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SOCIETAL LCA • METHODOLOGY

Socioeconomic indicators as a complement to life cycle assessment—an application to salmon production systems

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Abstract
Background, aim, and scope There is a growing recognition on the part of industry, policymakers, and consumers that sustainable industry practices are needed to maintain environmental and social well being. Life cycle assessment (LCA) is an internationally standardized analytical framework that has traditionally focused on evaluation of the environmental impacts of processes or products using a cradle-to-grave approach. Yet, sustainability, defined generally, requires that assessments consider not only environmental but also social and economic impacts—the other two pillars of sustainability. Even though the LCA methodology has the potential to include both social and economic indicators, and SETAC guidelines recommend the inclusion of such impact categories in all detailed LCAs, no established set of metrics exists to describe the relationship between socioeconomic indicators (SEIs) and a specific product or process; nor is there a common understanding on how such metrics might be developed. This article presents the methods for and development of a suite of socioeconomic indicators that complement the LCA methodology and provides a comprehensive approach for assessing the cradle-to-grave sustainability of a product or process.
Methods A combined top-down and bottom-up approach serves as the basis for development of the set of socioeconomic indicators presented here. Generally recognized societal values, industry specific issues, and financial constraints associated with collection of data necessary for measurement of the indicators are all factors considered in this approach. In our categorization, socioeconomic indicators fall into two types: *additive indicators* and *descriptive indicators*.
Results Indicators are categorized based on fundamental methodological differences and then used to describe the socioeconomic impacts associated with salmon production. Additive indicators (e.g., production costs and value added) and descriptive indicators (e.g., fair wage and contribution to personal income) are both discussed.
Discussion There is a need to further develop and refine methods to assess the results of socioeconomic indicators using a life cycle perspective. It would be most interesting to conduct additional case studies that focus on such methodological development, particularly trade-offs between stakeholder groups and pillars of sustainability. Additional areas of discussion are (1) the need for data to populate socioeconomic indicators and (2) defining system boundaries for socioeconomic indicators.
Conclusions This article presents a set of socioeconomic indicators designed to serve as a complement for the LCA framework, thus, increasing the framework's effectiveness as a measure of the overall sustainability of a product or process. Development of socioeconomic indicators as a complement to LCA is still in its early stages, however, and further research is required.

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Recommendations and perspectives The SEIs presented here are discussed theoretically within the context of salmon food production systems, but a test of the practicability and validity of the indicators (i.e., a practical application) is also necessary. The practical application of the topic will be presented in a forthcoming paper.

Keywords Indicators · LCA · Salmon · Seafood · SEIs (socioeconomic indicators) · Socioeconomic · Sustainability

1 Background, aim, and scope

With the increasing awareness of the importance of maintaining the life-support systems of our planet, methods for assessing "best practices" are gaining salience not only with a growing number of policymakers and consumers but also among industry intent on supporting sustainable business practices. The majority of existing sustainability concepts is based on the seminal definition of the term given by the United Nations Brundlandt Commission in 1987, according to which sustainability "is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED 1987). While scientific and societal efforts to concretely define "sustainability" and "sustainable development" are still ongoing, the concept itself is widely accepted. Consensus more or less exists regarding the following two principles: (1) sustainability is a global and integrative concept that balances economic development with social development and environmental protection and (2) sustainability includes a responsibility for present and future generations.

Since the Rio Earth Summit in 1992, sustainable development has emerged as the new paradigm for long-term development. According to the global program "Agenda 21," which was adopted in Rio, fundamental changes in global consumption and production patterns are necessary for the successful management of natural resources and the eradication of poverty. Consequently, a movement away from unsustainable consumption and production became one of the priorities of the United Nations Environmental Program (UNEP) after the Johannesburg Summit in 2002 and is also one of the overriding issues in the work program of the Commission on Sustainable Development (UNEP 2002; UNEP/SETAC Life Cycle Initiative 2005[1]).

Using life cycle thinking is "a prerequisite of any sound sustainability assessment" (Klöpffer 2003). As the only internationally standardized environmental assessment method (ISO 14040 and 14044 2006a, b) that provides a cradle-to-grave assessment of a product or process, life cycle assessment (LCA) is particularly well suited to meet the challenge of addressing environmental, social, and economic impacts from a holistic perspective. To date, however, the main focus of LCA has been on environmental and human health impacts related to the biophysical flows associated with a process or product, even though the methodology has the potential to include both social and economic indicators. This shortcoming is addressed by Dreyer et al. (2006), who emphasizes that "recommendations based on LCA fail to address possible trade-offs between environmental protection and both social and economic concerns in the product life cycle." The inclusion of social and economic dimensions would create a framework that has the capacity to address the overall sustainability of a product or process. The economic dimension, relative to the social, is further along in its development, and there are several tools currently available that use a life cycle perspective to analyze the economic aspects of a product or process, such as life cycle costing and total cost assessment (Norris 2001).

While methods exist to assess social impacts (along with the other sustainability aspects), no corresponding code of practice currently exists for the social dimension that includes life cycle thinking. SETAC guidelines recommend the inclusion of a "social welfare" impact category in all detailed LCAs (Consoli et al. 1993); yet, no established set of metrics exists to describe the relationship between socioeconomic indicators (SEIs) and a specific product or process, nor is there a common understanding how such metrics might be developed. To date, there have been only limited attempts to include social aspects in the LCA framework, though the effort has been increasing (Jørgensen et al. 2008; Klöpffer 2008; Hunkeler 2006; Hofstetter et al. 2006; Norris 2006; Weidema 2006; Dreyer et al. 2006; Labuschagne 2006; Hunkeler and Rebitzer 2005; Klöpffer 2003; Heller and Koeleian 2000; O'Brien et al. 1996). The methods used are largely inconsistent with one another, however, and the majority of studies have concluded that more research and development is needed in this area.

The focus of this article is on ways to take accepted sustainability standards and make them operational as a set of widely applicable socioeconomic indicators that complement the LCA methodology, thus, providing policymakers, industry, and consumers with a comprehensive approach for assessing the cradle-to-grave sustainability of a product or process. More specifically, the intent is to use SEIs to help identify opportunities to significantly improve the economic and social performance of industrial processes. Using the example of salmon, the article illustrates the sort of comparative information about the relative socioeconomic costs associated with comparable products

[1] http://www.uneptie.org/pc/sustain/lcinitiative

coming from different production systems (e.g., wild salmon fillet versus farmed salmon fillet) that can inform both consumers' personal practices and policymakers' decisions. We will first discuss the development of socioeconomic indicators and their integration with the traditional LCA framework. The set of indicators will then be discussed in more detail within the context of salmon production systems.

2 Methods

The goal of integrating socioeconomic indicators into the LCA framework requires some discussion of the approach used to identify and select indicators as well as how indicator definition differs between the traditional framework and a framework that includes socioeconomic indicators. It should be noted, because the focus is on indicator development, that the interpretation phase of LCA is considered outside the scope of this article.

2.1 Indicator selection

Similar to Dreyer et al. (2006), we believe that a combined top-down and bottom-up approach must be used in order to develop a defensible suite of indicators. A top-down approach, in this context, is one that selects indicators that are representative of broadly recognized societal values. To the extent possible, indicators are based on various international conventions, agreements, and guidelines (such as the International Labor Organization (ILO), United Nations Global Compact, The Universal Declaration of Human Rights, Corporate Social Responsibility Europe, Global Reporting Initiative. This type of approach is also in accordance with the International Standards Organization's (ISO) recommendations for environmental life cycle impact assessment methods, which state that "the impact categories, category indicators and characterization models should be internationally accepted, i.e., based on an international agreement or approved by a competent international body" (ISO 2006b). While the top-down approach ensures that selected indicators define and measure impacts that have a high societal value, it does not account for the potential lack of measurement methods and/or lack of access to data which could limit real world application of the indicator(s).

In contrast, we define a bottom-up approach as one that identifies indicators based on industry or stakeholder interests and/or data availability. Socioeconomic impacts have the potential to vary between industries due to the nature of the process or product with which a given industry is involved. It is crucial that any set of socioeconomic indicators used as a complement to LCA be able to adequately address industry specific impacts. Additionally, a bottom-up approach focuses on use of readily available data; however, as Dreyer et al. (2006) notes, it is important to avoid an inconsistent indicator selection process based only on data availability and/or impacts for which industries are willing to be held accountable.

During the indicator development process in the context of an international comparison of seafood (salmon) production systems, it became clear that a linkage needed to be created between broadly defined societal values and the on-the-ground application of the indicators. As such, a combined top-down bottom-up approach was used in the selection and definition of the suite of socioeconomic indicators presented here. We believe that such a hybrid approach will be useful in other food system applications and other industries.

Pintér et al. (2005) identified a number of challenges related to successfully integrating indices or indicators into mainstream sustainable policy and practice. Those challenges could be categorized as institutional, methodological, and technical. Institutional challenges relate to ensuring that indicators are brought to bear on key policy decisions, i.e., they carry sufficient relevance and influence. From a methodological perspective, challenges exist regarding proper measurement techniques, standards for indicator measurement, and comparability of indicators across regions or nations among others. Technical challenges, to a large extent, revolve around data access, more specifically, "the lack of long-term consistence monitoring mechanisms that supply data with adequate temporal and spatial resolution" (Pintér et al. 2005).

In light of those recognized challenges to indicator development, we have developed three criteria for indicator identification: (1) relevance, (2) practicability, and (3) validity. Indicator relevance requires that indicators must address established sustainability standards in a way that is meaningful. The second criterion, practicability, prescribes that data needed to accurately measure or describe each indicator should either currently exist or can be readily collected with justifiable expenditure and effort (discussed more in Section 4). Indicator validity is the final criterion and relates specifically to the methods for measuring indicators. Measurement of the indicator needs to take into consideration both the sustainability standard being addressed and the availability of data; as such, the method and/or metric used might vary between indicators. In some cases, an indicator can be measured quantitatively without losing its "richness," i.e., its success in meeting the three criteria outlined; but, other indicators may only be describable qualitatively. For example, describing "employee benefits" as simply the dollar value of the benefits package per functional unit eliminates the possibility of describing the types of benefits offered, the value of the benefits as they relate to the regional or national norm, and/

or differences in benefits offered to different groups of employees in the production chain. Additionally, questions of interpretation of the indicator and limitations of the indicator and/or the possible combination of indicators are all dependent both on the data and on how the indicator is calculated. The development of indicator categories and defining of indicators is presented in the next section.

2.2 Indicator categorization and definition

This analysis considers both the social and economic impacts of a product's life cycle, hence, the term socioeconomic indicators. The term "socioeconomic" typically refers to the relationship between economic activity and social life. In the context of LCA, socioeconomic indicators are meant to describe not only the relationship between social life and economic activity but also the relationship of both with environmental aspects of a product life cycle. Given those defined relationships, we believe that a socioeconomic LCA should not be and does not have to be conducted independently of a biophysical LCA but rather, at a minimum, can complement the biophysical LCA and in many cases can, at least partially, be integrated. The purpose of integrating socioeconomic indicators in the LCA framework is to create a methodology for examining a product or process life cycle from a comprehensive, sustainable development perspective.

Life cycle assessment traditionally requires that all flows considered are related to a functional unit. In the case of biophysical flows (i.e., raw materials, energy, emissions, etc.), these relationships are generally direct, quantifiable, and easy to establish. Describing the causal relationship between a socioeconomic impact and the product in question, however, may not be as straightforward, nor, in some cases, as easily quantifiable. We suggest that multiple measurement methods are needed for SEIs in order for them to accurately describe the relationship between the socioeconomic impact and the product in question, as well as to be successfully integrated into the LCA framework. This new approach is best described through a categorization based primarily on the methodological differences between the indicators. In our categorization, socioeconomic indicators fall into two types: *additive indicators* and *descriptive indicators*.

2.2.1 Additive indicators

Additive indicators (must) meet two criteria: (1) they can be measured quantitatively and (2) they relate to the functional unit (i.e., they are additive through the chain). The first criterion, a quantitative measure of the indicator, is a necessary but not sufficient condition for integration of the indicator into the traditional LCA framework. For example, an indicator used to describe whether or not the average wage paid to workers at each point in the chain is a "living wage," i.e., adequate for the worker to survive on in the country or region in which they live can be measured quantitatively as a dollar value and it can be described at each point in the chain; however, it cannot directly be related to the functional unit. As all additive indicators relate to the functional unit, they are methodologically identical to the traditionally (defined) biophysical indicators. This distinction makes them widely applicable and directly comparable across different life cycle assessments. As discussed previously, the LCA framework is currently restricted mainly to biophysical indicators that meet the conditions we have set for additive indicators; there are, however, indicators that describe additional environmental and socioeconomic impacts that fail to meet one or both of those conditions. To date, such indicators have often been left out of LCA. Additionally, it should be pointed out that there is a deficiency even within environmental life cycle assessment; land use, for example, and its impacts on biodiversity and soil quality, among others, is just one area that is not sufficiently addressed by the current methodology, though progress is being made on these impacts (Milà i Canals et al. 2006; Milà i Canals et al. 2007).

2.2.2 Descriptive indicators

A number of widely recognized socioeconomic sustainability concerns, particularly those related to working conditions, are described by indicators that fail to meet the additive indicator criteria and are neither strictly quantitative nor additive along the chain (i.e., related to the functional unit). Under our categorization, such indicators, instead of being left outside the framework, will comprise a second category of indicators, descriptive indicators. We suggest that even if impacts cannot be related to a functional unit, they can still capture life cycle thinking and, thus, be valuable from a sustainability perspective by being described at each point in the chain.

Consequently, descriptive indicators meet the following criteria: (1) they can be either quantitatively or qualitatively described and/or measured at each point in the chain and (2) they cannot be related to the functional unit (i.e., are not additive through the chain). This categorization is relevant in both a socioeconomic and environmental context, though this article will focus only on how descriptive indicators support the integration of additional socioeconomic indicators as a complement to the LCA framework. The category of descriptive indicators can be further broken down into two subcategories, general and specific, based primarily on the perspective or frame of reference being considered. Like additive indicators, descriptive general indicators are meant to describe broad societal values and be widely applicable, and to a large extent reflect a top-down approach (i.e., internationally established standards). For example, describing whether or not workers at each point in the value chain are paid a living wage or receive appropriate worker benefits.

Descriptive specific indicators, on the other hand, are those indicators that may not be widely applicable but, rather, are focused on the relevant socioeconomic impacts of a specific process or product. Similar to the descriptive general indicators, they may be measured quantitatively or qualitatively; however, the comparability of indicators across different life cycle assessments may be limited to comparison with production systems similar to the one in question. For example, an indicator relevant to a particular socioeconomic issue associated with a wild salmon production system might also be relevant for a farmed salmon production system or even another seafood production system and, as such, lend itself to comparisons between these systems.

From a sustainability perspective, descriptive specific indicators are important in that they allow an industry to focus on sustainability issues specifically related to the product or process on which the industry is focused.

Categorization of the indicators can be described summarily by differences in the indicators as they relate four key indicator characteristics: relationship to the functional unit, measurement method, applicability, and comparability (Table 1). Using these guidelines, a set of indicators was selected; while two of the three categories of indicators (i.e., additive and descriptive general) are widely applicable, we have chosen to discuss all three categories of indicators within the context of a specific case study, salmon food production, in order to better be able to illustrate the conceptual discussion with specific examples. The next section will first describe why seafood, and more specifically salmon, production systems were chosen as the case study before discussing the selected set of socioeconomic indicators.

3 An application to salmon food production systems

The overexploitation of fisheries' resources poses the greatest danger to the ocean environment and threatens the health, economy, and livelihoods of communities all over the world (The World Bank 2005). In recent years, an increasing awareness of the production limitations of marine resources has occurred not only in fisheries' management but also among consumers and seafood professionals. A recent survey conducted by the Seafood Choices Alliance (SCA) indicates that consumers want retailers to take a higher degree of responsibility to assist them in making environmentally responsible choices (SCA 2006a, b), while retailers (and other seafood professionals) state that they need more choices and more credible and actionable information about sources processes, and products of sustainable seafood.

Seafood currently accounts for approximately 15% to 20% of the animal protein consumed globally by humans (Delgado et al. 2003), and this percentage is expected to increase. Opportunities to meet this growing demand, however, are limited, and producers are looking at increasing production levels in seafood production systems as one option. Even at current levels of production, however, fishing and aquaculture—the two major seafood producing sectors—result in a wide range of negative environmental impacts that threaten their long-term sustainability and the integrity of the ecosystems within which they are embedded. The rapid growth of aquaculture, coupled with the vulnerability of global fisheries to further deterioration, only underscores the need to improve the management of seafood production systems and to understand the larger environmental and social implications of these industries. An additional impact category that has received only limited scrutiny, but is critical from a sustainability perspective, relates to socioeconomic impacts that form the focus of our discussion.

Originally developed to evaluate the life cycle impacts associated with manufactured products, LCA is increasingly being applied to a wide array of food production systems (see, for example: Andersson et al. 1998; Andersson and Ohlsson 1999; Haas et al. 2001; Hospido et al. 2003; Mattsson and Sonesson 2003; Pelletier et al. 2007), including a number of seafood production systems (Christensen and Ritter 2000; Seppälä et al. 2001; Ziegler et al. 2003; Thrane 2004; Hospido et al. 2006; Hospido and Tyedmers 2005). While it is not a standardized life cycle assessment, a study

Table 1 Indicator characteristics

Indicator Characteristic	Additive indicators	Descriptive indicators	
		General	Specific
Relation to the functional unit	Yes	No	No
Measurement method	Quantitative	Quantitative or qualitative	Quantitative or qualitative
Applicability	General	General	Specific
Comparability	Yes	Maybe	Maybe

by Heller and Keoleian (2000) used life cycle thinking to create and apply sustainability indicators (i.e., environmental, social and economic) to assess the food system in the United States.

Salmon is used in this study as an example of an international super commodity—available practically anywhere, anytime regardless of location or season. It is one of the most widely consumed seafood products in the industrial world and the two producers—capture fisheries and aquaculture—have production levels that are broadly comparable on a global scale and also have highly substitutable final products.

The salmon production value chain is illustrated in Fig. 1. The system boundaries, in this case, are the fishery on one end and the consumer on the other. Additional steps included are processing, retail, wholesale, and transportation (represented by the arrows between steps in the chain). It should be noted that feed production (in the case of farmed salmon) is not included as a part of the production value chain for the purposes of this discussion. Each step in the value chain has associated environmental, social, and economic impacts. Some of these impacts related specifically to the production of salmon food, while others are more general and would occur with any production chain. The subsections that follow will categorize and detail the indicators used to describe the socioeconomic impacts associated with salmon production.

3.1 Applying additive indicators to salmon food production

As mentioned previously, all additive indicators can be related to the functional unit and are, therefore, relevant for salmon food production systems, but they are also relevant and directly comparable across different life cycle assessments (Table 2). Additive indicators capture more economic aspects than social aspects, though several indirectly account for both. For example, both the costs indicator and the working hours indicator can be described and measured in terms of gender or migrant labor, making it possible to relate differences between different groups (i.e., male and female or migrant and nonmigrant) to the functional unit. These indicators are all quantitative and could be expressed in either US dollars or person hours of production as a measurement method. For example, choosing a functional unit corresponding to 1 kg of salmon ready to eat at the consumer stage would give the production cost or person hours of production through the entire value chain in relation to this functional unit.

It should be noted, however, that in some cases, two or more SEIs need to be combined to yield more relevant information about the system (i.e., not all of the indicators are "stand alone indicators"), which means that looking at a single indicator might not always be sufficient. For example, the gendered labor costs indicator addresses differences in the total amount of wages paid to males and females but says nothing about the hours worked by each group. Combining the gendered labor costs indicator with the gendered person hours of production indicator provides a better understanding of wage differences that may exist between males and females. For example, if twice as much is being spent on labor costs for male workers (from the gendered labor costs indicator) but the gendered person hours of production indicator shows that male and female workers are working the same number of hours, all else being equal, this would suggest that males are being paid twice as much as females.

The final additive indicator is death or accidents, which is one of the social indicators most frequently assessed. For example, this has been done for seafood production systems by Ellingsen (2004) and Thrane (2004). This indicator measures death or accidents as they relate to the functional unit, i.e., the number of deaths or accidents that occurred per 1 kg of consumer-ready salmon.

3.2 Applying descriptive general indicators to salmon food production

The descriptive general indicators, as the name implies and as explained earlier, are applicable and may be comparable across different life cycle assessments (Table 3). As such, these indicators generally focus on describing broad societal values related to working conditions (e.g., living wage, employment benefits, hours worked per week, right to organize, forced labor) and the labor force (e.g., age distribution of workers, education level of workers, gender of workers). These indicators capture aspects that the additive indicators fail to address and are the most crucial for measuring social impacts, specifically those related to broadly recognized societal values.

The two first indicators: fair wage and employment benefits (e.g., health care benefits, paid vacation days, sick days, maternity or paternity leave, and pension or retirement benefits), relate to the belief that workers should have an adequate and "safe" life outside of work. These two indicators should be considered related; if no employment benefits exist, the salary must be high enough to cover

Fig. 1 Salmon production system

Table 2 Additive indicators

Additive	Indicator definitions
Production costs	The cost to produce one functional unit (fu)
Labor costs	The labor cost to produce one fu
Gendered labor costs	Labor costs broken out by male/female
Migrant labor costs	Labor costs broken out by migrant/non-migrant
Value-added	The dollar value added per fu
Person hours of production	The total person hours required to produce one fu
Gendered person hours	Person hours broken out by male/female
Migrant person hours	Person hours broken out by migrant/non-migrant
Deaths/accidents	The loss of life/injury on the job per fu

expenses such as insurance, maternity leave, retirement savings, etc. The wage indicator can be measured quantitatively, but employment benefits may need to be addressed qualitatively due to the complex nature of "employee benefits."

The hours worked to produce one functional unit is assessed earlier under the additive indicators, but that does not say anything about the working hours for the individual worker, i.e., average hours worked per day and/or average hours worked per week. This indicator can be measured quantitatively, with the ILO conventions serving as reference, i.e., that the normal working hours should not exceed 8 h per day, 48 h per week, with 24 h rest per week (ILO: Hours of work (Industry) Convention, 1919 (No 1)). It should be noted though that in the context of fisheries, and perhaps other production systems, this indicator needs to be handled with care because there may be a difference in working hours in the fishery (a seasonal occupation) and salmon farms (normally a year round occupation). It should also be noted that the number of hours worked by a fishermen per day may vary substantially due to seasonality of the fishery, fisheries regulations, or the gear type, among other things.

The right to organize, forced labor, and discrimination indicators are all based on the fundamental ILO conventions (Table 4) and are all relatively difficult to assess. This is especially true for forced labor since survey questions to that effect are unlikely to be met with a truthful answer, and access for in-site observations may be limited. It may be possible that several other indicators could be combined and serve as a proxy indicator (e.g., fair wage, employment benefits, hours worked per week as a way to infer the degree of forced labor). For example, an unfair wage relative to the region or country norm, no employee benefits and excessive hours worked per week would serve as an indication that forced labor may exist.

The indicator "access to bathroom and potable water" could be used as a proxy measurement for the conditions of the workplace (since this could be seen as basic standard to which workers have a right); however, determining the correct method of measurement for this indicator may not be as straightforward as working conditions may vary by industry and/or by region. More specifically, simply having a toilet and a drinking fountain in a facility is not sufficient if workers are not provided reasonable opportunities to use them. The age distribution of workers and minimum age of workers indicators all describe the workforce at the company and could also be used as an indication of the industry (e.g., if all fishermen are old, that could be an indication of a "dying industry"). The former indicator could be described quantitatively by calculating the number or percentage of workers that fall within a certain age cohort (e.g., percentage of workers under 18); however, measuring minimum age of workers in a way that meaningfully addresses the issue of child labor is more difficult to do, again because of regional and cultural differences. The two last indicators in this section are industry concentration and distance traveled per

Table 3 Descriptive general indicators

Descriptive general	Indicator definitions
Fair wage	A wage adequate for a person to survive on
Employment benefits	The existence of and/or type of benefits
Hours worked per week	The number of hours worked per week by an average worker
Forced labor	The existence of compelled labor
Discrimination/gender	The breakdown of employees by gender
Right to organize	A right to freedom of association and collective bargaining
Age distribution of workers	The breakdown of employees by age
Minimum age of workers	A proxy for child labor
Access to bathroom/potable water	A proxy for working conditions
Industry concentration	The number of companies at each step in the value chain
Distance traveled	The distance between the different activities in the value chain

Table 4 Relevant ILO conventions

The fundamental ILO Conventions
C87: Freedom of Association and Protection of the Right to Organise Convention, 1948
C98: Right to Organise and Collective Bargain Convention, 1949
C29: Forced Labour Convention, 1930
C105: Abolition of Forced Labour Convention, 1957
C100: Equal Remuneration Convention, 1951
C111: Discrimination Convention, 1958
C138: Minimum Age Convention, 1973
C182: Worst Forms of Child Labour Convention, 1999

functional unit (or "by the product from production to consumption"), which both can be expressed quantitatively. The industry concentration indicator measures the number of permit holders or owners at each point in the chain. Such a measure provides information on the competition in the sector, and it is also relevant for sustainable development because small-scale fishing (i.e., lower concentration) has been discussed as an "ideal fishing model for sustainable and responsible fisheries" (Matthew 2005). The distance traveled indicator will measure how far the product travels between different points in the value chain and provide an indication of how global or local the product is—essentially a measure of 'food miles', i.e., the number of miles food travels from the place of production to consumption.

3.3 Applying descriptive specific indicators to salmon food production

While descriptive general indicators focus primarily on broadly recognized societal values, descriptive specific indicators, as their name implies, are focused on a specific product or process. From a sustainability perspective, this ability to create measurable indicators that describe the wide range of socioeconomic concerns attributable to different industries is critical. For example, the impact of pesticide use on workers may be of great concern in certain types of agriculture production (e.g., coffee), but is not a factor in wild salmon food production systems.

The descriptive specific indicators chosen in the context of salmon food production systems (Table 5) describe socioeconomic impacts at three different levels: individual, fishery, and societal. The contribution to income indicator measures the contribution of salmon food production to personal income (i.e., at the individual level). This indicator is important for both inter- and intrasystem comparison (i.e., over time and across different salmon production systems). For salmon food production systems, we expect that the first point in the value chain is where the highest contribution to personal income will be seen.

The following indicators describe fishery level socioeconomic impacts: fair price, access to fishery, and latent quota. Fair price, while likely applicable to other life cycle assessments as well, is used to assess whether or not the specific salmon food production systems (e.g., capture fishery, aquaculture) receive ex-vessel prices similar to the average regional price. Access to the fishery is meant to describe the entry cost to the industry (i.e., the value of a permit or to start up a farm) as a proxy measure for accessibility of the fishery. Latent quota refers to the production capacity of different salmon food production systems relative to actual production. For capture fisheries, this indicator could be measured as the percentage of total fishing permits for a given gear type that are not actively being fished. For salmon farms, it could be measured in contrast to the percentage of farms producing at maximum capacity.

The indicators relating to owner–operator, adjacency, and compliance are meant to describe the salmon food production industry on a broader level. The purpose of the owner–operator indicator is to describe the percentage of owners that are also operators. In the case of the capture fishery, this could be measured as the percentage of permit owners that fish their own permit. For salmon farms, this could be measured as the number of farms owned by a single individual or company.

The adjacency indicator measures the percentage of individuals working in salmon fishing or farming that are local and nonlocal residents. This indicator can be calculated as the percentage of workers that are residents of the case study area. The compliance indicator is meant to measure the compliance with regulations of fishermen or farmers in a region. This indicator will be measured in terms of the number of demerits or violations received per year. For several reasons (e.g., seasonality of the fishery, regulations, and access rights) seasonality of fisheries related employment may occur. The seasonality of employment indicator is meant to track these impacts on employment using qualitative methods to assess trends over time. This set of socioeconomic indicators is meant to serve as a complement to the traditional LCA framework and will serve as the starting point for a first attempt (in a forthcoming paper) to assess the overall sustainability of salmon food production, including environmental, social and economic aspects, using a life cycle approach.

4 Discussion

There are a variety of issues that need to be addressed when using SEIs as a complement to the LCA framework. Because SEIs are a new concept, relative to the traditional biophysical LCA for which a variety of databases currently exist, much of the data needed to populate the indicators are not readily

Table 5 Descriptive specific indicators

Descriptive specific	Indicator definitions
Contribution to income	Contribution of product/process to personal income
Fair price	Price paid to fishermen is fair
Access	Ability of a worker to enter the production process
Latent quota	Level of unused fishing permits
Owner-Operator	Level of permit owners who also fish the permit
Adjacency	Worker adjacency to point of primary production
Compliance	Compliance with regulations by industry

accessible, or in some cases are not currently being collected. Given this challenge, recommendations that data necessary to describe and measure SEIs collected may be one inevitable conclusion of our project. There are some sustainability standards for which data collection is likely to be extremely difficult (e.g., forced labor), and the use of proxy indicators should be considered as an alternative. As suggested by Weidema (2005), average data is a good way to fill in data gaps, but when performing studies on specific products and processes, the need for site-specific data may be a crucial issue, especially if the geographic or social context is more important than the activity itself. Alternately, the use of appropriate measurement methods that account for regional differences, i.e., of geography, culture, government, etc., and/or the relevance of particular indicators for a particular geographic area may be able to minimize the impact of such differences on the overall assessment.

4.1 System boundary considerations

Differences in data access and availability also relate to the issue of system boundaries. For example, consider a farmed salmon food production system. The system boundaries for the environmental LCA may include the production of the salmon feed as well as the feed production inputs (e.g., energy, fertilizers, pesticides, etc.). On the other hand, the inclusion of the socioeconomic aspects associated with each of these inputs would be very difficult to assess. This is due in part to the relative abundance of environmental data, and the fact that socioeconomic impacts may be more site-specific. For example, to produce salmon feed, one can estimate with a high degree of certainty the amount of energy and materials that are needed to produce one functional unit, but the same cannot necessarily be said for working conditions at all of the feed production sites in the system. This raises the question of whether it is really feasible to have the same system boundaries for a biophysical LCA and a socioeconomic LCA. While average data might be an option for certain socioeconomic indicators, it will most likely not be sufficient for indicators that can vary from site to site, such as working conditions.

In addition to data gaps, another challenge of system boundaries concerns the relative contribution of stages in the chain and/or inputs to the production of the functional unit under consideration. In a traditional LCA, "resources need not be expended on the quantification of such inputs and outputs that will not significantly change the overall conclusions of the study" (ISO 2006a). It may not be reasonable to assume, however, that inputs that are not significant from a biophysical perspective are also not significant from a socioeconomic one. It is conceivable that in the production of a complex product with many inputs, a traditional LCA would choose to exclude some inputs that are unlikely to contribute significantly to any environmental impact categories but which could be associated with a high socioeconomic impact. For example, a relatively minor input from an environmental perspective might be associated with poor working conditions and, therefore, would have a very high impact from a socioeconomic perspective. Therefore, one might have to add an additional criteria, social relevance, to expand the LCA to also include activities that might have minor impact on environmental results but which is important from a socioeconomic perspective (though this would mean to also enlarge the scope of biophysical LCA study).

Ideally, identical system boundaries would be used for both the environmental and socioeconomic components; however, at present, this may not be a realistic goal due to the limited development of the socioeconomic framework. ISO calls for the determination of system boundaries to take into account several measures of relevance of a flow or input: mass, energy, and environmental relevance and one alternative would be to include social relevance as an additional consideration. While it may be achievable in the future, such a constraint at this time could compromise the validity and/or reliability of the traditional LCA by limiting the focus of the assessment to only steps in the chain where socioeconomic data is available, presumably only a subset of the steps for which environmental data exists.

It may be, however, that identical system boundaries are not feasible even with sufficient data and knowledge of impact contributions. If this is discovered to be the case, one potential solution is that social or socioeconomic LCA is conducted as a separate analysis with different system boundaries, a complement to rather than an integrated piece of the biophysical LCA. Another solution might be to differentiate between the primary stage of production; in this case, the fishery or aquaculture farm, and the rest of the production chain, i.e., dock to consumer in order to get a comprehensive picture of both the environmental and socioeconomic impacts. In the case of salmon, and presumably with other food production systems, data are more available and specifiable to the functional unit for the primary stage of production, particularly for socioeconomic indicators, whereas the related socioeconomic impact categories have increasingly less “stickiness” to the functional unit as we move further through the chain. For example, the working conditions in freight transportation and retail are not likely to be specific to the salmon fillet that is moved along with other food stuffs. At present, however, there has not been sufficient experience with the system boundaries issues discussed here to propose a viable solution for dealing with them.

4.2 Indicator considerations

Another methodological issue that is difficult to address with a theoretical exercise is how the indicators should be interpreted. As suggested in Dreyer et al. (2006), a “two-layer structure” could be used, with one set of obligatory baseline criteria and another set of optional, self-determined criteria. Simply establishing a “baseline” can be very difficult, however, and for that reason, it is important to rely on international agreements and conventions (e.g., ILO, UN Global Compact). Our practical interpretation of this two-layer structure follows the discussion of the previous paragraph, in which we suggest that the “baseline” indicators focus on the primary stage of production (i.e., for food production systems).

An additional area where further methodological development would be useful is on assessing trade-offs, in particular, trade-offs between (1) stakeholder groups and (2) the pillars of sustainability. What is good for the employee may not be good for the employer or what is good for the producer may not be good for the environment. For example, consider different groups of stakeholders related to a particular product or process—improving working conditions for employees (i.e., one group of stakeholders) could mean increased production costs for the employers (i.e., another stakeholder group), which in turn translates into increased prices for the consumer (i.e., a third group of stakeholders). There could also be trade-offs between the different pillars of sustainability that must be addressed in the interpretation of the results. For example, how should machine labor, which results in varying levels of carbon dioxide emissions contributing to global warming, be handled in comparison to manual labor, with varying levels of working conditions? Finally, because this article focuses primarily on indicator development, additional work is still needed on classification, and possible characterization, of the indicators in order to achieve more logical divisions for reporting purposes. The indicators, as presented here, are only divided by their methodological differences and not according to stakeholder, impact category, and other dimensions. This next step will be presented in a separate forthcoming case study paper on socioeconomic indicators applied to salmon production systems.

5 Conclusions

This paper has presented a set of socioeconomic indicators meant to serve as a complement to the LCA framework. The indicators presented here are categorized based on their methodological differences. The first category, additive indicators, is measured quantitatively and, as the name implies, additive through the chain. The second category, descriptive indicators, is divided into two subcategories: general and specific, and can be measured either quantitatively or qualitatively, but descriptive indicators are not additives through the chain. Two of the indicator categories (i.e., additive and descriptive general) are meant to be widely applicable, while the descriptive specific indicators are meant to be product or process specific.

As mentioned previously, the development of a “sustainability LCA” (i.e., including socioeconomic aspects into the traditional LCA framework) is still in its nascent stages, but a rising demand from stakeholders, along with the increasing research or publications on the topic, shows that there is both a need for and interest in a methodology or framework that provides a comprehensive measure (i.e., environmental, social and economic) of process or product sustainability using a life cycle perspective.

6 Recommendations and perspectives

Although an increasing number of articles on the integration of social and economic aspects into the LCA framework have been published in the last several years, methods for SEI development are still very much under development, and more research will be needed to test the relevance, practicability, and validity of the indicators presented here. While the theoretical exercise of selecting indicators considers their relevance, this exercise alone is not sufficient to determine their practicability and validity. In order to test both the criteria for indicator selection, the indicators just discussed (i.e., additive, descriptive general, descriptive specific) will be tested through a practical application to salmon food production systems in the Northeast Pacific, more specifically both capture and culture systems.

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