



A review of key international biomass and bioenergy sustainability frameworks and certification systems and their application and implications in Colombia

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ABSTRACT

This document presents the results of an analysis of the key sustainability certification systems applicable to biomass and bioenergy. A review was made of the state-of-the-art sustainability frameworks at the international level. The improvements that have been made in these standards in recent years to reduce social, environmental and economic impacts were identified. In addition, it was determined how some of the initiatives analyzed were implemented in a country such as Colombia, where the establishment of a bio-based economy is being carried out. It was noted that most of the certification systems analyzed have been updated in the last two years. The main adjustments made to the standards are based on criteria developed by the European Commission through the Renewable Energy Directive (EU2015/1513). For environmental issues, it was found that the key update was the inclusion of the indirect land-use change (ILUC). Another key issue addressed is the obligation to calculate and publish the GHG emissions generated annually. Social issues have increased the focus on food security of the population regarding local areas of influence such as the price of the family food basket and food supply. Regarding economic issues, the requirement for a business plan is highlighted to contribute to the economic viability of a certified company. Colombia is one of the countries in the world where the basic conditions support a future sustainable bio-based products sector. Not only does the country have a large amount of land suitable for cultivation, but the land does not require the forests deforestation. However, it must be borne in mind that in a megadiverse country like Colombia, a joint effort (integration) is required between the application of strict laws for the protection of natural resources and the use of certification systems for sustainable products.

1. Introduction

There is a growing global interest in biomass as a sustainable energy source: the use of biomass for energy and materials is expected to grow over the next 20 years [1,2]. Biomass-generated primary energy is expected to increase to the equivalent of 1827 Mt of oil by 2030 (12% of total world primary energy demand) [3]. The opening of new markets based on biomass (a bio-economy) implies increased investment in research and innovation. These markets can contribute to social development in terms of creating new jobs and food security, however, at the same time, the increase in the use of biofuels and bioenergy, generates new concerns about the use of biomass. These concerns involve indirect land use change (ILUC), negative impacts on biodiversity, greenhouse gas (GHG) emissions, water use, competition between uses of land, and possible pressure on food prices, along with other important socio-

economic conditions [4,5]. It is important to note that these concerns are still present, and if not adequately addressed, could become barriers to the development of bioenergy and biofuels.

In order to reduce the concerns about biomass-use mentioned above, a number of organizations and governments have developed certification systems to define indicators that can be used to reduce negative impacts on the environment, society and the economy. One of the major focuses has been the reduction and prevention of impacts to the environment, but greater attention should be given to the social component because there are still concerns that have not been taken into account especially in the area of food security and well-being of employees and the surrounding community [4]. On the other hand, it is understandable that the certified companies expect to receive an economic benefit when marketing sustainable biomass or sustainable bio-based products. In recent years, sustainability criteria and indicators for

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biomass products have been developed and implemented by the European Commission (EC) and also by some private organizations such as Global Bioenergy Partnership (GBEP), International Organization for Standardization (ISO), and others [6–9].

In Latin America, there is considerable experience with generation of bioenergy [10] and Colombia is a key country in Latin America, because Colombia has a potential for agricultural development of biomass as a source of renewable energy. The modern use of bioenergy in the country is currently limited to the production of first-generation biofuels from sugarcane and palm oil, as well as the use of biomass residues to supply own heat and electricity in biofuel production facilities and injecting surplus electricity to the power grid. In 2015, Colombia produced roughly 20 PJ and 8.25 PJ of biodiesel and ethanol, respectively, in addition to 1.85 PJ of surplus bio-electricity [11,12]. These volumes represent minor shares of their respective energy sectors, where the final energy consumption in the road transport sector reached 405 PJ while about 197 PJ of electricity was consumed through the national grid [12]. The theoretical biomass energy potential in Colombia was estimated between 2007 and 2011 in the range of 210–900 PJ. This range included biomass categories from agricultural and forestry residues, biofuels, animal manure and urban waste. By taking into account different factors that may constrain the availability of biomass for energy purposes (e.g. competing uses, ecological and technical constraints), the technical potential was estimated at 36–420 PJ [13].

The future sustainable potential of biomass supply for energy purposes largely depends on the management system of the agricultural and livestock sectors [14]. If Colombia pursues highly efficient and intensified agricultural practices, up to 60 Mha of surplus land could become available for energy purposes compared to a business-as-usual scenario [15]. If one-quarter of this area is allocated to purpose-grown perennial energy crops (e.g. eucalyptus), up to 4600 PJ of technical potential could become available by 2050 from this biomass category. By extrapolating future agricultural production and consumption trends to the future, additional 80–250 PJ of technical potential may become available from agricultural residues by 2050; excluding residues from sugarcane and palm oil sectors [16]. Moreover, forestry residues, animal manure, and urban waste may contribute to the technical potential of about 300 PJ, 27 PJ and 14 PJ by 2030, respectively [13]. Overall, the future technical biomass supply potential in Colombia is significant and may reach up to 5200 PJ within the next four decades, which is 6.5 folds the current total final energy consumption in the country [16].

Since 2001, the Colombian government has adopted a series of laws to promote the production and use of biofuels and bioenergy (Law 693/2001, Law 939/2004, and Law 1715/2014). These laws have encouraged the cultivation of sugar cane and oil palm for the production of bioethanol and biodiesel respectively, as well as the use of biomass for cogeneration. For instance, in 2017, the sugarcane sector had a 1% share in the national electricity generation [17]. Consequently, to continue to expand the use of renewable energy and reduce the fossil fuel use, the government has issued laws (such as Resolution 1283/2016) that provide tax benefits to companies that generate and manage the use of renewable energy in the country [18]. Although Colombia is on the path to sustainability, a route to implement specific criteria and indicators for sustainability in the use of biomass from agricultural crop waste has not yet been defined. This is needed to realize transition from a fossil-based economy to an economy based on biomass [19].

Therefore, in this work, review and analysis of the certification systems available at the international level were carried out to identify the sustainability criteria applicable to crop residues (biomass) and bio-based products. The guideline for this document was the Renewable Energy Directive (RED 2009/28/EC), which is mandatory for the use of renewable energy in Europe. Because this directive was updated in 2015 (Directive (EU) 2015/1513), to add new guidelines for such as reducing ILUC, limiting the use of agricultural land for energy purposes, and increasing the amount of GHG emission savings [20], some

voluntary certification systems have also updated their indicators to adjust to the RED.

There were three primary aims of this study. The first was to carry out a state-of-the-art review of key sustainability frameworks for bioenergy at the international level. To meet this goal, their sustainability criteria (social, environmental, and economic) were identified, it assessed their status and improvements over the last five years, and it determined how the sustainability frameworks compare and what their key strengths and weaknesses are. The second aim was to determine how some of the initiatives analyzed have been implemented in Colombia. This is because this country is characterized by an abundance of valuable resources such as natural biodiversity, water, and substantial land available for cultivation. The third aim was to identify drivers of the environment, social and economic issues in the country that could affect the establishment of a bio-based economy. It should be noted that the initiatives analyzed in this report are among the best known and the European Commission has accepted some of them. The paper has the following structure. First, it discusses the selection of certification systems and the criteria for selecting them. Then, it makes a general description of the systems and their content. Subsequently, it analyzes and compares them from the point of view of environmental, social, and economic criteria, as well as procedures for governance.

2. Methodology

To identify and analyze the most relevant certification systems used in the evaluation of products made from biomass (bioenergy, biofuels, biomaterials), a bibliographic review was carried out. First, the list of voluntary certification schemes recognized by the European Commission¹ to meet biofuel sustainability criteria was taken into account. This implies that the standards cover, among others, criteria such as non-use of land with high carbon stock, protection of biodiversity, reduction of GHGs, and protection of water. Following this, the work of several authors who have gathered and evaluated long lists of sustainability initiatives [4,21,22] were reviewed. Third, the initiatives that have been updated in the last five years were identified. Last, the biomass sustainability certifications systems that apply to Colombia were taken into account. Because of the review, eleven certification schemes were selected that includes the use of biomass at the agricultural, biofuel and energy levels (see Table 1).

3. Data/review

This section is divided into four parts. In Section 3.1, the strengths and weaknesses of each of the certification systems shown in Table 1 were identified. In Section 3.2, the certification systems applicable to Colombia were discussed. In Section 3.3, the aspects that should be taken into account when planning sustainable biomass production and use were discussed. Specific attention was paid to the conditions in Colombia, where high biodiversity and specific socioeconomic matters are very prominent. In Section 3.4, the use of Good Governance for both certification systems and national governments were discussed.

3.1. General certifications

Table 1 shows the eleven (11) certification systems for sustainable bio-based products or sustainable biomass evaluated in this document. There are ten (10) international certification systems and one certification system specific to Colombia (Icontec-GTC 213).

3.1.1. Renewable Energy Directive (RED)

One of the main objectives of the Renewable Energy Directive from the European Union (EU) is to ensure a sustainable production of

¹ <https://ec.europa.eu/energy/node/74>.

Table 1
General characteristics of certification systems included in this overview. • = Included; X = not included.

| Level system | Initiative | Principal scope | Additional scope | Analyzed publication | Type of scheme | Initiator | EC-RED ^a | GHG tool/method |
|----------------------------|-----------------|----------------------------------|---|--|----------------|--|---------------------|---|
| General Certification | ISCC | Raw materials and products | Bioenergy, food, feed and chemical/technical | ISCC 202. Version 3.0/2016 | Voluntary | Multi-stakeholder process | • | GHG emissions calculation methodology |
| | RSB | Biomaterials | Biofuels, biomass derived products or by-products | Version 3.0/2016 | Voluntary | Global multi-stakeholder coalition | • | GHG calculator tool (RSB, Biograce, others) |
| | Icontec-GTC 213 | Biofuel | X | 2011 | Voluntary | Multi-stakeholder process in Colombia | X | X |
| Bioenergy Certification | GBEP | Bioenergy | X | First Edition/2011 | Voluntary | G8 Leaders | • | Analytical tools |
| | BETTER | Bioenergy | Bioenergy and bio-based products | NTA 8080-1:2015 | Voluntary | The Netherlands Government | • | BioGrace GHG calculation tool |
| | BIOMASS | Bioenergy | X | 2015 | Voluntary | G8 Leaders | X | ISO/TS 14067:2013, GHG-Carbon footprint of products |
| Agricultural Certification | ISO 13065 | Bioenergy | Woody biomass (pellets and wood chips) | Version 1.0/2015 | Voluntary | European utilities that use biomass in thermal generating plants | X | X |
| | SBP | Bioenergy | | | | | | |
| | EC-RED | Bioenergy | Biofuels and bioliquids | Directive 2009/28/EC amended through Directive EU2015/1513 | Mandatory | European Parliament | • | GHG emissions calculation methodology |
| | RTRS | Sustainable soy production | X | Version 3.0/2016 | Voluntary | Multi-stakeholder process | • | GHG emissions calculation methodology |
| | RSPO | Sustainable palm oil production | X | RSPO P&C 2013 | Voluntary | Multi-stakeholder process | • | PalmGHG calculator |
| | BONSUCRO | Sustainable sugarcane production | X | Version 4.2/2016 | Voluntary | Multi-stakeholder process | • | Biograce GHG Calculator tool |

^a EC-RED (European Commission – Renewable Energy Directive).

biofuels [23]. RED (2009/28/EC) defines the scope for the progressive use of renewable energy in the coming years, through a series of sustainability criteria for biofuels produced or consumed in the EU. Thus, the EU anticipates that by 2020 the renewable portion of energy use will be at least 20% and by 2030, at least 27% [20]. In addition, in 2015, the RED became more stringent as it required the reduction of GHG emissions caused by indirect land uses with high carbon value. Thus, this directive was adjusted as EU2015/1513 to include GHG estimates for ILUC. The aim was to prevent land intended for food production from being converted to production of biofuels [24].

In addition, Article 17 (2) was replaced with “GHG emission saving shall be at least 60% for biofuels produced in installations starting operation after 5 October 2015. In the case of installations which were in operation on or before 5 October 2015, biofuels shall achieve a GHG emission saving of at least 35% until 31 December 2017 and at least 50% from 1 January 2018” [24]. Any company that is interested in meeting these criteria can demonstrate this through the use of national certification systems or voluntary systems recognized by the European Commission.

3.1.2. Better Biomass (NTA 8080-1)

Better Biomass is an international certification system used to evaluate the production of sustainable biomass to generate bio-based products. It is a voluntary scheme under the name NTA² 8080. Organizations can use it to demonstrate that the biomass that is produced, processed, marketed, or used is sustainable. The scope of NTA 8080 in the 2009 (first) edition was to produce biomass in a sustainable way for its application in bioenergy, but an increase in the use of biomass by the chemical industry to replace fossil resources led to the updating of the standard. In its second edition, NTA 8080-1:2015, the scope was expanded to demonstrate compliance with mandatory sustainability criteria for application in bioenergy (electricity, heating, refrigeration, and fuel transport) and for bio-based products. Among the adjustments made were: a) inclusion of the use of calculation tools for GHG emissions (Biograce I and Biograce II); b) inclusion of new developments in sustainability aspects such as ILUC and carbon debt; and (c) the certification document was split into two parts, one for sustainability requirements and the other for chain-of-custody requirements [25].

The NTA 8080-1: 2015 has six principles that refer to 1) GHG, 2) Competition between food and other local uses of biomass, 3) Biodiversity, 4) The environment, 5) Prosperity, and 6) Wellbeing. Within Principle 2, this standard highlights the use of “ILUC low risk” to demonstrate that the biomass being used does not induce any ILUC. In addition, it is emphasized that the production of biomass for the generation of energy, or its application in bio-based products on existing farmland does not lead indirectly to the conversion of land with high carbon content and/or for agricultural purposes. The standard asks that the Low Indirect Impact Biofuels (LIIB)³ methodology (or a similar method) be used with its most recent version (1 January 2015), as the reference date. On the other hand, the same principle highlights that Better Biomass requires organizations to monitor local prices of biomass or natural resources that are used to produce biomass and that are crucial for the basic needs of the local population. In addition, it also requires efficient use of biomass, especially that which could be used for both food and non-food-uses (bioenergy, biofuels). In order to comply with this criterion, the use must be justified according to environmental, economic, and logistical considerations.

3.1.3. ISO 13065

The International Organization for Standardization (ISO) developed ISO 13065 edition 2015 on sustainability criteria for all forms of bioenergy. This Standard aims to facilitate the assessment of

sustainability criteria in the bioenergy supply chain [26]. In this standard, the principles, criteria, and indicators cover the three dimensions of sustainability: environmental, social, and economic. Regarding the environment, aspects such as GHG, biodiversity, soil, water, air, energy efficiency, and waste are covered. At the GHG level, this standard emphasizes the reduction of anthropogenic emissions in bioenergy production. For this, the standard requests the use of the requirements described in clause 6 of the same standard, in conjunction with the use of ISO/TS 14067 (carbon footprint of products). Despite this, the standard clarifies that, if there is any difference between the requirements of ISO/TS 14067 and the requirements of Clause 6, the provisions of clause 6 shall prevail. On the other hand, the principle of “Promote positive and negative impacts on biodiversity” is highlighted, because both the direct operating area and the surrounding protected areas are taken into account [26].

Another interesting principle in this standard is “Promote efficient use of energy resources.” This principle requires energy balance involving all the energy sources used in the process. The social aspect focuses on respect for human rights, labor rights, the right to use land, and the right to use water (including gain free, prior and informed consent). Finally, the economic aspect focuses on economic sustainability in order to make production and commercialization of bioenergy economical and financially viable (fair business practices and financial risk management) [26].

3.1.4. Global Bio-Energy Partnership (GBEP)

GBEP was started in 2006 to implement sustainability indicators for bioenergy and biomass, and thus contribute to the reduction of GHG emissions and facilitate access to bioenergy [27]. In 2011, GBEP published 24 voluntary sustainability indicators for production and use of bioenergy. These indicators were developed to evaluate the sustainability of production and use of bioenergy. Each indicator is covered by methodology sheets providing the information needed to evaluate the selected indicators. Other situations such as data requirements, data sources, and potential bottlenecks to data acquisition are also described. One of the issues that concern GBEP is food security because food production has a complex and multifaceted relationship with bioenergy. GBEP aims to demonstrate that the production and sustainable use of bioenergy can contribute to both energy and food security. For this reason, the main indicators in GBEP are related to food security: 1) Price and supply of a national food basket, 2) Land use and LUC, 3) Allocation and tenure of land, 4) Change in income, 5) Bioenergy used to expand access to modern energy services, and 6) Infrastructure and logistics for distribution of bioenergy. This set of indicators is complemented by other indicators that affect food security, such as soil quality, landscape biodiversity, water use and efficiency, and jobs in the bioenergy sector [28].

In order to test the feasibility of the standard as a policy tool, countries such as Colombia, Germany, Ghana, Indonesia, and the Netherlands carried out pilot projects. The pilots varied in the approach adopted, specifically regarding aspects such as the chosen geographic and sectoral scope, and the selection of indicators appropriate within the context of each country. Among the lessons learned, the most important point identified was the availability and quality of relevant data. Data collection methodologies should be improved because some of the required data does not exist or is not reliable (e.g., water quality, GHG, productivity). For example, in some cases, the information available for the indicators was not complete or there simply was no data. In other cases, specific data for bioenergy were available at the regional level but not at the national level. In still other cases, the data were available at the national level but it was not possible to make clear application of the data for the bioenergy sector [29].

Situation for Colombia: In the particular case of Colombia, for instance, it was difficult to access specific water quality monitoring data for the bioenergy sector. Another key data issue was the difficulty in implementing the methodology to identify “areas of high biodiversity

² Netherlands Technical Agreement.

³ Visit the LIIB certification module website.

value” and “critical ecosystems.” It seems that the country did not have a clear definition of these issues at the time, so it was necessary to use a special interpretation during the pilot to complement the indicators [29].

3.1.5. Roundtable on Sustainable Biomaterials (RSB)

“RSB is an independent and global multi-stakeholder coalition which works to promote the sustainability of biomaterials, including biomass and biofuels.” This standard identifies two types of operators, each one with specific requirements: 1) Biomass Producers (farmers and plantations) and Industrial Operators (feed-stock processors, intermediary producers, and biomaterial producers). The RSB (Biomass Producers) standard has 12 principles and an optional module in which the operators demonstrate that biomass/biofuels/biomaterials were produced using Low ILUC Risk Biomass. The focus of social indicators is to ensure that the production of biomaterials improves local food security and livelihoods in regions of poverty. Environmental certification requires the preservation of biodiversity, as well as best practices in land and water management. The optional ILUC module assumes voluntary compliance, but when combined with the General Principles and Criteria, it allows operators to make a “low ILUC risk” claim. Like the standard NTA 8080-1, the RSB standard is based on the Low Indirect Impact Biofuels (LIIB) methodology. RSB recognizes three approaches for low ILUC risk biomass and biofuels production: Yield Increase, Unused/Degraded Land, and Use of waste/residues [30]. RSB Standard has a Certification of Smallholder Groups (RSB-STD-03-002 – version 1.1). This certification allows small farmers to group and works together to access certification. The group must appoint an administrator to maintain communication between all the members. The administration will be responsible for ensuring that all members comply with the requirements of the standard through periodic internal inspections. In addition, the administration will be responsible for establishing an internal management system and ensuring that all group members receive the benefits of the certification [31].

3.1.6. Sustainable Biomass Partnership (SBP)

SBP is a standard developed for evaluating woody biomass (pellets and chips) used in industrial energy production. It was created to continue the work of the former Initiative of Wood Pellet Buyers (IWPB). This standard ensures that certified woody biomass is sustainable and contributes to a low carbon economy. In addition, it confirms that the biomass is obtained from legal sources [32]. The SBP certification is based on the biomass sustainability criteria of European countries, in particular, the Netherlands, Denmark, Belgium, and the UK. The SBP certification system is founded on two principles: legality and sustainability. Those principles are broken down into 38 indicators of which eight relate to legal sourcing and 30 to sustainable sourcing. Each indicator is rated as either “low risk” or “specified risk.” For any indicator rated a “specified risk,” the biomass producer must put in place mitigation measures to manage the risk such that it can be considered to be effectively controlled or excluded [33].

This standard does not have a specific indicator to identify GHG emissions, nor a methodology to calculate GHG emissions. The SBP standard specifies “with the exception of an End-User, the Biomass Producer is not responsible for calculating the energy and GHG balance of the supply chain but must provide all necessary data to facilitate those calculations.” The information required is that mentioned in SBP standard 6 and SBP 5A (Data collection and communication). In addition, SBP gives as a source of information the link to the page of the European Commission,⁴ but nothing specific about GHG calculations. Nevertheless, criterion nine has two indicators that discuss maintaining or increasing regional carbon stocks. One of these requires that the raw material not come from areas that had high carbon stocks in January

2008 (wetlands, peatlands). The second indicator requires that the collection of raw materials not diminish the capacity of the forest to act as a sink for storage of carbon in the long term [33].

3.1.7. Roundtable on Responsible Soy Association (RTRS)

The Roundtable on Responsible Soy Association, created in 2006, is a voluntary initiative that fosters the growth of sustainable soy production (conventional, organic, and genetically modified), at all scales of production and in all the countries where soy is produced. The RTRS standard has a set of principles, criteria, and indicators that was adjusted in 2016 (version 3), to regulate the process of responsible soy production. RTRS includes key social aspects, such as the disposition to dialogue and communication with local communities on topics related to the activities of its operations and their impacts, or communications for resolving complaints [34]. To increase the number of producers included in the certification scheme, RTRS designed a methodology that allows producers to start certification in stages for a maximum of three years. Each stage requires compliance with specific indicators. In the first year, the producer must comply with 59 “immediate compliance indicators.” In the second year, the producer must comply with 33 short-term indicators. In the third year, the producer must comply with 14 mid-term indicators. At the end of the process, the producer must comply with 100% of the requirements and indicators to obtain certification of its process [35].

The RTRS standard (similar to the RSPO standard) developed a version to be applicable at the national level in soy producing countries. This allows the producer country to adjust the indicators to the specific social, economic, and environmental conditions of the country. Furthermore, RTRS has developed an additional voluntary complement called the EU-RED RTRS Compliance Requirements. It will allow soybean producers and processors to meet requirements for the supply of soy-based biofuels to EU member states. However, it is important to note that, given the default values assigned to soybeans, this does not match the savings required by the RED. In practice, this means that some agents in the supply chain will have to record the actual values, together with calculations demonstrating the minimum savings required [36].

3.1.8. Roundtable on Sustainable Palm Oil (RSPO)

The Roundtable on Sustainable Palm Oil was created in 2003 in response to worldwide concern about the negative environmental and social impacts of the rapid expansion of the palm oil sector in Southeast Asia [37]. It brings together stakeholders from the seven sectors of the palm oil industry to work towards a global supply of palm oil that meets the criteria of economic, social, and environmental sustainability. The RSPO Principles and Criteria are developed and revised every five years [38]. In the last update in 2013, four new criteria were included: ethical behavior, no forced labor, respect for human rights, and minimization of GHG emissions from new plantations [37]. The RSPO has a specific principle called “commitment to transparency,” in which it demands a commitment to ethical conduct in all the activities developed by the producer. A key point to highlight this certification system is that it has a principle for the responsible development of new plantations. This principle is focused on making an independent and participatory assessment of the technical, social, and environmental impacts, before establishing new plantations or operations. This principle promotes better decision making in order to prevent negative impacts on the project area (location, design, operation) [38].

The RSPO developed two additional voluntary complements. The first was RSPO-RED for compliance with the RED requirements. The second was RSPO NEXT,⁵ which was developed in response to the largest market commitments for non-deforestation, no development on peat, no fires, no human rights violations, respect for transparency, and

⁴ <http://ec.europa.eu/energy/en/topics/renewable-energy>.

⁵ <http://www.rspo.org/certification/rspo-next>.

reduction of GHGs. On the other hand, RSPO is in the process of public consultation of the "RSPO Smallholder Strategy", in which new approaches to the certification of excises for small independent farmers (less than 50 ha) are considered. With this new model, RSPO aims to increase the number of small farmers certified under the standard, guaranteeing compliance with the basic sustainability requirements. The system approach takes into account the needs and reality of the environment based on five key elements that include applicability (who), eligibility (meeting criteria), certification unit (collective work), continuous improvement (phased approach), and small credit producers (incentives for compliance) [39].

3.1.9. Bonsucro (BSI)

Bonsucro, a trade name of Better Sugarcane Initiative Ltd., has developed sustainability indicators for a production standard that applies to any sugarcane farm, mill, or area with which is involved in it [40]. The Bonsucro certification system is made up of five elements: Certification Protocol, Production Standard (including EU), Chain of Custody Standard, Audit Guidance, and Bonsucro Calculator [41]. The production standard has six principles. Principles 1 through 5 ensure that the sugar cane sector complies with legislation, respects human rights, manages the efficiency of the inputs and products, manages biodiversity, and improves key business areas. Principle 6 has an additional mandatory requirement for biofuels under the Fuel Quality Directive (2009/30/EC) and Directive (UE) 2015/1513 [40]. The Bonsucro Calculator is a tool, based on MS Excel, developed to demonstrate compliance with the principles of the standard. Access to this tool is exclusive to Bonsucro members [42]. The Bonsucro standard also authorizes the use of the BioGrace GHG calculation tool, which is in line with the RED sustainability criteria. Moreover, this tool is recognized as a voluntary scheme by the European Commission [40].

3.1.10. International Sustainability and Carbon Certification (ISCC)

ISCC is an independent multi-stakeholder organization providing a globally applicable certification system for the sustainability of raw materials and products (all types of biomass, including forestry and agricultural, bioenergy, waste and residues, food, feed, and bio-based products). Farms and plantations that produce sustainable biomass must comply with the sustainability requirements laid down in ISCC Document 202 "Sustainability Requirements." The requirements are divided into six principles [43]. Principle 1 is the strictest and total compliance with the standard and refers to the Protection of "Land with High Biodiversity Value or High Carbon Stock." This principle emphasizes the protection of biodiverse or high carbon areas where threatened or vulnerable species exist. It also covers the legal requirements of the RED as amended by Directive 2015/1513. Failure to meet the requirements of principle 1 related to land use makes the certification approval infeasible. Principle 2 contains the requirements for use of the best agricultural and forestry practices such as soil management, preservation, and requirements for reduction of water pollution. Principles 3 and 4 relate to social requirements for better working conditions and the rights of workers and the community. Principle 5 highlights the legitimacy of the rights of indigenous peoples, especially land rights [44].

Requirements pertaining to GHG emission calculations are listed in a document called ISCC-205. This document (ISCC 205) contains the requirements and methodology for calculating GHG emissions for the supply chain. ISCC will require a minimum GHG saving (50–60%) for biofuels as of 2018 [45].

3.1.11. Icontec GTC-213

This certification system will be analyzed in the next section because it is exclusive to Colombia.

3.2. Biomass certification systems applicable to Colombia

Taking into account, the certification systems analyzed previously, in this section it was discussed those that have been applied in Colombia in recent years. Specifically, it was analyzed four standards: the National Interpretation of RSPO (oil palm), Bonsucro (sugar cane), ISCC (carbon certification), and GTC 213 (biodiesel).

3.2.1. RSPO-National Interpretation for Colombia

The National Interpretation (NI) of the RSPO 2013 for Colombia was updated in 2016. A Technical Working Group composed of different stakeholder members who were part of the RSPO (growers, processors, industrialists, environmental NGOs and Social NGOs) developed this. Although the NI document has the same Principles and Criteria as RSPO 2013, the Colombian document added seven new indicators. One of those indicators was added to Principle 4, which is about the continuous training of small producers in social-business responsibility and RSPO. Four of those indicators were added to Principle 6, these refer to the adoption of appropriate measures for early education, and standards to ensure that those hired to provide private security are not people who have committed crimes against humanity. Finally, the two indicators added to Principle 7 are related to the training of employees in biodiversity and land acquisition issues. The backbone of the RSPO standard is the application of the principle "free prior and informed consent" of the communities involved with the operation. This principle ensures that certified areas do not present any conflict over land use or land acquisition. In addition, this seeks protection of the collective rights of indigenous peoples and local communities within the national territory. In this context, in Colombia, the relationship with communities is divided into 1) indigenous groups and ethnic groups in general⁶ and 2) non-ethnic local groups or communities⁷ [33,42].

On the other hand, the DAABON Group in Colombia was the first company in the world to be certified under RSPO NEXT. Additional criteria were applicable at the organization level, included investments, joint ventures, and a wider supply base for the organization. This certification included 122 smallholder farms that supply the palm oil fruit to the mill [47]. In some cases, there are economic barriers to the certification of small farmers due to the high costs of certification [48], but in Colombia, the RSPO model allows these producers to benefit from the certification of their crops with the support of the "Núcleo palmero"⁸ (group of producers) to which those small farmers belong. This means that the certifications of the large producers cover the small producers as well, therefore, the small producers are not excluded from the system [49]. Belonging to a "Núcleo Palmero" is not an obligation; however, the association with a group facilitates the participation of small farmers specially in projects that involve greater quantities of palm fruit production. Technical assistance is another example of the benefits received of the group's joint work (at no additional cost) to increase crop yield through implementing good agricultural practices [49]. In a case study carried out in small farmers crops, where the study

⁶ **Indigenous groups and ethnic groups in general:** the relationship is governed by ILO Convention 169, which was ratified by law 21 of 1991 through the figure called "prior consultation". To comply, the law requires the implementation of a series of steps that include ensuring the free, prior and informed consent of the indigenous communities and ethnic groups involved.

⁷ **Non-ethnic local groups or communities:** the guidelines indicated in the free, prior and informed consent RSPO guide must be followed, as well as due diligence by producers at all times, in order to respect, mitigate and remedy any impact generated.

⁸ "Núcleo palmero" is the grouping of fruit producers (small, medium, and large) and a palm oil mill (POM) close to its area of influence. This business union generates relations of cooperation and trust with a unified approach, thus allowing closing gaps in productivity and reducing production costs. In addition, strategies are developed to timely address phytosanitary risks and threats through comprehensive technical assistance so that group members can benefit.

area was 15% of the palm area in production at nationwide, the implementation of good agricultural practices allowed to increase fruit production by 35% (weighted average in $\text{t ha}^{-1} \text{ year}^{-1}$). Besides the increase in the productivity of those crops, the technologies (good practices) implemented allowed an increase in the efficiency of irrigation (50% less water consumed), the reduction of the incidence of diseases (less use of pesticides) and 8% of the reduction in production costs [50].

3.2.2. Bonsucro

In Colombia, there is around 225,560 ha planted in sugar cane in Cauca, Valle del Cauca, and in the south of Risaralda. It is considered a privileged region because it is possible to plant and harvest cane during all the months of the year. The climatic conditions of the region make productivity higher than in other regions of the world (14 t of sugar per hectare per year) [51]. Colombia is among the 15 largest sugar producers in the world and produces more sugar than is required for domestic consumption in the country. For instance, in 2016 sugar production was 2.1 million tons, compared to a national demand of 1.6 million tons [52].

At the industrial level, there are 14 sugar mills, of which six companies have associated distilleries for the production of fuel alcohol (Incauca, Manuelita, Providencia, Mayagüez, Risaralda, and Riopaila-Castilla). Over the last 10 years, the Colombian Sugar Sector has become an energy source due to its production of bioethanol and use of cogeneration. As of 2016, the installed capacity of bioethanol production in Colombia was 1,650,000 L/d and the bioethanol blend with gasoline was 6%. Colombian bioethanol reduces GHG emissions by 74% if compared to gasoline [52]. Despite the amount of area planted in the country, Bonsucro has only three member companies [52]. The first one is Asocaña, which is the Sugarcane Growers Association of Colombia. The other two companies are Manuelita Group and Riopaila Castilla. The Manuelita group was the first company in Colombia to obtain the Bonsucro certification (October 2017) [41] and Riopaila Castilla is working on its diagnosis and action plan to achieve the Bonsucro certification [53].

3.2.3. International Sustainability and Carbon Certification (ISCC)

In March 2017, three palm oil mills (POM) in northern Colombia received the ISCC certificate: Aceites SA,⁹ Palmaceite SA,¹⁰ and Extractora El Roble SAS.¹¹ These companies belong to CI Biocosta SA group, an international palm oil trading company, which in 2015 exported 169,766 t of crude palm oil (32.6% of the total exported by the country) [54]. All three companies met the RED requirements specified in the ISCC-EU¹² certification system. The certificate¹³ issued, specifies that the input material is bunches of fresh fruit (FFB) and that the output material is crude palm oil (CPO) and crude palm kernel oil (CPKO). Compliance with the requirements of principles 1–6 indicates that the biomass produced by these companies is considered sustainable [44].

3.2.4. Icontec GTC 213

ICONTEC is the Colombian Institute of Technical Standards and Certification. It represents Colombia at international and regional standardization bodies such as ISO. In addition, it belongs to IQNet, the most important international certification network in the world, which promotes the recognition of certificates of management systems in the international arena. Also, ICONTEC is present in different countries of the Americas and the Caribbean and it has 2236 affiliate companies that

support the standardization work [55]. As an advisor to the National Government in Colombia, ICONTEC has the mission of promoting, developing, and guiding the application of Colombian Technical Standards and other normative documents to obtain an optimum overall economy, improve quality, and facilitate customer-supplier relations at the corporate, national, or international level [56]. One of the standards developed by ICONTEC is standard GTC 213, elaborated through Technical Committee 186, which is chaired by those at Fedebio-combustibles [57]. This standard contains the basic agreements for the participation of Colombia in the development of the different sustainability standards that involve the biofuel sector, such as ISO 13065, where Fedebiocombustibles¹⁴ heads the Colombian delegation [57].

GTC 213 presents the principles, criteria, and recommendations of environmental, social, and economic sustainability that should be fulfilled in the stages of production and processing of biomass in the biofuels supply chain in Colombia. This does not include other parts of the chain such as transportation, storage, mixing, distribution, and final consumption of biofuels. The guide has 6 principles that include legal compliance, climate change mitigation and GHG reduction, conservation of biodiversity, respect for human and labor rights, economic viability, and commitment to transparency [58]. It should be noted that this guide does not specify indicators but gives recommendations or guidelines for the construction of the indicators. This means that biomass producers and processors must identify the indicators that are appropriate to each of their systems based on the guidelines set out in GTC 213. This type of certification system leads to confusion because each producer should create unique indicators, which will not allow comparisons between producers who obtain certification.

3.3. Key aspects

The eleven certification systems analyzed in this document have more than 50 sustainability criteria/indicators that cover social, environmental, and economic aspects (see Section 4.2). However, this section highlights four of the key methods: ILUC, water, biodiversity, and GHG. These criteria/indicators are paramount in the initial evaluation and design of a project for sustainable biomass production. In addition, the production of sustainable biomass in a megadiverse country like Colombia entails some challenges such as the efficient use of natural resources and the reduction of negative impacts on these resources.

3.3.1. Indirect land use change

This is one of the key impacts attributed to the use of biofuels [59] because the raw materials needed to produce them require water and productive land [60]. ILUC occurs when excessive agricultural pressure is applied on lands that are not available for crops (e.g., forests, wetlands) generating GHG emissions [61]. This can have significant impacts on food security [60]. Nonetheless, there is great potential for the production of land-based biofuels, if it is ensured that this is carried out in a sustainable manner [60,62]. In recent years, efforts have been made to include this indicator in issues related to the sustainability of bio-based products in some standards. This is the case for RED 2009/28/EC, as amended by Directive (EU) 2015/1513, RSB, and Better Biomass. Table 2 shows the requirements proposed by these three European standards. RSB included an optional module called “Low ILUC Risk Biomass.” This module has a set of criteria and compliance indicators for economic operators willing to show that their operations have a low ILUC risk claim [30]. Similarly, NTA 8080-1 has an optional compliance indicator to identify ILUC.¹⁵ This emphasizes that the production of biomass should not indirectly affect the conversion of

⁹ <http://www.aceitesa.com/index.php>.

¹⁰ <http://www.palmaceite.com/>.

¹¹ <http://www.extractoraeroble.com/>.

¹² Recognized by the European Commission (EC) to demonstrate compliance with RED and FQD.

¹³ <https://www.iscc-system.org/certificates/valid-certificates/>.

¹⁴ Colombia's National Federation of Biofuels.

¹⁵ <http://www.ecofys.com/en/project/low-indirect-impact-biofuel-methodology/>.

Table 2
Proposed requirement and databases for Indirect Land Use Change (ILUC) in certification systems.

| Initiative | Proposed requirement | Ref. |
|----------------|--|------|
| EC-RED | Low indirect land-use change-risk because the feedstocks were produced within schemes which reduce the displacement of production for purposes other than for making biofuels and bioliquids. | [24] |
| BETTER BIOMASS | Possible solutions to reduce the risk of ILUC by the use of biomass: 1) growing biomass on previously unused land 2) additional productivity increase, on top of the trend line (shortening the period that arable land is left fallow; intensifying the use of grassland, increasing the harvest frequency on arable land) 3) integrating existing agriculture or forestry with additional biomass production 4) use of waste and residual flows that had no other application before. | [25] |
| RSB | Low ILUC risk biomass: – Yield increase. Additional biomass was produced through an increase in yield compared to a reference date, without any additional land conversion. – Unused/degraded land. Biomass was produced out of land that was not previously cultivated or was not considered arable land (a reference date is also used). – Use of waste/residues. The raw material used is derived from existing supply chains (e.g. food production, wood processing, etc.) and do not require dedicated production out of arable lands. | [31] |

lands with high biodiversity value or high carbon value [25]. In the European Union, the objectives set out in the RED have been adjusted to reduce the risk of ILUC and to ease issues related to the production of biofuels. The adjustment is specified in Directive (EU) 2015/1513. In addition, “the amendment limits the share of biofuels from crops grown on agricultural land, harmonizes the list of feedstocks for biofuels across the EU and it includes a number of additional reporting obligations for the fuel providers, EU countries, and the European Commission” [20].

The Better Biomass and RSB standards use the LIIB (Low Indirect Impact Biofuel) methodology to identify the ILUC of raw materials for biofuels. This methodology aims to identify fuels with a low indirect risk of impacts in four categories, namely increased yield, unused land, sugarcane-cattle integration, and End-of-life products. Each category analyzes in a particular way the mitigation approaches. For the first category “increased yield”, the use of raw materials that have been produced by the increase in crop yield is evaluated. The second category “integration of sugarcane and cattle” evaluates the efficiency of the system with the production of raw materials from the integration of the two mentioned sectors. The third category “unused land” evaluates the use of unused land, with low carbon and low biodiversity, especially in countries with the available usable land. The last category “End-of-life products” evaluates, at a regional level, the use of waste that can be used to produce biofuels [60]. On the other hand, although to date, the standards do not have parameters defined for the ILUC, there are some studies that report the risk of ILUC in several European countries [62,63] and Indonesia [64]. That studies report that the risk of ILUC can be mitigated through the production of biomass in lands with low carbon reserves, in lands that are no longer used for food and feed production (e.g. 45–62% of total potential), and when there is an increase (improvement) in crop yield (e.g. 32–46% of total potential) [62–64].

Situation for Colombia: Although to date no specific studies of ILUC have been found in Colombia, some studies have worked in LUC [65,66]. The results indicate that changes in land use and coverage have varied as a result of some economic pressures (oil, agro-industry, forestry, livestock, infrastructure) generating changes in the landscape and biodiversity of the country [65,66]. However, the studies emphasize that in order to continue with sustainable development, it is necessary to preserve areas of ecosystem importance [65]. Although preserving biodiversity without affecting it is a great challenge, it has been identified that in Colombia it is possible to expand the cultivated areas (land suitable for crops), conserve biodiversity (exclusion areas), and continue with rural development [67,68].

Colombia has a continental area of 114.17 million hectares, of which 55.4% are non-agricultural use (natural forests, forest reserves, indigenous reserves and collective territories, and mining) and 44.6%

are for agricultural use [69]. Of the total national land, only 67% is properly used, while 13% is underutilized, and 16% of the land is overexploited [70]. Of the amount of land for agricultural use, 11.3 million hectares correspond to purely agricultural soils, however, only about 4 million hectares are used [69]. In recent years the country has worked to organize the management (use) of the national territory through the updating of key instruments for soil management (soil suitability map, soil conflict map, coverages map) [71]. In 2017, the organic carbon map of the country was presented. This map shows that the areas with the highest concentration of this element are in places with agricultural overload (e.g. the Andean region). It is also highlighted that the inadequate use of soil (e.g. tillage, intensive livestock, bad management practices) in the country is a global warming factor that must be monitored to conserve the most carbon-rich areas and implement improvement strategies in the zones of lower concentrations [72]. Colombia has a large land-surface but agriculture and livestock still have significant yield gaps and potential for efficiency improvement. That means there is a big potential in the country to reduce carbon footprint and to produce additional crops like energy crops [15]. As a result, it is expected the government specifies strategies that guarantee food security, mitigate climate change and protect water resources [72,73].

3.3.2. Water

Water is used to carry out all kinds of agricultural, industrial, domestic, and environmental activities. Extra water use can generate negative impacts such as degradation of water quality and reduction of the reliability of the water supply [28]. In addition, increased demand has made water scarce in many countries [74]. These problems have generated the development of actions for the care and use of water. For example, certification systems have developed monitoring and control criteria and indicators such as availability of water, accessibility, quality, identification, and protection of existing water rights (formal and customary), along with maintenance of areas of natural vegetation around wellsprings and natural waters, among others. RED does not emphasize the indicators to be measured for water sustainability because these requirements consist mainly of good agricultural practices, which at EU level is more effective to address through agricultural policy. However, the European Commission is preparing a report with adjustments to the Directive, which seeks to include measures to avoid excessive water consumption and to increase compliance with the targets set for 2030 (30% energy efficiency) [75].

Table 3 shows that all the standards recognize the need for water conservation from three points of view: availability, efficiency of use, and quality. In terms of availability, the watersheds of origin are the focus points for care due to the benefits this provides [76]. Standards such as ISCC, RTRS, RED, and RSPO have indicators that favor the

Table 3
Overview of environmental principles/criteria and indicators. • = Included; X = not included; ? = Uncertain^a.

| Principle/Topic | Criteria/Indicators | Certification system | | | | | | | | | | | |
|--|--|----------------------|----------------|-----------|-----|------|-----|------|--------|----------|------|-----|-----|
| | | GBEP | BETTER BIOMASS | ISO 13065 | RSB | ISCC | SBP | RTRS | EC-RED | BONSUCRO | RSPO | GTC | 213 |
| 1. Greenhouse gas emissions (GHG) and Carbon Stock | GHG emissions | • | • | • | • | • | • | • | • | • | • | • | • |
| | Emissions reduction | X | • | • | • | • | • | • | • | • | • | • | • |
| 2. Biodiversity | Biomass is not produced on land with high carbon stock | X | • | ? | X | • | • | • | • | • | • | • | ? |
| | HCV areas and risk. (maintain or enhance areas) | • | • | • | • | • | • | • | • | • | • | • | • |
| | Ecological corridors | X | • | ? | • | • | • | • | • | • | • | • | • |
| | Illegal or inappropriate hunting, fishing, trapping or collecting activities are controlled or prohibited. | X | • | ? | X | • | • | • | • | X | • | X | • |
| | Prevent invasive species from invading areas outside the operation site. | ? | • | • | • | • | X | • | • | X | • | • | • |
| | Proper use of genetically modified species | X | • | X | • | • | • | • | • | X | X | • | • |
| 3. Water | Water availability | • | • | • | • | • | • | • | • | • | • | • | • |
| | Efficiency of water use | • | • | • | • | • | • | • | • | • | • | • | • |
| | Water quality | • | • | • | • | • | • | • | • | • | • | • | • |
| 4. Air | Air quality | • | • | • | • | • | • | X | • | • | • | • | • |
| | Air pollutant emissions reduction (management plan) | X | X | • | • | X | • | X | • | • | • | • | • |
| | No open-air burning (residues, wastes, by-products, etc.) | ? | • | X | • | • | X | • | • | • | • | • | • |
| 5. Soil | Soil quality (use of best practices to maintain and improve soil fertility) | • | • | • | • | • | • | • | • | • | • | • | • |
| | Land use and land-use change (LUC) | • | • | • | • | • | • | • | • | • | • | • | • |
| | Indirect Land Uses Change (ILUC) | ? | • | X | • | X | X | X | • | X | • | X | • |
| | Maintain in the soil the content of organic matter necessary for its long-term stability (do not remove all residual agricultural products). | X | • | X | • | • | X | X | • | X | • | • | • |
| | Biomass/Feedstock is not produced on peatland | ? | • | X | • | • | • | • | • | • | • | X | • |
| | Restrictions on plant protection products and seeds | X | X | X | X | • | X | • | • | X | X | X | • |
| 6. Bioenergy | Avoiding plant protection products by integrated pest management (IPM) | ? | X | X | • | • | • | • | • | • | • | • | • |
| | Soil surveys and topographic information | X | X | X | X | • | • | • | X | • | • | • | • |
| | Bioenergy is used to expand access to modern energy services | • | X | • | X | X | X | • | • | • | • | X | • |
| 7. Waste management | Use of good practices for the storage, handling, use, and disposal of biofuels, fertilizers, and chemicals | X | • | • | • | • | • | • | X | • | • | • | • |

^a ? = *Uncertain*. This means that the certification system mentions the subject but does NOT define a specific criterion or indicator.

maintenance and restoration of water protection zones (basins, channels, and watercourses). Even in the specific cases of ISCC and RTRS, the care of natural wetlands is specified. Likewise, respect for water rights is dealt with in RSB, ISCC, SBP, RTRS, and Bonsucro. In terms of efficient use, it is important to consider both the volume of water used and the impacts of its use because both are affected by local conditions such as water availability, water balance, precipitation, temperature, soil properties, and water demand (regarding human beings, agriculture, and nature) [77]. For example, indicators that measure irrigation efficiency in biomass crops or agricultural crops for energy purposes are present in Better Biomass, ISCC, RTRS, GTC 213, and Bonsucro. Other indicators call for the use and monitoring of a water management plan such as RSB, ISCC, SBP, Bonsucro, or RSPO. There are some indicators with more technical or industrial focus that call for measurement of the amount of water consumed per unit of mass (or of product) as in the standards of Bonsucro, GBEP, and RSPO.

Last, water quality may vary depending on the specific type of demand (human, agricultural, environmental, or industrial). For example, quality indices have been established that evaluate the use of water for human consumption, but there are no defined indices for evaluation and use of water for irrigation in crops. However, to ensure that acceptable limits are maintained to allow sustainable end use, the discharge of water from agricultural and industrial activities must be controlled [78]. In this sense, standards such as GBEP, ISCC, RSPO, RED, RTRS, and SBP take into account the impact of agricultural practices on water quality and call for measurement of parameters such as nitrogen (N), phosphorus (P), and pesticides. Other standards such as Better Biomass and RSPO call for measurement of organic loading (BOD) in effluents. ISO 13065 is more accurate when information is provided about the possible impacts on water quality at the source and in the receiving bodies. This standard calls for identification of key parameters at the physicochemical and biological levels. It also requires the identification of potential impacts such as eutrophication and oxygen depletion.

Situation for Colombia: In general, Colombia is not a country that has a water shortage. It has a watersupply between 1400 and 2300 km³ year⁻¹ [79]. To take care of this water, there are clear policies to improve water quality and control polluting activities such as industrial and domestic discharges. Discharges affect the water quality when do not comply with the maximum permissible limits of contamination [80]. Moreover, there are some additional risks due to contamination such as oil spills, indiscriminate use of agrochemicals, and pollution caused by mining. Due to the aforementioned, the government is taking actions to reduce pollution from the source, encourage clean production and improve the wastewater treatment [80]. Resolution 0631 of 2015 makes the report of contamination parameters more stringent. Previous that standard, all productive activities had to comply with a percentage of elimination of contaminant load (kg/day) at a general level, but now, each economic activity must comply with specific maximum limits (mg/l) for each activity. The criteria that must be met include the ranges of admissible temperature, microbiological parameters, a content of active ingredients of pesticides and physicochemical parameters [81]. The greatest demand for the development of socio-economic activities is registered in the agricultural sector (54%), followed by the domestic sector (29%). The greatest water consumption has occurred in regions where water supply is less favorable, generating pressures on the resource (availability) especially during periods of extreme weather conditions [80,82]. Because mentioned before, biomass production clearly also will have to comply with this rules to improve the water quality and water consumption in the country.

3.3.3. Biodiversity

The certification systems include several approaches by which to categorize, select, and protect areas with high biodiversity that should not be used in the development of projects [4]. Table 3 shows that the standards analyzed bring together five major issues associated with

biodiversity. The first describes the need to maintain or improve areas of high conservation value (HCV). The second issue is the use of ecological corridors. In this case, because the fragmentation of landscape and loss of habitat are the main pressures on biodiversity [83], it is important to emphasize that most certification systems require the presence of a criterion to maintain a buffer zone around the project area and to facilitate the movement of wild species. The third issue controls or prohibits illegal or inappropriate hunting, fishing, or harvesting activities. The fourth issue is about invasive species in the production area and the fifth issue is the appropriate use of genetically modified species. In general, standards like Better Biomass, ISCC, and RTRS cover all of the above. RSPO has a principle that specifies “Environmental responsibility and conservation of natural resources and biodiversity.” There are six criteria associated with this principle and focused on 1) identification of environmental aspects and management plans, 2) areas of HCV, 3) wastes, 4) renewable energy, 5) fire, and 6) reduction of pollution and emissions [37].

Situation for Colombia: More specifically, Colombia is the second most biodiverse country in the world in terms of ecosystems. For example, forests cover about 53% of the national territory and contain a great diversity of fauna and flora and some endemic species, which makes the country highly vulnerable to changes that affect the environment [84,85]. This makes Colombia one of the “hotspots¹⁶” of biodiversity in the world [86]. In addition to this, Colombia has much land available for agricultural use: about 11 million hectares are suitable for the development of new crops, according to the national agricultural zoning map [87]. The appropriate zoning and efficient use of the land during the expansion of energy crops poses great challenges, especially for the inclusion of biodiversity indicators in the methodological framework of certification systems for biomass production [77,83,88].

Those in the oil palm sector in Colombia are developing a project to contribute to the conservation of biodiversity and the sustainable management of the palm agroecosystems in the country (called “Paisaje Palmero Biodiverso”: Oil palm biodiverse landscape). This project has three specific points: 1) regional planning and guidelines for the conservation of biodiversity, 2) conservation of biodiversity and ecosystem services, and 3) good agro-ecological practices. As a result of this project, it is expected that the oil palm plantations will be planned and managed properly to improve agricultural practices, to avoid contamination of natural resources (water, soil), to incorporate soil cover, to improve the recycling of nutrients, and to retain moisture. In addition, as a contribution to the RSPO certification process, the project is also developing a practical guide to facilitate implementation of the RSPO principles and criteria in the country to, for example, encourage the identification and proper management of HCV, to comply with national regulations, and to protect the forests and natural ecosystems [89,90].

3.3.4. Greenhouse gas emissions

At the international level, it is desirable to create a unified methodology for the identification of GHGs (data for calculations) [4]. It is known that ongoing efforts have been undertaken to discuss ways to harmonize these efforts. In 2009, a policy-making workshop was held that marked the beginning of the BioGrace¹⁷ Project to harmonize the European calculations of the biofuel GHG emission standards to be met, with the RED and the Fuel Quality Directive (FQD) [91]. The BioGrace tool has been recognized as a voluntary scheme by the European

¹⁶ Tropical Andes hotspot located in South America covers much of the territory of Colombia. This Hotspot is notable for its ecosystem services as it is the source of water for the main tributaries of the Amazon and Orinoco rivers and their forests store 5.4 trillion tons of carbon equivalent to the annual carbon emissions of one trillion cars.

¹⁷ www.biograce.net.

Commission [92]. Bonsucro, Better Biomass (NTA8080), and RSB use the BioGrace tool for GHG calculation. Despite this, some certification systems created their own calculation tools. For instance, RSPO has developed and adjusted its own calculator “PalmGHG.” This tool is based on a methodology for evaluation of the life cycle of the plantation and the palm oil mill [93]. PalmGHG, version 3.0.1 (2016) requires a year of data for the calculation of GHG emissions and it has some predetermined calculations (“biomass to carbon conversion factor, fertilizer sea transport distance, conservation sequestration”), but also provides the potential for users to enter their own values (“LUC emission, POME diverted to compost”) [38]. Moreover, it is interesting that RSPO criterion 7.8 specifies that new plantations should estimate carbon reserves in the soil and vegetation that would be replaced by oil palms, prior to development of the project, to minimize GHG emissions generated by LUC [38].

Other standards do not have calculation tools but instead have a written methodology that is in line with the RED requirements. ISCC follows the methodology outlined in ISCC 205 to calculate GHG for all elements of the supply chain and to determine emission savings [44]. The RTRS standard has a methodology that allows soybean producers and processors to comply with the requirements for the supply of soy-based biofuels to member states of the European Union [45]. In the same context, ISO 13065:2015, paragraph 5.2.1, specifies the requirements to reduce anthropogenic GHG emissions and clause 6 establishes the requirements to quantify the GHG emissions. This clause provides requirements and guidelines to complement ISO/TS 14067 (Carbon footprint of products: Requirements and guidelines for quantification and communication). However, it is specified that if there is a difference in the results from ISO/TS 14067 and those from Clause 6, the Clause 6 results take precedence [26].

Some frameworks have compliance ranges for GHG emissions and some do not. Regarding the frameworks that include values, RED (EU 2015/1513) specifies that the production of biofuels must have a GHG emission saving of at least 60% [24]. Better Biomass (NTA 8080-1) mentions the net savings of emissions must involve the entire biomass chain and must be calculated by taking into account the reference fossil fuel. The minimum percentages of savings will be for biofuels 50%, bioliquids 60%, solid and gaseous biomass 60–70% [25]. RSB, ISCC, and Bonsucro are in line with RED requirements, so the value of emissions savings for biofuels must be met with at least 60% [30,40,45]. On the other hand, regarding frameworks that do not include default values are ISO 13065, GBEP, SBP, RTRS, and RSPO. Those frameworks only mention the need to express the results in a known and quantifiable unit of measurement (e.g. g CO₂eq MJ^{−1} or g CO₂eq unit product^{−1}) [26,28,33,34,38]. RSPO includes recommendations for the development of new low-carbon plantations in such a way that net GHG emissions are minimized. In addition, existing companies must have an action plan to minimize emissions from routine operations [38].

There are considerations that allow establishing the use of biomass for energy generation to contribute to reducing GHG emissions compared to the use of fossil fuel. This depends on several factors such as the good agricultural practices applied to the crop (fertilization and transport) and most importantly, land use change (LUC). This is because any savings in emissions can be annulled if the LUC were not taken into account at the beginning of the project [94]. For example, according to Abdul-Manan, Malaysian palm oil biodiesel has a low probability (less than 16%) of compliance with the GHG emissions savings specified in RED for 2020. This is mainly due to problems presented by the LUC of oil palm crops in that country. The author also determined that Malaysian palm oil biodiesel has a GHG emission saving between 3.6% and 51.2%, in relation to the figure from the RED fossil fuel comparator (83.8 gCO₂eq/MJ) [59]. As mentioned above, some sustainability standards do not have specific ranges for GHG emissions. For this reason, some case studies are asses to obtain good examples calculations of complete GHG balances of biofuels. Some

examples are listed below. The bioethanol produced with *Miscanthus* generates less GHG emissions (0 to −78 kg GJ^{−1} ethanol) than the bioethanol of sugar beet (0–54 kg GJ^{−1} ethanol), due to the use of land in the Netherlands [95]. The production of bioelectricity reports savings of GHG emissions (−395 to 128 g CO₂eq kWh^{−1}) compared to conventional sources (mineral carbon 1000 g CO₂eq kWh^{−1}). While the use of biogas (biomethane) showed savings in GHG emissions (−104 to 51 g CO₂eq MJ^{−1}) compared to gasoline (79 g CO₂eq MJ^{−1}) [96]. Finally, it has been reported that the GHG emissions generated by the ILUC due to the biofuels production such as sugarcane ethanol, corn ethanol, and soybean biodiesel, are in a range of 10–60 g CO₂eq MJ^{−1} [97].

Situation for Colombia: The situation of oil palm crops, in Colombia, is different from that in Malaysia. In Colombia, oil palm biodiesel is linked to the potential reduction of GHG emissions (particularly carbon dioxide) of 83% compared to its fossil equivalent. In the determination of the GHG emissions, the LUC and other considerations such as fertilizers, energy consumed, etc., were taken into account over the entire biodiesel production chain: from cultivation to transportation of the biodiesel to the final destination [98]. On the other hand, in 2016, the country's first GHG inventory report was published. This report presents data for the period 1990–2012. During this period, the forestry (144.2–91.1 Mt CO₂eq), agricultural (46–66.3 Mt CO₂eq), and transport (18–28 Mt CO₂eq) sectors made the greatest contributions to the total emissions of the country, while the largest reductions were achieved by the permanent crops included in the agricultural group (−37 to −44 Mt CO₂eq). Within this period, it is highlighted that in all economic sectors of the country there has been a trend of growing GHG emissions, with the exception of the forestry sector. Since 2005, the latter has reduced emissions, mainly due to the reduction of deforestation. In the agricultural sector, the main GHG emissions come from enteric fermentation (livestock, 37%), and from burning and agricultural land management (34%). The growth of emissions associated with permanent crops (22%) is related to the renewal of coffee, oil palm, and fruit crops [99].

Taking into account the national GHG information and the commitments agreed to at COP 21 for GHG reduction, Colombia initiated the development of several strategies. The main strategies were focused on increasing the extension of protected areas and reducing deforestation [100]. Another measure approved was the carbon tax (Article 221, Law 1819 of 2016), which aims to discourage the use of fossil fuels and promote the implementation of more efficient and cleaner energy technologies. For 2017, the value of the tax is about USD 5 for each ton of CO₂ generated by burning fossil fuels, taking into account the CO₂ emission factor of each fuel [101].

3.4. Good Governance

The concept and evaluation of sustainability include not only environmental, social, and economic issues but also Good Governance. Good Governance includes everything related to policies, regulations, compliance, and evaluation of institutional capacities [22]. With regard to Good Governance, it was discussed two points. The first point is to provide evidence for the use of good governance in the certification systems, identifying how these were conceived and how it worked. The second point is to show how the national governments are generating public policies that will make the products in Colombia sustainable.

First, Good Governance in certification systems covers the creation and participation of a governance structure. This structure, in general, has a Board of Directors, Assembly, Committees, and Technical Working Groups. In the case of certification systems created under the Roundtable philosophy, joint work with interested parties is also involved [25]. Table 1 shows that most of the standards evaluated have been generated through a process of consensus building between the stakeholders (private industry, government, NGOs, civil society organizations, etc.). This multi-stakeholder representation often results in a

standard with a governance structure made up of a Board of Directors and Technical Working Groups, and which gives equal rights to all the interested parties [37]. Similarly, consistency and transparency in standards are key requirements for communicating sustainability results to stakeholders and to the general public. Some standards such as RSB, ISCC, Bonsucro, RSPO, and GTC 213 specify the commitment to transparency within their criteria. EC-RED in Article 24 speaks of a Transparency Platform to make relevant information public (for example, action plans, statistics, reports, and production). At the end of the process and in order to strengthen the credibility of a standard, the process of product certification with the required standard is carried out by accredited independent certification bodies [102].

In general, the certification systems do not describe the specific process for the selection of the criteria and indicators used. However, GBEP explains that the indicators used in its standard were developed in consensus by a work team. This team developed a list of criteria (themes) taking into account the relevance, the practical sense, and the scientific basis. The selected criteria were worked on separately in an environmental sub-group, a social sub-group, and an economic sub-group. At the end of the process, a total of 24 sustainability indicators were obtained, each with a methodology sheet that describes the information analyzed in each indicator (relevance, practical sense and scientific basis) [103]. On the other hand, as mentioned above, some standards mention the joint work with interested parties (Roundtable philosophy) and the execution of public consultations prior to the official publication of the final documents. For instance, ISCC specifies some points that must be met in order to a certification system to be transparent. a) the documents must be transcribed into the language of the country of the raw material coming from; b) have published a list of certified operators; c) allow access to the auditor's reports; d) take into account the participation of interested parties before making decisions (public consultation, consultation with indigenous and local communities) [104].

Second, Good governance regarding public policies. The value and impact of international standards must be recognized by decision-makers [102], especially in the public sector, because this sector is responsible for using the results of the sustainability assessments to formulate public policies [22]. The national governments must identify negative social, environmental, and economic impacts and generate policies or laws that reduce the impacts identified for the benefit of the country. For instance, the GBEP standard specifies the importance of measuring indicators transparently and placing them within an appropriate national context, including information on legal, policy, and institutional frameworks [28]. GBEP indicators were piloted in five countries (Colombia, Germany, Ghana, Indonesia, and the Netherlands) with the help of FAO and the governments of each country. This was done to test the efficiency in capturing information to measure the sustainability of bioenergy at the national level [29].

Situation for Colombia: Colombia was one of the countries selected by GBEP officials to pilot test its indicators to measure the sustainability of bioenergy at the national level. A group of national consultants made up of researchers from the National University of Colombia (UN), researchers from the International Center for Tropical Agriculture (CIAT), and officials from the Ministry of Agriculture and Rural Development (MADR) carried out the pilot test. FAO and international technical experts (Germany) supported this group. During the development of the pilot test, meetings were held between the working group and various stakeholders to analyze the information collected and study the possibility of developing new national policies. One of the results found in that pilot test was that bioenergy produced from cogeneration in sugar mills represents a significant part of the country's total primary energy supply [103]. In this context, in recent years, the Colombian Government has adopted a series of measures to promote the production and use of bioenergy (Decree 4892/2011, Resolution 90932/2013, Law 1715/2014) [105] and to reduce environmental pollution related to the use of biomass (Resolution 909/2008, Resolution 0631/2015). In

addition, Colombian officials are working on the formulation of policies to biomass use for the production of renewable energy and bio-based products [106].

4. Synthesis and discussion

In this section, it was discussed the content of the certification systems from two points of view, one general and one at the level of each of the components of sustainability (social, environmental, and economic).

4.1. General comments

Most of the certification systems analyzed in this paper (Table 1) have been updated in the last two years. The updates include adjustment of some indicators such as the mandatory reporting of GHG emissions and the inclusion of new indicators such as ILUC and carbon debt. These adjustments are based on Directive EU 2015/1513, which amends Directive 2009/28/EC, which governs the European Union. The GBEP standard is awaiting update because the process started in 2014 [107]. The RSPO was updated in 2013 and is expected to be updated again in 2018. There has been no update for the Colombian standard Icontec-GTC 213 to the present (late 2017).

The methodologies for evaluation of these certification systems show both similarities and differences in the ways in which the sustainability requirements were included. For example, in some standards, indicators are described only generally, and these do not clearly specify what the standard is intended to measure. This is the case of the Icontec-GTC 213 standard and the GBEP standard, where the descriptions of the indicators do not clearly define the requirements to be followed. These rules are limited to giving guidance or description that the reader must interpret. Likewise, the NTA8080: 2009 standard did not have concrete indicators, so it was updated in 2015 to a version called Better Biomass. With the adjustment, concrete indicators were defined that allow better evaluation of the requirements that must be met by organizations. For instance, in the 2009 version, it was only mentioned that the requirements of workers' rights (ILO) should be applied. While in the 2015 version, the working conditions that must be fulfilled are specified (e.g. "The organization shall demonstrate that the local statutory working hours are not exceeded or, if there are no statutory provisions, that a normal working week, without overtime, is not more than 48 h") [25].

Other standards (e.g. RSPO, Bonsucro, and RTRS) that were developed using the roundtable model, designed a methodology for evaluating their supply chains with the help of technical committees of interested parties. Fig. 1 shows a key methodology for obtaining sustainability criteria in bio-based products through a certification system. In general, stakeholders involve supply chain actors, consumer goods manufacturers, field experts, social and environmental NGOs, banks, and investors. The group work of technical committees facilitates the evaluation of sustainability indicators attributable to a supply chain. It also allows indicators to be changed according to the needs of stakeholders, although in some cases indicators such as ILUC, GHG, or social well-being may require further research to identify and allocate relative values [22]. An example of the work of the technical committees of interested parties was developed during the creation of the GBEP standard. The GBEP Standard Working Group developed and agreed upon a list of criteria to be subsequently evaluated. It then established three working subgroups to review the indicators needed for the selected criteria. At the end of the process, decisions were adopted by consensus among partners [28].

Another point to mention is the use of a national interpretation document applicable to some of the certification systems (a generic standard) of an international supply chain. In this case, the objective is to cover different national, geographic, and production aspects under the particular conditions of the country where the organization must be

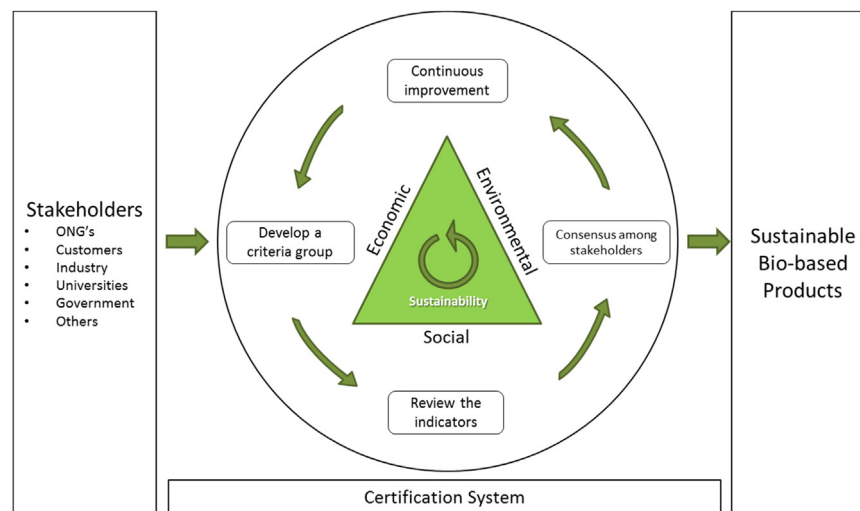


Fig. 1. Key methodology to obtain sustainability criteria in bio-based products through a certification system (Based on ISO 9001 and [109]).

evaluated using the generic standard [108]. It must be understood that the generic norm requires that national interpretations must comply with the laws and requirements of international conventions if the country of interpretation has no laws regulating these issues. This type of methodology is used in agricultural certification systems such as RTRS, RSPO, and Bonsucro. [109]

4.2. Indicators for each area of concern

For this section, it was analyzed each of the three dimensions of sustainability (social, environmental, and economic) taking into account the indicators present in the eleven certification systems analyzed in this document. The list of indicators is not exhaustive because it was intended that only those most relevant and common to all certification systems be analyzed. A total of 54 sustainability criteria/indicators were identified. Fig. 2 shows that, of those criteria or indicators, 44% are related to the environmental issues/aspects, 30% to the social area, and 26% to the economic area. In fact, to date, there is still a greater focus on environmental issues compared to the other issues of sustainability. However, in most certification systems the environmental and socio-economic issues get equal attention.

4.2.1. Environmental aspects

Table 3 shows the seven major principles or topics that were

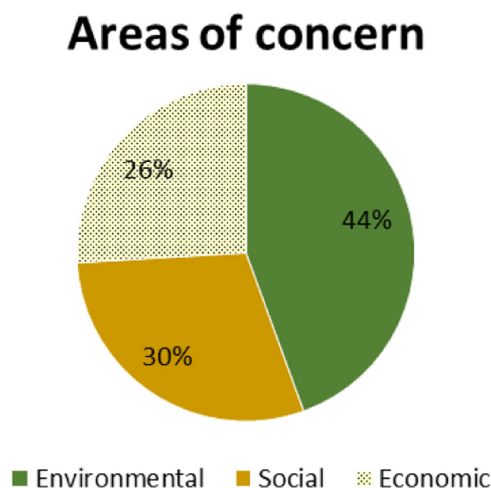


Fig. 2. Percentage of participation of sustainability indicators, by areas of concern, included in the eleven certification systems analyzed in this paper.

identified in this area. These include GHG emissions and carbon stocks, biodiversity, water, soil, air, bioenergy, and waste management. In total, 24 criteria/indicators, some of which were not included in all the certification systems, were identified. The criteria/indicators present in all standards were soil quality (best practices), areas of high conservation value (maintain or improve at the local, regional, or global level), and water care and conservation (use, efficiency, and quality). On the other hand, the criteria/indicators not consistently present in the standards were phytosanitary products and seeds (restrictions), ILUC, soil survey (topographic), and access to bioenergy. At the global level, the standards with the highest number of indicators for the environmental aspects were ISCC, RED, and RSPO. By contrast, the standard with the lowest number of indicators included in this aspect was GBEP, ISO 13065, and Bonsucro.

There is an interesting indicator in the Better Biomass, RSB, ISCC, and RSPO standards. It refers to the importance of not removing all residual biomass from croplands. It has been mentioned previously that agricultural biomass residues can be used for the development of new products with significant economic benefits, reducing the impact on food security and LUC caused by the production of first-generation biofuels [110]. However, excessive removal of crop biomass could trigger problems with the quality and stability of the soils in the long term. Depending on the particular conditions in the area of agricultural production, it is necessary to retain a certain amount of biomass to sustain soil fertility and to protect against erosion [111].

In the standards revision, no threshold value was reported for the amount of agricultural waste that must be returned (left) to the soil. The Better Biomass standard only relates the use of BioESoil tool to determine the impact of bioenergy production (loss of nutrients, flow of nutrients returning to the soil) on the crops soil quality (fertility and organic matter). Some studies report the benefit in the use of harvest residues (leaves, trunks, roots) [50,112,113] but do not relate a specific or general range for compliance in all cases. The amount of biomass that should be left on the field should be evaluated locally. This is because it depends on the type of crop, the climatic conditions of the area, the soil needs, the transport costs of biomass or the competition for the use of biomass in other economic activities (compost, pellets, cogeneration) [114,112]. A study in South Africa demonstrated who sustainable residues removal are determined by agriculture methods, soil, and climate. For instance, to control soil erosion it was estimated a minimum biomass requirement of 2 t ha^{-1} [115]. In Colombia, oil palm cultivation reported the use of pruning leaves and EFB (empty fruit bunches) around the palm to conserve soil moisture, promote root emission and increase nutritional efficiency [50]. While pruning leaves should always remain in the crop [116], the dose of EFB application

will depend on the cultivation age, the expected production and the specific requirements of the soil (fertilization). For example, for a young palm crop (< 7 years) the dose varies between 10 and 30 t ha⁻¹, while for an adult palm crop (> 7 years) the dose varies between 35 and 70 t ha⁻¹ [117].

Other key concerns are land use indicators. On this point, there are two visions in the standards. The first is about land rights and how were acquired. The second refers to changes in the use of the land where the crop is planted. All standards have an indicator associated with land rights but not all standards have a clear indicator to evaluate LUC. Land use has contributed significantly to increasing GHG levels in the atmosphere [118]. For instance, over the past two hundred years, extensive forest areas have been cleared for cereal and cotton production in the United States and Europe, as well as for livestock and plantations of coffee, sugar cane, rubber, tea, and oil palm in Asia, Africa, and Latin America [119]. Standards such as RTRS, RSPO and RSB have forest clearing and degradation safeguard indicators. However, these require continuous improvement because there is still no general consensus on what “deforestation-free production” means [120]. As a result, sustainable and responsible forest management requires the use of measurable indicators to identify progress in generating ecosystem services and reducing deforestation. In this way, successful decisions can be made by stakeholders (governments, private sector, non-governmental organizations, donor organizations, researchers, and the public) [121].

Situation for Colombia: The most relevant forestry plans and policies have been generated in Colombia since the 1970s [122]. Despite this, there are some natural ecosystems that have been transformed and degraded by deforestation caused by illicit cultivation, open-pit mining, and agricultural production, among others [123]. One of the drivers of the deforestation has been the agricultural sector; however, in the case of oil palm, expansion of this crop in the country has more often arisen by conversion of pastures (51%) and agricultural areas (29.1%) than by conversion of areas of natural vegetation (16.1%) [124]. To counteract the damage caused to the environment, in recent years the national government has approved several policies and plans of action. That involves such as 1) “Plan de Nacional de Restauración” (National Restoration Plan), 2) “Política Nacional de Biodiversidad” (National Biodiversity Policy), 3) “Política Nacional de Cambio Climático” (National Climate Change Policy), and 4) “Política Nacional para la Gestión Integral del Recurso Hídrico” (National Policy for the Integral Management of Water Resources).

4.2.2. Social aspects

The social aspects (see Table 4) include three major principles/topics: rural and social development, food security and human rights, and labor and land rights. These themes include two indicators in all the certification systems: child and woman labor, and land rights and land use rights (both formal and informal). On the other hand, the indicators that were not consistently included in the analyzed systems were: maintain or improve the local food security of the people directly affected and child education. In this order, the standards with the greatest social focus were ISCC, RSB, and RSPO. In contrast, the standards with the lowest level of consideration of social indicators were GBEP and RED. Food security is not the most discussed issue in these certification systems. According to Neydi Clavijo,¹⁸ when the certification system is designed for consideration of products from biomass to be extracted from large tracts of agricultural crops (monoculture), it is not possible to talk about food security. In this case, other indicators related to human well-being must be available [125]. For example, access to land, land use, access to energy, household incomes, and food supply and prices. These indicators are related to the four dimensions of food security (availability, access, stability, and utilization) [28]. However, it

Table 4
Overview of social principles/criteria and indicators. • = Included; X = not included; ? = Uncertain^a.

| Principle/Topic | Criteria/Indicators | Certification system | | | | | | | | | | | |
|---|---|----------------------|--------|---------|-----------|-----|------|-----|------|--------|----------|------|---------|
| | | GBEP | BETTER | BIOMASS | ISO 13065 | RSB | ISCC | SBP | RTRS | EC-RED | BONSUCRO | RSPO | GTC 213 |
| 1. Rural and Social development | Jobs related to the sector evaluated/local workers | • | • | | X | • | • | • | • | X | • | • | X |
| | Well-being of employees and families (additional to work rights) | X | ? | | X | • | • | ? | • | X | • | • | • |
| | Children education | X | X | | • | X | • | X | X | X | • | • | ? |
| | Social benefits or encourage the participation of women, youth, indigenous communities | X | • | | X | • | • | ? | • | X | X | • | • |
| 2. Food security | Community/worker/interested parties complaints | X | • | | X | • | • | • | • | X | • | • | • |
| | Price and supply of a local food basket | • | • | | • | • | • | X | • | • | X | ? | • |
| | Maintenance or improve the local food security of the directly affected people | X | X | | X | • | X | • | X | • | • | • | • |
| | Existing land rights and land use rights, both formal and informal | • | • | | • | • | • | • | • | • | • | • | • |
| 3. Human rights, labor rights and land rights | Free, Prior, and Informed Consents hall form the basis for all negotiated agreements for any compensation, acquisition, or voluntary relinquishment of rights by land users or owners | • | • | | • | • | • | • | • | X | • | • | • |
| | Training and re-qualification of workforce | • | • | | • | • | • | • | • | • | • | • | • |
| | Payment of legal salary/Fair farming agreements | • | • | | • | • | • | • | • | ? | • | • | X |
| | Child and women labor | • | • | | • | • | • | • | • | • | • | • | • |
| | Absence of discrimination | ? | • | | • | • | • | • | • | • | • | • | • |
| | Occupational safety and health | • | • | | • | • | • | • | • | • | • | • | • |
| | Freedom of association, the right to organize, and the right to collectively bargain. | X | • | | • | • | • | • | • | • | • | • | • |
| | No slave labor or forced labor | X | ? | | • | • | • | • | • | • | • | • | • |

^a ? = Uncertain. This means that the certification system mentions the subject but does NOT define a specific criterion or indicator.

¹⁸ Magister in Ecological Agriculture and professor of Faculty of Environmental and Rural studies at the Javeriana University (Colombia).

was mentioned that for small growers, it is possible to work with the term “Food self-reliance.” This is the ability to generate sufficient income (economic capacity) through agricultural activities to meet food needs (buy sufficient food) [125,126].

Some previous studies have reported several social indicators that cover different aspects and that have been used in different standards. Nevertheless, there are some social indicators that are less used than others as was mentioned before (gender, food security, children education) [4,127,128]. A study analyzed a methodology to quantify the socio-economic impacts (GDP, imports, and employment) generated by the production of bio-ethanol (sugarcane) in Brazil. The analysis highlights the need to include the interregional approach to identify more accurately the direct-indirect impacts of a sector in a region. For example, the inputs required for the production of bioethanol can come from the same region (direct) or in some cases from regions outside the area of influence (indirect), generating variations in the regional GDP. Also, the impact (positive/negative) of the use of mechanization in crops since it leads to a reduction in the use of workforce [129]. Not all studies focus on the indirect analysis of impacts, which creates a need to delve into issues that go beyond the regional boundaries of a sector at a social and economic level.

Situation for Colombia: In order to contribute to the improvement of the food situation and nutrition of the entire Colombian population, especially the poorest and most vulnerable, in 2013 the national government published the National Food and Nutrition Security Plan 2012–2014, in compliance with what was established in CONPES 113 of 2008 [125,130]. On the other hand, according to Miriam Martínez,¹⁹ to reduce the risk of negative impacts on the food security of the population close to oil palm plantations, the national interpretation of the RSPO for Colombia added this theme to the guidelines. One of them in criterion 6.1 (fostering local entrepreneurship projects) and the other one in criterion 7.1 (forced displacement and loss of food security of the local population are considered unacceptable). This theme contributes to the credibility of the standard because it requires the evaluation of the social impacts prior to establishing a new plantation or expanding existing ones [46]. Likewise, the RSPO is one of the certification systems with a greater focus on social issues because this contains the requirements of ISO 26000, and in some cases anticipates some additional ones. The RSPO standard demands compliance with the basic legal norms of the country and has a strong focus on human rights and their relationship with communities; for this reason, one of the basic guidelines of RSPO is free, prior, and informed consent. Among the countries that produce oil palm, Colombia has a greater number of regulations on labor issues, protection of ethnic communities, and the use of indigenous guards. The latter was added as a result of prior consultation (ILO Convention 169) [46].

In Colombia, both the national laws and the RSPO standard specify the need to identify the origin of the land upon which the oil palm is to be cultivated. In this regard, Miriam mentions the importance of establishing title to land, or leasing the land, to reduce the possibility of incurring problems such as deforestation or abandonment of crops. In spite of this, in Colombia, some laws have not been sufficiently clear about the titling of some land. In addition, in the last 50 years, Colombia has been subjected to armed conflict that has generated complications for the titling of some lands. For this reason before buying rural land to execute productive projects it is essential to verify: 1) the identity of the seller, 2) the physical aspects of the property, 3) current occupation of the property, 4) qualification documents, and 5) the legal conditions of ownership [46].

Some indicators were created to provide welfare to the local community close to the production unit (company). However, there are some companies to give an extra support to the workers or the community. The support includes the supply of drinking water, free

educational access, support for the creation of a microenterprise, housing construction, among others. In Colombia, there are companies, which benefit their workers and the nearby community through social management. One example is the Manuelita group that supported the creation of several productive units to increase the average monthly income both to the workers' families and to external families belonging to the surrounding communities. One of that microenterprise was created to make gloves for industrial use, where Manuelita provided the training, provided seed capital for the purchase of equipment and machinery, and at the end of the process, Manuelita group was the main client [131].

4.2.3. Economic aspects

Table 5 shows an overview of the economic principle/topic and criteria/indicators identified in the certification systems. The economic areas of concern were divided into three groups: economic viability, legal compliance, and good management practices and continuous improvement. The indicator present in all certification systems was to comply with all applicable laws and regulations (national and international) which include, for example, compliance with the payment of royalties and taxes. The ISCC and RSPO standards have large consideration of this economic area, and the largest number of criteria/indicators proposed. Within the Principle/Topic presented in Table 5 denominated “Economic viability,” the most relevant indicator, for compliance with a certification standard, is to have a business plan or management plan. In this regard, while ISO 13065 requests information on financial risk management, such as procedures to identify possible risks and possible measures to address them; other standards such as ISCC, RSPO, and GTC213 require that the business/management plan reflect a commitment to long-term economic viability. Other indicators such as commitment to transparency and anti-corruption documentation are present in most standards. The goal of these indicators is to build credibility among stakeholders in the supply chain and among certified companies.

The Principle/Topic of “Good management practices and continuous improvement” is present in many of the certification systems analyzed (Table 5). This issue is included in the economic area because the producers of biomass or bio-based products must maintain or improve the processes and conditions of their operations to reduce the use of resources (e.g., materials, supplies, fuel, energy, water, etc.). In fact, an interesting criterion in this topic is continuous monitoring to evaluate environmental, social, economic, and industrial impacts. Certification systems such as Better Biomass, ISCC, SBP, RTRS, Bonsucro, RSPO, and GTC213 include the continuous monitoring of impacts within their standards in order to identify possible positive and negative impacts before or during the projects. After their identification, it is necessary to generate action plans to implement monitoring of the impacts appropriately and in this way, reduce or avoid them as the need arises. Although current certification systems have several social and economic indicators, many lack precise definitions and methodologies for measurement [127], or these may be based on qualitative indicators [132]. Therefore, this could be considered a key issue (to work toward continuous improvement) in the certification systems for biomass and bio-based products.

Situation for Colombia: Because the environment cannot be separated from the economy, the national government is promoting a vision of climate finance. This vision allows the incorporation of climate change in the economic and financial planning of the country. In this way, it is expected to guarantee the necessary flow of public, private, and international cooperation financial resources for adaptation and mitigation of climate change. In Colombia, the existing legal framework includes instruments and incentives to favor public and private investment in climate change. However, to achieve effective finance to address climate issues, it is necessary for Colombia to strengthen other financial mechanisms regarding i) market allowances, ii) compensation fee for air emissions, iii) green bonds, and iv) access to mitigation and

¹⁹ Leader of Fedepalma Social Area. Colombia.

Table 5
Overview of economic principles/criteria and indicators. • = Included; X = not included; ? = Uncertain^a.

| Principle/Topic | Criteria/Indicators | GBEP | BETTER BIOMASS | ISO 13065 | RSB | ISCC | SBP | RTRS | EC-RED | BONSUCRO | RSPO | GTC 213 |
|--|---|------|----------------|-----------|-----|------|-----|------|--------|----------|------|---------|
| Economic Viability | Business plan/management plan | X | X | • | • | • | • | X | • | X | • | • |
| | Productivity | • | • | • | • | • | • | X | • | • | • | • |
| | Value added | • | X | X | X | X | X | X | X | • | X | X |
| | Change in consumption of fossil fuels and traditional use of biomass | • | • | X | X | • | X | • | X | X | • | X |
| Legal compliance | Anticorruption documents/activities | X | • | • | • | X | • | X | • | • | • | X |
| | Commitment to transparency | X | • | X | • | • | X | • | • | • | • | • |
| | Comply with all applicable laws and regulations of the country in which the operation occurs and comply with relevant international laws and agreements | • | • | • | • | • | • | • | • | • | • | • |
| | Documentation system and record-keeping economical/farm/process | X | • | • | • | • | • | • | • | X | • | • |
| Good Management Practices and Continuous Improvement | Continuous monitoring to determine impacts assessment | X | • | • | • | • | • | • | • | • | • | • |
| | Continuous improvement in activities | X | • | • | • | • | • | • | X | • | • | • |
| | Information on the use of technologies in operations (proprietary technology and intellectual property rights) | X | X | X | • | X | X | X | • | X | X | X |
| | Disclose technologies/chemical with hazardous or potentially hazardous | X | X | X | • | • | X | • | X | X | • | • |
| | Full compliance of subcontractors | X | • | X | • | • | X | • | • | • | • | • |

^a ? = Uncertain. This means that the certification system mentions the subject but does NOT define a specific criterion or indicator.

adaptation loans. The investments of the productive sector in mitigation and adaptation are of vital importance to achieve development compatible with the changing climate [133]. An example is the national energy system. Colombia has a large amount of unconventional renewable resources with which to complement this system. Developing this potential offers the country the opportunity to attract investments that increase access to capital and increase the competitiveness of the electricity sector. Although the government has already generated some tax, tariff, and accounting incentives for investment and the use of renewable resources, only 1% of the country's total energy generation corresponds to cogeneration with biomass [134]. Therefore, the potential for continued and increased investments in the energy sector of the country involving the use of bio-based products is substantial.

5. Conclusions and recommendations

In this document, it was analyzed (strengths and weaknesses) the key sustainability criteria of 10 international systems for certification of bioenergy. Also, it was analyzed how some of the initiatives have been implemented in Colombia. A key observation of the review is that most of the certification systems analyzed have been updated in the last two years. The most important update is the inclusion of the ILUC theme. The standards that have included, to date, this issue in their requirements are RED, Better Biomass, and RSB. RED included the ILUC to reduce the GHG generated by biofuels and thus prevent excessive use of land destined for food production for the production of biofuels. Both RSB and Better Biomass emphasize that in order to reduce the ILUC, the yield of the crops must be increased (higher yield on less land) and the crop residues must be used to generate new products. Another update includes the obligation to include GHG emissions within the sustainability requirements and to publish these emission records. In addition, the use of GHG calculation tools was highlighted to facilitate homogenization and comparison of the information obtained. BioGrace is a calculator recognized as a voluntary scheme by the European Commission for bio-liquids and biofuels. Finally, it was emphasized that despite requiring greater emphasis on the issue of food security, the certification systems evaluated have already included in their social concerns at least one indicator associated with food (e.g., family basket price, food supply).

It was noted that there is still a greater focus on environmental issues than on a balance among essential sustainability issues. However, social and economic issues have recently achieved greater importance within the requirements of the standards. The most representative requirements for each area of sustainability are highlighted below.

Environmental: The criteria/indicators present in all the standards were soil quality (best practices), areas of high conservation value, and water care and conservation. All the standards recognize the need for water conservation from three points of view: availability, efficiency of use, and quality; but the ways by which these topics were addressed differed. ISCC and RTRS prioritize the care of natural wetlands to maintain water availability. Better Biomass, ISCC, RTRS, GTC 213, and Bonsucro emphasize the efficiency of water use for irrigation. GBEP, ISCC, RSPO, RED, RTRS, and SBP take into account the impact of agricultural practices on water quality and call for the measurement of parameters such as N, P, and pesticides. ISO 13065 is stricter because it calls for the identification of physicochemical and biological parameters associated with possible impacts, such as eutrophication and oxygen depletion. With respect to biodiversity, it is emphasized that all the standards require maintaining or improving HCV areas. In addition, standards require the presence of ecological corridors to maintain a buffer zone around the project area and facilitate the movement (flow) of wild species. ISCC has a stricter requirement to protect land with HCV or high carbon content.

Social: Although in the last few years, the standards have included a greater number of social indicators within their requirements, it is necessary to have specific methodologies that allow for an accurate

quantification of social welfare at the local, regional, and national levels. Even, it is necessary to focus on the indirect impacts to go beyond the regional (sectoral) borders. The main issues in the social context, in the certification systems analyzed, were rural and social development, food security, and human, labor, and land rights. The standards under which social issues had the highest priority were ISCC, RSB, and RSPO. Although the GBEP standard has a strong focus on food security, it does not have specific indicators for issues such as child labor, the welfare of employees and their families, free association, and participation of women and indigenous communities in projects.

Economic: All the certification systems required compliance with all laws and regulations (national and international), which include, for instance, compliance with the payment of royalties and taxes. The ISCC and RSPO standards have substantial consideration of issues in this area and propose the highest number of economic criteria/indicators. Another issue that was highlighted is the requirement for a business or management plan to contribute to the economic viability of the certified company. In this regard, while ISO 13065 requests information on financial risk management, such as procedures to identify possible risks and possible measures to address them; other standards such as ISCC, RSPO, and GTC213 require that the business/management plan reflect a commitment to long-term economic viability.

In addition to the social, environmental, and economic issues, the issue of Good Governance, both within the certification systems and in the participating national governments, is essential to integrate efforts and achieve sustainable biomass production and sustainable bio-based products. Good governance in the certification systems provides for the creation and participation of a governance structure. This structure, in general, has a Board of Directors, Assembly, Committees, and technical working groups. In the case of certification systems that were created with the Roundtable philosophy, joint work with interested parties is also involved. The certification systems designed by consensus among interested parties are RTRS, RSPO, Bonsucro, RSB, and GBEP. The requirement for a commitment to transparency was also highlighted, especially in standards such as RSB, ISCC, Bonsucro, RSPO, and GTC 213. Moreover, RED specifies the importance of transparency, especially in the publication of information needed to strengthen the credibility of the standards.

Some certification systems stand out for having special strengths. 1) RTRS has a special certification scheme that allows the producer, especially small producers, to be certified through compliance with a certain number of short and medium-term indicators within a period of up to three years, until completing all requirements. 2) RSPO includes several key issues such as commitment to the acquisition of legal land for cultivation and the inclusion of a principle with guidelines for the responsible development of new plantations. These are intended to promote better decision making and avoid negative impacts on the project area. 3) Better Biomass, RSB, ISCC, and RSPO all have a specific indicator that refers to the importance of not removing all residual biomass from croplands. This means that the use of a portion of crop residues should be promoted but that the quality of the soil where the crop is grown should also be maintained. 4) Some certification systems allow a National Interpretation (NI) of their standards to accommodate different national, geographical, and production aspects under the particular conditions in the country where the producer is certified. Despite the above, there are still issues (weaknesses) in the certification systems that call for greater clarity. For example, although all standards have an indicator associated with land rights, not all standards have a clear indicator for assessing LUC. In addition, some standards should be clearer in their description of indicators, such as the Icontec-GTC 213 standard, which only gives a guide or description of the criteria, forcing the reader to interpret these guidelines and to generate the indicators that he considers appropriate to satisfy the criterion.

Situation for Colombia: Colombia is one of the countries in the world where the basic conditions for a future sustainable bio-based sector are mostly positive. This country has great natural resources that could be

used in a sustainable way. For instance, it has been determined that the country has a large amount of land suitable for cultivation without generating deforestation problems. However, this also presents several challenges when it comes to producing or seeding biomass. For this reason, the national government has worked to provide laws to protect the environment (climate, soil, biodiversity, water), increase the role of renewable energy, reduce GHG emissions, stimulate rural development, and build sectors competitive with a vision of climate finance. In other words, the plan is to incorporate climate change into the economic and financial planning of the country.

It is a major challenge to achieve a sustainable bio-economy where the agricultural sector has an important role in generating products first hand. It is important that the market for sustainable biomass products diversify sources of economic development to reduce dependence on chemicals and fossil fuels. In addition, development of a bio-economy represents an opportunity to address the challenges of food security, climate change, and the generation of clean energy. It should also be borne in mind that in a mega-diverse country like Colombia, the complexity of issues such as biodiversity, water, and soil, require integrated use of rigorous national laws for the protection of natural resources and the use of certification systems for sustainable products. Given Colombia's progress on legislation to address climate change (as reported in this paper), the empowerment of public and private sectors regarding sustainability issues have made them more competitive without their having to neglect environmental and social issues. The most widely used standards in the country are international in origins, such as RSPO, RTRS, and Bonsucro.

Finally, it is necessary to emphasize that despite the new requirements issued by RED (ILUC, mitigation options, and GHG calculation tools), to date very few certification systems have been adjusted to incorporate those aspects. On the other hand, although Colombia is already on track to have a sustainable bio-based economy, it faces great challenges such as the implementation and compliance with all the laws that have been generated in recent years in the country. In addition to continuing to develop government incentives to promote the use of bio-based products, and to use appropriate sustainability indicators (e.g., LUC, ILUC, food security); the generation of trust through good governance and inclusion of sustainable markets are also needed. Finally, at a scientific level, it recommends continuing with the generation of specific information such as land use data, biodiversity monitoring, improvement in worker well-being, and registration of changes in food security in local areas, among others. This information is basic to complement the national and global databases that companies and governments can use to continue reducing environmental, social, and economic impacts from the expanded bio-economy.

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