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Sustainability indicators for Brazilian dairy livestock: the perception of professionals in the sector

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ABSTRACT - The objective of this study was to analyze the perceptions of professionals in relation to the importance of indicators used to assess the sustainability of Brazilian dairy cattle. A survey method was used through a questionnaire. The target audience was professionals related to dairy cattle: researchers, professors, consultants, farmers, and other professionals. The total number of respondents to the survey was 347. Cluster analysis resulted in the formation of four distinct groups: G1 ("Holistic"), participants agreed that all indicators are very important or, at least, important; G2 ("Technician") considered the indicators important and desirable, except for some environmental indicators which were assessed as non-priority and expendable; G3 ("Socio-environmentalist") assessed the indicators as desirable, but environmental indicators received more importance; and G4 ("Skeptic") generally believed that indicators were non-priority and expendable. The groups showed significant differences in relation to knowledge about technical, economic, social, and environmental aspects of dairy cattle. More than 60% of professionals consider milk production per area, reproductive index, production costs, profit from the activity, milk quality, quality of life of the producer and employees, succession, protection of water courses, and soil management as very important indicators of the sustainability of dairy cattle. On the other hand, important environmental indicators such as emissions of gases and substances, energy use, nutrient balance, and land use were neglected by most respondents. These results can help select and implement policies and strategies for decision making, aiming at producing milk in a more sustainable way.

Keywords: cluster analysis, milk production, production cost, quality of life, soil management

1. Introduction

There have been several challenges and criticisms of technical, economic, environmental, and social aspects of dairy farming. There are concerns about conserving natural resources, reducing or minimizing environmental impacts, optimizing production, increasing profitability, increasing efficiency and economic return, meeting human needs and supplying the population with food without compromising future generations (WCED, 1987; Oudshoorn et al., 2012). The urgency of the sustainable development of agricultural production is increasingly recognized (Herrero et al., 2015; Olde et al., 2016).

However, how should a dairy farm be evaluated? It is important to use a tool that assists in the evaluation of farms to analyze the current production system and propose possible changes to produce in a way that seeks sustainability. Indicators are an appropriate tool (Lebacq et al., 2013; Olde et al., 2017).

The development and use of indicators must observe the dynamic and social context, with the participation of the community related to the activity, and the indicators must have meaning for users to guarantee the assessment of sustainability (Okumah et al., 2018; Munyaneza et al., 2019). There is no consensus in the literature about which sustainability indicators are better for evaluating animal production. Generally, the proposed indicators try to meet the criteria of easy to implement, understandable, sensitive to variations, reproducible, adapted to the objectives, and relevant to the user (Bélanger et al., 2012; Olde et al., 2017).

Understanding the opinions of professionals on the assessment of sustainability on dairy farms can help select and implement policies and strategies for decision making, aiming at producing milk in a more sustainable way. The knowledge and perceptions that individuals have of the indicators can affect the adoption and diffusion of farm evaluation.

Few studies have investigated the perceptions of professionals related to dairy farming as regards which indicators are important for assessing the sustainability of farms (Bélanger et al., 2015; Munyaneza et al., 2019). No published studies were found on this issue in Brazil. The participation of professionals who develop activities related to dairy farming is essential to propose a set of indicators that can efficiently evaluate Brazilian milk production. The objective of this study was to analyze the perceptions of professionals in relation to the importance of indicators used to assess the sustainability of Brazilian dairy cattle.

2. Material and Methods

This descriptive research employs the survey method through a questionnaire (Jackson, 2009). The target audience was professionals related to dairy farming in Brazil, such as researchers, professors, consultants, farmers, and other professionals (inspectors, dairy managers, farm association directors, and dairy company directors).

The questionnaire was divided into two parts: the first comprised questions about the participants' profiles, and the second consisted of questions about the importance of the indicators for assessing the sustainability of Brazilian dairy cattle. The responses in the second part were measured on a Likert scale, in which 5 = very important, 4 = important, 3 = desirable, 2 = non-priority, 1 = expendable, and 0 = I don't know, or I don't have knowledge) (Likert, 1932; Sullivan and Artino Jr, 2013). Other authors also utilized the Likert scale to evaluate sustainability indicators in milk production (Van Calker et al., 2005; Bélanger et al., 2015; Gazola et al., 2018; Munyaneza et al., 2019).

At the end of the first and second part, a question was asked about the participant's level of knowledge about dairy cattle activity, considering the technical, economic, social, and environmental aspects. Responses were measured in order of the degree of knowledge (1 = I don't have knowledge, 2 = reasonable, 3 = intermediate, 4 = advanced). The purpose of these two questions was to analyze whether the level of knowledge of the participants affected the responses to the second part of the questionnaire about the indicators.

The preliminary version of the questionnaire was based on a bibliographic review of the use of indicators to assess sustainability in dairy cattle production systems. The bibliographic review of scientific papers was carried out on the Science Direct, Web of Science, Scopus, and Google Scholar platforms, choosing scientific articles that used indicators (technical, economic, social, and environmental) to assess the sustainability of dairy farming, and that were published from 1999 to 2017. The search also used references from the papers found.

A pre-test was undertaken with 12 professionals selected in a non-probabilistic way by convenience criterion. Professors, researchers, and other professionals who work with dairy cattle were selected. The questionnaire was sent by email as an attachment in Word™ format to the participants. The responses were evaluated, and the final version of the questionnaire was developed, through the exclusion and/or inclusion of indicators. The evaluated indicators can be seen in Table 1.

Table 1 - Technical, economic, social, and environmental indicators evaluated by professionals

Technical indicators	Social indicators
IT_1 - Annual milk production (kg of milk/year) IT_2 - Stocking rate (LU/ha) IT_3 - Lactating cows per area (cows/ha) IT_4 - Milk production per area (kg of milk/ha/year) IT_5 - Milk production per permanent labor (kg of milk/one day of service provided by a worker) IT_6 - Lactating cows per employee (cows/employee) IT_7 - Milk production per lactating cow (kg of milk/day) IT_8 - Milk production per total cows (kg of milk/day) IT_9 - Ratio of lactating cows per total cows (%) IT_10 - Ratio of lactating cows per herd (%) IT_11 - Reproductive index IT_12 - Discard rate (%) IT_13 - Mortality rate (%) IT_14 - Food self-sufficiency (%) IT_15 - Consumption of concentrated feed per lactating cows (kg dry matter/lactating cow/year) IT_16 - Dairy efficiency (kg of milk/kg of dry matter) IT_17 - Milk and concentrate feed ratio (kg of milk/kg of dry matter) IT_18 - Body condition score of the cows per lactation phase (scale from 1 to 5)	IS_1 - Milk quality IS_2 - Penalty for irregularities in milk composition (%) IS_3 - Bonus on the price received for milk (%) IS_4 - Animal welfare index IS_5 - Employment (employee/day) IS_6 - Accidents at work (accidents/employee/year) IS_7 - Lost time (%) IS_8 - Working time (hours/employee/month) IS_9 - Rest days (rest days/employee/month) IS_10 - Employee salary (R$/employee/month) IS_11 - Remuneration of family labor (R$/year) IS_12 - Quality of life IS_13 - Education IS_14 - Entrepreneurship IS_15 - Social involvement IS_16 - Succession IS_17 - Training and professional development (hours/employee/year) IS_18 - Diversification of activities on the farm (activities/farm) IS_19 - Payment for ecosystem services (R$/ha/year)
Economic indicators	**Environmental indicators**
IE_1 - Gross income from dairy farm (R$/year) IE_2 - Gross milk income in relation to gross farm income (%) IE_3 - Expenditure on labor hired on the dairy farm per gross income from milk (%) IE_4 - Expenditure on concentrate on dairy farm per gross income of milk (%) IE_5 - Total cost of dairy farm (R$/year) IE_6 - Total unit cost of milk (R$/kg) IE_7 - Total cost of milk per milk price (%) IE_8 - Gross margin of farm (R$/year) IE_9 - Gross unit margin (R$/kg) IE_10 - Gross margin per area (R$/ha) IE_11 - Net margin of farm (R$/year) IE_12 - Unit net margin (R$/kg) IE_13 - Profit of farm (R$/year) IE_14 - Unit profit (R$/kg) IE_15 - Profit per area (R$/ha) IE_16 - Capital stock per area (R$/ha) IE_17 - Capital stock per kg of milk (R$/kg/day) IE_18 - Expenditure on the cost of food (R$/year) IE_19 - Rate of return on capital with land (%/year) IE_20 - Cost benefit ratio IE_21 - Solvency IE_22 - Profitability (%) IE_23 - Farm leveling point (kg/day)	IA_1 - Energy use per kg of milk (MJ/kg of milk) IA_2 - Use of renewable energies (%) IA_3 - Ammonia emissions (kg ammonia/ha) IA_4 - Global warming potential (kg of CO_2-eq./kg of milk) IA_5 - Acidification potential (g of sulfur dioxide equivalent/kg of milk) IA_6 - Eutrophication potential (g of phosphate or nitrate equivalent/kg of milk) IA_7 - Terrestrial and aquatic ecotoxicity (g of 1.4 dichlorobenzene equivalent/kg of milk) IA_8 - Nutrient balance (kg of nitrogen, phosphorus, and potassium/year) IA_9 - Efficiency in the use of nutrients (%) IA_10 - Land occupation (m^2/kg of milk) IA_11 - Air quality IA_12 - Use of water per kg of milk (m^3 of water/kg of milk) IA_13 - Consumption of surface, groundwater, and rain (%) IA_14 - Quality of water used for human and animal consumption and milking IA_15 - Wastewater reuse (%) IA_16 - Effluent production per milked cow (kg/number of milked cows) IA_17 - Manure treated and reused (%) IA_18 - Animal and human waste and manure management IA_19 - Use of chemical fertilizer (kg of NPK/ha) IA_20 - Soil quality IA_21 - Organic carbon in the pasture soil (tonnes/ha/year) IA_22 - Loss of soil (tonnes/ha/year) IA_23 - Erosion in the soil (% of farm area) IA_24 - Degraded areas (% of farm area) IA_25 - Soil management (yes or no) IA_26 - Management of veterinary and agricultural waste and disposal of animal carcasses IA_27 - Use of antibiotics (dose/animal/year) IA_28 - Disposal of milk from animals that received medication IA_29 - Use of pesticides (kg pesticides/ha) IA_30 - Degree of biodiversity IA_31 - Preservation area or legal reserve (% of farm area) IA_32 - Protection of the watercourse or permanent preservation area (% of farm area) IA_33 - Grant and license

The Google™ Forms platform, used for the research, was chosen due to its ease of access for participants, as it was made available on the internet. Professionals were selected in a non-probabilistic way for convenience criteria, such as being researchers, professors, consultants, and farmers, among others. The criterion used for the selection was the development of works involving aspects related to dairy cattle, from production to commercialization, social and economic issues, production, processing, and others.

The professionals contact database was formed through research on the websites of research institutions, extensions, teaching, assistance, consultancy, dairy companies, producer associations, and others; contacts raised through the papers; contacts at events; and a personal contact list. A total of 1,011 people were registered in the database.

Of the 1,011 professionals who were sent emails with the questionnaire link, 57 emails were not valid, 24 people said they would not answer, 644 did not answer, and 286 answered the questionnaire. Considering only valid emails, the percentage of responses was 29.98%. Participants invited other people to answer the research, and this meant that 61 more people answered the questionnaire. The total number of respondents to the research was, therefore, 347 professionals.

Cluster analysis was used to group the research respondents through the similarities in their responses to the indicators. Hierarchical agglomeration was used in the cluster analysis to determine the similarity between the participants, using the Ward method. Cluster analysis is an interdependence technique that results in groups composed of similar internal variables that are different from other groups (Hair et al., 2014).

The differences between groups and types of participants were measured using the Kruskal-Wallis test ($P<0.05$) and Dunn's multiple comparison procedure ($P<0.05$). These tests were used because the analyzed variables are qualitative with an ordinal scale (Sullivan and Artino Jr, 2013). Data were analyzed using the R language, version 3.5.3 for Windows.

3. Results

3.1. Profile of participants

The state of Minas Gerais had the highest number of professionals responding to the research, with 76 people (Figure 1). Of the participants, 39.77% (n = 138) were professors, 19.02% (n = 66) researchers, 14.12% (n = 49) consultants, 5.76% (n = 20) farmers, and 21.33% (n = 74) other professionals.

Environmental issues were the only aspect with a significant difference after evaluation of the indicators ($P<0.05$), according to the Kruskal Wallis test and Dunn's multiple comparison procedure (Table 2).

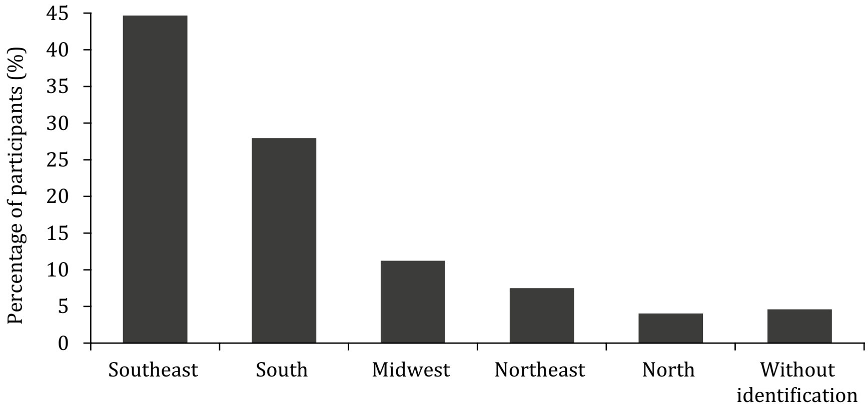


Figure 1 - Distribution of participants by Brazilian regions.

This means that professionals realized that they had less knowledge of environmental indicators after evaluating them, which can be observed by the statistically significant difference (Table 2).

Table 2 - Average and standard deviation of the participants' assessments of their degree of self-declared knowledge about dairy cattle activity considering the technical, economic, social, and environmental aspects (1 = I don't have knowledge, 2 = reasonable, 3 = intermediate, 4 = advanced), before and after evaluating the indicators

Item	Technical aspects	Economic aspects	Social aspects	Environmental aspects
Before evaluating the indicators	3.11 (0.88)aA	3.10 (0.83)aA	3.05 (0.75)abA	2.98 (0.79)bA
After evaluating the indicators	3.08 (0.88)aA	3.06 (0.83)abA	2.97 (0.76)bA	2.78 (0.86)cB

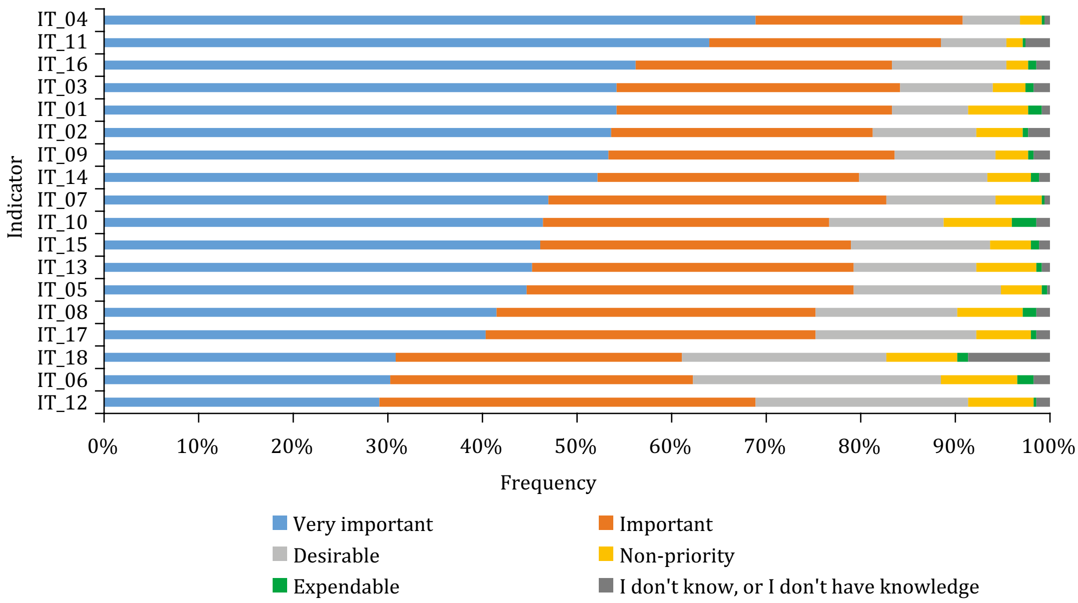
Different lowercase letters in the rows and uppercase letters in the columns differ significantly according to Dunn's test (P<0.05).

3.2. Technical indicators

Overall, the participants believed that technical indicators were very important and important for assessing sustainability on dairy farms. More than 60% of the participants believed that the indicators IT_04 (milk production per area) and IT_11 (reproductive index) were very important for evaluating a farm (Figure 2).

The indicators most often described as expendable were IT_10 (ratio of lactating cows per herd) and IT_06 (lactating cows per employee), with 2.59% and 1.73% respectively. However, these frequencies are negligible compared with those described as very important in the assessment of respondents: 46.40% for IT_10 and 30.26% for IT_06. Of the respondents, 8.65% did not know about indicator IT_18 (body condition score of the cows per lactation phase).

Participants suggested the inclusion of the following technical indicators for assessing sustainability: morbidity rate, average number of calves per cow, persistent production, and replacement rate.



IT_1 - Annual milk production; IT_2 - Stocking rate; IT_3 - Lactating cows per area; IT_4 - Milk production per area; IT_5 - Milk production per permanent labor; IT_6 - Lactating cows per employee; IT_7 - Milk production per lactating cow; IT_8 - Milk production per total cows; IT_9 - Ratio of lactating cows per total cows; IT_10 - Ratio of lactating cows per herd; IT_11 - Reproductive index; IT_12 - Discard rate; IT_13 - Mortality rate; IT_14 - Food self-sufficiency; IT_15 - Consumption of concentrated feed per lactating cows; IT_16 - Dairy efficiency; IT_17 - Milk and concentrate feed ratio; IT_18 - Body condition score of the cows per lactation phase.

Figure 2 - Evaluation of participants on the importance of technical indicators.

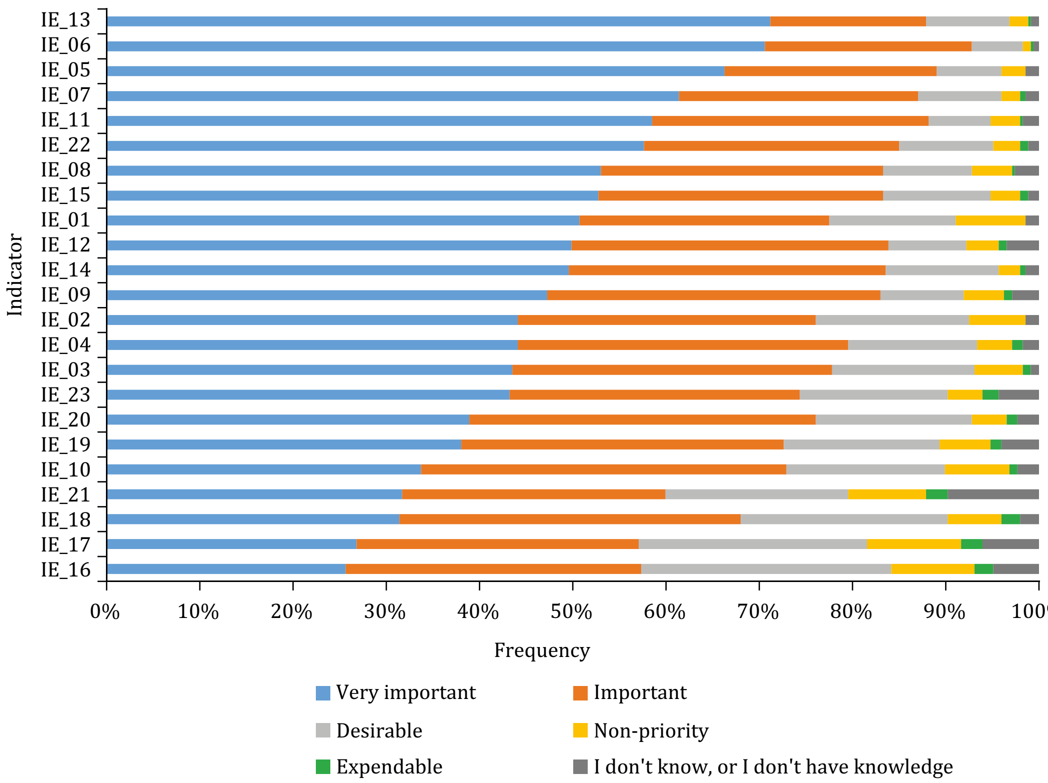
3.3. Economic indicators

Indicators IE_13 (profit of farm, R$/year), IE_06 (total unit cost of milk, R$/kg), IE_05 (total cost of the dairy farm, R$/year), and IE_07 (total cost of milk per milk price, %) were considered very important by more than 60% of respondents (Figure 3).

The indicators with the highest frequency of responses as expendable were IE_21 (solvency) with 2.31%, IE_17 (capital stock per kg of milk) with 2.31%, IE_16 (capital stock per area) with 2.02%, and IE_18 (expenditure on the cost of food) with 2.02%. Despite this, these indicators were described by 31.70% of respondents for IE_21, 31.41% for IE_18, 26.80% for IE_17, and 25.65% for IE_16, as very important.

Indicators IE_21 (solvency) and IE_17 (capital stock per kg of milk) were not known by 9.80 and 6.05% of the participants, respectively.

Participants suggested the inclusion of the following economic indicators for assessing sustainability: degree of indebtedness of the producer, milk price, net present value, discounted payback, changes in capital stock, and cash flow.



IE_1 - Gross income from dairy farm; IE_2 - Gross milk income in relation to gross farm income; IE_3 - Expenditure on labor hired on the dairy farm per gross income from milk; IE_4 - Expenditure on concentrate on dairy farm per gross income of milk; IE_5 - Total cost of dairy farm; IE_6 - Total unit cost of milk; IE_7 - Total cost of milk per milk price; IE_8 - Gross margin of farm; IE_9 - Gross unit margin; IE_10 - Gross margin per area; IE_11 - Net margin of farm; IE_12 - Unit net margin; IE_13 - Profit of farm; IE_14 - Unit profit; IE_15 - Profit per area; IE_16 - Capital stock per area; IE_17 - Capital stock per kg of milk; IE_18 - Expenditure on the cost of food; IE_19 - Rate of return on capital with land; IE_20 - Cost benefit ratio; IE_21 - Solvency; IE_22 - Profitability; IE_23 - Farm leveling point.

Figure 3 - Evaluation of participants on the importance of economic indicators.

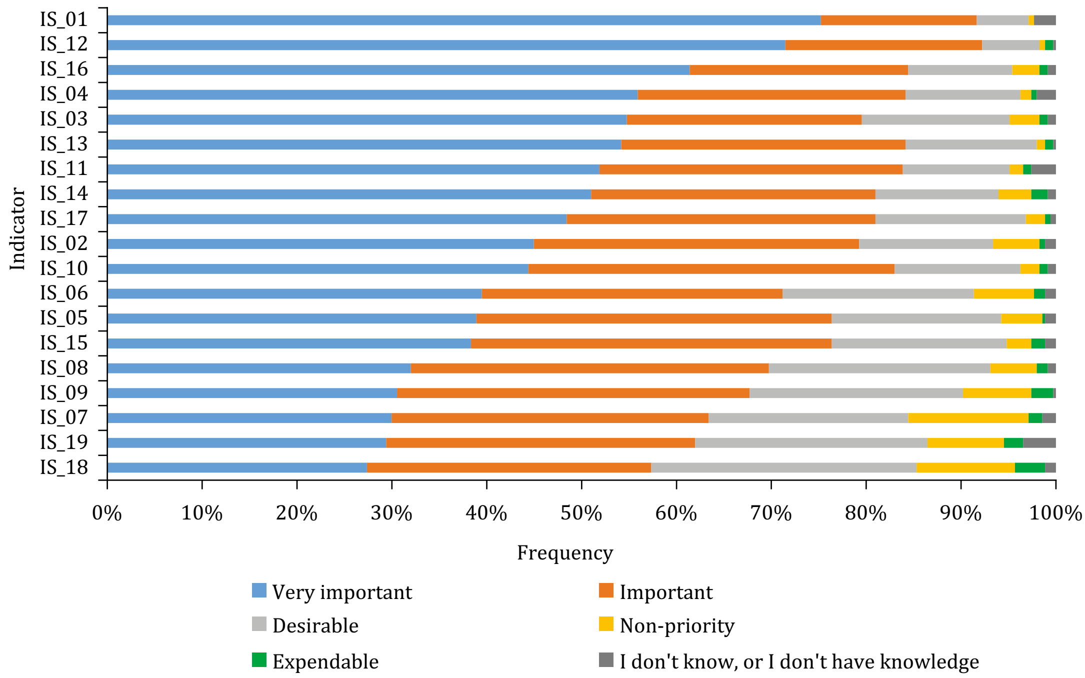
3.4. Social indicators

More than 60% of respondents believed that indicators IS_01 (milk quality), IS_12 (quality of life), and IS_16 (succession) are very important to assess farms (Figure 4).

The indicators considered as expendable were IS_18 (diversification of activities on the farm) with 3.17% and IS_09 (rest days) with 2.31% of responses. These indicators were considered very important by 30.55% of respondents for IS_09 and 27.38% for IS_18.

The indicators to assess social aspects were the best known by the participants, with less than 3.5% of responses claiming non-knowledge. The least known indicator was IS_19 (payment for ecosystem services).

Participants suggested the inclusion of the following social indicators for assessing sustainability: housing conditions for animals, shade, milking conditions, and aspects that respect animal behavior, access to leisure in IS_12, consumer goods, and the internet; and employee turnover.



IS_1 - Milk quality; IS_2 - Penalty for irregularities in milk composition; IS_3 - Bonus on the price received for milk; IS_4 - Animal welfare index; IS_5 - Employment; IS_6 - Accidents at work; IS_7 - Lost time; IS_8 - Working time; IS_9 - Rest days; IS_10 - Employee salary; IS_11 - Remuneration of family labor; IS_12 - Quality of life; IS_13 - Education; IS_14 - Entrepreneurship; IS_15 - Social involvement; IS_16 - Succession; IS_17 - Training and professional development; IS_18 - Diversification of activities on the farm; IS_19 - Payment for ecosystem services.

Figure 4 - Evaluation of participants on the importance of social indicators.

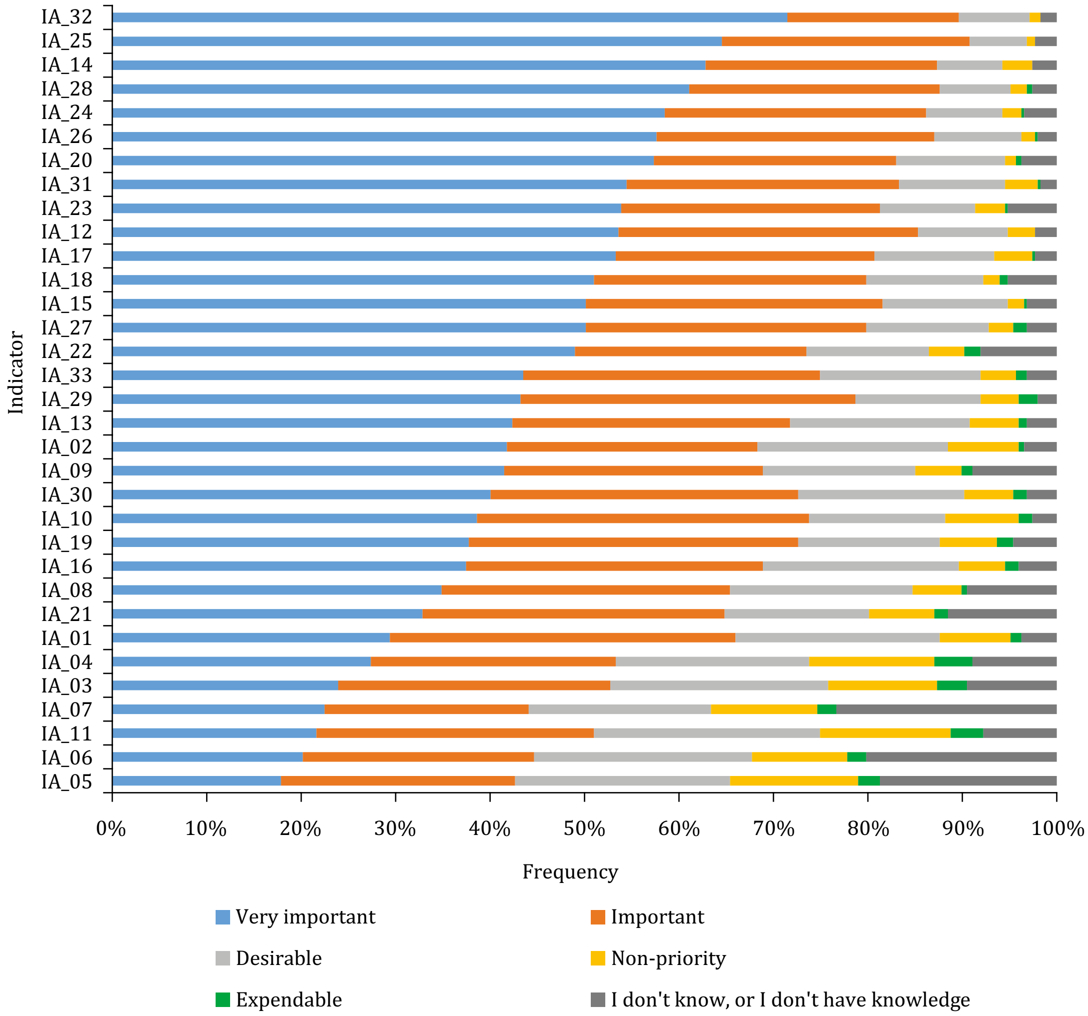
3.5. Environmental indicators

More than 60% of the participants considered IA_32 indicators (protection of the watercourse or permanent preservation area), IA_25 (soil management), IA_14 (quality of water used for human and animal consumption and milking), and IA_28 (disposal of milk from animals that received medication) as very important to assess dairy farms (Figure 5).

The indicators considered expendable were IA_03 (ammonia emissions), IA_04 (global warming potential), and IA_11 (air quality). Indicator IA_03 (ammonia emissions) was considered expendable by 3.17% of the participants, very important by 23.92%, and 9.51% did not know it. Indicator IA_04 (global warming potential) was rated as expendable by 4.03%, as not known by 8.93%, and as very important by 27.38% of the survey respondents. Indicator IA_11 was considered expendable by 3.46%, not known by 7.78%, and very important by 21.61% of the respondents.

Participants reported the highest percentage of non-knowledge for environmental indicators: 23.34% reported not knowing indicator IA_07 (terrestrial and aquatic ecotoxicity), 20.17% IA_06 (eutrophication potential), and 18.73% IA_05 (acidification potential).

Participants suggested the inclusion of the following environmental indicators for assessing sustainability: nitrogen excretion, carbon sequestration per kg of milk, milk production by renewable and non-renewable natural resources, and milk production by fossil energy source.



IA_1 - Energy use per kg of milk; IA_2 - Use of renewable energies; IA_3 - Ammonia emissions; IA_4 - Global warming potential; IA_5 - Acidification potential; IA_6 - Eutrophication potential; IA_7 - Terrestrial and aquatic ecotoxicity; IA_8 - Nutrient balance; IA_9 - Efficiency in the use of nutrients; IA_10 - Land occupation; IA_11 - Air quality; IA_12 - Use of water per kg of milk; IA_13 - Consumption of surface, groundwater, and rain; IA_14 - Quality of water used for human and animal consumption and milking; IA_15 - Wastewater reuse; IA_16 - Effluent production per milked cow; IA_17 - Manure treated and reused; IA_18 - Animal and human waste and manure management; IA_19 - Use of chemical fertilizer; IA_20 - Soil quality; IA_21 - Organic carbon in the pasture soil; IA_22 - Loss of soil; IA_23 - Erosion in the soil; IA_24 - Degraded areas; IA_25 - Soil management; IA_26 - Management of veterinary and agricultural waste and disposal of animal carcasses; IA_27 - Use of antibiotics; IA_28 - Disposal of milk from animals that received medication; IA_29 - Use of pesticides; IA_30 - Degree of biodiversity; IA_31 - Preservation area or legal reserve; IA_32 - Protection of the watercourse or permanent preservation area; IA_33 - Grant and license.

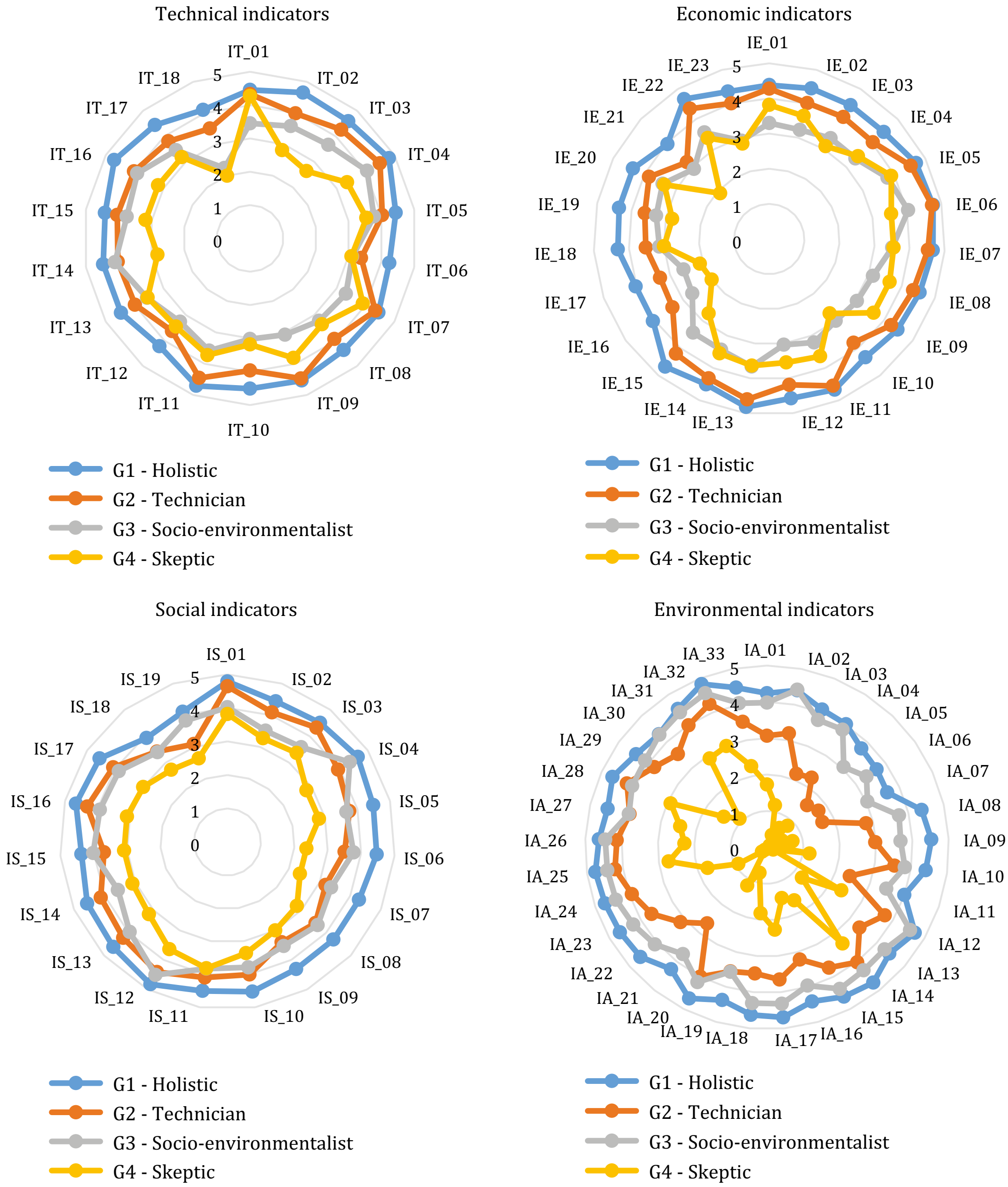
Figure 5 - Evaluation of participants on the importance of environmental indicators.

3.6. Cluster analysis

To start the cluster analysis, it is important to summarize the indicators that were considered the most important by the respondents in general: IT_04 (milk production per area), IT_11 (reproductive index), IE_05 (total cost of the dairy farm), IE_06 (total unit cost of milk), IE_07 (total cost of milk per milk price), IE_13 (profit of farm), IS_01 (milk quality), IS_12 (quality of life), IS_16 (succession), IA_14 (quality of water used for human and animal consumption and milking), IA_25 (soil management), IA_28 (disposal of milk from animals that received medication), and IA_32 (protection of the watercourse or permanent preservation area).

Cluster analysis was used to identify participants with similar response characteristics to the indicators. The cluster analysis resulted in the formation of four distinct groups, with similar characteristics within each group (Figure 6). The groups were named G1 ("Holistic"), G2 ("Technician"), G3 ("Socio-environmentalist"), and G4 ("Skeptic"), according to the participants' predominant views on the milk production system.

The G1 participants were defined as holistic, because they seek to understand the phenomena in their entirety, that is, a global view of the farm and its interactions, with weights relatively well distributed among all indicators. The G1 group contains 171 participants, who in general agreed that all indicators are very important or important. More than 80% believe that indicators IT_04 (milk production per area), IE_06 (total unit cost of milk), IE_13 (profit of farm), IS_01 (milk quality), IS_12 (quality of life), and IA_32 (protection of the watercourse or permanent preservation area) are very important.



Likert scale: 5 = very important, 4 = important, 3 = desirable, 2 = non-priority, 1 = expendable and 0 = I don't know, or I don't have knowledge.

Figure 6 - Average evaluation of the participants by groups about the importance of indicators.

Participants in G2 were called technicians because they proportionally valued technology and the profitability of the activity. This group saw technical resources as capable of offering solutions for the problems of milk production. The G2 group was composed of 112 respondents who considered all indicators, on average, to be important and desirable, except for IA_03 (ammonia emissions), IA_04 (global warming potential), IA_05 (acidification potential), IA_06 (eutrophication potential), IA_07 (terrestrial and aquatic ecotoxicity), IA_08 (nutrient balance), IA_09 (efficiency in the use of nutrients), IA_11 (air quality); IA_21 (organic carbon in the pasture soil), which were assessed as non-priority and expendable, all of which had an environmental element.

The G3 group was named socio-environmentalist for seeking to solve problems and processes based on valuing the environment, and with social awareness, aiming at environmental balance and the distribution of natural resources across society. It contains 53 participants, who approached the indicators in an intermediate way (3 = desirable) but agreed that environmental indicators were more important (4 = important). More than 60% considered indicators IS_12 (quality of life), IA_02 (use of renewable energies), IA_12 (use of water per kg of milk), and IA_32 (protection of the watercourse or permanent preservation area) as very important.

Participants in G4 were called skeptics because they did not claim any importance or certainty about the topic under study, tending to disbelieve almost anything, raising doubts and disbeliefs about the topic of sustainability indicators. It is composed of 11 people who generally considered that the indicators are non-priority and expendable, with the exception of the IT_01 (annual milk production) indicator, which was considered important. This group emphasized the importance of the production of milk sold and consumed on the farm per year: 64% reported that this is the most important indicator.

The groups showed significant differences in terms of knowledge about the technical, economic, social, and environmental aspects of dairy cattle ($P<0.05$), according to the Kruskal Wallis test and Dunn's multiple comparison procedure (Table 3). In general, participants in G1 ("Holistic") demonstrated to have greater knowledge in all aspects than the other groups, similar only in the economic with the G2 ("Technician") and in the environmental with the G3 ("Socio-environmentalist").

Table 3 - Average and standard deviation of the evaluation of the groups on the degree of knowledge about the activity of dairy cattle, considering the technical, economic, social, and environmental aspects (1 = I don't have knowledge, 2 = reasonable, 3 = intermediate, 4 = advanced), after evaluating the indicators

Group	Technical aspects	Economic aspects	Social aspects	Environmental aspects
G1 - Holistic	3.26 (0.83)aA	3.22 (0.68)abA	3.15 (0.68)bcA	3.05 (0.70)cA
G2 - Technician	3.00 (0.84)aB	3.04 (0.89)aA	2.77 (0.76)bBC	2.40 (0.85)cB
G3 - Socio-environmentalist	2.75 (0.94)abB	2.62 (0.90)bB	2.94 (0.79)aB	3.02 (0.84)aA
G4 - Skeptic	2.64 (1.21)aB	3.00 (1.09)aAB	2.36 (0.92)aC	1.45 (0.69)bC

Different lowercase letters in the rows and uppercase letters in the columns differ significantly by Dunn's test ($P<0.05$).

4. Discussion

The analysis of professional perceptions of the indicators must be seen as an important strategy in making the sustainability assessment process more effective and contributing to obtain a comprehensive view of the complexity of the transdisciplinary nature of the technical, social, environmental, and economic aspects.

Most participants reported having less knowledge about environmental aspects compared with other areas involving dairy farming. However, there were differences between the perception of environmental and social aspects among the study groups, in which the G1 ("Holistic") had greater knowledge of sustainability aspects, and the G4 ("Skeptic") had less knowledge of social and environmental aspects. This can be explained by the fact that—combined with knowledge about a given subject—beliefs, values, experiences, and personal interactions with society and the environment can influence the choices of how an activity should be evaluated and developed (McGuire et al., 2015). Furthermore, there is a difference in the way people perceive and interpret a given subject and its problems (Almeida et al., 2017). Therefore, the interview results point to a large knowledge gap about environmental issues among the evaluated participants.

One way to improve the perception and knowledge of those involved in milk production in Brazil would be through educational measures and dialogues between technicians and farmers. Some studies indicate measures that can be adopted in this regard, promoting the dialog between farmers and specialists (Cortner et al., 2019), and educational programs by research and extension institutions. All these actions can influence the perception of farmers and their behaviors in the quest to improve animal production (Cortner et al., 2019), and they can bring together different people, with different levels of knowledge to, together, promote more sustainable production techniques. However, for this to happen, professionals must be prepared for organizations to insert sustainable practices into their routines (Rampasso et al., 2019).

Another important result was that professionals realized that they had less knowledge about environmental issues after becoming aware of the set of indicators, confirming the need for training. Therefore, the indicators to assess sustainability must cover the main characteristics of the analyzed production system, and the results must be used by the public who are connected to the activity. To achieve this goal, it is necessary to understand and include the diversity of points of view held by professionals working in the activity. Participation makes it possible to analyze different views on technical, social, environmental, and economic complexities (Binder et al., 2010).

The participation of the actors involved enables efficient planning, increases the likelihood of successful implementation, and disseminates knowledge on the subject (Almeida et al., 2017). It is essential that society have transparent access to information, so that it can examine and adopt research results.

The choice of indicators is perhaps the most critical step in the sustainability assessment process. In addition to the perceptions of professionals, the choice process must consider the balance between validation, reliability, and significance of the indicators and the objectives to be achieved, under the restriction of data availability (Gaviglio et al., 2016).

In general, the results of this research, regarding the indicators considered most relevant by the respondents, are quite in line with the other results in the literature, except for the environmental indicators.

In terms of technical indicators, the literature mentions indicators such as productivity per cow, milk production per area, stocking rate, and milk production (Hagemann et al., 2011; Dolman et al., 2014; Battini et al., 2016; Salou et al., 2017; Silva and Gameiro, 2021). These parameters are important for assessing animal health, genetic improvement of animals, and reproductive and nutrition management.

In the economic aspects, indicators such as cost, margin, owner's income or remuneration for work, and income are considered important in the literature (Silva and Gameiro, 2021). Economic indicators are used mainly to analyze the viability of production. Dairy production—like any other commercial activity—is considered economically viable when it manages to generate enough income to remunerate productive resources (Van Passel et al., 2007). The cost indicator, which was chosen as important by respondents in this research, is appointed as a good indicator for assessing sustainability for several authors (Van Calker et al., 2007; Meul et al., 2012; Oudshoorn et al., 2012; Zucali et al., 2016).

In the social aspect, scientific literature divides it into issues related to the vision of society and the vision of farmers. Social issues related to the farmer are associated with social justice, social capital, culture, and physical and psychological health. Social issues related to society are health, animal welfare, and food security (Van Calker et al., 2007). The main indicators found in the literature to assess social aspects were labor education and training, animal welfare, product quality, and working conditions (Silva and Gameiro, 2021). Animal welfare was an important topic in the analysis of dairy farm sustainability (Van Calker et al., 2007; Meul et al., 2012; Zucali et al., 2016). In this study, the IS_04 indicator (animal welfare index) was rated as very important by 56% of respondents. The respondents were concerned with ensuring that products do not cause damage to the health of consumers and that, at the same time, the farmer has a dignified life, and that the activity passes from generation to generation.

On the environmental aspect, there was the main difference between the literature and our results. Indicators such as emissions of gases and substances, energy use, nutrient balance, and land use were not considered important by the interviewees of this study, but are often mentioned and considered in literature (Silva and Gameiro, 2021).

We highlight the focus on compliance with legislation, especially environmental issues. Our respondents emphasized the need for farmers to fulfil environmental requirements for sustainable production. The protection of a watercourse or permanent preservation area (IA_32) is established by law in Brazil. In 1965, the Brazilian Forest Code was created (Law No. 4,771/1965) and updated on May 25, 2012, by Law No. 12,651, which establishes the limits of use for the farm, with the purpose of respecting and conserving the vegetation (areas of native vegetation, legal reserves, and permanent preservation) existing on the farm (Brasil, 2012).

Participants were not aware of the indicators related to life cycle assessment (LCA), such as IA_05 (acidification potential), IA_06 (eutrophication potential), and IA_07 (terrestrial and aquatic ecotoxicity). Life cycle assessment was not familiar to research participants, but it has been used in several environmental assessment studies (Van der Werf et al., 2009; Hagemann et al., 2011; Dolman et al., 2014; Battini et al., 2016; Salou et al., 2017; Zucali et al., 2016; Mu et al., 2017). The LCA is based on international standards, such as the International Standardization Organization – ISO 14000 (Baldini et al., 2017; Mu et al., 2017). According to Thomassen and Boer (2005), the indicators of the LCA proved to be effective, as they are relevant and of good quality.

In general, the indicators that most respondents described as expendable were: IT_06 (lactating cows per employee), IT_10 (ratio of lactating cows per herd), IE_16 (capital stock per area), IE_17 (capital stock per kg of milk), IE_18 (expenditure on the cost of food), IE_21 (solvency), IS_09 (rest days), IS_18 (diversification of activities on the farm), IA_03 (ammonia emissions), IA_04 (global warming potential), and IA_11 (air quality). These indicators are important for sustainability because they include issues of production and efficiency of the herd (IT_06 and IT_10), the financial health of the enterprise (IE_16, IE_17, IE_18, IE_21), social (IS_09 and IS_18), and environmental issues (IA_03, IA_04, IA_11). Because they are indicators that are relatively easy to measure and have a low cost to obtain data, they are more feasible to be implemented on a dairy farm, thus enabling the comprehensiveness of the assessment for the three important aspects for sustainable development.

The indicators that the participants did not know about were IT_18 (body condition score of the cows per lactation phase), IE_17 (capital stock per kg of milk), IE_21 (solvency), IS_19 (payment for ecosystem services), IA_05 (acidification potential), IA_06 (eutrophication potential), and IA_07 (terrestrial and aquatic ecotoxicity). Most indicators are related to environmental aspects. This result highlights the importance of promoting actions that bring knowledge about ecology, environment, and animal production to professionals related to dairy cattle. This advance in knowledge about sustainability, not only in the environmental aspect, would bring an opportunity to understand the gaps and challenges of the sector, making it possible to make decisions for a better-quality product, more accepted by the consumer and less harmful to the environment.

The results of this research show that environmental sustainability is a crucial gap in the knowledge of Brazilian professionals as regards achieving the global sustainability of milk production. This knowledge would help to adapt the milk production to the interests of a cleaner, socially fair, and profitable production, thus, bringing benefits not only for the consumer but also for the professionals and farmers in the milk production.

However, it is important to emphasize that the results of this study should be considered with caution before generalization. The application of a questionnaire with a larger sample of professionals, in different regions, i.e., different cultures, can lead to different results.

5. Conclusions

Due to the concept of sustainability, it is understood that it would be desirable for professionals to present a holistic perception and concern of milk production regarding the pursuit of sustainability, that is, to be able to attribute relatively similar degrees of relevance to the different dimensions: technical, economic, social, and environmental. However, this was not the conclusion. Only one of the four clusters fits this profile (G1, "Holistic"). The others either attribute greater weight to a group of indicators, with a technical (G2, "Technician") or a socio-environmental (G3, "Socio-environmentalist") bias; or they are skeptical about the sustainability issue (G4, "Skeptic"). Furthermore, professionals in the G1 cluster ("Holistic") were exactly those who demonstrate the highest level of knowledge of sustainability indicators, indicating that knowledge allows people to acquire a more holistic view of the problem. This conclusion is also in line with the fact that social and environmental indicators are the least known by many professionals that still have a vision based mostly on productivism. Finally, the research also allows us to conclude that, despite the exhaustive literature review that was carried out, the interviewees suggested new sustainability indicators in milk production that were not found in the literature. This is evidence that there is still much to be done, not only in practical terms on farms, but also in academia.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Conceptualization: M.F. Silva. Data curation: M.F. Silva. Formal analysis: M.F. Silva. Funding acquisition: M.F. Silva. Investigation: M.F. Silva. Methodology: M.F. Silva. Project administration: M.F. Silva. Resources: M.F. Silva. Software: M.F. Silva. Supervision: A.H. Gameiro. Validation: M.F. Silva. Visualization: M.F. Silva. Writing-original draft: M.F. Silva. Writing-review & editing: M.F. Silva and A.H. Gameiro.

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