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Optimization of the Colombian biodiesel supply chain from oil palm crop based on techno-economical and environmental criteria

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ABSTRACT

During the last years the worldwide legal framework has stimulated the biofuel development, causing their production and use to be exhaustively studied. Biodiesel has been mostly produced in European countries, but the agronomic potential of the Latin-American countries has led the effort toward the biodiesel production, via regulations. This is the case of Colombia, where the oil palm has been exploited as the major biodiesel feedstock. The acts, laws and regulations indicate the mandatory expansion of biodiesel usage. Nonetheless, the laws do not explain the way in that those expansion targets will be done. In this work, the optimal conditions of the supply chain biodiesel were studied via the techno-economic and environmental analysis. Using logistic restrictions, environmental assessment and cost minimization (all of them were estimated in this work), the optimal expansion conditions were decided, taking into account the minimal emissions and the effect of the Land Use Change (LUC) for the oil palm crop expansion. The results showed that the Middle Region is the most promising zone for biodiesel expansion, as well as the Eastern Region is the most adequate zone for expansion crops since the LUC impact is lowest. Finally, the results indicated that the biodiesel based industry must be addressed toward other feedstocks.

1. Introduction

During the last decade the Colombian Government has promoted the production and use of biofuels as a part of a strategy to reduce the fuel oil dependence and to support the rural development (Quintero et al., 2008). This national policy is supported by different mandatories established to regulate, implement, control and support the production, transport and use of fuel ethanol and biodiesel in Colombia. The Law 693 of 2001 and the Law 939 of 2004 have been the basis for technical policies as well as tax exemptions and quality standards (Secretaría del Senado, 2001, 2004). It was established that all the fossil fuels (Gasoline and Diesel) in Colombia must contain a percent of fuel ethanol and biodiesel blended with gasoline and diesel, respectively (Ministerio de Medio Ambiente Vivienda y Desarrollo Territorial and Ministerio de Minas y Energía, 2005, 2007a,b; Ministerio de Minas y Energía, 2003, 2005, 2007, 2008; Secretaría del Senado, 2002). Particularly, for biodiesel and according to the policy act 2629 of 2007, B10 blends (10% biodiesel and 90% diesel) must be implemented since 2010 and B20 since 2012 (Presidente de la República, 2007). Nevertheless, these blending targets were not reached in these years. Indeed, at December of 2011, the biodiesel blends distributed throughout the Colombian territory were B2, B7, and B10 for the Eastern, the Middle and Western and the Northern and Western zones, respectively (Ferederación Nacional de Bicombustibles, 2012). The National Planning Department (DNP), via the National Council of the Economic and Social Policies (CONPES), has indicated that the biodiesel demand by 2020 can be covered with B10 blends, demonstrating that the current expansion policies will be continued (Consejo Nacional de Política Económica y Social, 2008). Nevertheless, the market growth in Colombia implicates the expansion on biodiesel demand from B10 to B20 blend for 2020 (Infante and Tobón, 2010).

Consequently, the biodiesel demand will increase during this period. In Colombia, the biodiesel is produced mainly from palm oil obtained from oil palm fruits. Currently, more than 150,000 ha of oil palm fruits are harvested per year. This production is used to cover food and industrial applications of palm oil in Colombia (Ferederación Nacional de Bicombustibles, 2012). Therefore, an expansion on biodiesel demand

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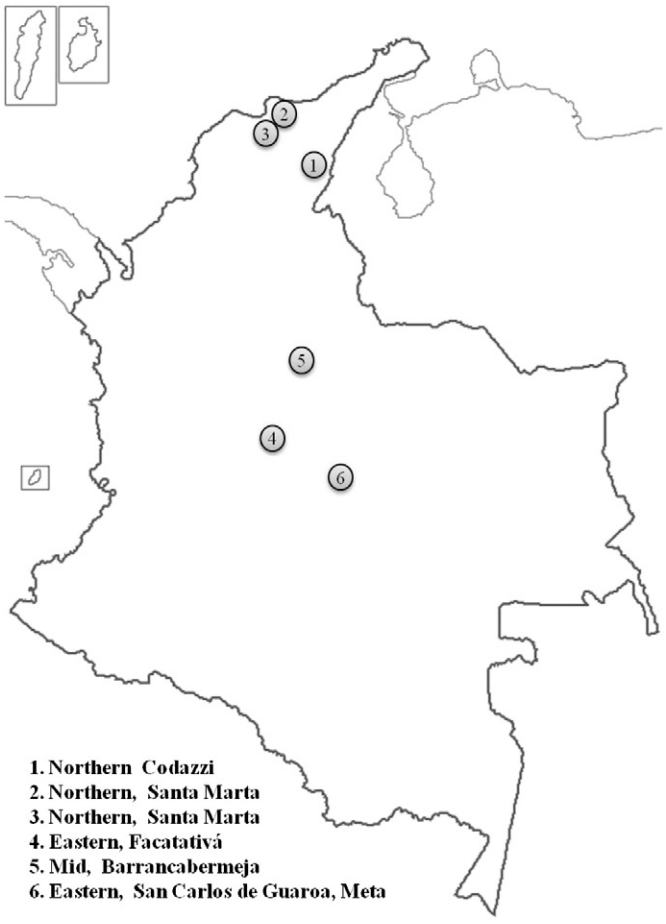

Fig. 1. Current biodiesel plant location.

will require an expansion of palm oil industry to cover all the requirements. In this sense, it is necessary to study the expansion of this industry, considering future expansion of planting oil palm areas and the requirement of increasing the production capacity of current plants or the location of new ones.

In this work, a supply chain assessment was carried out taking into account economic and environmental restrictions. According to Bai et al. (2012); Bonney and Jaber (2011); and Kretschmer et al. (2009), the environmental criteria should be included in the life cycle analysis. The main objective of this work was to evaluate the optimal conditions for oil palm expansion, based on the Greenhouse Gases (GHG) emissions, market conditions, production costs and locations. Different locations of potential biodiesel plants and expansion in oil palm areas were considered. Finally, the implications over Land Use Change (LUC) of the required crop expansion were analyzed.

Table 1
Regions for palm oil production in Colombia. Source: Calculated from data reported by Arias (2007).

Region	Departments	Total area (Ha) (including planted, mature and immature crops)	Available palm oil for biodiesel production (ton/year)
Northern	Magdalena, Cesar, Atlantico and Guajira	147,400	309,540
Middle	Santander, Norte de Santander, Bolivar	103,700	217,770
Eastern	Meta, Cundinamarca, Casanare, Caquetá	140,500	295,050
Western	Nariño	51,400	107,940
		443,000	930,300

Table 2
Biodiesel plants operating in Colombia by 2012. Source: Fedebiocombustible (2012).

Region	Company	Capacity (million L/year)	Processing capacity
Northern Codazzi	Oleoflores	60	Medium
Northern, Santa Marta	Odin Energy	40	Medium
Northern, Santa Marta	Biocombustibles Sostenibles del Caribe	100	High
Eastern, Facatativá	Bio D	100	High
Middle, B/bermeja	Ecodiesel de Colombia	100	High
Eastern, San Carlos de Guaroa, Meta	Aceites Manuelita	100	High

2. Methodology

In general, an oleochemical chain is comprised by three main echelons: Planting, extraction and refining. In Colombia, planting and extraction are integrated as the primary and intermediate echelons. Meanwhile refining includes all the industrial activities based on the production of the crude oil. In this work, the biodiesel supply chain system considers four echelons: Palm oil production, palm oil transportation, biodiesel conversion in plants and distribution to wholesalers.

Currently, the biodiesel supply chain in Colombia is distributed as follows: Four regions, which are comprised by 12 departments, containing the oil palm productive zones. The country has six production plants located in two of the four productive zones (see Fig. 1). In addition, the biodiesel can be transported by two methods: Tanker trucks (B100) and polyducts (B4 blending). The transportation through polyduct is restricted according to the region and volume. Besides, the transportation cost of the diesel in B4 blend must be assumed by the wholesaler. The biodiesel distribution to all the Colombian cities is carried out by forty eight wholesalers, authorized by the national government. Also the transportation and sale costs are regulated by the government. The distribution of the biodiesel blending is not uniform and it is regulated.

The expansion of the biodiesel industry was analyzed, considering a B20 target achievable at 2020, based on the expansion of the diesel fuel industry in Colombia reported by Mines and Energy Planning Unit of Colombia (UPME, 2012). In order to meet this biodiesel blending level, the palm oil production must be increased and new factories must be built. The first requirement is included considering local increases in regional palm oil production. The second requirement considers building new plants in each region. The total number of biodiesel plants is not defined, but the accumulative capacity per region is considered. The effect of changes in biodiesel production rates over the total costs, was previously analyzed. It indicates that at high production scales, the total costs per liter remain equal at different production rates.

2.1. System description

Oil palm grows in Colombia at 12 departments classified in four regions (see Table 1). In this model it was assumed that fresh fruit bunches (FFB) harvested at each plant site were sent to the local oil extraction plants in order to avoid FFB degradation. According to data from DANE, approximately 50% of the crude palm oil produced in Colombia is used for industrial applications, mainly biodiesel production. Conservative estimations of OECD-FAO expect that the share of vegetable oil consumption used for biodiesel production in the world reaches a 15% in 2019 (OECD-FAO, 2010). However, for the Colombian case, based on the current environmental concerns and the area restrictions of planting growth rates, it is necessary that at least the 50% of the palm oil be used in biodiesel production. This restriction allows to meet both the required B20 target and do not affect the food security. The remaining part is fractionated to