, el despojo de la tierra en Colombia, Primera Ed. Grupo Editorial Norma. Bogotá.

Proexport, Colombia, 2014. Informe sobre exportaciones. Available at: http://www.proexport.com.co/publicaciones/informe-turismo-inversion-y-exportaciones. Accessed 23.08.2014.

Puyana, A., 2013. Sojización y enfermedad holandesa en Argentina: ¿la maldición verde? Revista Problemas del Desarrollo 175, 81–100.

Ramírez, M., Martínez, H., Ortiz, L., González, F., Barrios, C., 2004. Respuestas de la oferta y la demanda agrícola en el Marco de un TLC con Estados Unidos. Available at: http://www.ibcperu.org/doc/isis/9821.pdf. (accessed 15.01. 2012).

Reboratti, C., 2010. Un mar de soja: la nueva agricultura en Argentina y sus consecuencias. Revista de Geografía Norte Grande 45, 63–76.

Reilly, J., Paltsev, S., 2008. Biomass Energy and Competition for Land. Cambridge, USA, pp. 2–42.

REN, 21, 2011. Renewable Energy, Policy Network for the 21st Century, 2011. Available at: http://www.ren21.net/ren21activities/globalstatusreport.aspx (accessed 25.07. 2012).

Reyes, A., 2009. Guerreros y Campesinos, el despojo de la tierra en Colombia, Primera Ed. Grupo Editorial Norma. Bogotá.

Riechmann, J., 2014. Un buen encaje en los ecosistemas. Segunda edición de Biomímesis. Ed. Catarata. Madrid.

Rincón, H., Garavito, A., 2004. Mercado actual de la gasolina y del ACPM en Colombia e inflación, Borradores de Economía, 287, Banco de la República. Available at: http://www.banrep.gov.co/docum/ftp/borra287.pdf. (accessed 18.09. 2014).

Rincón, H., 2009. Precios de los combustibles e inflación, Borradores de Economía, 581, Banco de la República. Available at: http://www.banrep.gov.co/docum/ftp/borra581.pdf. (accessed 18.09. 2014).

Rist, L., Feintrenie, L., Levang, P., 2010a. The livelihood impacts of oil palm: smallholders in Indonesia. Biodiversity and Conservation 19, 1009–1024.

Rist, L., Feintrenie, L., Levang, P., 2010b. The livelihood impacts of oil palm: smallholders in Indonesia. Biodiversity and Conservation 19, 1572–9710.

Roa, A.,Toloza, J., 2008. Dinámicas de una resistencia cantada. En CENSAT, Agua Viva. (Ed.), Llenando Tanques, Vaciando Territorios (pp. 181-191).Bogotá: CENSAT-PCN-ECOFONDO.

Romero-Ruiz, M., Galindo, G., Otero, J., Armenteras, D., 2004. Ecosistemas de la cuenca del Orinoco Colombiano. Instituto de Investigaciones de Recursos Biológicos Alexander von Humboldt. Bogotá.

Romero-Ruiz, M., Flantua, S., Tansey, K., Berrio, J., 2012. Landscape transformations in savannas of northern South America: Land use/cover changes since 1987 in the Llanos Orientals of Colombia. Applied Geography 32, 766–776.

Rosegrant, M., Cai, X., Cline, S., 2002. World water and food to 2025. Dealing with scarcity. Washington, D.C. Available at: www.ifpri.org/pubs/books/water2025/water2025.pdf. (accessed 15.01. 2012).

Ross, M., 2004. What Do We Know About Natural Resources and Civil War. Journal of Peace Research 41, 337–356.

RSPO, 2014. Versión 2014 de la interpretación Nacional para Colombia del estándar RSPO. Available at htpp://web.fedepalma.org/interpretacion-nacional-rspo.

Rudas, G., 2008. Subsidios al alcohol carburante en Colombia. Documento de trabajo IDEA-UN. Bogotá.

Rupilius, W., Ahmad, S., 2007. Palm oil and palm kernel oil as raw materials for basic oleochemicals and biodiesel. European Journal of Lipid Science and Technology. 109, 4, 433–439

Sachs, J., Warner, A., 1999. The big push, natural resource booms and growth. Journal of Development Economics 59, 43–76.

Sachs, J., Warner, A., 2001. Natural Resources and Economic Development. The Curse of natural resources. European Economic Review 45, 827–838.

Salgado, C., 2010. Procesos de desvalorización del campesinado y antidemocracia en el campo colombiano. En J., Forero (Ed.), El campesinado colombiano entre el protagonismo económico y el desconocimiento de la sociedad (pp.15-30). Bogotá: Pontificia Universidad Javeriana.

Salgado, C., 2011. Tierra y crecimiento agropecuario ¿Qué tanto campesinado? Política Tierras y Desarrollo Rural. ¿Cuál futuro para el campo colombiano? Revista Semillas, 44-45

Salinas, Y., Álvarez, P., 2011. Dinámicas en el mercado de la tierra en Colombia. INDEPAZ, Bogotá.

Sánchez, G., Machado, A., Meertens, D., Castro, J., Nieto, P., Pinto, E., Rincón, J., 2010. La tierra en disputa, memorias del despojo y resistencias campesinas en la costa Caribe 1960-2010, Primera. ed. Grupo de Memoria Histórica de la Comisión Nacional de Reparación y Reconciliación. Vicepresidencia de la República, Bogotá.

Sarmiento, E., 2011. Transformación productiva y equidad. Después de la Crisis. Primera Edición. Escuela Colombiana de Ingeniería. pp.453.

Sayer, J., Ghazoul, J., Nelson, P., Boedhihartono, A., 2012. Oil palm expansion transforms tropical landscapes and livelihoods. Global Food Security (2012), available at: http://dx.doi.org/10.1016/j.gfs.2012.10.003 Global Food Security. (accessed 28.09.2014)

Scarlat, N., Dallemand, J., 2011. Recent developments of biofuels/bioenergy sustainability certification: A global overview. Energy Policy, 39(3), 1630-1646.

Schlesinger, S., 2010. Caña de Azúcar y el cambio de uso de la tierra en Brasil. Cultivo de agrocombustibles, el cambio indirecto del uso de la tierra y las emisiones. Brussels, Belgium: Friends of the Earth Europe.

Searchinger, T., Heimlich, R., Houghton, R., Dong, F., Elobeid, A., Fabiosa, J., Tokgoz, S., et al., 2008. Emissions from Land-Use Change. Science, 319, 1238-1240.

Seeboldt, S., Salinas, Y., 2010. Responsabilidad y sostenibilidad de la industria de la palma. ¿Son factibles los principios y criterios de la RSPO en Colombia? .Available at:www.setianworks.net/indepazHome/index.php?...id. (accessed 28.07.2012)

Sheil, D., Casson, A., Meijaard, E., van Nordwijk, M., Gaskell, J., Sunderland-Groves, J., Wertz, K., Kanninen, M., 2009. The impacts and opportunities of oil palm in Southeast Asia: What do we know and what do we need to know? Occasional Paper N°. 51. CIFOR, Bogor, Indonesia.

Siebert, S., Burke, J., Faures, J., Frenken, K., Hoogeveen, J., Döll, P., and Portmann, F., 2010. Groundwater use for irrigation – a global inventory. Hydrology and Earth System Sciences, 14, 10, 1863-1880.

Sorda, G., Banse, M., Kemfert, C., 2010. An overview of biofuel policies across the world. Energy Policy 38, 6977–6988.

Steenblik, R., 2007. Biofuels at what cost? Government support for ethanol and biodiesel in selected OECD countries. Geneva, Switzerland. Available at: www.iisd.org/gsi/sites/default/.../oecdbiofuels.pdf. (accessed 28.07.2012)

Steinbuks, J., Hertel, T., 2012. Forest, agriculture and biofuels in a land use model with environmental services, GTAP Working Paper N° 71.

Suescún, R., Alonso, G., Trejos. A., 2011. Esquema de fijación de precios de los combustibles en Colombia , Notas Fiscales, 12, Ministerio de Hacienda y Crédito Público, Available at: http://www.minhacienda.gov.co/portal/page/portal/HomeMinhacienda/politicafiscal/reportesmacroeconomicos/NotasFiscales/Boletin%2012%20Esquema%20de%20fijaci%F3n%20de%20precios%20de%20los%20combustibles%20en%20Colombia.pdf. (accessed 28.08.2014)

Taheripour, F., Tyner, W., 2007. Ethanol subsidies, Who Gets the Benefits? Biofuel, Food and Feed Tradeoffs Conference. St. Louis Missouri.

Taheripour, F., Hertel, T., Tyner, W., Beckman, J., Birur, D., 2008. Biofuels and their By-Products: Global Economic and Environmental Implications Indiana. Department of Agricultural Economics, Purdue University.

Taheripour, F., Tyner, W., 2010. Handbook of Bioenergy Economics and Policy, in: Khanna, M., Scheffran, J., Zilberman, D. (Eds.), Policy. Springer New York, New York, NY, pp. 365–383.

Tenthoff, M., 2012. La Explotación petrolera en el Centro-Oriente y el oleoducto Bicentenario de Colombia. Revista Semillas 48, 68–73.

Thoenes, P., 2007. Biofuels and Commodity Markets_Palm oil Focus. FAO. Commodities and Trade Division. Available at: http://www.fao.org/es/ESC/common/ECG/122/en/full_ paper_English.pdf. (accessed 15.11.2012).

Thorvaldour, G., 2001. Natural resource, education, and economic development. European Economic Review 45, 847–859.

Tilman, D., Socolow, R., Foley, J., Hill, J., Larson, E., Lynd, L., Pacala, S., Reilly, J., Searchinger, T., Somerville, C., Williams, R., 2009. Beneficial Biofuels— The Food, Energy, and Environment Trilemma. Science 4–5.

Timilsina, G., Beghin, J., Mensbrugghe, D. van der, Mevel, S., 2010. The Impacts of Biofuel Targets on Land-Use Change and Food Supply A Global CGE Assessment. Agricultural Economics 43, 3, 315-332.

Timilsina, G., Shrestha, A., 2011. How much hope should we have for biofuels? Energy, 36, 4, 2055-2069.

Tirado, M., Cohen, M., Aberman, N., Meerman, J., Thompson, B., 2010. Addressing the challenges of climate change and biofuel production for food and nutrition security. Food Research International, 43,7, 1729-1744.

Tirole, J., 1988. La Teoría de la Organización Industrial. Ariel (Ed.). Barcelona.

Tudela, J., Rosales, R., Samacá, H., 2004. Un análisis empírico del Fondo de Estabilización de Precios en el mercado de aceite de palma colombiano. Revista Palmas 25, 3, 85-104.

Turner, K., and Pearce, D., 1994. “Sustainable economic development: economic and ethical principles”, in Barbier, Edgard B (1994). Economics and Ecology. New Frontiers and Sustainable Development, Springer- Science +Business Media, B.V.

UNEP, 2011. Biofuels vital graphics. Powering a green economy. Available http://www.unep.org/climatechange/mitigation/Portals/93/documents/Bioenergy/VBG_Ebook.pdf. (accessed 01.09.2009).

UNFCCC, 2001. Colombia primera comunicación nacional ante la CMNUCC. Available at: unfccc.int/resource/docs/natc/colnc1.pdf. (accessed 15.10.2013).

UPME-Ministerio de Minas y Energía (2009). Biocombustibles en Colombia. Available at: en www.upme.gov.co/Docs/Biocombustibles_Colombia.pdf. (accessed 20.05. 2011).

UPME-Ministerio de Minas y Energía (2009). Biocombustibles en Colombia, Available at: www.upme.gov.co/Docs/Biocombustibles_Colombia.pdf. (accessed 01.09.2009).

USDA, 2008. Cost-of-Production Forecasts, Data Sets. (U. S. Department of Agriculture)http://www.ers.usda.gov/Data/CostsAndReturns/ (accessed 05.08.2012)

USDA, 2012. Census of agriculture. Available at: http://www.agcensus.usda.gov/Publications/2012/ (accessed 13.08.2013)

Vallejo, G., 1996. Diseño de series temporales interrumpidas. Primera Ed. Ariel, Barcelona.

Varis, O., 2007. Water demands of bioenergy production. International Journal of Water Resources Development 23 (3), 519–535.

Veldkamp, A., Lambin, E., 2001. Predicting Land Use Change. Agriculture, Ecosystems and Environment 81, 1, 1-6.

Vermeulen, S., Cotula, L., 2010. Over the heads of local people: consultation, consent, and recompense in large-scale land deals for biofuels projects in Africa. Journal of Peasant Studies 37, 899–916.

Watkins, M., 1963. A Staple Theory of Economic Growth. The Canadian Journal of Economic and Political Science 29, 141–158.

Wiesner, E., 2008. La economía política de la justicia distributiva en Colombia. Desarrollo y Sociedad 117–164.

Wilcove, D., Koh, L., 2010. Addressing the threats to biodiversity from oil-palm agriculture. Biodiversity and Conservation 19, 999-1007.

Willebald, R., 2011. Natural Resources, Setter Economies and Economic Development during the First Globalization: Land Frontier Expansion and Institutional Arrangements. Thesis doctoral. Universidad Carlos III de Madrid.

Woltjer, A., Banse, M., Meijl, H. Van, Tabeau, A., 2007. Alternative Approaches to Extend GTAP to Biofuel Crops. Agricultural Economics Research Institute

World Agroforesty Center, 2013. Oil palm plantations in Indonesia: are they sustainable? Available at: http://blog.worldagroforestry.org/index.php/topics/oil-palm-3/ (accessed01.09.2010).

World Bank, 2010. Environmental, economic and social impacts of oil palm in Indonesia: a synthesis of opportunities and challenges. Washington, D.C., USA.

World Bank, 2012. World development indicators. The World Bank. Available: http://data.worldbank.org/sites/default/files/wdi-2012-ebook.pdf. (accessed01.10.2012).

Young, E., 2011. Biofuels and indirect land use change. The case for mitigation. London. Available at: www.endseurope.com/docs/111005a.pdf (accessed01.10.2012).

Yusoff, S., Hansen, S., 2007. Feasibility Study of Performing a Life Cycle Assessment on Crude Palm Oil Production in Malaysia. The International Journal of Life Cycle Assessment, 12, 1, 50-58.

Supplementary Material Chapter 3

Supplementary Table S1.Variables and their significance in the Time Series Intervention Model for oil palm plantation growth (1967-2020) in Colombia.

Variable	Coefficient	T statistic
Constant	6,708.417	2.688049**
Dummy 2002	17,335.12	6.98045**
AR(1)	0.889558	14.86155**
MA(1)	-0.989881	-8.198342**
R-squared	0.723776	
Adjusted R-squared	0.70138	
S.E. of regression	5,316.417	
Sum squared resid	1.05E+09	
Log likelihood	-4,077.928	
Durbin-Watson stat	2	

* significant at 0.05 ** significant at 0.01

Supplementary Table S2.Statistical results of the spatial logistic regression model of oil palm plantation presence.

Parameters	Estimate	Standard error	Wald Chi^2	p-value	
Constant	11.765	8.705	1.678	0.195	ns
Altitude	-0.008	0.002	10.154	0.001	**
Annual mean temperature	-0.293	0.292	1.01	0.315	ns
Annual rainfall of driest month	0.01	0.003	7.894	0.005	**
Effective depth	-0.223	0.073	9.407	0.002	**
Relative humidity	0.207	0.179	1.339	0.247	ns
Slope	-0.205	0.095	4.641	0.031	*
Solar radiation	-0.29	0.134	4.69	0.03	*
Distance to oil palm extraction plants	-0.07	0.009	89.486	0.0001	**
Distance to roads	-0.111	0.042	6.951	0.008	**
Distance to populated centers	-0.007	0.003	5.42	0.02	*
Distance to main cities	-8.80E-06	3.00E-06	8.677	0.003	**
Population density	9.70E-07	2.30E-06	0.173	0.677	ns
Afro-descendant communities	-1.852	1.181	2.458	0.117	ns
Indigenous reserve	-11.471	230.943	1.30E-12	0.97	ns
Natural protected areas	-11.317	364.949	5.10E-13	0.99	ns

* significant at 0.05 ** significant at 0.01 (ns) not significant

Supplementary Material Chapter 5

Appendix 1. Development of the mathematical model

The lineal version of the model can be summed up in the following equations:

Biodiesel demand (D_{bd}):

$$P_y - S = a_0 - a_1 M + a_1 y \quad (1)$$

Where Py corresponds to the price demand of a biodiesel ton; *y* corresponds to biodiesel demand; S is the subsidy to the demand; and M is the mandatory blend.

The supply of other necessary goods for biodiesel production (excluding palm oil) (S_W)

$$P_w = c_0 + c_1 w \quad (2)$$

Where P_w is the price of these goods per biodiesel ton; w is the demand for other goods expressed in units of crude palm oil.

The demand of crude palm oil for other uses which are different from biodiesel production ($D_{ACPotros}$)

$$P_x = d_0 + d_1 x_2 \quad (3)$$

Where Px is the price of a ton of crude palm oil, x_2 is the demand of crude palm oil assigned for other uses, different from biodiesel sector uses.

Total supply of crude palm oil (S_{ACPt})

$$P_x = h_0 + h_1(x_1 + x_2) \quad (4)$$

Where x_1 is the total amount of crude palm oil assigned to biodiesel production.

According to Gardner (2003), in order to solve this equation system, every quantity must be measured in crude palm oil ton units. In other words, if a crude palm oil ton generates 100 biodiesel gallons, then, when the price of one biodiesel gallon is \$200, a ton would represent \$20.000. In the same way, since all biodiesel production is made under fixed coefficients, then all quantities of the equation system can be expressed in tons of crude palm oil. This means that $y = z = w = x_1$. The equation system is composed by 6 unknown variables and six equations. The fifth equation is the crude palm oil demand of the biodiesel sector.

The expression is the following:

$$P_x = P_y - P_W \quad (5)$$

Replacing the expressions (1) and (2) in the equation (5), the following is obtained:

$$P_x = (a_0 - a_1 M - c_0) + (a_1 - c_1)x_1 + S \quad (5')$$

The sixth and last equation corresponds to the land requirements for crude palm oil production, which depends only on crude oil price.

Demand or land requirement for producing crude palm oil (DT)

$$T = k_0 + k_1 P_x \quad (6)$$

Where:

T: assigned land for African oil palm cultivation

Px: price of crude palm oil ton

k_0 y k_1: are parameters

This system can be reduced to a three equation system with three unknown values. The former corresponds to equations (3), (4) and (5'), and the latter are Px, x_1 and x_2.

$$P_x = d_0 + d_1 x_2 \qquad (3)$$

$$P_x = h_0 + h_1(x_1 + x_2) \qquad (4)$$

$$P_x = (a_0 - a_1 M - c_0) + (a_1 - c_1)x_1 + S \qquad (5')$$

The equation system has solution only if the supply and demand functions are continuous, monotone, with a positive slope (for the supply) and negative slope (for the demand) (Gardner, 2003). This model is used in order to determine the effects of biodiesel promotion politics on the equilibrium endogenous variables. Two actions are taken under consideration: (i) tax exemptions acting as a tax credit, which are equivalent to consume subsidies; (ii) mandatory blends which, as Gardner points out, correspond to regulations that lead to "increase in biodiesel demand".

The subsidy (S) is added to the equation (5') on the right side, whereas the mandatory blend is equivalent to a percentage of fuel consume. In order to analyze the effects of this variable –which is considered exogenous-, it is added as M to the right side of the equation (5').

The solution of this system can be obtained by using the next algorithm. First, $x_2$in the equation (3) must be cleared; then this result must be replaced in the equation (4'). This allows obtaining a two equation system with two unknown values: x_1 and Px.

$$X_1 = \left(\frac{1}{h_1} - \frac{1}{d_1}\right)P_x - \frac{h_0}{h_1} + \frac{d_0}{d_1} \qquad (6)$$

$$P_x = (a_0 - a_1 M - c_0) + (a_1 - c_1)x_1 + S \qquad (5')$$

The system can be written by using matrices:

$$\begin{bmatrix} 1 & -(a_1 - c_1) \\ -\left(\frac{1}{h_1} - \frac{1}{d_1}\right) & 1 \end{bmatrix} \begin{bmatrix} P_x \\ X_1 \end{bmatrix} = \begin{bmatrix} a_0 - c_0 - a_1 M + S \\ -\frac{h_0}{h_1} + \frac{d_0}{d_1} \end{bmatrix} \ (7)$$

It can be solved like this:

$$x_1 = \frac{\begin{vmatrix} 1 & a_0 - c_0 - a_1 M + S \\ -\left(\frac{1}{h_1} - \frac{1}{d_1}\right) & -\frac{h_0}{h_1} + \frac{d_0}{d_1} \end{vmatrix}}{\begin{vmatrix} 1 & -(a_1 - c_1) \\ -\left(\frac{1}{h_1} - \frac{1}{d_1}\right) & 1 \end{vmatrix}} \ (8)$$

After solving the determinants with some simplifications, the solution for $x_1$can be obtained:

$$x_1 = \frac{(a_0 - c_0 + S - a_1 M)(d_1 - h_1) - h_0 d_1 + d_0 h_1}{(a_1 - c_1)(h_1 - d_1) + d_1 h_1} \quad (9)$$

$$P_x = \frac{\begin{vmatrix} a_0 - c_0 - a_1 M + S & -(a_1 - c_1) \\ -\frac{h_0}{h_1} + \frac{d_0}{d_1} & 1 \end{vmatrix}}{\begin{vmatrix} 1 & -(a_1 - c_1) \\ -\left(\frac{1}{h_1} - \frac{1}{d_1}\right) & 1 \end{vmatrix}}$$

After solving the determinants with some simplifications, the solution for Pxcan be obtained:

$$P_x = \frac{(a_0 - c_0 + S - a_1 M)h_1 d_1 + (a_1 - c_1)(-h_0 d_1 + d_0 h_1)}{(a_1 - c_1)(h_1 - d_1) + d_1 h_1} \quad (9)$$

Appendix2. **Summary of regulations and state support policies for the biofuels sector and the cultivation and production of oil palm in Colombia.**

SUPORT POLICIES FOR THE BIOFUELS SECTOR		
Type of regulation	***Law, Decree or Resolution***	***Description***
Use of alcohol fuels	Law 693 of 2001	Gasoline must contain oxygenated compounds such as alcohol fuels. The use of these fuels receives a special treatment in the sectorial policies of energetic self-sufficiency, agricultural production and labor generation.
Biofuel production for diesel engines	Law 939 of 2004	The diesel fuel used in the country may contain biofuels (vegetal or animal) for its use in diesel engines, according to quality parameters established by the Mining and Energy Ministry, and the Environment, Habitat and Territorial Development Ministry.
Technical regulation	Resolution 18 0687 of 2003, modified by the Resolution 18 of 2005 (the Mining and Energy Ministry)	It defines the technical regulations in relation to production, gathering, distribution and mixture points of alcohol fuels and its use in national and imported fuels. The start dates of the fuel oxygenation program in Colombia are determined.
Tributary incentives for alcohol fuel.	Law 788 of 2002 (Tax Reform)	Art.31: alcohol fuel assigned to the mixture with regular fuel is exempt from tax (IVA). Art. 88: the percentage of alcohol fuel assigned to the mixture with regular fuel is exempt from the payment of the global tax and the surcharge.
Tributary incentives for biodiesel	Law 939 of 2004	Art. 8. National biofuel with a vegetal or animal origin, which is used in diesel engines and mixed with diesel, is exempt from sales taxes. Art. 9. National biofuel with a vegetal or animal origin, which is used in diesel engines and mixed with diesel, is exempt from the global diesel tax.

SUPORT POLICIES FOR THE BIOFUELS SECTOR		
Type of regulation	***Law, Decree or Resolution***	***Description***
Tributary incentives for oil palm production	Law 939 of 2004	Art. 1. Long-term crops such as cocoa, rubber, oil palm, citric and fruit crops are exempt from liquid income. This is determined by the Environment, Habitat and Territorial Development Ministry. The validity of the exemption will apply for the ten years following the promulgation of this law. Art. 2. The exemption described in the last article applies for oil palm, cocoa, rubber, citric and other fruit crops, for a ten year period which starts at the beginning of the production.
Tributary incentives – Decree of custom free areas	Decree 383 of 2007	Incentives for the implementation of custom free areas for agro-industrial projects dedicated to biofuels (differential income rate and benefits regarding tax exemptions of capital goods) and export-oriented projects
Price regulation	Resolution 18 1780 of 2005, (Mining and Energy Ministry)	A price band is defined. It takes the higher value between the opportunity costs of the raw materials used in biodesel production and the opportunity cost of diesel (fossil origin). The price today is $8161 per gallon (October 2010)
Price regulation	Resolution 18 0222 of 2006 (Mining and Energy Ministry)	A price band is defined. It takes the higher value between a stability price of $4.594 per gallon which acknowledges opportunity costs of raw materials used for producing alcohol fuel (parity exportation of refined surgar). The price today is $7.766 per gallon (October 2010)
Economic incentives	Law 101 of 1993	The Incentive of Rural Capitalization (ICR for its initials in Spanish) is created and defined as a contribution made by the Nation to those who execute new investment projects in the rural sector.
Tributary incentives	Law 1111 of 2006	It establishes a 40% reduction in the tax income for investments in fixed, real and

SUPORT POLICIES FOR THE BIOFUELS SECTOR		
Type of regulation	***Law, Decree or Resolution***	***Description***
		productive actives for agro-industrial projects, including financial leasing.
Economic incentives	Law 1133 of 2007	The Agro Ingreso Seguro (AIS, safe agricultural income) is created. It is oriented to the improvement of competitiveness of the Colombian agricultural sector in the process of economy internationalization.
Support fund	Decree 2594 of 2007	This Decree regulates the Article 10 of the lay 1133 of 2007, by which the Support Fund of Risk Capital is created.
Tributary incentives	Decree 1970 of 2005	Exemption from the payment of liquid income for long-term crops for a ten year period.

Sources: FAO, 2010, DNP, 2008, CENSAT, 2010.