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Sustainability of Ethanol Sector in Brazil: A Multicase Study

Karina R.O.V. Souza and Ronaldo Perez

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<http://dx.doi.org/10.5772/intechopen.71495>

Abstract

Sustainability has been worldwide discussed, and when it comes to sugarcane-ethanol production, there are many standards required from importing countries to its suppliers. Brazil is the second biggest producer of ethanol in the world, and it has a competitive advantage over other countries since it has a high established production and land for agricultural expansion. The aim of this research is to evaluate the situation of ethanol plants in Minas Gerais state concerning their compliance to sustainability criteria and to briefly present the current situation of ethanol plants in Brazil. This evaluation is based on Bonsucro certification. A multicase study, composed of four sugarcane-ethanol plants, was conducted. The results indicated that the studied plants were not prepared to receive Bonsucro certification. They justified it due to constant changes in legislation relating to sustainability, and the fact that these criteria are not required by their customers, however, was concluded that the companies did not take a proactive posture, seeking knowledge about standards related to the topic. Obtaining international certification did not look appealing by the time of the study, but attendance to national legislation is mandatory. In 2017, the number of certified plants has increased, showing that there has been progress.

Keywords: sustainability, ethanol plants, sugarcane, Bonsucro certification, Minas Gerais

1. Introduction

Discussions about sustainability and its importance to the planet have been intensified since 1990s. In the face of so many climate changes and environmental disasters, concerns that in the future such picture gets worse have led national and international companies and organizations to think about the best way to work with natural resources, to obtain minor environmental impact.

Sustainability is understood as the ability to use natural resources and, in whole or in part, to return them to the planet, guaranteeing a good quality of life for those living in the environment and for those who will live.

The sugar and ethanol trade in the international market has suffered from nontrade barriers, which has restricted the expansion of the sector, mainly in countries under development. These barriers are standards and directives related to sustainability, which have been imposed by importing countries. Examples are European Renewable Energy Directive 2009/28/EC [1], which was published in April 2009, and Bonsucro (Better Sugarcane Initiative) [2] which was last updated in April 2014.

The European Renewable Energy Directive 2009/28/EC deals with the promotion of the use of energy from renewable sources and sets out a number of requirements to be followed by all domestic and international biofuel producers and buyers.

Bonsucro is a worldwide multistakeholder association created to reduce the environmental and social impacts of sugarcane by designing a standard and program to transform the sugarcane-ethanol sector [2]. The adhesion favors the achievement of high standards of sugarcane production, far above what is determined by national environmental legislation.

The number of certified plants by Bonsucro has increased each year. Between 2015 and 2016, membership grew by 4.5%, and the number of Bonsucro production certificates by 24%, with 12 new certified mills, including first certifications in Guatemala, Nicaragua, Dominican Republic and Thailand, more than doubling the countries which have Bonsucro certifications to a total of 9 [3].

In this sense, this document aims to present the situation of sustainability in the sugarcane-ethanol industries of Minas Gerais state, Brazil, using as indicators the criteria required by international legislation, especially those from Bonsucro and the European Renewable Energy Directive 2009/28/EC. The goal is to present how sustainable the ethanol plants are according to those directives, and how much they could and should be. This is extremely important to sugarcane-ethanol plants, since in many moments, they have been held responsible for negative actions against environment and society, and so, the necessity for clarifications and proofs of compliance with standards on sustainability has been increasingly strong. In addition, it aims to demonstrate how the plants evolved in this topic in the last five years.

1.1. Sustainability in the sugarcane-ethanol sector

The process of man-nature interaction is exploratory since the first inhabitants, and thinking about this relationship without thinking about the transformation of the environment is impossible. This relationship was intensified and improved until in the eighteenth century the Industrial Revolution that began in England spread, reaching the other countries. This in turn stimulated by the accumulation of capital consolidated capitalism, an economic model that dominates until the present day [4]. Since then, natural resources have been explored intensively and the impacts of this unbalanced degradation began to be perceived in the twentieth century, causing concern to environmentalists and taking on increasing proportions [5].

In this sense, the discussion of environmental sustainability arises from the limitation and misuse of available resources and can be reversed by the use of clean technologies and, above all, by the creation and consolidation of administrative mechanisms of environmental protection [6].

Sustainability is understood as a combination of three pillars, economic, social, and environmental [7], or also as meeting the basic needs of all, giving them the opportunity to meet their needs in the future, aspiring for a better life [8].

Basurko et al. [9] argue that today there is a growing interest in sustainable products, and it is clear that this major shift toward sustainable development is essential for a competitive market. Moldan et al. [10] say that to improve the cost-effectiveness and operational value of environmental policies in the context of sustainable development, efforts should be made to improve information for decision-making by assessing progress through indicators.

A sustainability indicator can be understood as a quantitative or qualitative tool that allows the analysis of changes while measuring and communicating the progress toward the sustainable use and management of economic, social, and environmental resources [11]. According to [12, 13], there is a range of tools developed, which use indicators to measure sustainability. The use of indicators and indexes for sustainability assessment has increased a lot in recent decades, since it is an instrument that simply expresses a complex message, resulting from many factors [14].

A number of papers have been published about sustainability of sugarcane-ethanol production [15–17] and the impact of it on their countries [18–20]. In those papers, it is possible to observe the range of indicators used and the variety of certifications (compulsory and voluntary) that should be followed and attended.

1.2. Dimensions of sustainability

1.2.1. Environmental dimension

The sugar-ethanol sector is characterized by an activity that uses natural resources intensively. It exerts influence in the generation of foreign exchange for the country, through the production of its derivatives, demanding the attention of public and private entities in the environmental sphere, due to the problems of compaction of the soil, burning of the cane, and emission of gases, which intensify global warming and degrade the environment. The advantages are obtained with the mechanical harvesting without burning, due to the straw that is left in the soil [21, 22].

For the variables that make up environmental sustainability and will be taken as the basis of this study, mention should be made of areas for sugarcane expansion, compliance with legislation, treatment of effluents and waste, and mechanization of the harvest. These variables are of great importance when analyzing the behavior of companies, through the presence or absence of environmental practices internally, as well as meeting the Bonsucro certification indicators, the focus of the study.

Within this context, [6] affirm that an attitude based on immediacy still prevails in business actions, where the management of environmental practices only occurs when there is an imposition of the laws and regulations created in the country, so the importance of evaluating these aspects.

1.2.2. Social dimension

The socio-environmental theme, mainly on the focus of sustainability, is increasingly inserted in the different types of markets and involves several stakeholders that drive and direct the organizations to management practices and strategies aimed at minimizing the degradation of the environment, as previously mentioned, and social problems [22].

The social dimension seeks the vision of a balanced society, which seeks a new lifestyle appropriate to the present moment and to the future. It seeks economic development coupled with a significant improvement in the quality of life of the world population, that is, greater equity in income distribution, improvements in health, education, job opportunities, etc. [12].

In the sugar-energy sector, the challenges for social sustainability are related to access to land, working conditions, burning and mechanization of the harvest, and training of employees, linked to the qualification of the workforce. All these factors are addressed in Bonsucro and were evaluated in this study.

Rodrigues et al. [23] argue that monoculture farming practices, such as sugarcane, on large tracts of land have been identified as generating inequalities in the countryside, as well as an obstacle to the social reproduction of traditional populations. The absence of an effective legal system of the Brazilian land structure, capable of regulating and limiting the uses of properties, associated with the availability of cheap labor, has contributed to the expansion of monocultures. These authors also discuss the working conditions in the sugarcane-ethanol sector, addressing issues such as workload, wages, health and safety at work, and within this subject, the most discussed point is the manual harvesting of sugarcane.

After the Brazilian Federal Decree n. 2681, 1998, which determines the complete suppression of sugarcane burning until 2018, throughout Brazil, the harvest mechanization was encouraged and, together with this, the concern of governments and unions about the destination of the workforce will be dismissed from the sector with the growth of mechanization [24]. The change from manual harvesting of burned cane to mechanized harvesting of raw cane has major social implications because a harvester performs the work of 80 to 100 cane cutters [21].

Abreu et al. [25] affirm that it is necessary to carry out programs to requalify cutters who have been dismissed from the labor market to reintegrate them into the labor market and adds that, despite this negative social impact, there is also the positive side of improving workers' health and people living in the sugarcane areas.

1.2.3. Economic dimension

The economic dimension is often discussed together with the social dimension, as can be seen in European Renewable Energy Directive 2009/28/EC and Bonsucro Certification. Mello et al.

[12] state that economic and social factors are pooled, so that one helps the growth of the other. The economic growth refers to the question of productivity and competitiveness in order to insulate the economy of a particular region in the world market. As the economy grows, people must benefit from better living conditions: health, more education, more housing [26].

According to Ref. [12], the economic variable should be rethought in its macroeconomic sense. This is made possible through more efficient allocation and management of resources and a steady stream of public and private investments of endogenous origin aimed at achieving this new way of growing. Factors such as the decline in protectionist barriers between countries, the difficulty of access to new technologies, external and domestic debts, and the income inequalities of developing countries need to be considered.

As can be seen, these regulations do not evaluate the economic issue with business vision, the economic gains of the company, but protectionist vision and social development.

Thus, countries' demand for policies that aim a sustainable development has become a necessity for many over the past two decades. In addition to the social question, the fact that the process of environmental regeneration does not keep up with the current consumption pattern has led nations to sign agreements that aim a more equitable and less degraded development [27].

Evaluating the economic bias, the sugarcane harvest is a demanding factor for the plants. The production cost of a sugarcane-ethanol plant that manually harvests cane is 20–25% higher than the other that does not. The use of mechanical harvester increases the efficiency of work and reduces costs with labor [21]. However, as discussed earlier, this factor positively and negatively affects the social and environmental dimensions, and within this context, there is a gain of the environment and a loss for the workers.

In general, the greater or smaller financial performance of companies is what will determine the financial contribution destined to actions that aim sustainability. Therefore, the good functioning of the tripod is allied to good economic results that in turn will return to sustainability, thus forming a cycle [27]. So, these practices heavily rely on the financial performance of the industry to move forward.

2. Methodology

The study adopted the multiple case study methodology, with unit analysis, to investigate different practices related to sustainability adopted by four sugarcane plants of different sizes and positions in the sugar-ethanol market, previously selected by a primary and general questionnaire.

The research has qualitative character with descriptive nature. According to Ref. [28] when considering the scope of qualitative research, several approaches are possible, among them: case studies (for a deep contextual analysis of few facts or conditions), detailed interviews, and/or interviews with specialists (for information on influential or well-informed people in an organization or community), document review, and so on. In this work, all these approaches were combined to carry out the study of multicase.

2.1. Selection of the sample to the multicase (characterization of the plants)

As in Ref. [29], the type of sampling performed can be characterized as nonprobabilistic and subjective. Hair Junior et al. [30] explain that in nonprobabilistic sampling, the selection of elements for the sample is not necessarily done in order to be statistically representative of the population. Instead, the researcher can use subjective methods, such as personal experience, convenience, expert knowledge, etc., to select the elements of the sample.

Within this context, the data collected within a primary questionnaire were organized into groups according to similarities of information, and from these groups were selected four plants to compose the multicase study.

Eisenhardt [31] states that there is no ideal number of cases, but working with 4–10 cases is a good choice and works well. According to the same author, with less than four cases, it is difficult to generate a theory with great complexity, and with more than 10 cases, it is difficult to deal with the volume and complexity of the data obtained.

In addition, meetings were held with experts in the area, the environmental manager, and the executive director of the Association of the Sugarcane Industries of Minas Gerais, SIAMIG, to assist in the determination of the ethanol plants that have participated in the multicase study. The groups formed and the previously selected sample were presented to them to confirm the similarities and heterogeneity between the cases.

2.2. Elaboration of the main questionnaire

The questionnaire was prepared based on the criteria required by the Bonsucro certification because this certification has been looked for sugarcane-ethanol plants.

It contained open and closed questions, being the closed questions in the form of affirmations, that the interviewee should evaluate whether or not he agreed and how much he agreed or disagreed with each statement. Response options were organized on an unstructured, five-point scale, ranging from 1 to 5. In the beginning of the questionnaire, what each value represented was explained: 1—Strongly disagree, 2—Partially disagree; 3—I do not disagree, I do not agree; 4—Partially agree; and 5—Totally agree.

The content of this questionnaire was also discussed with the environmental manager of SIAMIG, to verify the adequacy of the indicators used and, thus, to validate the same.

2.3. Data collection

In this stage of data collection, the information was obtained through primary data, which refers to the survey research method. A personal interview with the agricultural, industrial, environmental, and administrative managers of the selected plants was carried out. As this multicase study consisted of a small sample, the survey was considered a good procedure for data collection.

During the interview, it was explained to the interviewees that they should interpret the statements and choose the answer that best represented the vision and practice of the plant. At no point was explained what sustainability is and what the requirements of Bonsucro and European Union Directive 28/2009 are.

2.4. Comparative analysis of the plants

The data analyzed were presented in the descriptive form, characteristic of the qualitative research, and in graphs [32]. The data of each case were first treated separately, carrying out a detailed description of each case, using the information collected with the questionnaires.

In this part, information obtained on the fulfillment of Bonsucro criteria was presented in a form of radar-type graphics. To obtain these graphs, the answers were separated by criteria (set of indicators), and for each, the percentage of attendance was calculated.

The next step was to perform the comparative case analysis. Each point on the unstructured scale of the main questionnaire corresponded to an index, and each index indicates a level of sustainability, as follows: Fully disagree: 1: Critical; Partially disagree: 2: Alert; Do not disagree or agree: 3: Reasonable; Partially agree: 4: Acceptable; Fully agree: 5: Ideal. With this information, the comparative analysis was carried out.

In this way, it is possible to identify the indicators that are or not met by the plants, and the level of attendance to these indicators. In addition to the mills, the environment manager of SIAMIG, an expert in the area and knowledgeable of all the plants, was also interviewed to obtain an external view of the plant and to compare and verify whether the responses of these mills match or not with reality. He was given the same instructions as the mills. The identity of the cases had to be revealed to the specialist so that he could answer the questions according to what he knows about each one.

3. Results and discussion

3.1. Multicase study

3.1.1. Case 1

Case 1 presents an ethanol plant that is part of an enterprise corporation which has its origin in the Northeast region of Brazil and that moved to Minas Gerais state with the intention of expanding its borders. This unit was founded in 2002, with only the ethanol distillery, inaugurating in 2004, and the sugar factory. Located in the *Triângulo Mineiro* mesoregion, it is a 100% national capital company.

Currently, this unit has 1347 permanent employees, with no temporary employees.

This plant has as main products crystal sugar, hydrated and anhydrous ethanol, and the electric energy. Ninety percent of the total sugar produced is destined to the foreign market, and the rest remains in the domestic market. As for ethanol, 100% is distributed in the national market. Crystal sugar contributes to 67% of the company's revenues, and ethanol accounts for 33% of revenues.

In the harvest of 2012/2013, the plant crushed 2,900,000 tons of sugarcane, producing 5.3 million bags of 50 kg of crystal sugar (266,800 tons) and 79,739 m³ of ethanol. Sugar production

corresponded to 7.8% of the total produced in Minas Gerais state, which was 3.42 million tons, and ethanol production corresponded to 4.0% of the total, which was 1.99 billion liters [33, 34].

The plant produces an average of 720,000 KW of energy per day, and of that total, 69.5% (500,000 KW / day) is sold to utilities. With this activity, the company was able to implement the Clean Development Mechanism (CDM) project in 2006 and receive a certificate of reduced emissions (CER), known as carbon credits, which are marketed in the Carbon Market [35].

The area of sugarcane harvested in the last harvest was 39,602 ha, and of that total, 12% correspond to the leased area and 88% of outsourced cane, which are distributed among the 60 suppliers that the plant has. This area of activity covers five municipalities in the region, and on average, the distance from the cane plantation to the plant is 30 km.

Sugarcane in the harvest of 2012 showed productivity of 75 t/ha, which is the average of the 2012/2013 harvest for the state of Minas Gerais. According to the Sugarcane Technology Centre (CTC, in Portuguese, Centro de Tecnologia Canavieira), the Minas sugarcane plantations had a significant improvement in agricultural productivity, closing with a growth of 10% over the last harvest. For the total of recoverable sugars, it presented 173 kg ATR/t cane. According to Ref. [36], in the south-central region, it was expected to obtain 135.60 kg ATR/t cane, in 2012/2013 harvest; thus, sugarcane from ethanol plant 1 was above-average quality of region. In the harvest 2016/2017, the average of total recoverable sugars for Minas Gerais was 137 kg ATR/t cane.

Attending the stipulated by the agro-environmental protocol for the sugarcane-ethanol sector of Minas Gerais state, since 2014, all plants that have a planting area in land with a slope lower than 12% must have the crop harvest 100% mechanized. Plant 1 had 98% of the harvest mechanized, in 2012, and the other 2% are from areas and places that it is not possible to use machines.

This company affirms that, in addition to the concern with the economic and production scenario, it also prioritizes the preservation of nature and care with the human being, promoting social programs directed to the community, approaching the areas of health, education, and leisure. When asked about the benefits that the plant's activity brings to the place it is located in, employment generation, local economy growth, partnership with the municipality, partnership with schools in the region, encouragement of culture and leisure, and community programs were cited.

Regarding the environmental practices adopted by the company, there is no-tillage, use of industrial coproducts, use of containment boxes in the soil, contour lines, use of straw to cover the soil, water quality monitoring, and collection and disposal of packaging of pesticides.

In the analysis of attendance of Bonsucro indicators, some criteria can be highlighted due to no attendance by the plant, such as accounting for greenhouse gas emissions (GHG), transparency in the sugarcane expansion process, research incentive (relative to the percentage of the payroll reserved for this purpose), impact mitigation plan, and the percentage of hours lost (**Figure 1**). It is important to observe that the left half of the circle (second and third quadrants) corresponds to the environmental dimension, and the right half (first and fourth quadrants) corresponds to the social dimension.

Case 1

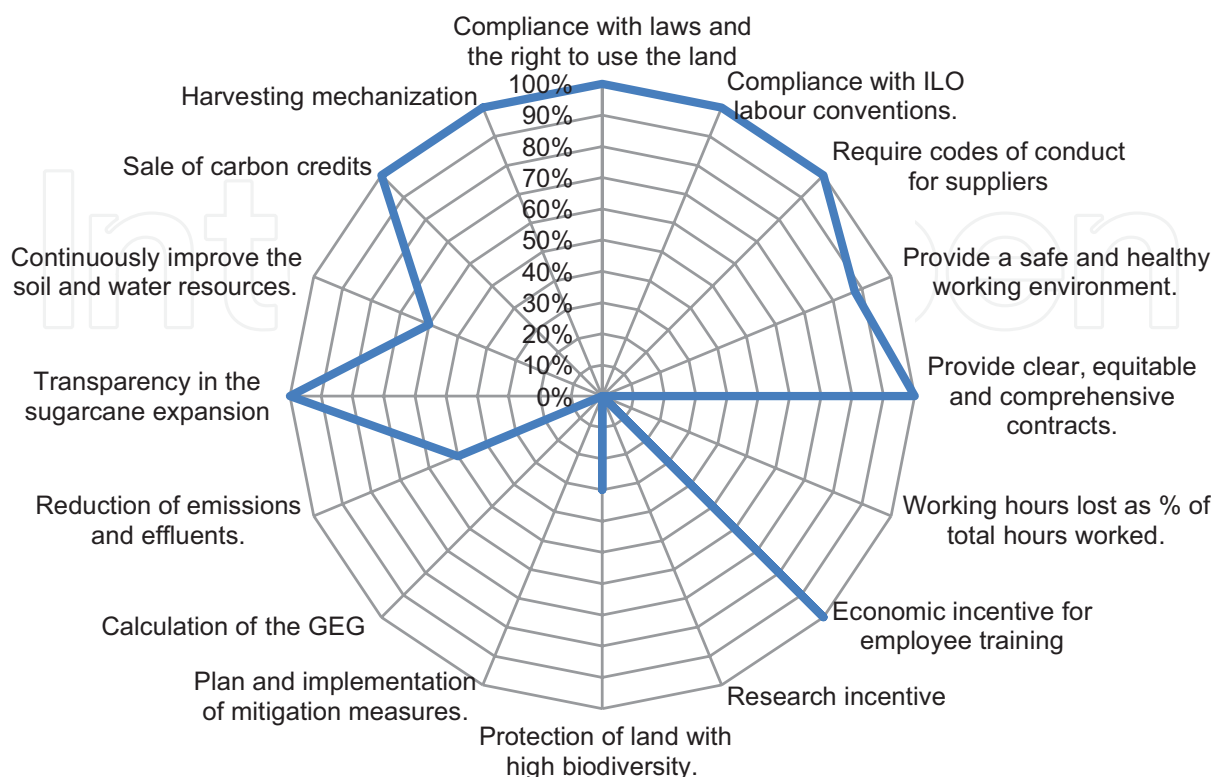


Figure 1. Attendance of Case 1 for each criterion of Bonsucro, in percentage.

3.1.2. Case 2

Case 2 presents a company that has 100% of national capital and which activities began in 1998. Currently, it has 800 permanent employees, no more temporary because according to the company, with the end of the manual harvest, there is no need of this type of work contract.

In the harvest of 2012/2013, the plant processed 1.1 million tons of sugarcane, producing 2 million bags of 50 kg of crystal sugar (100,000 tons) and 24,000 m³ of ethanol, corresponding to 2.9 and 1.2% of the total production of Minas Gerais state, respectively.

Crystal sugar corresponded to 70% of the production and was fully exported. Only ethanol was domestically marketed. Thus, for the company's revenue, crystal sugar had more relevance than ethanol.

The yield productivity showed good results, 80 t of sugarcane/ha, above the state average. For the total recoverable sugars, 130 kg ATR/t cane was obtained in the harvest of 2012, lower than the average of the center-south region, presented before.

The plant produces an average of 7500 kWh of energy through cogeneration. This energy is not exported (sold) and is fully consumed by the company.

The planting area had 21,733 ha, of which 9051 ha (41.6%) was the plant's own area, and the rest 58.4% are areas of partnerships, that is, leased areas. The mill had no suppliers of sugarcane, and on average, the distance from the sugarcane plantation to the sugar mill was 25 km.

As in the first case, this plant also signed the agro-environmental protocol for the sugarcane-ethanol sector of Minas Gerais state. The plant in question had 98% of its planting areas being mechanically harvested, where the other 2% also corresponded to areas where the machine could not reach or areas of greater slope; thus, the harvest was manual.

When asked about the benefits that the plant activity brings to the region (five municipalities of the northwest of *Triângulo Mineiro*), it cited employment generation with local economy growth, incentive to culture and leisure, incentive to research, and programs and partnerships with universities.

Regarding the environmental practices adopted by the company, the use of industrial coproducts, the use of containment boxes in the soil, contours, use of straw to cover the soil, water quality monitoring, and collection and disposal of packaging of pesticides were cited.

In the analysis of compliance to Bonsucro indicators, Case 2 had a different behavior from the previous plant, and the highlighted criteria for having 0% of attendance were economic incentive for employees training, hours lost at work, research incentive, transparency in the sugarcane expansion process, accounting for GHG emissions, and sale of carbon credit (**Figure 2**). In the same way as the previous case, it is interesting to observe that the left half of the circle (second and third quadrants) corresponds to the environmental dimension, and the right half (first and fourth quadrants) corresponds to the social dimension.

3.1.3. Case 3

Case 3 represents an ethanol plant that was founded in 1986. Like the other cases, it is also a company with 100% of national capital and covers five municipalities of *Triângulo Mineiro* mesoregion.

Currently, it has 1400 permanent employees, no more sugarcane cutters, who made up the temporary employees. With the end of manual harvesting, the plants practically do not hire temporary workers to cut the sugarcane because there is no demand.

The plant produces crystal sugar, ethanol, and energy, and in order of relevance to the company's revenue, sugar is the one that contributes the most, followed by ethanol. As for the distribution of its products in the market, 68% go to the foreign market and 32% to the domestic market.

In the harvest of 2012/2013, the plant crushed 2.35 million tons of sugarcane, producing 3.9 million bags of 50 kg of crystal sugar (195,000 tons) and 62,000 m³ of ethanol, corresponding to 5.7 and 3.1% of the total produced in Minas Gerais state, respectively.

The plant produced an average of 4000 kWh of energy through cogeneration. This energy was not exported, but the company said that the sale of this energy was already in process.



Figure 2. Attendance of Case 2 for each criterion of Bonsucro, in percentage.

The area of sugarcane harvested in 2012 was 24,835 ha. This was distributed in leased areas (31.2% of the total), outsourced areas (61.7%), and own area (7.1%). The average radius of the plantation at the plant is 17 km, smaller than the other cases.

The sugarcane yield showed high productivity, 85.8 t/ha, above the national average, but regarding the total fermentable sugars, it presented 123.6 kg ATR/t cane, which was lower than the average of the south-central region in that harvest.

Case 3, as well as previous mills, also signed the agro-environmental protocol for the sugarcane-ethanol sector of Minas Gerais state. Its entire planting area has a slope less than 12%; thus, the sugarcane harvest is 100% mechanized, fully complying the protocol.

This plant, also questioned about the benefits that the activity brings to the region, cited job creation, local economy growth, partnership with the municipality, partnership with schools and universities in the region, incentive to culture and leisure and research encouragement.

Regarding the environmental practices adopted by the company, the use of industrial coproducts, no-tillage, the use of containment boxes in the soil, contours, use of straw to cover the soil, water quality monitoring, and collection and disposal of packaging of pesticides were cited.

Case 3 also presented different information from the other two previous ones, when the analysis of attendance to Bonsucro indicators was done. The criteria that stood out because

they were not attended were economic incentive for employee training, hours lost at work, research incentive, reduction in effluent emissions, transparency in the sugarcane expansion process, GHG emission accounting, and sale of carbon credits (**Figure 3**).

3.1.4. Case 4

Case 4 represents one of the oldest ethanol plants in the state, which began its activities in 1920. Located in the mesoregion of *Zona da Mata*, today it is the only survivor in the region of successive crises that the sugar and ethanol industry passed in the last century. Of family origin, the company's capital is also 100% national.

The area of activity of the plant covers 13 municipalities of the mesoregion, which shows the importance of it with job creation and economic growth in the region. It has 1400 permanent employees and 1000 temporary works, differing from the other cases analyzed.

The plant produces crystal sugar, hydrated ethanol, anhydrous ethanol, and molasses, and in order of relevance to the company's revenue, sugar is the one that contributes most, followed by ethanol. As for the distribution of these products in the market, 100% is directed to the domestic market.

In the harvest of 2012/2013, 650,000 tons of sugarcane were crushed, producing one million bags of 50 kg of crystal sugar and 18,000 m3 of ethanol. Comparing with the state production, sugar corresponded to 1.46% of the total and ethanol corresponded to 0.9%. As can be observed among the cases studied, this plant is the smallest.

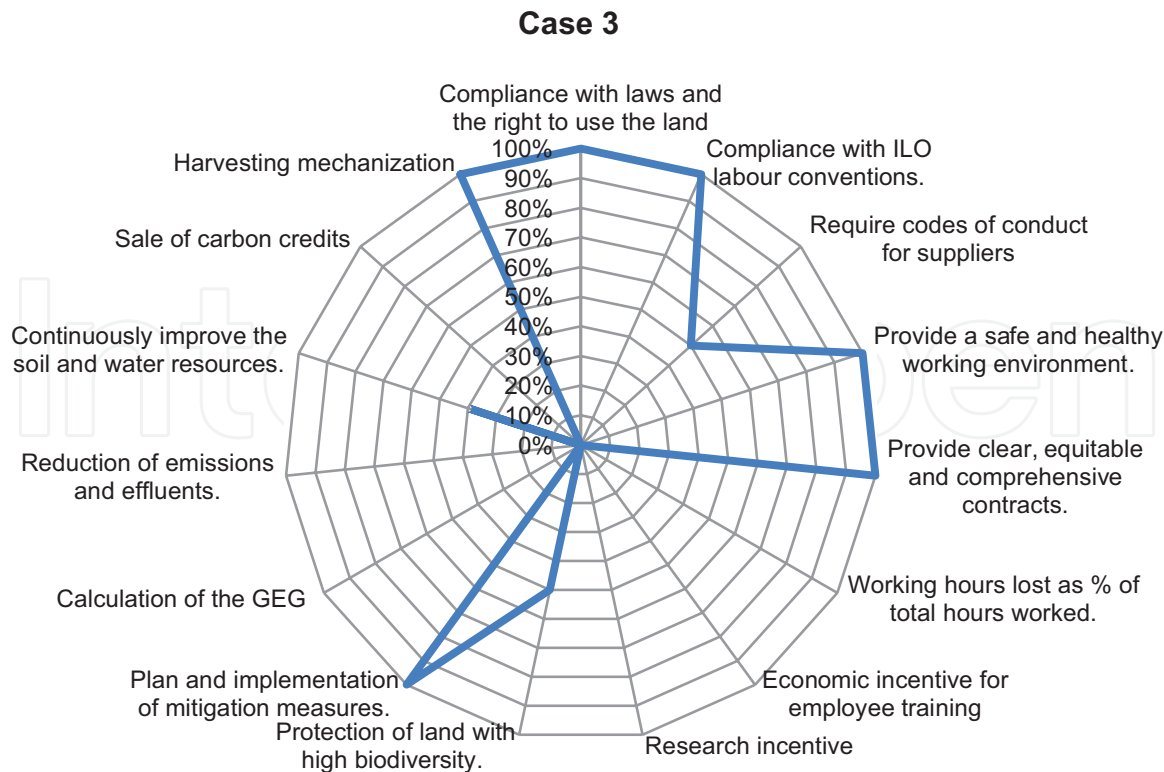


Figure 3. Attendance of Case 3 for each criterion of Bonsucro, in percentage.

By burning the bagasse, the plant produces an average of 4500 kWh of energy. This is totally consumed in the company, not being sold.

The sugarcane planted area had 10,800 ha, of which 60% was a leased area and 40% was its own area. Sixteen percent of the total crushed cane comes from suppliers. The average planting radius at the plant is 27 km.

The sugarcane yield had productivity of 70 t/ha, lower than the state average, which was 75 t/ha. In the harvest of 2011/2012, *Zona da Mata* mesoregion was affected by drought in 2012, a fact that justified the fall in sugarcane productivity. Regarding the total fermentable sugars, it obtained 145 kg ATR/t sugarcane, slightly above the Brazilian average, which was 135.6 kg ATR/t sugarcane.

Among the voluntary and mandatory certifications existing for the sector, the plant had only the agro-environmental protocol for the sugarcane-ethanol sector of Minas Gerais state, which is voluntary. This ethanol plant is located in a mountainous region, where 80% of the sugarcane plantation areas of this plant have a slope of more than 12%, so its harvest is 100% manual. Due to the lack of adequate equipment for sugarcane harvesting in areas with declivity above 12%, according to the agro-environment protocol, in projects implemented until 2007/2008, deadlines will be granted for proper adaptation, according to previous authorization of the State Council for Environmental Policy: COPAM.

Like other plants, environmental balance, rational exploitation, and respect for the environment are constant concerns of the company. As environmental practices, it adopts no-tillage, contour lines, water monitoring, and the collection and disposal of pesticide packaging. As social practices, it has partnerships with schools and universities in the region, and with the municipality, encouraging culture, leisure, and research.

In the analysis of compliance with the Bonsucro indicators, Case 4 also had a distinct behavior from the other three plants. As shown in **Figure 4**, the criteria that stood out because these were not met were suppliers' code of conduct requirement, economic incentive for employee training, research incentive, accounting for emissions of GHG, sale of carbon credit, and mechanization of the harvest until 2014.

3.1.5. *Comparison between cases*

The comparisons were done for each environmental and social dimension presented on Bonsucro and European Renewable Energy Directive. Also, the economic dimension, which is not treated on both certifications, was also assessed and compared between cases.

The first principle of the social dimension in Bonsucro, refers to compliance with the law, and the four ethanol plants affirm to attend completely. In the second principle, which refers to respect human and labor rights, there were some differences concerning their attendance, but all of them had an acceptable level of compliance for the criteria: noninterference of power plants in workers' representation groups; compliance of sugarcane suppliers with labor laws; the use and control of personal protective equipment; and first-aid care.



Figure 4. Attendance of Case 4 for each criterion of Bonsucro, in percentage.

The differences to be highlighted are the money set aside by mills to invest in employee training and research, which ranges from critical to acceptable; the percentage of hours lost at work; and the requirement of sugar mills to suppliers of codes of conduct, ranging from critical to ideal.

The similarities observed in all four cases, to the environmental dimension, refer to the areas of planting and expansion of sugarcane, which are not areas of high conservation value; the treatment and reuse of waste; the existence and implementation of an environmental management plan; the amount of water captured by industry and agriculture; and finally the practice of no-till. For all those criteria, the attendance ranged from acceptable to ideal. Another observation is that the mills presented better compliance on activities related to biodiversity and ecosystem service management, and the criteria related to Directive 28/2009 of the European Union had more variation, ranging the attendance from critical to ideal.

Other differences found are about the mechanization of sugarcane cultivation, both harvesting and planting, and the sale of carbon credits. It was verified that the plants exploit very little the carbon market and should invest more in the same, since besides the economic reimbursements they also have the environmental benefits, on which the participants of this market are certified by the reduction of greenhouse gas emissions.

About the economic dimension, some financial indicators were used to present the situation of the ethanol plants studied. Case 2 is the one that had the highest growth on revenues (25%), between 2011 and 2013, compared to the others. Case 4 did not present any increase.

The mills were also questioned about the company's profitability increase. According to Ref. [37], from the point of view of owners/shareholders, the most relevant financial measure is profitability, since it reveals the profits obtained by management efforts from the capital invested by the owners. Thus, profitability is the expected return on invested capital. All plants, except Case 4, have increased profitability in the last 3 years, and only Case 1 reported this increase, which was 0.09% a year.

The debt ratio was also used as a financial indicator. This rate measures how much the company is indebted to its creditors, which means the higher this index, the greater the degree of use of third-party capital. Indebtedness indices will more comprehensively visualize the company's financial situation [38]. Cases 1, 2, and 4 had an increase in this rate between 2012 and 2013, being 2.13, 20, and 20%, respectively. Case 1 has the lowest rate, and therefore, it can be concluded that it is the least indebted among respondents. Case 3 did not answer that question.

Among the mills studied, three of them showed an increase in revenues, profitability, and indebtedness rate between 2011 and 2013. It is noteworthy that the mills have used more third-party capital, as well as invested more on their business, and these investments have brought returns to companies. The economic dimension does not have indicators established in Bonsucro or in Directive 28/2009 of the European Union; therefore, the conclusion was based on the interpretation of the data shown here. It can be noticed that there was, in general, economic development in cases 1, 2, and 3 plants studied, but the fourth has been stable in recent years.

3.2. The current situation of sugarcane-ethanol plants, in Brazil

From 2012 to 2017, the number of plants certified by Bonsucro in sustainability criteria has increased from 28 to 61 mills [3]. In 2012, there were 26 Brazilian companies certified, and in 2017, this number increased to 43. In Ref. [15], the same behavior was observed in the center-south region, including plants from Minas Gerais state. These scenarios show the commitment of the Brazilian sugarcane industry to incorporate the best social and environmental practices into its agricultural and industrial processes.

The audited area of sugarcane planted advanced from 574,000 ha (or 6% of the total area of sugarcane plantation in Brazil), in 2012, to approximately 910,000 ha of sugarcane in 2017, representing 9.3% of the total harvested area.

The following plants were certified by Bonsucro until 2012: Adecoagro (Angelica; Monte Alegre); Alta Mogiana (Alta Mogiana); Biosev Bioenergy (Sta Elisa); BP Biofuels (Tropical Bioenergy); Bunge (Moema, Frutal, Itapagipe and Guariroba); Copersucar (Açucareira São Manoel, Santa Adélia, Quatá Zilor, Barra Grande of Lençóis Zilor, São José Zilor or Açucareira Zilo Lorenzetti Zilor); Odebrecht Agroindustrial (Conquista, Alcidia and Rio Claro); Raízen (Maracaí, Bom Retiro, Costa Pinto, Jataí, Bonfim, Gasa); Renuka (Equipav); São Martinho Group (Iracema); USJ (São João Araras); after 2012, they were certified: Raízen (Diamond, Destivale, Dois Córregos, Junqueira, Serra, Araraquara, Paraguaçu, Univalem); Copersucar (Santo Antonio Balbo, Uberaba Balbo and São Luiz); Guarani (Industrial Severina, Cruz High

Industrial, Verte: Andrade Sugar and Alcohol); Odebrecht Agroindustrial (Morro Vermelho); Adecoagro (Ivinhema Valley); São Martinho Group (São Martinho and Santa Cruz); Alto Alegre (Junqueira); Companhia Mineira de Açúcar e Alcool (Vale do Tijuco); Serra Grande Group (Serra Grande); Nardini Agroindustrial (Nardini); Not having renewed: Adecoagro (Angelica); Bunge (Guariroba); Odebrecht Agroindustrial (Alcidia); Raízen (Bom Retiro); Renuka (Equipav); São Martinho Group (Iracema);

In addition to the progress made in relation to the Bonsucro certification, in 2017, the agro-environmental protocol, cited and signed by all four cases, completed 10 years. This protocol was updated, and the main goals are still the end of sugarcane burning; the recovery of forests in springs and the protection of the preservation areas of other watercourses; and adoption of a series of management practices to guarantee sustainability in its production chain. By the year 2022, the plants expect to have completed the process of restoration of all these areas.

As general results for Brazil, we have that 97.5% of the sugarcane area of the State of São Paulo is mechanically harvested and the practice of burning is not applied. This means that since the beginning of the Protocol (2007), more than 9.27 million tonnes of CO₂ eq. and more than 56 million tonnes of atmospheric pollutants (carbon monoxide, particulate matter, and hydrocarbons) are not emitted to the atmosphere. The sugarcane-ethanol sector in the State of São Paulo accumulates an asset of 3747 harvesters (between own and outsourced), while in the 2007/2008 harvest, the total was 753. More than 200,000 ha of riparian areas and 8230 springs were protected and recovered; 60% of the signatory plants have forest restoration programs for their sugarcane suppliers; since 2010, the ethanol plants have reduced water consumption by 40% for industrial processing, due to reuse system.

In the last harvest (2016/2017), 131 mills and 25 associations of sugarcane suppliers received the Green Ethanol Certificate as a result of compliance with these actions. These signatories are responsible for approximately 95% of the sugarcane production in São Paulo and 47% of the national ethanol production [39].

4. Conclusion

Considering the proposed objectives, to identify and understand the indicators of the Bonsucro certification and the European Union Directive 28/2009, these were achieved when describing the criteria, adapting, and using them as a basis for the research.

Based on the results obtained, regarding the Bonsucro certification and EU Directive 28/2009, we can conclude that none of the plants studied, by 2012, could receive the Bonsucro seal, although some of them present high levels of attendance. Case 3 declared 77% of criteria attendance, despite the external agent declared that it has 38% of attendance.

The fact that none of the plants studied could receive this certification, and the variability between them, called for considerable attention, leading to the belief that all the ethanol plants in the sector, in Minas Gerais state, had followed the same rhythm, being none of them, by 2012, able to get this stamp.

Noncompliance is justified by the plants due to: (1) the constant changes in the legislations related to sustainability, which cause uncertainty and insecurity for mills and (2) the fact that these are not required by their customers. However, it can be concluded that the plants do not adopt a proactive stance, since they do not seek knowledge about norms and certifications related to the subject.

It is important to make a critical analysis of the international regulations that have arisen in recent years in the market. Most of these are based on parameters that are suitable for producers in the countries that gave rise to these standards, making it difficult for producers in other countries to meet these standards, as present throughout the chapter, since each site has characteristics with respect to environment, society, and economy. With this, it is suggested that there is not only a concern with the sustainability, but rather a way for preventing developing countries from growing and expanding their markets.

Despite this, there is still an effort on the part of the plants to comply with the legislation, being aware of their progress and the path that must be taken. As presented, there is a rush and pressure exacerbated by some international entities to meet all criteria and to be sustainable. However, the Brazilian society, its interests, and its criteria are not credited or listened to.

It is believed that sustainability in the sugarcane-ethanol sector should be sought by the plants, not only to meet criteria, but also to improve the sugarcane production system, since this effectively translates into opportunities, biodiversity, and economic gains. If this does not happen, the pace to pursue sustainability will continue to be slow and challenging.

However, if this translates into opportunities, the outputs indicated in this work to meet the sustainability criteria are to: (1) improve the training of employees in all work areas of the plant, explaining to them the importance of the theme, (2) facilitate the diffusion of information about sustainability, (3) organize technical team in the area near the plants to better implement the practices of sustainability, and (4) better control the techniques adopted by the suppliers of sugarcane and inputs, considering that not only the industry, but also the whole sugarcane-ethanol chain must be involved in this process.

Finally, the results obtained in this work indicate that the plants are adapting to the theme, but that several points, such as accounting for the emission of gases and the sale of carbon credits, must still be worked on to improve the situation of the same, regarding the obtaining of certifications. Although these do not seem attractive at the moment, compliance with national legislation is mandatory. It is noted that incorporating the vision of long-term sustainability within organizations is necessary for those who want to be sustainable, certified and expand the market.

Acknowledgements

We acknowledge the National Council for Scientific and Technological Development – CNPq for their financial support.

Author details

Karina R.O.V. Souza^{1*} and Ronaldo Perez²

* Address all correspondence to: karina.viana@ufv.br

1 Federal University of Viçosa, Florestal, Brazil

2 Federal University of Viçosa, Viçosa, Brazil

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