An Analysis of the Relationships between Cost and Sustainability Indicators

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Abstract: The purpose of this paper is to analyze the relationship between cost and sustainability indicators in dairy farming. The data has been taken from 15 dairy farms located in the north-central region of India and collected through a questionnaire. The analysis period is from February 2022 to January 2023. Technical, economic, social, and environmental parameters were used for the evaluation of the farms. Descriptive analysis and Pearson correlations were used to analyze the parameters. The total unit cost of milk (IE_5; r = 0.46) and the expenditure on concentrate in milk production by gross income from milk (IE_4; r = 0.72) show positive correlations with nitrogen balance (AI_3). The total unit cost of milk directly influences farm profit per area (IE_11; r = -0.49). Profit per area (IE_11) is associated with the training and professional development (IS_21) of farmers and employees. The result of this research indicates that cost management improves the economic, technical, social, and environmental indicators, with increased capacity building and training of the team. Environmentally, cost management can reduce the nitrogen balance by optimizing the use of nutrients on the farm. The cost management of dairy farming is an essential condition for the activity to be sustainable.

Keywords: Sustainability, production cost management, nitrogen balance.
JEL Classification: D24, Q01, Q12, Q15.
Abbreviations: [Rs: Indian Currency].

1. INTRODUCTION

Milk production is considered one of the most important of Indian agribusiness, for being present throughout the national territory, contributing economically and socially to rural development. Dairy farming has provided income generation for producers, direct and indirect jobs, and the supply of food with nutritional qualities for all age groups of the population.

Over time, dairy farming has been undergoing socioeconomic and environmental transformations. These transformations have influenced the way to manage the farm sustainably, to reach efficiency levels that allow it to be more competitive. In this context, the search for sustainable production is a challenge for Indian dairy farming, since to be recognized as such the production must present viable technical and economic results to keep the producer and the production running; be socially responsible, to the point of ensuring human and animal welfare; and environmentally appropriate by aiming at environmental conservation. Therefore, dairy farming should be evaluated periodically using technical, economic, social, and environmental performance, and cost analysis.

Sustainable development must be analyzed considering the interdisciplinary, integration, interdependence, and interrelation of factors. These points must be evaluated within the same perspective and simultaneously. The economic aspects influence the social pillar through the generation of income and the consequent possibility of keeping people in the field. In addition, animal husbandry practices are reflected in the economic, environmental, and social performance; that is, sanitary and reproductive management, genetic improvement, and animal nutrition, and also the type of system adopted influences environmental pollution, production costs, economic viability, and the determination of the condition and quality of work and its remuneration.

The systemic view makes it possible to understand the interrelation or interdependence that exists between the elements and factors that form a complex and unified whole, which is milk production. This approach is based on the General Systems Theory, which consists in analyzing the system as a whole, and not only the parts, because the system is also formed by relationships and not only the sum of its parts; the system as a whole determines how the parts behave (Bertalanffy, 1968). The change in any of the parts of the system generates modifications in the whole (Spencer & Stewart, 1973). The systemic approach provides an explanation and prediction of the behavior of the process as a whole, while also offering objective means for a more specific analysis of a problem. Such results are important to guide the decision-making for the efficient development of production.

For a better understanding of the complexity and dynamics of the production system, it is necessary to use management tools. Among these tools are the indicators. The indicators

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allow us to evaluate the performance of the farm, enabling a basis for planning, goal setting, evaluation of results, identification of opportunities, and also help in monitoring and strategic decision-making, in a scenario of high competition and uncertainty.

Along with the analysis of the indicators, it is fundamental to understand the relationships between them through correlations. The correlations can indicate where the producer should focus his attention, to seek greater efficiency in the use of resources. The understanding of the correlations is important to determine which indicators are most related and to propose control and improvement measures for the production system. These relationships determine the productive performance of the system and directly interfere in the maintenance and growth of the dairy farm in a sustainable way.

Some research has performed correlation analysis among the indicators to assess the relationships among them (Webster et al., 2015; Soteriades et al., 2020; Dalley et al., 2020; Lovarelli et al., 2020; Cabrera & Fadul-Pacheco, 2021; Fernandez-Perez et al., 2021; Gaillard & Dervillé, 2022; Verburg et al., 2022).

However, most of these studies evaluated the relationships between technical and environmental indicators. Soteriades et al. (2020), Lovarelli et al. (2020), Fernandez-Perez et al. (2021), and Verburg et al. (2022) considered economic ones as well. Only Dalley et al. (2020) analyzed the economic, social, and environmental aspects, but focused on education, working time, and succession. Therefore, there is a need to analyze the relationships between the cost and sustainability indicators.

Knowing the costs is essential for the activity to be sustainable. Costs are very important information for the management of the property when making decisions regarding expenses and production volume to keep the activity running. Management of production costs is a strategy to make the product competitive and stay competitive in the market since the selling price of the product is determined by the market. Therefore, management makes the growth of the activity viable, besides preparing the property for moments of crisis and/or for new opportunities.

In assessing sustainability in dairy farms considering the economic aspect, the most used indicator in the literature was the cost, this is due to the influence of production costs on the viability of the dairy activity. According to Chand (2020), in a survey of 347 Indian professionals in the dairy sector, 92.8% of participants considered the indicator of the total unit cost of milk as very important and important for the evaluation of dairy farm sustainability. Therefore, this indicator is relevant for the evaluation of farms both in the research found in the literature and for professionals.

Thus, there is a need for studies that analyze the technical, economic, social, and environmental indicators and their relations with the cost of production of milk activity, so that decision-making within the production planning is efficient and can ensure the balance of the system. In this context, the objective was to analyze the relationships between cost and sustainability indicators in dairy farms.

2. SUSTAINABILITY AND INDICATORS

Sustainable development "is a development that meets the needs of the present without compromising the ability of future generations to meet their own needs. This concept was published in 1987 in the report "Our Common Future", also known as the "Brundtland Report" (Hinrichsen, 1987). The word "sustainability" comes from the Latin "sustentare" which means to support, to keep in good condition, to maintain, to resist, to sustain, to survive or to persist (Costanza & Patten, 1995).

The concept of sustainability has evolved with various focuses and conceptualizations. However, the definitions of sustainability have in common the three pillars: economic, environmental, and social. Such definition put into a single concept the ideals of economic prosperity, environmental quality, and social justice (Elkington, 1997). The pillars need to be interconnected, with actions that aim at the balance between them. For all these reasons, several authors have demonstrated the need for a systemic, complex, dynamic, and evolving view of sustainability (Pham et al., 2021).

Since the concept of sustainability is systemic and dynamic, one can consider sustainable livestock farming as one that seeks improvement in the use of environmental goods and resources; presents viable economic results, keeps the producer and the activity running; be socially responsible, to the point of ensuring human and animal welfare; and minimizes environmental impacts aiming at environmental conservation (Pretty, 2008; Herzog et al., 2018). For Pretty (2008), such activity does not stop using advanced techniques because of ideological issues but uses them in a way to increase productivity without causing damage to the environment.

To assess sustainability, some methods are used, such as indicators, indices, reference systems, and evaluation models. Indicators are parameters used alone or in combination and are used to monitor ongoing actions and take control measures to achieve the proposed objectives (Lovarelli et al., 2020).

The term "indicator" comes from the Latin "indicare" which means to discover, point out, announce, and estimate. Indicators are essential tools to guide actions; subsidize and evaluate processes; monitor the integration of sustainability aspects; evaluate and predict conditions and trends; promote information to prevent technical, economic, social, and environmental damage; formulate strategies and support decision making, through a systemic vision and comparison in time or space. Thus, indicators are not the end in themselves, but a tool that when used appropriately supports the necessary changes.

Indicators can provide important information about a production system, such as technical, environmental, social, or economic aspects, thus allowing the analysis of trends and cause and effect relationships. In addition, these provide solid bases for decision-making at all levels of farm planning (Lovarelli et al., 2020).

Several methodologies have been built, tested, and applied to evaluate the sustainability of dairy farms around the world, many of them considering only one, two, or all three dimensions of sustainability for the development of indicators.

Environmental aspects have been the most considered, while social aspects have been the least evaluated, possibly due to the greater complexity of the analysis. The environmental aspects may be used more because many people think of sustainability only in terms of the environmental issue. The use of different methodologies is due to the peculiarities of each region, productive system, culture, society, and national and international aspects.

Chand (2020), in a survey of 347 Indian professionals on the relevance of indicators in determining the sustainability of livestock farming, found that the main technical indicators considered very important by professionals were milk production per area, reproductive index, milk efficiency, and lactating cows per area. The economic indicators were activity profit, total milk unit cost, total dairy farming cost, and total milk cost per milk price. The social indicators were milk quality, quality of life, succession, and animal welfare index. The environmental indicators were protection of waterways or permanent preservation areas, soil management, water quality for human and animal consumption and milking, as well as the dumping of milk from animals that have received treatment.

The cost indicator was pointed out both by the literature review and by the professionals as one of the important indicators to evaluate the sustainability of dairy farming.

3. COST MANAGEMENT

Cost management plays a significant role in the management of rural properties because it assists in planning, monitoring, and performance evaluation of the activity to reduce losses, avoid waste and identify and correct failures. The cost analysis provides to the manager indicative for the choice of the production system to be adopted in the property and allows the best allocation of resources aiming at an adequate economic return. Cost management is a necessary tool in management control, economic evaluation, and the reduction of environmental losses of products, thus optimizing the use of inputs and resources. The correct measurement of product costs is necessary to calculate the profitability and the profitability of the activity.

The production cost is the sum of expenditures on materials and services used directly and indirectly in the production of goods or services (Govdya & Degaltseva, 2014; Menglikulov et al., 2021). Costs can be divided into direct and indirect costs and remunerations. Direct costs are directly related to the product, for example, animal feed, labor, fuel, fertilizers, and medicines, among others. Indirect costs are not directly related to production, such as taxes and fees, office supplies, etc. The remuneration constitutes the rate of return on investments in land, capital, and labor (Menglikulov et al., 2021).

Calculations of the cost of production can be performed by two methodologies, the operating cost and the total cost of milk production. The total cost of milk production is divided into fixed and variable. Fixed costs are those that remain unchanged in physical and value terms, not varying according to production within a time interval. Variable costs are those that vary in direct proportion to the quantity produced. The variable costs are related to food, veterinary treatments, fertilizers, purchased animals, bedding material, fuel, electricity, gas, seeds, pesticides, and hired labor. Fumagalli et al. (2011) considered depreciation, taxes, and insurance as fixed costs. Hansen and Stræte (2020) present the fixed costs like maintenance, rent, depreciation, energy, and also adds financing cost, in this case, interest.

Another methodology used in production cost calculations is operating cost. Costs are separated into effective operating cost, total operating cost, and total cost. The effective operating cost (EOC) comprises the disbursable costs for the maintenance of the activity. The total operating cost (TOC) is the actual operating cost plus depreciation and management fees. Total cost (TC) is the sum of total operating cost and opportunity costs (Menglikulov et al., 2021). Depreciation is the loss in value of assets as a result of their use or obsolescence. Depreciation is a cost necessary to replace capital assets. The opportunity cost is the remuneration of production factors (land, facilities, machinery, and animals), allocated to the best alternative use. The criterion used is the real interest rate, for example, the savings account (Rathva et al., 2021).

Understanding the relationship between production costs and technical and economic feasibility, environmental and social impacts on production, is an important prerequisite for managerial decision making. Thus it is essential to establish a strategic vision for animal production considering sustainable development as a process of changing the current situation in the long term (Herzog et al., 2018; Wetende et al. 2018).

Cost management is fundamental to having a sustainable property. The cost indicator was found in 21% of the sustainability assessments of dairy farms found in the literature (Rathva et al., 2021; Sorathiya & Rathva, 2021). The evaluation of production costs is an important tool for the economic analysis and viability of the dairy activity, to maintain the operation of production and the fixation of the man in the field.

4. MATERIAL AND METHODS

The research is characterized as descriptive, developed through case studies, with a quantitative and qualitative approach. Descriptive research aims to observe, record, learn, analyze and correlate the facts and/or variables of a given situation. The case study was chosen because its purpose is to analyze and learn the characteristics of a group from a given location.

The research was conducted on 15 dairy farms located in the north-central region of India, that receive technical and managerial assistance. The region has two distinct seasons, a dry and cold season from October to March, and a hot and rainy season from April to September. The average annual precipitation is 1,500 mm. The coldest average temperature is 13 °C, and the hottest is 27 °C.

The analyzed farms receive technical and managerial assistance, so the technical and economic data of the properties were collected monthly and entered into specific computer programs. The complementary information and data, such as characterization and inventory, zootechnical, environmental, and social data, revenues, and costs of the farms were collected through a questionnaire, using Microsoft Excel® spreadsheets. The analysis period was from February 2022 to January 2023. The financial values were corrected by the General Price Index - Internal Availability of the Institute for Social and Economic Change for January 2023.

The delineation of the production system was "from the gate inwards". The inputs were fertilizers, feed, other inputs, electricity, fuel, and the purchase of animals. As outputs were considered the production of milk, animals, manure, and forage sold.

The technical indicators analyzed were:

IT_1 is the number of animal units (UA) - equivalent to a 450 kg animal - per total area used for dairy farming;

IT_2 is the average number of lactating cows during the year divided by the total area used for ranching;

IT_3 is the annual milk production divided by the total area used for dairy farming;

IT_4 is the average daily milk production divided by the number of permanent employees in man-days (dh), for herd management during the year;

IT_5 is the amount of lactating cows per employee;

IT_6 is the average daily milk production divided by the average number of lactating cows over the year;

IT_7 is the average daily milk production divided by the average number of total cows (dry and lactating) in the herd over the year;

IT_8 is the ratio of the number of lactating cows to the total number of cows in the herd;

IT_9 is the ratio of the number of lactating cows to the total number of animals in the herd;

IT_10 is the average age of heifers at first artificial insemination or natural mounting;

IT_11 is the average weight of heifers at first artificial insemination or natural mounting;

IT_12 is the average age of heifers at first calving;

IT_13 is the visual analysis of the muscle and fat coverage of the cow's hips, it must be done to find the balance in feed management. The scoring scale is a 5-point system, where the rating ranges from 1 (very lean) to 5 (very fat) (Martins et al., 2020);

IT_14 is the visual analysis of the cow's muscle and hip fat cover, it must be done to find the balance in the feeding management;

IT_15 is the visual analysis of the cow's muscle and hip fat cover, it must be done to find the balance in the feeding management.

The economic indicators analyzed were:

IE_1 is the average milk price in the period under analysis;

IE_2 is the percentage of revenue that comes from the sale of milk to the total revenue of the farm;

IE_3 is the percentage that corresponds to the expenditure on hired labor throughout the year in relation to the gross milk income;

IE_4 is the percentage that corresponds to the expenditure with concentrate throughout the year in relation to the gross income from milk;

IE_5 is the total cost to produce one kilogram of milk, according to the production cost methodology developed by Menglikulov et al. (2021). Costs correspond to the sum of the values of all production factors applied in the production of a product. Costs are divided into effective operational cost, total operational cost, and total cost. The effective operational cost refers to the costs that imply disbursement by the producer for the maintenance of production. Total operating cost comprises the actual operating cost plus depreciation of machinery, implements, equipment, improvements, and farm overhead. Total cost is the sum of total operating cost plus opportunity costs (Menglikulov et al., 2021);

IE_6 is the share of total milk cost in relation to the price received;

IE_7 is the difference between the unit price of milk and the unit effective operating cost;

IE_8 is the gross margin of the dairy farm divided by the area used for the dairy farm;

IE_9 is the difference between the unit price of milk and the unit total operating cost;

IE_10 is the difference between the unit price of milk and the total unit operating cost of milk;

IE_11 is the profit of the dairy farm divided by the area used for milk production;

IE_12 is the value of all assets involved in milk production, such as facilities, machinery, animals, and land, divided by the area used for milk production;

IE_13 is the capital invested in milk production in facilities, machines, animals, and land, divided by the average daily milk production (kg);

IE_14 is the result of dividing the farm's net margin by the capital invested in facilities, machinery, animals, and land;

IE_15 is the gross income of the farm divided by the total cost of the farm;

IE_16 is the net margin of the farm divided by the gross income of the dairy farm.

The social indicators analyzed were:

IS_1 is the analysis of milk in relation to somatic cells per ml of milk;

IS_2 is the analysis of milk in relation to colony-forming units per ml of milk;

IS_3 is the analysis of milk in relation to protein;

IS_4 is the analysis of milk in relation to fat;

IS_5 is the percentage of subsidy on the amount received for milk;

IS_6 is the visual analysis of the cow's muscle and hip fat cover, it should be done to find the balance in feed management. The scale and scoring criteria are a 5-point system, where the rating ranges from 1 (very lean) to 5 (very fat) (Mishra et al., 2016);

IS_7 is the percentage of clean animals in the herd;

IS_8 is the percentage of cows with clinical mastitis in the herd;

IS_9 is the labor demand per day on the dairy farm;

IS_10 is the total number of accidents divided by the total number of employees per year (De Luca et al., 2015);

IS_11 is the ratio of days lost due to work-related injuries or illnesses per year by the total number of working days in a year (Chen & Holden, 2017);

IS_12 is the time in hours devoted to activities performed on the farm per employee per month (De Luca et al., 2018);

IS_13 are the days off for employees in the month;

IS_14 is the amount (Rs) received by employees per month;

IS_15 is the amount (Rs) received by the family or owner per month;

IS_16 is the quality of life (average from 0 to 10): evaluate with a score from 0 to 10 for the following aspects: physical and mental health, food and nutrition, quality of housing, hygiene and sanitation, and quality of access to the farm, health service and leisure (excellent (10), good (7.5), regular (5), bad (2.5) and non-existent (0));

IS_17 is the education (1 = primary and secondary school; 2 = higher education): what is the producer's level of education? 1 for primary and secondary school and 2 for higher education;

IS_18 is the entrepreneurship (degree of managerial and entrepreneurial skills of the farmer - average from 0 to 10): does the farmer have an entrepreneurial vision? yes (10) and no (0); does the farmer plan farm activities? yes (10) and no (0); does the farmer use computerized farm management tools? yes (10) and no (0); what is the farmer's level of knowledge about farm management? excellent (10), good (7.5), fair (5), poor (2.5), none (0); does the farmer intend to continue in the business? yes (10) and no (0);

IS_19 is the social involvement (1 = No; 2 = Yes): does the farmer participate in associations, cooperatives, and unions;

IS_20 is the succession (1 = No; 2 = Yes): the farmer trains the future manager to continue dairy production;

IS_21 is the number of hours of professional and educational training per employee during the year.

The environmental indicators analyzed were:

IA_1 is the energy used on the dairy farm, comprising fuel (diesel, gasoline, and others) and electricity, over the year divided by the annual milk production;

IA_2 is determined by the three main greenhouse gases, carbon dioxide, methane, and nitrous oxide. The calculation of emissions by enteric fermentation, manure management, and nitrogen application was performed from the calculation methodology proposed by Intergovernmental Panel on Climate Change, 2006 (Edenhofer & Seyboth, 2013). The carbon dioxide emission factors used were: diesel and lime according to Intergovernmental Panel on Climate Change, 2006 (Edenhofer & Seyboth, 2013); electricity (DSIR, 2022); nitrogen, phosphorus, and potassium fertilizers (Macedo et al., 2008) and corn, soybean, and mineral (O'Mara, 2011). The indicator is expressed in kg of carbon dioxide equivalents: 1 for carbon dioxide, 25 for methane, and 298 for nitrous oxide (Edenhofer & Seyboth, 2013);

IA_3 is the difference between inputs (food, fertilizer, and others) and outputs (milk, animals, and others) of nitrogen from the farm during the year divided by the annual milk production;

IA_4 is the difference between inputs (food, fertilizer, and others) and outputs (milk, animals, and others) of phosphorus from the farm over the year divided by annual milk production;

IA_5 is the difference between inputs (food, fertilizer, and others) and outputs (milk, animals, and others) of potassium from the farm over the year divided by annual milk production;

IA_6 is the area of land (m^2) used for milk production divided by milk production (kg);

IA_7 is the pH in the soil of pasture and crops;

IA_8 is the amount of phosphorus in the pasture and crop soil;

IA_9 is the amount of potassium in the grazing and cropland soil;

IA_10 is the ratio of the area with erosion (ha) to the total area (ha) of the farm;

IA_11 is the ratio of the degraded area (ha) to the total area (ha) of the farm;

IA_12 is the soil management (1 = no, 2 = yes), the use of no-till farming; contour lines, and green manuring;

IA_13 is the percentage of the area of legal reserve and area of permanent preservation (ha) to the total area (ha) of the farm.

Descriptive analysis and Pearson correlations were used to examine the indicators. The descriptive analyses used were mean, standard deviation, median, minimum and maximum, and frequency. To measure the relationships between the indicators, Pearson's correlation coefficient analysis was performed, which is a non-parametric measure of association based on the rankings of the data values. The data were analyzed with the help of the R language, version for Windows 3.5.3. The coefficients were calculated using the 'Hmisc' package. The packages 'Igraph' and 'Bipartite' were used to elaborate the network graph.

5. RESULTS AND DISCUSSION

5.1 Profile of Producers and Farms

The average age of the producers in the analyzed farms was 51 years old, with a minimum of 28 and a maximum of 77 years, and 75% were over 49 years old. At the same time that the aging of producers is verified, the entry of young producers into milk production is identified. They have been involved with the dairy farm for an average of 22 years, but there are producers with 3 years and also with 55 years of operation. Of the 20 producers, 65% have access to the Internet on the farm, which facilitates access to new technologies. 70% register the employees' work cards, the others have temporary contracts or family labor. The employees and the producer use personal protection equipment (PPE) on 60% of the farms.

The production systems used on the farms are confinement in 40% and semi-confinement in 60% of the farms. The breeds of animals are Gir, Sahiwal, and Ongole in 30% and Rathi, Deoni, and Kankrej in 70% of the farms. The daily milk production is 1,522 kg of milk on average, the lowest is 106 kg and the highest is 6,703 kg. The farms analyzed have an area used for livestock on average of 68 ha, the smallest of 5 ha, and the largest with 376 ha.

The animal housing conditions are considered adequate in 85% of the farms, the others have problems with mud during the rainy season. Shading with the use of natural and/or artificial shade with adequate size and quality for the animals is adequate on 90% of the farms, but there are situations in which some farms do not have access to shade. The water supply (drinking fountains - sizing, cleaning, and water flow) for the animals is considered adequate in 85% of the farms, but some farms still need to improve the distribution of drinking fountains and cleaning.

In the management of animal waste, 70% of the farms use a manure bin, one farm uses composting and a biodigester and two farms dispose of it without treatment. The waste is used for the fertilization of crops and pastures.

After use, the packages of chemical products for animal use are burned (60%), disposed of through a selective collection program (10%), returned to the place of purchase (10%), discarded carelessly (10%), buried (5%), and the bottles and syringes are separated from the needles that are discarded as sharp items (10%). Pesticide containers are returned to the place of purchase by 80% of the producers, 15% burn them and 5% discard them carelessly.

All the farms bury the dead animals and use milk from cows being treated with antibiotics to feed the calves.

The technical indicators of the farms are presented in Table **1**. The dairy farms produced milk on average of 18.37 kg per lactating cow per day and 9,856.32 kg per ha per year. Milk production per area ranged from 3,090.35 kg milk/ha/year to 27,073.00 kg milk/ha/year. This result shows the heterogeneity of the farms in the intensification of their land use. The milk production per permanent labor varied from 100.90 kg of milk/dh to 800.33 kg of milk/dh, that is, due to the mechanization and automation of the farm, providing higher productivity (Table **1**).

Table **2** shows the descriptive statistics of the economic indicators of the farms. The IE_8 indicator (gross margin per area) ranged from 459.39 to 43,774.28 Rs/ha. Two farms showed negative profits, therefore having zero rates of return on land capital per year (IE_14). Dairy farms are heterogeneous in relation to the capital invested in milk production in facilities, machinery, animals, and land (IE_12 and IE_13). One farm has no expenditure on hired labor (IE_3), the work is performed by the family.

Table 1. Technical Indicators of the Farms.

Indicator	Mean	Standard Deviation	Median	Minimum	Maximum
IT_1 - Stocking Rate (UA/ha)	3.17	1.40	3.19	1.00	5.68
IT_2 - Lactating cows per area (cows/ha)	1.42	0.62	1.35	0.54	2.75
IT_3 - Milk production per area (kg milk/ha/year)	9.856.32	6.000.74	8.063.23	3.090.35	27.073.00
IT_4 - Milk production per permanent labor force (kg of milk/dh)	313.14	148.27	297.83	100.90	800.33
IT_5 - Lactating cows (cows/employee)	16.77	6.05	14.70	9.43	32.75
IT_6 - Milk production per lactating cow (kg milk/day)	18.37	3.99	18.29	10.70	26.97
IT_7 - Milk production per total cows (kg milk/day)	15.31	3.97	15.14	6.78	24.15
IT_8 - Ratio of lactating cows to total cows (%)	82.65	7.19	85.87	63.30	90.09
IT_9 - Ratio of lactating cows per herd (%)	45.21	8.83	43.06	35.03	68.70
IT_10 - Age at first coverage (months)	18.96	5.57	16.25	11.90	30.00
IT_11 - Weight at First Cover (kg)	341.40	19.77	350.00	280.00	360.00
IT_12 - Age at first calving (months)	29.04	5.03	28.25	23.00	39.00
IT_13 - Body condition score of cows per lactation phase (Beginning of lactation period)	3.26	0.36	3.50	2.50	3.75
IT_14 - Body condition score of cows per lactation phase (Mid-lactation period)	3.18	0.26	3.25	2.50	3.50
IT_15 - Body condition score of cows per lactation phase (End of lactation period)	3.21	0.27	3.13	2.75	3.75

Table 2. Economic Indicators of the Farms.

Indicator	Mean	Standard Deviation	Median	Minimum	Maximum
IE_1 - Average milk price (Rs/kg of milk)	1.53	0.11	1.51	1.38	1.78
IE_2 - Share of gross milk income in relation to gross farm income (%)	94.85	5.11	95.97	80.20	100.00
IE_3 - Dairy farm labor expenditure by gross milk income (%)	10.09	5.69	8.54	0.00	24.21
IE_4 - Dairy farm concentrate expenditure by gross milk income (%)	31.77	5.48	31.98	20.74	45.43
IE_5 - Total unit cost of milk (Rs/kg of milk)	1.31	0.17	1.31	1.07	1.73
IE_6 - Total milk cost per milk price (%)	85.62	11.90	79.32	70.97	116.56
IE_7 - Unitary gross margin (Rs/kg of milk)	0.49	0.18	0.55	0.15	0.72
IE_8 - Gross margin per area (Rs/ha)	6.071.89	9.075.62	4.052.82	459.39	43.774.28
IE_9 - Unitary net margin (Rs/kg of milk)	0.31	0.19	0.38	-0.18	0.56
IE_10 - Unit Profit (Rs/kg of milk)	0.19	0.19	0.27	-0.30	0.43
IE_11 - Farm profit per area (Rs/ha)	2.042.05	2.527.13	1.502.59	-940.22	10.210.48
IE_12 - Capital stock by area (Rs/ha)	33.625.35	13.729.25	30.740.38	16.382.97	73.758.67
IE_13 - Capital stock per kg of milk (Rs/kg of milk/day)	1.456.22	540.27	1.511.18	669.05	2.657.98
IE_14 - Rate of return of capital with land (% p.a.)	9.57	6.89	8.47	0.00	26.12
IE_15 – Cost-Benefit Ratio	1.15	0.14	1.20	0.83	1.35
IE_16 - Profitability (%)	18.92	11.59	23.51	-12.16	33.71

Table 3. Social Indicators of the Farms.

Indicator	Mean	Standard Deviation	Median	Minimum	Maximum
IS_1 - Milk Quality - Somatic cell count (CSx1000/mL)	771.41	1.163.65	468.50	238.73	5.593.84
IS_2 - Milk Quality - Total Bacterial Count (CFUx1000/mL)	348.21	564.85	156.64	15.17	2.527.66
IS_3 - Milk quality - Protein (%)	3.25	0.15	3.22	3.00	3.53
IS_4 - Milk Quality - Fat (%)	3.74	0.29	3.77	3.27	4.24
IS_5 - Subsidy on the price received for milk (%)	2.37	2.71	1.30	0.00	7.65
IS_6 - Animal Welfare - Body Condition Score (scale of 1 to 5)	3.22	0.21	3.25	2.58	3.67
IS_7 - Animal Welfare - Animal Hygiene (%)	73.43	24.27	84.73	15.38	100.00
IS_8 - Animal Welfare - Clinical Mastitis (%)	3.43	1.58	3.33	1.14	6.39
IS_9 - Employment (employee/day)	4.08	2.56	3.54	1.05	9.73
IS_10 - Work accidents (accidents/employee/year)	0.09	0.23	0.00	0.00	0.73
IS_11 - Lost time (%)	1.02	1.44	0.00	0.00	4.48
IS_12 - Working time (hours/employee/month)	198.69	12.40	201.33	173.33	211.33
IS_13 - Rest days (rest days/employee/month)	3.08	1.55	2.75	1.50	6.25
IS_14 - Employee Salary (Rs/employee/month)	1.473.15	753.22	1.497.53	0.00	3.448.80
IS_15 - Family labor wage or pro-labor (Rs/month)	2.031.08	1.230.41	1.778.34	517.54	5.527.25

IS_16 - Quality of life (average from 0 to 10)	8.44	0.74	8.50	7.00	9.75
IS_17 - Education (1 = elementary and high school; 2 = higher education)	1.30	0.47	1.00	1.00	2.00
IS_18 - Entrepreneurship (degree of managerial and entrepreneurial skills of the producer - average from 0 to 10)	8.58	1.99	9.50	1.50	10.00
IS_19 - Social Involvement (1 = No; 2 = Yes)	1.40	0.50	1.00	1.00	2.00
IS_20 - Succession (1 = No; 2 = Yes)	1.40	0.50	1.00	1.00	2.00
IS_21 - Training and professional development (hours/employee/year)	3.86	7.67	0.31	0.00	27.78

The social indicators of the farms can be seen in Table **3**. The milk quality of the farms showed a wide variation in somatic cell count (from 238.73 to 5,593.84 CSx1000/mL) and total bacterial count (from 15.17 to 2,527.66 CFUx1000/mL).

One farm analyzed has no employees, the farm work is performed by family people. Therefore the wage of employees is zero, as observed in the IS_14 indicator in Table **3**. The family labor wage or pro-labor (IS_15) was on average 2,031.08 Rs/month, ranging from 517.54 to 5,527.25 Rs/month.

Table **4** presents descriptive statistics of the farms' environmental indicators. The indicator AI_6 (land occupancy) averaged 1.37 m²/kg of milk, ranging from 0.37 to 3.24 m²/kg of milk. This indicator is the inverse of milk production per hectare, it determines the demand for the area to produce one kg of milk (Gaillard & Dervillé, 2022).

The variation in soil fertility indicators was particularly wide for the amount of phosphorus and potassium in the soil of pasture and farm crops (Table **4**).

Knowing and analyzing the type of system and the factors involved in the activity are essential to understanding the costs and how they interrelate to the system as a whole. This evaluation generates managerial actions such as resource allocation, adopting management, and/or making investments, to improve production performance to ensure the sustainability of the activity. Besides, it is a dynamic process, which seeks to achieve the objectives and goals, through the use of available resources.

5.2. Analysis of Indicator Relationships

The result reinforces that to evaluate sustainable development one must analyze it considering the interdisciplinary, integration, interdependence, and interrelation of factors. The sustainable development of a milk production system can be defined as the result of the combination of different indicators, which through the dynamism between the factors, generate synergistic effects or trade-offs.

The sustainability indicators analyzed present interconnections among themselves. Zootechnical practices influence the economic, environmental, and social performance of the farms. The economic aspects provide income generation, which reflects on the social pillar and consequent maintenance of the man in the field.

To evaluate how changes in one indicator can influence the other indicators, here is the example of indicator IE_5 (total unit cost of milk (Rs/kg of milk)). This indicator was chosen because it is related to the total cost to produce one kilogram of milk and its relevance to the evaluation of the sustainability of dairy farming. Total cost is the effective operational cost, plus depreciation, producer remuneration, and capital, according to the cost of production methodology developed by Menglikulov *et al*. (2021).

Total unit milk cost relates directly with positive correlations with the indicators dairy farm concentrate expenditure by gross milk income (IE_4), total milk cost per milk price (IE_6), and nutrient-nitrogen balance (IA_3), and negatively with the indicators unit gross margin (IE_7), unit net margin (IE_9), unit profit (IE_10), farm profit per area (IE_11), rate of return on land capital (IE_14), cost-benefit ratio (IE_15) and profitability (IE_16).

According to General Systems Theory, managing the production cost per unit of product alters the activity as a whole, due to the synergies and trade-offs among the system components. Actions to solve a given problem should always be taken considering and evaluating the dynamic relationships of the components of the total system.

The total unit cost of milk directly influences economic indicators such as unit gross margin (IE_7), unit net margin (IE_9), unit profit (IE_10), farm profit per area (IE_11), rate of return on capital with land (IE_14), cost-benefit ratio (IE_15) and profitability (IE_16) of the dairy farm. The cost is related to production and productivity (IT_3, IT_4, IT_5, IT_6, and IT_7) and stocking rate (IT_1 and IT_2). Regarding social indicators, the cost is influenced by training and professional development (IS_21). The cost relates directly to the nitrogen balance indicator (AI_3), due to the purchase of food and fertilizers for production.

Total unit cost of milk (IE_5; $r = 0.46$), concentrate expenditure on milk production by gross milk income (IE_4; $r = 0.72$), total cows (IT_7; $r = 0.49$) and milk production per lactating cow (IT_6; $r = 0.47$) show positive correlations with nitrogen balance (AI_3). Flaten et al. (2019) found that increasing concentrate use increases the balance. These relationships point to a dependence on external inputs for feed (concentrate feed) for the animals and as a consequence increased production causes an increase in the balance. Increased use of concentrate is directly related to the increased cost of production.

Table 4. Environmental Indicators of the Farms.

Indicator	Mean	Standard Deviation	Median	Minimum	Maximum
IA_1 - Energy use per kg milk (Megajoule (MJ)/kg milk)	0.50	0.22	0.44	0.24	1.07
IA_2 - Global warming potential (kg carbon dioxide equivalent/kg milk)	0.93	0.23	0.90	0.59	1.52
IA_3 - Nutrient balance - Nitrogen (g nitrogen/kg milk)	59.00	9.50	59.68	39.83	72.73
IA_4 - Nutrient balance - Phosphorus (g phosphorus/kg milk)	6.51	2.13	6.68	1.93	10.55
IA_5 - Nutrient balance - Potassium (g potassium/kg milk)	6.32	2.79	6.44	1.82	13.58
IA_6 - Land occupancy (m^2/kg of milk)	1.37	0.77	1.24	0.37	3.24
IA_7 - Soil Fertility - pH	5.65	0.35	5.65	5.06	6.20
IA_8 - Soil fertility - Phosphorus (mg/dm^3)	21.12	14.96	16.85	0.66	58.40
IA_9 - Soil Fertility - Potassium (mg/dm^3)	89.20	33.89	88.90	27.00	155.00
IA_10 - Soil erosion (% of farm area)	0.22	0.50	0.00	0.00	1.67
IA_11 - Degraded areas (% of farm area)	0.20	0.50	0.00	0.00	1.67
IA_12 - Soil management (1 = no, 2 = yes)	1.55	0.51	2.00	1.00	2.00
IA_13 - Permanent preservation area and legal reserve (% of total farm area)	22.45	19.12	14.01	2.70	68.37

Nutrients enter the farm in the feed and fertilizer. The animals take the nutrients from the feed for the milk production metabolism. Some nutrients leave the farm in the milk, but many are excreted in the manure and remain on the farm. The use of manure returns the nutrients to the soil, where they can be reused for more food production. In cost management, it means expenses with animal feed and fertilizers and income from the sale of milk, animals, and others. And the correct management of waste can generate income and/or reduce spending on the purchase of fertilizer.

To improve the use of nutrients should adopt animal husbandry and precision agriculture, improving the flow of nutrients in the system. Precision animal husbandry seeks to adapt diets according to the nutritional requirements of each animal category and physiological stage (González *et al*., 2018). Reducing crude protein in the diet and balancing energy correctly can increase the efficiency of nitrogen use in feed (Powell & Rotz, 2015). Reducing the intake of minerals can reduce their excretions (Boerman *et al.*, 2015). And precision agriculture seeks to reduce agricultural inputs with targeted nutrient applications in the field, better targeting nutrients to plant needs (Higgins *et al*., 2019). The application of manure and fertilizers to the soil should be done considering climatic conditions, soil fertility, and the nutrient requirement of crops.

Therefore, the use of animal husbandry and precision agriculture contributes to the optimization of the purchase of inputs, thus collaborating with cost management. Cost management helps in the formulation of efficient diets to meet nutritional needs and to reduce nutrient losses to the environment with the best cost-benefit. The analysis of production cost is one of the important issues because it provides the producer with indicative information for the choice of inputs to be used to reduce environmental losses, besides allowing the best allocation and use of resources aiming at an adequate economic and environmental return.

Total unit milk cost directly influences farm profit per area (IE_11; r = -0.49). Profit per area (IE_11) is associated with training and professional development (IS_21) of producers and employees. Hansson (2008) found a significant positive relationship between return on equity and the use of continuous training.

Labor productivity (IT_4) is positively correlated with milk production per lactating cow (IT_7; r = 0.58), farm profit per area (IE_11; r = 0.55) rate of return on capital with land (IE_14; r = 0.62) and negatively correlated with global warming potential per kg of milk (AI_2; r = -0.56). This finding is confirmed by the literature which shows that raising milk production per cow increased labor productivity, and reduced global warming potential (Lovarelli *et al*., 2020). According to Yi & Ifft (2019), higher labor productivity and cost efficiency (cost of hired labor per unit of milk sold) is associated with the better financial performance of dairy farms.

Cost management depends on the capacity building and training of the producer, to better manage the factors of production. With knowledge, the producer and the technician can optimize the input and management of nutrients in the property to reduce losses to the environment, consequently reducing the environmental impact and increasing the farm's profit. The management of costs and systemic knowledge contribute to the reduction of expenses and losses involved in the production process and consequently improvements in the sustainability of production.

By seeking improvements in cost management, it will influence the entire production system, that is, production techniques, input expenses, profitability and profitability results, labor remuneration and training, and nutrient losses to the environment, which can consequently make the activity more sustainable.

6. CONCLUSION

The result of this research indicates that cost management improves the economic, technical, social, and environmental indicators through increased capacity building and staff training. Environmentally, cost management can reduce the nitrogen balance by optimizing nutrient use on the farm.

Dairy products should be understood from a systemic and dynamic perspective, consisting of several interacting factors. A change in one of the components generates changes in the whole, having synergistic effects or trade-offs.

The evaluation of the relationship between indicators and the dimensions of sustainability is important for sustainable development. And the cost management of dairy farming is essential to understand the results obtained in the activity and provide management actions to have sustainable and responsible milk production.

The analyzed properties have the potential for sustainable milk production, through the more efficient use of available resources, with the help of production cost management, using a systemic vision of the activity.

Cost management is indispensable for the sustainable development of milk production, to obtain better technical, economic, social, and environmental results, and to remain active in the market.

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