



Impact of environmental strategies and practices on the socioeconomic development of the Brazilian sugar-energy sector

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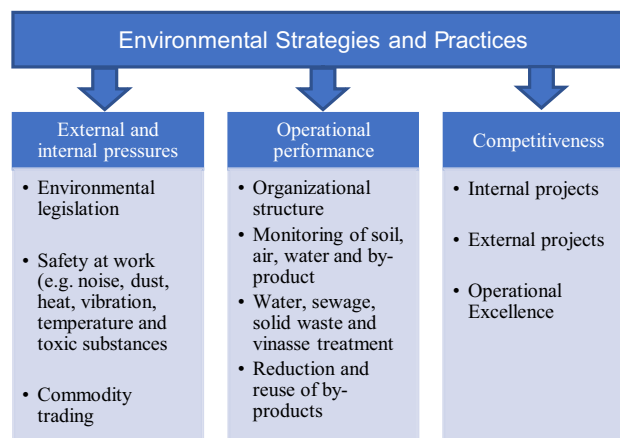
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Abstract

Different environmental strategies have been devised and implemented as instruments to change companies' socio-environmental behavior worldwide. In this study, we investigated the motivations for implementing environmental strategies and practices in Brazilian mills, as well as their organizational profile, and evaluated the effects of adopting environmental practices on competitiveness. Through case studies using face-to-face interviews with key people, we surveyed six medium- and large-sized Brazilian mills. The results highlighted that the main motivations for implementing environmental strategies and practices in the mills were external and internal pressures, operational performance, and the improvement in competitiveness. In relation to external and internal pressures, environmental legislation and regulations, safety at work, and commodity trading were the parameters that guided the adoption of environmental strategies. Regarding operational performance, we observed that the mills linked environmental issues to an organizational structure in conjunction with the company's strategic decisionmakers, as well as monitoring and treating soil, water, air, and sugarcane by-products and reducing and reusing by-products in order to prevent environmental impacts and reduce operating costs, which provided them with improvements in operational excellence. Our results also showed that the use of environmental strategies led to improvements in mills' competitiveness, as it enhanced the company's image in the most demanding markets and guaranteed a better position in the current market, besides raising employee satisfaction through participation in internal and external projects. Therefore, adopting environmental strategies and practices in the sugar-energy sector can contribute to improving the mill's operational performance, reducing social pressures, and gaining competitive advantages, as well as leading to sustainable production.

Graphic abstract



Keywords Environmental management · Social responsibility · Sustainable development · Social pressure · Agribusiness

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Introduction

The world's interest in the production and consumption of biofuels has been growing annually and, in Brazil, it has been strongly stimulated by the interest in alternative sources that contribute to the diversification of the energy matrix, aiming to reduce greenhouse gas emissions and generate less impacts on ecosystem, land and water resources and biodiversity (Guarengi and Walter 2016; Walter et al. 2014). The business case for improving environmental performance is increasingly evident and international markets are demanding deforestation-free agriculture and that meet environmental conservation criteria (Lambin et al. 2018; Stabile et al. 2020).

Management scholars have responded continuously to the evolution of the environment of competing companies in the field of environmental strategy and social management. The emergence of the concept of sustainability as a new variable of the external environment is a new strategic management challenge for companies. Concern about the quality of the natural environment, while maintaining economic well-being, population growth, and increasing consumption levels, has been one of the main drivers of the modern view of sustainability (Spetic et al. 2012). Over the last decades, a series of changes have occurred in the business environment regarding current strategic contexts. The effect that sustainability provides in the way companies operate and compete has influenced most companies around the world (Fowler and Hope 2007).

Due to pressure from the social sector, sustainability criteria have been proposed to promote the efficient, sustainable production of biofuels. Adopting sustainability criteria may result in the certification of biofuel production, and some producing countries, such as Brazil, have concerns that a certification process may impose new barriers to the international trade in ethanol (Walter et al. 2011). However, it can be observed that establishing international standards for the trade of environmentally certified products has been the central objective of political interactions that defend environmental protection, agricultural consolidation, and international marketing (Hoff and Rajão 2020).

Environmental management arises in the context in which the environmental variable is inserted into the organizational field of companies both by market pressure and by the growing development of environmental movements and pressure from political and social institutions. Thus, companies should be committed to protecting and conserving nature, which will also serve to inform the market about the environmental quality included in the product and production processes (Martínez et al. 2019).

The sugar-energy sector stands out because of its high economic potential due to the commercialization of

products and by-products of sugarcane processing, such as sugar, ethanol, and bioelectricity (Figueiredo and Scala 2011). Brazil's sugarcane ethanol has been indicated as an alternative to fossil fuels with an average greenhouse gas emission reduction of 86% compared to fossil fuels (Wang et al. 2014). The future of sustainable energy depends on the increased use of renewable energy. The first generation of ethanol production in Brazil was based mainly on locally developed technology and, in contrast to other alternatives for renewable energy, it does not depend on imports and the technology can be transferred to other countries (Silva et al. 2019).

There is great worldwide interest in the knowledge of environmental strategies and practices that support the decision-making by governments and key managers in various sectors of the economy, such as the sugar-energy sector, and assisting in the development and improvement of public policies for the land use and conservation of, water, air, and biodiversity. Few studies have reported the impacts of environmental strategies on the socioeconomic development of sugarcane mills (e.g., Gilio and Moraes 2016; Postal et al. 2020; Sozinho et al. 2018). Thus, the research can contribute to the knowledge of coordinating environmental strategies and practices and their implications on social and governmental pressures, operational excellence, and the competitiveness of companies in the sugar-energy sector.

Encouraging companies to adopt environmental management collaborates to achieve global conservation goals plays an important role in reducing negative impacts on the environment and increases operational performance (Comini et al. 2019; Pacheco et al. 2018), especially in developing countries due to the transformational nature of their economies and because their agricultural and industrial policies are premature and experimental (Ju et al. 2019). Thus, the objectives were to analyze the main motivations for implementing environmental strategies in mills, verify the organizational profile in relation to the adopted environmental strategies, and evaluate the mills' competitiveness in the use of environmental practices.

Theoretical background and hypothesis development

Characterization of the sugar-energy sector

Sugarcane is one of the main and most environmentally friendly crops in Brazil (Matos et al. 2020). Products such as Brazil's sugarcane-based ethanol, sugar, and electricity have drawn the attention of the international community because of their alleged respect for the environment. Advocates cite industry as a successful alternative energy model, contributing to the renewable energy matrix, and it does not compete

with global food production, unlike ethanol produced from grains mainly in the USA (Matos et al. 2020; Miranda and Fonseca 2020).

Brazil is a key producer in the world market for ethanol and sugar (Kennedy et al. 2018; Markert et al. 2020). Local conditions for ethanol and sugar production are favorable, taking into account factors such as land availability and climate, long-term experience, agricultural and industrial technology, and the enormous existing domestic market (Guarengi and Walter 2016). Brazil is the world's largest producer of sugarcane. According to the National Supply Company (CONAB 2020), Brazilian sugarcane production in 2019 was approximately 642.7 million tonnes, compared with 620.4 million tonnes in 2018. The total area of sugarcane in 2019 was 10 million hectares, similar to 2018 (CONAB 2020).

The total number of sugar-ethanol mills in 2019 was estimated at 359 units (USDA 2020). Investments in new greenfield projects remain scarce. Concurrently, several units have been closed in the past couple of years, mainly due to financial constraints. It was noted that some of these units have been acquired by larger and financially healthy groups (Flexor and Leite 2017).

Brazil and the USA dominate the global market, accounting for 84% of production in 2019 of the world's ethanol trade (RFA 2020). However, Brazilian ethanol is produced from sugarcane, whereas US ethanol uses corn (Correll et al. 2014). Brazil's ethanol production depends on the world economy of the price of sugar and the growth of Brazilian domestic consumption of this fuel (USDA 2019a). The Brazilian government recently raised the blend mandate of ethanol in gasoline from 25 to 27%, which should boost domestic use (Brasil 2015).

Global sugar production in 2019 was 174 million tonnes, whereby Brazil and India were the main producers (USDA 2019b). Sugar consumption is expected to increase slightly, reflecting population growth and an expanding food processing sector. Brazil exported around 18.9 million tonnes of sugar in 2019 (CONAB 2020), a value that was above that exported by Thailand, ranked second in exports (USDA 2019b).

Sustainability and environmental management

Environmental sustainability has become an important business issue in recent times. Faced with social pressures to engage in sustainable practices, companies may react symbolically or take substantial actions to mitigate their environmental impacts (Homroy and Slechten 2019). In this context, it cannot be denied that significant progress has been made in the way organizations interpret and deal with the sustainability issue (Winn et al. 2012). One of the main factors that lead organizations to adopt

an environmental strategy refers to the requirements of the stakeholders involved, especially regarding their operational practices as they are able to reduce resource consumption and waste generation (Homroy and Slechten 2019).

In recent years, mills have established some important self-regulatory measures. These measures can be broken down into organizational programs, individual and collective initiatives, and formal commitments to national and international law. Some of these initiatives are related to social and ethical issues with the external community, as well as international environmental standards such as Bonsucro Certification and ISO 14001. This attempt to gain acceptance in the international market is especially important for the traded products by mills such as ethanol (Zeidan et al. 2015). According to the reported observations, the following hypothesis is proposed:

H1 External and internal pressures have a positive influence on the implementation of environmental strategies.

Some studies have pointed out the negative impacts of ethanol and sugar production, especially regarding water pollution; threats to biodiversity as a result of extensive monoculture; and the atmospheric pollutant emissions from the burning sugarcane process (Cristale et al. 2012; Filoso et al. 2015; Postal et al. 2020). The effects of direct and indirect land use changes are also considered, such as the intensive use of forests to increase biofuel production, which reduces the carbon content stored in forests, having negative consequences on the balance of carbon (Fargione et al. 2008; Hoel 2020; Lapola et al. 2010). However, there are several studies that presented possible alternatives for the adequacy of sugarcane production to sustainability criteria, such as proposals to reduce water consumption, soil conservation, and measures to improve working conditions (Costa 2020; Denny 2020; Postal et al. 2020; Sun and Fan 2020). There are also studies that reported the contributions of sugarcane ethanol to climate change mitigation (Zuurbier and van de Vooren 2008).

Other possible motivations in the companies for adopting environmental management are those related to improving operational performance through saving resources by improving efficiency and reducing costs with energy and water, materials and residues, fines and penalties; increasing organizational and international competitive advantages; reducing company risk by government regulatory agencies, insurance companies, and financial institutions; increasing awareness of environmental impacts among employees; and establishing a strong image of corporate social responsibility (Bagur-Femenias et al. 2013; Leonidou et al. 2017; Martínez-del-Río and Céspedes-Lorente 2014). Considering this, the second hypothesis was formulated:

H2 The adoption of environmental practices is related to operational excellence.

Environmental strategies involve management planning, organization, and standardized structures used by companies to systematically manage activities that affect the natural environment by integrating procedures and processes, involving training, monitoring, and documented records. These activities include people, instruments, and actions to collect and process data that enable environmental information for management and decision-making, serving as a tool for companies to better visualize their environmental obligations, identify significant threats, and minimize environmental risks associated with their businesses (Cary and Roberts 2011).

Environmental Impact Assessment (EIA) is a systematic process of environmental control planning, and its purpose is to prevent any environmental impact. Cultural, social, and health effects are considered to be an integral part of EIA, and particular attention is paid to the practical application of this assessment to prevent and mitigate the significant negative effects of environmental impacts. The EIA aims to improve environmental awareness and attitudes and seeks to ensure that environmental values are included in decision-making processes. These are steps to achieve ecological sustainability and compliance of sustainable communities (Martínez et al. 2019).

Over the last two decades, organizations have generally perceived the benefits that can be gained from proactive positioning in their relationships with social and environmental aspects, improving their efficiency, gaining competitive advantage, and reducing compliance costs through legal compliance actions, complying with sector regulations (Hashmi et al. 2015). Yang et al (2010) reported that the practice of effective environmental management in organizations can increase their manufacturing competitiveness, leading to consequent reductions in costs and improvement of quality, as well as the development of new products and processes.

Thus, considering that environmental sustainability has become a critical focus in industrial activities in general (Walker et al. 2014) and the sugar-energy sector, in particular, and also the fact that every organization generates environmental impacts that must be managed (Arnaut et al. 2012), it is relevant and essential to incorporate environmental management within contemporary organizations.

According to Paulraj (2009), in addition to legal requirements, adopting environmental practices by companies occurred for several other reasons, such as increased competitiveness and ethical concerns. Environmental competitiveness is the extent to which companies compete regarding environmental issues and the potential for environmental strategies to provide them with a competitive advantage

(Martínez-del-Río and Céspedes-Lorente 2014). In addition to ethics and social responsibility, environmental management, in particular, has a strong influence on managerial decision-making (Lee 2009). On the basis of the submitted evidence, the third hypothesis is proposed:

H3 The use of environmental strategies improves competitiveness of the mills.

Methodological approach

In this research, we chose a multiple-case study to increase and diversify the amount of information and made a comparison between the cases, thus providing a better understanding of the organizational phenomena (Almeida et al. 2018). Evidence from multiple cases is usually more attractive and the study is considered more robust, as there is a comparison between the cases studied in the research. Furthermore, each case study consists of a complete study in which the evidence converges to a conclusion (Yin 2018).

Our case studies combine data from different sources, such as interviews, internal and external documents, site visits to establish the validity and reliability of deepening our understanding (Eisenhardt 1989). The most important advantage of using multiple sources of evidence is the development of convergent lines of inquiry, a process of triangulation and corroboration (Yin 2018). Thus, a descriptive and exploratory approach was adopted in this study.

The data collection procedure consisted of using semi-structured questionnaires with open and closed questions (Supplementary Material), thus allowing greater interaction between the researcher and interviewees. The interviews took between 90 and 120 min per participant. By using this procedure, the interviewee can achieve the necessary freedom and spontaneity, enriching the research.

The data used for the empirical analysis were taken from a survey based on face-to-face encounters with three participants from each of the six surveyed mills, making a total of 18 participants. Participants were at a direction, management, or coordination level, for example environmental engineers, agronomists, and biologists (Table 1). The period from the first contacts with the mills until completing the data collection was from June 2019 to February 2020.

The choice of the surveyed mills was intentional and non-probabilistic. We surveyed six medium-sized and large-sized Brazilian mills. This sample represents a share of 4.86% from the total sugarcane processed in the largest Brazilian producing region (center-south). Merriam (2009) highlights that it is in non-probabilistic, intentional, or purposeful sampling that the maximum degree of understanding the research objective is reached. This type of sampling is a selection based on the researchers' criteria, which implies a

Table 1 Description of the position and function of the employees interviewed in the mills. *Source:* Elaborated by the author based on data from the field research

Mill	Position in the company	Function
1	Coordinator	Biologist
	Manager	Agricultural
	Director	Industry
2	Coordinator	Environmental Engineer
	Manager	Agricultural and Industry
	Director	Industry
3	Coordinator	Environmental Engineer
	Manager	Agricultural
	Director	Industry
4	Manager	Agricultural
	Coordinator	Environmental
	Director	Agricultural and Industry
5	Coordinator	Agronomist Engineer
	Manager	Agricultural
	Manager	Administrative
6	Coordinator	Biologist
	Manager	Agricultural
	Director	Agricultural and Industry

list of attributes to be met (Almeida et al. 2018). Our sampling criteria were: (1) mills that process and produce sugar, ethanol, and/or bioelectricity; (2) mills with some implemented environmental strategies and an environmental department; (3) multinational or funded by national private capital; (4) mills that showed interest in participating in the research and authorized strategic managers and decision-makers to participate in the interviews.

Table 2 presents general information on the six mills surveyed, such as the inauguration date, the annual sugarcane milling, the quantity of ethanol and sugar, cogeneration of clean electricity exported to the Brazilian public network, and the number of employees. Mills A, B, C, D, and E are located in the state of São Paulo. The main activity of company A is to transform cane into refined and liquid sugar, ethanol, and bioelectricity. The second mill, B, dates back to the 1980s, producing several crystalline sugars and ethanol.

Table 2 Data related to the mills in relation to the inauguration date, annual milling, sugar and ethanol production, and energy cogeneration. *Source:* Elaborated by the author based on data from the field research

Parameters	Mill					
	A	B	C	D	E	F
Inauguration date	1987	1981	2007	2006	1990	2007
Sugarcane milling × 1000 (Tons/year)	4400	2600	2200	2400	3200	3000
Ethanol (m ³ /year)	90,000	100,000	210,000	75,000	170,000	340,000
Sugar (Tons/year)	460,000	216,000	–	237,000	184,000	–
Exported bioelectricity—for sale (GWh)	140,000	–	–	90,000	–	150,000
Employees	2540	1750	1200	1370	1690	1500

Mill C started its activities in 2007, producing 100% of ethanol. Mill D is also a new company (2006) that produces ethanol, sugar, and bioelectricity, while Mill E produces ethanol and sugar and dates back to the early 1990s. All these mills have multinational private capital. Mill F is located in the state of Mato Grosso do Sul and started operating in 2007. This mill has Brazilian private capital and produces ethanol and electricity through biomass from sugarcane bagasse.

After analyzing several studies on the positive and negative impacts of implementing environmental strategies in different types of companies, we observed that several items can determine the environmental strategies (Bagur-Femenias et al. 2013; Gupta and Nagpal 2020; Kazancoglu et al. 2020; Pakzad et al. 2017). Thus, we use the following parameters: environmental legislation and government regulations; safety at work (noise, dust, toxic substances); commodity trading; organizational structure; monitoring of soil, air, water, and by-product sugarcane; water, sewage, solid waste and vinasse treatment; reduction and reuse of by-products; internal projects; external projects; and operational excellence.

Results and discussion

External and internal pressures in the sugar-energy sector

In this study, internal and external pressures directly influenced the implementation of environmental strategies and practices in the mills. We note that the main external pressures that encourage mills to adopt environmental strategies were legislation and government regulations and the marketing of their products, motivated by the need for operating licenses, the influence from their customers, new “green” markets and social pressures. As for internal pressures, the main one refers to security at work, motivated by its employees and by the government and society. Pakzad et al. (2017) also observed that internal and external customers, as well as political issues and city strategies (social pressure), economic benefits and legislation are the main arguments that

influence the definition of the company's environmental strategy, as observed in the mills surveyed.

According to our results, all the interviewees had a clear idea about the environmental management system and the sustainability assumptions and were able to point out several issues, such as the advantages and difficulties to implement and manage them. They reported that the main requirements of customers were issues related to environmental, product delivery regularity, and quantity (100% of interviewees selected these options), followed by product mix (50% of interviewees—mills B, D, and E). The quality and price issues were not mentioned by the interviewees as a differential related to environmental practices because sugar, ethanol, and electricity products are commodities.

Regarding the environmental legislation, all the mills in the sample (100%) have environmental licenses (Table S1 in the Supplementary Material) and consider that they were working according to the relevant environmental legislation and regulations, prioritizing preventive actions. All the researched mills have other types of licenses in common (i.e., for gas stations, water collection), as well as legal reserves and permanent preservation areas. Mills A, D, and F differed from the others in terms of electricity generation because they sell the surplus electricity to the Brazilian public grid; therefore, they need other licenses, such as electric power substation and transmission lines.

It was observed that the environmental legislation fulfillment was an important aspect prioritized by all researched mills. However, only mills A and B (33%) frequently access the municipal, state, and federal legislation applicable to their environmental aspects (Table S1) and use them consciously to increase the company's

sustainability. Abreu et al (2013) reported that the motivation for environmental investments was fundamentally to comply with legislation, and later to improve the quality of pollutant emissions, reduction in waste and fines. From environmental policy-making perspective, it is essential to understand the level of awareness of companies about existing environmental legislation in their country, only then can compliance be encouraged without fear of fines (Alotaibi et al. 2020).

In this study, three indicators were developed in order to verify which stage each mill fits in the environmental context. Indicator 1 (Table 3) refers to environmental strategies and environmental impact studies in production processes or throughout the production chain. Companies that carry out environmental impact studies in accordance with the legislation, developing actions to protect natural resources and prevent environmental impacts and have a standardized and formalized environmental management system indicate that they fulfil actions from the first to the third stage. Whereas the strategy that assumes that agricultural and industrial activities should not be considered in isolation, but as an ecosystem that functions within the natural ecological ecosystem, prioritizing actions for the optimization of resource use, minimizing pollutant emissions, and post-consumer (community) actions, falls into stage 4. The results for indicator 1 (Table 3) were based on participants' response to question 9 of the questionnaire (Supplementary Material).

Regarding indicator 1, only mills A and B are in stages 3 and 4. In general, most mills are at an intermediate stage in environmental strategies, that is, in stage 2. The researched mills consider that they are implementing environmental strategies to avoid problems with legislation, prioritizing

Table 3 Stages of mills surveyed regarding management of environmental strategies (indicator 1). *Source:* Elaborated by the author based on data from the field research

Environmental strategies—management	Mill					
	A	B	C	D	E	F
Stage 1						
It produces environmental impact studies according to the requirements of the legislation and focuses its preventive action on processes that offer potential damage to the health and risk to the safety of its employees	Y	Y	Y	Y	Y	Y
Stage 2						
In addition to fulfilling the legal obligation, it knows and develops actions to prevent the main environmental impacts caused by its processes and products or services	Y	Y	Y	Y	Y	Y
Stage 3						
It has a standardized and formalized environmental management system, including broad risk identification, action plans, resource allocation, training for employees and auditing	Y	Y	N	N	N	N
Stage 4						
In addition to having environmental management systems, it produces impact studies in the entire production chain; it develops partnerships with suppliers to improve its environmental management processes and participates in the final destination of products and post-consumption processes	Y	Y	N	N	N	N

Y = Yes—the action is contained in the premises of the strategic instrument

N = No—the action is not contained in the premises of the strategic instrument

preventive action strategies, such as monitoring and control activities of the main existing environmental risks.

It was reported by all respondents that the use of environmental strategies and practices was beneficial for employees in terms of improvement in safety at work (Table S1), and it was understood in this study that safety at work and environmental issues must be treated in an integrated way. This was observed by improvements in practices related to controlling and monitoring, both in the industry and in the agricultural field, of noise, dust, exposure temperature, and mainly in the use of toxic substances (example vinasse, pesticides, and industrial chemicals). Testa et al (2020), who studied the oil and gas industry, also reported that environmental issues and safety at work should be discussed together, in an integrated manner, in which all employees, and not just managers, have the opportunity to influence on environmental issues that are directly involved with your security.

Except for Mill C, the others (83% of mills, Table S1) believe that environmental strategies help in commodity trading and add value in the form of an increase in the number of more demanding customers ("green" markets) and with long-term contracts. The interviewees reported that large clients demand some action on environmental and social issues, including companies such as Petrobras and Shell, Danone food and Coca-Cola and Guarana Antarctica beverages. The interviewees of mill C reported that environmental strategies do not directly help commodity trading and add value because, according to them, the price of ethanol is determined by the market.

In the Brazilian sugarcane agroindustry, some studies pointed out that the company seeks to incorporate environmental and sustainability principles into its agricultural operations (i.e., not contribute to direct deforestation, reduction in water and fertilizer consumption) (Bordonal et al. 2018) and in supply chain, leading to positive repercussions in its image, increased competitiveness in current and new markets, access to international markets, and improved financial performance (Andrade and Paiva 2012).

In the opinion of all interviewees of the mills surveyed, the advantages of using an environmental management system outweigh the disadvantages. Although the objective of this system's adoption is not to directly generate profit, despite the relatively high investments, there is compensation for the credibility with the local community, in negotiating with large and demanding clients, new "green" markets, as well as the possibility of international business.

Most respondents reported that they have the ISO 14001 and Bonsucro environmental certifications (83% of mills, Table S1). Only mill F did not yet have environmental certification. The interviewees stated that certifications are one of the main devices to achieve sustainability standards. Certifications are voluntary schemes that aim to show internal and external stakeholders the performance of the mills in terms

of sustainability issues (Sozinho et al. 2018). The ISO 14001 adoption has a significant impact on improving environmental management and firm performance (Arocena et al. 2021) and Bonsucro certification helps to mainstream sustainability into the production lifecycle and address relevant social and economic issues (Sozinho et al. 2018).

Internal and external pressures are the first step for the company to become more environmentally sustainable (Bagur-Femenias et al. 2013) and in the case of the researched mills, a influence of these pressures for the implementation of environmental strategies was observed, so H1 was confirmed (Table 3). Figure 1 briefly depicts the parameters related to internal and external pressures and their motivations for the use of environmental strategies and practices in the mills.

Operational performance improvements

Two important facts were observed in the six mills researched: The first was the existence of an environmental department; the second referred to using external consultancies. All respondents reported that qualified labor and outsourced technical assistance are required to carry out environmental management in the mills (Table S1). In the environmental department, there is a person who participates directly in the strategic decisions of the company, taking part in meetings with top management and a differential of the mills was the participation in regional sustainability committees, such as micro-basins. Bagur-Femenias et al. (2013) showed a positive relation between environmental management practices and companies' organization and performance. Moreover, Abreu et al. (2012) noted a remarkable fact, which is the complexity of the environmental work and lack of internal human resources, therefore usually the companies end up hiring external consultants.

Table 4 presents the parameters related to the environmental department and external consultancies. At the

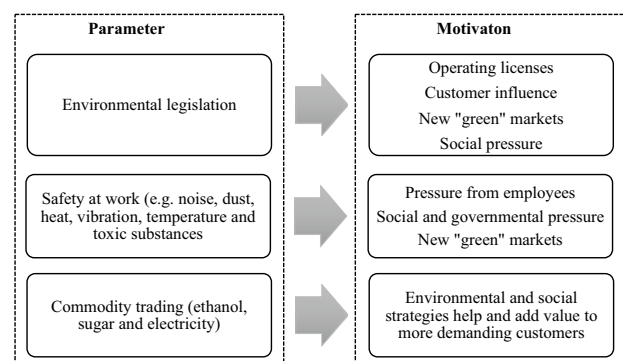


Fig. 1 Parameters related to internal and external pressures and their motivations for the use of environmental strategies and practices

Table 4 Number of employees, number of consultancies, consultancy costs, professional qualification, and subordination of the mills surveyed. *Source:* Elaborated by the author based on data from the field research

Parameters	Mill					
	A	B	C	D	E	F
Environmental Department						
Employees	4	1	1	2	2	2
Consulting Company	2	1	2	2	1	1
Monthly cost (USD)	35,000	22,500	32,000	30,000	26,000	27,500
Cost/Sugarcane milling (USD/Tons)	0.064	0.069	0.116	0.100	0.065	0.073
Professional qualification	Environmental and Agronomist Engineer and biologist	Environmental Engineer	Environmental Engineer	Environmental Engineer and biologist	Environmental and Agronomist Engineer	Environmental Engineer and biologist
Subordination	CEO	CEO	Industrial Manager	CEO	Agricultural Manager	CEO

researched mills, there are various consulting services, however, it was noted that in the new ones (C, D, and F), they play an essential role since they aim to streamline processes in public agencies, mainly in environmental licensing projects, generating a higher cost per ton sugarcane milling for these mills.

It was observed that in 67% of the mills (A, B, D, and F), the environmental department was directly linked to top management, such as CEOs, who participated in the company's strategic decisions (Table S1). This has made decisions about environmental strategies faster and more assertive, guiding the reduction in environmental impacts and the relationship with the community, through various educational programs. According to Homroy and Slechten (2019), companies can adopt symbolism or proactive measures to improve environmental ethics and sustainability, with top management and is responsible for implementing and monitoring such practices, providing information and strategic advice and generating knowledge about environmental strategies.

Although all interviewees stated that their companies periodically define environmental objectives and targets, only mills A, B, and C (Table S1) perform internal environmental audits through employees trained by a specialized team from the environment department. The audit was considered by the participants as an important management method to control and monitor environmental processes. Using auditing, it was possible to determine whether the activities were in compliance and identify opportunities for improvements, able to communicate the results of this process to internal and external customers and mainly to redefine, if necessary, the company's environmental objectives and goals.

The existence of treatment plants was similar among the researched mills. Regarding water treatment (100% of mills,

Table S1), this is done only for use in industrial processes, and for human consumption, water is taken from artesian wells and treated in drinking fountains distributed throughout the mills. None of the mills has a solid waste treatment plant (Table S1). The solid waste treatment is outsourced due to high costs, that is, they are sold to other companies for reuse. In companies C, D, and F (Table S1), sewage treatment is carried out at the industrial plant itself as the mills are newer and had more innovative industrial technologies, focusing more on the waste destined to the mill itself, whereas in A, B, and E, it is through the public sanitation network. It was also observed in all mills that there was a concern with the possible fines that could be imposed by the government for not treating sewage and vinasse, given the hazard of dumping these products in the ecosystems and water and soil contamination, causing serious risks to the environment.

A crucial point for the environmental management system to work relates to environmental impacts. It was observed that mills A, B, and C (50% of mills, Table S1) carry out constant identification and evaluation procedures in this regard, such as monitoring groundwater and surface waters, mainly using vinasse (by-product of sugarcane), air (pollution of cane burning and industry), soil (erosion and silting), and biodiversity (fauna and flora). As in the mills studied, Abreu (2009) observed in several branches of industrial activities that there was concern about the water quality, solid waste generation, energy consumption, atmospheric emissions, and nature resource depletion. It was also noted that the implementation of pollution prevention practices helps to minimize the energy and water consumption and reduces the rates of effluent treatment and waste discharge (Jabbour and Jabbour 2016; Kazancoglu et al. 2020).

Even by analyzing, monitoring, and controlling possible environmental impacts, the risk is imminent in the

researched mills. Mills A, B, and E, despite having environmental certifications (ISO 14001 and Bonsucro), were fined for non-conformities. Mill A had environmental problems with improper storage of agrochemicals; mill B had leaked vinasse and molasses from the industry (ethanol production by-products); and mill E was fined for removing trees without authorization from the competent authorities and sugarcane burning. In all these examples of environmental impacts, fines were imposed and repair or re-education work was requested. All the mills drew up plans to correct the damage caused and mitigated possible new failures. Preventive environmental measures carried out by the mills led to a reduction in costs with fines and environmental repairs. However, according to the interviewees, the actions elaborated by the mills were strictly related to the fulfillment of legal requirements (Brazilian environmental legislation), as well as the social pressures regarding the environmentally and socially correct issue. Sánchez-Medina et al. (2015) demonstrated in Mexican companies that the government's coercive pressure through monitoring and constant inspection of the company's environmental practices did not contribute to a change in the entrepreneurs' behavior, that is, companies simply complied with the established norms as they were afraid of penalties.

Mills C, D, and F were less susceptible to having this kind of environmental problems because they started operating more recently. These mills have more modern and efficient industrial processes, suggesting a lower level of environmental impacts due to their higher technological levels. Therefore, the use of innovative technologies indicates that improvements in agricultural and industrial sectors have led to a better sustainability and acceptance of products

produced by the mills (e.g., ethanol and sugar) in the global market (Bordonal et al. 2018).

The indicator 2 (Table 5) refers to the environmental strategies to minimize the inflow and outflow of materials. The results for this indicator were based on participants' response to question 30 of the questionnaire (Supplementary Material). Actions to reduce and prevent environmental damage began with the reduction of waste in the production process to evolve toward technological changes that optimize production, enabling the reuse of by-products from industry in its process or in the production system. Following this reasoning, the mill that adopted to monitor the consumption of natural resources and the production of waste in its mills was classified up to the initial three stages. Programs that establish reuse and environmental compensation actions that cover the entire production system (agricultural and industry) are the focus of stage 4, and only mills A and B carried out these environmental actions. Mills C, D, E, and F have not yet achieved an adequate level of environmental sustainability, however, they started the process (mills D, E, and F were in stages 1 and 2; mill C was in stage 3). Table 5 shows detailed information of all the stages of this indicator.

The mills surveyed have somehow applied environmental strategies to mitigate potential environmental risks and are seeking new technologies in agricultural and industrial areas to reduce and reuse various products, such as by-products from industry, vinasse, and bagasse, being used, respectively, as agricultural fertilizer and for bioenergy generation. This reuse of sugarcane by-products improves the financial revenues of the mills, through the electrical energy cogeneration and the use of vinasse as a fertilizer in agriculture, automatically mitigating possible environmental impacts

Table 5 Stages of mills surveyed regarding management of material inputs and outputs (indicator 2). *Source:* Elaborated by the author based on data from the field research

Environmental strategies—minimizing material inputs and outputs	Usina					
	A	B	C	D	E	F
Stage 1						
Without changing its current technological standard, it has sought to reduce the consumption of energy, water, toxic products, and raw materials and to implement processes for the proper disposal of waste	Y	Y	Y	Y	Y	Y
Stage 2						
It has invested in updating its technological standard, aiming at reducing and/or replacing incoming resources and reusing residues (by the company itself or by third parties)	Y	Y	Y	Y	Y	Y
Stage 3						
In addition to investing in the reduction and reuse of resources, it has a process to periodically measure, monitor and audit the significant environmental aspects related to the consumption of natural resources and the production of residues and waste, periodically establishing new goals	Y	Y	Y	N	N	N
Stage 4						
It is close to achieving a high level of environmental sustainability through reuse and environmental compensation strategies that encompass the entire production system	Y	Y	N	N	N	N

Y = Yes—the action is contained in the premises of the strategic instrument

N = No—the action is not contained in the premises of the strategic instrument

with these by-products. Thus, there was a direct reduction in operating costs, since the mills reduce the acquisition of fertilizers and the energy consumption. The by-products used (i.e., bagasse and straw) were considered as essential raw materials, mainly for generating electricity and obtaining second generation ethanol (Martins et al. 2018).

Those responsible for implementing or improving environmental management should be guided by some key principles based on recognizing that social and environmental management is among the highest priorities of the organization; establishing and maintaining communication with internal and external stakeholders; determining applicable legal requirements and environmental aspects associated with the company's activities and products; developing management and employee commitment to environmental protection; clearly defining responsibilities, stimulating environmental planning throughout the cycle, product, or process life; providing adequate and sufficient resources including training to achieve the intended performance levels; continuously assessing environmental performance regarding the company's environmental policy, objectives, and goals; always seeking a management process to audit and critically review environmental management and identifying opportunities for entire system improvement, resulting in better environmental performance, and encouraging its suppliers to establish a socio-environmental management system.

In terms of operational performance, the implementation of environmental practices has several consequences, such as the development of more strategic organizational routines, operating cost reduction, decreased environmental accident risks and government actions, less social pressure due to cleaner production in relation to the environment and improvement in financial revenue with the use of by-products from industrial and agricultural processes. Thus, the results indicated a positive impact of the adoption of environmental practices in operational excellence, therefore, H2 was supported. Figure 2 briefly depicts the parameters related to operational performance and their motivations for the use of environmental practices.

Environmental strategies and competitiveness

The use of environmental strategies and practices in the researched mills generated positive impacts on competitiveness. When a company adopts environmental management, it can improve its image, attract a new category of more demanding national and international customers ("green" markets), and further satisfy existing customers (Bagur-Femenias et al. 2013), as well as guaranteeing a better position in the current market (Leonidou et al. 2017). Furthermore, employees may have greater satisfaction with the environmental commitment, as well as opening a new communication channel between employees and management,

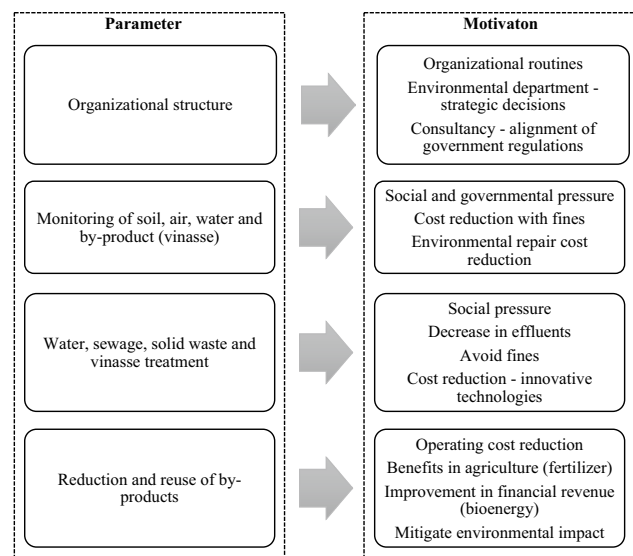


Fig. 2 Parameters related to operational performance and their motivations for the use of environmental practices

improving employee morale (Lee 2009). The adoption of environmental strategies also has an impact on competitiveness through improvements in operational performance, since the company can achieve savings in the consumption of materials, energy, and water, directly reducing operating costs (Fernández-Viñé et al. 2010).

The environmental strategy was considered formal in all researched mills (Table S1) by implementing simple but effective internal projects, such as the use of signage in the industry and in the administrative and agricultural sectors. Information leaflets and banners were distributed inside the mills and at strategic points, such as on roads and nearby cities. According to the interviewees, these internal projects produced greater communication between the employees and the top management of the mills, in addition opening up an interaction between the employees and the company, encouraging the sending of environmental suggestions.

Only the participation of mills A and B was observed in projects for the biodiversity preservation (Table S1), such as projects to recover rivers, reforestation, and monitoring of fauna, soil, and water in the regions close to the mills. Regarding environmental awareness, interviewees (mills A, B, E, and F, Table S1) reported that there are activities ranging from specific actions to the company's engagement with the socio-environmental leadership in its community. When implementing the projects, strategic procedures were adopted, such as actions to protect employees, public health, and the environment.

In this research, the indicator 3 refers to environmental practices related to effective internal and external projects. Briefly, stages 1 and 2 refer to employee training and environmental education activities focusing on the internal

public. Stages 3 and 4 presume environmental awareness actions at various levels, whether in its surroundings, for the partners of the productive chain and in the delivery of its products, as well as supporting or participating in sustainability projects. The results for this indicator were based on participants' response to question 37 of the questionnaire (Supplementary Material).

Table 6 shows the stages of mills surveyed in relation to indicator 3. In the stage 1, which refers to the environmental education of employees, all mills work on this subject, while in stage 2, only mill C does not systematically provide information to the internal public, due to the immaturity of the environmental manager. Regarding stages 3 and 4, the new mills C and D do not yet carry out environmental education campaigns with the families of employees, suppliers, consumers, and customers, and the immediate surroundings of the company. Mills C and D also do not support or participate in educational projects in partnership with non-governmental and environmental organizations. It is worth mentioning that mills A, B, and E carried out work in schools in the region of their mills to raise awareness and clarify environmental issues, and Mills A, B, and F gave talks to the external community with an environmental focus. Although most mills (A, B, E, F) develop awareness campaigns and participate in environmental education projects, these projects and actions are not documented, nor is there a pre-defined schedule and budget in mills E and F.

The commitment of employees of the mills to environmental concerns and practices increased their identification with the mill's values, mainly with their participation in social projects with the local community. Some interviewees (mills A and B) reported that the insertion in external

projects generated gains in competitiveness for the mills, in addition to improving their image before their stakeholders, domestic markets, and government. The social demand for a more sustainable environment, coupled with increased environmental care, forced the mills to carry out various educational activities and participate in extensive programs for the prevention, education, and mitigation of environmental impacts in the nearby cities.

The implementing environmental strategies and practices also affected the competitiveness of the mills through improvements in operational excellence. The reduction in operating costs resulting from the environmental management enhancements increased the mills' competitiveness, as it helped them to improve their current positions in a highly competitive market in commodity sales, in addition to differentiating themselves from their potential competitors and improving their image for the participation of new markets more ecologically demanding.

All interviewees stated that environmental issues affected the mills' competitiveness through continuous improvements in operational excellence (Table S1). The reduction in operating costs resulting from the environmental management enhancements increased the mills' competitiveness, as it helped them to improve their current positions in a highly competitive market in commodity sales, in addition to differentiating themselves from their potential competitors and improving their image for the participation of new markets more ecologically demanding.

Operational excellence combined with the growth of the company's reputation may lead to an increase in customer satisfaction. In addition, a reduction in fixed costs makes companies more competitive, as they need to sell

Table 6 Stages of mills surveyed regarding awareness of environmental challenges (indicator 3). *Source:* Elaborated by the author based on data from the field research

In order to contribute to the population's awareness of environmental challenges arising from human activity and cultivating values of environmental responsibility, the mill	Mill					
	A	B	C	D	E	F
Stage 1						
Develops environmental actions and training for employees on this topic, occasionally or as a result of external pressure (i.e., such as government or society and community requirements)	Y	Y	Y	Y	Y	Y
Stage 2						
Systematically develops environmental activities focused on the internal public, providing information, and encouraging discussions	Y	Y	N	Y	Y	Y
Stage 3						
In addition to internal campaigns, the mill develops environmental awareness campaigns aimed at family members of employees, suppliers, consumers, customers, and the community around the mill	Y	Y	N	N	Y	Y
Stage 4						
In addition to developing campaigns, the mill supports or participates in environmental education projects in partnership with non-governmental and environmental organizations, exercising social leadership in favor of this cause	Y	Y	N	N	Y	Y

Y = Yes—the action is contained in the premises of the strategic instrument

N = No—the action is not contained in the premises of the strategic instrument

less to cover their costs and therefore become more profitable (Bagur-Femenias et al. 2013). In fact, the competitive advantage derived from eco-friendly business practices strengthens current markets and the search for new customers, as well as cost savings generate more sales, profits, or other positive financial returns for companies (Leonidou et al. 2017).

Thus, our results indicated that use of environmental strategies improves the competitiveness of the mills, therefore, H3 was validated. Figure 3 briefly depicts the parameters related to competitiveness and their motivations for the use of environmental strategies.

Conclusions

The sugar-energy sector is undergoing a process of change in environmental issues, presenting well-defined environmental processes or seeking this definition. There is a scenario of technological innovations in industry and agriculture, such as the generation of clean electricity through biomass, use of industrial waste in agriculture, and new forms of administrative management, inserted by multinational companies that are acquiring and building mills in Brazil.

Currently, few studies have reported the effects of environmental strategies and practices on the socioeconomic development of companies based on social pressures, excellence operational, and competitiveness (e.g., Gupta and Nagpal 2020; Obeidat et al. 2020; Postal et al. 2020). Our findings showed that mills that adopt environmental strategies and practices may be able to differentiate themselves from the others, especially in reducing social pressures and improving operational performance and competitiveness, due to the acceptance of their products by the most demanding foreign markets and in the domestic market, the reduction in fines, the greater use of industrial by-products, such

as vinasse, generating a residue reduction, and an increase in stakeholders satisfaction through compliance with work safety and participation in water, air, land, and biodiversity conservation projects.

The choice of environmental management paths will depend mainly on some factors, such as the organization's profile, the company's size, and the technological innovations, i.e., whether orderly and consolidated management can facilitate the introduction of environmental strategies and determine possible advantages in competitiveness, influenced by aspects such as current reputation (image) and commercial relations with current customers and new markets.

Given the structural differences (i.e., size, inauguration date, number of employees, ethanol, sugar and energy production, among others) between the researched mills, the information obtained in this research on environmental strategies cannot be generalized, however, with the strong social and governmental pressures, the environmental issue should be implemented in a short time in all Brazilian mills and any other company that is in the market. Our study provided necessary and relevant information for mills and companies in other sectors and for those directly responsible for sustainable management, for a more in-depth understanding of coordinating environmental strategies and their implications for operational excellence and the competitiveness of companies.

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Declarations

Conflict of interest The authors declares that they have no conflict of interest statement.

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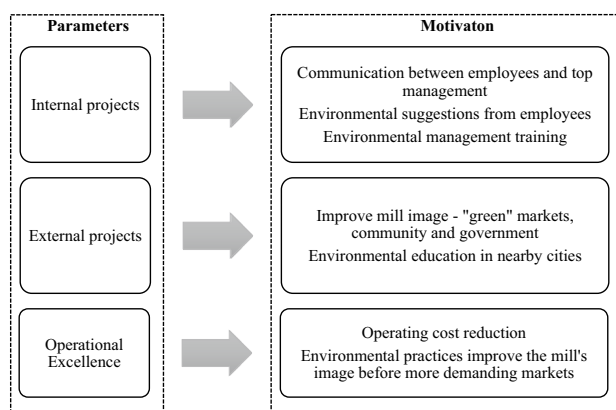


Fig. 3 Parameters related to competitiveness and their motivations for the use of environmental strategies

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