Milk Production's Sustainability
Case Study: Azores

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Abstract

The aim of the following paper is to analyse if the intensification of dairy farms is an aggravating factor to sustainability. To this end, a framework composed by several KPIs was built in order to assess the sustainability of milk production, following the 17 Sustainable Development Goals of the UN Agenda for 2030. The framework was applied to the case study, evaluating the sustainability of milk production of three dairy farms, with different production regimes, in the island of S. Miguel, in the Autonomous Region of the Azores. To each dairy farm participating in the case study was given a letter. The dairy farms A and B have a production in extensive regime, with movable milking system and mechanic milking system in room, respectively. Dairy farm C has intensive production regime with a robotic milking system. To reach the data that helped quantifying the KPIs under analysis, a survey was built to be answered by the dairy producers. Data from farms with increasing intensification were treated in the light of the sustainability theme and the reference values for each indicator. Dairy farm C presented a performance map that was closer to ideal, thus a more sustainable production. Analysing the case study, using the framework, the answer to the main research question is: "Is an intensive dairy farm more sustainable than an extensive dairy farm?". It is therefore concluded that the intensification of the production system of the dairy farm is not an aggravating factor to sustainability.

Keywords: milk production; SDG; intensification of dairy farms; KPI; Azores.

1. Introduction

The contamination of the biophysical environment is a current challenge. The intensification of the dairy farms' production type is a more controlled option, since it happens in a more confined space, unlike the reality of extensive regime production. In the latter often occur unattended discharges that harm the environment.

Milk production is defined by all the milk produced: milk used in the farm (intended to animal feeding except for the suckled directly from the offspring, self-consumption and processed into dairy products), deliveries to industries and direct sales (INE, 2018a).

In this paper it will be made an analysis of primary production, namely, all stages that occur on the dairy farm, excluding the collection of fresh milk for transport and its processing onto dairy products. It is also intended to achieve a sustainable mode of production by assessing the sustainability of different dairy farms.

There is a continuous growth of the world population, which in 2050 will reach an average of 9 billion people (United Nations, 2017a). There is then a high demand for food, which has tripled in the last 50 years (United Nations, 2017a).

The dairy industry, in order to maximize its profits, has integrated technology into its processes over the last decade (Jacobs & Siegford, 2012). This technological integration takes place in the dairy farms, which vary in size, number and degree of intensification.

This degree of intensification in dairy production varies among extensive production systems in which cows graze outdoors and feed on pasture; and intensive production systems, where cows are kept indoors and fed a large proportion of concentrated feed, cereals, silage, among others (European Commission, 2012). A good example of these intensification mechanisms is the dairy industry in the Netherlands, which has revolutionized itself in the last 50 years, increasing its productivity even with a decrease in the number of farms in the country (Struik, Kuyper, Brussaard, & Leeuwis, 2014).

In this way three dimensions are interrelated: social inclusion, environmental protection and economic development. Given the tendency towards intensification of Portuguese dairy farms, the **main research question** of this master's thesis is: **"Is an intensive dairy farm more sustainable than an extensive dairy farm?".**

This study aims to investigate whether intensification of dairy farms is an aggravating factor to sustainability. The main objective of the study is to increase the sustainability of milk production through:

a. Definition of the **main challenges** in the area of global production of cow's milk;
b. Development and definition of the ***framework* for the sustainability assessment** of milk production, following the United Nations goals for 2030;
c. **Assess and contribute to the sustainability** of milk production in the case study, situation of S. Miguel Island, using the developed *framework*.

Having in mind all the following themes: increased demand for milk, conflicts caused by resource scarcity, human health and the technology present in milk production; the research problem is defined pointing towards an increase of the production, which will happen in the intensive regime, in response to the high demand for food caused by population growth and resource scarcity

Above all, it is necessary to assess the needs of the different *stakeholders*, from the producers to the final consumer. It needs to be understood whether this intensification could be socially, economically and environmentally sustainable. Keeping in mind the animal welfare and the relationship of the dairy farms with the biophysical environment.

1.1. The concept of sustainability

It is currently the UN Agenda for 2030, which emerged in 2015, that structures the sustainability analysis. Its 17 Sustainable Development Goals (SDGs) are the most appropriate and practical way to assess and achieve sustainability in the world.

The UN agenda is created in 2015, based on the progress with the *8 Millennium Development Goals* established between 2000 and 2015. It is the result of the joint work of governments and citizens, which aims to create a new global model for sustainability (Centro Regional de Informação das Nações Unidas, 2019).

It is clear throughout the document that the 17 goals and 169 comprehensive targets created, in their genesis integrated and interconnected, are universally applicable to design a sustainable development. The UN states that each country has responsibility over its own social and economic development, and that these goals must respect the different countries' realities, levels of development and national priorities. In this sense, the goals are universally defined. However, it is up to each government official to set their own goals given the level of ambition, depending on their country's contexts.
In many situations, the SDGs are analysed individually according to the project area or research direction. The "*cherry picking*" then occurs, where goals are selected one by one, or by groups (Partidário, 2019).

In the following study it is taken into account this network approach, because their goals are indivisible and integrated. The sustainability of the activity is then analysed and assessed through the network with the 17 SDGs. Being the common goals of the different objectives linked, an overall picture of the problem under analysis is obtained (Le Blanc, 2015). Of all 169 comprehensive targets, 60 of them refer to at least two goals. The goal that has the most connections to the rest is Goal 12 - to ensure responsible consumption and production.

1.2. Milk production

After the milk production and its nutritional aspects have been analysed, it can be concluded that its quality is closely related to the patterns of the animal that leads to it. The welfare of the dairy cow and all the required management of the farms, whether under intensive or extensive production, are highlighted.

As the dairy farm is an ecosystem with several parties involved, it is important to understand its role in the surrounding reality and the interactions with the environment. Understanding whether there is proper management of the effluents generated by this activity is an important step towards achieving sustainability of production. It is concluded that agricultural valorisation is given priority by returning to the soil the mineral components and organic matter needed for plant development, minimizing the negative impacts of effluents on the environment.

1.3. The sustainability of milk production

The intensification of production is thus a trend, and the question is how to produce more milk sustainably, with less resources, fewer cows, and to keep a smaller ecological footprint as possible.

Sustainable intensification is defined as the process of producing more food in the same area of land, while reducing environmental impacts (Godfray, et. al, 2014).

According to the FAO guide (2011), the farms adopting a sustainable intensive regime will achieve several environmental benefits, including adaptation to climate change, reduction of greenhouse gas emissions and carbon footprint of agriculture. The socioeconomic benefits will be based on productivity and profitability levels, which, in addition to being high, will be stable.

1.4. Analysis of the UN goals on milk production

Examining the literature on milk production, arguments that were related to each of the 17 SDGs were searched for. In addition to each goal, the correspondent comprehensive targets and indicators were analysed. For any goal there is one or more comprehensive targets to be achieved (169 in total). For each of these comprehensive targets, there is an associated indicator. The agenda includes 244 indicators, however the official number is 232, since 9 indicators are repeated in different comprehensive targets.

The document elaborated by INE in 2018 was also analysed, Sustainable *Development Goals - Indicators for Portugal*, which transports the comprehensive targets and the correspondent indicators to the Portuguese reality and population statistics.

A table was then created (Appendix I), which connects the goals with the milk production, comprehending which contributions already exist to meet the comprehensive targets for sustainable development and seeking to define the indicators to be assessed in this activity.

With the different examples of dairy activity mentioned in the table, many of the goals are already being implemented in the Portuguese reality. Namely those related to Partnerships: goal 17; with Peace: goal 16; with Prosperity: goals 8, 9 and 10; and with People: goals 2, 3 and 4. However, the goals to be implemented: 1, 5, 6, 7, 8, 12, 13, 14 and 15, should be analysed, being necessary to define the indicators for its assessment, in this thesis. Looking at the various contributions of milk production to the 17 SDGs, it appears that this sector has the potential to generate sustainable development as it **generates** wealth and economic income by employing specialized local population. However, it has to improve its relationship with the biophysical environment as it produces an essential good, highly nutritious for the general population.

1.5. Framework for assessing the sustainability of dairy production

The definition of key performance indicators (KPI), is essential for assessing the sustainability of dairy farms' production. To measure performance, it is necessary to quantify the efficiency and effectiveness of an action (Neely et al., 2005). Not only at the corporate level, but also from the scientific point of view, there has been a need to measure this performance and to define its indicators (Domingues, 2015). These performance indicators, *Performance Indicators* (PI), are accompanied by a comprehensive target, or benchmark, that creates a goal in a given activity or process.

Although an extended list of indicators assessing the activity is created, it is necessary to define which are the indicators of the critical headings of the process under review. This set is named Key Performance Indicators, *Key Performance Indicators* (KPI). It is these indicators that allow the entity responsible for the process to assess and monitor the evolution over time of the activity under study (Global Dairy Plataform, International Dairy Federation, Sustainable Agriculture Initiative, & European Dairy Association, 2015).

A table is then created with the KPIs (Appendix II.) that assess the sustainability of milk production, along with the bibliographic sources that instil these indicators.

This *framework* results from the intersection of the SDG, not only the "not performed", but also those "already performed" in the reality of dairy production (Appendix I.) highlighting the SGD: 1, 5, 6, 7, 8, 12, 13, 14 and 15. However, extra analysis of SDG 2, 4, 9 and 11 is suggested; in order to increase the effectiveness of the assessment of the selected dairy farms. It was also taken into account the indicators suggested in the Dairy Sustainability Framework (DSF) and the indicators that assess the production of agro systems in literature.

In order to ease the interpretation of the selected KPI, two additional tables are created with reference values for the indicators, as well as whether they are qualitative or quantitative and their adapted measurement scales. The Appendix III refers to the KPI that are essential for assessing the sustainability of milk production (relation to the "outstanding SDGs"). The Appendix V has the KPI related to the SDG already executed, but which analysis is worth and will contribute to enrich this framework

2. Research Methodology

To characterize dairy farms, it was necessary to elaborate a survey with different groups. Each set of questions has different themes, in order to obtain a characterization from several aspects of the dairy farm:

1) **Identification of the Farm** - situate the farm in the Portuguese territory, identify its owner and production regime;
2) **General Characterization of the Farm** - calculate areas dedicated to the farm, identify possible renewable energy source, water source and the types of housing and milking;
3) **Livestock Herd** - calculate animal head and characterize the livestock;
4) **Reproductive and Feeding Management** - assess the technology usage through artificial insemination and characterize the type of animal feed;
5) **Labour Force** - characterize the workforce of the dairy farm in terms of sex, age, residence and wage gain;
6) **Milk Production** - quantify the milk production of the dairy farm, assess the importance of production support, understand the evolution in terms of profitability, herd and milk production;
7) **Hygiene and Welfare**- characterize sanitary management and animal welfare;
8) **Effluent Production** - identify possible separation of effluents and its use;
9) **Contribution to the Region** - characterize the social interaction of the dairy farm with the community.

In order to maintain the confidentiality of the data to be collected, the dairy farms that are selected for the study will be coded with a letter, always being identified throughout the thesis with that code.

It is intended to compare the results obtained in each of the KPI in the different dairy farms with the reference value, if it exists, since some KPI are based on UN indicators, which arise through targets not yet achieved in Portugal.

It will be necessary to interpret the *gap* between the KPI of each dairy farm with the reference values, and also compare and analyse the selected dairy farms, based on their production regime and milking typology used.

At the end of the analysis and data processing, it is intended to obtain per dairy farm map with colour mark:

- Green - Indicator that receives Good or Excellent in the formulated scale;
- Red - Indicator that receives Bad on the formulated scale;
- Yellow - Insufficient information to calculate indicator;

Given that all SDG have the same relevance and that all formulated KPI have the same importance, the network approach is used to be indivisible and integrated (LeBlanc, 2015). A map with more indicators in green than in red is expected to be achieved by the most sustainable dairy farm.

3. Case Study: The Autonomous Region of the Azores

The island of S. Miguel represents 32.1% of the archipelago's surface, representing more than 50% of the ARA population. It also holds the largest amount of milk produced for human consumption, around 122 000 tonnes in 2017 (IAMA - Instituto de Alimentação e Mercados Agrícolas, 2017).

In order to answer the research's main question, **“Is an intensive dairy farm more sustainable than an extensive dairy farm?",** and achieve the main objective of the thesis, **to increase the sustainability of milk production**, it is necessary to evaluate the activity of three farms with different degrees of intensification each. With the case study analysis, we try to answer the following questions: “What is the sustainable milk production model?”; "Is an intensive exploration regime generating a more sustainable production?" and “Does the introduction of robotic milking increase the sustainability of milk production?”. The following are economic, social and environmental factors that justify the relevance of choosing S. Miguel Island as a case study.

Economic Factors

Following its integration into the European Economic Community (E.E.C.) in 1985, the Portuguese milk sector had to apply to the milk quota scheme. One of which limits direct sales at farm level and another for the maximum quantity of milk delivered to collection centres. However, in 2015, these quotas were no longer in force and the ARA is overproducing.

In the ARA, the dairy cattle represents the largest contributory valuation for farms, and the type of farming (TF) was determined from the Standard Output (SO) (PRORURAL, 2007). The dairy sector thus constitutes a pillar of Azorean agriculture, representing 70% of agricultural activity, the island of S. Miguel producing about 65% of the Azorean milk (Freire, 2016).

Since the year of 2003, that milk production in the Northern Region - Between Douro and Minho and the Autonomous Region of the Azores represents 2/3 of the national production (INE, 2015). This activity is present in about 19% of the farms, represents 30% of the national herd and takes 56% of the Utilized Agricultural Area (UAA), representing 53% of the Standard Gross Margin (SGM) generated by the agricultural sector (PRORURAL, 2007).

Between 2003 and 2015, the ARA had the highest average annual growth rate of milk collection, over 1.8% at national level, but the number of dairy cattle decreased, what suggests an intensification of the farms (INE, 2015).

In 2017, 1.8 million tonnes of cow's milk were collected in Portugal (INE, 2018c). At a national level, in the same year, 72 657 tonnes of milk for consumption were registered (INE, 2018c) , of which 20% were produced in the ARA (IAMA, 2017). Compared to mainland Portugal, the ARA has competitive advantages in terms of very favourable edaphic-climatic conditions for milk production.

Social Factors

This island has the largest number of workers corresponding to 60% of all milk sector employees in ARA (IAMA - Instituto de Alimentação e Mercados Agrícolas 2017).

Tradition dictates the lives of the inhabitants, who dedicate to the dairy activity. Corporates are small and family-owned, and the culture of milk production is intrinsic (Notícias Magazine, 2016).

Environmental Factors

The dairy sector has significant environmental impacts, including high water consumption, untreated wastewater generation and greenhouse gas emissions (Moutinho et al., 2011). In a study conducted on dairy activity, most of the waste declared in the ARA Environmental Inspections was produced on the island of S. Miguel (5669.46 tonnes), being relevant to evaluate this island in this topic.

Water, besides representing a high economic and social value in island regions, also has a very strong environmental potential. Given that aquatic ecosystems have weaknesses, their proper management contributes to sustainable environmental development.

This island of the Azores suffers from a serious environmental problem, the eutrophication of lagoons, which is closely connected to milk production. Processes such as broadening of pastures, increased head stocking, endemic forest clearing, and excessive application of inorganic fertilizers, allied to the characteristics of the S. Miguel territory, caused an excessive nutrient load on the aquifers, disabling regeneration of the ecosystems (Porteiro, et al., 2004).

Between 2013 and 2016, an Azorean study followed the evolutionary process of the eutrophication state of S. Miguel's lagoons. In a sample of 88 lagoons inventoried at the regional water level, Furnas, São Brás and Verde das Sete Cidades are the lagoons classified as eutrophic, having used the Carlson’s Trophic State Index (TSI) methodology, which was calculated from the partial indexes for water transparency, chlorophyll *and* total phosphorus (Medeiros Pacheco, et. Al., 2016).

In the same study, Medeiros Pacheco, et al. (2016) also states that Lagoa do Congro presents mesotrophic levels, in the years of 2014 and 2015, and eutrophic levels in 2013 and 2016, having been verified an aggravating factor in the eutrophication process. They were classified as oligotrophic water bodies, obtaining the best state of water quality, the Lagoa do Fogo, in the years of 2013 and 2015, and the Lagoa Azul das Sete Cidades in 2014.

It is concluded that lagoons have a high environmental importance, because they are considered water reserves and aquatic life ecosystems. On the other hand, given their contribution to the typical Azorean landscape and leisure potential are important from a socioeconomic point of view (DROTRH/INAG, 2006).

3.1. Analysis and discussion of results

This chapter aims to expose and discuss the results of the case study. In particular, the application of the survey (Appendix II.) to the three dairy farms in S. Miguel Island, in order to assess the sustainability of milk production through the formulated KPIs.

First, livestock farms are characterized and codified. Second, the dairy farms are analysed by assessing KPI of the SDG "to be performed" using the methodology outlined in the previous chapter. Next, the remaining framework KPIs are evaluated, which relate to SDG operating, but their analysis enriches the Case Study chapter. Subsequently, farm data is presented and analysed, which did not directly contribute to the evaluation of the KPIs, but which deserves an examination.

A. General characterization of the dairy farms

The three farms that have responded to the survey are located in the western region of S. Miguel Island, with a growing degree of intensification, both in the production regime and in the technology they use in the dairy at the time of milking. Dairy farms A and B are farms of single producers, while Dairy farm C is a family-owned livestock farm.

Table 1 - Codification of the dairy farm and characterization of the production regime and milking mechanism.

Dairy Farm	Production regime	Milking System
A	Extensive	Movable mechanic
B	Extensive	Mechanic with herringbone room
C	Intensive	Robotic

At the time of the conclusion of this survey, the livestock herd was distributed as follows:

- **Dairy Farm A:** 55.6% of lactating cows; 0% of dried cows; 0% of breeding bulls and 44.4% of heifers;
- **Dairy Farm B:** 41.6% of lactating cows; 5.9% of dried cows; 1% breeding bulls; 26.7% of heifers and 24.8% remaining animals under 4 months;
- **Dairy Farm C:** 45.6% of lactating cows; 3.1% of dried cows; 0.4% breeding bulls; 45.2% of heifers and 5.7% remaining animals under 4 months.

Using the values of the table of Decree-Law No. 202/2005 of November 24, referring to the values of CN, the total number of CN in each of the dairy farms was calculated using the following equation:

$$\begin{aligned} CN\ (total) &= Nr.of\ CN\ (animals\ -\ 24\ months) \\ &+ (0{,}6 \times Nr.animals\ \text{over 6 and under 24 months}) \\ &+ (0{,}4\ \times\ Nr.animals\ under\ 6\ months) \end{aligned} \quad (3.1.)$$

- Animals older than 24 months (1 CN) - lactating cows, dry and breeding bulls;
- Animals over 6 and under 24 months (0.6 CN) - heifers;
- Animals under 6 months (0.4 CN) - males sold to weaning and calves.

The following results were obtained after calculating the equation:

Table 2 - Results of the calculation of the total CN, in each farm.

Dairy Farm	CN (Total)
A	22.2
B	70.2
C	201.8

In relation to the work force, the dairy farm A has no employees, being only exploited by the sole producer, the owner. In contrast, dairy farm B, despite being considered a sole producer farm, has a family workforce and employs three male employees. Of those three employees, only two work full time. Dairy Farm C, which belongs to a family company, employs four male employees, working full time.

B. KPI's of the not executed SDG

Then, the farms are analysed in relation to the KPIs SDG that are yet to be implemented in the reality of milk production. KPIs 1, 5, 8, 12 and 15 are quantitative and some calculations need to be performed on the examination of some of them. The KPI's 6, 7, 13 and 14, despite being qualitative, apply the formulated scale.

Considering that the reference performance map of a sustainable farm would have all KPI's with green icons, a gap between the ideal and the reality of each farm is shown in the table.

In the KPI for SDG 1, it is only possible to make a comparison between B and C, since they have more employees besides the producer. Dairy farm B, although green in this indicator, performs worse than C, since the lowest paid employee earns a monthly income lower than the average amount paid to men in 2016. In dairy farm C, all employees earn more than the average monthly compensation.

In relation to the KPI - percentage of women on the farm, it was expected that the contribution of women to the farms would be more expressive, but in the farms that participated in the case study this is not the case.

Another indicator that had a bad overall performance was the KPI for SDG 7, since in the studied farms there are no renewable energy mechanisms.

Given the reality experienced on the island of S. Miguel and the decrease in the amount paid to producers for milk produced in the last five years, it is to be noted that the extensive dairy farms: A and B show a negative variation in the economic profitability of the holding. Meanwhile, dairy farm C produces more intensive milk and overcomes these difficulties and is also profitable.

In the indicator for SDG 14, methane emissions, it was found that dairy farm C presented a higher EF than the reference value for Holstein-Friesian breed (Cardoso, 2014). These emissions are aggravated by the excessive heading of animals and their concentration in a confined space. Whereas in an extensive production regime, which respects the animal head norms, these emissions are diluted, contributing the pastures to this same effect.

In relation to the KPI - effluent management, good performance is attributed to dairy farms B and C, as they have storage mechanisms according to the PGE regulations, for the effluents formed by animal excreta, food waste, white and green waters.

Given the limited information to analyse the KPI of SDG 14, it was decided to put the performance maps of the three farms in yellow, in this section.

Finally, in table 16, the poor performance of the dairy farm B is highlighted, in the KPI of SDG 15, since considering the extensive production regime, it has a header higher than the reference value in the legislation (Decree-Law no. 202/2005 of November 24).

In the KPIs of SDG not executed, the most outstanding farm with the highest rated performance map is dairy farm C.

Table 3 - Performance map from KPI's of the not executed SDG.

SDG	KPI	Dairy farm A	Dairy farm B	Dairy farm C
1	Workers Income	Insufficient information	Good performance	Excellent performance
5	Percentage of women on the farm	Bad performance	Bad performance	Bad performance
6	Exploration Water Source	Bad performance	Bad performance	Good performance
7	Presence of renewable energy sources	Bad performance	Bad performance	Bad performance
8	Change in economic profitability of the farm	Bad performance	Bad performance	Good performance
12	Emissions of CH4	Good performance	Good performance	Bad performance
13	Effluent Management	Insufficient information	Good performance	Good performance
14	Contamination of watercourses	Insufficient information	Insufficient information	Insufficient information
15	Exploration header	Good performance	Bad performance	Good performance

Legend: Excellent performance; Good performance; Bad performance; Insufficient information

C. KPIs of SDG running

Table 4 shows the performance map of the extra KPIs, which were analysed in order to enrich the evaluation of the sustainability of milk production in the three farms. With reference to a sustainable dairy farm, which would obtain an all-green performance map, it was observed that dairy farm A is the one with the largest gap from the ideal. It got a bad performance on KPI's of SDG: 2, 4, 9, and 11.

In terms of the KPI's of SDG 2, which assesses milk production, the dairy farms B and C stand out positively, since their production is equal to and higher than 20 kg/cow/day (Bessa, 2014).

Already the KPI's selected for SDG 4, percentage of employees with higher education or agricultural training, performed well overall. This is because, in all of the dairy farms, farmers have agricultural training.

The KPI that evaluates the milking typology of each dairy reveals the innovation present in each one of them, and is therefore related to the SDG 9. The increasing degree of technology found in the dairy farms, A <B <C, determined the bad performance attributed to the first, the good to the second and the excellent to the third.

Finally, it was expected that the KPI for SDG 11 would obtain the best performance. However, the three farms are not visited by outside entities, such as schools or community associations.

Table 4 - Appendix VI - Performance map from KPI's of the SDG running.

SDG	KPI	Dairy farms A	Dairy farms B	Dairy farms C
2	Milk Production	Bad performance	Good performance	Good performance
4	% employees with higher education courses; % employees with agricultural training.	Good performance	Good performance	Good performance
9	Milking Typology	Bad performance	Good performance	Excellent performance
11	Number of visits to the farm	Bad performance	Bad performance	Bad performance

Legend: Excellent performance; Good performance; Bad performance; Insufficient information

4. Conclusion and suggestions of future work

The objectives set out in the first chapter have been achieve the development of the *framework* containing the KPIs that allow the assessment of the sustainability of milk production, according to the United Nations 2030 agenda. This *framework* developed in the thesis was applied in the present case study, but can also be applied in other work that have the purpose of analysing the sustainability of dairy farms.

The examination of this case study allowed to investigate whether the intensification of dairy farms on the island of S. Miguel was an aggravating factor to sustainability. Analysing the reality of the case study, the answer to the central research question of the dissertation is: "Is an intensive dairy farm more sustainable than an extensive dairy farm?". By assessing sustainability through KPI analysis, dairy farm C provides a performance map that is closer to the desirable. However, this analysis has several limitations, for example insufficient information on dairy farm A, which was not compared with the others in the indicators regarding workers' wages and effluent management.

It is suggested to complete procedure that would have been applied in the analysis of KPI – contamination of watercourses and that can be adopted in future works:

1) Locating the farms geographically through geographic data reading software (ArcGIS; Geomedia Pro or AutoCAD Map);

2) Identify possible water lines and planes that are susceptible to contamination, taking into account the slope and soil type of the region;

3) Based on the norms of Ordinance No. 631/2009 of June 9, verify the influence radius of the effluents of each farm, thus calculating the minimum safety distance to which a watercourse should be, in order to ensure no contamination;

4) Based on this value, make a "buffer" in the dairy farms, followed by an "intersect" with the region's water resources, in order to understand whether there is a risk of contamination or not;

5) At the same time, it would be necessary to perform effluent analyses in the vicinity of livestock exploitation and in the water of ponds and surface water lines:
   - Physicochemical: humidity, organic matter, total carbon (or C/N ratio), pH, electrical conductivity, total nitrogen, total phosphorus, total potassium, total calcium, total magnesium, total manganese, total boron, as well as heavy metals, total cadmium, total lead, total copper, total chromium, total mercury, total nickel and total zinc;
   - Particle size: 95% of solid effluent shall pass through a 25 mm square mesh screen;
   - Microbiological: *Salmonella* and *Escherichia coli.*

6) Conclude about possible contamination hazards.

It has also been confirmed that the introduction of the robotic milking system has increased the sustainability of milk production, allowing the dairy farm to stimulate cows in production and increase their productivity. Although this last parameter will stimulate the EF of the dairy farms, as the higher the average annual productivity of a dairy farm, the higher its EF. However, from a theoretical point of view, methane emissions are obtained by the product between the EF and the livestock, with the emissions directly related to the type of production and number of heads.

For KPIs that assess workers' wages and effluent management, it is not possible to compare dairy farm A with the others. This being a limitation of the case study, it is favourable to increase the sample of dairy farms under analysis, located in different regions of the island of S. Miguel. These KPI's are not analysed in dairy farm A, due to the lack of collaborators other than the sole producer and the effluent management that does not occur, because the cows are grazing. However, given the use of the mobile milking system in this farm in accordance with Decree-Law 202/2005 of 24 November 2005, the following milking conditions must be met: existence of the drinking water supply system, according to current parameters, and equipment must be easy to clean, wash and disinfect (Ministério da Agricultura, 2005). When being mobile, the same Decree-Law also states that this system must be located in a soil free of accumulation of waste; ensure the protection of milk during the period of its use and be produced from materials that ensure the sanitation of the system.

The assessment of KPIs for SDG 5 and 7, percentage of women on the farm and the presence of renewable energy sources, respectively, performed badly in all three dairy farms. This was not expected, given that women also participate in livestock, the proportion of women in the total of self-employed managers was 30.7% in 2015 (INE, 2016). Already the same source, says that the production of renewable energy was the non-agricultural profitable activity of the farm that had the highest evolution compared to 2009 (+473.9%), but no signs of this activity were found in the farms that participated in the study.

It is concluded that all the analysed dairy farms have yet to be executed SDG 5: Achieve gender equality and empower all women and girls and SDG 7: Ensure access to affordable, reliable, sustainable and modern energy for all. As well, SDG 11: Make cities and communities inclusive, safe, resilient and sustainable; given the answers obtained from the KPI - number of farm visits.

Despite mentioning that they contribute to the region, none of the farms "opens the door to the community", no visits from schools or associations have been recorded. This is an aspect to be improved, and it should contribute to increasing the sustainability of production. There would be a sharing of knowledge between the producers and the final consumer, sharing the authenticity of the dairy farms and making visitors understand the process of milk's production, doing justice to the expression: "From stable to table."

Regarding the socioeconomic assessment of farms, questions should have been asked in the survey concerning their economic size as well as the economic income of the producer's household.

These limitations, along with the challenges encountered in the cattle ranches, suggest further research on the following themes: livestock effluent management; assessment of possible contamination of watercourses due to poor management of the valorisation of agricultural effluents; challenges and opportunities in the use of renewable energy sources in cattle farms; the role of women in farms and consumers' perceptions of the reality of cattle farms.

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Appendix I. - Relationship between the 17 SDGs and the reality of milk production.

SGD	The production of milk
1	Unileite states that its mission is fulfilled by receiving all the milk from its producers, generating wealth that remains in the region (Unileite, 2019). **Not executed.**
2	Despite the downward trend in human consumption, milk and milk products contribute to the needs of calcium, magnesium, selenium, vitamins B5 and B12 and play a crucial role in our development (Bylund & Pearse, 2019).
3	In 2016, about 304 people per 100,000 inhabitants died prematurely in Portugal due to circulatory diseases, malignant tumours, chronic respiratory diseases and diabetes, being the first two disease groups accounted for more than 50% of all deaths in the country. (INE, 2018b). Milk consumption is beneficial to human health, reducing the risk of osteoporosis, cardiovascular disease, type 2 diabetes, hypertension, and overweight (McBean, Miller, & Heaney, 2004).
4	The professionalization of producers, including improvements in health control, animal feed and genetics (as a result of breeding programs and the purchase of high genetic value cows from other Member States such as France, the Netherlands and Denmark), allowed Portugal to achieve European standards (INE, 2015).
5	In 2016, 38.7% of the agricultural population was owned, while in 2013 this proportion was 36.7% (INE, 2018b). The proportion of women in total as self-employed farm managers increased from 29.1% in 2013 to 30.7% in 2016 (INE, 2018b). **Not executed.**
6	An analysis of the CWU / kg ECM ratio, the ratio of the amount of water to produce 1 kg of milk energy, indicates that extensive small farm based systems with lower yielding cows require more water / kg ECM than that higher intensive production systems (Sultana, Uddin, Ridoutt, Hemme, & Peters, 2015). **Not executed.**
7	Dairy producers have renewable energy sources in their dairy farm, such as using solar panels, turning solar energy into electricity, or to heat the water used on the premises. Additionally, anaerobic digestion, depending on the configuration and internal temperature of the digester, produces methane-rich biogas, which generates electricity and heat. In addition to this gas, an odour free mixture is produced which can be spread on farmland as fertilizer (National Farmers Union, 2019). **Not executed.**
8	Sustainability includes, not only, the economic profitability of the farm, but also, relates to environmental and social concerns, including the quality of life of the workers and the animals(von Keyserlingk et al., 2013).**Not executed.**
9	Over the past 100 years, dairy farms have incorporated innovative technology into their daily activities, from automation of milking, to computerization of production data (Jacobs & Siegford, 2012).
10	Given the relevance of the sector, this is important to reduce inequalities. Portugal in 2013 had a higher productivity than the EU10 average, 7 tonnes of milk/head (+0.2 tonnes/head). And it was below the EU10 average in number of cows/farm (-20 heads) and production per farm (-128 tonnes of milk per farm) (INE, 2015).
11	In the turn of the twentieth century, the general population moved from small rural villages to large cities, thus necessitating the mass production and distribution of dairy products, and this supply chain needs to be sustainable (Jacobs & Siegford, 2012). Dairy farms are the target of field trips, increasing knowledge sharing and social inclusion (Sa, 2019).
12	Accompanied by the increase in consumer options, there should be a decrease in consumer prices, making green products and services more accessible and cheaper. Thus creating a closed cycle that leads to the sustainable consumption and production system (Staniškis, 2012). **Not executed.**
13	Climate change is largely caused by the livestock sector, which contributes to high emissions. However, through mitigation plans, it is possible to adopt sustainable production measures (FAO, 2006). **Not executed.**
14	Milk production has impacts on water quality and utilization. However, through mitigation measures to reduce the use and contamination of this resource, it is possible to achieve sustainable development (FAO, 2006). **Not executed.**
15	Livestock plays a crucial role in the biodiversity crisis, directly or indirectly affecting the drivers of biodiversity (changes in habitat, climate change, invasive species, pollution and overexploitation of resources) (FAO, 2006). Soil degradation results from poor livestock management, either by excessive stocking or no pasture rotation (FAO, 2006). **Not executed.**
16	In Portugal, vocational training and attendance in specific programs in dairy farms by prisoners has already been carried out during the execution of their sentence (Silva, 2009).
17	Projects such as the *National Strategy for the School Fruit and Milk Scheme, as well as the Chain Relationship Monitoring Platform;* allow the promotion of healthy eating habits and dialogue between the different agro-food actors. In the ARA, measures stand out in favour of local agricultural production, namely the Azores Rural Development Program 2014-2020 (PRORURAL +(Ministério dos Negócios Estrangeiros, 2017).

Appendix II. - KPIs for assessing the sustainability of milk production.

Nr.	State	KPI	Bibliography
1	*Not executed*	Workers Income	(Herzog & Gotsch, 1998) (United Nations, 2017b)
2	*Extra*	Milk Production kg milk/animal/day	(Chigwa, et al., 2015) (Global Dairy Plataform et al., 2015) (United Nations, 2017b)
4	*Extra*	% employees with higher education courses; % employees with agricultural training.	(Herzog & Gotsch, 1998) (Van Cauwenbergh et al., 2007) (United Nations, 2017b)
5	*Not executed*	Percentage of women on the farm	(Alkire et al., 2013) (Global Dairy Plataform et al., 2015) (United Nations, 2017b)
6	*Not executed*	Exploration Water Source	(Hayati, et al., 1995) (Van Cauwenbergh et al., 2007) (Gafsi & Favreau, 2010) (Global Dairy Plataform et al., 2015) (United Nations, 2017b)
7	*Not executed*	Presence of renewable energy sources	(United Nations, 2017b)
8	*Not executed*	Change in economic profitability of the farm	(Keating et al., 2010)
9	*Extra*	Milking Typology	(SAI Platform Dairy Working Group, 2009)
11	*Extra*	Number of visits to the farm	(Hoang, Castella, & Novosad, 2006)
12	*Not executed*	Emissions of CH_4	(United Nations, 2017b) (Global Dairy Plataform et al., 2015)
13	*Not executed*	Effluent Management	(United Nations, 2017b) (Global Dairy Plataform et al., 2015)
14	*Not executed*	Contamination of watercourses	(United Nations, 2017b)
15	*Not executed*	Exploration header;	(Global Dairy Plataform et al., 2015)

Appendix III. - KPI's of "not executed" SDG with reference value and correspondent scale adopted.

State	SDG	Reference value	Scale
Not executed	1	**Average monthly wage of employees in Agriculture and Fisheries** Monthly base remuneration (2017) Average: € 738.4; Men: € 766.0; Women: € 673.2 (PORDATA, 2018)	**Good:** equal to or greater than the average remuneration; **Bad:** below average remuneration.
	5	**Proportion of women in the total of managers, self-employed farm managers (30.7 %)** (INE, 2018a)	**Good:** equal to 50%; **Bad:** bellow 50%.
	8	**Positive** (Suggestive, given the economic growth)	**Excellent:** positive; **Good:** null; **Bad:** negative.
	12	**EF for dairy cows: 93.53 - 131.13 kg CH4/head/year** (Pereira et al., 2014)	**Good:** EF within the range; **Bad:** EF over the range.
	15	• **Up to 1.4 CN/ha + grazing - limit for extensive regime;** • **Over 2.8CN/ha without grazing - values for intensive regime.** (Decree-Law No. 202/2005 of November 24)	**Good:** respects the legislation; **Bad:** does not respect the legislation.
	6	Water from the network (Suggestive, more controlled, than from well, borehole or spring.)	**Good:** water from the network; **Bad:** borehole or spring water.
	7	**Renewable energy production was the largest non-agricultural profitable activity on the holding compared to 2009 (+473.9%)** (INE, 2018a)	**Excellent:** presence of two types of renewable energy; **Good:** presence of one type of renewable energy; **Poor:** absence of renewable energy.
	13	**Effluent Management Plan (PGE): effluent storage and treatment**	**Excellent:** well-sized effluent storage systems as well as treatment system; **Good:** well-sized effluent storage systems; **Bad:** does not comply with legislation.
	14	**Article 10 - Prohibitions and restrictions on agricultural valuation**	**Good:** no data on water contamination; **Bad:** water contamination.

Appendix III. - KPI's of "extra" SDG with reference value and correspondent scale adopted.

State	SGD	Reference value	Scale
Extra	2	**20 kg of milk/day/cow** (Bessa, 2014)	**Good:** equal to or greater than 20 kg milk/day/cow **Bad:** less than 20 kg milk/day/cow
	4.	**Farmer** • **Higher Education: 5,8 %;** • **Agricultural Training: 1.3%** (INE, 2018a)	**Good:** at least one person with higher education or agricultural background **Bad:** no people with training
	11	**1 visit/ year** (Suggestive)	**Good:** more than one visit a year **Bad:** no external visits to the farm
	9.	**Robotic Milking** (Suggestive, given technological innovation)	**Excellent:** Robotic milking **Good:** Mechanic milking **Bad:** Hand milking