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REGULAR ARTICLES

On-farm assessment of the sustainability of small-scale dairy systems with three methods based on indicators

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Abstract

Small-scale dairy systems are important contributors to national milk supplies in many areas of the world, and an option to ameliorate rural poverty in developing countries. In Mexico, they comprise over 78% of dairy farms. These systems must be sustainable in order to persist in the future. By applying several methods to assess the sustainability of farms, valuable information is collected on the practical, operational, and systemic requirements, as well as an insight into the difficulties in the use of each tool in practice. The objective was to assess the sustainability of small-scale dairy systems during the rainy season. Three methods were compared (IDEA, RISE, and SAFA) to evaluate their ability to deal with such systems in the Mexican context. Ten small-scale dairy farms were assessed from June to November 2018. Monthly semi-structured interviews were applied to collect economic, social, and environmental information. The three methods met criteria for on-farm assessments, with no large differences among them. The IDEA method was more applicable in the context of small-scale dairy systems because its indicators may be collected on-farm and were easy to measure. RISE requires more specialized technical information not always available at the small-scale farm level, and SAFA covered the largest number of indicators but is better suited for large-scale systems. The IDEA and RISE methods are adequate tools to assess the sustainability of small-scale dairy systems. The mean overall sustainability score over the three methods for the 10 assessed farms was 55.3±5.7 over 100. This medium level of sustainability indicates areas of opportunity to enhance the sustainability of small-scale dairy systems.

Keywords Rural development, · IDEA method, · RISE method, · SAFA Framework, · Comparison of methods

Introduction

There is a need not only to increase food production in the coming years to cope with demand from a growing population (FAO 2013), but agricultural production must be sustainable in its economic, environmental, and social dimensions. Sustainability of agricultural production is based not only in increased production of goods and services, but on its robustness, rooted in the local communities, being autonomous, and with a global responsibility (Zahm et al. 2015), within a holistic approach (Van Passel et al. 2007; Zahm et al. 2008).

Sustainable agricultural systems involve production following a good management of the environment and looking after the social context and wellbeing of farming families and their communities (Van Passel et al. 2007). However, assessing the sustainability of agricultural systems is complex, since it deals with dynamic and holistic issues that develop and evolve in a specific site and relies on the perspective of who undertake the assessment (Webster 1997).

Different methods have been developed for the assessment of differences and variations of the sustainability of farming systems (Hayati et al. 2010). These methods can be based on simple indicators, i.e., from information taken from records or simple questions, or on complex ones that require a higher degree of knowledge or specialized equipment (Bockstaller et al. 2015).

The Intergovernmental Panel on Climate Change (IPCC) (2014) states that greenhouse gas emissions by dairy

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production account to 4% of the world total, and 22% of all agricultural emissions. Thus, the assessment of sustainability in dairy systems is relevant since these have been pointed out as having a large environmental footprint (Flysjö 2012). All agricultural systems must engage in sustainable production, especially the small-scale dairy systems because they comprise the majority of dairy farms worldwide even in developed countries as the European Union where the mean herd size in 2016 was 18 cows (IFCN 2017). Therefore, small-scale dairy systems represent a large potential to reduce their environmental impacts and develop sustainable production (FAO 2014a).

In Mexico, 78% of specialized dairy farms are small-scale defined by a small agricultural land, with a herd size between 3 and 35 cows plus replacements (Prospero-Bernal et al. 2017). Milk sales are the main source of income in 90% of these farms (Martínez-García et al. 2012). The small-scale farms are considered as a viable option for territorial development, as they are a source of full-time employment, enabling rural populations to remain in their communities (FAO 2010). Farmers are linked to informal milk markets, and they have developed a strong relationship with milk collectors and artisan cheese producers, giving strength to the agri-food chain (Espinoza-Ortega et al. 2007). However, the economic disparities between prices paid for milk and costs of inputs put extra strain on the economic scale of their sustainability, which is the weakest part in these systems (Fadul-Pacheco et al. 2013).

On the other hand, the literature states the need to compare methods that provide information to integrate criteria for the assessment and understanding of the sustainability in a given context (Bockstaller et al. 2009). However, there are few reports that compare methods on-farm. De Olde et al. (2016) compared the IDEA (*Indicateurs de Durabilité des Explotations Agricoles*) (Vilain et al. 2008), RISE V 3.0 (Response-Inducing Sustainability Evaluation) (Grenz et al. 2016) and SAFA V-3 (Sustainability Assessment of Food and Agriculture systems) (FAO 2014b) in dairy and pig farms in Denmark, stating that RISE was the method better adapted to the Danish context; noting its relevance, easiness of use, understandable, and with advantages in the software. In addition, de Olde et al. (2016) identified out of 48 methods for the assessment of sustainability, that only IDEA, RISE, and SAFA met criteria for on-farm assessments, while Binder et al. (2010) out of 35 methodologies selected IDEA and RISE.

The three methods (IDEA, RISE, SAFA) allow the on-farm assessment of sustainability, through scientifically rigorous indicators, integrated by the ecological, economic and social dimensions of sustainability (De Olde et al. 2016). They also enable the self-evaluation of each farm and the comparison among farms and do not require an optimal or reference farm for comparison (Häni et al. 2003; Zahm et al. 2008; FAO 2013). Table 1 shows the characteristics of each of these methods.

The IDEA method is the most accessible and easiest to understand. RISE and SAFA require more complex technical data. The objectives of each method address different dimensions and topics, through indicators that comprise the holistic sense of sustainability (De Olde et al. 2016), with the end goal of guiding farms towards sustainable development (Zahm et al. 2015).

The IDEA method enables the assessment of the sustainability of individual farms with a score that may be compared against other farms within the same production system, or even compare among different systems (Zahm et al. 2008). There are reports of its successful application in developing countries such as Algeria (Ghozlane et al. 2006), Tunisia (M'Hamdi et al. 2009), and Uruguay in dairy systems (Tommasino et al. 2012), also, for sheep and goat systems in Algeria and Lebanon (Ghozlane et al. 2008; Srour et al. 2009).

In Mexico, Fadul-Pacheco et al. (2013) and Prospero-Bernal et al. (2017) assessed the sustainability of the small-scale dairy systems, applying for the first time the IDEA method; and Salas-Reyes et al. (2015) also applied the same method to assess the sustainability of dual-purpose small-scale cattle farms in a subtropical area. These studies showed that the IDEA method enabled the identification of areas for improvement in the economic scale which limits the sustainability of these systems, basically in the need to reduce feeding costs to enhance the profitability and economic viability of farms.

However, there were questions on the suitability of the IDEA method, developed in France, when applied in the Mexican context. Therefore, the need arose to evaluate different methods for the assessment of sustainability within and between farms and systems that may be better adapted to the context of small-scale dairy systems with low availability of data and that are easy to apply considering the limited time and financial resources for the assessment.

From these, the IDEA, RISE, and SAFA methods were applied in the work herein reported, selected for the quality of indicators, their scientific framework and that they can be applied at farm level, and in multiple systems. The IDEA method was included as a reference for comparison, given the previous experience of the research team with this method (Fadul-Pacheco et al. 2013; Prospero-Bernal et al. 2017).

The assessment of the sustainability of small-scale dairy systems with the three methodological tools was aimed at discerning their strengths and weaknesses in the Mexican context; as well as providing a better understanding of the sustainability dynamics in these farms to identify areas of improvement and support for decision making. Therefore, the objective was to assess the sustainability of small-scale dairy systems during the rainy season. Three methods were compared (IDEA, RISE, and SAFA) to evaluate their ability to deal with such systems in the Mexican context.

Table 1 Comparison of sustainability assessment tools

Methodology and version	*Indicateurs de Durabilité des Exploitations Agricoles - IDEA V 3*	Response-Inducing Sustainability Evaluation- *RISE V 3.0*	Sustainability Assessment of Food and Agriculture systems *SAFA V 3.0*
Origen	France	Switzerland	Multiple countries
Institution	Multiple institutes	Bern University of Applied Sciences	Multiple institutes
Normative aspects			
Sustainability development concept	Economic viability, social liveability and environmental reproducibility (Vilain et al. 2008).	Environmental non-degrading, technically appropriate, economically viable and socially acceptable (WCED 1987).	
Goal setting	Provide an operational tool, top-down approach	Holistic assessment, top-down approach	Holistic on four domains, top-down approach
Application level	Multiple systems Farm level	Multiple systems Farm-level	Multiple systems Regional level, Farm level
Aggregation method	Scale (3) Component (10) Indicator (42) Criteria (126)	Dimension (3) Topic (10) Indicator (50) Criteria (156)	Dimension (4) Theme (21) Subtheme (58) Indicator (116)
Scoring systems	Attributes scores to measured indicators and sums them up into ten components and three scales. For each indicator, a certain amount of points can be obtained. Sustainability score of the farm is the lowest of the three scales.	The farm data is normalized to a scale from 0-100. A topic is calculated using the arithmetic mean of several indicator scores, with all indicators being given equal weighting.	The score of each indicator is evaluated on a scale from 1 to 5, SAFA indicates ways to measure the indicator. The score indicator is aggregated to the subtheme and theme level.
Dimensions and scoring range	Agroecological (0-100) Socioterritorial (0-100) Economic (0-100)	Environmental (0-100) Social (0-100) Economic (0-100)	Environmental (0-100) Social (0-100) Economic (0-100) Governance (0-100)
Farms assessed	> 1500	> 2300	> 8600
Reference	Vilain et al. (2008)	Grenz et al. (2016)	FAO (2014a)

Materials and methods

Study area

The work took place in the central highlands of Mexico (Fig. 1), between coordinates 20° 06' and 20° 17' N and at 99° 40' and 100° 00' W and mean altitude of 2440; a sub-humid temperate climate with rains in summer, and a dry season with frosts in winter (INEGI 2009). Mean temperature was 16.4°C and mean rainfall 776.7 mm (SMN-CONAGUA 2019).

Almost 90% of dairy farms in the study area were small-scale dairy producers (INEGI 2007), who relied on milk sales for their livelihoods (Martínez-García et al. 2012). Farms were characterized by herds between 3 and 35 cows plus replacements, two milkings per day, and small land areas, that relied on family labour (Fadul-Pacheco et al. 2013).

Feeding is based on cut-and-carry of temperate cultivated pastures (ryegrasses with white clover), forages as oats or bought-in alfalfa hay, complemented with cereal straws (maise, oats, barley, and wheat) and commercial concentrates (Martínez-García et al. 2015a). Some farms graze native grasslands, and some have incorporated grazing their cultivated pastures and maise silage (Prospero-Bernal et al. 2017).

Selection of farms and data collection

Ten farms participated in the study. They have participated in the project to which this work belongs (Prospero-Bernal et al. 2017), initially selected by snow-ball non-probabilistic sampling (Goodman 2011; Sedgwick 2013). Farmers accepted to participate in the study voluntarily and were informed at all times of the objectives and scope of the work under a participatory rural research approach (Conroy 2005).

At the start of the assessment, the indicators of each methodology were revised to identify their specificity and applicability (FAO 2014b; Prospero-Bernal et al. 2017; Berbeć et al. 2018; Soldi et al. 2019). Data were collected with a structured questionnaire for each method (IDEA, RISE y SAFA) (Vilain et al. 2008; FAO 2013; De Olde et al. 2016).

Questionnaires included the indicators for the environmental, social and economic dimensions (Appendixes A1, A2, and A3), adapted to the study area (Zahm et al. 2015) to ensure an approach compatible with the Mexican context (Prospero-

Fig. 1 Geographical location of the study area

Bernal et al. 2017). Appendix B shows the indicators that were not included for each method.

Information was collected during monthly visits to each farm when questionnaires for the three methods were applied; always by the same member of the team to reduce potential bias.

Since farmers do not keep records, semi-structured questionnaires were also applied during each visit to collect information on the quantity of feeds, milk sales, and productive, reproductive and economic information from the previous month. Milk and feed samples were collected during those visits and analyzed in the laboratory for milk composition (milk fat and protein) and chemical composition of feeds (dry and organic matter, crude protein, neutral and acid detergent fiber, and in vitro organic matter digestibility) following Fadul-Pacheco et al. (2013) and Prospero-Bernal et al. (2017).

Data collection was during the rainy season from June to November 2018, so that there were 60 questionnaires and collected data from farms for each method. Previous research with the IDEA method was in the rainy season (Fadul-Pacheco et al. 2013), and the IDEA method was taken as reference given the experience of the research team. Also, budget constraints limited the duration of the study.

Indicators were adapted to current Mexican standards for milk composition and environmental issues, and those not applicable to the Mexican context were not considered as was done in previous work (Fadul-Pacheco et al. 2013; Salas-Reyes et al. 2015). The economic analyses followed Prospero-Bernal et al. (2017) through partial budget analyses, just considering the dairy operation as the basis of livelihoods.

Interpretation of sustainability level by IDEA, RISE, and SAFA

Results for each dimension (environmental, social, and economic) were from weighing scores where each dimension may get a score from 0 to 100. SAFA scores (0–5) were transformed to a 0-100 scale to compare methods.

Sustainability score in IDEA is from the dimension with the lowest score (limiting scale) (Zahm et al. 2019). Sustainability from RISE and SAFA was from the average of the three and four dimensions, respectively (FAO 2014b; Grenz et al. 2016).

Scores for each indicator (on a 0 to 100 scale) are classified as (Grenz et al. 2016): 0–33: problematic, 34–66: critical, and 67-100: positive (Appendix A). Mean results for each method are presented in radar graphs (Figs. 2, 3, and 4).

Statistical analyses

Descriptive statistics were applied to the 10 participating farms to justify that the sample is representative of farms encountered in the study area. Data from each method was organized following the guidelines from IDEA (Vilain et al. 2008), RISE (Grenz et al. 2016) and SAFA (FAO 2014b) (Table 2).

Indicators were analyzed for each dimension. The level of sustainability was described as suggested by Binder et al. (2010) and de Olde et al. (2017) since the number of indicators and topics are different for each method, so

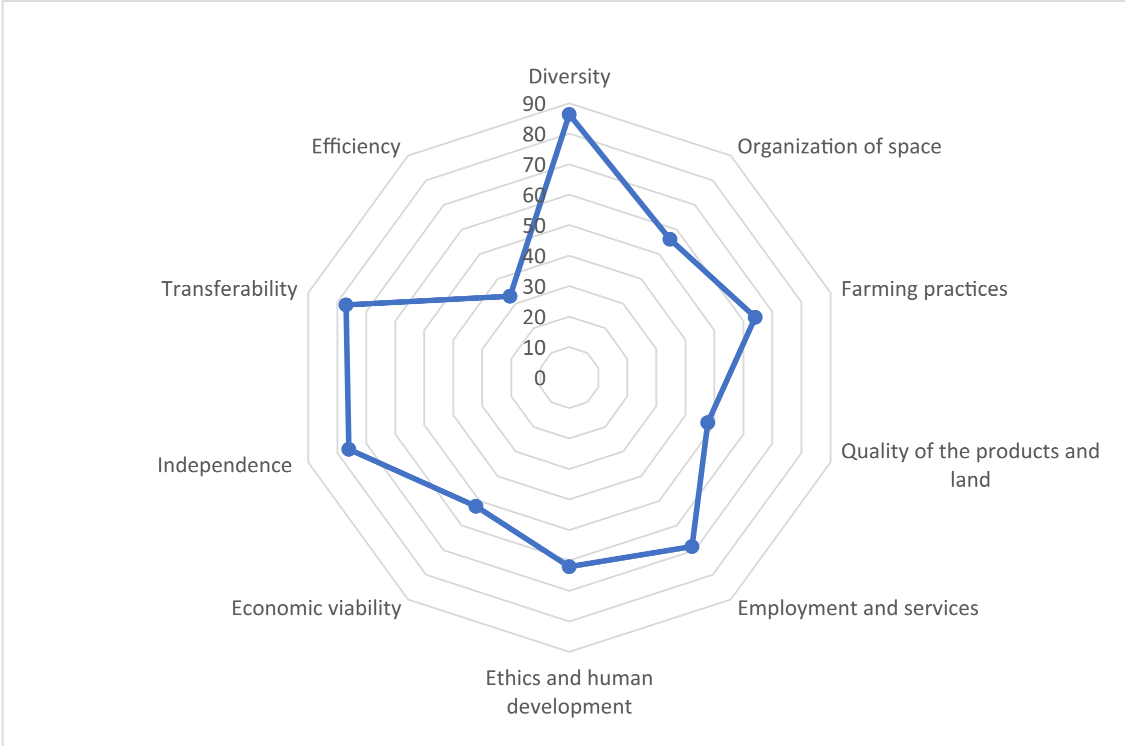

Fig. 2 Average score by themes of the IDEA method

that results are presented as independent indicators without considering interactions between them.

The Shapiro-Wilk test recommended for samples under 50 observations did not show a normal distribution of data (Field 2013); therefore, the comparison within dimensions and the level of sustainability for each method were analyszed with the Kruskal-Wallis test and the Mann-Whitney U test to detect differences (Field 2013).

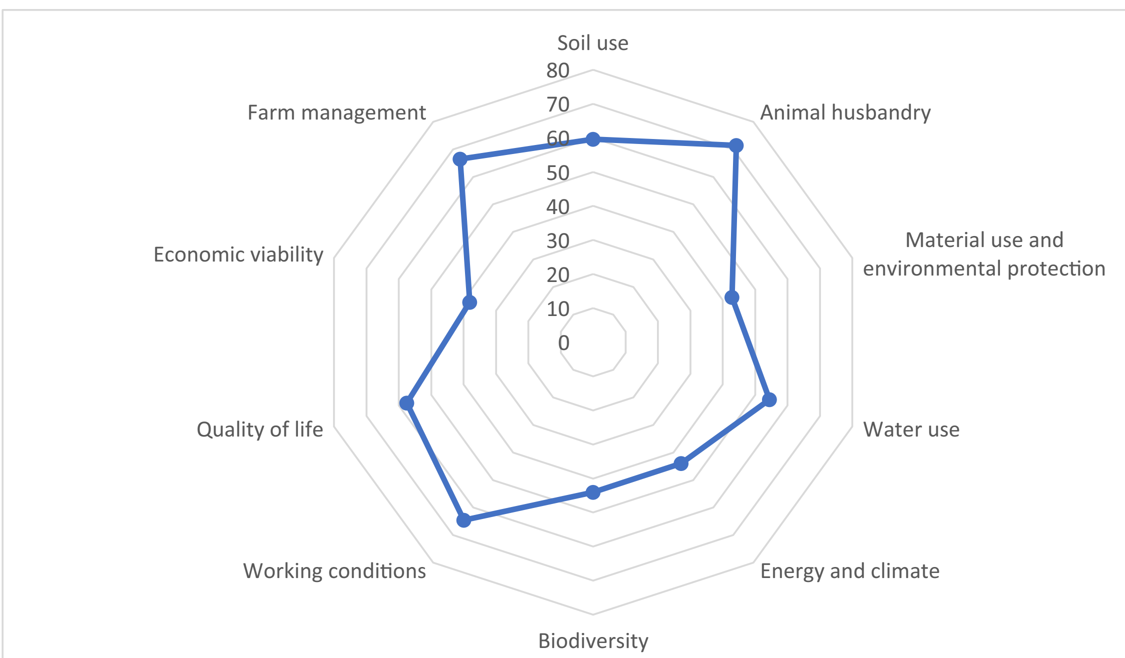

Fig. 3 Average score by themes of the RISE method

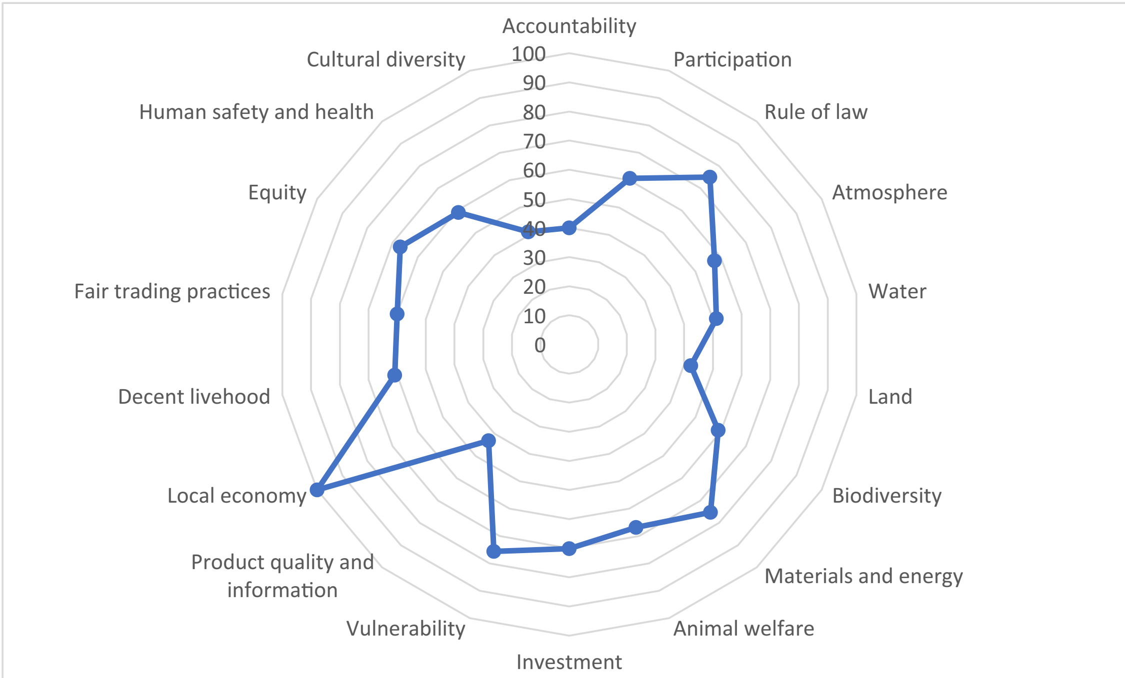

Fig. 4 Average score by themes of the SAFA method

Results

Characteristics of participating farms

Table 2 shows the characteristics of the participating farms, with the largest variation in farmland size (ha) and the number of cows; with the lower variation for milk fat and protein content among farms. Farms rely on family labor, with temporal hiring of labor during harvesting of forages and crops like maise and oat.

Table 2 Farm characteristics in the assessment of the sustainability of small-scale dairy systems by three methods (*n*=10)

	Mean	SD[1]	Maximum	Minimum
Total farm size (ha)	8.2	6.7	21	2
Total pastures (ha)	1.9	1	4	0.5
Other crops (ha)	3.7	3.3	12	1
Milking cows (n°)	8.2	4.2	17	2
Dry cows (n°)	3.6	3.6	13	1
Milk yield (kg/v/d)	15.2	3.1	21	10
Milk Protein (%)	2.8	0.1	2.92	2.58
Milk fat (%)	3.7	0.3	3.97	3.2
Family labour (persons)	1.5	0.53	2	1
Payed labour (persons)	0.25	0.42	1	0

[1] *SD* standard deviation

Indicators classification by color code (green, amber, and red)

Table 3 shows the classification of indicators by score, identified as positive (green), critical (amber), and problematic (red) for each method. Appendixes A1, A2, and A3 show all indicators reported in terms of their maximum possible score, the mean score and maximum and minimum scores for farms for each method.

In the environmental scale, indicators for fertilisation have problematic scores in the three methods, with positive scores for the majority of indicators relating to animal production diversity and water management. Indicators for energy and materials use were problematic in IDEA and RISE, although positive in SAFA. However, all the others indicators in this scale having high scores, the environmental scale was classified as positive (see Appendices A1, A2, and A3).

Also, on the social scale, the majority of indicators in IDEA showed a positive score, while in RISE and SAFA most indicators are at a critical score. Indicators relating to health and safety at work have similar scores in the three methods, and it is in the social scale where fewer indicators are problematic. Most indicators are qualitative and with similar content in the three methods, which weigh scores similarly.

In the economic scale, most indicators in IDEA and SAFA showed positive scores, in contrast with RISE where most indicators were classified as problematic.

Table 3 Indicators by color code

	Green Positive (67-100)	Amber Critical (34-66)	Red Problematic (0-33)
Environmental			
IDEA	Diversity of annual or temporary crops. Animal diversity. Dimension of fields. Organic matter management. Effluent processing. Animal wellbeing. Water resource protection	Diversity of perennial crops. Forage area management. Pesticides and veterinary products. Soil resource protection.	Cropping pattern. Ecological buffer zones. Stocking rate. Fertilisation. Energy dependence.
RISE	Soil reaction. Soil erosion. Opportunity for species-appropriate behaviour. Living conditions. Animal health. Water supply. Energy intensity. Ecological infrastructures.	Soil management. Crop productivity. Soil organic matter. Soil compaction. Livestock productivity. .materials flows. Plant protection. Air pollution. Soil and water pollution. Water management. Water use intensity. Irrigation. Energy management. Biodiversity management. Distribution of ecological infrastructures.	Herd management. Fertilisation. Intensity of agricultural production. Diversity of agricultural production.
SAFA	Air quality. Ecosystem diversity. Genetic diversity. Materials use. Energy use. Waste reduction and disposal. Freedom from stress.	Greenhouse gases. Water withdrawal. Water quality. Soil quality. Species diversity. Animal health.	Land degradation.

Assessment of sustainability by the three methods

Figure 2 shows results for IDEA. Two of the four themes (components) that had the lowest scores were for the economic scale: economic efficiency and viability. The other two components with a low score were the organization of space and quality of products of the land. The highest scores were for the environmental scale.

Figure 3 shows the results of the RISE method. Scores for economic viability were the lowest, similar to IDEA. The highest scores were those related to animal welfare (environmental scale) and farm management.

It is the RISE method that resulted in the lowest score for the environmental scale. This is due to more exhaustive and detailed indicators on soil management, as well as indicators on environmental protection and energy use. In contrast, IDEA takes into consideration more general indicators on crops, land areas, and the territory.

SAFA results (Fig. 4) showed that the indicator for local economy had the highest score; with overall high positive scores for the economic scale. One aspect valued by SAFA is local trade, which in the farms studied refers to the sale of milk destined to local small artisan cheesemakers obtaining a 100 score for this indicator which influence the overall high score for the economic scale. However, SAFA indicators for profitability and liquidity that reflect the economy of each farm were not high scores.

IDEA and RISE results showed that farms are at a critical (amber) level of sustainability. IDEA results indicated that the economic scale limits the sustainability of these systems. RISE and SAFA have the environmental and social scales with lower scores than for the economic scale.

Themes on product information and quality, responsibility, and land use showed the lowest scores in SAFA, which differ from IDEA and RISE in those scales.

Comparison of dimensions and sustainability level

Table 4 shows results for the scores for each environmental, social, and economic dimensions and the overall level of sustainability for each of the studied methods. There were highly significant differences among methods ($P<0.001$) for the environmental and economic dimensions with RISE showing the lowest score for environmental dimension.

There were no statistical differences among methods for the social dimension ($P>0.05$), and there were highly significant differences ($P<0.001$) among methods for the economic scale. SAFA had the highest mean score for the economic dimension, with similar scores between IDEA and RISE.

In terms of overall sustainability scores, there were highly significant differences ($P<0.001$). The SAFA score was the highest, while IDEA and RISE showed a similar sustainability score. In spite of differences, the three methods showed an overall medium (critical) sustainability score.

Discussion

Farm characteristics

Participating farms were similar to those reported by Romo-Bacco et al. (2014) and Prospero-Bernal et al. (2017) in small-scale dairy systems in two different areas of the Mexican highlands. Both works reported the reliance on family labour (by two family members), and about 10% of hired labour. Farms have between 6 and 7 ha of farmland, with 9 to 15 milking cows that yield between 14 and 16 litres of milk per day.

Assessment of the environmental, social, and economic components of sustainability

The three methods applied enabled the assessment of the sustainability of participating farms and were sensitive to detect problematic, critical, and positive points (Grenz et al. 2016).

In the environmental scale, the three methods identified problematic indicators in crop management, due to high fertilizer use and soil degradation. Farmers are aware of the high amounts of fertilizers applied, but few have reduced their use.

Given the low schooling level of small-scale farmers, they are generally unwilling to introduce changes in their practices (Martínez-García et al. 2015b), and changes happen usually until they are convinced by the influence of their social referents from whom they take advice (Martínez-García et al. 2018).

As positive indicators, the 10 farms use manure as organic fertilizer for their pastures, and having mixed grass-clover pastures is also a positive indicator. Other positive indicators were diversity, animal welfare, and water use.

The IDEA method showed the highest scores for the environmental scale, attributed to the indicators the method evaluates, centered in diversity, management, and the territory.

RISE and SAFA, on the other hand, evaluate very specific indicators on issues of air, water, and soil, with sub-topics and indicators for a detailed assessment that requires specific information that farmers do not have and are not easy to obtain, as the balance of greenhouse gases (that were not measured) in RISE, and a whole theme on the atmosphere in SAFA.

De Olde et al. (2016) and Berbeć et al. (2018) mentioned that RISE and SAFA have the largest number of specialized indicators. Under these methods, positive indicators were those related to animal and plant diversity. Jouzi et al. (2017) pointed to one of the advantages of small farms is the rational use of local resources.

Table 4 Sustainability scores of small-scale dairy systems by dimension and method

	IDEA		RISE		SAFA		*P*-value
	Median	IQR	Median	IQR	Median	IQR	
Environmental	70[a]	7.5	52[c]	6.8	58[b]	2.8	0.001***
Social	60	8.0	61	10.0	58	4.3	0.193
Economic	58[b]	15.7	52[b]	13.0	72[a]	5.5	0.001***
Good governance	-		-		58	5.5	-
Sustainability level	58[b]	10.4	56[b]	10.5	63[a]	2.0	0.001***

Results values are a scale 0 to 100, 0 is lower value, 100 is upper value; IQR Interquartile Range; ***$P \leq 0.001$ (Kruskal-Wallis test); [a, b, c] ($P < 0.05$ by Mann-Whitney *U* test)

The three methods utilized have strengths but also weak points. In the IDEA method, water is a weak issue, since IDEA only has an indicator for water management related in the studied farms to the availability of irrigation for pastures. RISE and SAFA, with similar scores, have water as a specific topic with indicators on measures for the saving and control of water, water quality and availability, and amounts of water used in the farm and for irrigation.

The IDEA method is general and does not consider important issues for the assessment of sustainability; while RISE and SAFA include more indicators that yield more reliable results. However, the inclusion of more themes to the assessment implies more specialized indicators that require more information and data that are not available in small-scale farms, as well as resources and time for the assessments.

In terms of the social component of sustainability, social indicators in the three methodologies are similar. IDEA, RISE, and SAFA established as positive indicators animal welfare, labor security, economic incomes above the community means, low generation of residues, and freedom to make decisions.

Indicators for the social dimension of sustainability are complex given the constant evolution of society, which makes it difficult to develop simple and precise indicators, and the fact that assessments take place at a specific moment in time (Vilain et al. 2008).

Hayati et al. (2010) stated that these indicators lead farms towards sustainable development. However, indicators as the intensity of work in IDEA are problematic due to the heavy workload, as has been identified in previous works (M'Hamdi et al. 2009; Fadul-Pacheco et al. 2013; Prospero-Bernal et al. 2017). Nonetheless, Moretti et al. (2016) mentioned that family labor strengthens farms making them more resilient to changes.

RISE identified a low quality of social relations, in contrast to IDEA and SAFA that identified strength in the relations among farmers. Even though social indicators have been developed since the inception of the sustainability concept (WCED 1987), methodologies have been negligent by diminishing their importance. Therefore, there is a need for the development of indicators to measure the creation of social capital (Vallance et al. 2011). In this work, social indicators (Table 3) and their objectives are similar in the three methods (Binder et al. 2010).

In the economic dimension of sustainability, positive indicators were the generation of economic incomes, adequate financial autonomy, low dependency of external subsidies, and the production of food for the community, key elements for farm resilience (Jongeneel and Slangen 2013).

Problematic indicators were low specialization of production, lack of available information and in the generation of information on the management of the farm. This affects decision making and results in a lack of knowledge of the actual processes, reducing economic efficiency as detected by IDEA and RISE.

SAFA results for the economic dimension agree with de Olde et al. (2016) who indicated that this method tends to overevaluate economic indicators, yielding results that do not coincide with the reality of farms that are not economically efficient. In contrast, IDEA and RISE are based on indicators as cash flow, incomes, and investments, which are easy to measure.

RISE allows for the lack of data in farms, while SAFA allows some specific themes to be omitted that may be irrelevant in a given context, avoiding the need for indicators that require unavailable data, using in place indicators based on practice (FAO 2013).

The economic scale is relevant in farm resilience, on which the continuity of farms relies (Hayati et al. 2010). Economic viability was an indicator with low scores in the three methods, which can be attributed to the expenditure in cattle feeding (purchase of external inputs), purchase of fertilizers, and dependence on fossil energy (gasoline and diesel). Therefore, the economic scale limits the sustainability of small-scale dairy systems (Prospero-Bernal et al. 2017).

Overall assessment of the sustainability by three methods

The three methods (IDEA, RISE, and SAFA) showed variation in the content of indicators, reference values, and methods for scoring and aggregation. This variation is due to the differences in judgment values, the context, and priorities of those involved in the development of each method (De Olde et al. 2017).

Variability in the methods gave rise to differences in the assessment of the sustainability of the studied farms, although results presented are transparent both in the use of the methods and in the results generated (De Olde et al. 2017), so that adaptation and integration of the various indicators are feasible due to their inter-relationships given their similarities as the three are multi-criteria methodologies (Binder et al. 2010).

Score values are different as each method values differently the indicators, assigning different scores based on their specific norms or assessment protocols for the scoring of indicators (Marchand et al. 2014). There are times when there are many possible variables integrating an indicator, and it may be difficult to decide which is best. At other times, variables are not easy to measure, or there are no data and must be changed for other less reliable variables (Sarandón 2002).

These aspects must be taken into consideration for a good assessment of sustainability in order to have an objective and reliable result for the farms that enable decision making in relation to weak points that need improvement.

The limitation of the three methods was the lack of information that could not be collected as farms have little data available, and there were not sufficient financial resources to undertake all laboratory analyses needed for a complete assessment.

RISE and SAFA offer possibilities to overcome the lack of information. RISE gives the option of qualitative measurements of indicators if specific data is missing as for economic or life quality indicators. SAFA allows for indicators of practice to be changed for indicators of yield which are easier to obtain. IDEA has indicators closer to on-farm situations that make it easier to adapt to specific contexts.

An aspect to take into consideration is that when adopting an existing method, like IDEA, RISE, or SAFA, the number of themes, indicators, and assessment procedures are defined, and most of the method to apply is fixed.

IDEA and RISE were specifically developed for the assessment of farm sustainability, while SAFA has a broader application that encompasses agriculture, forestry and fisheries, as well as the assessment of companies at a world scale (FAO 2013).

SAFA also proved to be the least applicable method for its use in small-scale farming. Firstly, some indicators require economic data of more than five previous years which are not available in the small-scale farms. Secondly, SAFA was not developed for small-scale farms, and thirdly, there is a large number of specialized indicators that are not easy to measure for lack of instruments, or financial and time resources. The interest in including SAFA in the study is that it was put forward as a probable better method given its development by a global organisation as FAO.

The proportion of sub-themes form a method that is dealt with by the other two is called sub-theme coverage. SAFA has an intermediate to high indicator coverage at 89% for IDEA and 92% for RISE. RISE has a coverage of 67% for SAFA and 81% for IDEA, and IDEA covers 59% for SAFA and 76% for RISE (De Olde et al. 2017).

SAFA is the method with the largest number of indicators also employed by IDEA and RISE. Soldi et al. (2019) mentioned that SAFA requires specialized work in the collection of information and is aimed at regional assessments, which are less sensitive at farm level. On the contrary, IDEA and RISE were developed to assess the sustainability of farms (De Olde et al. 2016).

IDEA has well-defined indicators, easy to collect that can be used at farms with limited information. On the contrary, RISE, as SAFA, has very specialized indicators at the environmental scale, and requires more technical and intellectual infrastructure for the assessment compared to IDEA, RISE, and SAFA may be considered for sustainability assessments with ample financial and time resources.

There will always be variability in the assessment tools as well as in the results since each method is based on the context, availability of scientific data, and knowledge of values and norms of those who develop the methods (De Olde et al. 2016).

The IDEA method was better adapted to the sustainability assessment of small-scale dairy systems in Mexico as most of its indicators may be collected on-farm and at easy to measure, compared to RISE and SAFA. Therefore, it is suggested to continue using the IDEA method in future assessments of sustainability in small-scale farming systems.

Conclusions

The IDEA, RISE, and SAFA methods share in essence the concept of sustainable development from the holistic integration of the environmental, social, and economic dimensions of sustainability, and are sensitive so that it is possible to identify problematic indicators, to make decisions that may guide farms towards an enhance sustainability.

IDEA and RISE were identified as the stronger methods for on-farm assessments and did not show differences in the social or economic scales, nor in the overall sustainability score.

IDEA was the less demanding method for environmental indicators in contrast to RISE and SAFA that concentrate efforts in this dimension. In SAFA, the economic scale is ambiguous since indicators are aimed at communities or larger regions. When applied at the farm level, SAFA does not detect small variations, particularly on the economic scale.

These three methods enable an understanding of sustainable development by generating an interaction between research institutions and farmers. Even though there is not a strong culture of sustainability in the study area, work undertaken enable to raise awareness of farmers, their families and communities.

The mean overall sustainability score over the three methods for the ten assessed farms was 55.3±5.7 over 100. There were no large differences between the three methods, even though indicators vary in the way of their measurement; they share more than 70% of objectives. This level of sustainability places farms at a critical level (Amber) following the color code, although towards the higher end, opening opportunities to enhance their sustainability.

Appendix A-1

Table 5. Score by indicators from the IDEA method in the assessment of sustainability of small-scale dairy systems.

Dimension	Theme	Subtheme or Indicator	Maximum possible	Mean	SD	Max	Min
Agroecological (100)	Diversity (33)	Diversity of annual or temporary crops	14	9	1.48	11	7
		Diversity of perennial crops	14	6	0.00	6	6
		Animal diversity	14	13	2.21	14	7
		Enhancement and conservation of genetic heritage	6	0	0.00	0	0
	Organisation of space (33)	Cropping pattern	8	1	1.64	5	0
		Dimension of fields	6	6	0.00	6	6
		Organic matter management	5	5	0.00	5	5
		Ecological buffer zones	12	3	0.63	5	3
		Measures to protect the natural heritage	4	0	0.00	0	0
		Stocking rate	5	1	1.90	5	0
		Forage area management	3	2	0.97	3	0
	Farming practices (34)	Fertilization	8	2	2.90	6	0
		Effluent processing	3	3	0.00	3	3
		Pesticides and veterinary products	13	8	1.03	9	7
		Animal well-being	3	3	0.00	3	3
		Soil resource protection	5	3	0.57	4	2
		Water resource protection	4	3	0.95	4	1
		Energy dependence	10	0	0.00	0	0
Socio-territorial (100)	Quality of the products of the land (33)	Quality of foods produced	10	5	0.63	5	3
		Enhancement of buildings and landscape heritage	8	0	0.00	0	0
		Processing of non-organic waste	5	2	1.41	3	0
		Accessibility of space	5	5	0.00	5	5
		Social involvement	6	4	0.00	4	4
	Employment and services (33)	Short trade	7	4	1.26	4	0
		Autonomy and valuation of local resources	10	7	0.63	7	5
		Services, multi-activities	5	0	0.00	0	0
		Contribution to employment	6	6	0.00	6	6
		Collective work	5	4	0.42	5	4
		Probable farm sustainability	3	2	0.67	3	1
	Ethics and human development (34)	Contribution to world food balance	10	6	2.57	8	2
		Animal welfare	3	1	0.70	2	0
		Training	6	4	1.16	6	2
		Labour intensity	7	0	0.42	1	0
		Quality of life	6	3	0.48	4	3
		Isolation	3	3	0.00	3	3
		Reception, hygiene and safety	4	4	0.00	4	4
Economic (100)	Economic viability (30)	Available income per worker in relation to national legal minimum wage	20	15	2.26	19	12
		Economic specialization rate	10	1	1.20	3	0
	Independence (25)	Financial autonomy	15	10	6.60	15	0
		Reliance on direct subsidies from governmental agency and indirect economic impact of milk and sugar quotas	10	9	1.70	10	6
	Transferability (20)	Total assets minus lands value by non-salaried worker unit	20	15	5.25	20	8
	Efficiency (25)	Operating expenses as a proportion of production value	25	8	4.30	9	2

Appendix A-2

Table 6 Score by indicators from RISE method in the assessment of sustainability of small-scale dairy systems.

Dimension	Theme	Subtheme or Indicator	Maximum possible	Mean	SD	Max	Min
Environmental (100)	Soil use (100)	Soil management	100	51	1.25	67	25
		Crop productivity	100	38	1.64	75	20
		Soil organic matter	100	62	2.08	98	23
		Soil reaction	100	67	0.00	67	67
		Soil erosion	100	95	0.77	100	84
		Soil compaction	100	45	1.35	65	15
	Animal husbandry (100)	Herd management	100	28	1.92	67	0
		Livestock productivity	100	88	1.15	100	71
		Opportunity for species-appropriate be-haviour	100	78	1.80	100	50
		Living conditions	100	94	0.72	100	79
		Animal health	100	70	1.67	83	25
	.materials use and environmental protection (100)	.materials flows	100	47	0.86	58	30
		Fertilization	100	23	1.28	44	9
		Plant protection	100	36	1.19	50	25
		Air pollution	100	49	1.29	66	29
		Soil and water pollution	100	59	0.83	69	43
	Water use (100)	Water management	100	46	0.69	54	35
		Water supply	100	70	0.67	83	63
		Water use intensity	100	41	0.64	52	34
		Irrigation	100	61	0.99	70	43
Environmental (100)	Energy and climate (100)	Energy management	100	55	1.57	70	25
		Energy intensity	100	76	3.38	100	3
		Greenhouse gas balance	100	0	0.00	0	0
	Biodiversity (100)	Biodiversity management	100	36	0.62	42	26
		Ecological infrastructures	100	88	3.11	100	2
		Intensity of agricultural production	100	28	2.25	80	0
		Distribution of ecological infrastructures	100	41	1.88	63	18
		Diversity of agricultural production	100	28	0.62	39	19
Social (100)	Working conditions (100)	Personnel management	100	72	2.06	94	39
		Working hours	100	74	1.27	100	56
		Safety to work	100	62	0.92	85	55
		Wage and income level	100	50	1.12	67	31
	Quality of life (100)	Occupation and training	100	44	1.62	75	25
		Financial situation	100	44	2.08	88	25
		Social relations	100	79	0.99	88	63
		Personal freedom and values	100	49	1.08	67	33
		Health	100	73	1.54	88	38
Economic (100)	Economic viability (100)	Liquidity	100	23	2.49	75	0
		Stability	100	33	2.64	75	0
		Profitability	100	35	0.80	50	25
		Indebtedness	100	54	4.72	100	0
		Livehood security	100	46	2.33	75	0
	Farm management (100)	Business goals, strategy and implementation	100	80	0.91	88	63
		Availability of information	100	33	0.91	49	21
		Risk management	100	91	0.95	100	7
		Sustainable relationships	100	62	0.82	75	50

Appendix A-3

Table 7 Score by indicators from SAFA method in the assessment of sustainability of small-scale dairy systems.

Dimension	Theme	Subtheme or Indicator	Maximum possible	Mean	SD	Max	Min
Good governance	Corporative ethics	Mission statement	100	0	0	0	0
		Due diligence	100	0	0	0	0
	Accountability	Holistic audits	100	0	0	0	0
		Responsibility	100	40	0	40	40
		Transparency	100	0	0	0	0
	Participation	Stakeholder dialogue	100	63	14	87	40
		Grievance procedures	100	0	0	0	0
		Conflict resolution	100	60	23	100	20
	Rule of law	Legitimacy	100	60	0	60	60
		Remedy, restoration and prevention	100	0	0	0	0
		Civic responsibility	100	0	0	0	0
		Resource appropriation	100	90	0	90	90
	Holistic management	Sustainability management plan	100	0	0	0	0
		Full-cost accounting	100	0	0	0	0
Environmental integrity	Atmosphere	Greenhouse gases	100	37	4	40	33
		Air quality	100	78	8	83	67
	Water	Water withdrawal	100	55	0	55	55
		Water quality	100	48	14	54	21
	Land	Soil quality	100	62	11	75	39
		Land degradation	100	27	18	50	0
	Biodiversity	Ecosystem diversity	100	71	13	92	50
		Species diversity	100	36	11	51	22
		Genetic diversity	100	75	15	89	52
	Materials and energy	.materials use	100	69	0	69	69
		Energy use	100	77	13	94	50
		Waste reduction and disposal	100	84	8	94	78
	Animal welfare	Animal health	100	52	17	60	30
		Freedom from stress	100	80	15	100	63
Economic resilience	Investment	Internal investment	100	90	11	100	80
		Community investment	100	92	25	100	20
		Long-ranging investment	100	42	14	70	30
		Profitability	100	57	31	67	0
	Vulnerability	Stability and production	100	80	9	88	63
		Stability and supply	100	77	0	77	77
		Stability of market	100	83	0	83	83
		Liquidity	100	50	0	50	50
		Risk management	100	90	32	100	0
	Product quality and information	Food safety	100	23	5	33	20
		Food quality	100	65	14	100	50
		Product information	100	0	0	0	0
	Local economy	Value creation	100	100	0	100	100
		Local procurement	100	100	0	100	100
Social wellbeing	Decent Livelihood	Quality of life	100	69	2	100	30
		Capacity development	100	60	0	60	60

Table 7 (continued)

Dimension	Theme	Subtheme or Indicator	Maximum possible	Mean	SD	Max	Min
		Fair access to means of production	100	56	2	80	20
	Fair trading practices	Responsible buyers	100	54	2	60	0
		Right of supplies	100	0	0	0	0
	Labour right	Employment relations	100	0	0	0	0
		Forced labour	100	0	0	0	0
		Child labour	100	0	0	0	0
		Freedom of association and right to bargaining	100	0	0	0	0
	Equity	Non discrimination	100	60	0	60	60
		Gender equality	100	50	0	50	50
		Support to vulnerable people	100	91	0	100	10
	Human safety and health	Workplace safety and health provisions	100	48	5	50	33
		Public health	100	65	21	75	25
	Cultural diversity	Indigenous knowledge	100	0	0	0	0
		Food sovereignty	100	82	5	84	67

Appendix B. 2. Indicators not considered in the assessment of the sustainability of small-scale dairy systems by three methods.

Table 8 IDEA method.

Indicator	Reason
Enhancement and preservation of genetic heritage	This indicator is to valorise species that are in danger of extinction, which was difficult to evaluate because of a lack of background information.
Ecological buffer zones	The information was not available.
Measures to protect the natural heritage	This indicator is to evaluate the conservation of native species or breeds, which was difficult to assess due to lack of information.
Enhancement of landscape	Evaluates the heritage of the landscape, mostly referring to the European Common Agricultural Policy, which is not applicable to the context of Mexico.
Services and multi-activities	The farms do not offer services of agro-ecotourism or educational farms, so this indicator was not relevant at the moment of the evaluation.
Short trade	As farmers do not have any direct contact with final consumers, this indicator was not applicable.

RISE method

The only indicator not included was the greenhouse gas (GHG) balance, since there was no possibility to measure GHG emissions.

SAFA method

Social	
Rights of suppliers	Not applicable to small-scale dairy farms
Labour relations	Small-scale dairy farms rely on family labour
Forced labour	There is no forced labour in the study area
Child labour	Children help with chores on the farm, but there is no forced child labour
Freedom of association and right to bargaining	Does not apply to small-scale family farms
Indigenous knowledge	There are no indigenous communities in the study area
Economy	
Information about the product	Milk is sold raw to local buyers in informal markets
Governance	
Mission explicitness	These indicators refer to formal enterprises. Small-scale family farms do not have these.
Due diligence	
Holistic audits	
Transparency	
Complaint procedures	
Civil responsibility	
Sustainability management plan	
Full-cost accounting	

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Data availability The data that support the findings of this study are available from the corresponding author upon reasonable request.

Code availability (software application or custom code) Not applicable

Declarations

Ethics approval The work with collaborating farmers followed guidelines accepted by Instituto de Ciencias Agropecuarias y Rurales (ICAR) of Universidad Autónoma del Estado de México.

Consent to participate On-far work herein reported was carried out with ten collaborating farmers, who were aware of the objectives of the work, were duly informed, consulted and their decisions respected at all times, actively participated in the study, and their privacy and that of their families respected by not disclosing their names.

Consent for publication Not applicable.

Conflict of interest The authors declare that they have no conflict of interest.

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