Evaluation of the Sustainability of Sugarcane Expansion in the State of Goiás

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Abstract

The expansion of sugarcane cultivation, and the development and modernization of the sugarcane sector, have contributed to the strengthening of Brazilian agribusiness, thereby contributing to the growth of the country's economy. Thus, it is necessary to adapt agricultural or agro-industrial activities so that the entire productive system has a positive impact on the environment and society. In this sense, the objective was to evaluate the sustainability of the expansion of sugarcane cultivation in the State of Goiás. The methodology was based on the application of the Sustainability Barometer-SB Method. Thus, subsidies were provided to create a portrait of the sustainability of the expansion of the culture in the state. The results indicated that the sector occupies a medium/intermediate position in relation to Sustainability according to SB. We conclude that the method has the potential to be an important tool in assessing the sustainability of the sugar-energy sector in Goiás.

Keywords: sustainability indicators, sustainability barometer, sugar-energy sector

1. Introduction

1.1 Introduce the Problem

Sugarcane represents one of the oldest crops in Brazil. According to data from the Brazilian Institue of Geography and Statistics - IBGE, the cultivation of sugarcane accounted for the production of 715,659,212 tons in the country in the last harvest, of which 72,012,198 tons were produced in the State of Goiás alone, as recorded in the last census of 2021 (IBGE, 2022).

In terms of the planted area, the state of Goiás is second in the ranking with 971,600 hectares, among the largest sugarcane producers in the country, with the state of São Paulo in the first place, while Minas Gerais is in third and the state of Mato Grosso do Sul, fourth. Monocrop production in these four states totaled more than 547.8 million tons, with the state of Goiás alone responsible for the production of 74.1 million tons (Companhia Nacional de Abastecimento [CONAB], 2021).

The areas of expansion of sugarcane as the only crop in the cerrado of Goiás encompass a mobility paradigm formed by the flows of goods, capital, and workers. Thus, the current agricultural production practices began to be observed for sustainability. It is noted that the intense use of pesticides and soluble fertilizers, in addition to polluting the environment and generating ecological imbalances, also turns agriculture energy negative, as these inputs are produced from fossil fuels. Modern agriculture consumes more energy with machinery, agrochemicals, and fertilizers than for the agricultural products themselves (Gliessman, 2001). From the 1980s onwards, the discussion on sustainability began intensively, focusing on the model of industrial agriculture and rural development employed.

Thus, the objective was to evaluate the sustainability of the expansion of sugarcane cultivation in Goiás. The methodology of the Sustainability Barometer (SB) was applied, with the use of Sustainability Indicators. The SB is a sustainability assessment methodology that was conceived by researcher Prescott-Allen (2001), with the approval of the International Union for Conservation of Nature and Natural Resources (IUCN) and the International Development Research Center (IDRC).

The methodology for building the SB is flexible, as there is no fixed number of indicators in its composition and the choice of indicators to be used is made by the analyst based on the possibility of building performance scales, domain research, and the availability of information. SB can be applied locally or globally, allowing comparisons between different locations and a given period (Kronemberger, Clevelário Junior, Nascimento & Collares, 2008). To this end, the work of the authors Guimarães, Turetta & Coutinho (2010) was used as a basis.

The structure of this article is composed of an Introduction where the problem is addressed and the objective is exposed. Next, a literature review is carried out, subdivided into topics: the first characterizing the expansion of sugarcane cultivation in the country and in the state, and the second pointing out the aspects and particularities of the Sustainability Barometer Method. The methodology characterizes the study area and the method used. Following this, the Results and a Discussion are offered, and finally, some Final Considerations and References are made.

1.2 Expansion of the Sugar-Energy Sector

The national expansion of sugarcane production began with the conception of the federal program, called PRÓALCOOL, in response to the oil crisis in the 1970s, whose primary objective was to create a substitute for oil that would reduce the country's dependence on its price variation (Pacca & Moreira, 2009). This expansion of sugarcane areas occurred specifically by encouraging local development and seeking solutions to environmental challenges.

According to CONAB (2022), the country should produce 572.9 million tons of sugarcane in its next harvest (2022/23). The result of which represents an increase of 1.6% relative to the national average in the yield of the country's crops, which is a counterpoint to the 2.6% reduction in the area of cultivation. However, it also represents a slight drop of 1% compared to the previous cycle.

The national sugar-energy sector is benefiting from current national policies to stimulate the production of biofuels, such as Renovabio, which is presented as the National Biofuels Policy, constituted by Law No. 13,576, of December 26, 2017, whose purpose is to increase the production of biofuels in Brazil. This should further increase the use of renewables such as ethanol, with the objective of reducing greenhouse gas emissions. It also enters a new cycle of expansion as foreign markets open up and accept Brazilian sugar and alcohol.

However, it is worth noting that, according to the development trend of sugar and ethanol production in Brazil, the increase in sugarcane production is necessary to sustain the emerging expansion of the sector, based mainly on new production areas, since, in recent years, the productivity of the sector has not increased substantially (Ferraz, Simões & Dubreuil, 2013).

The growth of the sector is accompanied by concerns due to the environmental impacts caused by agriculture and livestock, especially water consumption, use of pesticides and fertilizers, methane gas emission, fires, and deforestation of native vegetation derived from the expansion of agribusiness (Assad, Martins & Pinto, 2012).

The expansion of sugarcane cultivation in the Midwest is, in principle, a technically and economically viable alternative, but given the conditions of sustainability and in areas of significant environmental, social and economic importance, resulting from the change in the dynamics of land use associated with the risk of impact. Thus, the expansion of sugarcane in the state of Goiás is characterized by the expansion of agricultural frontiers.

However, so that these changes do not compromise sustainability, it is necessary to identify sustainability tools and indicators that can show which dimension (social, environmental, economic or institutional) is most affected (Rodrigues & Najberg, 2013), mitigating negative impacts and enhancing positive ones.

For some time, agricultural sustainability assessments focused mainly on environmental and technical issues, leaving aside economic and social issues, ignoring the versatility of agriculture and the applicability of results. Thus, as a way to integrate these dimensions, several integrated methods of assessing sustainability have emerged, aimed at serving rural environments (Seidler, Andreatta, Ciechowicz & Spanevello, 2018).

Thus, the application of indicators not only indicates the degree of sustainability of these agro ecosystems but also detects critical points and weaknesses in their structure and function, encouraging recommendations for interventions to improve the level of sustainability (Ferraz, 2003).

However, sustainability indicators are tools composed of one or more variables that relate in different ways, revealing the broader implications of the phenomena to which they refer. They are important tools to guide action and support the monitoring and evaluation of progress toward sustainable development (IBGE, 2008).

1.3 Sustainability Barometer Method

A group of experts linked to the International Union for the Conservation of Nature (IUCN) developed the Sustainability Barometer (SB) and the International Development Research Center (IDRC), whose main objective in using the method is to assist in the analysis of sustainability. It is intended for use by governmental and non-governmental agencies and policymakers alike (Van Bellen, 2002).

The underlying assumption of the Sustainability Barometer (SB) is that sustainable development should consider both human well-being and the well-being of ecosystems. In this approach, the two dimensions are considered together but measured separately. Information is divided into two subsystems: people (communities, economies, and other elements) and ecosystems (ecosystem services, processes, and resources) (Prescott-Allen, 2001).

Prescott-Allen (2001) states that indicators that address various issues or dimensions are necessary to assess the state of people and the environment in the pursuit of sustainable development. Data related to various aspects of the system need to be integrated. This data refers to water quality, employment, economy, education, crime, violence, etc. While each indicator can represent what is happening in a given region, the lack of order and coherence in the combination of signals they send can lead to correlated and highly confusing data.

Each indicator enunciates a signal, and the more indicators used, the more signals can be observed. Isolated indicators cannot reflect the general situation and only by combining indicators can one fully understand the state of society and the environment. Indicators can be combined in two ways: by converting to the same scale or by using performance scales (Van Bellen, 2002).

The SB is a tool to combine indicators and display their results through indexes, graphically presented to help understand and provide an overview of environmental and social conditions (Amorim, Araújo & Cândido, 2014).

Thus, the method proposes a systematic approach that combines different indicators that, when presented individually, show only the situation of the subjects they represent, while the SB reveals the situation of places relevant to sustainable development, allowing the comparison of socioeconomic conditions and physical-biological environments to be made (Kronemberger et al., 2008).

Due to its holistic nature, this is the most relevant method for analyzing local sustainability. It covers areas related to the environment, economy, and society, with indicators adapted to the local reality and components for assessing inequalities between populations. Thus, the importance of the relationship between indicators and sustainability is that it allows a demonstration of the relationship between environmental health, human well-being, and sustainability (Graymore, Sipe & Rockson, 2008).

The scale used in the Sustainability Barometer, ranging from 0 to 100 for each axis, is composed of points 100 and base 0. It is divided into five 20-point sections. Each sector is represented by a color, ranging from red to green (Table 1):

Table 1. Sustainability Barometer Scales

Sector	Scale Points	Color
Great	81-100	
Good	61-80	
Medium	41-60	
Bad	21-40	
Terrible	1-20	

Discription: According to Prescott-Allen (2001), the color scale indicates environmental well-being, with 100 being great and 1 being terrible

Scaling should be adjusted for each metric, which involves defining the best and worst values for a given metric. The endpoints are critical in size and importance (Van Bellen, 2002).

Prescott-Allen (2001) believes that a good way to adjust the beginning and end of the scale is to use historical values, appropriate for these points, and look to the foreseeable future. The goal to be achieved may be an important factor, but it should not be used as an optimal value.

In this way, the tool is easy to understand because it generates a two-dimensional graph in which the state of human and ecosystem well-being is placed on a relative scale, from 0 to 100, moving from bad to good in its consideration of sustainability. The location of the points defined by these two axes provides a measure of the sustainability or unsustainability of the system (Amorim et al., 2014).

The well-being of an ecosystem is the characteristic that maintains its diversity and quality, its ability to sustain people and the rest of their lives, and its potential to adapt to change and offer opportunities for the future (Prescott-Allen, 2001).

However, ecosystem quality includes its ability to maintain the growth cycle, productivity, and physicochemical integrity of the soil, water, and the atmosphere. Consequently, activities that stress ecosystems, such as conversion and occupation, and extraction of resources beyond their natural recovery capacity, lead to a decline in their diversity and quality, thereby reducing their ability to sustain life (Machado, Duft, Picoli & Walter, 2014).

In short, the SB is the tool of choice because it is an easy-to-apply and easy-to-understand tool, as the results are presented through a two-dimensional graph, which helps facilitate understanding for managers and decision-makers.

2. Method

2.1 Characterization of the Study Area

The State of Goiás has an area of 340,106 km2 and a population of 7,206,589 inhabitants (IBGE; UNDP, 2021) distributed among 246 municipalities (Figure 1).

Figure 1. Location of the State of Goiás on the map of Brazil

Description: Map of Brazil identifying the State of Goiás and next to it, the map of the State.

Goiás is located in the Midwest region and is in a privileged position, being the seventh state in terms of territorial extension, of the 26 Brazilian states. In addition, the State has good road infrastructure which qualifies it as a distribution center, as it is bordered to the North with the state of Tocantins, to the South with Minas Gerais and Mato Grosso do Sul, to the East with Bahia and Minas Gerais and to the West with Mato Grosso (Mauro Borges Institute for Statistics and Socioeconomic Studies - IMB, 2022).

The state's economic growth presents ample opportunities, which is attractive to many immigrants. Despite having an industrial park, the service sector is the backbone of its economy. This significant result is due to the development of Goiás agribusiness, trade, and the growth and diversification of the industrial sector. The main highlights of the sector include the food and beverage industry, the automotive industry, the pharmaceutical industry, mineral processing, and, more recently, the sugarcane production chain (IMB, 2022).

Regarding the cultivation of sugarcane, according to IBGE (2021), the State presents the following situation (Table 2):

Table 2. The sugarcane culture in the state of Goiás

Characteristics	Quantity
Quantity produced (Ton)	72,012,198
Value of production (R$ 1000)	7,084,432.00
Planted Area (ha)	930,954
Harvested area (ha)	926,609
Average yield (kg/ha)	77,716

Discription: Sugarcane: quantity produced, value of production, area Planted, harvested, and average yield.

With the data from 2021, the projection is that for the 2022/2023 cycle, there will be an increase of 2.8%, thus consolidating the state as the second largest of the culture (CONAB, 2022).

2.2 Methodology for Applying the Sustainability Barometer Method

Guimarães et al. (2010), by using sustainability indicators and applied through the Sustainability Barometer method, the authors studied the State of Mato Grosso do Sul, and the result is the article "A Proposal to Evaluate the sustainability of the expansion of sugarcane cultivation in the State of Mato Grosso do Sul", published in the journal Society &Nature.

The method developed by Guimarães et al. (2010) was used and considered the selection of sustainability indicators, in which it established the multidisciplinary criterion according to its three dimensions: environmental, economic, and social.

Sustainability indicators were selected for the State of Goiás, evaluated and compared using the Sustainability Barometer methodology. Thus, sustainability indicators are listed in Table 3.

Table 3. Sustainability indicators selected for application of the Barometer Method

Size	Description	N. of Indicators
Environmental	Referring to information about changes in natural resources such as soil and water.	2
Social	Characterized by measures referring to income conditions of the population with indicators that include income and employment distribution.	2
Economic	Characterizing the conditions of the production of microregions in the development process.	2
Total		6

Discription: Description of Dimensions for evaluation through the Sustainability Barometer Method

Table 4 shows the description and sources where the indicators were obtained.

Table 4. Sources where the indicators were obtained

Indicator	Description	Source
Consumption of pesticides	Pesticides are chemicals used to destroy or control pests on agricultural crops. They are divided into classes of herbicides, fungicides, and acaricides, among others. Each group has an active component with a specific degree of toxicity and dangerousness, both for the environment and for humans. This indicator shows the total number of tons of pesticides consumed in the microregion in a given period.	Sustainable development indicators. The Brazilian Environment and Renewable Natural Resources Institute (IBAMA)
Access to the water supply system	Percentage of households with access to water supply by general network. The indicator is the ratio in percentage, between the population with access to water by general network and the total population in permanent private households. Due to Brazilian legislation, all water supplied to the population by a general supply network must be treated and be of good quality.	IBGE, Demographic Survey.
Gini index	It expresses the degree of concentration in the distribution of population income in a given period. The Gini Index is expressed by a value ranging from 0 (zero), the situation of perfect equality to 1 (one), the situation of maximum inequality.	Atlas of Human Development – UNDP
Personnel employed in the Agricultural sector	Percentage of people employed in different economic sectors.	IBGE – Central Business Register
GDP *per capita*	The Gross Domestic Product *per capita* indicates the average income of the population in a country or territory. The variables used to construct this indicator are the Gross Domestic Product – GDP, at constant prices, and the estimated resident population. The indicator expresses the ratio between GDP and the resident population. The Gross Domestic Product *per capita* is usually used as an indicator of the pace of economic growth of the territory under analysis.	IBGE, Demographic Survey. IBGE - Gross Domestic Production in the Municipalities IBGE - Population estimate
Trade balance	It presents the balance between exports and imports of goods from a given territory, in a given period. Its value is expressed in U$ FOB.	Ministry of Development, Industry and Foreign Trade Secex

Discription: Descriptions of indicators and research sources to obtain data from the Sustainability Barometer method in the sugar-energy sector in Goiás

Thus, data collection was carried out with the research sources mentioned in Table 4, with reference to 2020 data. The indicators that did not have data available in that year, used data from the last year available, in order to later make use of the Sustainability Barometer. Therefore, the values of the indicators must first be normalized, which are achieved as follows:

(a) calculating the relationship between the upper limit minus the lower limit of the indicator and the upper limit minus the lower limit of the Barometer, where it considers the range that the value of the indicator is;

(b) calculating the relationship between the value of the indicator minus the lower limit of the indicator and the value obtained in (a);

(c) the result obtained in (b) is added to the lower limit of the Barometer scale where the indicator value is.

Another point to be taken into account is the definition of the sustainability limits of each indicator. Thus, to reduce subjectivity to establish limits, values from the literature on the subject are used (Guimarães et al., 2010). In this way, the threshold values will be the same as those applied by the authors.

Thus, the index is the result of the average score of the indicators that make up the theme of the respective dimensions. Then, the average is calculated to obtain the human well-being index, using the results of the social and economic indexes (social; agricultural/industrial; products/by-products; technological, and political). The ecological well-being index is represented by the arithmetic mean of the environmental dimension.

Finally, for the division of the scale, five intervals were used as defined by Prescott-Allen (2001) through values that represent conditions, ranging from unsustainable to sustainable.

3. Results

3.1 Evaluation of the Sustainability of Sugarcane Expansion in the State of Goiás

To evaluate the sustainability of the expansion of sugarcane cultivation in Goiás, the criteria recommended by Guimarães et al were adopted (2010).

Table 5 shows the normalized values for the State of Goiás, using the scales defined for the indicators by the Sustainability Barometer method.

Table 5. Sustainability Barometer Scale

			0-20	21-40	41-60	61-80	81-100
Indicators	Indicator Value	Normalized values	Terrible	Bad	Medium	Good	Great
Pesticide Consumption (sugarcane planted area)	3,261	76	> 836,110	836.109-30.099	30,099-15,001	15,000-2,129	2,128-0
Access to Water	86.8	57	0.69.9	70- 79.9	80-89.9	90-94.9	95-100
GINI Index	0.46	56	1.00-0.80	0.79-0.50	0.49 - 0.40	0.39-0.20	0.19 - 0
People Employed	28.7	67	<3	3 - 6.5	6.5-13	13-34	>34
GDP per capita	29,732	74	<1,999	2,000-5,999	6,000-11,999	12,000-14,000	> 40,000
Trade Balance (%) share of GDP	3.15	38	< 0	0-1.9	2-4.9	5-10	>10
Final Score	62		Good / potentially sustainable				

Discription: Scales defined for the indicators and scale of the Sustainability Barometer to assess the sustainability of the expansion of sugarcane in the State of Goiás.

The data suggest the need for measures to control activity in the State of Goiás so that the expansion of sugarcane culture can bring more improvements to the population, which are positively reflected in the values of the indicators.

The bottom line of Table 5 shows the final classification of the State of Goiás, according to the Sustainability Barometer, totaling (62.0), which results in a classification of the sustainability of the expansion of the sugarcane sector as “good / potentially sustainable”.

Thus, the ecological well-being index was rated by the representation of the arithmetic average of the environmental dimension, which is (66.0), being configured as "good/ potentially sustainable". To obtain the human well-being index, the arithmetic average of the social and economic indexes was performed, with a score of (58.0), which configures a “medium/ intermediate” situation (Figure 2).

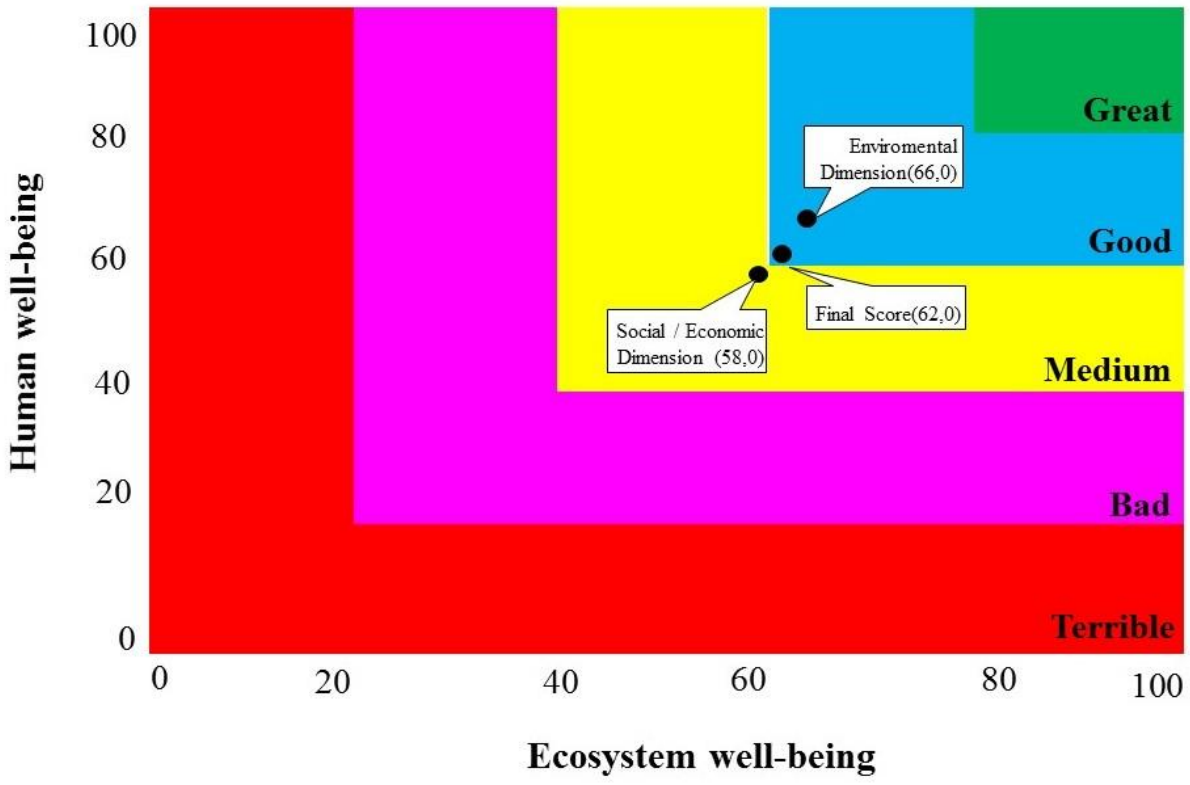

Figure 2. Position of Goiás in the Sustainability Barometer in relation to the expansion of sugarcane

Discription: Location of the final score in the Barometer for evaluating the ecological well-being index represented by the environmental dimension and the human well-being index represented by social and economic indices.

The well-being of an ecosystem is the condition that maintains its diversity and quality, its ability to sustain people for the rest of their lives, and its potential to adapt to change and provide opportunities for the future (Prescott-Allen, 2001).

However, ecosystem quality includes its ability to maintain the growth cycle, productivity, and physicochemical integrity of the soil, water, and the atmosphere. Consequently, activities that stress ecosystems, such as conversion and occupation, and extraction of resources beyond their natural recovery capacity, lead to a decline in their diversity and quality, thereby reducing their ability to sustain life (Machado, Duft, Picoli & Walter, 2014).

In the case of the State of Goiás compared to other academic works, such as those by Amorim et al. (2014) and Kronemberger et al. (2008), which study other Brazilian states, the “ecological well-being index” is better than the “human well-being index” when evaluated.

However, according to the SB methodology, a dimension always represents the average of the indicators that compose it. Therefore, if all indicators are bad, the end result will be unsustainable or almost unsustainable. If there are “bad” and “good” indicators, the situation will be intermediate. If everyone, or almost everyone, behaves well, the results will be sustainable. Even with these issues, SB remains a fast, simple, and inexpensive method for assessing the level of sustainable development of a territory and for monitoring its evolution over time (Kronemberger et al., 2008).

This result can direct the formulation of public policies to include the sustainability of culture in the state and also in the country. However, it is expected that the production of sugarcane follows the indications of environmental legislation – federal and state – and that its planting is done in such a way as to avoid “competition in grain production areas and in areas with anthropogenic environmental restrictions" (Amazonian Biome, Pantanal, protection areas, indigenous areas, etc.)” (Guimarães et al., 2010).

4. Discussion

The study aimed to evaluate the sustainability of the expansion of sugarcane cultivation in the State of Goiás through

the application of the Sustainability Barometer Method. This method proved to be a robust tool, capable of satisfying the proposal to assess sustainability. Nevertheless, in order to apply this method, it was difficult to obtain the available data regarding the specific indicators for microregions, which would help to better investigate this process in a smaller territorial space.

Thus, the application of the SB shows us how difficult it is to achieve positive results in different dimensions simultaneously, which would reveal a state of "equilibrium" that some see as the ideal state for achieving sustainable development. In practice, this condition is difficult to achieve due to the necessary compromises and contradictions between the different dimensions.

In this way, the SB can be considered an incentivizing tool for progress towards sustainable development. The tool promotes a common understanding about which actions should be integrated, in all dimensions of development, and which sectors should be prioritized in the application of public and private resources.

In view of this, it is recommended that other necessary studies be carried out, which should also consider other indicators, for a more detailed assessment of the sustainability of the expansion of sugarcane in the State of Goiás and in Brazil.

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Authors' contributions

Dr. Antonio Pasqualetto was responsible for the design and review of the study. Mateus Resende Oliveira was responsible for collecting data, investigation and writing the final manuscript. Dr. Jeferson de C. Vieira & Dr. Sergio D. de Castro were responsible for orientation and revising. All authors read and approved the final manuscript.

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The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Data sharing statement

No additional data are available.

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