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Indicators of sustainability to assess aquaculture systems

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ABSTRACT

Aquaculture is one of the fastest-growing food-producing sectors worldwide, making it desirable to assess the sustainability of aquaculture systems. The objective of this study was to develop a portfolio of quantitative indicators of economic, environmental and social sustainability to assess different aquaculture systems. The indicators were developed from 2003 to 2016, combining top-down and bottom-up methods, together with practical observations in experimental and commercial aquaculture facilities. A total of 56 economic (14), environmental (22) and social (20) indicators are proposed. Economic sustainability indicators reveal the degree of efficiency in using financial resources, the economic feasibility, resilience, and the capacity to absorb negative external costs and to generate funds for reinvestment. Environmental indicators reflect the use of natural resources, the efficiency in using resources, the release of pollutants and unused byproducts, and the risk of reducing biodiversity. Social sustainability indicators reflect the capacity to generate benefits for local communities, including jobs and food security, equitable income distribution, equality of opportunity, and inclusion of vulnerable populations. The indicators thus developed can be used on farm, regional, global or sectorial scales. They are quantitative, broad, scientifically sound, easy to understand and interpret, feasible to obtain on farms or on research stations, and permit comparison at different scales of space and time. Thus, they can be used to assess production systems and to compare different experimental treatments in research experiments. They also can be used by certifying organizations, investors, and policymakers. They allow performing diagnostics, identifying strengths and weaknesses, setting goals and determining actions, and assessing the effectiveness of actions and public policies.

1. Introduction

Aquaculture development has yielded many positive socio-economic results. This is one of the fastest-growing food-producing sectors worldwide and provides slightly more than half of all fish for human food (FAO, 2016). Nonetheless, the impact of aquaculture farming on the environment and the prospects for its sustainability have raised concern since the early 1990s (Folke and Kautsky, 1992; Naylor et al., 2000; Samuel-Fitwi et al., 2012; Perdikaris et al., 2016). These impacts may generate costs for society as a whole as well as problems for the farmers themselves, via negative feedback on production (Neiland et al., 2001). Estimating the magnitude of these external factors and including them in the cost of production has been a challenge for environmental economists and scientists involved with aquaculture sustainability. In addition, the impacts of aquaculture on the local economy, food security, and social development of rural communities are key topics for policies of sustainable development (Costa-Pierce, 2010; Béné et al., 2016).

Sustainability has been described in many ways by different authors and institutions (see Johnston et al., 2007). However, there is agreement on some fundamental points. Thus, one can define sustainability as the management of financial, technological, institutional, natural and social resources, ensuring the continuous satisfaction of human needs for the present and future generations. Sustainability is an anthropocentric concept that considers human needs above everything, excluding other kinds of life, unless they affect the human species. Moreover, sustainability involves perenniality in time. Time scale is the duration of the human generations. Therefore, sustainable ventures should persist throughout human generations. Every future generation must inherit a stock of natural resources, equal to or larger than the one

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inherited by the previous generation (WCED, 1987). Sustainability requires a human lifestyle within the limits imposed by nature; we must live within the capacity of the natural capital.

Nowadays, there is a consensus that production systems such as aquaculture should be sustainable. However, it is essential to define what is sustainable and to know how sustainable systems really are. Totally sustainable systems are still far from being realized. However, there is a gradient between unsustainable and sustainable systems, and therefore we can recognize different levels of sustainability. Achieving sustainability is an awkward task that must be carried out step by step, based on sustainable interventions in the existing systems. The main rationale of sustainable actions is assuming that natural resources are finite, changing the neoclassical economic vision that there are no limits to growth. The adoption of more-sustainable practices, such as the use of best management practices (Boyd, 2003), is a start on the long road to attainment of sustainability, but it is not enough. Production systems are not necessarily sustainable just because best management practices are applied (Belton et al., 2009). Thus, it is essential to measure sustainability to assess the strengths and weaknesses of each current aquaculture system, the new technologies available, and the efficacy of interventions toward sustainability.

Nevertheless, methods to assess aquaculture sustainability are not commonly used. The major difficulty is the challenge of exploring and analyzing the production systems in a holistic way. It is essential to contemplate the economic, environmental and social dimensions of sustainability (UN, 1992). Thus, comparing measurements of variables of a very different nature is mandatory. Some complex methods that are sometimes used to evaluate aquaculture sustainability are ecological and carbon footprint (Folke et al., 1998; Gyllenhammar and Håkanson, 2005; Madin and Macreadie, 2015), life cycle assessment (Gronroos et al., 2006; Aubin et al., 2006, 2009; Santos et al., 2015; Medeiros et al., 2017) and emergy analysis (Cavalett et al., 2006; Vassallo et al., 2007, 2009; Lima et al., 2012; Shi et al. 2013; Zhao et al., 2013; Garcia et al., 2014; Wang et al., 2015; Williamson et al., 2015). These methods give an integrated overview of the systems. However, they require a vast amount of data that are difficult to obtain. In addition, the first method focuses mainly on the environmental dimension, and the results of other methods are very difficult to interpret.

On the other hand, aquaculture sustainability can be divided into parts that can be evaluated using sets of indicators. Indicators are variables defined to reflect a phenomenon or a process in a simplified way. They measure specific attributes of a system. Indicators are a powerful tool to reduce system complexity and can be used to compare different systems or the evolution of the same system over time. Their fluctuations reveal the variation in the elements that they represent. Indicators allow incorporating science-based knowledge into decision-making (UN, 2007) and afford a connection between objectives and actions (FAO, 1999). They can be used individually or as aggregated indices, in which individual scores are combined (Waas et al., 2014). The development and choice of indicators are related to the adopted concept of sustainability and the purpose of the indicator set (UN, 2007).

Following the Rio Conference in 1992 (UN, 1992), many indicators were developed mainly to assess environmental sustainability. In this context, some groups of indicators have been proposed to evaluate aquaculture sustainability (FAO, 1998, 1999; EAS, 2005; Boyd et al., 2007; Pullin et al., 2007; Rey-Valette et al., 2008, 2010; Valenti, 2008; FOESA, 2010; Valenti et al., 2011; FAO, 2011; Fletcher, 2012; Hofherr et al., 2012; Fezzardi et al., 2013). Only a few of them were published in scientific journals and thus, most of the information is hidden in grey literature. On the other hand, particular certifier institutions have developed indicators to assess the compliance of production systems with legislation, rules, and regulations defined in response to the consumers' desires. The most known are the Aquaculture Stewardship Council (ASC Certification; Aquaculture Stewardship Council, 2017) and Global Aquaculture Advocate (BAP Certification; Best Aquaculture Practices, 2017). Others have developed guides to responsible consumption, such as Monterey Bay Aquarium (Seafood Watch, 2017). Certifiers and guiders aim to help the consumers select products that match their food postures and preferences (Alfnes et al., 2017); thus, they define indicators based on the market. They try to measure responsible farming practices instead of focus on the central rationale of sustainability that is the capacity of a system persists in time. Some articles using indicators of sustainability to assess aquaculture systems have been published (Dalsgaard et al., 1995; Lightfoot et al., 1996; Dalsgaard and Oficial, 1997; Caffey et al., 2001; González et al., 2003; Stevenson et al., 2005; Tipraqsa et al., 2007; Bergquist, 2007; O'Ryan and Pereira, 2015; Chowdhury et al., 2015; Ting et al. 2015, Moura et al., 2016). However, most of the indicators proposed are qualitative, restricted to environmental dimension, specific regions, species or systems, must be obtained from secondary data (which often are not available), or were developed to help the consumer decisions. In addition, generally, their efficacy in comparing different systems remains to be demonstrated. Therefore, much more science-based information is necessary in this field.

The objective of this study was to develop a portfolio of quantitative indicators of economic, environmental and social dimensions of sustainability, based mainly on primary data, to assess aquaculture systems. The indicators developed are easy to obtain worldwide, enable comparison of the enormously diverse aquaculture systems in different regions and using different species, allow monitoring the evolution of aquaculture on different time scales, and are clearly understandable. In addition, they reflect the concept of sustainability instead of other concepts based on conventions of farmers or consumers, frequently used by certifier institutions.

2. Methods

The set of indicators were developed based on studies performed in Brazilian universities, public agencies, and commercial farms from 2003 to 2016. Generally, indicators are defined according to criteria proposed by committees of experts or by panels involving all actors and stakeholders of the production chain. The first situation is called top-down and the second, bottom-up method. In the present study, we used a combination of both methods, combined with practical observations in experimental and commercial aquaculture facilities.

From 2003 to 2008, we conducted several discussions among scientists and graduate students from different institutions, combined with practical tests carried out in experimental aquaculture units at the Aquaculture Center, São Paulo State University. This included two international and some local workshops. During this time, we have established a set of indicators by the top-down method (Valenti, 2008; Valenti et al., 2011). In 2009, we discussed them with a panel of actors and stakeholders of aquaculture in Brazil during meetings promoted by the Brazilian Ministry of Fisheries and Aquaculture. Thus, we created a new set of indicators approved by all groups.

From 2010 onward we started the validation phase. This set of indicators was tested on 22 commercial aquaculture farms in all regions of Brazil. These included different grow-out system farms of marine shrimp, freshwater prawns, oysters, mussels, carps, tilapia, tambaqui (cachama), lambari (bait fish) and multitrophic culture systems. One fish and one prawn hatchery were also studied. Besides, the same indicators were used in Master's and Ph.D. dissertations to assess different treatments in experiments (Boock, 2012; Proença, 2013; Dantas, 2016). Data on economic and social indicators were obtained by interviews conducted with farm owners and employees, using semi-structured questionnaires. Direct observations "in loco" were also conducted to check and complete the information. Secondary data including gender, race, ethnicity, and mean income of the local populations were obtained from official local institutions, generally available at the certified websites. To obtain and process the environmental samples, we selected the relevant methods and units defined in the Standard Methods for the

Examination of Water and Wastewater (APHA, 2005) and Official Methods of Analysis of AOAC International (AOAC, 1995). For greenhouse gases, we adapted the sampling and analysis methods from Matvienko et al. (2000). After six years of tests, we selected those indicators that are feasible and easy to obtain, universal, clearly understandable and broad to assess the sustainability of different aquaculture systems. Then, we reviewed the mathematical formulae and obtained the final set of indicators.

The method for building the indicators was the dimensions-principles-criteria-indicators framework (Rey-Valette et al., 2008, 2010). This approach is based on a hierarchical nesting array, which links the indicators to typical components of sustainability. Dimensions and principles were defined based on the sustainable-development postulates established in Agenda 21 (UN, 1992), which were adapted to aquaculture. The three dimensions of sustainability used were economic, environmental and social. For each dimension, we defined principles, e.g., high-level targets or issues components of sustainability concept. Each principle was divided into criteria, which were specific features or characteristics of the systems that we want to assess and monitor. To represent each criterion we developed an indicator. Indicators are relevant variables to be measured that reflect each criterion and can be determined qualitatively or quantitatively. Indicator fluctuations reveal the variations of the criteria (FAO, 1999) over time and spatial scales or among different production systems or regions. An indicator is a measurable variable used to report a non-measurable reality.

Indicators were defined to assess and monitor sustainability on different scales, which were arranged in four hierarchical levels: farm, regional, global and sector levels. Farm indicators are suitable for use at the production unit. Regional indicators should be used in a particular geographical region with specific characteristics, or inserted into a context, which includes small homogenous zones and large territories, or political divisions, such as provinces or countries. Global indicators are suitable for use on the world scale. Sectorial indicators should be used to assess and monitor different segments of aquaculture, such as tilapia culture, shrimp culture, mollusk culture, integrated systems and others. Some indicators are specific for one level, whereas others may be applied at different levels.

3. Results

Principles, criteria, and indicators for each dimension are shown in Table 1. A total of 56 economic (14), environmental (22) and social (20) indicators of sustainability were selected. They are explained below. The most appropriate scales (levels) of application are indicated following the name of each indicator (F = farm; R = regional; G = global; S = sector). Data needed for calculating these selected indicators were obtained on different farms from different regions without difficulty. The procurement of data and the results were well received by the farmers who were visited.

3.1. Economic sustainability indicators

Economic sustainability indicators show the efficiency in using financial resources, the economic feasibility, the capacity to absorb negative externality costs, the capacity for resilience, and the capacity to generate capital for reinvestment.

1. Ratio between Net Income and Initial Investment (RII) F

   Net income corresponds to the sum of the profit and the opportunity cost. The opportunity cost includes farmer remuneration, interest over investment and operating capital, and land leasing (Shang, 1990).

   RII = Net income/initial investment

Indicators 2 to 6 were defined based on indicators of economic feasibility that are generally used in neoclassical economics. These include the Internal Rate of Return, Payback Period, Benefit-Cost Ratio, Net Present Value, and Profit (Shang 1990; Jolly and Clonts, 1993; Engle, 2010). However, for analyses of sustainability, we have included the externality costs (e) in the equations and defined the minimum time in operation as 20 years, which is a baseline to estimate the human generation time.

2. Internal Rate of Return (IRRe) F

$$\sum_{i=0}^{n} \frac{Bi - Ci + \mathrm{Ep}i - \mathrm{En}i}{(1 + IRR)^{i}} = 0$$

in which:

B_i = total benefit (or revenue) of year i;
C_i = total cost of year i (capital + operating costs);
$E\mathrm{p}_i$ = total positive externalities;
$E\mathrm{n}_i$ = total negative externalities;
n = the number of years in operation, $n \geq 20$;
i = the ith year.

3. Payback Period (PPe) F

$$\sum_{i=0}^{j} NCF_i = 0$$

in which:

j = PP in years;
NCF_i = annual net cash flow of year i;
i = 0,1,2,…j…, n. n ≥ 20

4. Benefit-Cost Ratio (B/Ce) F

$$B/C = \frac{\sum_{i=0}^{n} \frac{Y_i}{(1+r)^i}}{\sum_{i=0}^{n} \frac{K_i}{(1+r)^i}}$$

in which:

Y_i = net annual benefit of year $i = B_i - O_i + Ep_i - En_i$
B_i = total benefit (or revenue) of year i;
O_i = operating cost of year i;
Ep_i = total positive externalities;
En_i = total negative externalities;
K_i = capital outlay for assets of year i (initial investments + reinvestments);
r = discount rate;
n = number of years in operation. $n \geq 20$.

5. Net Present Value (NPVe) F

$$NPV = \sum_{i=0}^{n} \frac{B_i - C_i + \mathrm{Ep}i - \mathrm{En}i}{(1 + r)^{i}}$$

in which:

B_i = total benefit (or revenue) of year i;
C_i = total cost of year i (capital + operating costs);
Ep_i = total positive externalities;
En_i = total negative externalities;
r = discount rate;
n = number of years in operation (0, 1, 2,…, n), $n \geq 20$;
i = the ith year.

6. Net Profit (NPe) F

$$NPe = GR - TPC + Ep_i - En_i$$

Table 1
Dimensions, principles and criteria used to define the indicators. See the text for the name of indicators.

Dimension/Principle	Criteria	Indicators	Justification	Data source
Economic				
1. Ensure efficient use of capital and profitability, including externalities	Level of capital efficiency	RII	Economic sustainability is based on the efficient use of financial capital to promote profitable and resilient enterprises, which pay for negative externalities, reinvest and receive for ecosystem services	In situ interviews and personal observation
	Level of profitability	IRRe, PPe, B/Ce, NPVe, NPe		
	Level of externalities	En, Ep		
2. Improve farm longevity, and the capability of its resilience and development	Capacity of permanence in the aquaculture sector	AI, PA		In situ interviews and personal observation, and some secondary data from micro-economy obtained on the internet
	Capacity of resilience to changes in scenarios	RR, DP, DM		
	Capacity of development of the farm or a sector	ICGA		
Environmental				
3. Ensure the minimum use of natural resource and maximum efficiency in using resources	Level of use of space, water, energy and materials	S, W, E, PRE, N, P	Environmental sustainability is based on the use of the lowest amount of natural resources with the maximum efficiency and minimum negative impact to surrounding environment.	In situ samples and measurements followed by laboratory analyses
	Level of efficiency in using materials and energy	EE, EN, EP, PU		
4. Ensure the minimum release of pollution and useless by-products, and the lowest risk to biodiversity	Level of pollution	PEn, PEp, POP, PS, PGW, GCP, PH, PHM, PA		
	Level of material accumulated inside production systems	AP, AOM, APM		
	Level of risk of the cultured species to biodiversity	RFS		
Social				
5. Improve local economy, employment, safety at work, and food security	Proportion of payments to persons and companies at local community	LE, LW, RLUP	Social sustainability is based on local development, with gains to local communities, while respecting their culture and habits.	In situ interviews and some secondary data from the farm region, obtained in official institutions
	Level of new jobs created, and quality of the jobs	ICDE, ICTE, SE, PA, WA, WP		
	Level of risk to employees at farm	SW		
	Level of products consumed by local population	LC		
6. Improve income equality and social benefits	Level of income distribution	PE, PCW, ID		
	Level of access to social benefits	AHP, Sc, PCA		
7. Ensure inclusion of minorities and vulnerable people	Level of inclusion of genera, race and age	GI, RI, AI		

in which:
GR = Gross revenue;
TPC = Total production cost = Fixed cost + Variable cost;
Ep_i = total positive externalities;
En_i = total negative externalities.

For comparing farms of different sizes, NPe should be divided by the farm areas.

Indicators 7 and 8 measure the positive or negative effect on the third part. Farms with a lower total cost of all negative externalities, or a higher total income from all positive externalities, per unit of product, are more sustainable. The sum of positive and negative externalities (with minus sign) per unit of product should be compared with the profit per unit of product.

7. Negative Externalities (En) F, R, G, S
This measures the damage caused to unrelated third parties (Pigou, 2005) as a consequence of the aquaculture activity, in US$ per unit of production. This includes the damage caused to traditional economic activities in the region, such as artisanal fisheries or even other sectors of the economy. Damage to the environment or other common resource, such as that caused by pollution, is also damage to unrelated third parties, i.e., the people affected.
En = sum of the negative externalities generated during setup and operation phases/mass or units produced.

8. Positive Externalities (Ep) F, R, G, S
Measures the benefits provided to unrelated third parties as a consequence of the aquaculture activity, in US$ per unit of production
Ep = sum of the environmental services (and other benefits) generated during the operation/mass or units produced.

9. Annual Income (AI) F
Annual income is defined as the sum of the profit to the opportunity cost. Taxes and fees vary among locales, states, provinces, and countries. Thus, these two variables should be deleted for comparisons between systems at different sites. For comparing farms of different sizes, AI should be divided by the farm areas.

$$AI = GR - OC - D - T - F$$

in which:
GR = Gross revenue;
OC = Operating costs;
D = Depreciation;
T = Taxes;
F = Fees.

10. Permanence of the Farmer in the Activity (PA) R, G, S
This indicator measures the average business lifetime based on the time, in years, that each company dedicates to aquaculture.

$$PA = \sum_{i=0}^{n} \frac{Fi}{n}$$

in which:
F_i = number of years in operation of the farm *i;*
i = the *i*th farm;
n = total number of farms.

Indicators 11 to 13 measure the system resilience, i.e., the capacity of the system to support changing situations and crises over time.

11. Risk Rate (RR) F, S
The Risk Rate includes 11 factors that increase the risks of negative impacts on aquaculture:
   a. Lack of a business plan during the planning stage;
   b. The owner/manager lacks technical or administrative capacity, or there is no trained staff;
   c. Administrative deficiencies in logistics and troubleshooting, such as neglect emergency systems to prevent disruption of the electrical supply on farms that depend on electricity to operate equipment;
   d. Lack of a well-established market for the product, i.e., the producer needs to develop the market;
   e. Farm is installed at an inappropriate site, such as subject to flooding, drought or other climate constraints; urban, rural and industrial pollution; legal restrictions (e.g. environmentally protected area), etc.;
   f. Lack of technical support and/or extension services to improve management and to solve problems, such as diseases, sanitary, economic and market issues;
   g. Lack of nocturnal and weekend supervision and/or surveillance and security systems against theft;
   h. Practice of intensive system, adding much material and energy and operating close to the carrying capacity of the system;
   i. Institutional instability: continual changes in laws and regulations by funding, regulatory and enforcement agencies;
   j. Agglomeration: close proximity to other farms producing the same organism, which use the same environmental services and produce the same type of pollution;
   k. The farm faces conflicts with the local community and/or NGO.

RR = number of risk factors observed/number of risk factors analyzed

12. Diversity of Products (DP) F, S
Number of products and services traded, such as the number of fish species, other agricultural products and/or services.

$$DP = \{1,2,3,4,5,6,\ldots,n\}$$

13. Diversity of Markets (DM) F, S
Number of markets exploited by the enterprise to trade the products and services, such as foreign markets (exportation), wholesale, retailers, hotels, restaurants, farmers' markets, farm-gate (farm stands), and others.

$$DM = \{1,2,3,4,5,6,\ldots,n\}$$

14. Invested Capital Generated in the Activity (ICGA) F, S, R
Capacity of development of each farm or aquaculture sector (e.g. tilapia culture, shrimp culture, etc.) can be evaluated based on the proportion of the investment that has been generated by the aquaculture activity on the farm or in the sector itself.

$$ICGA = \text{part of the investment generated in the activity/total investment}$$

3.2. Environmental sustainability indicators

These indicators were defined to reflect the use of natural resources, the efficiency in using resources, the release of pollutants and unused byproducts, and the risk of damaging genetic diversity and biodiversity. The indicators include the amount of materials and energy used to produce each unit of product (measured in kilograms, tonnes, numbers or other relevant units), the quantity of material and energy that is assimilated into the product, and the amount of pollutants released into the environment for each unit of product.

Indicators 1 to 6 measure the use of the main natural resources, such as space, water, energy, nitrogen, and phosphorus. Indicators 1, 2, 5 and 6 may be quoted as an adaptation from Boyd et al. (2007), although they were developed by our group before that publication.

1. Use of Space (S) F, S
   This indicator measures the area used (ha, m^2) per unit of production (kg, t, units)
   S = area used/production

2. Dependence on Water (W) F, S
   This indicator measures the volume of water used per unit of production. Only the consumed water should be considered. The water that returns to the environment in a similar condition to which it was withdrawn is not considered consumed, but if it returns polluted, it should be considered consumed.
   W = consumed volume/production

3. Use of Energy (E) F, S
   This indicator measures the total energy applied to the system in its various forms, such as food, fertilizer, electricity, fossil fuels, and others, per unit of production.
   E = energy applied/production

4. Proportion of Renewable Energy (PRE) F, S
   Measures the relative amount of renewable energy applied in the system. Renewable energy sources include food, organic fertilizer, ethanol, biodiesel and other energy obtained from live organisms, and solar (photovoltaic), wind, tidal and geothermal energy. Hydropower is not considered renewable because water reservoirs have a limited life span.
   PRE = amount of renewable energy/total amount of applied energy

Indicators 5 and 6 measure the use of materials. They are measured based on the mass of a given material used in farming for each production unit. Nitrogen and phosphorus were used as key materials.

5. Use of Nitrogen (N) F, S
   N = mass of nitrogen applied/production

6. Use of Phosphorus (P) F, S
   P = mass of phosphorus applied/production

Indicators 7 to 10 measure the efficiency in using resources. They show whether or not the resources are being incorporated into production.

7. Efficiency in the Use of Energy (EE) F, S
   EE = energy recovered in production/energy applied

8. Efficiency in the Use of Nitrogen (EN) F, S
   EN = mass of nitrogen recovered in production/mass of nitrogen applied

9. Efficiency in the Use of Phosphorus (EP) F, S
   EP = mass of phosphorus recovered in production/mass of phosphorus applied

10. Production Actually Used (PU) F, S
    This indicator shows the proportion of unused wastes in the biomass of the farmed species. Examples of wastes are fish guts and heads, shrimp heads and shells, mollusk shells and others.
    PU = mass of unused portions of the farmed organism/total mass produced

Indicators 11 to 18 measure pollutants released to the environment and reflect negative environmental impacts of aquaculture. They measure the potential for pollution. Indicators 11, 12, and 13 may be quoted as an adaptation from Boyd et al. (2007), although they were developed by our group before that publication.

11. Potential of Eutrophication (PE_N and PE_P) F, R, S
    PE_N = Load (mass) of nitrogen released in effluents/mass or units produced
    PE_P = Load (mass) of phosphorous released in effluents/mass or units produced

12. Potential of Organic Pollution (POP) F, R, S
    POP = Load (mass) of organic matter released in effluents/mass or units produced

13. Potential of Siltation (PS) F, R, S
    PS = Load (mass) of total suspended solids released in effluents/mass or units produced

14. Potential of Global Warming (PGW) F, R, G, S
    PGW = Load of greenhouse-effect gases released to the atmosphere/mass or units produced
    Greenhouse gases = mass of $CO_2 + CH_4 + N_2O$, measured in CO_2 equivalents

15. General Chemical Pollution (GCP) F, R, S
    GCP = Load of applied chemical products = mass of herbicides, insecticides, anti-algals, antibiotics, and other chemicals applied/mass or units produced

16. Pollution by Hormones (PH) F, R, S
    PH = Load (mass) of hormones applied/mass or units produced

17. Pollution by Heavy Metals (PHM) F, R, S
    PHM = Load (mass) of heavy metals applied/mass or units produced

18. Potential of Acidification (PA) F, R, S
    PA = Load of acidifying gases released to the atmosphere/mass or units produced
    Acidifying gases = ammonia + nitrogen oxides + sulfur oxides, measured in SO_2 equivalents

Indicators 19 to 21 measure pollutants accumulated in ponds or on the bottom of a water body in open-water systems, such as net-cages, long lines, trays, and others.

19. Accumulation of Phosphorus (AP) F, R, S
    AP = Load (mass) of P accumulated in sediment/mass or units of organism produced

20. Accumulation of Organic Matter (AOM) F, R, S
    AOM = Load (mass) of Organic Matter accumulated in sediment/mass or unities of organism produced

21. Accumulation of Particulate Material (APM) F, R, S
    APM = Load (mass) of Particulate Material accumulated in sediment/mass or units of organism produced

Indicator 22 measures the risk of the farm to the conservation of genetics and biodiversity.

22. Risk of Farmed Species (RFS) R, S

    RFS = {1,2,3,4,5,6 or 8}

    in which:
    1 = Local strain farmed in an open or closed system;

2 = Species within the same basin (but not local strain) farmed in a closed system;
3 = Species within the same basin farmed in an open system;
4 = Allochthonous species, native species with reduced genetic variability, or hybrid (native or allochthonous species) farmed in a closed system;
5 = Allochthonous species, native species with reduced genetic variability, or hybrid (native or allochthonous species) farmed in an open system;
6 = Transgenic variety of any species farmed in a closed system;
8 = Transgenic variety of any species farmed in an open system.

3.3. Social sustainability indicators

Social sustainability indicators should reflect the capacity to generate benefits to local communities, including jobs and food security, equitable income distribution, equality of opportunities and inclusion of vulnerable populations. Social benefits, such as health insurance paid by the company and opportunities to continue studies also should be considered.

1. Development of Local Economy (LE) R
   This indicator measures the proportion of expenditures for goods and services that are acquired in local markets.
   LE = use of products and services from local markets ($)/total products and services used ($)

2. Use of Local Workers (LW) F, R
   LW = number of jobs generated that permit recruitment among the local population/total number of jobs generated

3. Remuneration of Work per Unit of Production (RLUP) F, S
   RWUP = Value paid for remuneration of work, including the owner/mass or units produced

4. Investment to Create Direct Employment (ICDE) F, R, S
   ICDE = investment/number of jobs generated

5. Investment to Create Total Employment (ICTE) F, R, S
   ICTE = investment/number of jobs and self-employed jobs generated (direct + indirect)

6. Proportion of Self-Employments (SE) F, R, S
   SE = number of self-employed jobs generated/total number of jobs generated

7. Permanence in the Activity (PA) F, R, S
   PA = average time spent by each worker in the aquaculture industry (in years)

8. Required Work per Unit of Occupied Area (WA) S
   WA = person–hours per year/occupied area. Work by the owner and family members should be included, if they work at the farm.

9. Required Work per Unity of Production (WP) S
   WP = person–hours per year/mass or units produced. Work by the owner and family members should be included, if they work at the farm.

10. Safety at Workplace (SW) F
    The following items should be analyzed, when relevant:
    a. Use of life vest;
    b. Use of sunglasses;
    c. Use of protective goggles against mud, scale, and for other uses;
    d. Use of pigmented gloves;
    e. Use of waterproof and antiskid boots;
    f. Use of protective clothing against sun or rain;
    g. Use of equipment to relieve physical stress;
    h. Use of proper lighting in the work area;
    i. Use of proper electrical and plumbing installations;
    j. Use of machines, equipment, implements, furniture, and tools that provide the employee a position with good posture, visualization, movement, and operation;
    k. Use of machines and equipment by a qualified professional;
    l. Use of protective lab coat (or common apron) when indicated;
    m. Guaranteed rest breaks for activities that require standing;
    n. First-aid kit, well equipped and easy to access;
    o. Signs indicating possible danger areas;
    p. Availability of fire extinguishers and other emergency equipment;
    q. Training program for workers to operate equipment properly.

    SW = number of equipment pieces, actions, and practices that provide safety for workers available in the farm/number of analyzed equipment pieces, actions and practices that provide safety for workers

11. Local Consumption of Production (LC) R
    This indicator measures the possible improvement in food availability for the local community
    LC = mass of product sold in the local market/total production

12. Pay Equality (PE) F, R, S
    PE = 1 − (Standard deviation of salaries/mean of salaries)

13. Proportional Cost of Work (PCW) F, S
    This indicator shows if the system is work-intensive or uses machines and automation, reducing the number of jobs, and/or paying very low salaries. In family-based aquaculture systems, the family work should be included.
    PCW = Cost of work/cost of production

14. Income Distribution (ID) F, S
    ID = value paid with salaries + social fees + social benefits/profit generated

15. Access to Health-Insurance Programs (AHP) F, R, S
    AHP = number of employees and owners with health-insurance/total number of employees and owners

16. Schooling (Sc) F, R, S
    This indicator measures if the workers have opportunities for formal schooling or professional training during the work day or during their free time.
    Sc = number of employees that study/total number of employees

17. Participation in Outside Community Activities (PCA) F, R, S
    PCA = number of workers participating in community activities/number of total workers

18. Gender Inclusion (GI) F, R, S
    This indicator measures if the gender composition of jobs occupied by employees reflects the gender composition of the local population. The identity of sexual minorities should be included if data are available.

    $$GI = \sum \min\{a,b\}$$

    in which:
    min = minimum value;
    a = proportion of one gender among employees in the enterprise;
    b = proportion of the same gender in the local community.

19. Racial Inclusion (RI) F, R, S

    This measures if the racial composition of positions occupied by employees reflects the racial composition of the local population. The ethnic groups vary in different regions and the degree of segregation may be based on skin color, religion, language, and others. Therefore, the composition is site-specific. An example of classification by skin color might be white, brown, black, yellow (Asiatic) and red (indigenous). Groups may be constituted according to their qualitative and quantitative importance in each specific country or region.

    $$RI = \sum \min\{a,b\}$$

    in which:
    min = minimum value;
    a = proportion of one racial group employed in the enterprise;
    b = proportion of the same racial group in the local community.

20. Age Inclusion (AI) F, R, S

    This measures if the age composition of employees reflects the demographic structure of the local population. We suggest to consider four age groups: young (16–21 years), adults (22–40), middle-aged (40–60) and elders (> 60). However, the age classes are site-specific.

    $$AI = \sum \min\{a,b\}$$

    in which:
    min = minimum value;
    a = proportion of an age group among employees in the enterprise;
    b = proportion of the same age group in the local community.

4. Discussion

Based on the main international documents focusing on sustainability (WCED, 1987; UN, 1992, 2007; FAO, 1995, 1997, 1999; NACA/FAO, 2000), we defined sustainable aquaculture as the cost-effective production of aquatic organisms, which maintains a harmonious and continuous interaction with the ecosystems and the local communities. The aquaculture farm should be productive and profitable, generating and distributing benefits; and should optimize the use of capital and natural resources, conserving the surrounding ecosystems. The farm must generate employment for local communities, increasing the quality of life, respecting the local culture and promoting human development. In addition, the farm should be resilient in order to persist over time. The set of 56 indicators developed in the present study are broadly conceived, in order to address all the aspects comprised in the above concept. Thus, this set of indicators is comprehensive and may be a useful tool for assessing and monitoring the sustainable development of aquaculture in all dimensions.

The economic indicators developed in the present study cover the major issues of economic sustainability. The ratio of net income to investment indicates the efficiency of the use of capital. Enterprises with lower initial investment that generate the same net income are more sustainable, as they correspond to a more adequate use of resource capital. The economic feasibility indicators (Internal Rate of Return, Payback Period and Benefit-Cost Ratio) can be computed for real farms or for simulated ones when new technologies are tested. They provide important and understandable information to entrepreneurs and investors. For small farmers, who are generally interested only in maintaining a good standard of living for their families, they may be irrelevant. For small farmers, the Annual Income indicator (AI) is suitable. A positive annual income indicates that the farm may be sustainable. Nevertheless, this is not sufficient. The annual income must ensure that the farmer can continue to pursue the activity, acquiring from aquaculture all or a substantial part of his maintenance needs. Summing profits to opportunity costs should result in an annual wage that is large enough to provide the farmer and his family with an acceptable life style in the municipality where they live. Thus, a reference value is the annual per capita income in the area where the farm is located. The analysis should take into account that if the regional per capita income is not enough to allow adequate access to maintenance entitlements, people may abandon aquaculture.

We have introduced the computation of externalities in the economic indicators, and have used a human generation time scale (> 20 years) as the time unit. Although these concepts are not new, these variables are seldom used in studies on production systems. Externalities provide essential information for public polices related to taxes or compensations. Major positive externalities are the environmental services provided by aquaculture, such as sequestering P and N from a water body, which are retained in the biomass produced; accumulation of water; improvement of air relative humidity, in the case of dry regions; and absorption of CO_2 from the atmosphere. Negative externalities include the removal of vegetation and soil erosion during pond construction, displacement or elimination of extractive areas, disrespect to common property affecting traditional populations, and release of pollutants and exotic species to environment. We defined the generation time as the period from birth to first reproduction. Our approach takes into account the concept that each generation should inherit the same natural resources as the previous generation. Generation time is quite variable among countries, regions, and epochs (OECD, 2017). This variable is dynamic and usually ranges from 20 to 32 years. We used 20 years for approximately the time scale for a human generation as a baseline; however, this value can be modified for each analysis. Resilience indicators assess the farm's capacity to resist changes in the current conditions.

Resilience is an important factor for the success of any activity in a changing world. The capacity to self-reorganize and persist in adverse situations allows farms to remain in the activity for longer periods; low risk factors and higher diversity of products and markets also increase the resilience. The financial success of each farm or aquaculture sector (e.g. tilapia culture, shrimp culture, and others) can be evaluated by the proportion of the investment that has been generated by the aquaculture activity in the farm or the sector itself. Sectors that grow with the capital generated in other sectors of the economy or with governmental subsidies are not sustainable. This analysis can be done every five years on a local, regional or country basis, considering each sector separately, or for the entire aquaculture sector.

The environmental indicators developed in the present study are generally based on production as the reference value. Thus, the use of resources and the load of pollutants generated are divided by the production obtained. From this perspective, we can compare extensive, semi-intensive and intensive systems. Nominal values or substance concentrations in effluents are useless for comparing different systems. Intensive production systems may be much more sustainable (or not) than extensive systems if the production is high enough to counterbalance the resources used and pollutants generated. We have used nitrogen and phosphorus as key materials to assess the use of natural resources. These nutrients can be a proxy for other materials. However, the same concept can be applied to any other important material, such as carbon. Scarce materials are of special interest; they should be identified and specific indicators should be created. Much of the materials and energy added as diet is not incorporated into the target (reared) organisms, but instead is assimilated by the natural biota associated with the culture, dispersed to the surrounding environment as pollution, or accumulated within the system (David et al. 2017a, b). The indicators showed here measure the proportion of energy, nitrogen, and phosphorus incorporated into the target species. Much of the energy and material embodied in the farmed organisms is not consumed by humans. These wastes are often discarded unused, and carry with them large amounts of energy and materials that have been supplied during the rearing period. Systems that lose less energy and materials as waste are more efficient and more sustainable, and therefore it is important to include an indicator for this issue in the portfolio. The efficiency of the system can be increased by developing a useful disposal procedure for generated wastes, and the evolution in this technology can be monitored based on the Production Actually Used indicator (PU). The eutrophication potential can be measured as a function of the main limiting element of the receiving water body. In marine environments, photosynthesis is limited mainly by nitrogen availability, whereas in freshwater it is generally limited by phosphorus. Aquaculture may impact biodiversity and genetic resources. The indicator proposed here measures the risk due to the reared species only, which is certainly insufficient. Other indicators should be created to complete the assessment of impacts on biodiversity and genetic health.

Indicators to measure the use of natural resources, the efficiency in the use of resources, and pollution were previously proposed in the report of the EVISE group (EAS, 2005) and by Boyd et al. (2007). Both show very important methods to assess aquaculture production systems. However, the first is practically hidden of the scientific community because it is really a report, and indicators were proposed before validation in farms. The authors of the second one proposed indicators to measure the efficiency of resources use and the waste produced in fish and shrimp culture, based on theoretical deductions, although examples of application are showed. The main differences of the present work is that we have developed a broader set of indicators to cover the main features of the environmental dimension of sustainability; they were developed based on a long discussion of experts, farmers and other stakeholders, using a combination of top-down and bottom up methods; they can be used to assess any farmed species or any system; and we have collected an enormous amount of data from different production systems, on farms and on research stations in different climate zones, during 6 years, to test the feasibility and validity of each proposed indicator. In this way, we have validated the attainability of the indicators for different systems and species. The real data acquired support the proposal that the set of indicators described in the present article is suitable to assess, monitor and compare different aquaculture systems.

Farms that generate more inputs for the local community and distribute wealth are more sustainable. Therefore, the percentage of the break-even price expended to pay work, the ratios of work cost to gross income and work cost, plus other social benefits/profit and the number of jobs created per ton of product may be useful social indicators. Farms with higher values of these indicators are more socially sustainable. Indicators to assess the generation of self-employment, as well as racial and age inclusion have not been used in aquaculture. These indicators can be an important tool to monitor the role of aquaculture in promoting the inclusion of more vulnerable people and alleviate poverty. Gender equality and equity have long been an issue in rural sectors, including fisheries and aquaculture (FAO, 2017). We have proposed an indicator that assesses the participation of males and females (and can incorporate other sexual identities) in aquaculture activity, based on the proportion of the relevant group in the local community.

An example of the results obtained with the set of indicators developed in the present work is shown in Tables 2, 3 and 4. These results exemplify the use of the indicators and may help to understand what they indicate. These values were obtained by Moura et al. (2016), studying tilapia culture in net-cages in a reservoir in a semi-arid region of Brazil. The indicators of economic sustainability (Table 2) showed that the system is economically feasible, since it shows an internal rate of return greater than the attractive rate of return (considered equal to 8%). The positive net present value reinforces the position of the venture as economically valid, whereas the benefit-cost ratio indicates that each US$ 1.00 invested yielded US$ 1.35 in benefits for those involved. Nevertheless, the ratio of mean annual income to investment was relatively high. Profit and income were economically satisfactory. The venture markets 5 products and exploits 5 markets, which makes the activity more resilient to production interruptions and market fluctuations. All capital invested comes from a sector other than aquaculture, which does not guarantee that the activity is economically healthy enough to allow reinvestment.

Table 2
Indicators of economic sustainability (adapted from Moura et al., 2016). All monetary values were converted from Brazilian reals to US dollars, based on the average trading price of the dollar for the period April through September 2012 (US$ 1.00 = R$ 1.99).

Indicator	Value
Ratio between Net Income and Initial Investment	$ 2.67
Internal Rate of Return	52%
Payback Period	3.22 yr
Benefit-Cost Ratio	$ 1.35
Net Present Value	$ 47,773.09
Net Profit	$ 10,361.65
Annual Income	$ 12,360.42
Risk Rate	75%
Diversity of Products	5
Diversity of Markets	5
Invested Capital Generated in the Activity	0

Table 3
Indicators of environmental sustainability (adapted from Moura et al., 2016). OM = organic matter; PM = particulate matter.

Indicator	Value
Use of Space	0.01 m^2/kg
Dependence on Water	4.69 m^3/t
Use of Energy	98.02 MJ/kg
Proportion of Renewable Energy	0%
Use of Nitrogen	82.49 kg N/t
Use of Phosphorus	10.39 kg P/t
Efficiency in the Use of Energy	5%
Efficiency in the Use of Nitrogen	21%
Efficiency in the Use of Phosphorus	17%
Production Actually Used	89%
Potential of Eutrophication	56.95 kg P/t
General Chemical Pollution	0.00 kg/kg
Pollution by Hormones	0.00 kg/kg
Potential of Acidification	7.68 kg S/t
Accumulation of Phosphorus	0.88 kg P/t
Accumulation of OM	67.20 kg OM/t
Accumulation of PM	78.90 kg PM/t
Risk of Farmed Species	5

Table 4
Indicators of social sustainability (adapted from Moura et al., 2016). MHY = men-hour by year; MH = man-hour.

Indicator	Value
Development of Local Economy	44%
Use of Local Workers	100%
Remuneration of Work per Unit of Production	1.29 $/kg
Proportion of Self-Employments	100%
Permanence in the Activity	3.25 yr
Required Work per Unit of Occupied Area	29.75 MHY/m^2
Required Work per Unity of Production	0.44 MH/kg
Safety at Workplace	91%
Local Consumption of Production	100%
Pay Equality	100%
Proportional Cost of Work	42%
Access to Health-Insurance Programs	0%
Schooling	10%
Participation in Outside Community Activities	100%
Gender Inclusion	48%
Racial Inclusion	55%
Age Inclusion	66%

The indicators of environmental sustainability for this farm (Table 3) showed a low dependence on water and space, using an area of 0.01 m^2 per kg of fish produced and a volume of 4.7 m^3 per tonne. The system, however, showed inefficiencies in the use of nutrients and energy, because only 21% of the nitrogen, 17% of the phosphorus and 5% of the energy used for production was recovered in animal biomass. The system also released particulate matter into the environment at a rate of 0.08 kg per kg of fish produced. Approximately 90% of this was organic matter, generating 0.07 kg of organic matter per kilogram of fish. The eutrophication potential was estimated at 56.95 kg of phosphorus released per ton of fish produced. The potential for acidification of the environment was estimated at 7.68 kg of sulfur released per ton of fish produced. Pollution from herbicides, pesticides, and hormones was zero since none of these products was used in the culture. This production system allows an accumulation of about 79 kg of particulate matter in the bottom of the reservoir, contributing to increase the clogging process and reducing the useful life of the reservoir. There is a high risk that the farm will disseminate exotic species or microorganisms into the environment.

The indicators of social sustainability (Table 4) showed that the work required is 29 person-hours per year per square meter (MHY/m^2), or 0.4 person-hours per kilogram of fish produced (MH/kg). The system still produces an income distribution of ~US$ 2.00 and remuneration of relevant work at ~US$ 1.30 per kilogram of fish produced, which is high. The salary equity of the company is 100% because it is a cooperative. The inclusion of race (55%) and age (66%) is reasonable, while the inclusion of gender (48%) is not satisfactory because the association is comprised of men. A drawback of the system is the generation of only a small number of jobs and direct employment, considering the amount invested in the venture. Only 2% of the total cost (fixed and variable costs over time) is spent locally, but taking into account that the associates spend their salaries in the city, the income fixation was estimated at 44%. The total production is consumed by the local population, showing that the farm contributes significantly to local food security. Access to health programs and education is low, but participation in community activities is high. The safety of workers during their tasks is high. Aquaculture is a new job because the workers have remained in the activity for about 3 years.

Data obtained in different aquaculture systems during the past 6 years indicated that the set of indicators developed here is a powerful tool to identify the strengths and weaknesses of aquaculture systems. Each indicator is associated with an important component of the system or the production chain. The indicators measure the sustainability of each compartment of the system independently. Thus, they allow independent diagnosis and assessment of each element, revealing limitations and which elements should be improved to evolve toward a sustainable system. This information allows punctual and precise actions to improve the system sustainability. After adjustments in the system, the indicators can be used to assess the efficacy of the interventions and follow the progress toward sustainability.

Sustainability evaluations are part of a dynamic learning process to attain sustainable systems (Sala et al., 2013). Realistic goals are established and reformulated when they are being accomplished, in a continuous progress toward sustainable systems. Sustainability is not a static state and depends on the general scenario. Aquaculture systems are highly adaptable and undergo evolution (Costa-Pierce, 2010). Therefore, the challenge in building sustainable aquaculture goes through a continuous learning process, and the capacity to create systems that are able to respond to coming changes in the economic, environmental and social situation. The set of indicators defined in the present paper is certainly a useful framework to face this question. It can easily be adapted to new scenarios if necessary, and new indicators can also be created using the same background.

A more general picture of the systems can be obtained by subjecting the set of indicators to multivariate analyses, consolidating them in radial graphs or combining them in sustainability sub-indices and a general index. These tools integrate all information and allow general comparisons. In addition, indicators can be subjected to traditional statistic comparisons of means, such as the *t*-test, parametric and non-parametric ANOVA and others. Indicators can be converted to a performance scale, using science- or policy-based definitions of standard values and reference points. We can assign zero to the worst score and 100 to the best one (Valenti et al., 2011), which transforms all indicators to dimensionless variables. By this means, we can organize the indicators in dashboards of sustainability or combine them to obtain indices relevant to the specific principles or criteria. A higher weight should be attributed according to the importance of each indicator. For instance, resources that are not renewable at the same rate at which they are used by economy, such as phosphorus, could be assigned a higher weight. Sub-indices can be calculated for economic, environmental and social dimensions. The arithmetic mean among the three sub-indices generates a single sustainability index. Aggregated indicators are better to compare systems and assess performances, whereas individual indicators allow detailed understanding of the systems and identification of strong and weak points (Boockstaller et al., 2015).

Sustainability indicators and indices can be very useful for rapid and clear communication among stakeholders and with consumers. Decision-makers have difficulty in understanding biological and social concepts, but they normally understand numbers, indices, and values. On the other hand, sustainable aquaculture certification may be a “commodity per se”, in which values emerge for financial, reputational or market access (Havice and Iles, 2015). Modern consumers of aquatic food generally support sustainable production (Simões et al., 2014; Risius et al., 2017). Thus, labeling a food as “sustainable” adds value to farm or sectorial products. Tools for assessing farms and aquaculture sectors are required to provide consistent and realistic certification. The set of indicators proposed in the present article matches the needs of certifying organizations. They are broader and more realistic than the indicators normally used by the main certifiers. For instance, certifiers have not used economic indicators for labeling products, although this dimension is essential for a sustainable system; social indicators are generally restricted to detect unfair wages, the use of forced or child labor, or the compliance with local trade legislation, instead of focus on the aquaculture perennity. Conversely, the indicators showed in the present article take into account the three dimensions and the main principles of sustainability, and reflect the main features of aquaculture. They are broad enough to compare different products and can be easily understood by farmers and auditors. In addition, they can be combined into a general index of sustainability, which should be promptly understood by consumers.

The indicators and indices can be calculated for different spatial and temporal scales. This means that the indicators can be used to access production systems in the level of farms, groups of farms, cities, states, countries or even globally. In addition, it is possible to assess the increase/decrease of sustainability in production systems during the time, by calculating the indicators in successive periods. According to Fezzardi et al. (2013), the level of applicability of indicators may be on the farm (level of production unit), local, national or regional. The set of indicators developed in the present study comprises suitable indicators for these levels, also on the global scale, and on the sectorial level (culture of certain species or systems). In addition, farm-level indicators can be calculated for different farms in a region or sector and the mean value used as a sectorial or regional indicator. Similarly, the standard deviation or variation coefficient can be an indicator of the variation among farms of a sector or region.

Some related topics of the aquaculture process that are not covered in the present study are animal welfare and governance. Neither is included in any of the three main dimensions of sustainability, but each is important. Welfare of the animals produced for feeding human beings is increasingly being demanded by consumers and may be very important in niche markets. Many consumers are willing to pay a premium price for welfare-assured seafood (Alfnes et al., 2017). Therefore, the level of animal welfare in production system may affect economic sustainability. Valenti et al. (2011) and Feucht and Zander (2015) supported the inclusion of animal welfare measures in sets of sustainable aquaculture indicators. Governance is essential for the success of local production arrays (Fezzardi et al., 2013). Weak governance may impair the persistence of productive ventures and, therefore, sustainability. Indicators to assess governance were shown by FAO (2011), Lazard et al. (2011), Fletcher (2012), Hofherr et al. (2012) and Fezzardi et al. (2013).

In conclusion, the portfolio of sustainability indicators developed in the present work covers the three dimensions and the major principles of sustainability, as well as the major issues of aquaculture. They are quantitative, broad, scientifically sound, easy to understand and interpret, feasible to obtain on farms or on research stations, permit comparison at different scales of space and time, and were well received by aquaculture stakeholders in Brazil. Thus, they can be used in the aquaculture production sector to assess farms, regions or different aquaculture segments (sectors) and in research and development to assess new technologies or compare different experimental treatments. They also can be used by certifying organizations to classify products, by consumers to choose sustainable products, by investors to evaluate different projects to be supported, and by policymakers to assess and monitor public policies. They allow performance of diagnostics, identification of strengths and weaknesses, setting goals and actions, and assessments of the effectiveness of actions and policies.

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