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Assessing Social Sustainability for Biofuel Supply Chains: The Case of Aviation Biofuel in Brazil

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***Abstract*—Aviation fuels derived from biomass are generally perceived as sustainable alternatives compared with their fossil counterparts. However, the production of jet biofuels will have impacts on environment, economy and society simultaneously. Despite that a large number of studies have evaluated environmental impacts or techno-economic feasibility of aviation biofuels, very few studies took social aspects into consideration. Thus, this study seeks to provide a social sustainability evaluation for aviation biofuels with a supply chain perspective. Three potential jet biofuel supply chains, based on different feedstocks, i.e. sugarcane, eucalyptus and macauba, were analyzed in the context of Brazil. The assessment is performed mainly with a process-based approach combined with input-output analysis. A set of social sustainability issues, including employment, working condition, labor right, gender equity and social development, were evaluated in a quantitative manner. The results show the three supply chains lead to differentiated levels of social effects. The macauba-based supply chain generates the highest number of jobs and highest GDP value, whereas the eucalyptus-based supply chain offers more employment opportunities for women. In comparison, the sugarcane-based supply chain has relatively moderate social effects. For future work, the assessment of social sustainability needs to cover a wider range of social issues, in order to extend the comprehension of social sustainability regarding biofuels. Additional research is suggested to bridge the methodological gaps in social sustainability assessment.**

Keywords*—Social sustainability; jet biofuel; sustainability assessment; social effects; socio-economic impacts; biobased supply chain

I. INTRODUCTION

The aviation industry has committed to lower its greenhouse gas (GHG) emissions to reach carbon neutral by 2020 and a further reduction of 50% emissions by 2050 compare to the 2005 level [1]. Jet fuel derived from biomass is generally considered a sustainable alternative in terms of emissions reduction compared with conventional fuels [2-4]. However, the production of biofuel will have impacts on environment, economy and society when taking the whole supply chain into account. While most studies examined environmental impacts and/or techno-economic feasibility of aviation biofuels, very few studies took the social /socioeconomic dimension into consideration [5]. Despite the shortage of discussion on social issues, the importance of social sustainability has been recognized by an increasing number of studies [6-13]. In conceptual studies, food security, rural development, small holder involvement, employment, working condition, health and safety, training and education, energy security, equity, land tenure, welfare and so forth have been discussed as relevant social sustainability issues associated with biofuels production and supply chain [14-19]. Nevertheless, to the best of the author's knowledge, the social/socioeconomic aspects of sustainability have rarely been analyzed for aviation biofuels in a systematic manner. The aim of this study is, thus, to perform a social sustainability assessment for aviation biofuel with a supply chain perspective, through evaluating a set of specific social sustainability issues.

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II. APPROACH

Brazil is chosen for case study in this research mainly due to its successful experiences in biofuels development [20]. The scope of this study (see Fig. 1) covers essential phases of jet biofuel supply chain, from feedstock production to biofuel distribution. The aviation biofuel supply chains are designed to cover 10% fuel demand for two Brazilian airports, i.e. Guarulhos airport (in Sao Paulo State) and Galeão airport (in Rio de Janeiro State) for the year 2020, which is around 200 kilo tons (kton) per year [21, 22]. The blending of jet biofuel is assumed to be 50% based on the ASTM certificate standard (ASTM D7566). The selling price of jet biofuel is assumed 900 US$/ton, which is the minimum biojet selling price that covers operational and capital expenses, according to Santos et al. [21]. Sugarcane, eucalyptus and macauba are identified as optimal feedstocks among sugar-bearing crops, lignocellulose crops and oil-bearing crops, respectively, to establish aviation biofuel industry in Brazil [21-23]. Therefore, the assessment of social sustainability is conducted for three jet biofuel supply chains, i.e. sugarcane-based supply chain (SS), eucalyptus-based supply chain (ES) and macauba-based supply chain (MS). A comparative analysis of social sustainability effects for SS, ES and MS is represented in the next section. The main characteristics of the jet biofuel supply chains considered in this study are listed in Table 1 [21, 22].

Over the supply chains, a set of social sustainability issues were evaluated in a quantitative way, namely employment, working condition, gender equity, labor right and social development (presented by GDP). The selection of these social issues is based on two criteria: (1) these issues are highly important related to jet biofuel production; (2) methodologies and data sources are available for assessing these issues. The employment effects and GDP effects were assessed with a process-based approach combined with input-output (IO) analysis. IO analysis is a macroeconomic assessment approach that allows the evaluation of not only direct but also indirect macroeconomic effects in various economic sectors caused by a new economic activity [24, 25]. Direct employment refers to the employment generated in sectors directly participating in jet biofuel production whereas indirect employment is created in sectors providing intermediate products or services for the production of biofuel. Specifically, to produce the final demand of 200 kton jet biofuel, inputs (in monetary terms) are required from various economic sectors, such as agriculture, forestry, chemicals, transport, trade, utilities etc., thereby creating economic activities which can be translated into socioeconomic effects, i.e., employment and added value (GDP).

TABLE I. MAIN FEATURES OF THE JET BIOFUELS

Jet biofuel supply chain	Jet biofuels characteristics		
	Feedstock	*Biorefinery type*	*Conversion pathway*
SS	Sugarcane	1G/2G ethanol	ETJ[a]
ES	Eucalyptus	2G ethanol	FP[b]
MS	Macauba	Vegetable oil	HEFA[c] + FP

a. ETJ: ethanol to jet; b. FP: fast pyrolysis; c. HEFA: hydro-processed esters and fatty acids

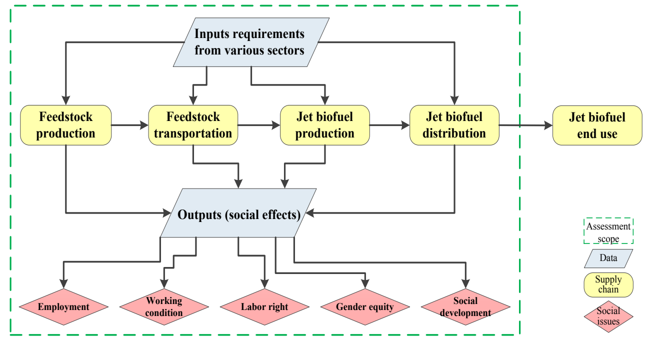

Figure 1. Scope for social sustainability assessment

Based on the employment effects calculated with IO analysis, it is then possible to evaluate working condition, gender equity and labor right over the supply chains, through analytical methods. More specifically, working condition was assessed with the potential number of occupational accidents in each sector involved in jet biofuel supply chain while gender equity was analyzed with the share of female employees in each sector. Similarly, labor right effect was evaluated with the fraction of potential informal employment, i.e. employment without a labor contract. Relevant data were acquired from Brazilian official statistics websites such as Brazilian Institute of Geography and Statistics (IBGE) [26], Ministry of Labor and Employment (MTE) [27] and Ministry of Social Security (MPS) [28].

III. RESULTS AND DISCUSSION

A. *Employment*

As shown in Fig. 2, MS generates the largest number of employment, which is more than 10000 in total throughout the entire chain. In comparison, around 8100 and 7800 jobs are created in SS and ES, respectively. Over the three supply chains, similar sectors such as agriculture, forestry, transportation, trade and chemicals are where the majority of direct jobs are generated, indicating these industries are activated in the production of aviation biofuel.

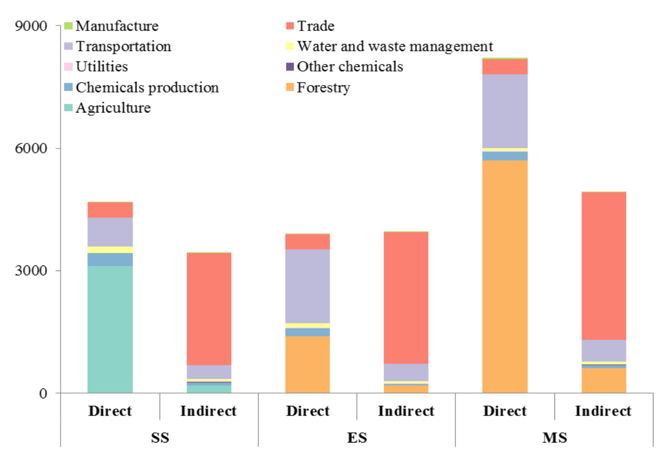

Figure 2. Employment number over jet biofuel supply chains, for a 200 kton/yr capacity

High demand of feedstocks for producing jet biofuel leads to high input requirement in the agriculture and forestry sectors. Next to this, the labor-intensive feature of these two sectors also contributes to the large number of employment. Indirect employment, on the other hand, is predominantly created in trade and transportation sectors, in order to facilitate the functioning of jet biofuel supply chains.

B. Working condition

Working condition related to aviation biofuel is assessed with the potential occupational accidents in each sector involved in SS, ES and MS. As shown in Fig. 3, MS has the lowest share of job-related accidents among the three. Fig. 4 shows the majority of potential accidents are associated with agriculture, chemicals and transportation industries in SS, while those are related with forestry, chemicals and transportation sectors in ES and MS. This is mainly due to the large number of employment in the these sectors as well as higher values of the corresponding occupational accident coefficients (number of accidents per thousand workers) in those sectors. From the whole chain perspective, MS sees the largest number of occupational accidents. However, the percentage of its occupational accidents turns out to be the lowest among the three.

C. Gender equity

Gender equity over the jet biofuel supply chain is represented by the fraction of female employees in each sector. The total numbers of female employees in SS, ES and MS are projected to be around 2300, 2400 and 3400 respectively. Nonetheless, the shares of female employees in all supply chains remain relatively low, i.e. less than 40%. As shown in Fig. 5, in both direct and indirect employment, ES has a slightly higher percentage of female workers compared with SS and MS. This is due to that employment in ES is predominantly created in sectors such as chemicals and trade, where the value of female employee coefficient (number of female workers per thousand workers) is higher than other sectors. The relatively bigger share of female workers might suggest that ES tends to be relatively more activated in engaging female employees.

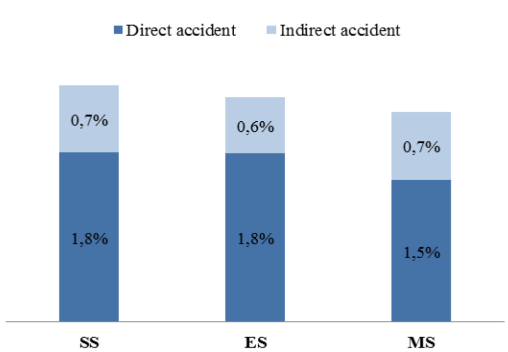

Figure 3. Potential occupational accidents over the supply chains

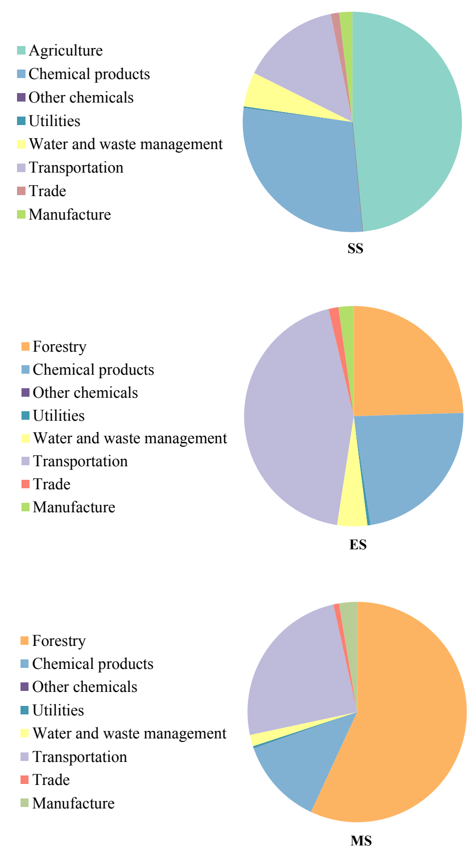

Figure 4. Composition of total occupational accidents in each supply chain

D. Labor right

Labor right, in this study, is measured by the percentage of employment without a labor contract, which in the meanwhile reflects the level of job security of the employees. The highest number of informal employment is observed in MS (more than 3000 overall) whereas SS and ES have less informal labor. This result is expected since MS has the largest number of employment. Throughout the supply chains, the percentages of informal labor are quite close in the three supply chains (see Fig. 6). Specifically, in MS about 76.1% jobs are provided with labor contract, which is slightly higher than that in SS (75.8%) and ES (75.5%). This implies that sectors with lower risk of no contract are relatively more activated in MS than the other two supply chains.

E. Social development

In line with the above defined production scale, i.e. 200 kton per year, SS, ES and MS will contribute around 210, 210 and 300 million US$ GDP, respectively, to the national economy (see Fig. 7). The key contributors in SS are direct GDP from agriculture, chemicals and transportation sectors, as well as indirect GDP from trade sector. In ES and MS, in comparison, direct GDP is mainly created in forestry, transportation and chemicals sectors whilst trade sector is highly activated with regard to the indirect GDP effects.

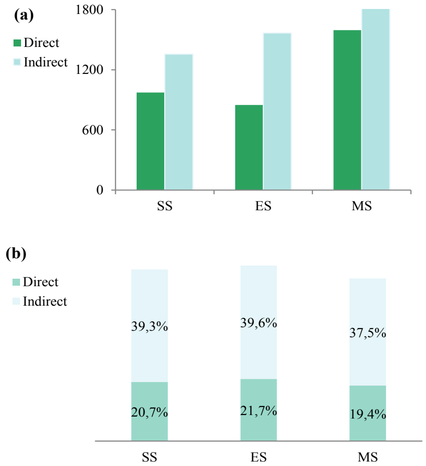

Figure 5. Comparison of (a) number and (b) percentage of female employees

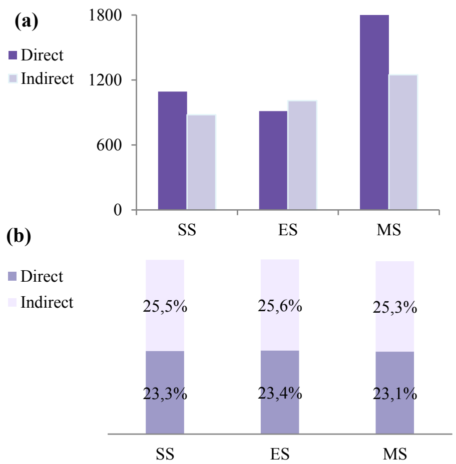

Figure 6. Comparison of (a) number and (b) percentage of informal labor

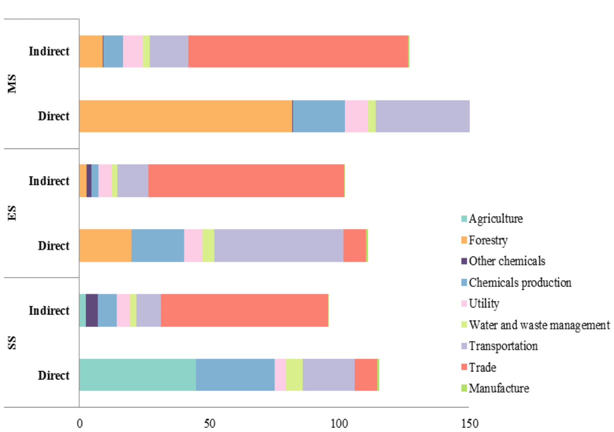

Figure 7. GDP effects over different biojet fuel supply chains

IV. CONCLUSION

As an alternative to fossil jet fuel, aviation biofuel has revealed significant potential in reducing emissions [21], while the production of it, on the other hand, raises specific concerns such as land use change or food safety issue, mainly attributed to feedstocks cultivation stage. Despite that, the prospective social benefits related to aviation biofuel cannot be denied. Jet biofuel industry, as a new addition to economy, is expected to generate employment opportunities and stimulate local development, especially in rural areas. Therefore, the social aspects play a vital role in establishing a truly sustainable supply chain for jet biofuel.

This study contributes to enhance the social pillar of sustainability with an assessment of social sustainability issues, applied to the Brazil case. Differentiated levels of social effects are estimated in different aviation biofuel supply chains. As shown in Fig. 8, MS generates the largest number of employment, highest GDP value and performs the best regarding working condition and labor right. In comparison, ES offers more job opportunities for women while SS generally has intermediate social effects in various aspects.

Although MS seems to outperform the other two supply chains, it is still challenging to draw a conclusion on which jet biofuel supply chain would be the most favorable merely depending on the social issues included in this single study. A broad range of important social sustainability issues, such as human health and safety, livelihood, food security, energy security, etc., have not been analyzed yet due to methodological challenges. Hence, the exploration of a wider range of social issues is needed to expand the comprehension of social sustainability for biofuel supply chains. This means the methodological gaps in social sustainability assessment need to be bridged as well. In addition, it would be also interesting to further investigate the possible interactions between different social issues, which might be responsible for the diversified social/socioeconomic effects over different jet biofuel supply chains.

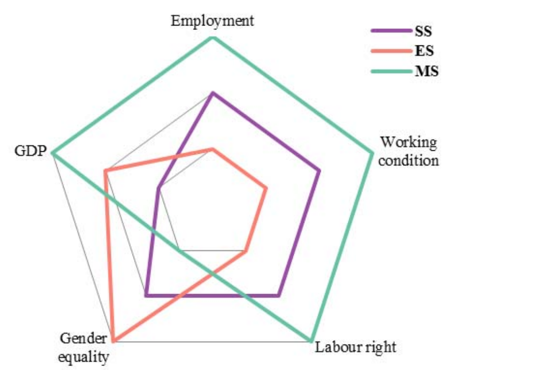

Figure 8. Overview of social effects over different biofuel supply chains, with the outer circle representing best performance among the three, the inner circle indicating the poorest performance and the middle circle showing the intermediate performance.

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