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Sustainable initiatives of Colombian palm oil-based biodiesel production

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Abstract

Greenhouse gas emissions (GHG) play a significant role in global warming. Energy use represents by far the largest source of anthropogenic GHG emissions accounting for 70% in 2010, mostly related to carbon dioxide (CO_2). Increasing demand for energy comes from worldwide economic growth and development. Cumulative use of vehicles and the strong growth in freight traffic increase health impacts. However, biofuel production arises as a sustainable alternative to replace conventional energy resources. In Colombia, different factors, mainly associated with decreasing fossil fuel dependency, energy security and reduction on GHG emissions have motivated the biofuels production with further promotion of sustainable development. The national production of palm oil and biodiesel has increased over the years due to efforts and technology improvements throughout the chain. In that sense, we review the current scenario of palm oil-based biodiesel in Colombia by focusing on sustainable aspects and their challenges.

As a result of the country's engagement towards biodiesel, Colombia was the largest palm oil producer in Latin America and the fourth producer in the world in 2014. Palm oil production accounted for 3.3% of agricultural gross domestic product and around 16% of the total production was exported. Moreover, the municipal incomes have increased over the years in those regions with oil palm production. Regarding the biodiesel production, more than 600 million liters contributed to reach the blending mandate of 10% (v/v). Even though the emissions of CO_2eq are not as high as other countries, Colombia must ensure the sustainable expansion of biofuels in the future.

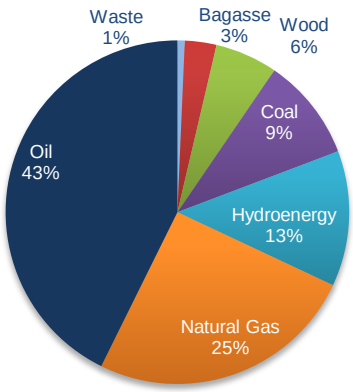
Keywords: Biofuel, renewable energy, Latin America, oleaginous industry, current scenario.

1. Introduction

Worldwide, energy demand has increased constantly in recent years and fossil fuels still remain as the major energy source [1]. Oil, coal and natural gas accounted for 33%, 30%, and 24% of the world primary energy consumption in 2013, respectively [2]. The use of energy represents by far the largest source of anthropogenic greenhouse gas emissions (GHG), approximately 70% in 2010 and mostly carbon dioxide (CO_2) [3]. In 2013, global CO_2 emissions from fossil fuel combustion and industrial processes increased 0.7 Gt than the previous year by releasing 35.3 billion tones (Gt) CO_2eq [4]. Moreover, technologies for fossil fuel extraction, transportation and processing also have harmful impacts on the environment, which can cause direct and indirect negative effects on human health and economy [5]. The increasing use of motor vehicles not only generates additional emissions (principally CO_2), but also results in growing air pollution and associated health impacts, increased vehicular congestion, more accidents and reduced competitiveness of cities [6]. In that sense, the use of alternative sources that are less energy-intensive can help improve energy security, reduce environmental impacts, such as global warming, and improve human health conditions. Due to the contribution to the greenhouse effect and other environmental issues from the use of fossil fuels, there is an increasing interest to diversify the resources of the world energy matrix to meet the growing demand of energy in a sustainable manner. One of these resources are biofuels that already represent 0.8% of total final energy consumption worldwide [7].

In Colombia, about 78% of the energy use comes from fossil fuel resources, mainly oil and natural gas (Fig. 1). Therefore, there is a great opportunity on reducing fossil fuel use and environmental impacts. Different factors, mainly associated with promoting energy security and reducing GHG emissions, have motivated the biofuels production with further promotion of sustainable development. The biofuels program began in 2001, focused on sugarcane and palm oil as the main feedstocks for ethanol and biodiesel production, respectively. In addition, Colombia was the first palm oil producer in Latin America (LA) and the fourth palm oil producer in the world [8]. In 2013, the country was the thirteenth biofuels producer in the world with 1 billion liters of biofuels, ethanol (0.4 liters) and biodiesel (0.6 liters), and the third biofuels producer in LA, after Argentina and Brazil [7].

Fig. 1. Total primary energy supply (TPES) in Colombia in 2012 [9].



In 2012, total national GHG emissions were 0.17 Gt CO_2eq (less than 1% of the global carbon emission), primarily associated with energy use. Even though the emission levels are not as high as other countries, Colombia is not excluded from climate change and efforts are needed to ensure the sustainable expansion of biofuels. In order to overcome these challenges, biodiesel has become a promising alternative to reduce fossil fuels consumption. Therefore, this paper aims to describe the current scenario of palm oil-based biodiesel production in Colombia and enlighten the current sustainable initiatives involved into the production chain. We first present the relevant aspects of the biodiesel production followed by an analysis of social, economic and environmental initiatives that have been developed by Colombia.

2. Energy situation in Colombia

2.1. Energy balance

In 2012, the Colombian total primary energy supply (TPES) was 38 Mtoe [9]. Since 70s, the total final energy consumption has continuously increased, with a total final energy consumption of 26 Mtoe in 2012. Among renewable energy sources, hydroenergy contributes to 13% of the TPES, followed by woodfuel with 6% and bagasse with 3%. Ethanol and biodiesel accounted for around 2.5% of the total final national energy consumption but growing over the years [10]. Transportation sector accounted for 44% of total final consumption, followed by industrial sector with 21%; fossil fuel dependency has been prominent along the years. Diesel represented 25% of this energy consumption followed by gasoline, which represents 13%.

2.2. Biofuels in Colombia

In Colombia, biofuel policies implemented the gasoline-ethanol and diesel-biodiesel blends. In 2013, gasoline and diesel production were more than 70,000 and 90,000 barrels/day, respectively [11]. Since 2005, gasoline consumption has declined while diesel has increased. More than 70% of the national diesel consumption is accounted by transportation sector [9]. Because of environmental issues, most of the diesel distributed in the country contains only 50 ppm of sulfur since 2013, showing an improvement of almost 95% since 1990 [12].

Moreover, biofuel initiative was launched in 2001 in Colombia with the establishment of Law 693 that sets rules and incentives for ethanol. The main drivers to encourage the biofuels program were diversifying energy production, employment creation, agribusiness development and environmental impacts reduction [13]. Therefore, in 2005 the MME (Ministry of Mines and Energy) set a mandatory (resolution 181069) fuel blending of 90% of gasoline and 10% of

ethanol (v/v) for cities with more than 500 thousand inhabitants; the blending can be modified by MME under exceptional situations or when the national supply of biofuels is too low to comply with it [14].

Following this law, in 2004 was enacted the Law 939 stimulating the production and commercialization of vegetable and animal oil for use in diesel fuel engines. Palm oil biodiesel production began in 2007, with an initial mandatory diesel-biodiesel blending of 5% (v/v) in some regions of the country. Through the years, the blending has increased and since 2013 it has been between B8 and B10 (Fig. 2). Initial production of biofuels started with 27 million liters of ethanol (2005) and 127 million liters of biodiesel (2008), and total final production in 2014 was almost 400 million liters of ethanol and 600 million liters of biodiesel (Fig. 3) [15].

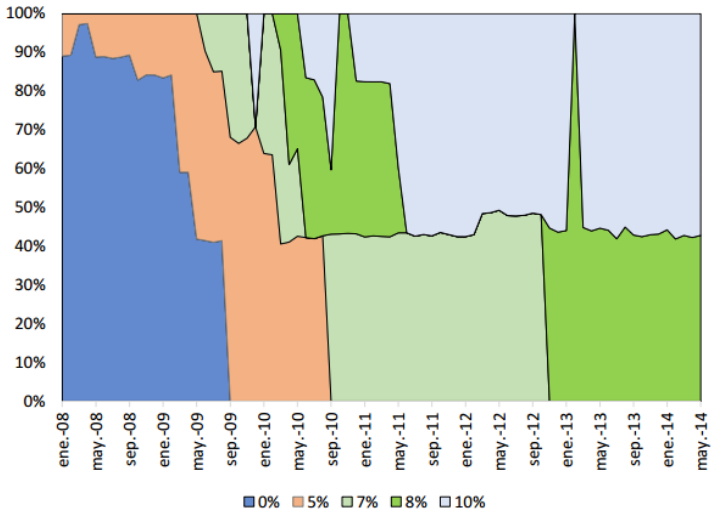


Fig. 2. Biodiesel blends trend in Colombia [16].

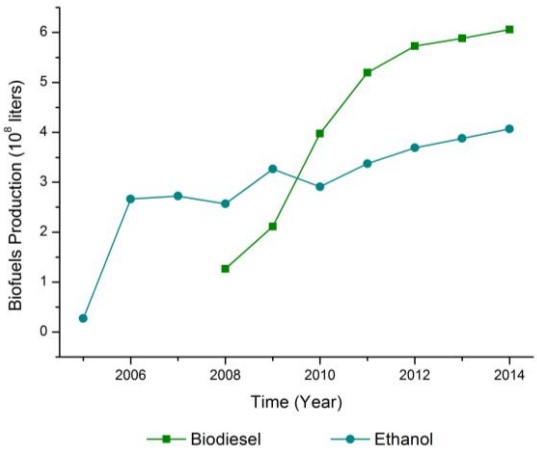


Fig. 3. Biofuels production in Colombia. Source: Data from [17].

In 2008, the Inter-Sectorial Commission for Biofuel Management (ISCBM) was established in order to coordinate the formulation and implementation of biofuel policies (Decree 2328/2008). Other initiatives have also encouraged the biofuels production and use, such as the Conpes 3510/2008, which provides guidelines to promote the sustainable production of biofuels in Colombia [13], the quality criteria of diesel-biodiesel blending (Resolution 180782/2007-90963/2014), the technical specifications for biodiesel (NTCC 5444), the good managing practices for biodiesel and blends (NTC 6032), and the transportation requirements for biodiesel B100 (NTC 5708). The MME defines the biodiesel price structure according to the regions and was initially set through the Resolution 182158/2007. Furthermore, a Sustainability Guide in Biomass Production and Processing in the Biofuel Chain, namely GTC 213, was introduced in

2011 in Colombia. This guide promotes the sustainability principles, criteria and recommendations for biofuels production [18]. Colombian biofuels are stimulated through incentives and blending mandates in order to attend the current domestic demand, such as tax exemption for net revenue from exploitation of new oil palm plantations.

3. Current scenario of oil palm in Colombia

Worldwide, there are more than 15 million hectares of oil palm that supply over 25% of the global oil consumption and approximately 60% of the international trade in vegetable oils [19]. Most of the expansion of the palm oil industry has taken place by bringing more land into production rather than through yield improvements [20]. Total global area has expanded by 4.8% per year over the last two decades while yield has increased only 1% per year [20]. Nevertheless, oil palm is among the most productive and profitable tropical crops for biofuel production. The high productivity is nearly eight times higher than other plants (soybean, sunflower and rapeseed) [21]. The higher yields are found in Malaysia and Indonesia [22]. In 2011, with 5,500 hectares Colombia was responsible for 90% of the organic palm oil fruit production worldwide [8], although it represents only 4% of the total palm oil production in the country and penetration of the Roundtable on Sustainable Palm Oil (RSPO) is 2% [8]. Oil palm introduction in the country was around 1932, mainly used for ornamental purposes [23]. In 2014, total cultivated area was almost 500 thousand hectares where the mature area represented 66% of the planted area and the immature area the remaining part [24]. The area is distributed along the central, north, east and southwest of the country with 37%, 30%, 29% and 4%, respectively. The average palm yield in Colombia was 3.25 ton/ha in 2012, with a decrease of 8.3% compared with the previous year. As consequence of improved planting materials, crop management and higher rates of extraction [24], the eastern and northern regions contributed to improve the palm oil production in 2013 by 4.5% and 3%, respectively.

Palm oil is mainly used by food and cosmetic industries and, recently, as biofuel. Palm oil demand has increased and production has been predicted to double or even triple by 2050 [25]. Since 2012, more than 50% of the palm oil production in Colombia has been for biodiesel production [24]. In 2014, the country processed more than 5 million tons of oil palm fruits, increasing 7.3% compared with the previous year. Crude palm oil (CPO) production in 2014 was over 1.1 million tons, an increasing of 6.6% compared with 2013. Therefore, the palm sector has found in biodiesel industry a way to assure a stable and continuous market for palm oil [26]. The culture of oil palm also produces a larger amount of biomass, which aggregates value to the industrial process and to the agricultural production [21]. In the extraction process, the empty fruit bunches (EFB) are sent to the field to be used as green fertilizer. The fiber and the shell are used for energy purpose. From the extraction process of the kernels, it is obtained crude palm kernel oil, which is sold to the oil-chemical industry to produce soaps and cleaning products, and to the food industry to make ice cream and for confectionery. The palm kernel meal is used as an animal feed [27]. The water contaminated with oil is centrifuged to recollect the remaining oil. After that, all water is sent to the wastewater treatment system (Fig. 4) [28].

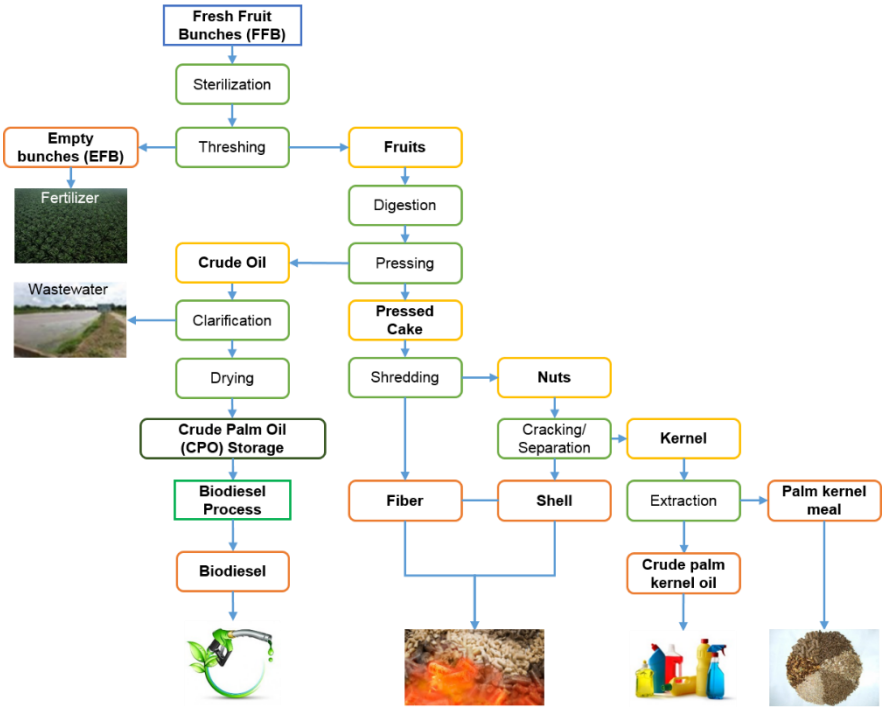


Fig. 4. Oil palm production process in Colombia.

4. Current scenario of biodiesel in Colombia

Biodiesel is a liquid biofuel from oil seeds that can be used to replace fossil fuel diesel. The main advantages of producing and using biodiesel are the reduction on fuel imports and the fuel specification, which do not require new engine technologies [29]. From 2010 to 2012, imports of ultra-low sulfur diesel (ULSD) where around 53,000 barrels/day. In 2012, the biodiesel program prevented the further importation of 9,600 barrels/day of ULSD [30]. Benefits include fossil fuel use reduction, emission savings, specifically particulate matter, and rural development.

The biodiesel production in Colombia began in 2007 with the construction of two plants in the north of the country (Atlantic Coast) able to attend the B5 blending mandate [31]. In 2014, there were six plants distributed over north, eastern and central regions which capacity surpass 500 thousand tons of biodiesel (Table 1) per year. Biodiesel supply is consumed domestically and there are neither exports nor imports of this fuel [14]. Pure biodiesel is transported in tanker trucks or ducts to the 48 regional wholesalers where the blending is done according to the current regulation, and then transported to the fuel stations across the country [32]. The crude and refined glycerin are used for cosmetics, personal hygiene products and as an additive to the tobacco industry.

Table 1. Biodiesel producers in Colombia [33].

Producers	Capacity (Tons/year)	Localization
Odin Energy	36,000	Santa Marta, Magdalena. Northern.
Oleoflores	60,000	Codazzi, Cesar. Northern.
Biocombustibles Sostenibles del Caribe	100,000	Santa Marta, Magdalena. Northern.
BioD	120,000	Facatativá, Cundinamarca. Eastern.
Aceites Manuelita	120,000	San Carlos de Guaroa. Meta, Eastern.
Ecodiesel de Colombia	120,000	Barrancabermeja, Santander. Central.

5. Towards palm oil-based biodiesel sustainability in Colombia

Many concerns have been risen about the impacts of expanding biofuels production even though they are often seen as low-carbon alternative fuels [34]. Biofuels are mainly pointed out as alternative to reduce GHG emissions. Yet, other sustainability issues have also become important. During the past decade, Colombia has adopted different strategies to promote biofuels production and use. As for biodiesel case, sustainability initiatives and some challenges are shown as following.

5.1. Social

Despite many problems regarding tenure systems, land-use rights, labor-rights and armed conflict in oil palm areas, there are socio-economic benefits on promoting the palm industry [35], which include poverty alleviation and long-term employment opportunities [19]. Since 2013, the Colombian palm oil industry provides 74,000 and 112,000 direct and indirect jobs, respectively [36]. Work conditions in this sector showed that, on average, the workers have better life quality in terms of formality, salary and compensation than other rural jobs [37]. Although better income for oil palm producers does not guarantee an increased equity in the distribution of regional incomes and a reduction of the rural and regional poverty, Castiblanco et al. [38] confirmed the improvement in municipal incomes in oil palm producer municipalities. Regarding the biodiesel industry, approximately 24,000 direct jobs and 49,000 indirect jobs were generated since de beginning of the program [33]. It is expected that the job creation due to CPO production for biodiesel from 2007 to 2025 will be up to 60,000 with a minimum monthly income of 600 US$ [30]. Furthermore, the participation of producers in the Strategic Productive Alliances scheme (SPA) stimulates gain of productivity and competitiveness. SPA is an economic and social model that associates producers (small, medium and large) in order to promote productive, profitable and sustainable projects. In 2012, there were 126 alliances with more than 70,000 planted hectares and approximately 6,000 small producers [39]. Moreover, since 2013 the Oil Palm Woman Award is given for the most outstanding woman and her contribution in the oil palm plantations.

One of the social challenges on producing biodiesel is related to the current debate on using land for biofuels versus food production. Some specialists defend that the use of crops for fuel production drives the increasing trend in global food price, while other specialists state that the rising prices are primarily due to other factors such as oil price developments, unfavorable weather conditions, financial speculation and the recent strong economic growth of China [21,40,41]. In that sense, the emergence of agro-energy on a large scale has altered the land use dynamic contributing to increase the food prices in the short run, but some authors suggest that this impact is not significant [40, 42, 43]. In Colombia, food security risk is mainly related to low productivity, lack of infrastructure and logistic, imbalance in the income and wealth distribution, currency devaluation, urban and rural unemployment and the inefficient use of land, water and genetic resources [45]. Furthermore, Castiblanco et al. [38] concluded that high levels of land concentration and violence obstruct the development in oil palm producer regions. In 2009, Rangel et al. [46] found that by intensifying the livestock density, about 6.5 million hectares can be released, which could be used for oil palm plantations without touching forest or penetrating the Colombian agricultural frontier and thus with no impact on food production. Moreover, the rural soil use is inefficient; there are 15 million hectares underutilized and 18 million hectares are overexploited. Additionally, there are 22 million hectares for agriculture and only 5.3 million hectares are properly used. Currently, livestock is using almost 39 million hectares and only 68% have an adequate use [47]. However, despite the potential for using land for biofuels without interfering on food production, expansion over new lands must also consider sustainable aspects and its potential impacts.

5.2. Environment

In 2013, oil palm cultivation was the third largest in extension, after coffee and bananas, and for the next 20 years it is expected to be the crop with the largest planted area in the country [48]. Resolution 1023/2003 adopted the Environment Guidelines as an instrument of self-management and regulation in all the productive sectors. As for palm oil sector, the guide comprises good agricultural and manufacturing practices and environmental planning. Moreover, the industry must meet the emission parameters stablished by Resolution 909/2008. In 2013, there was an improvement of oil palm production as consequence of RSPO standards, which stimulated oil palm companies supported by Farmer Support Program to move towards sustainable production [49]. Among other programs, the Sustainable Trade Platform between Colombia and Netherlands attempts to strengthen and promote sustainable production, trade and consumption of Colombia's main agricultural export products, including palm oil [50]. Also, the "Mainstreaming Biodiversity in Palm

Cropping in Colombia with an Ecosystem Approach" project aims to adopt the biodiversity friendly agro-ecological practices in the northern and eastern regions of the country, which are prioritized for the expansion of oil palm cultivation approved by the Global Environment Facility [48]. Under Umbrella Project MDL, endorsed by United Nations, a company is producing clean energy through fuel conversion of methane gas resulting from the treatment of wastewater, reducing GHG emissions [51]. This project, which involves 32 palm oil companies, is about methane capture, fossil fuels displacement and cogeneration [52] [53]. Moreover, there were 19 Colombian members certified by the RSPO standard in 2014, including 6 oil palm growers, 7 oil palm processors and traders and 3 organizations. RSPO standard has become a way to promote rural development and sustainable production. Additionally, 25 companies from oil palm sector signed a commitment declaration assuring sustainable practices over the production chain. They are committed to have at least 15,000 hectares harvested in a sustainable way by small producers and at least 200.000 certified tons of oil palm in 2016 [54].

The Colombian palm biodiesel reduces the GHG emission by 83% compared with diesel. There is a high methane emissions during the wastewater treatment, but efforts under Umbrella Project aim to reduce such emission. Colombian palm oil biodiesel performs well compared with other biofuels produced internationally and meet the GHG emissions savings defined by the international standards [28]. Additionally, in 2009 biodiesel was tested in 12 articulated buses from the national transport system with 5, 10, 20, 30 and 50% (v/v) blending and they travelled 100,000 km. Under quality specifications given by Resolution 1820782/07, the Umbrella project results showed that even with 50% blending, vehicles have good performance and reduces GHG emissions [55]. In 2013, it was also tested in 9 cargo vehicles with 10 and 20% blending and results showed that the performance remains between the medium range and most of the GHG were reduced when the concentration increased [56].

Two important environmental issues are direct land use change (dLUC) and indirect land use change (iLUC). The first refers to a change in the use or management of that area, which may lead to a change in land cover [57]. In Colombia, oil palm has mainly expanded over areas previously used as pastures [34]. Oil palm plantations account for less than 1% of the total agricultural lands and 0.3% of the country area [34]. Around 43.5 million hectares could be destined to agricultural production according to Law 2/1959 [45]. Because oil palm plantations have higher carbon stock compared with grasslands, the dLUC improves GHG balance by about 25% since most of the palm plantations were established on grasslands [28]. Rincón et al. [32] found the actual land use showed net emissions saving using the standard agronomic conditions and thus concluded the palm expansion requires adequate land use strategy to reduce LUC effects. Furthermore, potential available land for oil palm plantations in the country is 4.7 million hectares, assuming all the restrictions of RSPO [58].

Otherwise, iLUC is defined when the existing agricultural land is turned over biofuel production and agriculture has to expand elsewhere to meet the existing demand for food crops, resulting in substantial increasing in GHG emission from soil and removed vegetation [59]. The assessment of carbon reserves changes is highly important for the assessment of the biofuels potential expansion [28]. In this way, if the production of oil palm indirectly affects forest or tropical rainforest, the potential global warming impacts of biofuels are much higher compared with fossil fuels [14]. Consequently, the country requires strong political commitment for adequate land use. The iLUC consequences can be avoided by increasing agriculture and livestock efficiency, decreasing degradation and including sustainable land use planning. For Colombia, these actions might include yield intensification on existing cultivation areas and promoting land expansion over low carbon reserves such as bushes or agricultural practices that protect the existing carbon reserves and the biodiversity [28].

Besides land, water is also a key driver of agricultural production. The water footprint of crop global production was about 7,404 Gm^3/yr between 1996 and 2005, where 30% was accounted for irrigated agriculture [61]. The global average water footprint for oil palm plantation and oil production were 1,098 m^3/ton and 5,000 m^3/ton, respectively [62]. In 1999, water demands for oil palm in Colombia was 584 m^3/ton less than Indonesia (857 m^3/ton) [61].

Pests and diseases, among which stand out the bud rot and lethal wilt, are one of the main challenges faced by oil palm industry [13]. Due to bud rot disease, Colombia has lost almost 100 thousand hectares of oil palm crops in the last five decades. Similar impact has been observed in other Latin American countries, including Guyana, Ecuador and Brazil [63]. In 2008, Cenipalma (Centro de Investigación en Palma de Aceite) found the causing agent of the bud rot disease, *Phytophthora palmívora*, and since then has been efforts to reduce the incidence, such as responsible management and

best agricultural practices [63]. Also, improving the yield of existing plantations has environmental benefits once higher production reduces the impacts regarding land use change [64].

5.3. Economic

Palm oil production in 2014 accounted for 3.3% of the agricultural GDP and around 16% of the total production was exported [54]. In 2013, total palm oil exportation where around US$ 181 million, representing 7% of the total agricultural exports [54]. In 2014, financing oil palm sector represented 2.4% of the national agricultural credits and total investment was around US$110 million [65]. In the first semester of 2014, the Rural Capitalization Incentive (RCI), an economic benefit to producers that are developing new agricultural projects, invested US$ 3.7 million in the oil palm sector with an increase of 22.8% compared to the same period in the previous year [65]. Between 2002 and 2007, the Agricultural Guarantee Fund, that support credits that will finance new projects in the rural sector, invested approximately US$ 50.7 million and the RCI invested US$ 36.4 million.

Palm oil and biodiesel prices are restricted by market and government regulations. Production costs of oil palm fruit and palm oil extraction are around 574 USD/ton, leading to a total biodiesel production cost of around 0,66 USD/liter [32]. The biodiesel price is usually more expensive than diesel price [66]. In 2013, the B8 (diesel-biodiesel blending) price in Colombia was composed by taxes (16%), mark-up (11%), transportation fee of diesel and biodiesel (6%), biodiesel producer income (8%) and diesel producer income (60%). Although biodiesel production costs outweigh the diesel costs and has impact over the final price, the benefits associated with this activity will prevail over the costs in a period from 2007 to 2025 [30].

The lack of irrigation system, storage, transportation and logistics affects the industry development and thus are key issues when planning biofuels expansion. In Colombia, the low-quality of roads, railroads and ports, as consequence of complex topography and political dependency [67] [68], is considered the second most problematic factor for business agreement [67].

6. Conclusions

Biodiesel experience in Colombia has been successful due to the integration with palm oil industry. The production of palm oil and biodiesel has been increasing over the years due to the efforts and technology improvements along the chain. Biodiesel has helped diversify the fuel supply in the transportation sector, to decrease fossil fuel dependency and importations of foreign diesel. Moreover, there are greater opportunities to decrease GHG emissions and other environmental issues. Socially, does not exists a competition between food and biofuels but a set of complex situations that restrict the food availability in the country. It is important to regulate the concentration of economic power and ownership of the land and improve rural development. Environmentally, there are significant studies being developed in the country that suggest the sustainable expansion of biofuels. In the long term, the country should consider developing advanced biofuels and the integration with biorefineries in order to produce added value products, besides stimulating R&D of new technologies. In closing, the Colombian potential to become a major palm industry relies on the country's commitment and on international policies based on promoting sustainable biofuels.

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